Journal of Research and Development

A Multidisciplinary International Level

Referred and Double Blind Peer Reviewed, Open Access Journal

ISSN:2230-9578 April - 2026 Volume-18 Issue-4(XI)

Mob: +91-9552416001 Website: https://jrdrvb.org Chief Editor: Prof. Ramesh V. Bhole

MULTIDISCIPLINARY INTERNATIONAL JOURNAL

Website: https://jrdrvb.org

JOURNAL OF RESEARCH AND DEVELOPMENT
ISSN: 2230-9578

ISSN: 2230-9578
April - 2026
Volume-18 Issue-4 (XI)

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Journal of Research and Development
Peer Reviewed International, Open Access Journal.
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4(XI)| April 2026

Journal of Research and Development

A Multidisciplinary International Double Blind Peer Reviewed Refereed International Research Journal

Volume-18, Issue-4 (XI) |April 2026
Publication Language – English, Hindi, Marathi and other Indian Languages
Periodicity of Publication- Monthly
Email: jrdrvb.org@gmail.com
Journal Website: https://jrdrvb.org

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Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

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Name of Journal	JOURNAL OF RESEARCH AND DEVELOPMENT
Frequency	Monthly : Jan to Dec (12 issues per year)
ISSN	2230-9578
Publisher	Dr. Ramesh V. Bhole
Chief Editor	Dr. Ramesh V. Bhole
Copy right	Journal of Research and Development
Starting Year	January 2010
Subject	Multi-Disciplinary
Review Process	Double Blind Peer
Language	English, Hindi, Marathi, and other Indian Constitutional Languages.
Publication Format	Print
Access	OPEN ACCESS
License	Creative Commons (CC BY-NC-SA 4.0)
Phone No.	+91 93256 65856, +91-8888454089
Email	jrdrvb.org@gmail.com
Journal Website	https://jrdrvb.org
Registered office Address	'Ravichandram' Survey No-101/1, Plot, No-23, Mundada Nagar, Jalgaon, Maharashtra, India
Admin. Office Address	'Ravichandram' Survey No-101/1, Plot, No-23, Mundada Nagar, Jalgaon , Maharashtra, India
Printing	**Amitsons Digital Copiers** 106 and 110, Paras Chambers 1st Floor, Near Laxmi Narayan Theatre, Above Bank Of India, Swargate-411042

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

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A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

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Journal of Research and Development
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ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

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Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

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Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Original Article

A critical review on limnology with respect Maharashtra

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Manuscript ID:
JRD -2026-180401
ISSN: 2230-9578
Volume 18
Issue 4(XI)
Pp. 1-4
April - 2026

Submitted: 10 Mar. 2026
Revised: 20 Mar. 2026
Accepted: 25 Mar. 2026
Published: 30 April2026

Abstract:
In the review paper, discuss the growth and the expansion of the modern limnology has been indicated by a vigorous and growing limnological research, especially in academic institutions.Recent limnological studies have resulted into an improved understanding of the physical, chemical, and biological processes affecting the properties and behavior of flowing water. Many of these studies and explorations have come out with the fundamental conceptual findings that have contributed in solving the problems related to human impacts on aquatic resources. A satisfactory knowledge about the aquatic life can be gained by comprehensive information about not only the organisms themselves but also of those external influences which directly or indirectly affect them. In these studies, to give an extensive review of literature related to limnology. Here's a comprehensive critical review of limnology with a specific focus on Maharashtra, its freshwater ecosystems (lakes, reservoirs, ponds, dams), research status, key findings, challenges, and recommendations drawn from published scientific literature.
Keyword: *limnological studies, Review literature, Maharashtra*

1. Introduction

Over the past quarter century; Limnology, emerged as an integrative science which has made a significant transformation in the studies of inland aquatic ecosystems, especially Rivers. Traditionally; over the past several decades; the multidisciplinary field of limnology relies upon various inland aquatic ecosystems like lakes, streams & Rivers of all sizes from the tropics to the Polar Regions. Recent limnological studies have resulted into an improved understanding of the physical, chemical, and biological processes affecting the properties and behavior of flowing water. Many of these studies and explorations have come out with the fundamental conceptual findings that have contributed in solving the problems related to human impacts on aquatic resources.However; vigor of modern limnology has not been reflected, may be due to the fragmented works, narrow interests of researchers & insufficient linkage between academic research and the practice of limnology in the protection, management, and restoration of aquatic ecosystems. This issue of concern has been addressed by several recent studies and reports. Thus, there is a need for providing the basis for the relevance and importance of broad limnological training, practical recommendations to revitalize education in limnology.

Review

In Maharashtra; Gandhi (1952) recorded freshwater 79 Diatoms of Kolhapur region.Physico chemical analysis of polluted water from Bhusawal Railway locoshed area at Bhusawal has been carried out by Jawale et.al. (1989). Shastri et. al. (1999) studied algal diversity of percolation tank in Malegoan and diversity and recorded 92 algal taxa in three sampling stations. Shastri (2000) studied the physico-chemical parameter of Mosam River, Malegaon. Likewise; Pandse et.al. (2000) studied physico chemical parameters related to the algae and identified 45 algal taxa from percolation tank of village, Dasane.

Quick Response Code:
Website:
https://jrdrvb.org/
DOI:
10.5281/zenodo.21101291
OPEN ACCESS

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How to cite this article:
Patil, Y. S. (2026). A critical review on limnology with respect Maharashtra. Journal of Research and Development, 18(4(XI)), 1–4. https://doi.org/10.5281/zenodo.21101291

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

The studies on the algal flora of the Mutha River, Pune has been conducted by Jafari and Gunale (2006). Thakur and Behere (2008) studied the filamentous algal diversity of Gangapur Dam and recorded 25 species of algal taxa. Gonjari and Patil (2008) have studied hydrobiological aspects on Tripatireserviour near Satara, Maharashtra. Likewise; such studies have been conducted by, Deshpande and Gondwale (2009).Rathod and Patil (2009) studied assessment of some hydrological parameters of Ulhas River estuary in the vicinity of Thane city. Patil and Lohar (2009) studied seasonal variations in physicochemical parameters of Patalganga River at Raigad, Maharashtra.

Talekar et.al. (2010) recorded 33 algal taxa belonging to Oscillatriaceae at Ashti, Beed in Maharashtra. Puri et.al. (2010) carried out limnological studies at Lakes in Nagpur City. Bhosale et.al. (2010) conducted studies on algal flora of water bodies in and around Kolhapur city. In this study; 174 species of phytoplanktons and algae in group Chlorophyceae, Cyanophyceae, Euglenophyceae, Bacillariophyceae, Dianophyceae, Xanthophyceae and Chrysophyceaewere recorded. Bankar et.al. (2010) studied physico chemical analysis of Kathralu pond water near Chitradurga, Karnatka. Quadri et.al. (2010) studied physico chemical characteristics of River Bindusara, Beed, Maharashtra. Rakh and Bhosle (2010) studied physical, chemical and biological parameter of Vashisti river water at Chiplun.

The physico chemical analysis of water quality with an attention to the limnology and Biodiversity was assessed by Ingole and Kakde (2011). Patil et al. (2011) studied algal population from river, lake, dams in Jalgaon district.

Similarly, Jogdand and Shirsath (2012) studied 48 algal species from Domri reservoir Beed. Likewise; Kshirsgar et.al. (2012) studied 162 species from 75 algal genera recorded from Mula River at Pune. Likewise; Pawar and Vaidya (2012) studied the physicochemical parameters of Krishna River at Wai, Maharashtra.

Similarly; water quality of Godavari River at Nasik had been investigated by Bawa and Gaikawad (2013) and found that the River highly polluted due to domestic low DO and High BOD. Water quality parameters with the seasonal variations at Pindavani Pond, Chandrapur district was conducted by Harney et.al. (2013).Amdar (2013) conducted limnological studies at Morna Lake Sangli and recorded 17 algal species. Similarly; Dalal et.al. (2013) studied physico chemical parameters and algal flora of the Dham River, Wardha, Maharashtra. He recorded 53 algal species during this study. Patil et.al. (2013) carried out an analysis of physico-chemical parameters of fresh water reservoir near Khanapur, Maharashtra and reported the suitability of water for drinking and fishing purposes.

The study of correlation between algae like Diatoms with the physic chemical parameters of Budki Dam Shirpur, Dhule had been studied by Agale and Patel (2014). Water quality index of Panchganga River had been studied by Gaikwad and Kamble (2014).Deshmukh and Sathe (2014) studied the physicochemical parameter of Pravara River and found that nitrate, phosphate and chloride levels increased due continuous discharge of the sewage in the River. Similarly; 75 species of phytoplanktons belonging to Chlorophyceae, Charophyceae, Bacillariophyceae and Cyanophyceae was reported by Mahadik and Jadhav (2014) during algal diversity studies at Ujani reservoir. Tidame and Thakare (2014) conducted Limnological study of a fresh water pond,Prayagtirth, located at Trimbakeshwar in Nashik district and recorded high values of physico-chemical parameters due to the entry of agricultural runoff and occasional flow of sewage into the pond. Also, dense algal growth was noticed which is caused by surge of nutrients whenever there was a rainfall Patil et.al. (2015) conducted Limnological study of Venna Lake, Mahabaleshwar, and Maharashtra.

Kale (2017) reviewed the consequence of temperature, pH, and turbidity and dissolved oxygen as water quality parameters at Nasik, Maharashtra. Similarly; Hardikar et.al. (2017) conducted seasonal distribution of Phytoplankton and its association with physico-chemical parameters in coastal waters of Malvan, west coast of India and found that the Temperature and TSS were the most significant parameters influencing the distribution and seasonal shift in total 57 phytoplankton species recorded during post monsoon.

Ajagekar and Nikam (2018) conducted Limnological study of water from Khanapur dam, Ajara, district Kolhapur.In this study they found that the physico-chemical parameters of the reservoir are well under the prescribed limits for inland surface waters and can be used for aquaculture and for irrigation purpose. Likewise; Durge et.al (2018) carried out studies on physico-chemical characteristics of a fresh water pond of Ghugus, Chandrapur district and found that the water of the pond lies just below the level of eutrophication. Humane et.al. (2018) carried out Limnological studies of Gadchiroli Lake, Maharashtra using Hydro Sediment chemistry and Sedimentary diatoms. In this study, the spread of sedimentary diatom species was strongly linked to environmental parameters. Patil et.al. (2018) carried out studies on Diversity of genus *Scenedesmus* (Meyen) from Anjani dam of Erandol tehsil, district Jalgon, Maharashtra and recorded dominant species of genus *Scenedesmus* (Meyen) from Anjani dam. Leena Muralidharan et.al. (2018) carried out Physico chemical analysis of water samples collected from Jummapatti area, Neral, Maharashtra. Dhawde et.al. (2018) carried out Physicochemical and Bacteriological analysis of water quality in drought prone areas of Pune and Satara districts of Maharashtra. In this study; Physical and chemical properties of water were expressed in the form of modified water quality index (WQI). Additionally, the modified WQI was compared to an overall Pollution Index (OPI) for rivers. The modified WQI values and bacterial counts were found to be at maximum during the onset of the monsoon. Likewise; Singh et.al. (2018) conducted Comparative Limnological and Physico-Chemical studies at Lonar Crater Lake, Maharashtra and documented changes in the various components of lake water and strongly recommended for removing the causes of contamination for the support of aquatic biodiversity.Bhutekar et. al. (2018) studied Spatial and seasonal variation in Physico- Chemical properties of Godavari River water at Ambad region, Maharashtra and found that the water of Godavari River at Ambad region moderately polluted due to discharge of sewage, agricultural and industrial runoff and religious activities. Saner and

Patil (2018) carried out assessment of water quality from Chanakapur Dam of Kalwan tahsil, Nasik district, Maharashtra Khairnar et. al.(2022) has study on microalgal flora of nakane lake of Dhule district. Finding of all the Physical and Chemical Properties of Nakane Lake water were within desirable limits Chaudhari & Patil (2024) has the study of physico-chemical parameters of Amravati reservoir of malpur. Chaudhari V.P (2024) investigated the algal flora at Tapi river, Bhusawal

Conclusion

Limnological research in Maharashtra spans **physico-chemical studies, biological indicators, trophic assessments, and seasonal analyses** across lakes, reservoirs, ponds, dammed rivers, and unique systems.. Restoration of a deteriorating water body by limnologists who can achieve this through integrating the many factors that influence aquatic ecosystems. In this regard; the limited gains that are achieved to date; are a result of focusing inputs to lakes, rivers, and wetlands from point sources; and at the same time' exclusion of many other factors that influence water quality. Changes will be needed in the infrastructure underlying limnology education, limnological research institutions in order to train the next generation of limnologists. Modern approaches increasingly incorporate biological bioindicators and statistical techniques for more reliable assessment. There remains a **need for integrated, policy-relevant limnological research** to support sustainable water management in Maharashtra.

Reference

1. Agale M. C. and Patel N.G. (2014): Diatoms and their correlation with physicochemicaparameters and seasonal variations of Budki medium irrigation tank, Shirpur (M.S.) India. *Indian Journal of Plant Sciences, 3 (3) :44-51.*
2. Ajagekar V.V. and Nikam K.N. (2018). Limnological study of water from Khanapur Dam Ajara Dist:-Kolhapur, MS, India *Int. Journal of life Sciences* Special Issue A 10 No 48951
3. Amdar M. R. (2013): Physico-chemical characteristics and phytoplankton of Morna Lake,
4. Bankar A.B; Poojitha Thirumala S; Manjappa, S. and Puttaiah, E.T. (2010), Physico-chemical analysis of Kathralu pond water near Chitradurga, Kadnataka. *J.Aqua. Biol.* 25 (2): 70-74.
5. Bawa K. V. and Gaikawad V. B. (2013): Water Quality Assessment of Godavari River at Nashik, India: Impact of Sewage and Industrial, *Universal Journal of Environmental Research and Technology,* 3, (4): 452- 457.
6. Bhosale L.J, Patil S.M, Dhumal S. N. and Sathe S.S. (2010): Occurrence of phytoplankton in the water bodies of Miraj Tahasil of Maharashtra, *The Eco Scan*, 4(1): 73-76
7. Bhosle A.B. Rakh M. S. (2011). Evaluation of Vashisti river water quality at Chiplun. Advances in Applied Science Research, 2 (5):104-109
8. Bhutekar D.D., Aher S.B. and Babare M.G. (2018): Spatial and seasonal variation in Physico- Chemical properties of Godavari River water at Ambad region, Maharashtra. *Journal of Environmental Biosciences* , 32 (1)
9. Chaudhari V.P (2024) : Diversity of fresh water algae of river Tapti. Part-II (Bhusawal, Maharashtra, India), International Journal of Applied Research 2024; 10(5): 130-133
10. Dalal L.P., Kalbende S.P., Nisal R.S (2013): Physico-chemical Assessment of Water Quality of River and the Hydro-biological Study of Algae, *Intn. J. of Scientific & Engineering Research* Vol. 4(3).
11. Deshmukh B.S. and Sathe, S.D. (2014): Physico-chemical characteristic of Pravara river, Maharashtra, *Journal of Aquatic Biology and Fisheries* 2: 101- 105.
12. Deshpande S. M. and Gondwale V. (2009); Physico-chemical analysis of ground water in the Chikalthana industrial complex, Aurangabad, Maharashtra, *J. Aqua.Bio.* 24 (2);99-102.
13. Durge L.S., Dhammani, A. A. Chavhan R. N. (2018). Physico-Chemical Characteristics of a Fresh Water Pond of Ghugus, District Chandrapur, Maharashtra (India) *International Journal of Scientific Research in Biological Sciences.* 5(3) : 59-64.
14. Humane S. K., Humane S. S., Chalakh S. (2018). Limnological studies of Gadchiroli Lake, Maharashtra using Hydro Sediment chemistry and Sedimentary diatoms. *Int. Journal of Scientific Research in Science and Technology(IJSRST)* 4(5).
15. Ingole S.P., Kakde A.U. (2011): Physico–chemical analysis of Sipna River, melghat region M.S." *International Journal of Research in Biological Sciences*; 1 (4): 65-70.
16. Kale V. S. (2017). Consequence of Temperature, pH, Turbidity and Dissolved Oxygen Water Quality Parameters*IARJSET*; 3(8).
17. Kshirsgar A.D., Ahire M.L. and Gunale V.R. (2012): Phytoplankton diversity related to pollution from Mula River at Pune city, *Terrestrial and Aquatic Environmental Toxicology, Global science book*, 6(2), 136-142.
18. Gandhi, H. P. (1952). A systematic account of the diatoms of Bombay and Salsette. *J. Indian Bot. Soc*, 31(3), 117-151.
19. Gandhi, H. P. (1952). A systematic account of the diatoms of Bombay and Salsette. *J. Indian Bot. Soc*, 31(3), 117-151.

20. Dnyanesh Khairnar, Tejas Saner, Nikhil Patil, Pruthviraj Shinde, Karan Patil (2022) : Limnological Study On Microalgal Flora Of Nakane Lake Of Dhule District Of Maharashtra, India. IJRAR
21. Gonjari, G. R., & Patil, R. B. (2008). Hydrobiological studies on Triputi reservoir near Satara, Maharashtra. *Journal of Aquatic Biology*, 23(2), 73-77.
22. Jafari, N G; Gunale, V R (2006): Hydrobiological Study of Algae of an Urban Freshwater River, *J. Appl. Sci. Environ*. Mgt. 10 (2) 153 – 158.
23. Jawale S.M, Choubey S.M., Mahajan R.T. and Karnik A.G. (1989): Physico-chemical Characteristics of a Stream Polluted by Effluents from the Railway Locoshed Area, Bhusawal, *Prog. in Pollution- Res, Na.. Young Scientists Semin. Environ. Pollu*, pp.10·14.
24. Jogdand S. K. and Sirsat P. B. (2012): An assessment of phytoplankton from Domri resrvoir district Beed (M.S.) India, *TLS* 1 (2):13-15.
25. Muralidharan L., Gaur S. and Muralidharan C. (2018): Physico chemical analysis of water samples collected from Jummapatti area, Neral Maharashtra. *International Journal of Trend in Scientific Research and Development (IJTSRD)*.2 (6)
26. Mahendra D Chaudhari & Prof. Dr. Madhukar. B. Patil(2024): The Study Of Physico-Chemical Parameters Of Amravati Reservoir Of Malpur, Maharashtra, India., IJCRT.
27. Shastri Y.(2000) Physical,chemical characteristic of river Mosam *Geobios*, 27:195-197.
28. Shastri Y., Bhogaonkar P.Y. Manude Y.B. and Pandse D.C.(1999): Hydrological studies of percolation tank – physico-chemical characteristics , *J. Aqua. Bio.* 14 (1&2): 43-46.
29. Patil AR, Lohar PS. (2009) Seasonal variations in physico-chemical parameters of river Patalganga, Raigad district, Maharashtra. *Journal of Aquatic Biology*. 24(2):109-112.
30. Pawar S. and Vaidya Ramesh (2012): Studies on Physico Chemical Characteristics and Level of Sewage Pollution in Krishna River at Wai, Dist: Satara, *International Conference SWRDM*.
31. Pandse D. C, Shastri yogesh and and Bhogaonkar P.Y (2000): Hydrobiological study of percolation tank of village, Dasane, *Ecol. Env. And cons*. 6 (1) pp. 93-97
32. Thakur H. A and Behere K. H. (2008): Study of filamentous algae biodiversity of Gangapur Dam – Nasik Dist., *The 12th word lake conference*, pp. 456-461
33. Puri P. J., Yenkie M.K.N., Battalwar D. G., Gandhare N V. and Dhanorkar D. B. (2010): Study and interpretation of physico-chemical characteristic of lake water quality in Nagpur city (India), *RJC*, 3,4: 800-810
34. Rathod S. D. and Patil N. N. (2009) studies on Assesment of some hydrological parameters of Ulhas River estuary, in the vicinity of Thane city, Maharashtra, *India J. Aqua. Biol.* Vol 24(2), 103-108.
35. Talekar S. M., Jadhav M. J., Jogdand S. K (2010). Biodiversity Studies on Oscillatoriaceae form Jalgaon Nala of Ashti Taluka in Beed District, India, *Journal of Experimental Sciences* 1(2): 3-4.
36. Saner M. and Patil N. (2018). Assessment of water quality from Chanakapur Dam of Kalwan tahsil, Nasik district, Maharashtra. *International Journal of Botany Studies*, 39(1); 92-94
37. Quadri Naveed.N., Seema Hashmi., Asef Iqbal and Mohammed Shaker (2010): A study on the physicochemical characteristics of river Bindusara, Beed, Maharashtra. *J.Aqua.Biol.* 25(2):100-103

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Original Article

Algae: Diversity, Ecology, and Emerging Significance

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Manuscript ID:
JRD -2026-180402
ISSN: 2230-9578
Volume 18
Issue 4(XI)
Pp. 5-7
April - 2026

Submitted: 10 Mar. 2026
Revised: 20 Mar. 2026
Accepted: 25 Mar. 2026
Published: 30 April2026

Abstract
Algae comprise a diverse and ecologically significant group of photosynthetic organisms that play a fundamental role in sustaining life on Earth. They are major contributors to global primary productivity, oxygen generation, and carbon sequestration. In India, algal diversity spans marine, freshwater, and terrestrial ecosystems, reflecting the country's varied climatic and ecological conditions. This chapter presents a comprehensive analysis of algal diversity, taxonomy, ecological roles, and emerging applications, with particular emphasis on the Indian context. It also explores recent advancements in algal biotechnology, the role of algae in climate change mitigation, and their contribution to sustainable development. Challenges and future research directions are discussed to highlight the need for integrated approaches in algal research and utilization.
Keywords: *Algae, Biodiversity, Phytoplankton, Seaweeds, Biofuels, Ecology*

Introduction

Algae represent a heterogeneous assemblage of photosynthetic organisms ranging from microscopic unicellular forms to large multicellular seaweeds. They are primarily aquatic but can also inhabit terrestrial and extreme environments. Unlike higher plants, algae lack true roots, stems, and leaves; however, they possess chlorophyll and other pigments that enable photosynthesis. The significance of algae extends beyond their biological diversity. They are responsible for nearly half of global oxygen production and form the base of aquatic food chains. Their evolutionary history is complex, involving multiple endosymbiotic events that have given rise to diverse lineages.

India, with its extensive coastline of over 8000 km, numerous rivers, lakes, wetlands, and varied climatic zones, provides ideal conditions for algal growth. The country's algal wealth includes marine macroalgae (seaweeds), freshwater phytoplankton, and soil algae. Despite this diversity, algal resources in India remain underexplored and underutilized.

2. Diversity of Algae

2.1 Taxonomic Diversity

Algae are classified based on morphological, biochemical, and molecular characteristics. Major groups include:

2.1.1 Chlorophyta (Green Algae)

Green algae are characterized by chlorophyll a and b, cellulose cell walls, and starch as a storage product. They are predominantly freshwater forms but also occur in marine and terrestrial habitats. Examples include *Chlorella*, *Volvox*, and *Spirogyra*.

2.1.2 Rhodophyta (Red Algae)

Red algae contain phycoerythrin, which gives them their characteristic red color and allows them to absorb blue light efficiently. They are mostly marine and include economically important genera such as *Gracilaria* and *Gelidium*.

Quick Response Code:
Website: https://jrdrvb.org/
DOI: 10.5281/zenodo.21101735
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How to cite this article:
Jadhavar, P. B. (2026). Algae: Diversity, Ecology, and Emerging Significance. Journal of Research and Development, 18(4(XI)), 5–7. https://doi.org/10.5281/zenodo.21101735

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

2.1.3 Phaeophyceae (Brown Algae)

Brown algae are multicellular and mostly marine, with pigments such as fucoxanthin. They include large seaweeds like *Sargassum* and kelps, which form underwater forests.

2.1.4 Bacillariophyceae (Diatoms)

Diatoms are unicellular algae with silica-based cell walls known as frustules. They are abundant in both marine and freshwater environments and are major contributors to global primary productivity.

2.1.5 Cyanobacteria (Blue-Green Algae)

Cyanobacteria are prokaryotic organisms capable of oxygenic photosynthesis. They play a crucial role in nitrogen fixation and are common in rice paddies in India.

2.1.6 Dinophyceae (Dinoflagellates)

Dinoflagellates are mostly marine and can be autotrophic or heterotrophic. Some species are bioluminescent, while others are responsible for harmful algal blooms.

2.2 Morphological Diversity

Algae exhibit remarkable morphological diversity in its forms like unicellular (*Chlorella*), colonial (*Volvox*), Filamentous (*Spirogyra*), siphonaceous (*Vaucheria*) and parenchymatous (*Ulva*, kelps). This diversity reflects adaptation to different environmental conditions.

2.3 Algal Diversity in India

India is rich in algal diversity due to its varied ecosystems like marine algae are abundant along the coasts of Gujarat, Tamil Nadu, Kerala, and Maharashtra. Island ecosystems such as Andaman & Nicobar Islands and Lakshadweep harbor unique species. Freshwater algae are widespread in rivers like the Ganga, Yamuna, Godavari, and Narmada

2.4 Factors Influencing Algal Diversity

Light intensity and quality, Temperature, Nutrient availability (nitrogen, phosphorus), Salinity, Water movement are the factors influence distribution, growth, and seasonal variation.

3. Ecology of Algae

3.1 Role in Primary Productivity

Algae are primary producers that convert solar energy into chemical energy through photosynthesis. Phytoplankton form the base of aquatic food webs and support higher trophic levels, including fish. In Indian waters, phytoplankton productivity is closely linked to monsoon cycles, nutrient influx, and coastal upwelling.

3.2 Oxygen Production

Algae contribute approximately 40–50% of global oxygen production. Marine phytoplankton are particularly important in maintaining atmospheric oxygen levels.

3.3 Carbon Sequestration and Climate Regulation

Algae absorb carbon dioxide during photosynthesis, playing a key role in mitigating climate change. The biological carbon pump transfers carbon from surface waters to deep oceans.

Seaweed cultivation in India is being explored as a strategy for carbon capture.

3.4 Nutrient Cycling

Cyanobacteria fix atmospheric nitrogen; algae assimilate phosphorus and other nutrients and decomposition releases nutrients back into ecosystems. In Indian agriculture, cyanobacteria are used as biofertilizers in paddy fields.

3.5 Symbiotic Associations

Algae form symbiotic relationships with fungi (lichens), with corals (zooxanthellae) and with protozoa and invertebrates. Coral-algal symbiosis is crucial for reef ecosystems in regions like Lakshadweep.

4. Economic Importance of Algae

4.1 Food and Nutrition: Seaweeds are rich in Proteins, Vitamins (A, B, C, E) and minerals (iodine, iron), In India, seaweed consumption is limited but growing, particularly in coastal regions.

4.2 Industrial Applications

Algae are sources of hydrocolloids:

1. Agar (from *Gelidium*)
2. Carrageenan (from *Kappaphycus*)
3. Alginate (from brown algae)

These are widely used in food, pharmaceuticals, and cosmetics.

5. Emerging Significance of Algae

5.1 Role in Climate Change Mitigation

Algae are being explored for:

1. Carbon capture
2. Biofuel production
3. Climate-resilient agriculture

5.2 Blue Economy in India

The Indian government is promoting:

1. Seaweed farming

2. Coastal employment
3. Marine biotechnology

Seaweed cultivation initiatives in Tamil Nadu and Gujarat are notable examples.

5.3 Biotechnology and Genetic Engineering

Advances include:

1. Genome sequencing
2. Metabolic engineering
3. Synthetic biology

These technologies enhance productivity and enable novel applications.

6. Conclusion

Algae are indispensable to ecological balance, economic development, and sustainable future strategies. India's rich algal diversity offers immense opportunities, yet remains underutilized. Strategic research, technological advancement, and policy support are essential to harness algal potential effectively.

References:

1. Becker, E.W. (1994). *Microalgae: Biotechnology and Microbiology*. Cambridge University Press.
2. Borowitzka, M.A. (2013). High-value products from microalgae. *Journal of Applied Phycology*, 25, 743–756.
3. Falkowski, P.G., & Raven, J.A. (2007). *Aquatic Photosynthesis*. Princeton University Press.
4. Graham, L.E., Graham, J.M., & Wilcox, L.W. (2009). *Algae*. Pearson.
5. Guiry, M.D. (2012). How many species of algae are there? *Journal of Phycology*, 48, 1057–1063.
6. Mantri, V.A., et al. (2020). Seaweed biodiversity of India. *Diversity*, 12, 13.
7. Mata, T.M., et al. (2010). Microalgae for biodiesel production. *Renewable and Sustainable Energy Reviews*, 14, 217–232.
8. Singh, J., & Gu, S. (2010). Commercialization potential of microalgae. *Renewable Energy Reviews*, 14, 2596–2610.
9. Spolaore, P., et al. (2006). Commercial applications of microalgae. *Journal of Bioscience and Bioengineering*, 101, 87–96.
10. Whitton, B.A., & Potts, M. (2012). *The Ecology of Cyanobacteria*. Springer.
11. Kumar, A., et al. (2024). Algal blooms in Indian coasts. *Discover Oceans*.
12. Choudhury, R., & Sahoo, N. (2021). Algal diversity in India. *Pharmacognosy Reviews*, 15, 199–208.

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Original Article

Anthocyanin-Based Smart Packaging: Using Red Cabbage Extract as a Natural Spoilage Indicator

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Manuscript ID:
JRD -2026-180403
ISSN: 2230-9578
Volume 18
Issue 4(XI)
Pp. 8-13
April - 2026
Submitted: 10 Mar. 2026
Revised: 20 Mar. 2026
Accepted: 25 Mar. 2026
Published:30 April2026

Abstract:
Rising concern for safer foods and environment friendly sustainable packaging materials has led to rise in interest for plant-based colourants that can indicate product quality. Anthocyanins extracted from red cabbage have been used in biodegradable chitosan films as a pH-responsive indicator for smart packaging applications. The pigments were extracted by ethanol and water at low pH-2 and identification was checked through colour changes associated with acids/alkaline pH as indicators of anthocyanin pigments. Extract used to create chitosan films, which were later studied for their physical and pH-responsive colour changing properties. The films reveal consistent surface characteristics and a flexible nature, while the moisture absorption was enhanced by the polar and hydrophilic properties of the pigments. Additionally, the films displayed a clear and gradual change in colour, response to varying pH levels, serving as a visible indicator of food spoilage. The chitosan and anthocyanins exhibit natural antimicrobial, antioxidant properties that will also aid in reducing degradation of freshness for food, in addition to the role of indicator. There are limitations like stability of pigments and moisture sensitivity, this study indicate that the potential for a functional, low-cost, sustainable alternative for synthetic indicators in a red cabbage-based film is promising and could facilitate future innovations for smart packaging options for food.
Keywords: *Smart packaging, Red Cabbages, Anthocyanin, Biodegradable Polymer, Food Preservation.*

Introduction

Food packaging plays an important role in maintaining food quality and safety by regulating oxygen flow and preventing microbial contamination, thus providing effective measures to preserve food freshness and prolong shelf life [1]. Considering the need for safe and fresh food products, innovative smart food packaging, created to monitor and convey information about the condition of the packaged goods. This research utilized pH-sensitive films infused with anthocyanin [2]. Biodegradable packaging materials obtained from anthocyanins are well regarded for their cost-effective components and their capacity to protect food products from physicochemical damage as well as significant microbial and environmental threats [2]. At present, smart packaging films that employ pH-sensitive indicators have been extensively developed to efficiently monitor food freshness in real-time [3]. Anthocyanin displays color changing properties across a broad pH range; these natural indicators are designed to evaluate freshness [4]. These cutting-edge smart pH indicator films have gained attention because of their attributes such as rapid response, preservation of food quality, convenience, and the ease of freshness detection by visual cues [5]. They typically consist of dyes that react to subtle shifts in the pH level of the food's surface. Recent research has focused on natural pigments, as they are regarded as eco-friendly and safe for consumption compared to synthetic dyes. Anthocyanins, which belong to the group of water-soluble flavonoids with a phenolic nature, exhibit varied colour spectra due to structural changes at differing pH levels [2, 5]. They are responsible for the red, orange, pink, and blue hues and it can be taken from natural sources, vegetables like red cabbage, purple carrot, and fruits such as grapes, pomegranate seeds, and flowers like butterfly pea, red rose [1, 6].

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How to cite this article:
Raut, R. P., & Yadav, A. (2026). Anthocyanin-Based Smart Packaging: Using Red Cabbage Extract as a Natural Spoilage Indicator. Journal of Research and Development, 18(4(XI)), 8–13. https://doi.org/10.5281/zenodo.21102079

Quick Response Code:
Website: https://jrdrvb.org/
DOI: 10.5281/zenodo.21102079
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Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

The hydrophilic properties of anthocyanins and their compatibility with natural polymer formulations makes them idealized for smart packaging materials [7]. Red cabbage represents an affordable source of natural anthocyanins with significant nutritional benefits and positive health impacts due to its richness in micronutrients and various phytochemicals, including oligosaccharides, minerals, vitamins, and bioactive compounds such as high levels of anthocyanins, flavonols and glucosinolates [4,7,8].

Red cabbage extract (RCE) serves as a common and rich source of anthocyanins, which correlate closely with the pH of their surroundings, displaying a visual colour shift as pH changes [6,9]. The preparation of RCE is easy and less costly compared to other plant sources. These characteristics render red cabbage anthocyanins (RCAs) a suitable choice for pH responsive indicator films [6,10]. Red cabbage extract(RCE) is a good source of anthocyanins that are closely related to the pH of their environment, changing from red at a pH level of 1-2, to pink at a PH of 3, violet at pH 4-6, blue at pH 7-8, green at pH 9-11 and finally yellow at a pH of 12 [9,11]. Recently, the trend in food packaging has leaned towards more environmentally friendly and biodegradable materials by opting for natural substances over synthetics.

Even with these benefits, current research also find issues that needed to be fixed to make sure anthocyanin-based smart films work well. When anthocyanins are exposed to heat, light, or oxygen, they can break down [3,12]. Also, natural biopolymer films may not be very strong or stable in high-moisture environments [1,7,12]. To solve the issues researchers have suggested ways to make things better like Nano-encapsulation, co-pigmentation, polymer crosslinking, adding essential oils or nanoparticles, and multi-layer hybrid film systems [13, 14]. Moreover, achieving industrial scalability and ensuring regulatory acceptance for further development [12,14].

Biodegradable based polymer pH indicator for smart packaging films that incorporate anthocyanins are effective for visualising the food freshness [5,13]. The primary biopolymers used to make smart packaging films include polysaccharides, proteins, and lipids. The spoilage of food products is directly linked to pH changes within the product [11,15]. Consequently, the use of smart packaging films containing natural colorants is suggested as an appropriate alternative for consumers to evaluate food quality and safety in real-time [15].

Methodology

Materials & Reagents

Red cabbage bought from a local market. Chitosan was obtained (from shrimp shell, 75% (acetylated), Spain. Ethanoic acid, HCL, NaCl, glycerol, ethanol, was taken from Sigma Aldrich Company, Spain [16].

Extraction of Anthocyanins

First, 150 g of chopped red cabbage was combined with 80 mL of a 70:30 ethanol–water solution, and the pH was set to 2 [3,16]. This mixture was stored at 5°C for 24 hours in a dark location. After this time, the supernatant was separated by filtration and centrifugation at 6000 rpm for 20 minutes. A 2.5 M NaOH solution used to neutralize the red cabbage anthocyanin extract before it was taken to prepare the film [4,16].

Test for Anthocyanin

NaOH and HCl tests used to validate anthocyanins. These tests are necessary as anthocyanins are sensitive to pH and change its colour when comes in touch with acidic or alkaline solutions colour will change [12,17].

NaOH Test: This test involves mixing a few drops NaOH solution with a tiny quantity of the anthocyanin-containing material. After that, the mixture is checked for any color changes.

The combination will become blue or green if anthocyanins are present [3,9,17]. The response is as follows: NaOH + anthocyanin = blue-green color

HCl Test: Few drop of hydrochloric acid (HCl) solution are combined with a tiny quantity of the anthocyanin-containing material. After that, the mixture is checked for any color changes.

The mixture will become pink or reddish if anthocyanins are present [9,17].

The response is as follows: HCl + anthocyanin = red.

To determine whether anthocyanins are present in a sample, both procedures can be performed as first assessments. They do not, however, offer any details on the type of anthocyanins that are present. To determine and measure the precise anthocyanins in a sample, further analysis— such as high-performance liquid chromatography (HPLC)—might be necessary [10,18].

Preparation of Film

1 g of chitosan powder added to 100 ml of a 1% v/v ethanoic acid solution, continuously stirred for 2 hours at 25°C. Glycerol (30% w/w of soluble solid weight) was combined with the various RCA concentrations (2.5, 5, and 10% (v/v)) as a plasticizer. Polyethylene plates with a diameter of 10 cm were filled with film-forming solutions, were dried for 48 hours at 25°C. As the control sample, a composite film RCA was created with no RCA [1,18]

Characterization of the smart composite films

The thickness

A digital micrometer use to measure the thickness, average value of ten random sites on test and control films was recorded (±0.001 mm) [18].

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Content of moisture (MC)

Moisture of every film was determined by calculating the weight loss % 2 × 2 cm2 film piece after drying at 105°C for 24 hour [18].

Solubility in water (WS) [1,12,19]

After being submerged in 50 ml of D/W (distilled water) for twenty-four hours at room temperature, the solubility of dried films (2 × 2 cm2) was assessed. Following a 24-hour drying period at 105°C, the weight of the undissolved films was measured at the conclusion of the incubation period, and each film's WS was computed using the following formula.

$$WS\ (\%) = \frac{m1 - m2}{m1} \times 100$$

Here, m_1 = original dried film mass (g)

m_2 = dried undissolved film mass (g)

Sensitivity to different pH buffers

In some applications, packaging film's pH sensitivity is crucial, particularly when packaging goods that are susceptible to variations in acidity or alkalinity. A substance's pH, which ranges from 0 to 14 with 7 being neutral, indicates how basic or acidic it is. Acidic substances have a pH of less than 7, whereas basic substances have a pH of more than 7 [2,3,9,11,17].

Anthocyanin colour and spectrum at different pH levels:

Red hue (low pH):

1. Anthocyanins usually have a red hue when the pH is lower (acidic). This is because the anthocyanin molecule looks red when it is in its flavylium cation state in an acidic environment.
2. The red form of anthocyanins has a peak in the absorption spectra between 520 and 550 manometers [2, 3,12,18].

Intermediate pH, or purple colour:

Anthocyanins become purple when the pH rises from acidic to neutral. The transformation of the flavylium cation into the quinoidal base form is linked to this transition.

The purple form's absorption spectra have a peak at a wavelength that is somewhat higher than the red forms [2,6,10,17].

Blue Color (High pH):

1. Anthocyanins can appear blue in alkaline environments (higher pH). The anthocyanin molecule is in its anionic form in this environment.
2. The blue form of anthocyanins has an absorption spectrum with a peak at a longer wavelength, which is in blue region [5,7,14,18].

Test for freshness

Strawberries, were cut into small-rectangular pieces and wrapped with the indicator film. And stored at both cold and room temperatures for 1-7 days to observe colour change[19].

Result and Discussion

Red cabbage anthocyanin was extracted by an ethanol–water solvent method using (70:30) ratio and pH 2, producing a highly stable and intensely coloured extract that can be appropriate for incorporation into the biodegradable film. In this work, the acidic medium preserved the flavylium cation form of anthocyanin, which gives the typical red–purple colour. This behaviour reported by [2,9,10]. Centrifugation followed by neutralization resulted in a highly clear and coloured extract, demonstrating minor degradation of the pigment. The colour changes after NaOH and HCl application confirmed that anthocyanins were successfully extracted. The colour turned to blue-green in alkaline conditions and red in acid medium, due to their acid–base properties required for freshness indication in smart packaging systems. This observation are compatible with work reported by [4,8,16]. Where some authors mentioned that both solvent polarity and pH control significantly affect anthocyanin yield and colour stability [12,18].

The chitosan films infused with RCA looked uniform, transparent, and flexible, especially in contrast to control film that didn't have any anthocyanin. Noticed a minor increase in average thickness of the films as we raised the RCA concentrations (from 2.5% to 10%), suggesting that adding the pigment influenced the solid content and the interactions between molecules in the matrix. Incorporating glycerol as a plasticizer significantly enhanced the elasticity of the film while reducing its brittleness [16] reported in their study. The rise in moisture content (MC) seen in the anthocyanin-loaded films can be linked to the hydrophilic properties of both chitosan and anthocyanins, that permitted greater water absorption. [16,20] observed similar behaviour in their study of chitosan–basil seed gum composite films included RCA extracts. We also found that the water solubility (WS) of the films were increase slightly with higher anthocyanin concentrations, likely because of hydrogen bonding between the –OH groups of anthocyanins and the amino groups of chitosan. This research on the interactions between polymers and anthocyanins has extensively documented by [18].Despite this, all the films held up well in water, proving they are suitable for food-contact uses. Overall, the

findings indicate that there is an optimal level of RCA loading that boosts functionality without sacrificing mechanical strength or stability.

The coated strawberries retained its aroma throughout the seven-day of incubation. This suggests that the edible coating slowed down natural deterioration, particularly when the fruits were stored at low temperature or frozen conditions. In contrast, uncoated strawberries showed faster quality loss, likely due to the collapse of their internal structure. The pH sensitive films functioned effectively as freshness indicators throughout storage. As the strawberries aged, their pH dropped, showing an increase in acidity. This change was reflected in the film colours. Under cold storage, the films gradually shifted to red by the final day, signalling the fruit's increasing acidity. In contrast, films kept at room temperature turned brown as early as day three, a change likely linked to protein breakdown in the red cabbage extract. These colour transitions clearly show both the progression of fruit deterioration and the impact of storage temperature on film stability. Overall, these findings show that the edible coating can increase the shelf-stability of strawberries and that the pH sensitive film works well as a simple visual indicator of freshness under proper storage conditions.[19].

The implanting of RCA in chitosan matrices not only gave a colorimetric character but also elevated the antioxidant and antimicrobial activities of the films. This is because anthocyanins are the most radical-scavenging agents and, therefore, by their nature, they help in delaying the oxidation of the foodstuff packaged [2,9,18] reported in their studies. Besides, the chitosan which is a naturally antimicrobial polymer was in a synergistic manner enhancing the preservation capability of the packaged food [7,19]. As a result, the maintained food quality became better during storage due to the combined effect.

Among the most important parameters for intelligent packaging, the visual color response to pH changes is one of them. The RCA-chitosan films underwent a distinct color transformation in the range of pH, confirming high sensitivity upon environmental changes. For instance, at low pH values, that is, pH between 2 and 4, this film looked reddish-pink due to the dominance of the flavylium cation form of anthocyanins. This structural chemistry described by [9,20]. The films turned violet to blue at neutral pH, that is, pH 6-7, matching the presence of quinoidal base structures. In an alkaline pH, that is, pH 9-11, this film changed to greenish blue tints because the formation of chalcone and anionic species.

These gradual and reversible colour transitions suggest that the film holds promise as a freshness indicator for non-durable such as fish and meat, for which microbial spoilage normally increases pH. This observation is in strong agreement with what is reported by [15,16,20] who illustrated that the films based on RCA biopolymer reflect spoilage in foods by way of visible colour change.

The performance of the film to visually indicate pH changes is basically due to the protonation– deprotonation mechanisms of anthocyanins at different pH levels. The pH change occurring in the area because the release of volatile amines or acids as food spoils instantaneously calls for the structural rearrangement of anthocyanins leading to colour change. The clever response generated by the smart packaging will eliminate the necessity for chemical testing, allowing anyone can easily know the freshness of food by simply looking to it [18,21,22] that is on the development of intelligent food packaging systems mention to their results.

The RCA–chitosan film we developed stands up well against other biopolymer-based indicator films, like those made from starch–anthocyanin and cellulose–anthocyanin composites. What sets chitosan apart is its impressive film-forming ability, clarity, and how well it works with anthocyanins. The reason it's sensitive to pH changes lies in the reversible structural shifts among different anthocyanin forms — mainly the flavylium cations (which appear red), quinoidal bases (showing purple to blue), and chalcones (leaning green to yellow). This flexibility at the molecular level allows the indicator film to perform effectively across a broad pH spectrum. Additionally, the hydrogen bonding between the hydroxyl groups of anthocyanins and the amino groups in chitosan adds to the film's structural stability. This interaction helps minimize pigment leaching and promotes a more uniform appearance. On the downside, these films do tend to be a bit more sensitive to moisture. However, we can tackle this issue by adding Nano fillers or encapsulating the anthocyanins, which would boost their resistance to humidity and light degradation. These strategies are backed by research from [9,10,21,22].

Conclusion

The paper discussed in this article shows how red cabbage anthocyanin (RCA) used as natural, environmentally friendly, and effective pH-sensitive indicator for intelligent food packaging. The red cabbage-derived anthocyanin had significant color changes throughout the pH range, going from red in acid to blue-green in base. The pigments provided the best visual sensitivity, flexibility, and compatibility when these were mixed in biodegradable chitosan films, and no synthetic dyes were needed.

The RCA-chitosan composite films has better physical properties like uniform texture, moderate water solubility, and improved moisture retention, which suggested that they were suitable for direct food contact. This films were highly susceptible to the changes in the surrounding pH and thus, they are liable for real-time freshness indicators for respiratory items like fish and meat. The co-existence of antioxidant and antimicrobial properties in anthocyanin and chitosan, respectively, is the primary factor contributing their food preservation potentials, thus, being safe and sustainable at the same time.

This study highlights the feasibility of employing natural pigments, such as red cabbage anthocyanin, to phase out the use of synthetic indicators in smart packaging systems. The results obtained will contribute to the implementation of the eco-friendly packaging material trend that, while helping to cut down plastic waste, gives consumers a visual freshness indicator.

Even though, there are few problems, for example, the stability of the pigment to light, temperature, and moisture, which need to be solved. Subsequent works should focus on the protection of anthocyanin by such means as encapsulation, nanocomposite reinforcement, or co-pigmentation methods. Combining these biopolymer films with color-sensing digital devices may also result in better precision and a higher potential for market acceptance.

In conclusion, the chitosan film based on RCA is an excellent example of a sustainable solution in the area of intelligent food packaging, whereby the film is not just biodegradable yet functional.

Reference

1. Liu, X., Xu, F., Yong, H., Chen, D., Tang, C., Kan, J., & Liu, J. (2024). Recent advances in chitosan-based active and intelligent packaging films incorporated with flavonoids. International Journal of Biological Macromolecules, 258, 128919. ISSN: 0141-8130.
2. Edward, E. G., Rovina, K., Zuldin, W. H., Pindi, W., Mantihal, S., Suriati, L., & Supri, S. (2025). Purple Power: Unleashing the Vibrant Potential of Red Cabbage Anthocyanins in Functional Food Packaging Systems. Comprehensive Reviews in Food Science and Food Safety, 24(1),13550. ISSN: 1541-4337.
3. Abedi-Firoozjah, R., Yousefi, S., Heydari, M., Seyedfatehi, F., Jafarzadeh, S., Mohammadi, R., Rouhi, M., & Garavand, F. (2022). Application of Red Cabbage Anthocyanins as pH-Sensitive Pigments in Smart Food Packaging and Sensors. Polymers, 14(8), 1629. ISSN: 2073-4360.
4. Junka, N.; Rattanamechaiskul, C.; Wongs-Aree, C.; Kanlayanarat, S. Comparative study of organic solvents and extraction conditions on colour and antioxidant capacity in red cabbage. Int. Food Res. J. 2017, 24, 518–524. ISSN : 1985-4668
5. Westlake, J. R., Burrows, A. D., & Xie, M. (2025). Turmeric and Red Cabbage Extract Composites with Chitosan as Natural Ingredient-Based pH-Responsive Intelligent Packaging Strips. ACS Food Science & Technology, 5(8), 1684–1693. ISSN: 2692-1944.
6. Wang, B., Liu, R., Ma, C., Liu, C., Zhang, H., Ren, F., Ma, W., & Chen, J. (2022). Recent Advances in pH-Responsive Freshness Indicators Using Natural Food Colorants to Monitor Food Freshness. Sensors, 22(13), 4786. ISSN: 1424-8220.
7. Hou, S., Yang, J., Geng, J., Cheng, Q., Li, W., He, Q., & Lin, C. (2025). Advancements in Chitosan–Anthocyanin Composite Films: Sustainable Food Preservation with Biodegradable Packaging. Polymers, 17(10), 2008. ISSN: 2073-4360.
8. Chandrasekhar, J., Madhusudhan, M. C., & Raghavarao, K. S. M. S. (2012). Extraction of anthocyanins from red cabbage and purification using adsorption. Food and Bioproducts Processing, 90(4), 615-623. ISSN 0960-3085.
9. Castaneda-Ovando, A., Pacheco-Hernandez, M. L., Páez-Hernandez, M. E., Rodríguez, J. A., & Galan-Vidal, C. A. (2009). Chemical studies of anthocyanins: A review. Food Chemistry, 113(4), 859–871.ISSN 0308-8146.
10. Constantin, O.E, & D.L (2022). Extraction, Quantification and Characterization Techniques for Anthocyanin Compounds in Various Food Matrices – A Review Horticulturae 8(11),1084. ISSN: 2311-7524.
11. Hamzah, N. H. C., Khairuddin, N., Hassan, M. A., & Muhamad, I. I. (2024). Preparation and characterization of starch-based pH indicator films for anthocyanin release. Food Research, 8(4), 11-20. ISSN: 2709-9377 (Print).
12. Hamzah, N. H. C., Khairuddin, N., Muhamad, I. I., Sarbini, S. R., & Hassan, M. A. (2025). Brassica oleracea L. Anthocyanin-based films for intelligent packaging: A concise review. Journal of Food Measurement and Characterization, 19, 1–15. ISSN: 2193-4126
13. Abdelkader, R. M. M., Hamed, D. A., & Gomaa, O. M. (2024). Red cabbage extract immobilized in bacterial cellulose film as an eco-friendly sensor to monitor microbial contamination and gamma irradiation of stored cucumbers. Journal of Polymers and the Environment, 32(9), 4047-2. ISSN: 1566-2543.
14. Aida, F., Gueddou, A., Zerrouki, A., & Gueddou, K. (2024). Intelligent and active films with thymol and red cabbage anthocyanin for advanced fish packaging. Journal of Polymers and the Environment, 32(9), 4166. ISSN: 1566-2543.
15. **Shreenhithi, V. C., Shivani, R., Aparnna, P. S., & Pooja, K. (2024).** Development of Active Packaging by Extraction of Anthocyanin from Red Cabbage. *International Journal of Engineering Research & Technology (IJERT), 13*(5). **ISSN 2278-0181.**
16. Nadi, M., Rahmani-Cherati, T., Barani, M., Taghinezhad, E., Eskandari, M. H., & Kia, S. M. (2023). Fabrication of green colorimetric smart packaging based on basil seed gum/chitosan/red cabbage anthocyanin for real-time monitoring of fish freshness. Food Science & Nutrition, 11(3), 1157-1171. ISSN: 2048-7177.

17. Ahmad, N. A., Heng, L. Y., Salam, F., Zaid, M. H. M., & Hanifah, S. A. (2019). A Colorimetric pH Sensor Based on Clitoria sp. and Brassica sp. for Monitoring of Food Spoilage Using Chromametry. Sensors, 19(21), 4813. ISSN: 1424-8220.
18. **Sharma, A., & Pathania, S. (2021).**Advances in smart packaging for food quality assessment. *Journal of Food Science and Technology*, *58*(9), 3453–3465. **ISSN 0022-1155.**
19. Suzihaque, M. U. H., & Zamroni, N. F. B. M. (2019). Development of intelligent food packaging from red cabbage anthocyanin pigment. International Journal of Recent Technology and Engineering (IJRTE), 8(4), 6798–6802.ISSN: 2277-3878
20. Huang, X., Zhang, K., Li, Z., Zhang, J., Zhai, X., Zhang, N., Du, L., & Qin, Z. (2024). Exploring the Integration of Anthocyanins with Functional Materials in Smart Food Packaging: From Stabilization to Application. Foods, 13(16), 2533. ISSN: 2304-8158.
21. Remedio, L. N., & Parada Quinayá, C. (2024). Intelligent Packaging Systems with Anthocyanin: Influence of Different Polymers and Storage Conditions. Polymers, 16(20), 2886. ISSN: 2073-4360.
22. Cata, A., Țolea, N. S., Lazăr, A. E., Ienașcu, I. M. C., & Pop, R. (2024). Recent Advances in Sustainable Anthocyanin Applications in Food Preservation and Monitoring: A Review. Sustainability, 16(22), 10104. ISSN: 2071-1050.

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Original Article

Antioxidant Profile of Antidesma Fruits

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Manuscript ID:
JRD -2026-180404
ISSN: 2230-9578
Volume 18
Issue 4(XI)
Pp. 14-18
April - 2026
Submitted: 10 Mar. 2026
Revised: 20 Mar. 2026
Accepted: 25 Mar. 2026
Published: 30 April2026

Abstracts

Antidesma Burm. ex L. is a dioecious plant that belongs to the family Euphorbiaceae. The fruits are globose to ellipsoid and resemble a drupe. Fruits are edible and medicinally important. Within the present investigation, antioxidant analyses of fruits were studied by various assays. The extraction of fruit was done as per the need of the assay. The methanolic extract of mature and ripened fruits was used for free radical scavenging antioxidant investigation.

In non-enzymatic antioxidant analyses, ripened fruits of A. acidum and A. ghaesembilla show higher content of carotenoids. Ascorbic acid content was high in mature fruits of A. acidum and A. ghaesembilla (103 ± 0.00 mg/100g and 90 ± 0.00 mg/100g). The α-tocopherol content is comparatively high in mature and ripened fruits of A. acidum 33.67 ± 0.00 mg/100g, 53.98 ± 0.00 mg/100g. In assays of free radical scavenging activity was found that antioxidant activity increases with an increase in concentration of the extract. DPPH, FRAP and ferrous ion chelating ability of mature fruits are high, while higher reducing and total antioxidant capacity is represented by ripened fruits. In the enzymatic antioxidant analyses higher catalase and peroxidase are characterize by mature fruits and high superoxide dismutase activity by ripened fruits. Antioxidant profile of fruits represents its therapeutic property therefore it could be helpful in preparation of medicine as well as food ingredient.

Key words: *Antidesma, fruits, enzymatic, nonenzymatic antioxidant, free radicals scavenger analysis.*

Introduction

The genus *Antidesma* Burm. ex L. belongs to family Euphorbiaceae. It is a dioecious plant commonly found in tropical rain forest and in shrubby vegetation. The globose to ellipsoid fruits resemble a drupe. Their colour vary from green to red and black. The fleshy and juicy fruits are edible with a sour to sweet taste. Fruits are used as Ranmeva; mature and ripened fruits are edible. Traditionally the mature fruits are used for the preparation of pickles and ripened fruits are used fresh as well to prepare juice, jam and jelly. The dried, ripened fruits used to prepare Borkut (Fruit Powder). The fruits have traditional medicinal value and were used in various diseases like blood dysentery, muscular pain, pneumonia, dropsy, venereal diseases and rabies dog (Adhikari *et al.*, 2007). Due to these therapeutic properties, fruits of *Antidesma acidum* Retz. and *Antidesma ghaesembilla* Gaertn. were selected for the present work.

Materials And Methods

I. Non- Enzymatic antioxidants

The carotenoids were estimated by following the method of Kirk and Allen (1965). The method of Folin and Denis (1915) was followed to determine the total polyphenol content. Total polyphenols were calculated with the help of a standard curve of tannic acid (0.1 mg/ml). The method of Omaye *et al*. (1979) followed for analysis of ascorbic acid content. α-Tocopherol activity of fruit was evaluated through the method of Backer *et al*. (1980); results were compared against the α- tocopherol standard graph.

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DOI: 10.5281/zenodo.21102458
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How to cite this article:
Panaskar, P. (2026). Antioxidant Profile of Antidesma Fruits. Journal of Research and Development, 18(4(XI)), 14–18. https://doi.org/10.5281/zenodo.21102458

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II. Free radical scavenging and antioxidant activity of plant material

A Methanolic extract of fruits was used to analyze free radical scavenging activity. The method of Lee et al. (2003) was followed to evaluate the percentage (%) of free radical scavenging activity through 1, 1-diphenyl-2-picrylhydrazyl (DPPH). The Benzie and Strain (1996) method was followed to find ferric reducing antioxidant power (FRAP). Ferrous ion chelating ability was determine by using the Decker and Welch (1990) method**.** According to Oyaizu (1986), reducing the power of methanolic extract of fruits was determined. The total antioxidant capacity of methanol extracts of fruits was evaluated by the method of Prieto *et al.* (1999). The results were expressed as equivalents of ascorbic acid.

III. Enzymatic Antioxidants

Catalase activity of fruits was evaluated by following the method of Luck (1974) as described by Sadasivam and Manikam (1992). The enzyme activity of catalase was expressed as units ΔOD/min/mg protein, as described by Bergmeyer (1974). Peroxidase activity was measured as per the method of Maehly (1954), and the Giannopolitis and Ries (1977) method was followed to determine superoxide dismutase activity. The enzyme activity was expressed as ΔOD/min/mg protein. Albumin (0.1 mg/ml) was used for the preparation of the standard curve of protein.

Results and Discussion

In higher plants the antioxidant systems are characterized by non-enzymatic, enzymatic and free radical scavenging antioxidants. The non-enzymatic antioxidants in plants are represented by vitamins C and E, polyphenols, flavonoids, carotenoids, glutathione, isoprenoids, ubiquinone, and plastoquinone (Rudenko et al., 2023). The enzymatic antioxidant revealed by catalase, peroxidase and superoxide dismutase. 'Free radical scavenging activity refers to antioxidants' ability to neutralise harmful reactive oxygen species (ROS) and free radicals, thereby preventing oxidative stress, cellular damage, and disease. This process typically involves electron or hydrogen atom transfer, which is measured using DPPH, ABTS, or FRAP assays to assess the antioxidant potential of natural compounds, food, or drugs' (Baliyan et al., 2022). As a result, the antioxidant capacity of *A. acidum* and *A. ghaesembilla* fruits was assessed in various ways. It was discovered that the fruits had significant antioxidant potential.

I. Non enzymatic antioxidants

Mature and ripened fruits of *A. acidum* show 4.06 ± 0.00 mg/100g and 6.33 ± 0.05 mg/100g and *A. ghaesembilla* shows 4.02 ± 0.23 mg/100g and 7.55 ± 0.00 mg/100g carotenoids. Comparatively in both species, ripened fruits have higher concentrations of carotenoids (Fig.1). It may be due to variation in the colour of ripen fruits. A relatively same quantity of total polyphenols was found in mature and ripened fruits of *A. acidum* (219 ± 0.00 mg/100g and 212 ± 0.00 mg/100g) and *A. ghaesembilla* (236 ± 0.01 mg/100g and 229 ± 0.00 mg/100g). High amount of ascorbic acid was found in mature fruits of *A. acidum* and *A. ghaesembilla* (103 ± 0.00 mg/100g and 90 ± 0.00 mg/100g) than in the ripened fruits (90 ± 0.00 mg/100g and 74.40 ± 0.00 mg/100g). Maybe the sour test of fruits is due to higher ascorbic acid in mature fruits. The α-tocopherol content is more in mature and ripened fruits of *A. acidum* 33.67 ± 0.00 mg/100g, 53.98 ± 0.00 mg/100g than in *A. ghaesembilla* 26.99 ± 0.00 mg/100g, 50.51 ± 0.00 mg/100g.

II. Free radical scavenging and antioxidant activity of fruits

Free radical scavenging activity of fruit was analyzed by a number of assays. Higher percent inhibition of DPPH was shown by mature and ripened fruits of *A. acidum* (70.24 ± 0.001 and 75.94 ± 0.001) and *A. ghaesembilla* (61.68 ± 0.004 and 85.25± 0.001) at 100 µg/ml (Fig. 2). The ferric reducing antioxidant power of mature and ripened fruits of *A. acidum* 0.84 ± 0.004 AAE/g and 0.90 ± 0.002 AAE/g was lower than the *A. ghaesembilla* 1.24 ± 0.004 AAE/g and 1.28 ± 0.031 AAE/g (ascorbic acid equivalent per gram) shows at 1 mg/ml extract (Fig. 3). Comparatively the mature and ripened fruits of *A. acidum* 46.88 ± 0.01% and 46.34 ± 0.01% and *A. ghaesembilla* 43.59 ± 0.07% and 38.61 ± 0.02% show high percent ferrous ion scavenging activity at 1 mg/ml than the ascorbic acid (Fig. 4). More reducing power of mature and ripened fruits was recorded at 0.5 mg/ml extract of *A. acidum* 0.617 ± 0.001 and 0.926 ± 0.001 and *A. ghaesembilla* 0.732 ± 0.001 and 0.865 ± 0.001 (Fig. 5). Total antioxidant capacity of fruits is represented in Fig. 6. The graph shows the total antioxidant capacity of fruit extract was increased by the increasing concentration of extract.

All assays of free radical scavenging activity denote that if the concentration of the extract increases the percent of antioxidant capacity gets increased. Mature fruits of both species show a higher percentage of DPPH, FRAP and ferrous ion chelating ability, while ripened fruits represent higher reducing and total antioxidant capacity. It may be due to the higher concentration of ascorbic acid and polyphenols in mature fruits.

III. Enzymatic antioxidants

The enzymatic antioxidant profile of fruits represents higher catalase and peroxidase in mature fruits while having higher superoxide dismutase activity in ripened fruits. The mature and ripened fruits of *A. acidum* were show 0.22 ± 0.00 ΔOD/min/mg protein, 0.18 ± 0.00 ΔOD/min/mg protein, *A. ghaesembilla* mature and ripened fruits were show 0.21 ± 0.00 ΔOD/min/mg protein, 0.18 ± 0.00 ΔOD/min/mg protein catalase activity. Whereas the mature and ripened fruits of *A. acidum* were show 0.16 ± 0.01 ΔOD/min/mg protein, 0.13 ± 0.001 ΔOD/min/mg protein, *A. ghaesembilla* mature and ripened fruits exhibited 0.15 ± 0.00 ΔOD/min/mg protein, 0.10 ± 0.001 ΔOD/min/mg protein peroxidase activity. The mature and ripened fruits of *A. acidum* were show 0.015 ± 0.001 ΔOD/min/mg protein, 0.032

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± 0.00 ΔOD/min/mg protein superoxide dismutase, while *A. ghaesembilla* mature and ripened fruits were revealed 0.021 ± 0.001 ΔOD/min/mg protein, 0.032 ± 0.001 ΔOD/min/mg protein superoxide dismutase activity.

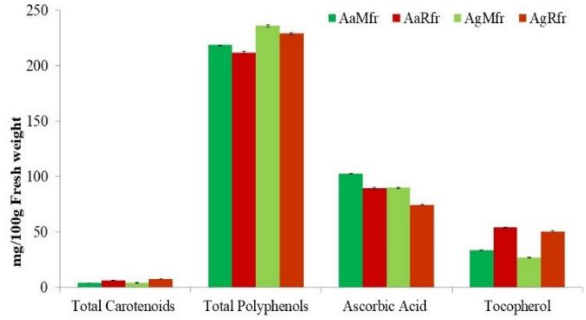

Fig. 1. Non enzymatic antioxidant analysis of fruits of *Antidesma species*.

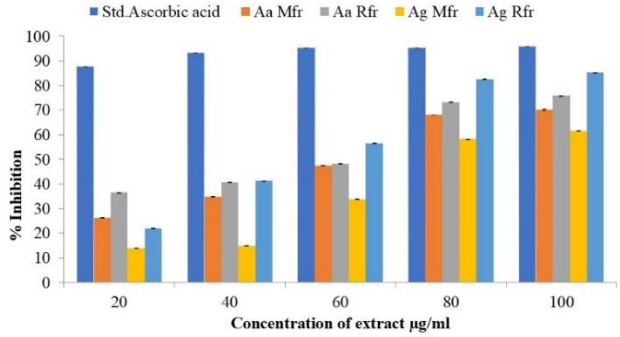

Fig. 2. DPPH radical scavenging activity of fruits of *Antidesma species*.

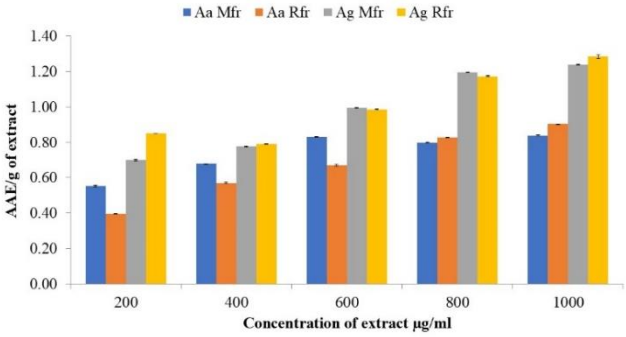

Fig. 3. Ferric reducing antioxidant power (FRAP) of fruits of *Antidesma species*.

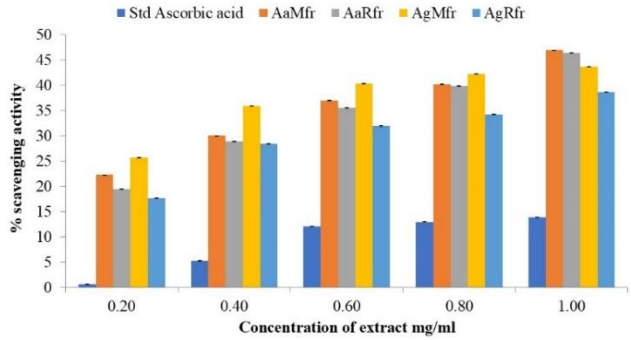

Fig. 4. Ferrous ion chelating ability of fruits of *Antidesma species*.

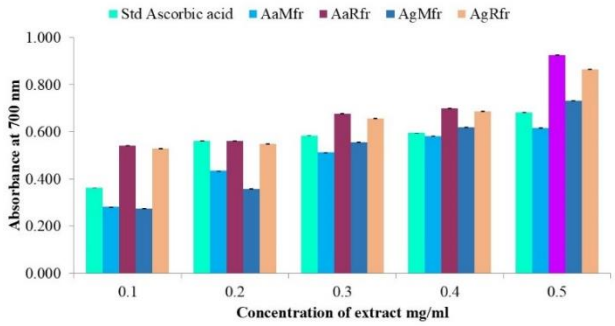

Fig. 5. Reducing power assay of fruits of *Antidesma species*.

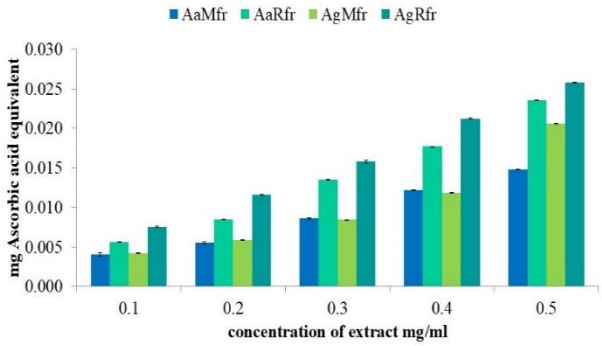

Fig. 6. Total antioxidant capacity of fruits of *Antidesma species*.

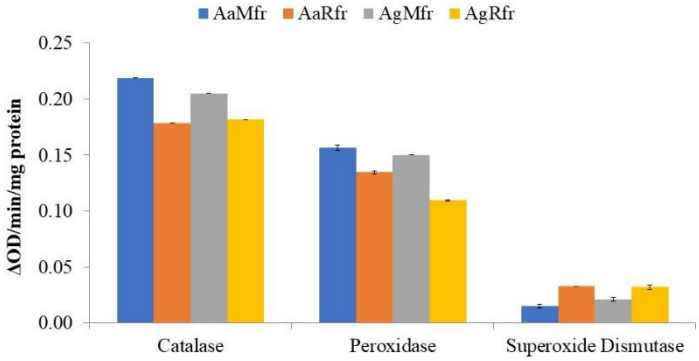

Fig. 7. Enzymatic antioxidant analysis of fruits of *Antidesma species*.

(AaMfr- *A. acidum* mature fruits, AaRfr- *A. acidum* ripened fruits, AgMfr- *A. ghaesembilla* mature fruits and AgRfr- *A. ghaesembilla* ripened fruits)

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Discussion

Present investigated fruits of *A. ghaesembilla* represents more carotenoid content than the mature and ripened fruits of *A. ghaesembilla* studied by Valvi *et al*. (2014). It may be due to vary place and soil fertility. Optimum quantity of total carotenoids reported in the *A. velutinosum* Blume. (Judprasong *et al*., 2013), *A. Acidum* (Patil and Jadhav, 2017) fruits. Sripakdee *et al*. (2015) stated the ascorbic acid content in *A. thwaitesianum* Mull. Arg. was more and *A. bunius* S. (Khomdram and Devi, 2010) was lower than the present investigated fruits. Fruits of *A. bunius* S. (Butkhup and Sampaio, 2008, Butkhup and Samappito, 2011), *A. ghaesembilla* (Basak *et al.*, 2013) *A. thwaitesianum* Mull. Arg. (Sripakdee *et al.*, 2015, Puangpronpitag *et al*., 2008, Hansakul *et al*., 2015, Dechayont *et al.*, 2012), *A. acidum* (Nayak and Basak, 2015) *A. velutinosum* Blume. (Judprasong *et al*., 2013, Jorjong *et al*., 2015) have high DPPH and FRAP activity. The antioxidant activity of fruit juice of different species exhibited DPPH and $ABTS^+$ radical scavenging and ferric-reducing activities (Tinchan et al., 2022, Nguyen-Ngoc et al., 2024). The results noted in different areas for same assay and for same plant part was vary.

Conclusion

The antioxidant analysis of mature and ripened fruits of both species of *Antidesma* represents the potential source of antioxidants. It may be due to the higher vitamins, enzymes, free radical scavengers and polyphenolic content in fruits. Plant represents its therapeutic value in traditional medicine as well diets. Therefore, fruits of *Antidesma* could be a source of natural antioxidant for food sources and medicine.

References

1. Adhikari, B. S., Babu, M. M., Saklani, P. L. And Rawat, G. S. (2007). Distribution, use pattern and prospects for conservation of medicinal shrubs in Uttaranchal state, India. *J. Mountain Sci*. **4 (**2): 155-180.
2. Backer, H., Frank, O., De Angells, B. and Feingold, S. (1980). Plasma tocopherol in man at various times after ingesting free or ocetylaned tocopherol. *Nutrition Reports Int*. **21**: 531-536.
3. Baliyan S, Mukherjee R, Priyadarshini A, Vibhuti A, Gupta A, Pandey RP, Chang CM. Determination of Antioxidants by DPPH Radical Scavenging Activity and Quantitative Phytochemical Analysis of Ficus religiosa. Molecules. 2022 Feb 16;27(4):1326. doi: 10.3390/molecules27041326. PMID: 35209118; PMCID: PMC8878429
4. Basak, U. C., Mahapatra, A. K. and Mishra, S. (2013) Assessment of protective antioxidant mechanisms in some ethno- medicinally important wild edible fruits of Odisha, India. *Agrotechnol.* **2** (3): 1-4.
5. Benzie, I. F. F. and Strain, J. J. (1996). The ferric reducing ability of plasma (FRAP) as a measure of "antioxidant power: the FRAP assay. *Analytical Biochem.* **239**: 70–76.
6. Bergmeyer, H. U. (1974): Methods of enzymatic analysis. Second edition Academic Press, London: 727–773.
7. Butkhup, L. and Samappito, S. (2008). Analysis of anthocyanin, flavonoids, and phenolic acids in Tropical Bignay Berries. *Int. J. Fruit Sci.* **8 (**1-2): 15-34.
8. Butkhup, L., and Samappito, S. (2011). Changes in physico-chemical properties, polyphenol compounds and antiradical activity during development and ripening of maoluang (*Antidesma Bunius* L. Spreng) fruits. J. *Fruit Ornamental Plant Res*. **19** (1): 85-99.
9. Dechayont, B. Hansakul, P. and Itharat, A. (2012). Comparison of antimicrobial, antioxidant activities and total phenolic content of *Antidesma thwaitesianum* fruit extracts by different methods. *J. Med. Assoc. Thai*. **95** (1): 147-153.
10. Decker, E. A. and Welch, B. (1990). Role of ferritin as a lipid oxidation catalyst in muscle food. *J. Agric. Food Chem*. **38**: 674-677.
11. Folin, O. and Denis, W. (1915). A colorimetric estimation of phenols (and phenolic derivatives) in urine. J. Bio. Chem. 22: 305-308.
12. Giannopolitis, C. N. and Reis, S. K. (1977). Superoxide dismutase I. Occurrence in higher plants. Plant Physio. 59: 309-314.
13. Hansakul, P., Dechayont, B., Phuaklee, P., Prajuabjinda, O., Juckmeta, T. and Itharat, A. (2015). Cytotoxic and antioxidant activities of *Antidesma thwaitesianum* Mull. Arg. (Euphorbiaceae) fruit and fruit waste extracts. *Trop. J. Pharma. Res*. **14** (4): 627-634.
14. Jorjong, S., Butkhup, L. and Samappito, S. (2015). Phytochemicals and antioxidant capacities of Mao-Luang (*Antidesma bunius* L.) cultivars from Northeastern Thailand. *Food Chem.* **181**: 248- 255.
15. Judprasong, K., Charoenkiatkul, S., Thiyajai, P. and Sukprasansap, M. (2013). Nutrients and bioactive compounds of Thai indigenous fruits. *Food Chem.* **140**: 507–512.
16. Khomdram, S. and Devi, G. A. (2010). Determination of antioxidant activity and vitamin C of some wild fruits of Manipur. *The Bioscan.* **5** (3): 501-504.
17. Kirk, J. O. T. and Allen, R. L. (1965). Dependance of chloroplast pigment on actidione *Arch. Biochem. Biophys. Res. Commun*. **21**: 523-530.
18. Lee, H. C., Kim, J. H., Jeong, S. M., Kim, D. R., Ha, J. U. and Nam, K. C. (2003). Effect of far infrared radiation on the antioxidant activity of rice hulls. *J. Agri. Food Chem.* **51** (15): 4400–4403.
19. Luck, H. (1974). In: methods in enzymatic analysis. II (ed.) Bergmeyer. (Publ.) Academic Press, New York.: 885.

20. Maehly, A. C. (1954). Methods in biochemical analysis (Ed.) Glick D. (Publ.) Interscience publishers Inc. New York: 385-386.
21. Nayak , J. and Basak, U. C. (2015). Antioxidant potential of some lesser known wild edible fruits of Odisha. *European J. Experimental Bio.* **5** (8): 60-70.
22. Nguyen-Ngoc H, Le-Thi-Phuong T, Vu-Van T, Pham-Ha-Thanh T, Nguyen-Huu T. Phytochemical and Pharmacological Review of the Genus Antidesma. *Natural Product Communications*. 2024;19(4). doi:10.1177/1934578X241247990
23. Omaye, S. T., Turnbull, J. D. and Sauberlich, H. E. (1979). Selected methods for the determination of ascorbic acid in animal cells, tissues and fluids. *Methods in Enzymology.* **62**: 3-11.
24. Oyaizu, M. (1986). Studies on products of browning reactions: Antioxidative activities of products of browning reaction prepared from glucosamine. *Jpn. J. Nutri*. **44**: 629-632.
25. Patil, P. and Jadhav V. (2017). Nutritional and Antioxidant Assessment of Fruits of *Antidesma acidum* Retz. IJPPR Human, **8** (3): 151-163.
26. Prieto, P., Pineda, M. and Aguilar, M. (1999). Spectrophotometric quantification of antioxidant capacity through the formation of phosphomolybdenum complex: specific application to the determination of vitamin E. *Anal Biochem*, **269**: 337-341.
27. Puangpronpitag, D., Areejitranusorn, P., Boonsiri, P., Suttajit, M. and Yongvanit, P. (2008). Antioxidant activities of polyphenolic compounds isolated from *Antidesma thwaitesianum* Mull. Arg. seeds and marcs. *J. Food Sci.* **73** (9): 648- 653.
28. Rudenko NN, Vetoshkina DV, Marenkova TV, Borisova-Mubarakshina MM. Antioxidants of Non-Enzymatic Nature: Their Function in Higher Plant Cells and the Ways of Boosting Their Biosynthesis. Antioxidants (Basel). 2023 Nov 17;12(11):2014. doi: 10.3390/antiox12112014. PMID: 38001867; PMCID: PMC10669185.
29. Sadashivam, S. and Manikam, A. (1992). Biochemical method for agricultural sciences, Willey, Eastern Ltd.: 105.
30. Sripakdee, T., Sriwicha, A., Jansam, N., Mahachai, R. and Chanthai, S. (2015). Determination of total phenolics and ascorbic acid related to an antioxidant activity and thermal stability of the Mao fruit juice. *Int. Food Res. J*. **22** (2): 618-624.
31. Tinchan P, Sirijariyawat A, Prommakool A, Phattayakorn K, Pheungsomphane S, Tayuan C. *Antidesma thwaitesianum* Müll. Arg. Fruit Juice, Its Phytochemical Contents, Antimicrobial Activity, and Application in Chiffon Cake. Int J Food Sci. 2022 Jan 28; 2022:5183562. doi: 10.1155/2022/5183562. PMID: 35127933; PMCID: PMC8816606.
32. Valvi, S. R., Jadhav, V. D., Gadekar, S.S. and Yesane, D. P. (2014). Assessment of bioactive compounds from five wild edible fruits, *Ficus racemosa, Elaegnus conferta, Grewia tillifolia, Scleichera oleosa* and *Antidesma ghaesembilla. Acta. Biologica*. **3** (1): 549- 555.

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Original Article

Assessment of Urban Noise Pollution Impact on Plant Growth & Physiological Responses in Metropolitan Zones

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Manuscript ID:
JRD -2026-180405
ISSN: 2230-9578
Volume 18
Issue 4(XI)
Pp. 19-24
April - 2026
Submitted: 10 Mar. 2026
Revised: 20 Mar. 2026
Accepted: 25 Mar. 2026
Published: 30 April2026

Abstract
Urban noise pollution is an emerging environmental stressor that not only affects human health but also influences plant growth and physiology. Plants, though lacking auditory systems, respond to mechanical vibrations and environmental stress through biochemical and physiological changes. The present study investigates the temporal variation of noise levels in a metropolitan traffic zone and evaluates its impact on selected plant species.
The present study investigates the temporal variation of sound levels by use of across different time intervals in a metropolitan traffic zone and evaluates its statistical significance using advanced analytical approaches. A calibrated digital sound level meter was employed to record decibel (dB) values at multiple intervals during peak and non-peak hours. Simultaneously, plant parameters such as leaf area, chlorophyll content, stomatal frequency and growth rate were analyzed in plants exposed to varying noise intensities The collected data were analyzed using descriptive statistics and one-way Analysis of Variance (ANOVA) to determine significant fluctuations in noise intensity and confirmed significant variation in noise levels and corresponding plant responses. This study highlights the ecological significance of noise pollution and emphasizes the need for integrating green infrastructure in urban planning.
Keywords: *Noise Pollution, Plant Physiology, ANOVA, Environmental Stress.*

Introduction

Sound is a fundamental physical phenomenon that plays a vital role in the functioning of natural and human-made environments. It is defined as a mechanical longitudinal wave that propagates through a medium such as air, water, or solids by means of particle vibrations. However, when sound exceeds acceptable limits or becomes unwanted, it transforms into noise, thereby contributing to what is known as noise pollution (Basner *et. al*., 2014). Despite its intangible nature, noise pollution has profound impacts on human health, psychological well-being and environmental stability. It is increasingly recognized as a major environmental stressor in modern urban societies, particularly in rapidly developing metropolitan regions (World Health Organization [WHO], 2018). Plants perceive mechanical vibrations caused by sound waves, which can influence cellular processes, gene expression and hormonal balance. Studies suggest that prolonged exposure to high-intensity sound can: alter membrane permeability, affect enzyme activity, disrupt photosynthesis, and modify growth patterns.

Urban plants, particularly roadside vegetation, are constantly exposed to fluctuating noise levels. These plants serve as natural buffers, reducing pollution and improving air quality. However, continuous exposure to high decibel levels may reduce their efficiency and survival. The intensity of sound is measured in decibels (dB), a logarithmic unit that quantifies sound pressure levels. The human ear is capable of detecting sounds ranging from 0 dB (threshold of hearing) to approximately 140 dB (threshold of pain). However, prolonged exposure to sound levels above 70 dB can lead to adverse health effects, while exposure above 85 dB significantly increases the risk of hearing impairment (Basner *et al*., 2014).

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How to cite this article:
Kumar, A. (2026). Assessment of Urban Noise Pollution Impact on Plant Growth & Physiological Responses in Metropolitan Zones. Journal of Research and Development, 18(4(XI)), 19–24. https://doi.org/10.5281/zenodo.21102671

Quick Response Code:
Website:
https://jrdrvb.org/
DOI:
10.5281/zenodo.21102671
OPEN ACCESS

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

International organizations such as the World Health Organization (WHO) have established guidelines to regulate permissible noise levels in different environments. For instance, recommended limits for residential areas are typically 55 dB during the day and 45 dB at night, beyond which negative health effects may arise (WHO, 2018).
Auditory effects primarily include temporary or permanent hearing loss, tinnitus, and acoustic trauma. Non-auditory effects, on the other hand, encompass a wide range of physiological changes in plants. While, psychological consequences such as increased blood pressure, cardiovascular diseases, sleep disturbances, annoyance, reduced concentration and impaired cognitive performance (Stansfeld & Matheson, 2003).
Recent studies have highlighted the association between chronic noise exposure and cardiovascular health risks. Prolonged exposure to high noise levels can trigger stress responses in the human body, leading to the release of stress hormones such as cortisol and adrenaline. This, in turn, can result in hypertension, increased heart rate and long-term cardiovascular complications (Basner et al., 2014).

Apart from human health, noise pollution also has significant ecological consequences. Excessive noise can interfere with these signals, leading to behavioural changes, habitat displacement and reduced reproductive success. Thus, noise pollution is not only a human health concern but also a critical ecological issue that affects biodiversity and ecosystem stability. Noise levels are typically higher during peak traffic hours in the morning and evening, while relatively lower during midday or late-night periods.
The concept of temporal variability in noise pollution is gaining increasing attention in recent research. By analysing noise levels across different time intervals, researchers can obtain a more comprehensive understanding of noise patterns and identify critical periods of exposure. These modern digital sound level meters are equipped with high sensitivity and wide frequency response ranges, allowing precise measurement of sound intensity. Furthermore, statistical tools such as Analysis of Variance (ANOVA) are widely used to assess the significance of variations in noise levels across different conditions or time periods. These analytical techniques provide a scientific basis for evaluating noise pollution and formulating effective mitigation strategies.
In the context of developing countries, the problem of noise pollution is particularly severe due to rapid urban growth, inadequate infrastructure, and lack of strict regulatory enforcement. Metropolitan cities often experience noise levels that exceed permissible limits by a significant margin. Factors such as unregulated traffic, frequent use of horns, construction activities, and social events contribute to the escalation of noise pollution. Public awareness regarding the harmful effects of noise is also relatively low, further exacerbating the problem (Singh & Davar, 2004).

The present study aims to contribute to the existing body of knowledge by focusing on the temporal dynamics of sound pollution in an urban environment. Unlike conventional studies that rely on static measurements, this research emphasizes time-based variability in noise levels, providing a more realistic representation of urban noise patterns. By integrating field measurements with statistical analysis, the study seeks to evaluate the significance of variations in noise levels across different time intervals.
The study aims to compare observed noise levels with internationally recommended standards and assess their potential implications on plants growth. It underscores the importance of recognizing noise pollution as a critical environmental issue and highlights the need for sustainable solutions to mitigate its impact on phyto-systems.

Material and Methods

The study was conducted in a busy urban roadway zone characterized by continuous vehicular movement and moderate pedestrian activity. A digital Sound Level Meter with an approximate range 30 dB – 130 dB of responding frequency 20 Hz – 10 kHz was used to determine the sound. The instrument was pre-calibrated before measurements.
The noise levels were recorded at three different time intervals with a set of triplets between the following periodical

a) Morning (8:00 AM – 10:00 AM).
b) Afternoon (1:00 PM – 3:00 PM)
c) Evening (6:00 PM – 8:00 PM)

The common roadside plants such as ***Azadirachta indica, Ficus religiosa*** **and** ***Polyalthia longifolia*** were selected and analyzed for its Leaf area measurement, Chlorophyll content (SPAD method), Stomatal frequency (microscopic analysis), Growth rate (height increment).
Observations were noted at consistent intervals around 7 days to ensure reliability. The statistical study was performed followed by graphical representation (bar graph) and a One-way ANOVA used to test significance followed with the plant response towards the sound pollution.

Results

The below is the observation of the experiment; Table 1 carried out to determine the noise pollution with the help of Digital Sound meter followed by the calculation of One-way ANOVA, test of significance mentioned in Table 3. The Table 2 represents the data of observations noted through experimentation of plants response towards the noise stress followed by a mean value presented with results in Table 4 and Table 5. The graphical presentation

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

of Table 1 presented in Figure 1. The Standard reference study is presented in Table 6, Table 7, Table 8, Table 9, Table 10 and Table 11.

Sr. No	Morning (dB)	Afternoon (dB)	Evening (dB)	Mean (dB)
1	72.5	68.3	80.2	73.6
2	74.1	70.5	82.6	75.7
3	73.8	69.2	81.3	74.8
4	75.0	71.1	83.5	76.5
5	72.9	68.9	80.8	74.2

Table 1: Periodical observation of Sound by use of Digital sound meter

Parameter	Unit	Morning (72–75 dB)	Afternoon (68–71 dB)	Evening (80–83 dB)
Chlorophyll Content	SPAD Units	38.6 ± 2.0	42.5 ± 2.1	34.2 ± 1.8
Leaf Area	cm^2	49.2 ± 3.2	52.8 ± 3.5	45.6 ± 2.9
Stomatal Frequency	No./mm^2	255 ± 14	285 ± 15	230 ± 12
Growth Rate	cm/week	3.2 ± 0.3	3.8 ± 0.4	2.6 ± 0.3

Table 2: Plant response under noise

One-Way ANOVA at α= 0.05 Level of significance					
Source of Variation	SS	df	MS	F-value	F - Critical value
Between Groups	82.45	2	41.22	**5.67**	**3.89**
Within Groups	65.30	12	5.44		
Total	147.75	14			

Table 3: One Way ANOVA to determine the level of significance

Parameter	Low Noise	High Noise
Chlorophyll Content (SPAD)	42.5	34.2
Leaf Area (cm^2)	52.8	45.6
Stomatal Frequency (no./mm^2)	285	230
Growth Rate (cm/week)	3.8	2.6

Table 4: Mean value of the plant response towards the noise stress

Parameter	Low Noise	High Noise
Chlorophyll Content	High	Reduced
Leaf Area	Normal	Slight reduction
Stomatal Frequency	Stable	Irregular
Growth Rate	Optimal	Reduced

Table 5: Plant Response observations towards the mean value obtained with reference to Standard scales and records.

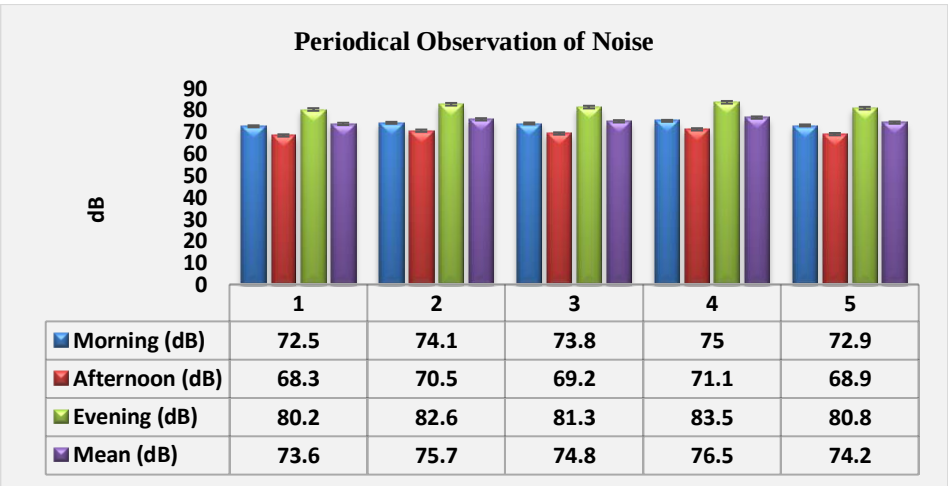

Figure 1: Graphical presentation of the observed values

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

(Basner *et. al.*, 2014 & World Health Organization, 2018)

Noise Level (dB)	Impact
50–60	Mild discomfort
60–70	Annoyance
70–80	Increased stress
80–90	Hearing risk on prolonged exposure
>90	Severe hearing damage

Table 6: Health Impact Analysis

(World Health Organization, 2018 & Central Pollution Control Board (CPCB), 2000)

Environment	Recommended Limit (dB)
Residential (Day)	55 dB
Residential (Night)	45 dB
Commercial	65 dB
Industrial	75 dB

Table 7: Standards and Guidelines

SPAD Value	Interpretation
> 45	Very High (Healthy plant)
40 – 45	Optimal
30 – 40	Moderate stress
< 30	Severe stress

Table 8: Standard scale for chlorophyll content

% Reduction	Interpretation
0–5%	Normal
5–15%	Mild stress
15–30%	Moderate stress
>30%	Severe stress

Table 9: Standard scale for % reduction in leaf area

Range (no./mm^2)	Interpretation
260–300	Normal
220–260	Mild stress
180–220	Moderate stress
<180	Severe stress

Table 10: Standard range for stomatal frequency

Growth Rate (cm/week)	Interpretation
>3.5	Optimal
2.5–3.5	Moderate
1.5–2.5	Reduced
<1.5	Severely inhibited

Table 11: Standard reference for growth rate of plant

The recorded noise level data presented in Table 1 reveals a clear pattern of variation in sound intensity across different time intervals of the day. The observations indicate that noise levels during the morning hours ranged between 72.5 dB and 75.0 dB, reflecting moderate traffic activity typically associated with the beginning of daily urban routines. In contrast, the afternoon readings showed comparatively lower noise levels, ranging from 68.3 dB to 71.1 dB, which can be attributed to a temporary reduction in vehicular movement and human activity during mid-day hours. However, a significant increase in noise intensity was observed during the evening period, where values ranged from 80.2 dB to 83.5 dB, representing the peak of traffic congestion and heightened urban activity.

The calculated mean values further support this trend, with overall average noise levels ranging between 73.6 dB and 76.5 dB across all observations. These values consistently exceed the recommended permissible limits for residential and urban environments, indicating a persistent presence of noise pollution in the study area. The comparatively higher evening noise levels suggest that this period poses the greatest risk for prolonged exposure and associated health impacts. Overall, the table demonstrates not only the elevated levels of environmental noise but also highlights the importance of considering temporal variability in assessing urban sound pollution.

The One-Way ANOVA analysis presented in Table 2 was conducted to determine whether the differences in recorded noise levels across morning, afternoon, and evening time intervals are statistically significant. The calculated F-value (5.67) is greater than the F-critical value (approximately 3.89 at 0.05 level of significance), indicating that the variation among group means is not due to random chance. Furthermore, the P-value (approximately 0.018) is less than the standard significance level of 0.05, which provides strong statistical evidence against the null hypothesis.

Since the calculated F-value exceeds the F-critical value and the P-value is less than 0.05, the null hypothesis is rejected, and the alternative hypothesis is accepted. This confirms that there is a statistically significant difference in noise levels

across different time periods of the day affecting the plants condition. The analysis clearly demonstrates that temporal variation plays a crucial role in sound pollution dynamics, with certain time intervals—particularly the evening—showing significantly higher noise levels. This statistical validation strengthens the reliability of the observed data and supports the conclusion that urban noise pollution is influenced by time-dependent human activities.

The results demonstrate that sound pollution in urban environments is not constant but varies significantly with time, as clearly observed in the recorded data. Peak noise levels during evening hours are primarily due to increased vehicular density and human activity. The observed noise levels exceed recommended limits for residential and commercial areas, indicating potential environmental stress conditions. In addition to its known effects on human health, the present study provides clear evidence that noise pollution also acts as an abiotic stress factor influencing plant growth and physiological responses**.** The plant response data (Table 2 and Table 4) indicate a progressive decline in physiological efficiency with increasing noise intensity from afternoon to evening.

Chlorophyll content showed a noticeable reduction from optimal levels (42.5 SPAD units) under low noise conditions to moderate stress levels (34.2 SPAD units) under high noise exposure. This decline suggests a reduction in photosynthetic efficiency, possibly due to vibration-induced disturbance in chloroplast functioning and enzyme activity. Similarly, the observed reduction in leaf area indicates that prolonged exposure to noise may affect cell expansion and overall plant morphology**,** leading to decreased surface area for photosynthesis.

Stomatal frequency also decreased from normal to mild stress range, indicating possible disruption in stomatal regulation and gaseous exchange mechanisms. Such changes can directly affect transpiration and carbon dioxide uptake, thereby influencing plant metabolic processes. The reduction in growth rate from 3.8 cm/week to 2.6 cm/week further supports the conclusion that noise stress impacts overall plant vigor and biomass accumulation.

The intermediate values recorded during morning hours confirm that even moderate noise levels can induce partial physiological stress, though less severe than evening peak exposure. This establishes a clear gradient response pattern, where plant health declines progressively with increasing noise intensity.

The results demonstrate that sound pollution in urban environments is not constant but varies significantly with time. Peak noise levels during evening hours are primarily due to increased vehicular density and human activity. The observed noise levels exceed recommended limits for residential and commercial areas, indicating potential health risks. Continuous exposure to such levels may lead to: Hearing impairment, Psychological stress, reduced work efficiency and sleep disturbances. The study also reveals that temporal monitoring provides better insights compared to single-time measurements, making it a more effective approach for environmental assessment.

The study also highlights that roadside plants, which act as natural environmental buffers, may experience reduced efficiency under continuous exposure to urban noise. This has broader ecological implications, as compromised plant health can affect urban air purification, carbon sequestration and overall ecosystem stability. Furthermore, the findings emphasize that temporal monitoring provides better insights compared to single-time measurements, not only for noise assessment but also for understanding dynamic plant-environment interactions.

Conclusion

The study confirms that urban noise pollution is a significant environmental concern with clear temporal variability and measurable impacts on plant systems. Noise levels recorded in the study area consistently exceed recommended safety limits, particularly during evening hours, indicating persistent environmental stress conditions.

The integration of plant physiological analysis reveals that noise pollution adversely affects key growth parameters, including chlorophyll content, leaf area, stomatal frequency and growth rate. The observed decline in these parameters under high noise conditions demonstrates that plants respond to sound as a form of mechanical and environmental stress, leading to reduced physiological efficiency and growth performance.

Statistical analysis validates that these variations are significant and not random, confirming a direct relationship between noise intensity and plant stress response. The gradient pattern observed from afternoon (optimal conditions) to evening (high stress) further supports the concept of noise as a time-dependent ecological stressor.

These findings highlight that urban vegetation, particularly roadside plants, may gradually lose their functional efficiency when exposed to continuous high noise levels. This can have long-term implications on urban ecological balance, environmental sustainability, and green infrastructure performance. The study emphasizes that noise pollution requires integrated management strategies for sustainable urban development followed by an implementation of strict environmental policies

References

1. Basner M., Babisch, W., Davis, A., Brink, M., Clark, C., Janssen, S., & Stansfeld, S. (2014). Auditory and non-auditory effects of noise on health. *The Lancet, 383*(9925), 1325–1332.
2. Shannon, G., McKenna, M. F., Angeloni, L. M., Crooks, K. R., Fristrup, K. M., Brown, E., Warner, K. A., Nelson, M. D., White, C., Briggs, J., McFarland, S., & Wittemyer, G. (2016). A synthesis of two decades of research documenting the effects of noise on wildlife. *Biological Reviews, 91*(4), 982–1005.
3. Singh, N., & Davar, S. C. (2004). Noise pollution—Sources, effects and control. *Journal of Human Ecology, 16*(3), 181–187.

4. Stansfeld, S. A., & Matheson, M. P. (2003). Noise pollution: Non-auditory effects on health. *British Medical Bulletin, 68*(1), 243–257.
5. World Health Organization. (2018). *Environmental noise guidelines for the European region*. WHO Regional Office for Europe.

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Original Article

Banana Peel-Derived ZnO Nanoparticles: Characterization and Evaluation of Antioxidant, Antimicrobial, and Water Treatment Efficiency

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Manuscript ID:
JRD -2026-180406
ISSN: 2230-9578
Volume 18
Issue 4(XI)
Pp. 25-37
April - 2026
Submitted: 10 Mar. 2026
Revised: 20 Mar. 2026
Accepted: 25 Mar. 2026
Published:30 April2026

Abstract:
Zinc oxide (ZnO) nanoparticles were synthesized using banana peel extract via an eco-friendly green synthesis approach. The extract, rich in phytochemicals such as phenolics, flavonoids, and alkaloids, acted as natural reducing and stabilizing agents, as confirmed by phytochemical analysis.
The formation of ZnO nanoparticles was confirmed by UV–Visible spectroscopy, exhibiting a characteristic absorption peak around 287 nm. FTIR analysis revealed Zn–O bond formation along with functional groups derived from plant biomolecules, while X-ray diffraction (XRD) confirmed a crystalline hexagonal structure with nanoscale dimensions. The antioxidant potential of the synthesized nanoparticles was evaluated using DPPH and FRAP assays, demonstrating significant free radical scavenging activity and reducing power. Total phenolic content analysis further indicated the contribution of phytochemicals to the observed antioxidant activity.
The bioremediation potential was assessed using water samples, where a decrease in absorbance at 254 nm indicated effective removal of organic contaminants. Additionally, significant reductions in Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) were observed, confirming the removal of both biodegradable and non-biodegradable pollutants.
Antimicrobial activity studies revealed notable inhibitory effects against selected microorganisms.
Overall, banana peel-mediated ZnO nanoparticles present a cost-effective and sustainable approach for multifunctional applications in antioxidant activity, antimicrobial action, and water purification.
Keywords: *Green synthesis, Zinc oxide nanoparticles, Banana peel extract, Antioxidant activity, Bioremediation, Antimicrobial activity*

Introduction

Water pollution has become a major global concern due to rapid industrialization, urbanization and agricultural activities, which release a wide range of contaminants such as organic pollutants, heavy metals, and pathogenic microorganism into aquatic systems which can cause serious health and environmental issues if not treated properly. Increase in the production of wastewater has made treatment methods more important. Nanotechnology has emerged as an advanced approach for wastewater treatment. Green synthesis of nanoparticles using plant extracts has attracted interest because it is simple, non-toxic, and environmentally friendly. Banana peel, an agricultural waste, it's easily available which attracted in synthesis of nanoparticles.

Zinc oxide nanoparticles from banana peel

Banana peel, a commonly discarded agricultural waste, where nanoparticle is synthesized due to its rich phytochemical compositions such as flavonoids, phenolics and alkaloids that act as natural reducing and stabilizing agents (Al-Khaial *et al.*, 2024). Green synthesized ZnO nanoparticle has shown significant biological activities.

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How to cite this article:
Bhandary, S., cm, H., & Swarnalatha. (2026). Banana Peel-Derived ZnO Nanoparticles: Characterization and Evaluation of Antioxidant, Antimicrobial, and Water Treatment Efficiency. Journal of Research and Development, 18(4(XI)), 25–37.
https://doi.org/10.5281/zenodo.21102841

Quick Response Code:
Website:
https://jrdrvb.org/
DOI:
10.5281/zenodo.21102841

Journal of Research and Development
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ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Their antioxidant potential, commonly examined using DPPH and FRAP assay (Bhandary *et al.*, 2026) Also, their antimicrobial activity against both gram-positive and gram-negative bacteria (Pullapukuri and Kumar, 2023).

Bioremediation efficiency of zinc oxide nanoparticles in wastewater

The bioremediation efficiency of zinc oxide (ZnO) nanoparticles has significance due to their ability to e remove a pollutant from wastewater. ZnO nanoparticles possess a large surface area and strong adsorption capacity, which helps them to interact with and remove organic contaminants, and microbial pollutants present in contaminated water (Ojha *et al.*, 2021).

The effectiveness of ZnO nanoparticles in wastewater treatment is commonly examined using parameters such as biochemical oxygen demand (BOD), chemical oxygen demand (COD), and organic matter content. A significant reduction in BOD and COD values indicates the removal of both biodegradable and non-biodegradable pollutants, which shows improved water quality.

Materials and Methods

Materials and Equipment:

The following materials were used in this study: Water sample, nutrient broth, distilled water, conical flasks, Petri plates, and test tubes, BOD bottles, COD digestion condenser, muffle furnace, UV spectroscopy, burette, pH meter.

Synthesis of ZnO Nanoparticles from banana peel extract:

Preparation of Banana peel extract

Banana peels were chopped into small pieces and dried at 50–60 °C. The dried peels were ground into a fine powder. Five grams of the powder were weighed and suspended in 100 ml of distilled water. The mixture was stirred using a magnetic stirrer and then filtered to obtain the extract.

Synthesis of ZnO Nanoparticles

While stirring, 50 ml of zinc nitrate solution was added dropwise to 50 ml of the banana peel extract using a burette. The pH of the solution was adjusted to 9–10 using 1 M NaOH. The mixture was centrifuged at 3000 rpm for 10 minutes. The supernatant was discarded, and the precipitate was washed with distilled water or ethanol. The precipitate was then calcined in a muffle furnace to obtain zinc oxide nanoparticles in powder form.

BANANA PEEL POWDER ZnO NP POWDER

Characterization of synthesized zinc nanoparticles

FTIR

Confirms the synthesis of ZnO nanoparticles. It identifies the presence of hydroxyl, carbonyl, and amine functional groups from banana peel.

XRD

The synthesized zinc oxide nanoparticles were characterized by X- diffraction (XRD) which confirms the presence of crystalline hexagonal wurtzite ZnO. The observed peak broadening indicates the formation of ZnO nanoparticles in the nanometer range, while minor additional peaks may be attributed to phytochemical residues from the peel extract used in green synthesis.

UV Spectroscopy:

Confirms formation of nanoparticles and their properties. Specific absorption peak indicates Zinc oxide nanoparticles

SEM:

Using focused beam of electron to scan the surface of sample, where high energy electron hits the sample, they interact with atoms on the surface and produce different signals.

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Phytochemical Screening of Peel Extract:

Test for Alkaloids: Two milliliters of peel extract were treated with 2 drops of dilute HCl, followed by 2–3 drops of Dragendroffs reagent. The resulting color change was observed.

Test for Flavonoids (Lead Acetate Test): A few drops of 10% lead acetate were added to 2 ml of peel extract, and any color change or precipitation was noted.

Test for Phenolics: Two to three drops of ferric chloride solution were added to 2 ml of peel extract and mixed gently. Any color change was recorded.

Organic Matter Removal Study:

Zinc oxide (ZnO) nanoparticles were used to remove organic matter from water through adsorption and degradation processes. A decrease in absorbance after treatment indicated the removal of organic matter. The water samples containing organic matter were first filtered to remove suspended particles. The initial absorbance of the untreated water samples was measured at 254 nm using a UV–Visible spectrophotometer.

The water samples were then treated with different concentrations of ZnO nanoparticles (100 mg/L, 500 mg/L, and 1000 mg/L). The mixtures were stirred for 30 minutes and allowed to settle for some time. The treated samples were filtered to remove the ZnO nanoparticles, and the final absorbance was measured at 254 nm.

BOD (Biological Oxygen Demand):

Biochemical Oxygen Demand (BOD) is a measure of the amount of dissolved oxygen required by microorganisms to decompose organic matter present in water. Wastewater containing high levels of organic matter requires more oxygen for microbial degradation, and higher BOD values indicate greater organic pollution.

Wastewater samples were treated with different concentrations of ZnO nanoparticles (100 mg/L, 500 mg/L, and 1000 mg/L) and compared with an untreated sample for estimation. The mixtures were stirred continuously for 2 hours at room temperature, allowed to settle for some time, and then filtered. The filtrates were collected for BOD estimation. Burette readings were recorded on day 1 and day 5.

COD (Chemical Oxygen Demand):

Chemical Oxygen Demand (COD) measures the amount of oxygen required to chemically oxidize organic matter present in water. In this method, organic compounds were oxidized by potassium dichromate under acidic conditions. Silver sulfate acted as a catalyst, and mercuric sulfate was added to eliminate chloride interference. After digestion, the excess dichromate was titrated with ferrous ammonium sulfate (FAS) using a ferroin indicator. The difference between the blank and sample titration values indicated the amount of organic matter present. A decrease in COD value after treatment indicated the removal of organic matter.

Ten milliliters of the sample were placed in a round-bottom reflux flask with a few glass beads. One milliliter of $HgSO_4$ solution was added and mixed well, followed by 5 mL of $K_2Cr_2O_7$ solution. Fifteen milliliters of silver sulfate–sulfuric acid solution were added slowly, and a reflux condenser was attached. The mixture was digested on a hot plate for 2 hours. After digestion, the flask was allowed to cool, and the condenser was rinsed with approximately 25 mL of distilled water, collecting the rinse in the same flask. Two to four drops of ferroin indicator were added, and the mixture was titrated with ferrous ammonium sulfate until the endpoint was reached. A blank was prepared in the same manner using distilled water instead of the sample.

DPPH METHOD:

The DPPH assay was used to evaluate the antioxidant activity of the samples. DPPH is a stable free radical that exhibits a deep violet color and absorbs at around 517 nm. When an antioxidant was added, it donated hydrogen or electrons to DPPH, reducing it to a colorless or pale-yellow compound, which resulted in a decrease in absorbance. A reduction in absorbance indicated the free radical scavenging activity of the sample.

A stock solution of ascorbic acid (10 mg/10 ml) was prepared as the standard, and ZnO (10 mg/10 ml) was used as the test sample. The stock solutions were aliquoted to concentrations ranging from 20 µg to 100 µg per 0.1 ml. The aliquots were then made up to 1 ml using methanol, followed by the addition of 2 ml of DPPH solution. The tubes were incubated in the dark for 30 minutes, and the absorbance was measured at 517 nm.

Frap Method:

The FRAP (Ferric Reducing Antioxidant Power) assay was used to measure the antioxidant activity of the samples based on their ability to reduce ferric ions (Fe^{3+}) to ferrous ions (Fe^{2+}). In this method, the ferric–tripyridyl triazine (Fe^{3+}–TPTZ) complex was reduced to a blue-colored ferrous form (Fe^{2+}–TPTZ) in the presence of antioxidants, resulting in an increase in absorbance at around 593 nm. Higher absorbance indicated greater reducing power of the sample.

A stock solution of ascorbic acid (10 mg/10 ml) was prepared as the standard, and ZnO (10 mg/10 ml) was used as the test sample. The stock solutions were aliquoted to concentrations ranging from 20 µg to 100 µg. The aliquots were made up to 1 ml using ethanol, followed by the addition of 1 ml distilled water, 1.5 ml of 1 M HCl, 1.5 ml of potassium

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ferric cyanide, 0.5 ml of 1% SDS, and 0.2 ml of 0.2% ferric chloride. The tubes were incubated in a boiling water bath for 20 minutes, and the absorbance was measured at 700 nm.

Total Phenolics:

The Total Phenolic Content assay was used to determine the amount of phenolic compounds present in the samples. The assay is based on the reaction of phenolic compounds with the Folin–Ciocalteu reagent, resulting in the formation of a blue-colored complex. This color develops due to the reduction of the reagent by phenolic compounds under alkaline conditions. The intensity of the blue color was measured spectrophotometrically (at 725 nm) and was directly proportional to the phenolic content of the sample.

A stock solution of gallic acid (10 mg/10 ml) was prepared and diluted to obtain a working standard of 100 µg/1 ml. The working standard was aliquoted at concentrations ranging from 20 µg/0.2 ml to 100 µg/1 ml. ZnO nanoparticles and banana peel extract were taken as test samples and aliquoted in the same concentration range as the standard. The aliquots were made up to 1 ml with distilled water, followed by the addition of 1 ml methanol, 5 ml distilled water, 0.5 ml Folin–Ciocalteu reagent, and 1 ml Na_2CO_3 solution. The tubes were incubated in the dark for 45 minutes, and the absorbance was measured at 725 nm.

Antimicrobial Activity:

The antimicrobial assay was used to evaluate the ability of samples to inhibit the growth of microorganisms. In this method, zinc oxide (ZnO) nanoparticles interacted with microbial cells and inhibited their growth by disrupting the cell membrane, generating reactive oxygen species, and interfering with cellular functions. The effectiveness of antimicrobial activity was determined by measuring the zone of inhibition around the sample, where no microbial growth occurred. A larger zone of inhibition indicated stronger antimicrobial activity.

Nutrient agar was prepared as a growth medium to support a wide range of microorganisms. Untreated water samples and water samples treated with ZnO nanoparticles were prepared. Different test samples were swabbed onto the plates, and wells were made using a cork borer. The samples were added into the wells using a micropipette, and the plates were incubated for 24 hours at 37 °C. The zones of inhibition were measured, and the diameters were recorded.

Results and Discussion

Phytochemical screening of peel extract:

The phytochemical screening of the peel extract confirmed the presence of alkaloids, phenolics and flavonoids.

Characterization of zinc oxide nanoparticles

UV-spectroscopy:

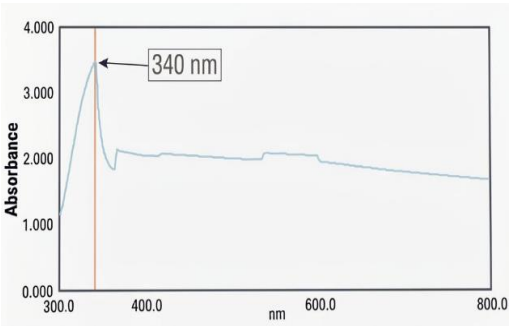

Fig-1

The successful formation of Zinc oxide nanoparticles (ZnO NPs) was first confirmed using UV – Visible spectroscopy. The solution showed a distinct peak at 340nm indicates the formation of zinc oxide nanoparticles. The sharp peak corresponds to the characteristic band gap absorption of ZnO, arising due to the excitation of electrons from the valence band to the conduction band, thereby confirming the semiconducting nature of the material. Additionally, the peak observed at 287nm indicates the presence of phytochemicals from banana peel extract, which acts as reducing and stabilizing (capping) agent.

UV–Visible (UV–Vis) spectroscopy was employed to analyze the optical properties and to confirm the formation of zinc oxide nanoparticles (ZnO NPs). The spectra were recorded in the wavelength range of 200–800 nm, where a prominent absorption peak was observed in the ultraviolet region (Kamaruddin & Abdol Aziz, 2016). This absorption occurs due to the excitation of electrons from the valence band to the conduction band, confirming the semiconductor nature of the material. The presence of a clear and distinct peak indicates successful nanoparticle formation, while the absence of additional peaks suggests good purity of the synthesized sample (Mohammed Qahtan Al-Khaial & Siok Yee Chan, 2024). The appearance of a Sharp Absorption Peak at ~ 340nm in the spectra can be attributed to the materials natural band gap absorption cost by electron transition (Kalyani Pullapukuri & Sravan Kumar, 2023).

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FTIR (Fourier Transform Infrared Spectroscopy):

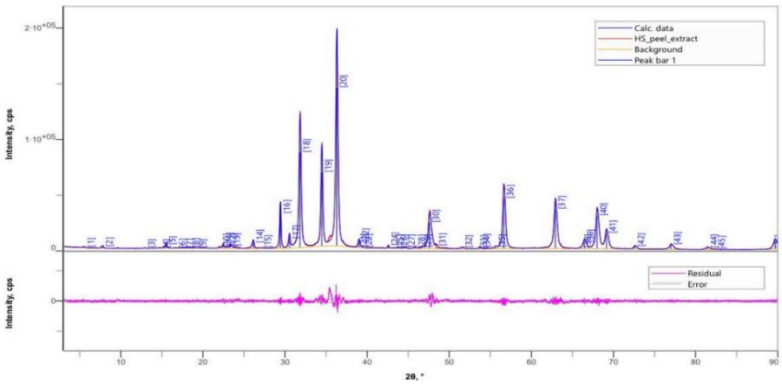

Fig-2

The FTIR spectrum of the synthesized Zinc oxide nanoparticles (ZnO NPs) exhibited several prominent absorption peaks indicating the presence of various functional group involved in the reduction and stabilization of nanoparticles. A broad peak was observed at 3372.25cm $^{-1}$ indicates O-H stretching from banana peel extract which acts as reducing agents in nanoparticle synthesis. The peak at 1640 cm $^{-1}$ indicates proteins and biomolecules which act as capping agents. The peak below 500cm^{-1} confirms the formation of ZnO Nanoparticles.

The FTIR spectrum of the synthesized sample reveals the presence of various functional groups associated with phytochemicals from banana peel extract. A broad absorption band observed in the region 3200–3500 cm^{-1} is due to O–H stretching vibrations of phenolic compounds. The peak around 1600–1650 cm^{-1} corresponds to C=O stretching, indicating the presence of proteins an

biomolecules that act as capping agents. Peaks observed near 1400–1450 cm^{-1} and 1000–1100 cm^{-1} are assigned to C–H bending and C–O stretching vibrations, respectively, confirming the involvement of organic compounds in the synthesis process. Importantly, the presence of a characteristic absorption band below 500 cm^{-1} corresponds to Zn–O stretching vibration, confirming the formation of zinc oxide nanoparticles.

XRD (X- Ray Diffraction)

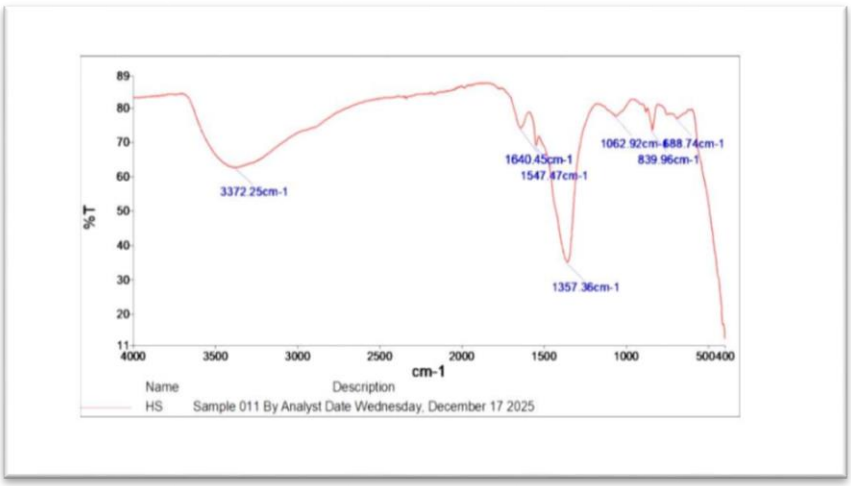

Fig3

The XRD pattern of the synthesized nanoparticles exhibited prominent diffraction peaks at 2θ values of 31.81°, 34.45°, and 36.29°, corresponding to the (100), (002), and (101) planes of hexagonal wurtzite ZnO, confirming the formation of crystalline zinc oxide nanoparticles. Additional minor peaks observed at lower angles are attributed to organic compounds from the banana peel extract, indicating successful green synthesis and surface capping. The sharp and intense diffraction peaks suggest good crystallinity, and the broadening of peaks indicates the nanoscale size of the particles.

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The X-ray diffraction (XRD) pattern of the synthesized sample exhibits characteristic diffraction peaks at 2θ values of 31.81°, 34.45°, 36.29°, 47.56°, 56.61°, 62.89°, and 67.96°, which correspond to the (100), (002), (101), (102), (110), (103), and (112) crystallographic planes of zinc oxide, respectively. These peaks match well with the standard JCPDS data, confirming the formation of ZnO nanoparticles with a hexagonal wurtzite crystal structure. The sharp and intense nature of the peaks indicates high crystallinity of the synthesized nanoparticles. The absence of significant impurity peaks suggests good phase purity. Additional minor peaks at lower angles may be attributed to residual organic compounds from the banana peel extract used in green synthesis.

SEM (Scanning Electron Microscopy):

The SEM analysis of ZnO nanoparticles synthesized using banana peel extract shows irregularly shaped, agglomerated nanoparticles with sizes in the nanometer range. The particles exhibit rough surface morphology and form clusters due to high surface energy and partial stabilization by plant-derived biomolecules. This morphology is characteristic of green-synthesized ZnO nanoparticles.

Scanning electron microscope investigation was used to examine the produced ZnO-NPs' surface morphology (Kalyani Pullapukuri & G. Sravan Kumar). Bioorganic capping molecules and NPs have formed hydrogen bonds and electrostatic interactions that have caused them to collect together (Jiang *et al.,* 2020). The relatively rough surface morphology further suggests the adsorption of organic biomolecules from the extract onto the nanoparticle surface. Similar morphological features, including aggregation and variable shapes, have been reported in green-synthesized ZnO nanoparticles using banana peel extracts and other plant-based sources, confirming the influence of natural capping agents on particle formation (Hussien *et al.,* 2023; Rajeshkumar *et al.,* 2020)

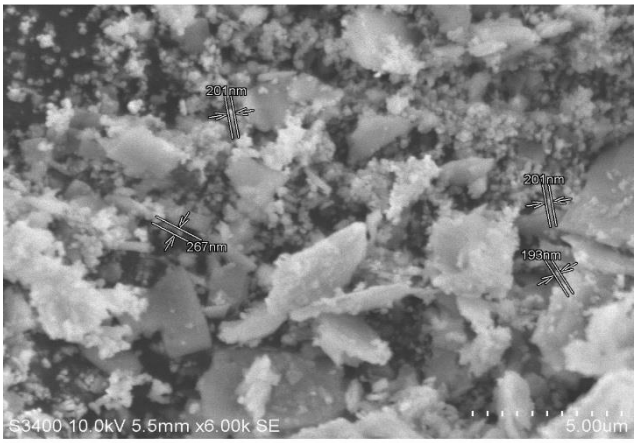

Fig 4

Water treatment efficiency
Organic matter efficiency:
The results indicate a clear increase in removal efficiency with increasing nanoparticle concentration. At 100 mg, the removal efficiency is about 96.92%, showing that even a low concentration of ZnO nanoparticles is effective in removing organic compounds. At 500 mg, the efficiency increases to 98.5%, indicating improved degradation or adsorption of organic matter. At 1000 mg, the highest removal efficiency of about 99.08% suggesting near-complete removal of UV-absorbing organic substances.

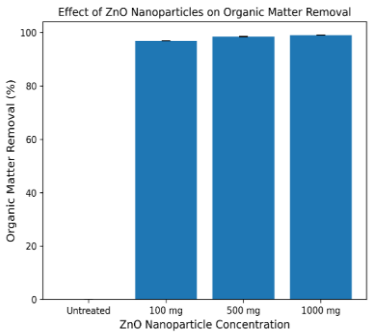

Fig-5

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BOD (Biological Oxygen Demand):

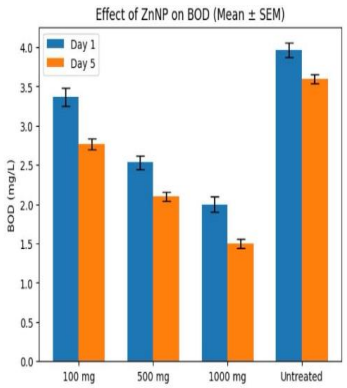

Fig-6

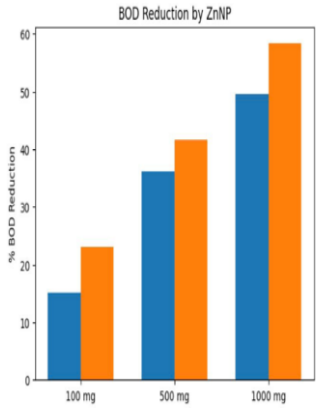

Fig-7

The application of zinc nanoparticles (ZnO NP) resulted in a significant reduction of biochemical oxygen demand (BOD) across all treated groups compared to the untreated control. Statistical analysis using one-way ANOVA confirmed that these differences were highly significant on both Day 1 ($p = 3.19\times10^{-6}$) and Day 5 ($p = 4.59\times10^{-8}$). These values confirm that the ZnO NP effect is real and not due to random variation. On Day 1, t-test comparisons against the untreated control showed significant reductions at the 100 mg concentration ($p = 0.0158$) and highly significant reductions at 500 mg ($p = 0.00033$) and 1000 mg ($p = 0.00012$). By Day 5, the efficacy increased further, with all concentrations reaching highly significant levels of reduction ($p < 0.001$). Specifically, the 100 mg dose reached $p = 0.00070$, while the 1000 mg treatment group exhibited the greatest impact ($p = 0.000013$), achieving an approximate 58% reduction in BOD.

The present study demonstrates that zinc oxide nanoparticles (ZnO NP) significantly reduced biochemical oxygen demand (BOD) in a concentration- and time-dependent manner. Statistical analysis confirmed that all treated groups differed significantly from the untreated control, with highly significant reductions observed particularly at higher concentrations and at Day 5 ($p < 0.001$). The decrease in BOD values indicates improved water quality, as lower BOD reflects reduced microbial oxygen consumption. This suggests that ZnO NP effectively inhibit microbial activity and enhance degradation of organic matter present in water. Similar findings have been reported in previous studies, where ZnO nanoparticles were shown to reduce microbial load and organic pollutants in wastewater systems (Sirelkhatim *et al.*, 2015; Yagoub *et al.*, 2022). The concentration-dependent reduction observed in this study is consistent with the known antimicrobial and catalytic properties of ZnO NP. These nanoparticles are capable of generating reactive oxygen species (ROS), which induce oxidative stress in microorganisms, leading to cell membrane damage and eventual cell death (Tiwari *et al.*, 2018). This reduction in microbial population directly contributes to lower oxygen consumption and hence reduced BOD. The greater reduction observed at Day 5 compared to Day 1 suggests a sustained or cumulative effect of ZnO NP over time. This aligns with previous reports indicating that nanoparticles can exhibit prolonged activity in aqueous systems, enhancing pollutant degradation and microbial inhibition over extended periods (Gudkov *et al.*, 2021). The highest reduction was observed at 1000 mg ZnO NP, where BOD decreased by approximately 58% by Day 5. This indicates that higher concentrations provide greater efficiency, although practical applications may require optimization to balance effectiveness and environmental safety. The results confirm that ZnO NP are effective agents for improving water quality by reducing BOD, primarily through antimicrobial action and enhanced degradation processes. These findings support the potential application of ZnO NP in wastewater treatment and environmental remediation.

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COD

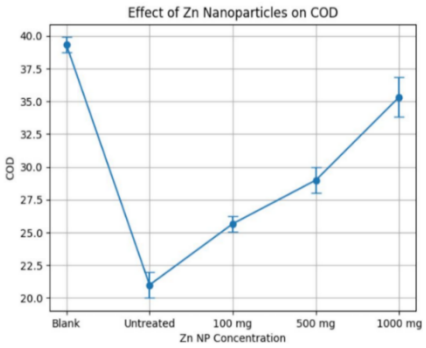

Fig-8

The present study evaluated, of zinc oxide nanoparticles (ZnO NPs) on chemical oxygen demand (COD), a indicator of organic pollution in water. The results revealed a clear and statistically significant variation in COD values across different ZnO NP concentrations (ANOVA, $p < 0.001$). The untreated sample showed a relatively low COD value (21.0 ± 1.0), indicating a lower level of oxidizable organic matter compared to the blank (39.33 ± 0.58). However, upon the addition of Zn nanoparticles, a progressive increase in COD was observed with increasing concentration. Specifically, COD values increased to 25.67 ± 0.58, 29.0 ± 1.0, and 35.33 ± 1.53 at 100 mg, 500 mg, and 1000 mg concentrations, respectively. This demonstrates a clear dose-dependent manner. An effective treatment process is expected to reduce COD, reflecting the removal or degradation of organic pollutants. However, in this study, the opposite was observed, suggesting that ZnO nanoparticles did not contribute to COD reduction. Instead, their presence appeared to elevate COD levels. This increase in COD may be attributed to several factors. First, ZnO nanoparticles or their dissolved ionic forms (Zn^{2+}) may participate in oxidation reactions during COD analysis, thereby artificially increasing the measured oxygen demand. Second, ZnO NPs could catalyse the formation of intermediate compounds that are more readily oxidizable, contributing to higher COD values. Third, possible interference with the dichromate-based COD assay may lead to overestimation of organic load. These findings suggest that the observed increase in COD may not necessarily reflect a true increase in organic pollution but rather an analytical or chemical interference caused by ZnO nanoparticles.

Anti-oxidant assay

DPPH Assay:

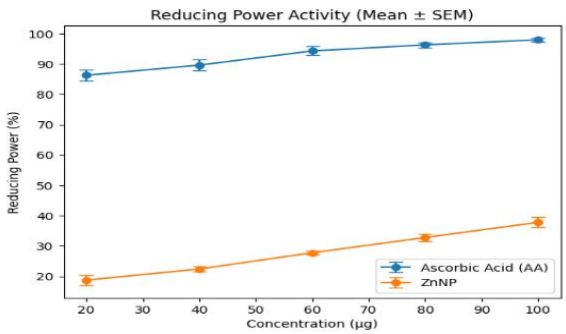

Fig-9

The antioxidant activity was evaluated through a reducing power assay, measuring the ability of Zinc oxide Nanoparticles (ZnO NP) to scavenge free radicals compared to Ascorbic Acid (AA). The results demonstrate a clear concentration-dependent increase in reducing power for both substances. At the lowest tested concentration of 20 µg, ZnO NP exhibited a reducing activity of approximately 18%, which increased steadily to approximately 38% at 100 µg. In comparison, the Ascorbic Acid standard showed significantly higher potency, maintaining a scavenging activity between 86% and 98% across the same concentration range. The reducing power of a compound is a critical indicator of its potential antioxidant activity, often associated with the presence of reductones that exert antioxidant action by breaking free radical chains through the donation of a hydrogen atom. In this study, the observed increase in the reducing capacity of ZnO NP with rising concentrations suggests that the nanoparticles possess inherent antioxidant

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properties, likely due to their high surface-area-to-volume ratio which provides more active sites for electron donation. The ability of a substance to reduce other compounds is a good sign that it can work as an antioxidant. Our findings show that ZnO NP have a natural ability to donate electrons, which helps neutralize free radicals. The fact that the activity increased right along with the concentration suggests that the more nanoparticles we use, the more "active sites" are available to react. Even though the ZnO NP are not as powerful as pure Ascorbic Acid, they still show a meaningful amount of antioxidant work. This is important because it shows these nanoparticles don't just sit in the water; they are chemically active. This ability to react with different species in the water likely helps them break down pollutants and interact with bacteria, which fits with what we saw in the BOD and COD tests. Overall, these results

prove that ZnO NP have a steady antioxidant effect that could be very useful for cleaning up contaminated water.

FRAP Assay

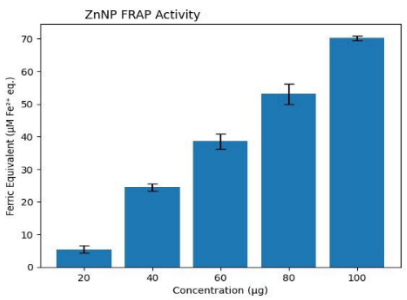

Fig 10

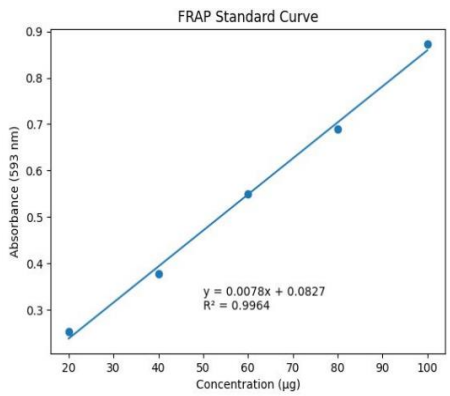

Fig 11

The curve showed a very steady, straight-line relationship between concentration and absorbance,

with an R^2 value of 0.9964. Using the equation from the curve ($y = 0.0078x + 0.0827$). When tested the ZnO NP, the results showed that their reducing power increased as more nanoparticles were added. At the lowest concentration of 20 µg, the activity was around 5.5 µM Fe^{2+} equivalents. With increasing doses, the activity steadily rose, reaching approximately 70 µM Fe^{2+} equivalents at 100 µg. The small error bars on the graph indicate that the results were consistent and reliable. The FRAP assay measures antioxidant activity by showing how well a substance can donate electrons to reduce other chemicals. The results confirm that ZnO NP are effective electron donors. The high R^2 value from the standard curve shows that the assay worked accurately. The nearly straight-line increase in antioxidant activity with higher concentrations suggests that more nanoparticles provide a larger surface area, allowing more reactions to take place. Even at lower doses, ZnO NP were active, but their activity increased significantly at 80 µg and 100 µg. This ability to reduce ferric ions to ferrous ions demonstrates that ZnO NP have strong antioxidant properties.

Total phenolic content:

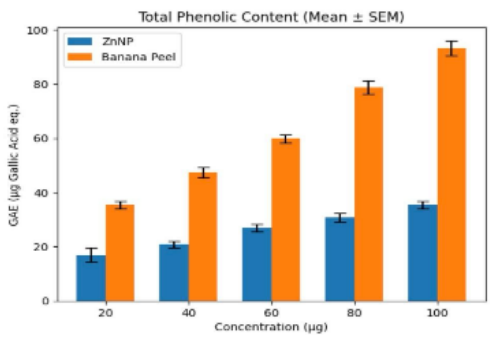

Fig-12

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A standard curve for gallic acid showed a strong linear correlation between concentration and absorbance with an R^2 value of 0.9948. Analysis revealed a concentration-dependent increase in phenolic content for both the synthesized Zinc oxide Nanoparticles (ZnO NP) and the banana peel extract. The banana peel extract exhibited higher levels of phenolic compounds, ranging from approximately 35 µg GAE at 20 µg to over 90 µg GAE at 100 µg. ZnO NP showed lower values but displayed a consistent presence of phenolic groups, increasing from roughly 17 µg GAE to 35 µg GAE across the same concentration range. The high phenolic content in the banana peel extract confirms its role as a rich source of bioactive secondary metabolites. The detectable phenolic content in ZnO NP indicates that these compounds were successfully incorporated or capped onto the surface of the nanoparticles during the green synthesis process. This capping effect enhances the stability and biological activity of the nanoparticles.

Antimicrobial activity:

Antimicrobial activity of ZnO nanoparticles against and gram- positive bacteria (staphylococcus)

Staphylococcus -ve control

Staphylococcus +ve control

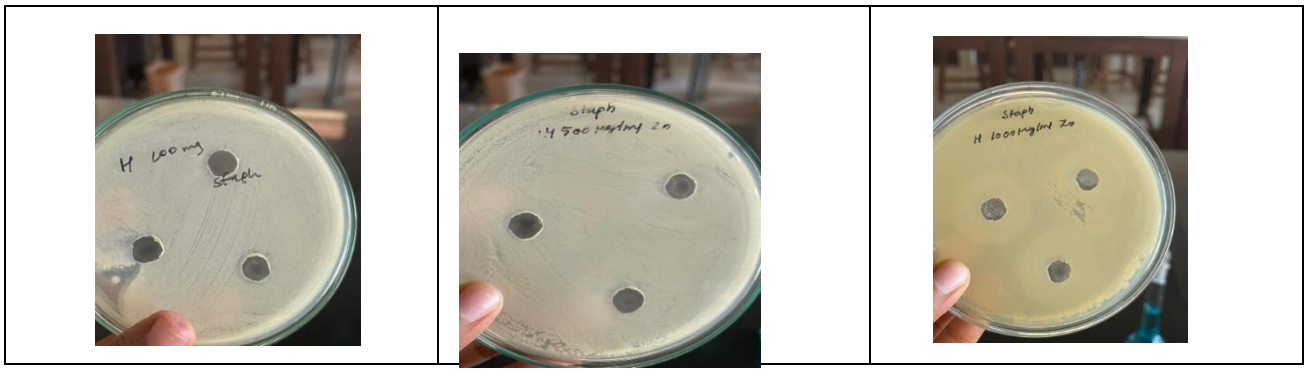

Fig 13

Anti-microbial activity of ZnO nanoparticles against and Gram-negative bacteria (E. coli):

E. coli -ve control

E. coli +ve control

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100mg ZnO NPs | 500mg ZnO **NPs** | **1000mg ZnO NPs**

Fig 14

ZnO NP showed a clear dose-dependent antibacterial effect against both organisms, with the inhibition zone increasing from 100 mg to 1000 mg. The positive control produced the largest zones, while the negative control showed no inhibition. Staphylococcus showed slightly larger inhibition zones than E. coli at each ZnO NP dose. ZnO NP exhibited significant concentration-dependent antimicrobial activity against both E. coli and Staphylococcus, with comparable efficacy between the two organisms under the tested conditions.

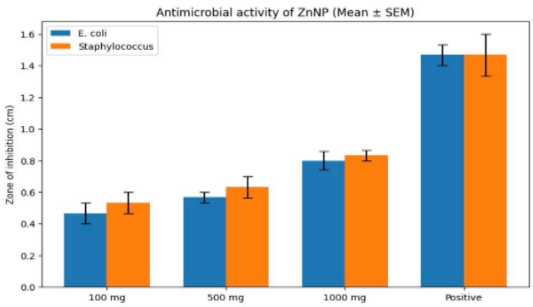

Fig-15

Zinc oxide nanoparticles (ZnO NP) exhibited significant antimicrobial activity against both E. coli and Staphylococcus, with inhibition zones increasing progressively with concentration. One-way ANOVA confirmed significant differences among treatment groups for both E. coli ($p = 3.49 \times 10^{-8}$) and Staphylococcus ($p = 1.32 \times 10^{-6}$), while analysis of ZnNP doses alone also showed significant dose-dependent effects. The highest activity was observed at 1000 mg ZnNP, whereas the positive control produced the maximum inhibition and the negative control showed no activity. The observed dose-dependent antibacterial activity is consistent with previous studies reporting that zinc oxide nanoparticles exhibit strong antimicrobial properties through multiple mechanisms (Sirelkhatim *et al.,* 2015; Gudkov *et al.,* 2021). These mechanisms include the generation of reactive oxygen species (ROS), disruption of bacterial cell membrane integrity, and release of Zn^{2+} ions, which collectively lead to bacterial cell damage and death (Tiwari *et al.,* 2018; Mendes *et al.,* 2022). In the present study, Staphylococcus showed slightly higher inhibition zones compared to E. coli at all concentrations; however, the differences were not statistically significant. This is in agreement with previous reports suggesting that Gram-positive bacteria are generally more susceptible to ZnO NPs than Gram-negative bacteria due to structural differences in their cell walls. Gram-negative bacteria possess an outer membrane that acts as an additional barrier, reducing nanoparticle penetration (Gudkov *et al.,* 2021; Goyal *et al.,* 2023). Despite this observed trend, statistical analysis indicated no significant difference between E. coli and Staphylococcus at corresponding concentrations, suggesting comparable antibacterial efficacy of ZnNP under the experimental conditions. Similar findings have been reported in studies where ZnNP demonstrated broad-spectrum antibacterial activity without strong selectivity between bacterial types (Yagoub *et al.,* 2022). The results confirm that ZnNP possess significant and concentration-dependent antimicrobial activity against both Gram-positive and Gram-negative bacteria.

Conclusion: The study successfully demonstrates an eco-friendly and cost-effective green synthesis of zinc oxide (ZnO) nanoparticles using banana peel extract, which contains phytochemicals like phenolics and flavonoids that act as

natural reducing and stabilizing agents. Characterization through UV-Visible spectroscopy, FTIR, and XRD confirmed the formation of high-purity, crystalline hexagonal wurtzite nanoparticles with nanoscale dimensions. The synthesized nanoparticles exhibited significant concentration-dependent biological activities, including notable free radical scavenging in antioxidant assays and broad-spectrum antimicrobial inhibitory effects against both Gram-positive (Staphylococcus) and Gram-negative (E. coli) bacteria. The study highlights the strong bioremediation potential of these nanoparticles in water treatment, achieving up to 99.08% removal of organic contaminants and a significant reduction in Biochemical Oxygen Demand (BOD), overall presenting a sustainable multifunctional approach for environmental and biological applications.

References:

1. Kamaruddin NA, Abdol Aziz RA. 2026 – Synthesis of zinc oxide nanoparticles with banana peel extract (BPE) from Musa corniculata (Pisang Tanduk): Effects of precursor concentration and reaction temperature. Chemical Engineering, 30(3), 54–60.
2. Lodhi GS, Sharma J, Singh L. 2024 – Metal oxide (zinc oxide) nanoparticles: Enhancing photocatalytic and antimicrobial function for industrial wastewater treatment. Journal of Chemical Health Risks 14(3), 3322–3327.
3. El Golli A, Contreras S, Dridi C. Bio-synthesized ZnO nanoparticles and sunlight-driven photocatalysis for environmentally-friendly and sustainable route of synthetic petroleum refinery wastewater treatment. Scientific Reports. 2023;13(1):20809. doi:10.1038/s41598-023-47554-2.
4. Ojha N, Karn R, Abbas S, Bhugra S. 2021 – Bioremediation of industrial wastewater: A review. IOP Conference Series: Earth and Environmental Science 796, 012012.
5. Al-Khaial MQ, Chan SY, Abu-Zurayk RA, Alnairat N. 2024 – Biosynthesis and characterization of zinc oxide nanoparticles utilizing banana peel extract. Inorganics 12, 121.
6. Mohammad AZ, Ainuddin AR. 2022 – Bio-synthesized zinc oxide nanoparticles using plant extracts. Research Progress in Mechanical and Manufacturing Engineering 3(1), 424–434.
7. Pullapukuri K, Kumar GS. 2023 – Green synthesis of zinc oxide nanoparticles with biological activity using banana peel extract. Chelonian Conservation and Biology 18(2), 689–701.
8. Yashni G, Al-Gheethi A, Mohamed R, Al-Sahari M. Reusability performance of green zinc oxide nanoparticles for photocatalysis of bathroom greywater. Water Practice & Technology. 2021;16(2):364–375. doi:10.2166/wpt.2020.118.
9. Aderibigbe FA, Mustapha SI, Mohammed IA, Adewoye TL, Babatunde EO, Aminullah HI, et al. green synthesis of zinc oxide nanoparticles for the removal of phenol from textile wastewater. Discover Chemical Engineering. 2024;4(1):24. doi:10.1007/s43938-024-00061-w.
10. Bhardwaj K, Singh AK. Bio-waste and natural resource mediated eco-friendly synthesis of zinc oxide nanoparticles and their photocatalytic application against dyes contaminated water. Chemical Engineering Journal Advances. 2023; 16:100536. doi: 10.1016/j.ceja.2023.100536.
11. Islam KS, Mustaka MH, Shishir MKH, Karim MM, Khan GMA. Biosynthesis of ZnO nanoparticles using banana peel pectin for antibacterial and photocatalytic applications. South African Journal of Chemical Engineering. 2025; 52:127–140. doi: 10.1016/j.sajce.2024.11.011.
12. Rosli NA, Aziz RAA. Effect of pH on zinc oxide nanoparticles synthesized with banana peel extract. Universiti Teknologi MARA; 2017. Available from: https://ir.uitm.edu.my/id/eprint/21151/1/21151.pdf
13. Yagoub AEA, Al-Shammari GM, Al-Harbi LN, Subash-Babu P, Elsayim R, Mohammed MA, et al. antimicrobial properties of zinc oxide nanoparticles synthesized from Lavandula pubescens shoot methanol extract. Applied Sciences. 2022;12(22):11613. doi:10.3390/app122211613.
14. Raghupathi KR, Koodali RT, Manna AC. Size-dependent bacterial growth inhibition and mechanism of antibacterial activity of zinc oxide nanoparticles. Langmuir. 2011;27(7):4020–4028. doi:10.1021/la104825u.
15. Al-Khaial MQ, Chan SY, Abu-Zurayk RA, Alnairat N. Biosynthesis and characterization of zinc oxide nanoparticles (ZnO-NPs) utilizing banana peel extract. Inorganics. 2024;12(4):121. doi:10.3390/inorganics12040121.
16. Karthick V, Ganesh Prabu P, Amarnath V, Suganthi V. Green synthesis of selenium, zinc oxide, and strontium nanoparticles and their antioxidant activity - A comparative in vitro study. J Appl Pharm Sci. 2023;13(12):142-51. Available from: https://doi.org/10.7324/JAPS.2023.151241
17. Yahya MA, Al-Shammari GM, Yagoub AEA, Al-Harbi LN, Subash-Babu P. Sustainable eco-friendly synthesis of zinc oxide nanoparticles using banana peel and date seed extracts: Characterization and cytotoxicity evaluation. Appl Sci. 2023;13(13):7537. Available from: https://doi.org/10.3390/app13137537
18. Aboul-Enein AM, Salama ZA, Gaafar AA, Aly HF, Bou-Elella FA, Ahmed HA. Identification of phenolic compounds from banana peel (Musa paradaisica L.) as antioxidant and antimicrobial agents. J Chem Pharm Res. 2016;8(4):46-55.

19. Aboul-Enein AM, Salama ZA, Gaafar AA, Aly HF, Bou-Elella FA, Ahmed HA. Identification of phenolic compounds from banana peel (Musa paradaisica L.) as antioxidant and antimicrobial agents. J Chem Pharm Res. 2016;8(4):46-55.
20. Sahoo S, Sahoo S. Green synthesis of zinc oxide nanoparticles from aqueous extract of Musa balbisiana (banana) peel and its antibacterial activity. Res J Pharm Technol. 2019;12(4):1500-6
21. Sirelkhatim, A., Mahmud, S., Seeni, A., et al. (2015). Review on Zinc Oxide Nanoparticles: Antibacterial Activity and Toxicity Mechanism. Nano-Micro Letters, 7, 219–242.
22. Gudkov, S. V., Burmistrov, D. E., Serov, D. A., et al. (2021). A Mini Review of Antibacterial Properties of ZnO Nanoparticles. Frontiers in Physics, 9, 641481.
23. Tiwari, V., Mishra, A., Kobayashi, H., et al. (2018). Mechanism of antibacterial activity of zinc oxide nanoparticles. Frontiers in Microbiology, 9, 1218.
24. Mendes, C. R., Dilarri, G., Forsan, C. F., et al. (2022). Antibacterial action of ZnO nanoparticles. Scientific Reports, 12, 356.
25. Goyal, R., Singh, P., Kumar, S., et al. (2023). Antibacterial activity of ZnO nanostructures. Applied Physics A, 129, 530.
26. Yagoub, A. E. G. A., Tayel, A. A., Khairy, A. M., & Moussa, S. H. (2022). Antimicrobial properties of ZnO nanoparticles. Applied Sciences, 12, 11613.

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
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Original Article

Comparative Analysis of Chemically Synthesized and *Colocasia esculenta*-Mediated Zinc Nanoparticles for Biofilm Inhibition

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Manuscript ID:
JRD -2026-180407
ISSN: 2230-9578
Volume 18
Issue 4(XI)
Pp. 38-44
April - 2026
Submitted: 10 Mar. 2026
Revised: 20 Mar. 2026
Accepted: 25 Mar. 2026
Published:30 April2026

Abstract

Nanotechnology has emerged as a rapidly developing field with extensive applications in medicine, biotechnology, environmental science, and industrial research. Among various nanomaterials, zinc oxide nanoparticles (ZnO NPs) have attracted considerable attention due to their remarkable physicochemical, antimicrobial, antioxidant, and antibiofilm properties. The present study comparatively evaluates chemically synthesized and Colocasia esculenta-mediated biologically synthesized zinc nanoparticles for their antioxidant and biofilm inhibition activities. Green synthesis was carried out using Colocasia esculenta leaf extract as a reducing and stabilizing agent, while chemical synthesis involved the conventional precipitation method using zinc acetate and sodium hydroxide. The synthesized nanoparticles were characterized using FTIR, SEM, and XRD analyses, which confirmed the successful formation of crystalline ZnO nanoparticles. FTIR results revealed the presence of phytochemical functional groups in biologically synthesized nanoparticles, indicating effective capping and stabilization. SEM analysis demonstrated that biologically synthesized nanoparticles possessed better dispersion and porous morphology compared to chemically synthesized nanoparticles, which exhibited aggregation. Antioxidant activity assessed through the DPPH scavenging assay showed concentration-dependent radical scavenging potential in both nanoparticle types. Furthermore, biofilm inhibition studies against Pseudomonas aeruginosa revealed significant antibiofilm activity, with chemically synthesized nanoparticles showing stronger direct inhibition at higher concentrations, while biologically synthesized nanoparticles exhibited enhanced biocompatible interactions due to phytochemical coating. The study highlights the eco-friendly and sustainable potential of green synthesized ZnO nanoparticles as promising agents for biomedical and antimicrobial applications.

***Keywords**: Nanotechnology, Zinc oxide nanoparticles, Colocasia esculenta, Green synthesis, Biofilm inhibition, Pseudomonas aeruginosa, DPPH assay, Antioxidant activity, FTIR, SEM.*

Introduction

Nanotechnology has emerged as a rapidly advancing field with significant applications in medicine, electronics, environmental science, and biotechnology. Among the various components of nanotechnology, nanoparticles have gained considerable attention due to their unique physicochemical properties, including small size, high surface area-to-volume ratio, and enhanced surface reactivity. These properties enable nanoparticles to exhibit behaviors distinct from their bulk counterparts, making them highly valuable in diverse scientific and industrial applications (*Joseph et al., 2023)*. Metals are often used in the production of nanoparticles, as they have exclusive and advantageous properties that can be manipulated to find use in the electronic fields, medicine, catalysis, and other industries. Nanoparticles are prepared by a variety of method, of the processes used to prepare metallic nanoparticles (NPs), two broad categories are possible: top - down and bottom-up. In a top-down method, suitable bulk material is subdivided into small particles by using various methods depending on the size of these particles.*(Harish et al., 2022)*

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How to cite this article:
C, N., Swarnalatha, Suvarna, S., & Bhavya, D. K. (2026). Comparative Analysis of Chemically Synthesized and Colocasia esculenta-Mediated Zinc Nanoparticles for Biofilm Inhibition. Journal of Research and Development, 18(4(XI)), 38–44.
https://doi.org/10.5281/zenodo.21103132

Quick Response Code:
Website:
https://jrdrvb.org/
DOI:
10.5281/zenodo.21103132
OPEN ACCESS

Journal of Research and Development
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ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

The most common method of synthesizing NPs in a bottom-up method is chemical reduction. Another way is biological approaches, in which some biological materials are employed, such as plants and microorganisms. Production can be made using leaves, bark, roots, fruit and even seeds in plants.

Zinc nanoparticles were prepared in the present research through both chemical and biological processes.*(Gaur et al., 2024)* Zinc oxide is a functional substance due to its special physical and chemical properties that are, including high chemical stability, high electrochemical coupling coefficient, a wide range of radiation absorption and a high level of photo stability, among other methods that have been employed to make ZnO nanoparticles. *(Abou El-Nour et al., 2010)* Metal and metal oxide nanoparticles, particularly zinc oxide (ZnO) nanoparticles, are widely studied due to their remarkable chemical stability, biocompatibility, and multifunctional properties. ZnO nanoparticles possess notable antimicrobial, antioxidant, and photocatalytic activities, which make them suitable for applications in biomedical fields, environmental remediation, and food safety (Raha & Ahmaruzzaman, 2022). Their effectiveness is largely dependent on parameters such as particle size, morphology, surface characteristics, and degree of dispersion.

Other, more eco-friendly ways of creating metallic nanoparticles have also been suggested, and these involve biological synthesis of NPs, which utilise plant extracts and bacteria.

The comparison between Zn NPs synthesis chemical and biosynthesis is followed by the current study. Colocasia esculenta leaf was selected and used in the biological preparation of zinc nanoparticles.*(Tanwar et al., 2024)*

Plant material: *Colocasia esculenta*
Kingdom: Plantae
Clade: Angiosperms
Family: Araceae
Subfamily: Aroideae
Genus: *Colocasia esculenta*

Fig 1: *Colocasia esculenta*

Colocasia esculenta is very unique and special in the sustainability of the production of nanoparticles. There are bioactive compounds present in this plant, which include flavonoids, polyphenols and other phytochemicals, which can reduce the metal ions to nanoparticle dimensions. Besides the production of metal ions through the process of reduction to nanoparticles, in Colocasia leaves stabilize the particles are stabilised and prevent their agglomeration.*(Sakib et al., 2025)* This dual role improves the efficiency and stability of the produced nanoparticle. And they also proved to have good antibacterial properties and thus applicability in medical practices. The use of Colocasia leaves, which are abundant and sustainable, would enhance the effectiveness and environmental impact of the NPs synthesis process. Biosynthesis has better biocompatibility and is eco-friendly, and because it is important to reduce toxicity and ecological impact, it is safer and more sustainable to be used where biocompatibility and controlled antioxidant activity are important the biofilm formation process entails an irreversible growth and adhesion of bacteria

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to a surface with the help of extracellular polymers which assists in the production of the matrix and its adhesion. This modification of the organism's phenotype of the growth rate and gene transcription.*(Natsheh et al., 2023)* The powerful and tough have significant problems in various industries. Particularly, biofilms are notorious in the development of long-term and chronic infection in clinical environments, especially on medical equipment such as instruments, implants and the prosthesis. Moreover, water systems can harbour biofilms composed of harmful microbes, which can pose a threat to public health. It has biofilm protective and durable features that make it harder to wash, and food manufacturing plants contribute to high chances of contamination and spoilage.

Having significant effects in both medical and industrial applications, zinc nanoparticle specifically zinc oxide nanoparticle, have proven to have potential as an agent in the battle against biofilm formation. Biofilm-organised colonies of microorganisms surrounded by a self-produced extracellular matrix pose major challenges due to their resistance to conventional antibiotic therapies. *(Natsheh et al., 2023)* The unique physicochemical property of zinc nanoparticles, combined with antibacterial activity, gives a diverse technique of biofilm inhibition.

Zinc nanoparticles also interfere with the development of biofilm by weakening bacterial cell membranes, undermining cell integrity, and preventing cell adhesion to surfaces. Moreover, Zinc nanoparticles initiate the production of reactive oxygen species (ROS) that damage cellular components, including proteins, lipids, and DNA, and cause oxidative stress and cell death. *(Mohammed et al., 2025)* Zinc nanoparticles are also shown to inhibit coordinated biofilm formation by disrupting the quorum-sensing bacterial communication mechanism required to attain biofilm development. Moreover, the release of Zn^{+2} ions has the direct capability to inhibit the development of bacteria and the formation of biofilms. Zinc nanoparticles can be considered a potential strategy against biofilm-related diseases due to the combination of various effects attracted by them.*(Bianchini Fulindi et al., 2023)*

Materials and methods

Chemical synthesis of nanoparticles: Zinc acetate solution was prepared by dissolving 5.5 g of zinc acetate in 100 mL of distilled water. Separately, 20 g of sodium hydroxide (NaOH) was dissolved in 100 mL of distilled water. The NaOH solution was added dropwise to the zinc acetate solution under continuous stirring while maintaining the temperature at 90 °C on an electric heating plate. After complete addition, the reaction mixture was allowed to proceed under the same conditions. The obtained product was then dried in a hot air oven at 100 °C for 30 minutes. The dried sample was collected and stored for further characterization.

Green synthesis of nanoparticles

Fresh leaves of *Colocasia* were collected, washed thoroughly with distilled water, and shade-dried for 48 hours. The dried leaves were powdered, and 5 g of the powder was mixed with 100 mL of distilled water. The mixture was heated at 90 °C on a magnetic stirrer for 1 hour and then filtered using Whatman filter paper to remove plant debris. The filtrate was collected and used as the plant extract.

A sodium hydroxide solution was prepared by dissolving 4 g of NaOH in 50 mL of distilled water. A 1 M zinc acetate solution was prepared in 50 mL of distilled water. The NaOH solution was added dropwise to the zinc acetate solution under continuous stirring, and the mixture was stirred for 30 minutes to ensure complete mixing. Subsequently, 50 mL of the prepared leaf extract was added dropwise to the reaction mixture. A precipitate formed, which was then collected by filtration and dried in a hot air oven at 80 °C for 12–16 hours. The dried material was ground to obtain nanoparticle powder (Vijayashree *et al*., 2017).

Antioxidant assay:

DPPH scavenging assay:

The antioxidant activity of the samples was determined using the DPPH radical scavenging assay. The DPPH reagent was dissolved in methanol to obtain a deep violet-colored solution. The test samples were prepared at various concentrations for analysis.

An aliquot of the DPPH solution was mixed with each sample solution in test tubes and incubated for 30 minutes at room temperature in the dark to facilitate the reaction. During this period, the antioxidants present in the samples reduced the DPPH radicals, resulting in a decrease in the intensity of the violet color.

After incubation, the absorbance of the reaction mixtures was measured at 517 nm using a spectrophotometer. A control sample containing only the DPPH solution without any antioxidant was used for comparison. The decrease in absorbance of the samples relative to the control indicated the radical scavenging activity.

The proportion of DPPH scavenging of chemical and biosynthesised nanoparticles and standard compounds was computed with the help of the following formula.

Biofilm inhibition assay

$$\% \text{ Inhibition} = \frac{\text{Absorbance of control} - \text{Absorbance of sample}}{\text{Absorbance of control}} \times 100$$

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Biofilm formation was assessed using the crystal violet microtiter plate assay. Microorganisms were inoculated into sterile 96-well microtiter plates containing appropriate growth medium and incubated under suitable conditions to allow biofilm development. Following incubation, the planktonic culture was carefully removed, and the wells were gently washed with sterile distilled water (or phosphate-buffered saline) to eliminate non-adherent cells. The remaining attached biofilm was fixed and stained with 0.1% (w/v) crystal violet solution and allowed to stand for a specified period to ensure adequate staining. Excess stain was removed by washing the wells thoroughly with distilled water, and the plates were air-dried. The bound crystal violet was then solubilized using ethanol (or 95% ethanol/acetone solution). The absorbance of the solubilized dye was measured at 570 nm using a microplate reader.
The absorbance values obtained were directly proportional to the biofilm biomass. The assay provided a quantitative measure of biofilm formation and enabled comparison between different samples or experimental conditions. (O'Toole, 2011)

Result and discussion:

The FTIR spectrum was obtained to identify the potential phytochemicals that effectively capped and stabilised the zinc nanoparticles produced by the plant extract. Figure 2 (a) shows chemically synthesized zinc nanoparticles, and the absorbance bands of Figure. A were found at 400 cm-1, attributed to ZnO, and a small peak was observed at 1034 cm-1, attributed to C-OH vibration. And Figure 2(b) shows Colocasia esculenta synthesised zinc nanoparticles using plant extract. Figure 3 was observed to have absorbance bands at 400 cm-1, which are assigned to the ZnO, 1619.12 C=C alkene (weak),1444.07 -CH2 band with an intense peak formed at 1034 cm-1, which is attributed to C-OH stretch. The comparative FTIR analysis shows apparent differences in chemically produced and green-produced NAA and NAC nanoparticles. NAA has characteristic aromatic and carboxyl functional group peaks with a slight fluctuation. Conversely, NAC exhibits other wide and high peaks (-OH, -NH, -SH), which proves the phytochemical capping, increased surface functionality, and the successful production of the green nanoparticles. *(Aalami et al., 2024).* The presence of these biomolecules on the nanoparticle surface suggests enhanced stabilization and reduced aggregation in green synthesized nanoparticles. This functionalization is likely to contribute to improved dispersion and increased biological activity.

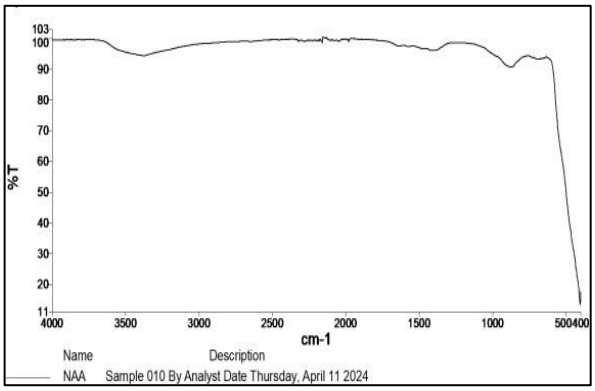

Fig 2(a): Chemical synthesized NPs

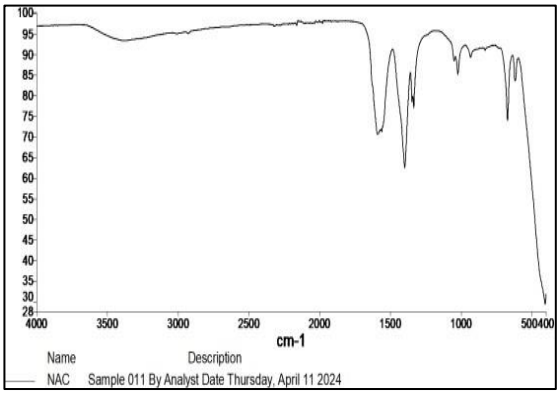

Fig 2(b): Biologically synthesized NPs

Scanning electron microscopy (SEM).

The chemically synthesized nanoparticles exhibited irregular shapes with dense aggregation and compact structures. Such aggregation may be attributed to the absence of stabilizing agents during synthesis, leading to reduced control over particle growth and dispersion.
In contrast, the biologically synthesized nanoparticles demonstrated relatively well-dispersed structures with a more porous and flake-like morphology. The improved dispersion can be attributed to the capping effect of phytochemicals present in the plant extract, which prevent particle agglomeration and promote uniform distribution. (Noguti *et al.*, 2025). These morphological differences indicate that green synthesis offers better control over nanoparticle formation, resulting in enhanced surface characteristics that are favorable for biological applications.

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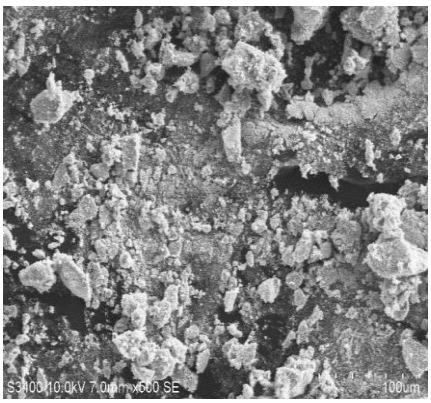

Fig. 3(a) : Chemically synthesised NPs

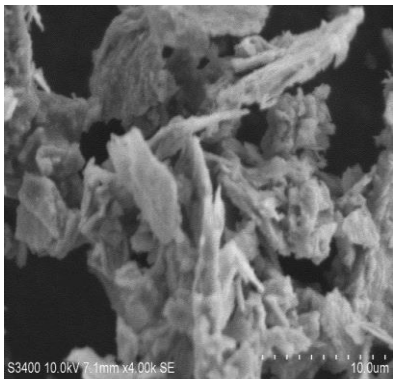

Fig 3 (b): Biologically synthesized NPs

X-ray diffraction

Both chemically and biologically synthesized nanoparticles exhibited distinct diffraction peaks corresponding to the characteristic crystal planes of zinc oxide, confirming the successful formation of crystalline ZnO nanoparticles. The similarity in peak positions indicates that both synthesis methods produce nanoparticles with comparable crystal structures. However, the biologically synthesized nanoparticles displayed relatively higher peak intensities, suggesting enhanced crystallinity or larger crystallite size compared to chemically synthesized nanoparticles. This improved crystallinity may be attributed to the controlled nucleation and growth facilitated by phytochemicals in the plant extract. Overall, the XRD results confirm that green synthesis does not compromise the structural integrity of ZnO nanoparticles while potentially improving their crystallinity.*(Iqbal et al., 2021)*

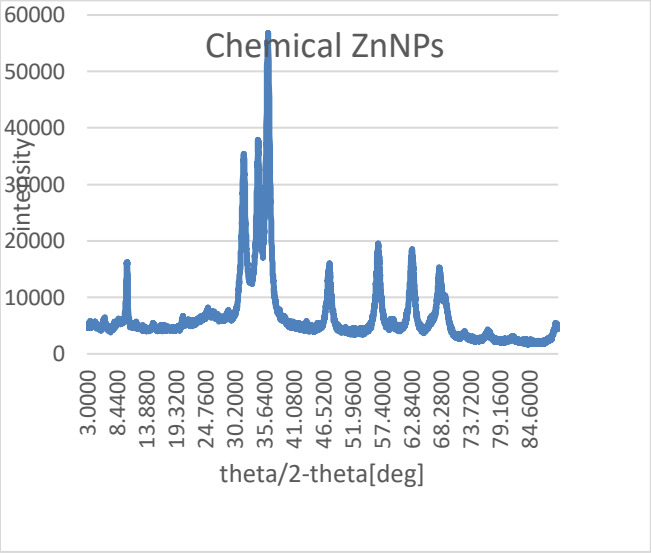

Fig 4(a): XRD chemically synthesized NPs

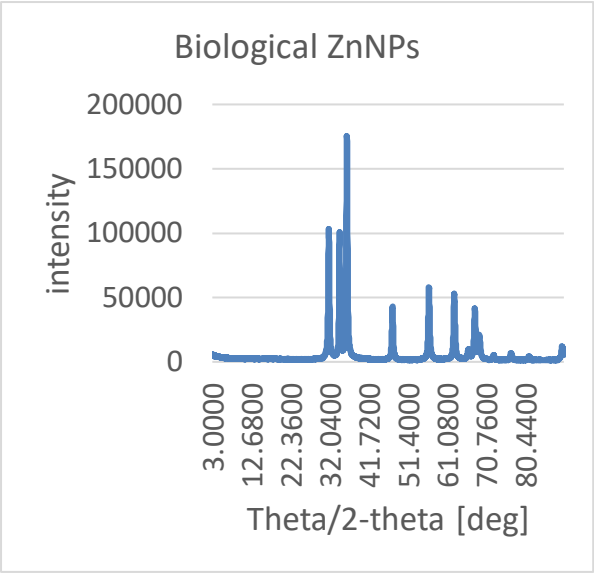

Fig 4(a): XRD chemically synthesized NPs

Antioxidant assay:

DPPH scavenging assay: The DPPH radical scavenging assay was used to ascertain the antioxidant activity of chemically synthesized and green synthesized nanoparticles. The percentage inhibition (%inhibition) of the scavenging ability of the methanol and chemically synthesized nanoparticles is lower than that of the aqueous *C. esculenta* nanoparticles. Biological NPs work more effectively with concentration, and hence, Chemical nanoparticles (NPs) have high levels of repeatability at various levels, which means that the effect of changing concentration in the observed scale does not influence the efficiency of the particle significantly

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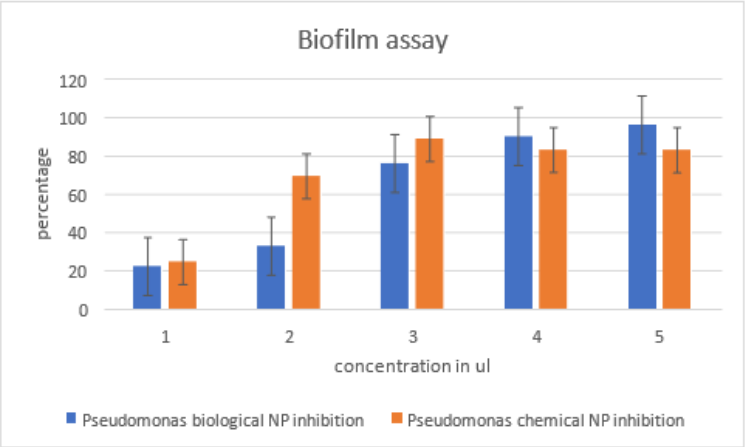
The DPPH assay indicate that chemically synthesized nanoparticle exhibit Higer radical scavenging activity with increasing concentration compared to biologically synthesized nanoparticle. However, bio-NPs shows relatively stable activity. the enhanced activity of chemical NPs may be due to greater surface reactivity, while bio NPs reflect controlled antioxidant potential from biomolecule capping *(Salari et al., 2019)*

Fig 5: Comparison of Chemical & Biological NPs

Biofilm assay:



The antibiofilm activity of the synthesized nanoparticles was assessed against *Pseudomonas aeruginosa*, a well-known biofilm-forming pathogen.

Both types of nanoparticles demonstrated significant inhibitory effects on biofilm formation, although variations were observed depending on concentration and synthesis method. Chemically synthesized nanoparticles showed strong inhibition at higher concentrations, indicating their effectiveness in disrupting established biofilms.

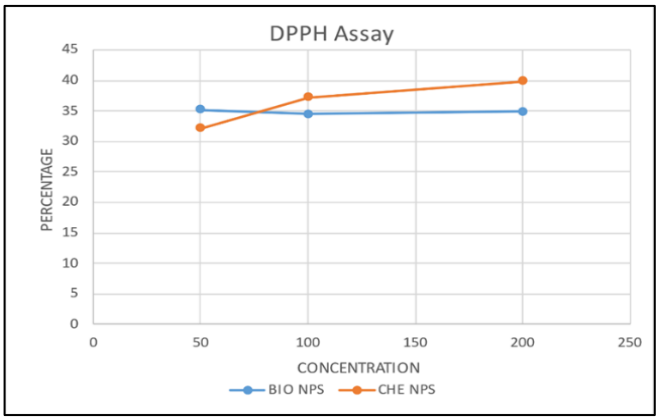
Fig 6: Comparison of Chemical & Biological NPs

Biologically synthesized nanoparticles also exhibited notable antibiofilm activity, particularly at optimal concentrations. The presence of phytochemical residues on the nanoparticle surface may enhance interaction with bacterial cells, contributing to inhibition of biofilm formation through mechanisms such as disruption of cell adhesion and interference with quorum sensing.

The differences in antibiofilm activity between the two nanoparticle types suggest that the mechanism of action may vary depending on surface chemistry and structural properties. While chemically synthesized nanoparticles may exert stronger direct antimicrobial effects, biologically synthesized nanoparticles may provide a more targeted and biocompatible approach to biofilm inhibition.

Conclusion:

One of the most important areas in the sphere of nanotechnology in creation of the stable and environmentally friendly procedure of producing metallic nanoparticles. They are getting considered as basic blocks of nanotechnology. In the present study irregular shaped zinc nanoparticles have been prepared successfully through the application of



chemical method zinc acetate and *C esculenta* leaves extract as a bio reducing agent. This method represents a quick, inexpensive, and easy pathway to the synthesis of zinc nanoparticle.

The concentration percentage of Chemical nanoparticles decreases marginally at 100 and marginally at 200 concentrations studied, however, it remains relatively stable. This implies that the concentration of Chemical nanoparticles does not have a significant influence on the proportion in the measured range. The percentage of the same increases with higher concentrations of biological nanoparticles. With in the studied concentration range, % inhibition shows a concentration -dependent increase for chemically synthesized nanoparticle exhibit relatively stable % inhibition with minimal variation across concentration, suggest a less pronounced dependent response. The proportions of Pseudomonas chemical NPs vary with the increase in concentration. Although the proportion of Pseudomonas chemical NPs varies, proportion of Pseudomonas biological NPs varies with an increase in doses, which shows that there are different underlying mechanisms or behaviours between these two categories of nanoparticles.

Future studies should force on scaling up green synthesized ZnNPs using *C esculenta* with improved reproducibility and yield optimization. Detailed mechanistic studies on nanoparticle biofilm interaction. Including gene expression and quorum sensing inhibition in Pseudomonas aeruginosa are required. Toxicity and biocompatibility assessment in plant and mammalian system should be conducted to ensure safety. Further, field level application in agriculture, including plant protection and soil microbiome modulation, should be explored. Integration with nanocarrier system and formulation development could enhance stability and targeted delivery. Enabling border biomedical and environment application.

Bibliography

1. Aalami, Z., Hoseinzadeh, M., Hosseini Manesh, P., Aalami, A. H., Es'haghi, Z., Darroudi, M., Sahebkar, A., & Hosseini, H. A. (2024). Synthesis, characterization, and photocatalytic activities of green sol-gel ZnO nanoparticles using Abelmoschus esculentus and Salvia officinalis: A comparative study versus co-precipitation-synthesized nanoparticles. *Heliyon*, *10*(2), e24212. https://doi.org/10.1016/j.heliyon.2024.e24212
2. Abou El-Nour, K. M. M., Eftaiha, A., Al-Warthan, A., & Ammar, R. A. A. (2010). Synthesis and applications of silver nanoparticles. *Arabian Journal of Chemistry*, *3*(3), 135–140. https://doi.org/10.1016/j.arabjc.2010.04.008
3. Bianchini Fulindi, R., Domingues Rodrigues, J., Lemos Barbosa, T. W., Goncalves Garcia, A. D., de Almeida La Porta, F., Pratavieira, S., Chiavacci, L. A., Pessoa Araújo Junior, J., da Costa, P. I., & Martinez, L. R. (2023). Zinc-Based Nanoparticles Reduce Bacterial Biofilm Formation. *Microbiology Spectrum*, *11*(2), e0483122. https://doi.org/10.1128/spectrum.04831-22
4. Gaur, J., Kumar, S., Pal, M., Kaur, H., Batoo, K. M., Momoh, J. O., & Supreet. (2024). Current trends: Zinc oxide nanoparticles preparation via chemical and green method for the photocatalytic degradation of various organic dyes. *Hybrid Advances*, *5*, 100128. https://doi.org/10.1016/j.hybadv.2023.100128
5. Harish, V., Ansari, M. M., Tewari, D., Gaur, M., Yadav, A. B., García-Betancourt, M.-L., Abdel-Haleem, F. M., Bechelany, M., & Barhoum, A. (2022). Nanoparticle and Nanostructure Synthesis and Controlled Growth Methods. *Nanomaterials*, *12*(18), 3226. https://doi.org/10.3390/nano12183226
6. Iqbal, J., Abbasi, B. A., Yaseen, T., Zahra, S. A., Shahbaz, A., Shah, S. A., Uddin, S., Ma, X., Raouf, B., Kanwal, S., Amin, W., Mahmood, T., El-Serehy, H. A., & Ahmad, P. (2021). Green synthesis of zinc oxide nanoparticles using Elaeagnus angustifolia L. leaf extracts and their multiple in vitro biological applications. *Scientific Reports*, *11*(1), 20988. https://doi.org/10.1038/s41598-021-99839-z
7. Joseph, T. M., Kar Mahapatra, D., Esmaeili, A., Piszczyk, Ł., Hasanin, M. S., Kattali, M., Haponiuk, J., & Thomas, S. (2023). Nanoparticles: Taking a Unique Position in Medicine. *Nanomaterials*, *13*(3), 574. https://doi.org/10.3390/nano13030574
8. Mohammed, A. M., Mohammed, M., Oleiwi, J. K., Ihmedee, F. H., Adam, T., Betar, B. O., & Gopinath, S. C. B. (2025). Comprehensive review on zinc oxide nanoparticle production and the associated antibacterial mechanisms and therapeutic potential. *Nano Trends*, *11*, 100145. https://doi.org/10.1016/j.nwnano.2025.100145
9. Natsheh, I. Y., Elkhader, M. T., Al-Bakheit, A. A., Alsaleh, M. M., El-Eswed, B. I., Hosein, N. F., & Albadawi, D. K. (2023). Inhibition of Acinetobacter baumannii Biofilm Formation Using Different Treatments of Silica Nanoparticles. *Antibiotics*, *12*(9), 1365. https://doi.org/10.3390/antibiotics12091365
10. Noguti, F. S., Celestino, M. F., Mori, L. T., Martins, J. P. P., Linde, G. A., Colauto, N. B., Busso, C., & Eising, R. (2025). Sustainable Synthesis of Silver Nanoparticles (Chemical vs Biological) and Their Antimicrobial Activity against Clinical Pathogens. *ACS Omega*, *10*(39), 45656–45670. https://doi.org/10.1021/acsomega.5c05917
11. Sakib, Md. E. A., Hasan, Md. L., Roy, H., Hasan, Md. M., & Ali, Md. M. (2025). Colocasia esculenta leaf extracted cobalt oxide nanoparticles: A comprehensive investigation of the microstructural, morphological, antibacterial, and photocatalytic activity. *Next Nanotechnology*, *8*, 100215. https://doi.org/10.1016/j.nxnano.2025.100215
12. Salari, S., Esmaeilzadeh Bahabadi, S., Samzadeh-Kermani, A., & Yosefzaei, F. (2019). In-vitro Evaluation of Antioxidant and Antibacterial Potential of GreenSynthesized Silver Nanoparticles Using Prosopis farcta Fruit Extract. *Iranian Journal of Pharmaceutical Research: IJPR*, *18*(1), 430–455.

13. Tanwar, S. N., Parauha, Y. R., There, Y., Swart, H. C., & Dhoble, S. J. (2024). Plant-Based Biosynthesis of Metal and Metal Oxide Nanoparticles: An Update on Antimicrobial and Anticancer Activity. *ChemBioEng Reviews*, *11*(6), e202400012. https://doi.org/10.1002/cben.202400012

Journal of Research and Development
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Original Article

Comparative Anatomical Study of Two Closely Allied Taxa of Pogostemon, *P. Deccanensis* and *P. Jaitapurensis* (Lamiaceae)

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Manuscript ID:
JRD -2026-180408
ISSN: 2230-9578
Volume 18
Issue 4(XI)
Pp. 45-52
April - 2026

Submitted: 10 Mar. 2026
Revised: 20 Mar. 2026
Accepted: 25 Mar. 2026
Published:30 April2026

Abstract:
The Pogostemon is one of the widely distributed genus in the family Lamiaceae. In this current study, we compared newly described species P. jaitapurensis Chandore & S. R. Yadav anatomically with its formerly known and phylogenetically allied taxon P. deccanensis. Both the plants are erect herbs grows with horizontally creeping rootstock. Anatomically both the species varies significantly from each other, the aerenchyma in the horizontally creeper is wheel like and one cell thick diaphragm in both the species but the diaphragm is 2 cell long and straight in P. deccanensis whereas it is 5-7 cells long and diagonal in P. jaitapurensis. In leaf anatomy, it observed that both spongy and palisade containing oil globules in P. jaitapurensis while oil globules present only in palisade in P. deccanensis. Two types of trichomes namely glandular and non-glandular observed in both plants, the glandular ones are short stalked and 1 celled and non-glandular one are 1-2 cell long in P. deccanensis and 4-5 cells long in P. jaitapurensis.
Keywords: *P. jaitapurensis, P. deccanensis, anatomy, wheel aerenchyma, diagonal diphragm, glandular trichomes, oil droplets.*

Introduction:

The *Pogostemon* Desfontaines is one of the widely distributed genus in the family Lamiaceae represented by 86 species across tropical and subtropical regions of Asia, Australia and Africa (Cook 1996, Bhatti & Ingrouille 1997, Pradeep 1998, Mabberley 2008, Yao *et al.* 2015). The highest species diversity found in India and about 41 species reported from here and out of this 19 are endemic to India (Sampathkumar *et al.* 2004, SDunojkumar *et al.* 2014).

The presence of exerted stamens bearing moniliform hair is the peculiar characteristic of Pogostemon which distinguishes it from other genera of Lamiaceae. Pogostemon plant are diverse in habit from aquatic herbs to terrestrial herbs and subshrub (Pramali *et al.* 2018). Formerly on the basis of habit the genus has been treated as a two separate groups like two separate genera such as *Pogostemon* the terrestrial one and *Drysophylla* the aquatic or marshland one *Sensu stricto* (Bentham 1833, Hooker 1835 Airy Shaw 1967). The species belongs to terrestrial group bears opposite petiolate broad leaves more or less covered by hair, while the aquatic or marshland plants bears leaves with verticillate, sessile with linear to filiform lamina shape(El-Gazzar & Watson 1967).

Later on *Sensu lato* both the genera p*Pogostemon* and *Drysophylla* merged into single genus *Pogostemon* but sub classified into two sections *Pogostemon* and *Eusterallis* (Rafin.) Keng based on phyllotaxy (Keng 1978). Based on phenetic analysis of morphological characters Press. follows this chategarization of the genus (Press. 1982). Infragenerically s.l. based on inflorescence type and calyx morphology, *Pogostemon* classified into three subgenra; *Allopogostemon* Bhatti & Ingrouille, *Drysophyllus* (Blume) Bhatti & Ingrouille and *Pogostemon* (Bhatti & Ingroille 1997). However the morphological variations and putative convergent evolution within genus contradicts with this infrageneric classification (Yao *et al.* 2016).

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How to cite this article:
Sayekar, H. A. M., & Ghalme, R. L. (2026). Comparative Anatomical Study of Two Closely Allied Taxa of Pogostemon, P. Deccanensis and P. Jaitapurensis (Lamiaceae). Journal of Research and Development, 18(4(XI)), 45–52 https://doi.org/10.5281/zenodo.21103350

Quick Response Code:
Website:
https://jrdrvb.org/
DOI:
10.5281/zenodo.21103350

Journal of Research and Development
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ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

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Material and methods:

Plant Collection:

The fresh plant material of *P. deccanensis* collected from harvested paddy fields from Kharavate Village near Kalsoli Phata, Rajapur N16° 70' 48.13", E73° 54' 95.19" at 69.5m altitude and *P. jaitapurensis* from seasonal pond of Hurse - Jaitapur plateau, Rajapur, N 16° 35' 16.43", E73°23' 19.40"at -24.4m altitude Maharashtra, India. Collected material brought to the lab and after cleaning fixed in FAA solution for anatomical studies.

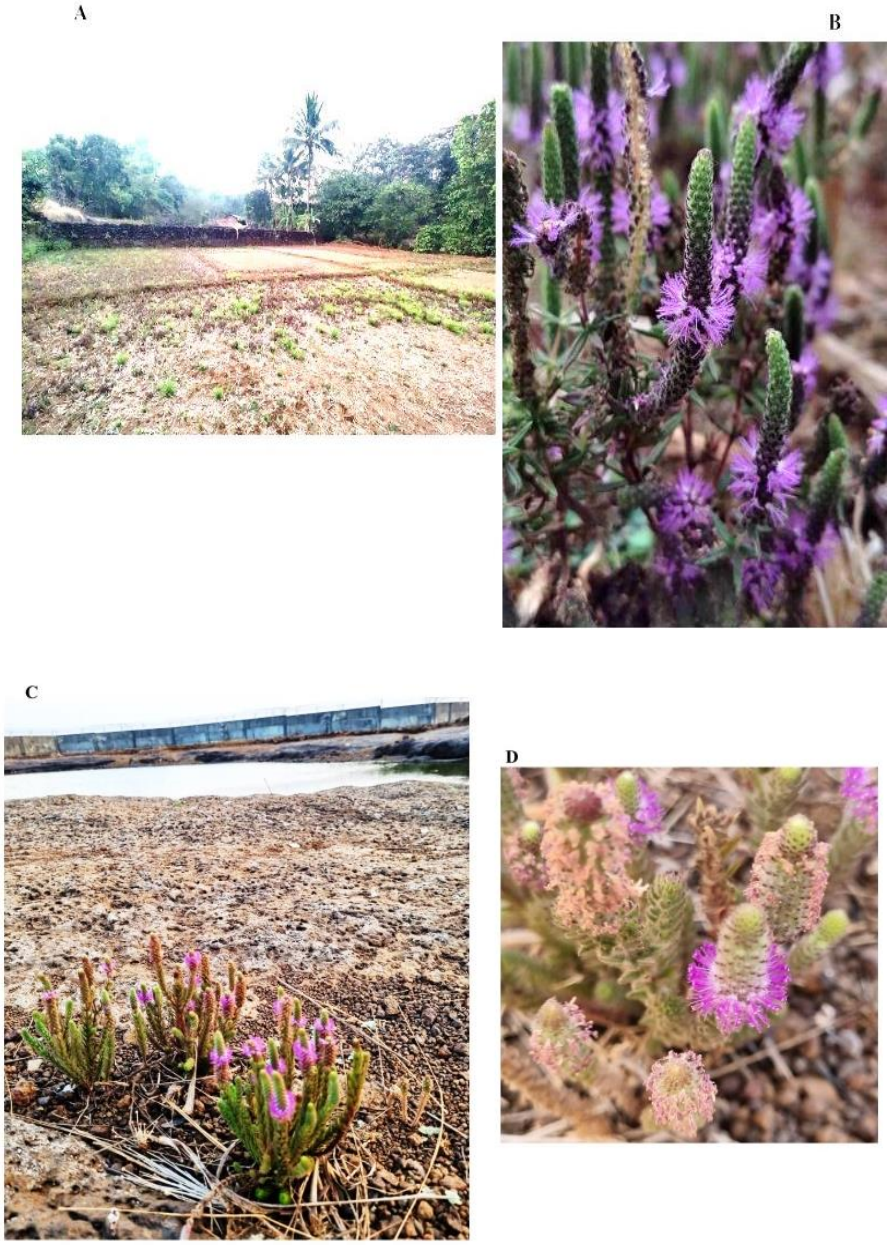

Fig. 1 Habitat and Habit: A& B *Pogostemon deccanensis* (Panigrahi) Press., C & D *P. jaitapurensis* Chandore & S. R. Yadav

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Anatomy:

For anatomical studies free hand section technique used for transverse section, thin sections cut by using razor blades. Then sections bleached by keeping into 37% Sodium hypochlorite (NaClO) solution for about 5-10 minutes to remove specific cell substances like chlorophyll. Afterwards sections washed several times to remove traces of liquid bleach and pre stained with toluidine blue O stain for about 30 sec. and to confirm the presence of oil it were stained with Sudan III then the sections washed and dehydrated in series of ethanol ranging from 10% to Absolute ethanol for 10-1 minutes. Finally, the sections mounted in 10% glycerin placed coverslip and observe under light microscope LX 500 trinocular and microscopic characters recorded by using video camera UCMOS10000KPA attached to microscope.

Results:

T. S. of Erect Stem:

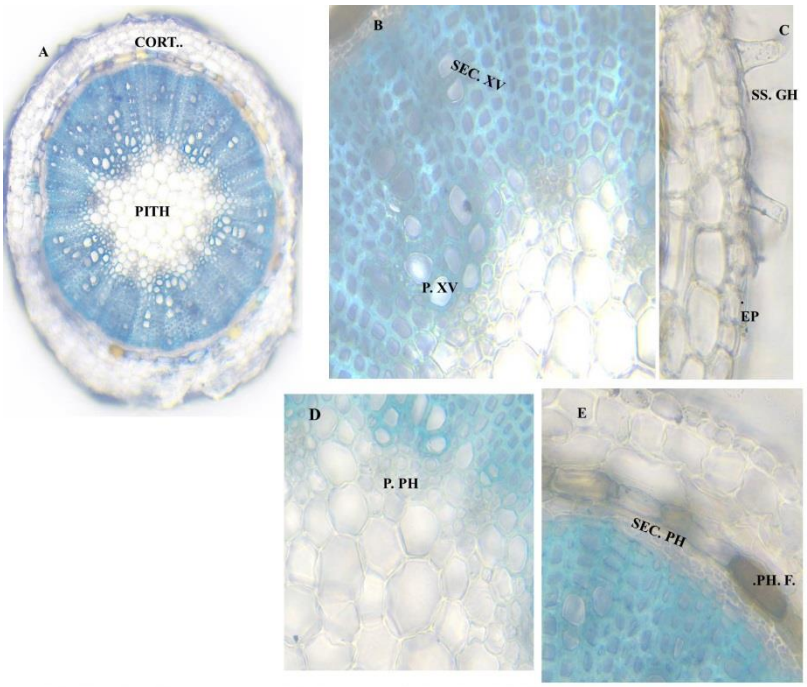

Fig.2 T. S. of Erect stem of *P. deccanensis* (Panigrahi) Press.: Fig. A, B,D & E complete section showing, cortex, vascular ring containing phloem fibre (*PH. F.*), sec. phloem (*SEC. PH.*), sec. xylem (*SEC. XV*), pri. xylem vessels (*P.XV*), pri. phloem (*P. PH.*) bundles and pith. Fig. C showing epidermis (*EP.*) and short stalked glandular trichomes (*SSGH*).

The transverse section of both *P.deccanensis* and *P. jaitapurensis* stem terete 103.99 µm and 1805.35 µm. The epidermis thinly cuticularized uniseriate and made of compactly arranged cuboidal to rectangular parenchyma cells from where two types of trichomes such as unicellular blunt ended glandular and multicellular tapered needle like non-glandular trichomes (Fig. 2 A-C) in *P.deccanensis* and 3-4 celled long needle like non glandular hair in *P. jaitapurensis* (Fig. 3A). The oil droplets often seen in secretory head of the glandular trichomes. Epidermis followed by 1 layered collenchyma and 1-2 layered parenchymatous and aerenchymatous cortex 59.66 µm thick, air cavities flattened and rectangular shaped, developed through schizogenous pattern by either breaking parenchyma cells or enlargements of intercellular gaps in *P.deccanensis* and 2 layered collenchymatous66.47µm thick with schizogenous cartwheel aerenchyma cortex in *P. jaitapurensis* where air cavities are cuboidal and 1395.61 µm. The parenchymatous endodermis containing phloem fibres in both the plants and it 12.55 µm in *P.deccanensis* whereas the size of phloem fibre in *P. jaitapurensis* 508.98 µm and oil ducts separates cortex and vascular stele showing usual ring like structure with slightly formed ridges and furrows in *P.deccanensis* however, in *P. jaitapurensis* prominent ridges and furrows pattern observed than the usual ring like structure (Fig. 3 B&C). Secondary phloem in *P. deccanensis* 23.19 µm and secondary xylem with 14.288 µm peripheral and annular pitted (Fig. 2 B&E), whereas primary xylem 76.56 µm and phloem 155.93 µm situated towards pith and forms traditional conjoint collateral vascular bundles however, sec. phloem forms continuous uniform ring around sec. xylem near periphery (Fig. 2A&D). Both the peripheral sec. xylem and primary xylem towards pith varies in size and about 292.81 µm and 237.68 µm in size respectively and the visible bundles of sec. phloem 695.94 µm observed around sec. xylem towards ridges whereas primary xylem only comprises phloem fibres 508.98 µm in vascular ring in *P. jaitapurensis* (Fig. 3 D & E). The ground parenchymatous pith made

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ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

of compactly arranged pentagonal to hexagonal shaped cells larger than cortical cells and slightly stellate in *P.deccanensis* whereas spherical in *P. jaitapurensis.*

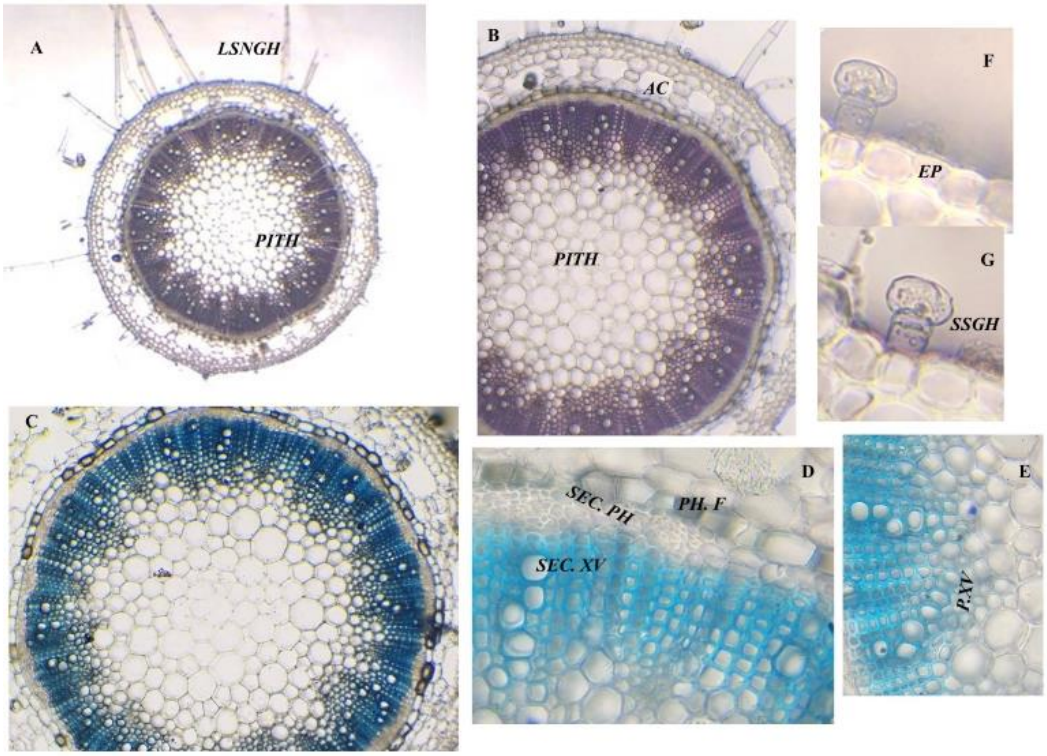

Fig.3 T. S. of Erect stem of *P. jaitapurensis*.: Fig. A, - C complete section showing epidermis *(EP.)*, cortex, air cavities *(AC)*, short stalked glandular trichomes *(SSGH)*,long stalked non glandular hair *(LSNGH)* and pith *(PITH)*. Fig. C - E showing vascular ring containing phloem fibre (*PH. F.)*, sec. phloem *(SEC. PH.)*, sec. xylem *(SEC. XV)*, pri. xylem vessels *(P.XV)*, pri. phloem *(P. PH.)* bundles and pith. Showing. Fig. F & G magnified short stalked glandular hair *(SSGH)*

T. S. of Creeping Main Stem:

The transverse section of creeping main stem terete and wavy, thinly cuticularized 3500 µm and in *P. deccanensis* and in *P. Jaitapurensis* its 4500-5000 µm made of small compactly arranged cuboidal to ellipsoid parenchyma cells (Fig. 4 A) . The glandular 47.88 µm and non-glandular trichomes are arises from epidermal cells (Fig. 4 D) in *P. deccanenesis* and 49.26 µm glandular trichomes and 133.93 µm non-glandular trichomes in *P. jaitapurensis*. Cortex comprises parenchyma cells 2 layered in *P. deccanensis* and 1 layered in *P. jaitapurensis* and cartwheel cuboidal aerenchyma of 331.38 µm of *p. deccanensis* and 955.75 µm in *P. jaitapurensis* formed schizogenously and the diaphragm one cell thick, 73.89 µm and 111.3 µm in *P. deccanensis* and *P. jaitapurensis* respectively. The oil droplets 301.68 µm in *P. jaitapurensis* and 212.75 µm in *P. deccanensis* present in cortical parenchyma cells as well as on epidermal cells (Fig. 4 D, E &Fig. 5G). Endodermis 37.51 µm thick separates cortex and vascular ring as well as containing phloem fibre 149.92µm and the vascular ring forms ridges 644.33 µm and small furrows in *P. deccanensis* the 86.97µm thick endodermal ring composed of phloem fibres 633.89 µm, ridges and furrows. The vascular tissue arrangement not traditionally enclosed in bundles arranged collaterally. Xylem annularly pitted, the secondary xylem 21.92 µm and phloem are peripheral while the primary xylem and phloem located near sharply stellate pith (Fig. 4 B&C). Whereas, secondary phloem 40.74 µm present in narrow strip below the endodermis and in furrows it was 206.13 µm in *P. deccanensis* and 157.68 µm secondary xylem, secondary phloem 86 µm in *P. jaitapurensis*(Fig. 4C & Fig. 5 C-E).

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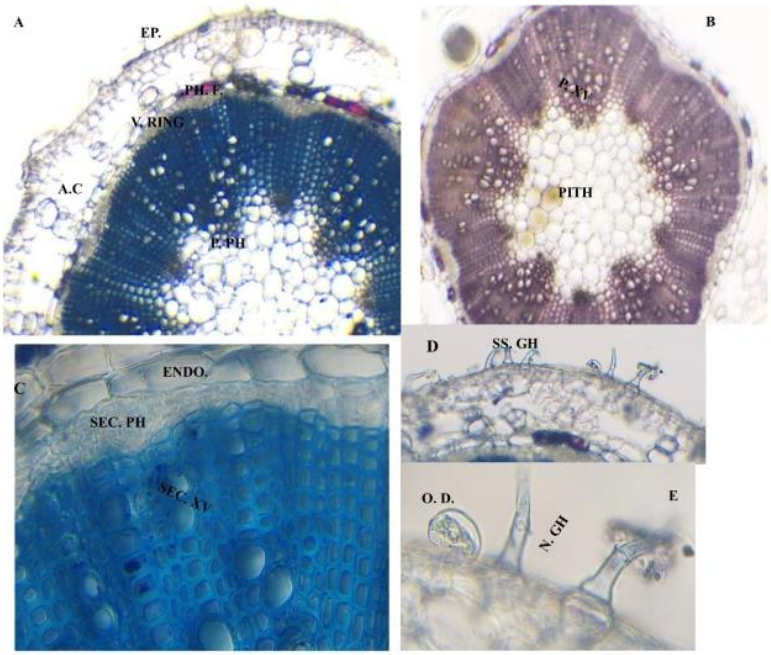

Fig. 4 T. S.of creeping stem *P. deccanensis*: A-C complete section showing epidermis *(EP.)*, cartwheel air cavities *(AC)*, phloem fibre *(PH.F)*, sec. phloem *(SEC. PH)*, sec. xylem *(SEC. XV)*, pri. xylem *(PXV)*, pri. phloem *(P.PH.)* & pith, D&E showing glandular & non glandular *(GH&NGH)* hair along with oil droplet *(O.D)*

However the primary xylem vessels in *P. deccanensis* 88.95 µm comparatively larger than the secondary ones the primary phloem forms small bundles below primary xylem near pith and 107.28 µm in *P. jaitapurensis* (Fig. 5C). The pith is parenchymatous stellate because of annular arrangement of axial parenchyma and ridges and furrows in endodermis, the cells are compactly arranged without any intercellular spaces hexagonal smaller towards vascular elements and larger towards centre in *P. deccanensis* whereas its wide 2678.73 µm wide with slight ridges and furrows than stellate in *P. jaitapurensis*.

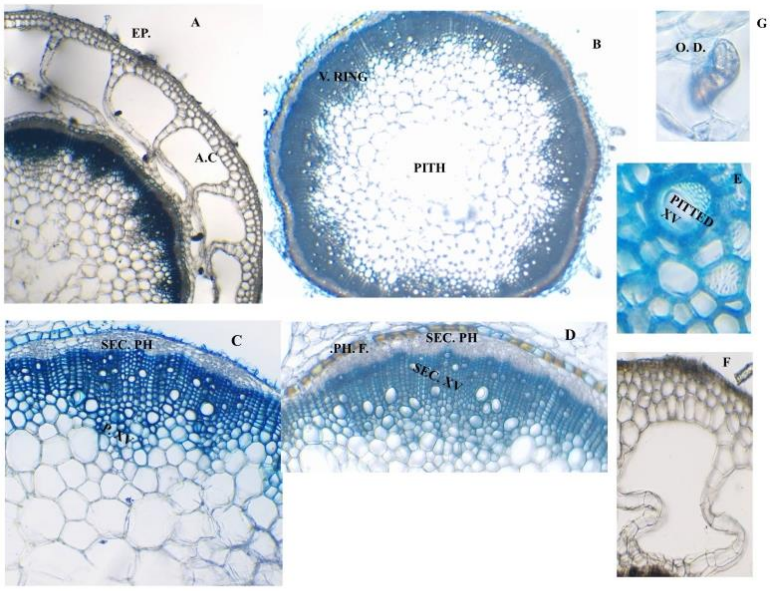

Fig. 5 T. S.of Creeping stem *P. jaitapurensis:* A-D complete section showing epidermis *(EP.)*, cartwheel air cavities *(AC)*, phloem fibre *(PH.F)*, sec. phloem *(SEC. PH)*, sec. xylem *(SEC. XV)*, pri. xylem *(PXV)* & pith, E pitted xylem vessel *(PITTEED XV)*, F showing air cavity diuaphragm and G oil droplet *(O.D)*

T. S. of Leaf:

The leaf margin in transverse section curved slightly wavy and drooping, thickly cuticularized 525.86 µm in *P. deccanensis* and 851.46 µm in *P. jaitapurensis.* Epidermis single layered made of crescentiform cells of unequal

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length. Abaxial surface slightly concave at midrib region with comparatively large and hinge like cells (Fig. 6 A-C air cavities towards lower epidermis however, spongy parenchyma restricted towards the midrib region only. Numerous small oil glands present in chlorenchymatous palisade. Stomata sunken and restricted towards lower epidermis only while oil droplets in *P. deccanensis* 179.54 µm and 205.45 µm in *P. jaitapurensis* mostly secreted on adaxial surface. The primary median vascular bundle conjoint collateral open in both the species, large vascular bundles with 4-5 vertical rows of xylem composed of meta xylem 125.60 µm, proto xylem 71.42 µm and meta phloem 242.15 µm surrounded by single layered incomplete parenchymatous bundle sheath and bundle cap in *P.* deccanensis (Fig. 6A-C).

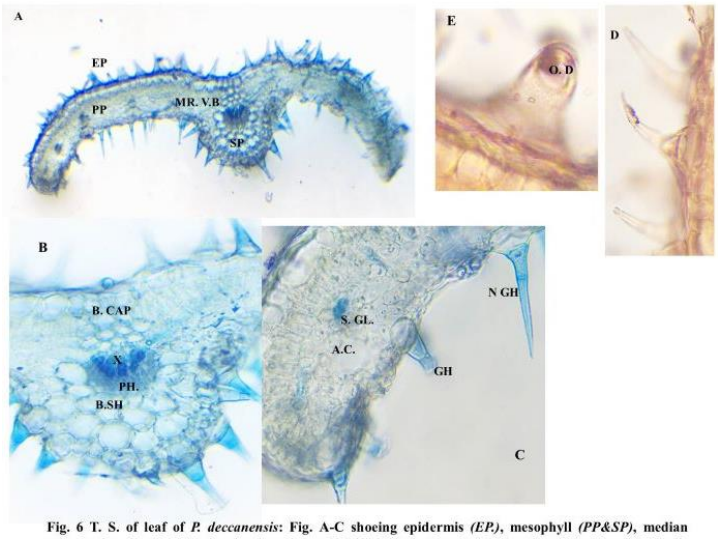

Fig. 6 T. S. of leaf of *P. deccanensis*: Fig. A-C shoeing epidermis *(EP.)*, mesophyll *(PP&SP)*, median vascular bundle *(MRVB)* showing bundle cap*(BCAP)*, bundle sheath *(BSH)*, *xylem* (X), phloem *(PH)*, air cavities *(AC), glandular and non glandular hair (GH.&NGH)*, Fig. D&E showing magnified glandular hair and oil droplet *(O.D).*

The bundle sheath is incomplete in both the species. However, the sheath is 2 layered and bundle cap cuboidal 5 cell long acting like hinge cells in *P. jaitapurensis* in this species the primary large median vascular bundle composed of meta xylem 123.53 µm, proto xylem 77.46 µm and meta phloem 771.46µm forming flat horizontal cylinder towards lower epidermis and xylem forms 5-7 vertical rows (Fig.7 A-D). The, small vascular bundles present at lateral sides 4 at each size in *P. deccanensis* and 1 lateral vascular bundle at each size with 3 traces of developing vascular elements in *P. jaitapurensis* (Fig.7 C). Two types of trichomes such as glandular short stalked unicellular trichomes observed in both plants however, 2-3 celled long non glandular trichomes with needle like ends 281.68µm, and 1 celled short stalked glandular trichomes 166.29µm in *P. deccanenesis* and 2 celled blunt end glandular 754.03 µm and 4-5 cell long needle like non glandular trichomes 766.28µm in *P. jaitapurensis* arises from both upper and lower epidermis (Fig. 6 C-E & Fig.7 E-F).

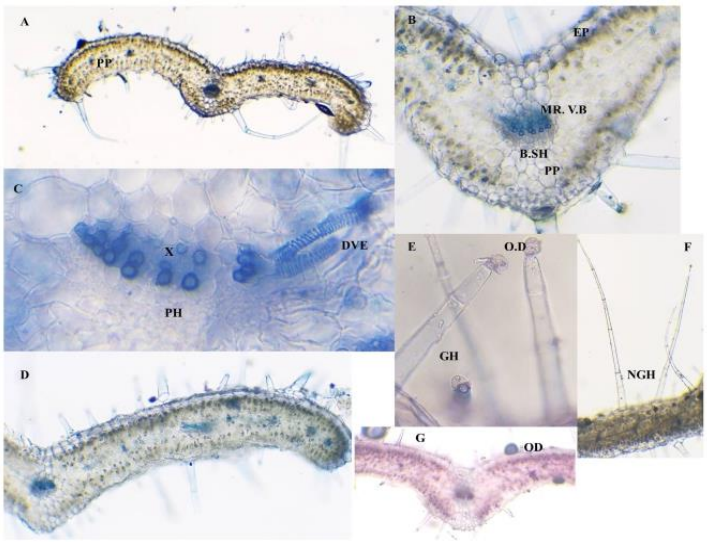

Fig. 7 T. S. of leaf of *P. jaitapurensis*: Fig. A-C showing epidermis *(EP.)*, mesophyll *(PP&SP)*, median vascular bundle *(MRVB)* showing bundle cap*(BCAP)*, bundle sheath *(BSH)*, *xylem* (X), phloem *(PH)*, Fig. D-G showing lateral side leaf, glandular and non glandular hair *(GH.&NGH)*, and oil droplet *(O.D).*

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Discussion:

Pogostemon plants have extended stamen and moniliform hair which is a peculiar characteristic of the genus and beside this plants varies from terrestrial subshrubs to aquatic herbs. The terrestrial group has opposite leaves while aquatic one has veticillate sessile leaves (Linh Thuy Thi Tran *et al*. 2022). In infrageneric classification of *Pogostemon* it was divided into three subgenera *Allopogostemon. Dysophyllus* and *Pogostemon*, this classification based on 135 morphological characters (Bhatti & Ingrouille 1997).

Both the taxa under study belongs to the same genus Pogostemon and subgenus Dysophyllus and morphologically look similar. There are visible morphological differences between them although they show morphological similarities. The *P. jaitapurensis* densely pubescent across all parts while *P. deccanensis* densely pubescent at erect stem and glabrous to glabrescent across the rest of the parts. The creeper robust slightly woody in *P. jaitapurensis* and herbaceous in *P. deccanensis*. Inflorescence scorpiod cyme and phyllotaxy sessile, whorl in both species. In *P. deccanensis* the whorl containing 6 leaves which are linear glabrescent on abaxial surface while 8 lanceolate to ovate leaves densely pubescent and ciliate at margins in *P. jaitapurensis* (Chandore S. R. Yadav 2021).

The anatomical study of *P. deccanensis* (Panigrahi) Press. and *P. jaitapurensis* conducted to delimit its taxonomic placement and the result shows presence of moniliform short stalked glandular and long stalked multicellular non-glandular hair, internal oil glands, leafy aerenchyma on abaxial surface of leaf, honeycombed aerenchyma in stem in both plants. Some characters such as glandular and non-glandular hair and oil glands also present in commercial oil crops like *P. cablin* and *P. auricularius* however, trichomes of *P. deccanensis* varies from them as the glandular trichome are short stalked single celled and with blunt end whereas the non-glandular ones are 2-3 cell long comprising basal cell, middle cell and pointed needle like head. However, glandular 1-2 cell long, non-glandular trichomes 4-5 cells long in *P. jaitapurensis*.

In *P. deccanensis* leafy aerenchyma observed in leaf at abaxial surface and lacks in *P. jaitapurensis* while wheel aerenchyma present in creeping main stem as well as erect stem of both the species. Both leafy and wheel arenchyma are key features of aquatic plants, the leafy aerenchyma formed via cell lysis while wheel aerenchyma develop through cell elongation and separation thus leafy aerenchyma follows lysigenous pattern and wheel aerenchyma follows schizogenous patterns of development (Jongdul Jung *et al*. 2008).

In *P. jaitapurensis t*he secondary phloem forms small bundles around secondary xylem than usual ring structure found in most of the Pogostemon species including *P. deccanensis*. The primary xylem in *P. deccanensis* comprises small phloem bundles near pith and phloem fibres in endodermis whereas the primary phloem bundles near pith absent in *P. jaitapurensis*. In case of leaf the air cavities absent, oil globules present abundantly on both the abaxial and adaxial surfaces in *P. jaitapurensis* and air cavities towards lower epidermis present along with oil globules in *P. deccanensis.*

Conclusion:

The present study conducted to delimit the taxonomic placement of these taxa in subgenus *Dysophyllus* under genus *Pogostemon* and the anatomical characters well matched with other species under the same genus specifically the *Pogstemon* species placed under subgenus *Dysophyllus.* The palisade comprises numerous small oil glands secreting oil droplets on surface and through secretory trichomes. The phytochemical constituents extracted from essential oil of *P. deccanensis* shows antioxidant richness with anti-inflammatory and anti-proliferative activities and the nature of essential oil was non-cytotoxic (Vinay Kumar *et al.* 2019) while the phytochemical and antimicrobial analysis of *P. jaitapurensis* need to be done in future to determine its active components and medicinal properties. Both anatomical and phytochemical studies concluded the potential of *P. deccanensis* to be used in pharmaceuticals because of presence of essential oil and its non-cytotoxicity hence further research needed.

Acknowledgement:

The authors are grateful to MAHAJYOTI for funding this research study.

References:

1. Amalia Rusydi, Noraini Talip, Jalifah Latip, Ruzi Abdul Rahman, and Idris Sharif (2013); Morphology of trichomes in Pogostemon cablin Benth. (Lamiaceae); Australian Journal of Crop Science 7(6): 744-749.
2. Arun Chandore, Asif Tamboli, Devidas BorudeAvinash Ghovale, Sanjay Govindwar & Shrirang Yadav (2021); *Pogostemon jaitapurensis* (Lamiaceae), a new species from India basefd on morphological and molecular evidence; Phytotaxa 502 (1):028-050.
3. Charles B. Beck, Rudolf Schmid and Gar w. Rothwell (1982); Stelar morphology and the primary vascular system of seed plants; The Botanical Review 48(4): 759-760.
4. Deolinda Lucianne Ferreira, Maria Silvia de Mendonça, Maria Graciomar Pacheco de Araujo, Branca Flor Murrieta Lescano, Maria Olívia de Albuquerque Ribeiro Simão(2020); Leaf anatomy and histochemistry of Oriza (Pogostemon cablin Beth., LAMIACEAE): Medicinal plant used in community Arari region, Itacoatiara, Amazonas; International Journal of Advanced Engineering Research and Science; 7(4): 27-37.
5. Habiba Sayekar and Raghunath Ghalme (2025); Comparative anatomical study of four species of *Eleocharis* (Cyperaceae) from the wetlands of Ratnagiri District, Maharashtra India; Journal of Economic and Taxonomic Botany 49(2): 63-72.

6. Jiansheng Guo and Cheng Zhou 92019); Secretory structures of Pogostemon auricularius: Morphology, development, and histochemistry; Symmetry 11: 13.
7. Jiansheng Guo, Yongming Yuan, Zhixue Liu, Jian Zhu (2013); Development and structure of internal glands and external glandular trichomes in Pogostemon cablin; Plos One 8(10): 1-12.
8. K. Shinoj, K. P. Vimal and P. Sunojkumar (2016); A checklist of the genus Pogostemon desf. in Southern Western Ghats,South Indian Journal Of Biological Sciences 2(1); 46-51.
9. Kanjana Pramali,a,b Bhanubong Bongcheewin,b Paweena Traiperma (2018); Leaf micromorphological adaptation of Pogostemon spp. (section Eusteralis) in Thailand, Agriculture and Natural Resources; 52: 250-258.
10. Linh Thuy Thi Tran , Tan Khanh Nguyen, Hoai Thi Nguyen, Phu Phong Nguyen, Nhi Yen Thi Dang, Manh Hung Tran ,VinhPhuTranPham and Anh Tuan Le (2022); Morpho-Anatomical Study And Botanical Identification of Pogostemon auricularius (L.) Hassk. (Lamiaceae), Science Progress 105(2) 1–15.
11. Linh Thuy Thi Tran, Tan Khanh Nguyen, Hoai Thi Nguyen, Phu Phong Nguyen, Nhi Yen Thi Dang, Manh Hung Tran ,VinhPhuTranPham and Anh Tuan Le (2022); Morpho-Anatomical Study And Botanical Identification of Pogostemon auricularius (L.) Hassk. (Lamiaceae); Science Progress Vol. 105(2) 1–15.
12. ongduk Jung, Seung Cho Lee , and Hong-Keun Choi (2008); Anatomical patterns of aerenchyma in aquatic and wetland Plants; Journal of Plant Biology 51(6) : 428-439.
13. Shigwan Ashwini V, Khade Amol B, Hatpakki Basawaraj C, and Ghurghure Shrishail M (2013); A Comprehensive Review on Pogostemon benghalensis (Burm. F.) O. Kuntze; Research and Reviews: Journal of Pharmacognosy and Phytochemistry 1(1): 10-15.
14. Vinay Kumar, Varsha Shriram, Rani Bhagat, Tushar Khare, Shivanjali Kapse, Narendra Kadoo (2019); Phytochemical profile, anti-oxidant, anti-inflammatory, and anti-proliferative activities of Pogostemon deccanensis essential oils; 3 Biotech 9:31.

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Original Article

Comparative Phytochemical Analysis of *Vitex negundo* Linn. And *Vitex trifolia* Linn

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Manuscript ID:
JRD -2026-180409
ISSN: 2230-9578
Volume 18
Issue 4(XI)
Pp. 53-59
April - 2026
Submitted: 10 Mar. 2026
Revised: 20 Mar. 2026
Accepted: 25 Mar. 2026
Published:30 April2026

Abstract:
In traditional healthcare systems Vitex negundo Linn. and Vitex trifolia Linn. belonging to family Lamiaceae are widely recognized medicinal plants with extensive therapeutic versatility; however systematic comparative phytochemical standardization remains limited. The present study aims to provide a comprehensive comparative evaluation of these two species specifically focusing on leaf and stem as the selected plant parts, through analysis of extractive values, proximate analysis, qualitative phytochemical profiling, Total Polyphenol Content (TPC) and Total Flavonoid Content (TFC). A strong influence of solvent polarity on extraction efficiency was demonstrated by successive extraction using solvents of increasing polarity. Methanol exhibited highest extractive value in both species, indicating the pre-dominance of polar bioactive constituents. Proximate analysis of leaf and stem samples established essential quality control parameters for pharmacognostic standardization. Preliminary phytochemical screening confirmed the presence of major secondary metabolites across different extracts. Quantitative estimation revealed that TPC determined using Folin- Ciocalteu method was highest in Vitex negundo leaf (79.29 mg GAE/g), followed by Vitex trifolia leaf (76.40 mg GAE/g), while stems showed lower values (Vitex negundo stem 50.63 mg GAE/g and Vitex trifolia stem 49.50 mg GAE/g). Similarly, TFC, estimated using $AlCl_3$ method was maximum in Vitex negundo leaf (4.01 mg QE/g), followed by Vitex trifolia leaf (3.96 mg QE/g), with reduced levels in stem. These findings support the richness of antioxidant- associated compounds with observable variation. Overall, the findings highlight significance differences in phytochemical composition and extraction profiles between the two species. This study provides a scientific basis for the selection, standardization and utilization of these species in herbal formulations and reinforces their potential as valuable sources of bioactive compounds for future pharmacological and formulation research.

Keywords: *Vitex negundo Linn., Vitex trifolia Linn., Phytochemical profiling, Total Polyphenol Content (TPC), Total Flavonoid Content (TFC)*

1. Introduction:

Medicinal plants remain crucial to healthcare systems globally, serving as the foundation of traditional medicine and playing a significant role in contemporary pharmacological research. The renaissance of scientific interest in plant-derived therapies is primarily fueled by the growing need for safer, more affordable, and naturally sourced biologically active compounds. A large segment of the world's population relies on herbal treatments for primary healthcare, highlighting the importance of systematic phytochemical and pharmacognostic studies of medicinal plants. These studies are vital for validating traditional knowledge and aiding in the creation of standardized herbal products.The secondary metabolites also known as phytochemicals like phenolics, flavonoids, alkaloids, tannins, glycosides and terpenoids are primarily responsible for the therapeutics properties of medicinal plants. A wide spectrum of biological activities such as anti-oxidant, antimicrobial, anti-inflammatory and anti-cancer effects are exhibited by these compounds.

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How to cite this article:
Parab, S., & Avhad, A. (2026). Comparative Phytochemical Analysis of Vitex negundo Linn. And Vitex trifolia Linn. Journal of Research and Development, 18(4(XI)),53–56.
https://doi.org/10.5281/zenodo.21103536

Quick Response Code:
Website:
https://jrdrvb.org/
DOI:
10.5281/zenodo.21103536
OPEN ACCESS

Phenolic compounds and flavonoids among these are considered of particular importance because of their strong free radical scavenging ability and their role in mitigating oxidative stress, which is a major factor contributing in the pathogenesis of chronic diseases. With several studies demonstrating a direct correlation between Total Phenolic Content (TPC) ,Total Flavonoid Content (TFC) and anti-oxidant activity, the consequence of these compounds has been entrenched in phytochemical research. (Prior *et al*.,2005).

A diverse group of medicinal plants widely distributed in tropical and subtropical regions encompasses of the genus *Vitex* belonging to family Lamiaceae. In traditional systems of medicine such as Ayurveda and folk medicine *Vitex negundo* Linn. and *Vitex trifolia* Linn. are two closely related species that have been conventional. Vitex negundo, commonly known as Nirgudi is customarily used for its anti-inflammatory, analgesic, anti-microbial and anti-oxidant properties. Numerous bioactive compounds which contribute in pharmacological activities such as flavonoids, iridoids, lignans and phenolic acids are found in *Vitex negundo* according to the modern phytochemical investigations (Phate and Patil, 2026).

Extracts of *Vitex negundo* possess significant anti-microbial and anti-inflammatory properties playing a crucial role in modulating oxidative stress and inflammatory pathways due to specific compounds such as quercetin and luteolin derivatives (Jaiswal and Kumar, 2025). These studies demonstrated, support the long-established use of the plant and highlight its potential as a source of natural therapeutic agents.

Likewise, *Vitex trifolia* Linn. is another medicamentally important species known for its remedial applications in the treatment of inflammation, respiratory disorders and skin diseases. Various studies have shown presence of secondary metabolites which are responsible for its medicinal potential. Attributed to its high phenolic and flavonoid content significant anti-oxidant activity has also been reported in recent research. (Chokpaisarn *et al*., 2024).

Inspite of in-depth analyses on individual species, comparative phytochemical analysis between *Vitex negundo* and *Vitex trifolia* remains moderately constrained. Understanding interspecies variation in phytochemical composition is crucial because comparative studies may substantially influence their clinical effectiveness. Biological activity can be affected by factots such as geographical location, environmental conditions and plant part used which may also lead to variations in phytochemical content. Hence, for identifying the species with superior phytochemical richness and potential medicinal value a systematic comparative evaluation is essential.

Furthermore, for the standardization and quality control of medicinal plant materials; phytochemical profiling, physiochemical parameters such as extractive values and proximate composition also play a crucial role. While ascertaining the purity and inorganic composition of plant samples proximate analysis including total ash, water soluble ash and acid-insoluble ash is helpful while, extractive values provide insight into the solubility and distribution of phytoconstituents in different solvents. To ensure quality of herbal drugs and to detect adulteration these parameters are widely used in pharmacological studies.

A systematic and comparative investigation of *Vitex negundo* and *Vitex trifolia* becomes highly relevant; considering the growing emphasis on plant-based interventions and need for scientific validation of traditionally used species. While both the species are recognized for their diverse pharmacological properties, differences in their phytochemical composition, extractive values and physicochemical parameters remain insufficiently explored. A comprehensive evaluation integrating preliminary phytochemical screening, proximate analysis and quantitative estimation of total phenolic and flavonoid content can provide deeper insights into their bioactive potential and anti-oxidant capacity. These comparative evaluations are crucial not only for determining which species or plant part is more effective but also for setting quality control benchmarks and promoting their logical application in the development of herbal medicines. (Sasidharan *et al*., 2011).

2. Materials and Method

2.1 Plant material collection and Authentication

Plant material of *Vitex negundo* Linn. was obtained from Jummapati, Neral-Matheran Road, Raigad – Maharashtra and *Vitex trifolia* Linn. was obtained from Gandaulim, Goa. The plant was authenticated at Blatter herbarium, St. Xavier's College, Mumbai. Both the plants match the Blatter specimen number A.R.-285 of A.J. Randeria and 142.1 of H. Santapau respectively. Plant was brought to the laboratory and washed using clean water to remove dust and dried before keeping separately as leaf and stem in oven to completely dry at 50-55 °C, plant parts were processed into fine powder using laboratory mixer grinder and passed through 180micron pore size sieve to obtain minimum and even particle size composition. The powder was stored in air tight container and further used for qualitative and quantitative estimations.

2.2 Extractive value Determination

Extractive values were determined using solvents of increasing polarity, namely methanol, ethanol, distilled water, acetone, ethyl acetate, chloroform and hexane. Approximately 1g of powdered plant material (leaf and stem separately) was accurately weighed and subjected to extraction with100ml of respective solvent in a closed flask using the maceration method mentioned in Ayurvedic Pharmacopoeia of India. The flasks were kept on shaker for 6 hours and allowed to stand for 6 hours and allowed to stand for 18 hours. After maceration, the extracts were filtered using Whatman No. 1 filter paper. The filtrates were then concentrated by evaporating the solvent in hot air oven. The dried extracts were then weighed and the extractive value was calculated in percentage.

Extractive value (%) = (Weight of dried extract/ Weight of sample) x 100

2.3 Preliminary Phytochemical screening

For Phytochemical profiling of *Vitex negundo* and *Vitex trifolia* the extracts were prepared in Distilled water, Methanol, Ethanol, Acetone, Ethyl acetate, Chlorofrom & Hexane by refluxing 1g of powder in 100ml solvent in water bath for 30mins. Corresponding filtrates were used and the tests were performed following the standard protocol by Harborne 1998, Patel & Avhad 2025.

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2.4 Proximate Analysis

Standard procedures from Ayurvedic pharmacopoeia of India, Javkar and Avhad 2021, Pathak *et al*.2023 were followed for the determination and calculation of Total ash content, Acid-Insoluble ash content and Water-Soluble ash content.

2.5 Quantitative Phytochemical Estimation

2.5.1 Plant extract preparation

1% plant extracts were prepared using 0.2g of plant powder in 20ml of solvent i.e methanol. The extract was prepared using ultrasonic bath sonicator for 45 mins to ensure maximum extraction at room temperature. After extraction the extract was centrifuged to get the clear supernatant which was further used for analysis.

2.5.2 Total Phenolic Content

Total Phenolic content was measured using The Folin's Ciocalteu reagent method by Singleton and Rossi (1965), Kangralkar and Avhad (2025) with few modifications. Breifly an aliquot of 1 ml of appropriately diluted extracts or standard solutions of gallic acid (20, 40, 60, 80, 100, 120mg/L) was added to a 25ml volumetric flask containing 9 ml of DW. A reagent blank using DW was prepared. 1ml Folin's Ciocalteu reagent was added to the mixture. After 5 mins, 10ml of 7% Na_2CO_3 solution was added with mixing. The solution was then consecutively diluted to 25ml with distilled water. After incubation for 90mins at room temperature the absorbance versus blank was read at 750nm. Total phenolic content of leaf and stem was expressed as mg gallic acid equivalents (GAE)/ gram dried sample. All samples were analysed in three replications.

2.5.3 Total Flavonoid Content

Total flavonoid content was determined using standard quercetin equivalence by Tristantini *et al.*, 2019. Quercetin concentration is first estimated by Aluminium chloride spectrophotometric method, 0.5ml of plant extract in 1.5ml distilled water and 0.1ml potassium acetate, 0.1ml aluminium chloride is subsequently added, volume is raised to 5ml by adding 2.8ml distilled water again. Quercetin was used as reference standard dilutions were made to achieve a calibration curve by standard series, 10, 20, 30, 40, 50, 60 mg/L treating with the same method as plant extract and absorbance was measured at 415 nm keeping one test as blank without plant extract or quercetin. Total Flavonoid content was calculated using equation as 1mg of quercetin equivalence QE per gram and by multiplying quercetin concentration in ppm (C) by the volume of solution in ml (V) and dividing by mass of sample in grams (W) (Bhandari et al., 2014)

3.Result and Discussion

3.1 Extractive value

Extractive values of *Vitex negundo* and *Vitex trifolia* varied significantly with the solvent polarity and plant part. Among all the solvents highest yield was observed in methanol especially leaf samples (Fig 1). *Vitex negundo* leaf showed maximum 35% yield followed by *Vitex trifolia* leaf which is 32%. Stems consistently exhibited lower extractive values than leaves. Distilled water showed considerable extraction efficiency, indicating the presence of polar constituents. Moderate yields were obtained with acetone and ethyl acetate while chloroform and hexane showed the lowest extractive values, reflecting limited non-polar compounds. Overall, leaves are richer in extractable phytoconstituents and polar solvents are more effective with *Vitex negundo* showing slightly higher yields than *Vitex trifolia*.

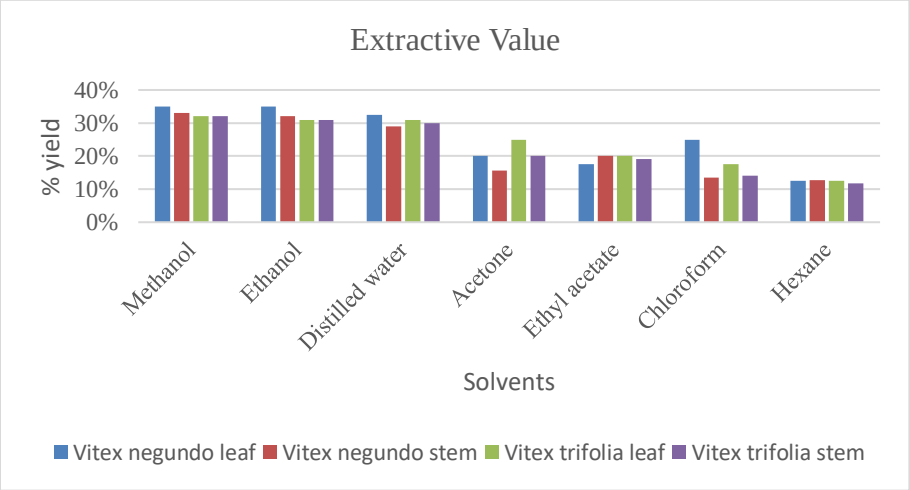

Fig 1: Comparative extractive values (% yield) of leaf and stem of *Vitex negundo* and *Vitex trifolia* using solvents of varying polarity.

3.2 Phytochemical Screening :

The qualitative phytochemical screening of *Vitex negundo* and *Vitex trifolia* (Leaf and stem) extracts revealed a diverse distribution of bioactive constituents across different solvents. Polar solvents such as methanol, ethanol and distilled water showed a higher abundance of phytoconstituents with consistent positive reactions for carbohydrates, proteins, alkaloids and phenolic compounds. Leaves of both species exhibited comparatively richer phytochemical profiles than stems, indicating higher metabolic activity and accumulation of secondary metabolites. Moderate presence of

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glycosides and flavonoids was observed, while non-polar solvents like chloroform and hexane showed limited extraction efficiency, yielding fewer positive results. Overall, *V.negundo* demonstrated slightly stronger phytochemical presence than *V.trifolia*, supporting its wider traditional medicinal use. These findings highlight the influence of solvent polarity and plant part on phytochemical extraction and suggest that polar extracts are more suitable for isolating bioactive compounds associated with therapeutic potential.

Table 1: Phytochemical Screening of *Vitex negundo* Leaf and Stem

Phytochemical tests	Methanol		Ethanol		Distilled water		Acetone		Ethyl acetate		Chloroform		Hexane	
	L	S	L	S	L	S	L	S	L	S	L	S	L	S
Fehling's Test	+	+	+	+	+	+	-	-	-	-	-	-	-	-
Benedict's Test	+	+	+	+	+	+	-	-	-	-	-	-	-	-
Sudan IV Test	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Ninhydrin test	+	+	+	+	+	+	-	-	-	-	-	-	-	-
Biuret Test	+	+	+	+	+	+	-	-	-	-	-	-	-	-
Drangendroff's Test	+	+	+	+	+	+	-	+	-	-	-	-	-	-
Wagner's Test	+	+	+	+	+	+	-	+	-	-	-	-	-	-
Keller-killani Test	+	+	+	+	-	+	+	+	+	+	-	-	-	-
Foam Test	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Salkowski Test	-	-	-	-	-	-	+	+	-	+	-	-	-	-
$FeCl_3$ Test	-	+	-	+	+	+	-	+	-	-	-	-	-	-
Alkaline reagent Test	+	+	+	+	+	+	-	-	-	-	-	-	-	-
Lead acetate Test	+	+	+	+	+	+	-	-	-	-	-	-	-	-
Ferric Chloride Test	-	+	+	+	+	+	-	-	-	-	-	-	-	-
Quinone Test	-	-	-	-	+	-	-	+	+	+	-	-	-	-
Braymer's Test	+	+	+	+	-	-	-	-	-	-	-	-	-	-

(In Table 1 "+" indicates presence while "-" indicates absence of the respective phytoconstituents as determined by standard qualitative tests. **"L"** stands for leaf and **"S"** stands for Stem)

Table 2: Phytochemical Screening of *Vitex trifolia* leaf and stem

Phytochemical tests	Methanol		Ethanol		Distilled water		Acetone		Ethyl acetate		Chloroform		Hexane	
	L	S	L	S	L	S	L	S	L	S	L	S	L	S
Fehling's Test	+	+	+	+	+	+	+	-	-	-	-	-	-	-
Benedict's Test	+	+	+	+	+	+	+	-	-	-	-	-	-	-
Sudan IV Test	+	+	+	+	+	+	+	+	+	+	+	+	+	+

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Ninhydrin test	+	+	+	+	+	+	+	-	-	-	-	-	+	-
Biuret Test	+	+	+	+	+	+	+	-	-	-	-	-	-	-
Drangendroff's Test	+	+	+	+	+	+	+	+	-	-	-	-	-	-
Wagner's Test	+	+	+	+	+	+	-	-	-	-	-	-	-	-
Keller-killani Test	+	+	+	+	+	+	+	+	+	-	-	-	-	-
Foam Test	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Salkowski Test	-	-	-	-	-	-	-	-	-	-	-	-	-	-
$FeCl_3$ Test	+	+	+	+	-	+	-	-	-	-	-	-	-	-
Alkaline reagent Test	+	+	+	+	+	+	-	-	-	-	-	-	-	-
Lead acetate Test	+	+	+	+	+	+	-	-	-	-	-	-	-	-
Ferric Chloride Test	+	+	-	+	+	+	-	-	-	-	-	-	-	-
Quinone Test	+	-	-	-	-	+	-	-	+	+	-	-	-	-
Braymer's Test	+	+	+	+	+	-	-	-	-	-	-	-	-	-

(In Table 2 **"+"** indicates presence while **"-"** indicates absence of the respective phytoconstituents as determined by standard qualitative tests. **"L"** stands for leaf and **"S"** stands for Stem)

3.3 Proximate Analysis

The proximate analysis of *Vitex* samples revealed that *Vitex negundo* leaf had the highest total ash content (7.02 ±0.05%), followed by *Vitex trifolia* leaf (6.05±0.03%) and Vitex trifolia stem (6.05±0.01%), and *Vitex trifolia* stem (5.92±0.04%). Acid-Insoluble ash was low across all samples(0.33-1.10%), indicating minimal siliceous contamination, while water-soluble ash constituted a major fraction, with the highest value again in *V.negundo* leaf (5.87±0.06%). Overall, leaves showed higher mineral content than stems, with *V.negundo* leaf exhibiting the richest inorganic compostion and good sample purity.

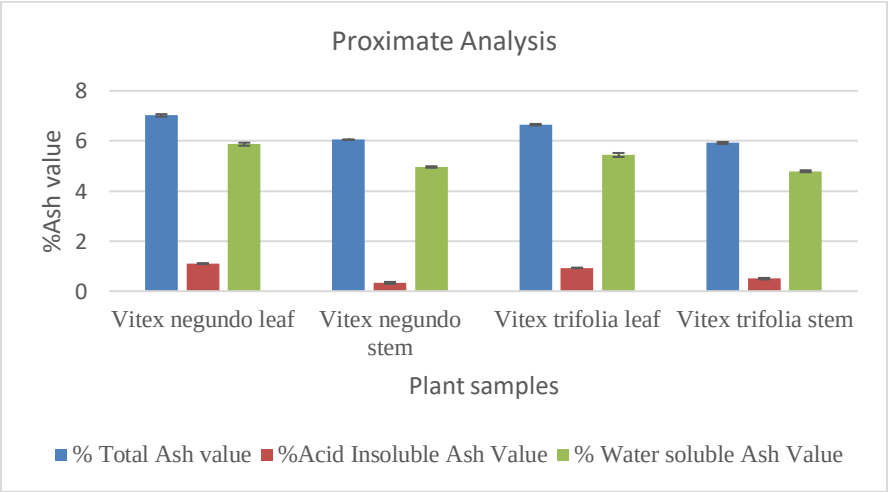

Fig 2: Proximate Analysis of Vitex species (Leaf and stem)

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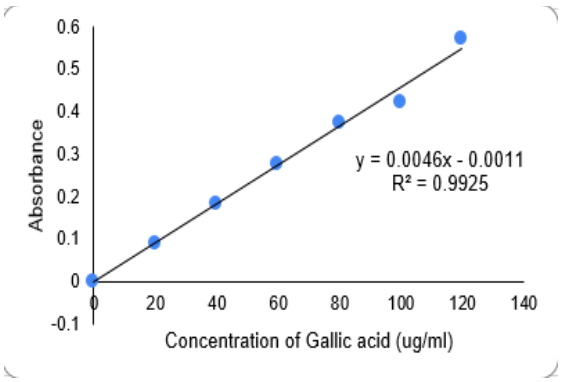
3.4 Quantitative Phytochemical Estimation

3.4.1 Total Phenolic Content

The calibration curve of Gallic acid showed good linearity (R^2= 0.9925), indicating reliable estimation of total phenolic content. Among the samples, *Vitex negundo* leaf exhibited the highest phenolic content of 79.29 mg GAE/g, followed by *Vitex trifolia* leaf (76.40 mg GAE/g), while stem samples showed comparatively lower values like 50.63 mg GAE/g and 49.50 mg GAE/g respectively. This suggests that leaves possess higher phenolic compounds than stems, indicating stronger anti-oxidant in leaf extracts.



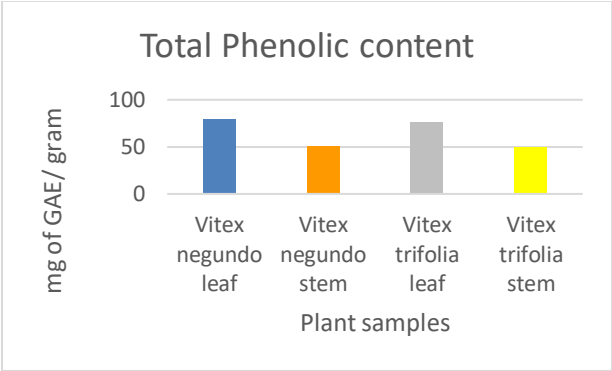
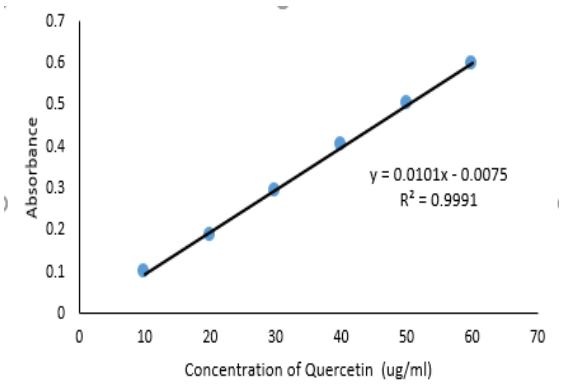


Fig 3. **Fig 4.**

Fig 3 and 4: Calibration Curve of Gallic acid for estimation of Total Phenolic Content and Total Phenolic Content (mg GAE/g) of selected plant samples.

3.4.2 Total Flavonoid Content

The calibration curve of quercetin exhibited excellent linearity (R^2= 0.9991), confirming the accuracy of flavonoid estimation. Among the samples, *Vitex negundo* leaf showed the highest flavonoid content of 4.01mg QE/g, followed by *Vitex trifolia* leaf (3.96 mg QE/g), while stem samples and comparatively lower values 2.03 mg QE/g and 1.97 mg QE/g respectively. This indicates that leaves are richer flavonoids than stems, suggesting better anti-oxidant potential in leaf extracts.



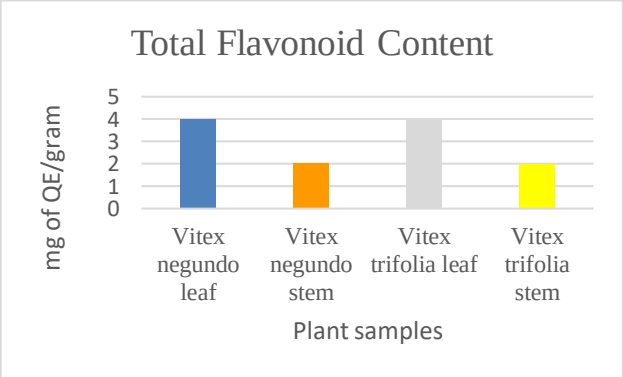


Fig 5. **Fig 6.**

Fig 5 and 6: Calibration Curve of Quercetin for estimation of Total Flavonoid Content and Total Flavonoid Content (mg QE/g) of selected plant samples.

4. Conclusion

This study confirms that both *Vitex negundo* and *Vitex trifolia* are rich sources of bioactive phytoconstituents, with polar solvents, especially methanol yielding the highest extractive values. Leaves demonstrated significantly higher phenolic and flavonoid content than stems, correlating with greater mineral richness and phytochemical diversity, Overall, *Vitex negundo* leaf exhibited superior phytochemical and antioxidant potential, supporting its traditional

medical prominence. Future prospects include *in vivo* bioactivity studies to validate therapeutic efficacy, isolation of individual bioactive compounds for drug development, standardization of polar extracts as herbal formulations.

5. Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

6. Acknowledgement

The authors wish to express their heartfelt gratitude to Dr. Usha Mukundan, Director, HVPS and Dr. Himanshu Dawda, Principal, Ramniranjan Jhunjhunwala College (Empowered Autonomous) for their continuous encouragement and the facilities made available throughout this investigation.

References

1. Ayurvedic Pharmacopoeia of India, Part I, Volume IX, New Delhi: Ministry of AYUSH, Government of India
2. Bhandari, L. and Rajbhandari, M. (2014). Isolation of quercetin from flower petals, estimation of total phenolic, total flavonoid and anti-oxidant activity of the different parts of *Rhododendron arboreum* Smith. *Scientific World*, 12(12), 34-40
3. Chokpaisarn, J., Paduka, W., Saeloh Sotthibandhu, D., Phoopha, S., Limsuwan, S., Maneenoon, K., Mahaprom, K., & Chaiwong, K. (2024). Evaluation of biological properties and phytochemical profile of *Vitex trifolia* L. extract and its infused oil as a value-added product for health promotion. *South African Journal of Botany*, 169, 543–552.
4. Jaiswal, N., & Kumar, A. (2025). Identification, quantification, and bioactivity of *Vitex negundo* phenolic acids as efficacious anti-candidal and antibiofilm agents targeting *Candida albicans*. *Medical Mycology*. 35(2).
5. Javkar, R. and Avhad, A. (2021). Proximate Analysis of Portulacaria afra. Jacq. *Applied Research in Botany*, Volume I,143-147
6. Kangralkar, S and Avhad, A. (2025). Unveiling the anti-oxidant power: In-vitro analysis of different plant parts of Wrightia tinctoria R.Br. International Journal of Biology Sciences, 7 (8), 121-126
7. Patel, A and Avhad, A. (2025). Phytochemical and Nutritional Evaluation of Solanum diphyllum L.: A Potential Medicinal Plant. Botanical Insights: From Traditional Knowledge to Modern Science. Nature Light Publications, Volume II ISBN-978-93-49938-03-8
8. Pathak, N., Avhad, A. and Dawda, H. (2023). Proximate Composition From Selected Members of Order Myrtales. *Journal of Advanced Scientific Research*,14(05): 16-25
9. Phate, P.V. and Patil, A. S. (2026). *Vitex negundo* Linn.: A decade of advances on phytochemistry , pharmacological activities and biotechnological interventions (2015-2025): A comprehensive review. *Phytomedicine*, 153, 157895.
10. Prior, R. L., Wu, X., and Schaich, K. (2005). Standardized methods for the determination of antioxidant capacity and phenolics in foods and dietary supplements. *Journal of Agricultural and Food Chemistry*, *53*(10), 4290–4302.
11. Sasidharan, S., Chen, Y., Saravanan, D., Sundram, K. M., & Yoga Latha, L. (2011). Extraction, isolation and characterization of bioactive compounds from plants' extracts. *Asian pacific Journal of Biomedcine*, 1(1), 1–10.
12. Singleton, V. L., Rossi, J. A. (1965). Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. *American Journal of Enology and Viticulture*,16(3):144-158
13. Tristantini, D., Amalia, R. (2019). Quercetin concentration and total flavonoid content of anti-atherosclerotic herbs using aluminium chloride colorimetric assay. *AIP Conference Proceedings.* AIP Publishing LLC, p.030012

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Original Article

Diversity and Abundance of Mangrove Fishes in Karli Belt, Malavan, Sindhudurg

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Manuscript ID:
JRD -2026-180410
ISSN: 2230-9578
Volume 18
Issue 4(XI)
Pp. 60-64
April - 2026
Submitted: 10 Mar. 2026
Revised: 20 Mar. 2026
Accepted: 25 Mar. 2026
Published:30 April2026

Abstract:
Mangrove the unique salt loving shrubs of tidal forests of coastal wet lands are part of the littoral ecosystem existing in the intertidal regions of back waters, estuaries, tidal, creeks, lagoons, marshes and mudflats of the tropical and subtropical river mouth this highly productive ecosystem having a nexus with biotic and abiotic components acts as the marginal land between the mainland and the Karli khadi is located between malavan and vengurla tahsil there are high diversity of fishes it shows high species richness in Karli belt, Malavan. Key words- Mangrove, Karli belt, Estuarie, Sindhudurg, biodiversity etc.

1. Introduction:

Mangrove the unique salt loving shrubs of tidal forests of coastal wetlands, are part of the littoral ecosystem existing in the intertidal regions of back waters, estuaries, tidal creeks, lagoons marshes and mudflats of the tropical and subtropical river mouths. This fragile ecosystem serves as an efficient fertilizer for the sea, lands potentials protection for the coastal virtually function as the feeding and breeding ground for source of the most commercially important fishes. Mangrove those predominantly tropical trees and shrubs growing in sheltered coastlines, mudflats and river banks in many parts of the world belong to a variety of plant families The common characteristic they all pressure tolerance to salt and brakish waters.

Methodology:

The Maharashtra coast (popularly known as konkan) harbour a significant diversity of atural resources. The region has enclosed with number of natural and Man- made assets that have attracted attention of scientists and communities konkan constitute a narrow belt between the western mountain range (regionally known as western ghats) and Arbian sea It stretches about 720km from the river Tapi in the north up to River Terekhol in the south and encompasses six districts. viz. The coastline in idented by numerous river mouths, creeks, small bags, head lands, sandy and rocky beaches, clifts etc.

Methods and Materials-
Data Observed Using Canon D 200 and Mobile Camera
Methods –
Site Selection Site Visit
Data Collection
Identification of Photographs
Results- ***Acanthopagrus Latus*** **Domain-Eukaryota**
Kingdon- Animalia Phylum-Chordata Class-Actinopterygii
Family-Sparidae

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How to cite this article:
Kamble, Y. G., & Jagadale, S. P. (2026). Diversity and Abundance of Mangrove Fishes in Karli Belt, Malavan, Sindhudurg. Journal of Research and Development, 18(4(XI)), 60–64. https://doi.org/10.5281/zenodo.21103753

Quick Response Code:
Website:
https://jrdrvb.org/
DOI:
10.5281/zenodo.21103753
OPEN ACCESS

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Common Name-Yellowfin Seabream Scientific Name-Acanthopagrus Latus Local Name-Seabass
Species-*A.Latus*

Area (Where They Found)-
Acanthopagrus Latus occurs in the east Asian shelf area of the western Pacific Ocean from Honshu, Shikoku and Kyushu in Japan the yellowfin seabream if found in warm shallow and coastal waters, frequently going in river mouths and estuaries It occurs at depths down to 50m (160ft).
Feeding Habit-
Mainly feed on small groups on tidal flats, mainly on benthic invertebrate such as echinoderms, molluscs, worms and crustaceans. BREEDING SEASON-Southern China spawning takes place in late winter while of Taiwan if occur in October the larvae move into estuaries after hatching.
Types of Body Features-
Acanthopagrus latus has 10 spines and 10 of 11 soft rays supporting the dorsal fin and spines and 8 and 9 soft rays supporting the anal fin. It has a deep body which has a standard length which is twice its depths The dorsal profile of the head has a noticeable bulge at the eyes, the overall colours is light grey to whitish darker on the upper body and typically being yellowish on the abdomen. The dorsal fin is greyish to hyaline, the pelvic
Siganus Vermiculatus
Domain-Eukaryota Kingdon- Animalia Phylum-Chordata
Class-Actinopterygii
Family- Siganidae
Common Name-Vermiculated Spinefoot Scientific Name-Signus Vermiculatu
Area (Where They Found)-The vermiculated spinefoot is found from southern India and Shri Lanka eastwards into the western Pacific Ocean. It is found in shallow coastal waters especially estuaries Both adults and juveniles are commonest shallow, sediment water in mangroves following the tide in and out.
Feeding Habit-Mainly feeds on small fishes, juveniles and sea grasses etc.
Type Of Body Features-The vermiculated spinefoot has a deep and laterally compressed body which has a depth which fits 1.9 to 2.2 times into its standard length the nape is bulging with a slight indentation above each eye The deep blunt snout also bulge The front nostril has a flange which is slightly widened to its rear. There is recumbent spine to the front of the dorsal fin like all rabbit fishes the dorsal fin has 13 spines and 10 soft rays, while the anal the has 7 spines and 9 soft rays. The fin spins hold venom glands. And anal fins are yellowish but may have blackish areas membranes between the fin rays. The caudal fin has a dark margin a yellow finge on the lower lobe the species has a maximum published total length of 40cm.

Ariopsis Seemanni
Domain-Eukaryota Kingdon- Animalia Phylum-Chordata
Class-Actinopterygii
Family- Arridae
Common Name-Catfish, Arius Seemanni Scientific Name-Ariopsis Seemanni
Species-A. Seemanni
Area (Where They Found)-

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Mostly they found in freshwater and saltwater native place is Pacific draining river and estuaries in central and south America. They are found worldwide in tropical to warm temperate zones.

Mostly they survive on small fishes, shrimp, crabs and phytoplankton.

TYPES OF BODY FEATURES-Catfish have a deeply forked caudal fin usually three pairs of barbels are present They posses some bony plates on their heads and near their dorsal fin. Some species have venomous spines in their dorsal and pectoral fins.

Arnolossus Scapha
Domain-Eukaryota Kingdon- Animalia Phylum-Chordata
Class-Actinopterygii
Family- Bothidae
Common Name-Arnolossus Scapha Scientific Name--Arnolossus Scapha Species-A. Scapha
Area (Where They Found)-
They mostly found in Sothern India, around china and New Zealand.
Feeding Habit-
They mostly survive on small fishes, insect, phytoplantons etc.
Body Features-

Their length is from 20 to 40 cm body compressed eyes and pigment usually sinistral singly lateral line present pelvic fin base on eye site longer then on the blind side. Adult both side have both eyes on the left side of the body and typically lie on their right side at the bottom often covered in sediment young both sides however swim up right and are bilaterally symmetrical they undergo metamorphosis at a length up to 120 mm.

Mangrove Red Snapper
Domain-Eukaryota Kingdon- Animalia Phylum-Chordata
Class-Actinopterygii
Family- Lutjanidae
Common Name-Mangrove Red Snapper
Scientific Name-Lutjanus Argentimaculatus
Species- L. Argentimaculatus

Area (Where They Found)- Red snapper is native to the Indian Ocean and the western Pacific Ocean from the African coast to in the south coast. Mangrove red snapper is commonly found in mangrove lined estuaries system.

Journal of Research and Development
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Feeding Habit-Mostly they are carnivorous. They feed on small fishes, planktons, crustaceans, gastropods etc
BODY FEAFTURES-The red bass now ever is usually darkers in coloration has fewer dorsal fin spines scale rows on the back that rise obligatory from the lateral line and deep groove from the nostril to the eyes. Mangrove red snappers is a popular and important commercial and recreational fish throughout its range.

Lutjanus Russellli

Domain- Eukaryota Kingdon- Animalia Phylum-Chordata
Class-Actinopterygii
Family- Lutjanidae
Common Name- Latjanus Russellii Scientific Name-Latjanus Russellii Species- L..Russeellii
Area (Where They Found)
Found mainly in the western pacific ocean from the Gulf of Thailand and Sumatra east to Tonga, north to Southern Japan and south to Australis The species is found at depths between 3 and 80m on off shore coral reef as well as in shore rocky and coral reefs. The juveniles in habit mangrove lined estuaries and the Lower parts of freshwater streams.
Body Features-
Lutjanus russellii has a moderately deep body to slender its standard length being 2.6 to 2.8 times its depth. The foreheads can be steep or moderately sloped and the knob and incision are poorly developed.
Silllago
Sihama Domain-Eukaryota Kingdon- Animalia Phylum-Chordata
Class-Actinopterygii
Family- Sillaginidae
Common Name- Sillago Sihama Scientific Name-Latjanus Russellii
Species- S.Sihama
Area (Where They Found)-The northen whitting in the most geographically wide spread of the sillaginidae, but is still confined to the Indian and Western pacific ocen. It is the common along the Indian and Asian Coast.

Feeding Habit-The Pricipal items of diet are polychaete worms small prawn and copepod with other crustacea, small fishes, are often taken and filamentos algae is consmers.
Breeding season-Northen whiting reach sexual maturity at a minimum 106 mm in males and 117mm in female although most individual from both sexes mature once they reach 130mm in length and one year of age growth in the species.
Body features-
The northern whiting similarily to all other species in the genes sillago has lead to many less abundant species being confused with it.
Conclusion-Karli belt is situated between vengurla and malvan tahsil. Very beautiful place it is. karli belt is highly diversity rich belt, not only fishes but also birds, molluscan, shrimp species etc. are mainly found in belt. This biodiversity shows great balance of biological pyramids in Karli belt.

References-

1Allen,G.R.1985 FAO Species Catalogue.vol.6.Snappers of the world An annotated and illustrated catalogue of lutjanid species known to date. FAO Fish.Synop.125(6): 208 P.Rome : FAO (Ref. 55).
2.Amaoka,K.,K.Matsuura,T., Inada,M. Takeda, H. Hatanaka ,1990.
3.Japan marine fishery resource Research Center, Tokyo, Japan.410 p.(Ref. 27073)
4.Felipe Guzman- Morales', Angelica Yomira Ramos-Avila',Mariana Diaz-Santana- Iturrios2, Esperanza Granados- Amores, jasmin Granados- Amores.
5.Acta Ichthylologica et Pisecatoria 53,2023, 45-49.

6.Frederick B Muyot,Myleen Magistrado,Myla C,Mulyot, Maria Theresa M. Mutia June 2021
7. The Philippine Journal of Fisheries DOI: 10.31398/tpjf/28.1.2020A0007
8.McKay,R.J., 1992.FAO Species Catalogue. Vol.14 Sillginid fishes of the world (family sillaginidae). An annotated and illustrated catalogue of the sillago, smelt or Indo- Pacific whiting species known to date.Rome: FAO fish.Synop.125 (14):87p.(Ref.6205)
9.Sourinejad,I. Nikkhah Khaje Ataei,S. Kamrani, E. Ghodrati Shojaei,M.(2015)
10.Caspian Journal of Environmental Sciences. Volume no.13 Page ranged- pp 31-39
11.Shalaka Rajesh Salunkhe, A.U.Pagarkar, Gajanan Ghode.(2023)
12.Journal of Experimental Zoology India November 2023.27 (1)

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Original Article

Therapeutic Role of Medicinal Plants in Promotion of Health & Wellness

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Manuscript ID:
JRD -2026-180411
ISSN: 2230-9578
Volume 18
Issue 4(XI)
Pp. 65-70
April - 2026

Submitted: 14 Mar. 2026
Revised: 29 Mar. 2026
Accepted: 05 Apr. 2026
Published:30 April2026

Abstract:

Medicinal plants are plants that contain natural bioactive chemical compounds like antioxidants, polyphenols, flavonoids etc and have been used from ancient times in the traditional medicine system to prevent and treat innumerable ailments, enhance immunity, reduce inflammation, lower dependency on chemicals, manage chronic disorders, stress, pain, promotion of health etc. Since ,the different parts of these plants like the leaves, roots, bark, seeds, flowers or extracts possess therapeutic properties they have been used in preparation of various medicines for complementary treatment in traditional medicine systems like Ayurveda, Siddha, Unani etc from ages . According to the World Health Organisation, 80% of the population worldwide depend on healing properties of medicinal plants for their primary healthcare as they are natural and considered safe. India boasts of a rich repository of medicinal and aromatic plants and about 8,000 herbal remedies have been already codified in AYUSH-Ayurveda, Unani & Siddha, traditional medicine system of India, as because they impart immense health benefits with least or no side effects when compared to modern time medicines. China and India are the two largest producers of medicinal plants contributing about 40% of global biodiversity . Lately, the demand for medicinal plants is increasing both in developed and developing countries due to growing recognition for natural products, their easy availability, affordability , cultural acceptance , and healing properties . Evidence based studies are leading to greater acceptance of Ayurveda in India and abroad. Medicinal plants are undoubtedly rich resources of ingredients which are used in the development of new drugs but rapid loss of natural habitats, expanding trade and overexploitation of these plants in the wild can pose a serious threat to the survival of several plant species.

Keywords: *medicinal plants, health, therapeutic uses, traditional medicine system.*

1. Introduction:

The World Health Organization (WHO) defines health as "a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity" and wellness as “the optimal state of health of individuals and groups” (Otorkpa, 2019). In recent years there has been a steep rise in lifestyle related diseases such as diabetes, cardiovascular diseases, obesity, hypertension, metabolic syndrome etc due to faulty dietary practices, sedentary lives, various addictions and increase in stress conditions. Despite advancements in research and medical science yet the number of people suffering from such non-communicable diseases is increasing alarmingly all across the globe which heavily contributes to morbidity, mortality and economical strain. (Sugandh, 2023;Khan and Ahmad,2019) Thus, lifestyle has a great impact on both the physical as well as mental wellbeing of an individual. (Farhud, 2015).One promising avenue is herbal based nutraceuticals, which offer potential benefits for managing lifestyle diseases.(Singh, 2024). Plants have been used as a source of medicine for the treatment of different diseases for thousands of years. Mother nature has blessed us with diverse varieties of medicinal plants which not only helps us to cure innumerable ailments but it also promotes positive health and wellbeing. The traditional system of medicine of India, China, Egypt, Greek and Rome have used the medicinal properties of medicinal plants for healing of diverse ailments from ancient times.

Quick Response Code:
Website:
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DOI:
10.5281/zenodo.21103912
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How to cite this article:
Shaw, A. (2026). Therapeutic Role of Medicinal Plants in Promotion of Health & Wellness. Journal of Research and Development, 18(4(XI)), 65–70.
https://doi.org/10.5281/zenodo.21103912

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

According to the World Health Organization (WHO,2008) – Medicinal Plants can be defined -as plants that synthesize metabolites which are utilized to produce useful drugs or plants that contain bioactive compounds like alkaloids, phenols, saponins, terpenoids, steroids, flavonoids, carbohydrates and tannins etc, that can be used for therapeutic purposes (Shodhganga; Bhat, 2022). As per the National Medicinal Plant Board (NMPB, 2018) "If the wisdom is herbal, many ailments are curable". India has been a rich repository of medicinal plants since time immemorial which has been extensively used in Traditional Medicine Systems (TMS) like Ayurveda for their natural healing action, therapeutic usage and remarkable immunity boosting properties (Khodadadi, 2015). Famous ancient Indian herbalists like Charaka and Sushruta have reported use and benefits of a vast range of medicinal plants /herbs in the fundamental texts of medical tradition in India i.e the Charaka Samhita (100-800 B.C) and the Sushruta Samhita (800-700 B.C) (Waghmare and Nakanekar, 2016; Singh.V.,2017) . The phytochemicals present in these plants have beneficial activities like anti-microbial, anti-malarial, anti-diabetic, anti-arthritic, anti-cancerous etc. Thus herbal remedies have been so popular from ancient times that the AYUSH system (Ayurveda, Unani and Siddha) of India has codified about 8,000 herbal remedies (National Health Portal;2016) . From the past two decades medicinal plants/ herbal remedies have gained immense global popularity as they are considered safe with no or minimal side effects and contain many bioactive ingredients that not only boosts our immune system but also provides relief from many lifestyle related ailments. According to the World Health Organization (WHO) 80% of people all over the world depend on herbal medicines for their primary health care needs. Looking at the immense popularity of medicinal plants in solving primary health care problems and growing global demands, the Government of India established - " The National Medicinal Plants Board" (NMPB) to coordinate all matters related to medicinal plants under the Ministry of Ayurveda, Yoga & Naturopathy, Unani , Siddha & Homeopathy in short known as AYUSH (Kala , Sajwan 2007). Ayurveda is considered not just as an ethnomedicine but also as a complete medical system that takes into the physical, psychological, philosophical, ethical and spiritual well being of mankind.(Kurup, 2004) According to Cordell (2004)- plant extracts and products contribute to four major areas of human health and wellness:

1)Foodstuffs 2) Flavouring agents & spices 3) Perfumes & cosmetics 4) Pharmaceutical & biological agents.

In light of the growing international attention and need, the World Health Organisation (WHO), in collaboration with the Government of India, inaugurated the WHO Global Centre for Traditional Medicine in March 2022. This establishment serves as a knowledge hub, aiming to facilitate the integration of traditional medicinal practices and contemporary scientific advancements to promote the health and welfare of individuals and the environment. (WHO, 2023)

Historical background of Traditional Medicine System TMS) of India & use of medicinal plants:

The Traditional Medicine System (TMS) is one of the oldest systems of medical practice in the world and has played a profound role in providing healthcare services to human civilization right from its inception. (Adhikari & Paul,2018). It is the "knowledge, skills and practices based on the theories, beliefs and experiences indigenous to different cultures, used in the maintenance of health and in the prevention, diagnosis, improvement or treatment of physical and mental illness". TMS of India includes- Ayurveda, Siddha, Unani and Yoga, Naturopathy and Homeopathy. Though Homeopathy came to India in the 18th Century, it completely assimilated into the Indian culture and got enriched like any other traditional system hence it is also considered as part of the Indian system of Medicine. (Ravishankar and Shukla, 2007).

Ayurveda means the " Science of life". It is presumed that the fundamental and applied principles of Ayurveda got organized and enunciated around 1500 B.C. Atharvaveda, the last of the four great Vedas, contains 114 hymns related to formulations for the treatment of different diseases. Around six hundred drugs of plant, animal and mineral origin have been mentioned in Charaka Samhita whereas Sushruta Samhita contains descriptions of about 650 drugs apart from surgical procedures. Till the medieval age it was perhaps the only system available in the Indian sub-continent which catered to the healthcare requirements of the people and their rulers also considered as the Golden period of Ayurveda. Repeated foreign invasions and advent of Britishers led to neglect of this medicine system and the Allopathy practice gained importance through official patronage. After India got its independence this ancient or traditional medicine system again gained a new momentum. Various initiatives and research centres were established by the Government of India to revive this system. (Ravishankar and Shukla, 2007).

Siddha system of medicine is practiced in some parts of South India especially in the state of Tamilnadu. The term Siddha means "achievement" and has close affinity to Ayurveda yet it maintains a distinctive identity of its own. (Narayanaswamy, 1975). Unani medicine has its origin in Greece. The Arabs were instrumental in introducing this medical system in India around 1350 AD. After the independence of India this system too received a boost through governmental support and agencies.

Reasons behind popularity of medicinal plants/ herbal medicines: (Patra and Samal, 2018; Singh 2024;Bhusan et al, 2024)

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Healing with medicinal plants is as old as mankind itself. Awareness of medicinal plants usage is a result of many years of struggle against illnesses due to which man learned to pursue drugs in barks, seeds, fruits and other parts of the plants. The recent resurgence of public interest in herbal remedies are associated with many factors, such as:

Growing Burden of lifestyle diseases: Lifestyle diseases such as obesity, diabetes, hypertension, cardiovascular diseases, metabolic syndrome etc also known as non-communicable diseases (NCDs) has emerged as a significant health burden globally including the Indian population. As per WHO health statistics 2022, almost 41 million people died due to NCDs globally of which low and middle income countries are the worst affected. Almost 60% of these deaths are related to lifestyle, individual health and quality of life of a person.

Cultural acceptance and traditional knowledge: This knowledge has been passed down through generations so over 80% of the population in many developing countries still rely on these remedies for primary healthcare needs, reinforcing their deep cultural roots. The knowledge of the development of ideas related to the usage of medicinal plants as well as evolution has increased the ability of pharmacists and physicians to respond to the challenges that have emerged with the spreading of professional services in facilitation of man's life.

Perceived safety and fewer side effects: Allopathic medicine has side effects and hazardous to human health, so after realizing the toxicity and adverse effects, a universal shift has been observed from synthetic to herbal medicines in both the developed and developing countries.(Gireesha and Raju,2013) Plant based products/medicines contain natural bioactive compounds usually considered safe in comparison to synthetic drugs thus consumers, all across the globe tend to shift towards natural traditional/ herbal medicines to get relief from a range of ailments, starting from common cold to chronic diseases. (Vyshnavi, 2021) .Contemporary science has acknowledged their active action and it has included in modern pharmacotherapy a range of drugs of plant origin, known by ancient civilizations and used throughout the millennia.The continuous and perpetual people's interest in medicinal plants has brought about today's modern and sophisticated fashion of their processing and usage.(Petrovska, 2012)

Accessibility and affordability: In rural areas and developing countries, medicinal plants are grown locally hence they are readily available to people and healers. This easy accessibility makes the treatment affordable in comparison to expensive medical treatment and modern pharmaceutical drugs.

Growing health consciousness: All across the globe people are taking great interest in improving their health and well being to enhance their quality of life and reduce old age complications. Such health conscious people show greater inclination towards natural foods and plant based medicines to prevent illnesses.

Dissatisfaction with conventional medicine: When conventional therapies fail to satisfy the much needed relief from health suffering, people tend to turn towards herbal or plant based remedies as it aligns with the patient's belief system, leading to fulfilment of the desire for individualised healthcare. (Bhusan et al, 2024)

Scientific validation and modern integration: Modern science has acknowledged the active compounds in many medicinal plants, which have served as the basis for numerous conventional drugs. Ongoing research into their pharmacological properties has led to greater scientific support and a move toward integrating some standardized herbal medicines into modern healthcare practices. This has also helped in shifting consumer preferences towards natural and holistic healthcare solutions.

Economic opportunities: The global market for medicinal plant products is a multi-billion dollar industry and has experienced consistent growth propelled by a number of factors leading to significant income opportunities for farmers, harvesters and related businesses in many parts of the world.

Environment friendly: Amidst rising concern for the environment herbal medicine presents a green solution.Their sustainable cultivation, minimal chemical processing,biodegradability and power of community empowerment make them a compelling and eco-friendly alternative against modern pharmaceuticals.

Diverse utilization across various sectors: Diverse industries have flourished around medicinal plants starting from food and flavour industry, cosmetic industry, pharmacological applications for example the olfactory perceptions of floral smells can exert beneficial impacts on mental well being, depressive symptoms and cognitive impairments associated with memory difficulties. (Bhusan et al 2024).

Increasing trends of self medication: Time crunch, fear of misdiagnosis, uncomfortable discussing medical problems, expensive treatments have seen increasing trends of self medication. In such cases people rely on natural products considering them to be safe and cost effective (Ekor, 2014)

Therapeutic action of medicinal plants; The curative properties of medicinal plants are due to the presence of a major group of active components which are mainly alkaloids, triterpenoids, essential oils and phenolic compounds etc. Alkaloids are the secondary metabolites of plants having noticeable pharmacological activity. Roots, leaves, bark and seeds are common parts of plants which contain alkaloids. Pharmacologically, alkaloids act as cardiac depressants, antihypertensive, anti-leukemic, analgesic, nerve stimulants and local anesthetic. Several plants contain volatile oils. The phenolic compounds present in medicinal plants include phenols, phenolic acids, flavonoid pigments, anthocyanins, flavonols, flavones and tannins. Multiple scientific studies have supported the therapeutic role of plant based medicines (Bhat, 2022)

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

These nutraceutical properties of these plants help to boost immunity, improve brain function, reduce stress, enhance digestion, prevent and cure innumerable lifestyle related diseases starting from cold and cough to diabetes, cardiovascular disease, cancers, metabolic diseases etc.(Singh, 2024; Gandhi et al. 2023).

Therapeutic Importance of Few Popular Indian Medicinal Plants Used in Managing Common lifestyle conditions: (AYUSHMAN BHARAT, 2020;Zhao et al,2022; Tesfaye, 2021;Varshney, et al 2023;Scandar,et al 2023; Patra and Samal, 2018;Singh, 2024)

Sl no.	Medicinal plants (Common name in English & Hindi)	Botanical name	Plant part	Active compound & phytochemicals	Health Benefits
1	Tulasi (Holy Basil, Tulsi)	*Ocimum tenuiflorum*	leaves	Eugenol, ursolic acid, rosmarinic acid, flavonoids	Boosts immunity, reduces metabolic stress, skin health, anti-microbial,treats respiratory infections like cold, cough
2	Haridra (Turmeric ,Haldi)	*Curcuma longa*	Rhizome	Curcuminoids-curcumin	Hepato-protective, blood purifier, diabetes/prediabetes, seasonal allergy, potent anti-inflammatory and anti-oxidant, aids joint health, digestion and skin health
3	Kumari (Aloe vera, Ghritkumari)	*Aloe barbadensis*	leaves/gel	Acemannan, anthraquinones, aloin	Treats skin burns, cuts, acne, improves digestion, reduces inflammation diabetes, eye disease, wound healing, spleen and liver complaints.
4	Ashwagandha	*Withania somnifera*	Root	Withanolides-A,D, withanone	Reduces stress, anxiety, improves sleep quality, boosts muscle strength, immunity
5	Shunthi (Ginger ,Adrak)	*Zinziber officinale*	Root	Gingerols, shogaols and paradols	Relieves nausea, motion sickness, digestive issues, and reduces inflammation, cough, joint pain.
6	Nimba (Neem)	*Azadiracta india*	leaves/bark	Azadirachtin, nimbin, nimbidin, nimbolide	Powerful antiseptic and antifungal, anti-diabetic, anti-cancer, oral health,treats skin diseases, acne and purifies blood, worm infestations, neuro-protective, hepato-protective.
7	Amalaki (Amla,Indian Gooseberry)	*Phyllanthus emblica L.*	fruit	Emblicanin, pedunculagin, quercetin, anti-oxidants, vit C	Boosts immunity heart health, anti-cancer,,urinary problem, reproductive health, anaemia, reduces hyperacity, promotes hair growth and improves vision
8	Pudina/Puthina (Pepperm, Pudina)	*Mentha piperita*	leaves	Menthol, menthone	Relieves irritable bowel syndrome, eases headaches, aids in digestion, treats respiratory congestion
9	Rasona/Lashuna (Garlic, Lahsun)	*Allium sativum*	cloves	Allicin	Improves heart health, anti-diabetes, anti-cancer, lowers blood pressure, lowers cholesterol, anti-microbial action, anti-inflammatory
10	Chandrika/Medhika (Fenugreek,Methi)	*Trigonella foenum-graecum*	seeds/leaves	Hydroxyisoleucine, saponins, galactomannan	Controls blood sugar(diabetes), aids digestion, reduces joint pain, promotes hair growth, anti-cancer, cardio-protective
11	Brahmi	*Bacopa monnieri*	Whole plant	Bacosides, bacopasides	Enhances memory, reduces anxiety, improves cognitive function,

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ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

					promotes hair growth, lowers high blood pressure, epilepsy.
12	Guduchi (Giloy)	*Tinospora cordifolia*	stem	Berberine, magnoflorine, palmatine, tinocordiside	Boosts immunity, treats chronic fever(dengue/ malaria) anti arthritic, reduces blood sugar
13	Dhanyaka (Coriandar ,Dhaniya)	*Coriandrum sativum*	leaves/seeds	Linalool, pinene	Regulates blood sugar, improves digestion, lowers bad cholesterol, contains antioxidants,obesity, diabetes
14	Shatavari	*Asparagus racemosus*	roots	Shatavarins, quercetin	Galactogogue, digestion, reproductive health,immunity booster, bone and neuro-degeneration, female health
15	Bala (Khareeti)	*Sida cordifolia*	Whole plant	Ephedrine, pseudoephedrine	Degenerative problems, leucorrhea
16	Shigru (Sahijan, Moringa)	*Moringa oleifera*	Leaves, bark, fruit , flower, seed	Quercetin, kaempferol	Anaemia, asthma, wound healing, heart disease, stabilizes blood pressure, lowers cholesterol, immunity booster, eyesight
17	Twak (Dalchini,Cinnamon)	*Cinnamomum zeylanicum blume*	bark	Cinnamaldehyde	Anti-oxidant, anti-diabetic, anti inflammatory
18	Lavanga (Clove, laung)	*Syzygium aromaticum*	Flower bud	Eugenol	Oral health, digestion, cough cold, pain relief,

Challenges faced: Ayurveda is the most lucrative intervention segment which has registered the fastest growth during the forecast period in terms of revenue in 2024. This increase in demand for medicinal plants by the drug industries and herbal products all across the globe is leading to over exploitation of most of the economically important species. So, proper documentation, systematic conservation and large scale cultivation has become a global concern. (Patra and Sasmal, 2018; Bhat,2022) The increase in health related disease conditions among people of all walks of life is the most important instrumental factor for greater demand for plant based medicines as they have no or limited side effects.

Conclusion:

India is one of the richest repositories of medicinal plants which has been used in the traditional medicine system from ancient times. The expansion of traditional herbal medicine remedies and their successful entry into global markets can be attributed to amalgamation of new findings and scientific insights derived from latest research backed studies about the healing properties of these plants. Herbal drugs are considered safer than synthetic so the global demand for traditional medicine has risen significantly. In terms of revenue, India accounted for 6.8% of the global herbal medicine market in 2024 (Indian herbal medicine market size and outlook) with Ayurveda being the most lucrative segment. Embracing sustainability, sourcing ethics and conservation can balance the increasing demand of herbal medicine with ecological harmony. At the same time, modification in lifestyle can reduce the incidence of ever growing rates of lifestyle diseases and greater burden on medicinal plant cultivation.

References

1. Adhikari,P.P. and Paul, S.B. (2018).History of Indian Traditional Medicine: A Medical Inheritance. Asian Journal of Pharm. Clinical Research; 11(1):421.
2. AYUSHMAN BHARAT .Common Medicinal Plants and Their Use.(2020)
3. .https://namayush.gov.in/sites/default/files/doc/Common_Medicinal_Plants_their_uses.pdf
4. Bhat, S.G. (2022). Medicinal Plants and Its Pharmacological Values. In Natural Medicinal Plants. IntechOpen. https://doi.org/10.5772/intechopen.99848
5. Bhusan, S. et al. (2024). Herbal drugs in the global market: a growing trend towards natural healthcare solutions. Futuristic Trends in Herbal Medicines and Food Products.e-ISBN:978-93-6252-403-4 IIP Series.

6. Cordell. G.A.(2004). Plants in Drug Discovery- Creating A New Vision, In Novel Compounds from National Products in the New Millennium;1-19 Available at :https://www.worldscientific.com/doi/abs/10.1142/9789812562210_0001
7. Ekor, M. (2014). The growing use of herbal medicines: issues relating to adverse reactions and challenges in monitoring safety. Front Pharmacol;4:177. doi:10.3389/fphar.2013.00177.
8. Farhud. D.D.(2015). Impact of lifestyle on health. Iran Journal of Public Health;44(11):1442-1444.
9. Gandhi, Y. et al.(2024) Emblica officinalis: A promising herb confining versatile applications. South African Journal of Botany;159:519-531.
10. Gireesha, J. and Raju, N.S.(2013). Ethno botanical study of medicinal plants in BR Hills region of Western Ghats, Karnataka. Asian Journal of Plant Science and Research;3(5):36-40.
11. Indian herbal medicine market size and outlook: https://www.grandviewresearch.com/horizon/outlook/herbal-medicine-market/india.
12. Kala.C.P. and Sajwan.B.S.(2007).Revitalizing Indian systems of herbal medicine by the National Medicinal Plants Board through institutional networking and capacity building. Current Science. 93(6): 797-806.
13. Khan, M.S.A and Ahmad, I. (2019). Herbal medicine: Current trends and future prospects.Advancements in Herbal Products as Novel Drug Leads;3-13.
14. Khodadadi. S.(2015).Role of Herbal Medicine in Boosting Immune System. Immunopathologia Persa; 1 (1): e01.
15. Kurup. P.N.V.Ayurveda-A potential Global Medical system. In: Mishra L.C.,editor. Scientific Basis for Ayurvedic Therapies. New York: CRC Press; 2004.pp. 1-15
16. Narayanaswamy, V. (1975). Introduction to the Siddha System of Medicine. T.Nagar, Madras (Chennai): Research Institute of Siddha Medicine.
17. National Health Portal.(2016) Introduction and Importance of Medicinal Plants and Herbs. Available at :www.nhp.gov.in
18. Otorpka. O.J. (2019).WHO Definition of Health.
19. https://www.researchgate.net/publication/387931721_World_Health_Organization_WHO.
20. Patra, S. and Samal, P.(2018).Medicinal Plants-Therapeutic Potential in Today's Context. International Journal of Current Microbiology and Applied Sciences;7(8):3841-3848.
21. Petrovska, B.B. (2012). Historical review of medicinal plants' usage. Pharmacognosy Reviews;6(11):1-5. doi:10.4103/0973-7847.95849.
22. Ravishankar. B. and Shukla, V.J. (2007). Indian Systems of Medicine: A Brief Profile. African Journal of Traditional Complement Alternative Medicine;4(3):319-337.doi: 10.4314/ajtcam.v4i3.31226.
23. Shodhganga: Chapter Nine : medicinal plants:-Available at :https://shodhganga.inflibnet.ac.in
24. Singh, A. (2024) Herbal based nutraceuticals in management of lifestyle diseases: experience from Indian population. Future Integrative Medicine; 3(2):106-115.
25. Singh. V. (2017). Sushruta: The Father of Surgery. National Journal of Maxillofacial Surgery;8 (1): 1-3.
26. Sugandh. F. et al. (2023).Advances in the management of diabetes mellitus: A focus on personalized medicine. Cureus;15:e43697. Doi: 10.7759/cureus.43697.
27. Tesfaye. A. (2021). Revealing the therapeutic uses of garlic and its potential for drug discovery. Scientific World Journal.
28. Varshney H. et al.(2023) Medicinal properties of fenugreek: a review. The Open Biology Journal.
29. Vyshnavi, N.(2021). Importance of Medicinal Plants in Medicine. Commentary-Journal of Medicinal and Organic Chemistry;1(1).
30. Waghmare. P.P., and Nakanekar. A.(2016) Charak Samhita : A Textbook of Ancient Research Methodology. International Journal of Ayurveda and Pharma Research; 4(2): 19-23.
31. World Health Organization(1946): Constitution of the World Health Organization. https://apps.who.int/gb/bd/PDF/bd47/EN/constitution-en.pdf

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Original Article

Diversity of Insect Pests on Cashew Plantation from Sattari Taluka, Goa, India

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Manuscript ID:
JRD -2026-180412
ISSN: 2230-9578
Volume 18
Issue 4(XI)
Pp. 71-75
April - 2026

Submitted: 14 Mar. 2026
Revised: 29 Mar. 2026
Accepted: 05 Apr . 2026
Published:30 April2026

Abstract
A survey on Insect pests on cashew plantations was conducted in Sattari Taluka of North Goa district. The importance of cashew (Anacardium occidentale) in the Indian economy has been due to its role as an earner of foreign exchange. Cashew being the cash crop leading to an economically important plant, it is vital to identify the pests affecting it. A total of 22 species of insect pest were recorded belonging to 7 different orders. Among these isopterans, damage by White Ants (termites) was observed in majority of plants .The current study represents the first formal survey of insect pests on cashew plants in Sattari Taluka of North Goa district.
Keywords: *Insect pest, Sattari Taluka, North Goa, Isopterans*

1. Introduction

The cashew, *Anacardium occidentale* belonging to the family Anacardiaceae, is an economically important tropical tree crop. The cashew tree is cultivated in the tropics between 25° North and 25° South . It is supremely adapted to hot lowland areas with pronounced dry season. The cashew plant is native of Northeast Brazil and was introduced to India and East Africa by the Portuguese in 16th century. The estimated area of cashew plantations in India is 8.55 lakh ha which gives production of approximately 5.73 lakh tons. currently India is the largest producer, processor, consumer and exporter of cashew in world. in India Cashew is mainly cultivated in states like Goa, Karnataka, Maharashtra, Kerala, Tamil Nadu, Pondicherry, Andhra Pradesh, Odisha, and West Bengal . Cashew is also grown to some extent at non-traditional areas, such as Bastar of Chhattisgarh and Kolar of Karnataka. In the current state, Maharashtra is the leading in production and productivity of cashew. Cashew play a vital role in uplifting the rural poor, socially and financially. Currently in Goa cashew is cultivated in around 55,000 ha with production of 23,138 tonnes. The cashew is widely cultivated in Talukas , like Sanguem, Canacona,Sattari, Bicholim and Tiswadi. Cashew being the most important cash crop in Goa.,The People of Taluka like Sattari depends economically on Cashew yield. Therefore, there is need to study the insect based on cashew plant to minimise the infestation as it is the major threat to Cashew nut production. There are more than 50 species of insect pests which attack the plant at different stages of plant. The present study aims to document diversity of insects on cashew plantation from Sattari Taluka, Goa, India.

Materials and Method

Survey on insect pests oncashew plantation were carried out from Sattari taluka Goa India in the year 2024 to 2025. They were collected by insect net and also by hand picking method. The images are taken by Samsung S14 mobile camera and Sigma 100 MM micro mobile lens. Identification of insects was done by research papers and books.

Study Area

Sattari taluka is known as the interior of rural Goa. It lies in North Goa district in the state of Goa India. It lies in the north eastern part of Goa and well known for greenery and dense evergreen Forest with annual rainfall ranging from 3000 MM to 4000 MM .With latitude and longitude 15.5616^{0}N and 74.1632^{0}E . In Goa State Sattari taluka is premier region for cashew production. Cashew is major source of income for many villagers in the State.

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How to cite this article:
Naik, R., & Jagdale, S. P. (2026). Diversity of Insect Pests on Cashew Plantation from Sattari Taluka, Goa, India. Journal of Research and Development, 18(4(XI)), 71–75. https://doi.org/10.5281/zenodo.21124337

Quick Response Code:
Website:
https://jrdrvb.org/
DOI:
10.5281/zenodo.21124337
OPEN ACCESS

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Result and Discussion

The entomological survey for cashew plant pest revealed a diverse assemblage of pests . A total of 22 species representing 7 different orders were identified. The result shows that the distribution of this pest was dominated by the orders Orthoptera and Coleopteran which together accounts 50% of total sample.

Table 1: List of insect pests, their classification and the associated part of cashew tree.

Sr no	Order	Common name	Scientific name	Part of tree affected
1.	Thysanura	Silverfish or bristletail	*Lepisma saccharina*	soil
2.	Orthoptera	Short horned grasshopper	*Anacridium aegyptium*	leaf
3.	Orthoptera	Spur-throat grasshopper	*Melanopus femurrubrm*	leaf
4.	Orthoptera	Great green bush cricket	*Terrigonia viridissima*	leaf
5.	Orthoptera	Bush cricket	*Gampsocleis .buergeri*	leaf
6.	Orthoptera	Field cricket	*Gryllus bimaculatus*	leaf
7.	Orthoptera	Grasshopper	*Aularches miliaris*	leaf
8.	Hemiptera	Tea mosquito bug	*Helopeltis antonii*	
9.	Isoptera	Formossan subterranean termite	*Coptotermes formosanus*	bark
10.	Isoptera	termite	*Odontoter mis redemanni*	Soil
11.	Lepidoptera	bagworm	*Dappula tertia*	Leaf
12.	Lepidoptera	Leaf minor	*Acrocercops syngramma*	Leaf
13.	Lepidoptera	Tiger moth	*Pyrrharctia isabella*	Leaf and fruit
14.	Lepidoptera	Leaf and blossom webber	*Lamida moncusalis*	Leaf and blossom
15.	Coleoptera	Leaf twisting weevil	*Apoderus tranquebaricus fabricius*	Leaf
16.	Coleoptera	Steam and root borer	*Plocaederus ferrugineus*	Steam and roots
17.	Coleoptera	Darkling beetle	*Luprops tristis*	fruit
18.	Coleoptera	Living beetle	*cybister chinensis*	Fruit
19.	Coleoptera	Tortoise shell beetle	*Cassida circumdata*	Leaf
20.	Coleoptera	Tortoise shell beetle	*Laccoptera nepalensis*	leaf
21.	Hymenoptera	Little black ant	*Monomorium minimum*	Leaf
22.	Hymenoptera	Red ant	*Oecophylla longinoda*	Soil

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ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

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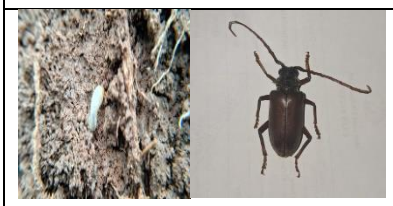 P	Q	R
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ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

V	A.Silverfish or bristletail, B.Short horne grasshopper,C .Spur throat grasshopper,D. Great green bush cricket,E. Bush cricket,F. Field cricket,,G. Grasshopper(*Aularches miliaris*),H. Tea mosquito bug,I. Formossan subterranean termite, J .termite,K. bagworm,L.. Leaf minor,M. Tiger moth,N. Leaf and blossom webber,O. Leaf twisting weevil,P. Steam and root borer,Q. Darkling beetle,R. Living beetle,S. Tortoise shell beetle (*Cassida circumdata*),T. Tortoise shell beetle(*Laccoptera nepalensis*),U. Little black ant,V. Red ant,

Plate 1: Insect Pests observed during the study period

Table 2: Showing the percentage (%) of insect pests collected order-wise .

Sr.No	Order	No of Insects	%
1	Thysanura	1	4.54
2	Orthoptera	6	27.27
3	Hemiptera	1	4.54
4	Isoptera	2	9.09
5	Lepidoptera	4	18.18
6	Coleoptera	6	27.27
7	Hymenoptera	2	9.09
Total		22	

As illustrated in table 1 and 2 , Orthoptera and Coleopteran showed the highest prevalence (27.27% each) , followed by Lepidoptera (18.18%), Thysanura and Hemiptera were least represented each contributing 4.54 % of total pest population studied. Hymenoptera and Isopteran contributed (9.09% each).

Conclusion

Diversity of Insect Pests on Cashew Plantation from Sattari Taluka, Goa, India is the preliminary study based on infestation caused by various insect pests of cashew trees. In the present study, a total of 22 different species belonging to 7 orders was observed. The observation reveals that majority of this insect damage the cashew tree through sap sucking ,defoliation girdling, stem and root boring. The Thysanura pest i.e silver fish mounted major damage to soil. Isopterans, the white ants (termites) damage was noticed throughout the year. The leaf and blossom Webber, bugworm ,leaf, minor little black ant, mosquito bug , leaf minor, leaf twisting weevil are pest that that cause less damage. Lepidoptera and Coleoptera which are recorded as established Major serious, were persistent throughout the year. The main objective was to study the insect pests infecting the cashew tree, identifying and classify them up to the family level. The study can help others in identifying the harmful pests which might help the farmers to manage the pests diseases and to minimise the destruction caused.

Acknowledgement

The authors are grateful to the management of Dapoli Urban Bank Senior Science College for giving necessary permission to proceed and complete this work.

References

1. Ali, S. & Ripley, S.D. (1983): Hand book of the Birds of India and Pakistan, Compact Edition. New Delhi, Oxford University Press APHA, AWWA and WPCF (1998): Standard methods for the examination of water and waste water, Publ: American Publication Health Association, Washington D.C. 20th edition, New York
2. Baker S.L. (1979): Specific status of Keretella cochlearis (Gosse) and K. Ahlastar (Rotifer: Brachionidae): Ecological consideration, Can. J. Zool
3. Bharucha, E. (2005): Biosphere; Publ: Campus Book International
4. Choudhary. A. and Ahi, J. (2015): Biodiversity of Freshwater Insects; International Journal of Engineering and Science; Vol: 4 Issue 10

5. D'Costa, A., & Sawaikar, A. (2026). Social and environmental impacts of rehabilitation in dam-displaced communities of Anjunem Dam Goa. *International Journal of Advance and Applied Research, 7*(4). DOI: 10.5281/zenodo.18477535
6. Kotpal, R.L. and Bali, N.P. (1996): Concept of Ecology; Publ: Satish Book Enterprises, Moti, Karta-Agra.
7. Kumar A. (1995): Role of species diversity of aquatic insects, in the assessment of pollution in wetlands of Santhal Pargana. J. Environment and Pollution
8. Kumar, N., Ponnuswami, V., Jeeva, S., Ravindran, C., & Kalaivanan, D. (n.d.). *Cashew Industry in India – An Overview*. The World of Horticulture. [Retrieved from ResearchGate].
9. Maruthadurai, R., Desai, A. R., Prabhu, H. R. C., & Singh, N. P. (2012). *Insect Pests of Cashew and their Management* (Technical Bulletin No. 28). ICAR Research Complex for Goa, Old Goa, India.
10. Metri, S. M., & Singh, K. (2010). Study of rainfall features over Goa state during southwest monsoon season. *MAUSAM, 61*(2), 155-162.
11. Misra, S.P and Pandey, S.N. (2008): Essential Environment Studies; Publ: Ane Books India.
12. Mitra, A. (2002): The study on the dragonfly (Odonata: Insect) fauna of the district Trahigang, East Bhutan, Environment and life support system of the Bhutan Himalaya, 1 : 30-70.
13. Needham, J.G., Westfall, M.J.Jr., May, M.L. (2000): Dragonflies of North America. Scientific Publishers, Gainesville, FL : 189
14. Odum E.P., Fundamentals of ecology, W.B. Saunder company, Philadelphia and London, Toppan company Ltd. (2003)
15. Patil, D. Y., Yadav, P. D., Shete, A. M., Nuchina, J., Meti, R., Bhattad, D., ... & Maurya, D. T. (2017). Occupational exposure of cashew nut workers to Kyasanur Forest disease in Goa, India. *International Journal of Infectious Diseases, 61*, 67-69. https://doi.org/10.1016/j.ijid.2017.06.004

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Original Article

Synthesis and characterization of nanoparticles from *Chamaecostus cuspidatus* (Nees & Mart.) C.D. Specht & D.W.Stev. And evaluation of natural lipid-based drug delivery system

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Manuscript ID:
JRD -2026-180413
ISSN: 2230-9578
Volume 18
Issue 4(XI)
Pp. 76-81
April - 2026
Submitted: 14 Mar. 2026
Revised: 29 Mar. 2026
Accepted: 05 Apr . 2026
Published:30 April2026

Abstract

Chamaecostus cuspidatus (Nees & Mart.) C.D. Specht & D.W.Stev. known by synonyms as Costus igneus N.E.Br. and Costus pictus D. Don. Commonly, it is also known as Insulin-Plant, Spiral Flag, etc. The plant is a perennial herb with a height of about 2-3 feet. C.cuspidatus plant is a member of the Costaceae family. C.cuspidatus is indigenous to Southeast Asia. C.cuspidatus offers multiple health benefits as the plant is traditionally used as a curative in the treatment of various health deteriorating conditions. C.cuspidatus has numerous pharmacological advantages, where it has the potential of being used as an anti-bacterial, anti-microbial, antioxidant, etc. However, it is mainly known for its anti-diabetic properties, which help maintain the insulin level.

Looking towards the plants exceptional pharmacological potentiality the present study aims to evaluate the probability of formulating a natural lipid-based drug delivery system from the phytochemical and fats present in the plant as this area of research has still not been explored well. Since lipid-based carriers can improve the solubility, absorption, dispersion and over all bioavailability of poor soluble drug utilizing the fat as a base from the C.cuspidatus it would be a novel approach for understanding the lipophilic nature of drug and emphasizing the medicinal importance of C.cuspidatus which indicate the potential role in formulation of natural lipid-based drug delivery system.

***Keywords**: Chamaecostus cuspidatus (Nees & Mart.), Costus igneus N.E.Br., Costus pictus D. Don., Insulin-Plant, Pharmacological, Phytochemical, Bioavailability, Lipophilic, Natural lipid-based drug delivery system (LBDDS).*

Introduction

Natural resources like plants are used traditionally as medicinal agents in the prevention and treatment of various health problems. Many modern drugs are formulated by isolating the required compound from the raw source, as the isolation of the required compound is referred to as its traditional use. Since plants are the primary raw source of supply for both traditional and conventional pharmaceutical products and medicinal drug which are used for the welfare of mankind, a huge percentage (80% approximately) of the global population is substantially dependent on natural medicines for their medicinal requirements to be fulfilled. Medicinal plants used in the traditional system of medicine are gaining weightage for the efficacy in treating different health problems and there is a fair increase in the use of medicinal plants as an alternative choice or option in prevention or treatment of long standing diseases in developing as well as developed nations around the globe as they have minimal to no major side effects which could be fatal.

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How to cite this article:
Bhosle, V. S., Dandekar, S. N., & Sarmalkar, N. R. (2026). Synthesis and characterization of nanoparticles from Chamaecostus cuspidatus (Nees & Mart.) C.D. Specht & D.W.Stev. And evaluation of natural lipid-based drug delivery system. Journal of Research and Development, 18(4(XI)), 76–81. https://doi.org/10.5281/zenodo.21124529

Quick Response Code:
Website: https://jrdrvb.org/
DOI: 10.5281/zenodo.21124529

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Since the traditional health care system primarily focuses on drug formulations based on an herbal medicinal approach found in a particular herb, as herbs are profoundly useful and easily available in rural parts, being proportionally cheap as compared to modern drugs. Nearly 70-80 % of the population around the globe fundamentally rely on the traditional health care system as being cost effective alternative to the modern health care system. According to the World Health Organization estimate about 80% of the population in underdeveloped countries solely stays dependent on plant-based preparations used in their respective traditional medicinal system and as the fundamental need for a primary health care option of mankind. Since the traditional medicinal system is based on herbal compounds or herbal drug components isolated from medicinal plants, this approach holds a strong historical and cultural value-based aspect over the wide variety of laboratory synthesized medication in modern times.

Therefore, a huge populace gets diverted towards traditional herbal medicinal system practitioners for their fundamental medicinal requirements. Looking towards the increase in the requirement of these herbal medicines there is a apprehension about their effect, safety, efficacy and over all potentiality which is a point of concern by developing as well as developed nations as these herbs possess a varied biological function with their bioactive as well as isolated compounds, that provoke the brainstorming aspects in the field of medicine (Arivu *et al*., 2023).

The present study, carried out primarily focused on the exploration of natural sources of diosgenin phytochemicals that help in preventing and managing multiple health diseases, where isolation of diosgenin was carried out, looking towards its valuable bioactive properties and wide use in pharmaceutical applications for its anti-inflammatory, antioxidant, and metabolic benefits, etc. Synthesis and characterization of diosgenin–silver nanoparticles was carried out to enhance the bioactivity, stability, and overall bioavailability of the compound using a safe, cost-effective, green nanotechnology approach. Where looking towards the insoluble nature of the silver nanoparticles, a step to develop a natural lipid-based drug delivery system to improve the solubility, absorption, and overall bioavailability of the formulated phytochemical–nanoparticle complex.

1. *Chamaecostus cuspidatus*: *Chamaecostus cuspidatus* (Nees & Mart.) C.D.Specht & D.W.Stev. *Costus igneus* Nak and *Costus pictus* D. Don are also known as Insulin plant, Spiral flag, etc. (Kankariya *et al*., 2015). Besides this, *Costus igneus* is also known by a synonym, *Chamaecostus cuspidatus*, which is also considered to be the accepted name. It is a medicinal herb that is traditionally well known for its medicinal uses and health benefits in the prevention and treatment of multiple health problems. The herb is a perennial plant that belongs to the family Costaceae, which spreads upright with a growth range of 2-2.5 feet approximately.

The herb has tremendous medicinal as well as health-benefiting properties with a wide range, primarily including anti-bacterial, anti-microbial, antioxidant, anti-cancerous, etc. Moreover, it is fundamentally known for its anti-diabetic property. The leaves are simple, entire, and arranged alternately to each other with a length of 4-8 inches. They show parallel venation and possess a distinctive characteristic of spiral phyllotaxy. The leaves are observed to have dark green coloration, the flowers show the presence of distinct orangish to yellow color, which has red strips over petals that end towards the outside, and are marked (Kaur and Mannan, 2021).

C.cuspidatus being a rhizomatous shrub, penetrates the earth's surface by its underground tuberous rhizome. The cylindrical rhizome, being fleshy and spongy, has a smooth, pale brown surface; the shrub has a pleasing scent. Full sunny or partial shade is suitable for spiral flag growth with a temperature ranging from 30 – 40°C. The plantation is generally carried out close to a source of water and needs rich soil and enough moisture to favor its growth and development. The offsets that grow below the flowers could be separated, divided into clumps, or removed as part of the propagation process. Mites and Nematodes are a threat to plants, which are particularly found in light, sandy soil.

However, the plant has no major illnesses that would disturb or hinder its growth at the moment. The stem contains steroid molecule compounds such as stigmasterol (a plant sterol) and the terpenoid lupeol (a cyclic compound found in many plants). The rhizome of *C.cuspidatus* has bioactive constituents like quercetin (a plant flavonoid) and diosgenin, which is a type of steroidal sapogenin (naturally occurring chemical compounds found in some plants). The elements K (potassium), Ca (calcium), Cr (chromium), Mn (manganese), Cu (copper), and Zn (zinc) are present in significant concentrations in the rhizomes and leaves of *C.cuspidatus, as identified by* trace elemental analysis. Clear, yellowish essential oils were obtained during steam distillation of the stems, leaves, and rhizomes of *C. igneus* (Kankariya *et al.*, 2015).

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

(a) (b) (c) (d) (e)

(a-Costus plant, b- Spiral phyllotaxy arrangement of plant, c- Flower of Costus plant, d & e- Inflorescence pattern in Costus plant)

2. Phytoconstituents: The preliminary evaluation of phytochemical testing reveals the presence of phytochemicals like alkaloids, phytosterol, saponins, glycosides, carbohydrates, tannins, phenolic compounds, terpenoids lignin and flavonoids in the plant, where as a systematic screening of phytochemical carried out with the leave of *Costus igneus* demarks the presence iron, antioxidant components such as ascorbic acid, β-carotene, α-tocopherol, terpenoids, steroids and flavonoids moreover the leave is also rich in protein content (Arivu *et al*., 2023).
3. Antidiabetic effect: Costus is an ornamental plant which is used as in beautification of the land space, however it is traditionally been used as a herb it is also known as insulin plant or anti diabetic plant where the leaves of this plant stays a major part that signifies the anti-diabetic property of the plant more over it also decreases fasting & post prandial blood sugar levels (Mathew & Varghese., 2019).
4. Diosgenin: A naturally occurring phytochemical that is found in number of plants which has a peculiar chemical structure and it possess multiple pharmacological benefits therefore it is also considered as a unique steroidal saponin, because of its vast therapeutic uses which includes its role as anti-inflammatory, scavenging of free radical resulting showing anti-oxidant properties, diosgenin plays a role in inhibition of cell proliferation which ultimately cause apoptosis which helps understand its anti-cancer activity, moreover it also shows anti-bacterial, anti-microbial properties, where it is predominantly known for its anti-diabetic properties which helps regulate insulin activity in treatment of diabetes essentially on considering the benefits of diosgenin it is crucial to understand the physical, chemical properties which include the stability, biochemistry etc. As well as the biological activity of this compound, so as to learn about the biosynthesis pathways that are responsible for the prevention and management of various types of diseases (Chaudhary *et al*., 2024). Presently, diosgenin and other similar steroidal saponins are mainly obtained by extracting them from tubers of different Dioscorea plant species. However, the decreased availability of this plant and the increase in its demand is the reasons why researchers are trying to identify new and alternative natural sources of this compound (Pazhanichamy *et al*., 2012). Hence, the present study aims to analyze *C. cuspidatus* as an alternative source for the presence of diosgenin compound.
5. Nanotechnology: Silver nanoparticles function as an antitumor agent due to their antiproliferative and apoptosis-inducing properties. The present study focused on emphasizing the complete natural approach in experimentation, and thereafter, the nanomaterials synthesized with the help of biological techniques could typically show higher biocompatibility. Since the method followed is termed green synthesis, it excludes the use of harmful chemical substances and reagents that could be toxic and hazardous for humans and the environment. The method efficiently holds the ability to rapidly produce high quality of nanomaterials in an eco-friendly manner and also at a distinctive low cost (Jayachandran *et al*., 2023).
6. Lipid-Based Drug Delivery System: The use of silver nanoparticles for medicinal purposes is frequently disturbed due to their low solubility of sliver based material in the solution. To overcome this problem, the silver nanoparticles are conjugated with biocompatible substances so as to increase the solubility of the material. However, the conjunction leads to enhanced interaction with desired biomolecules, which does not disturb the natural properties of the compound and provides an effective, high quality of silver nanoparticles. To overcome the poor bioavailability of a particular compound. The approach of encapsulation of nanomaterials into the lipid bilayer or the formulation of liposomes is carried out. Hence, that helps to enhance the bioavailability of the nanomaterial. The present study focuses on the drawbacks related to the nanoparticles and emphasizes the approach to subdue the challenges and develop a well-structured, systematic lipid-based drug delivery system (Jayachandran *et al*., 2023).

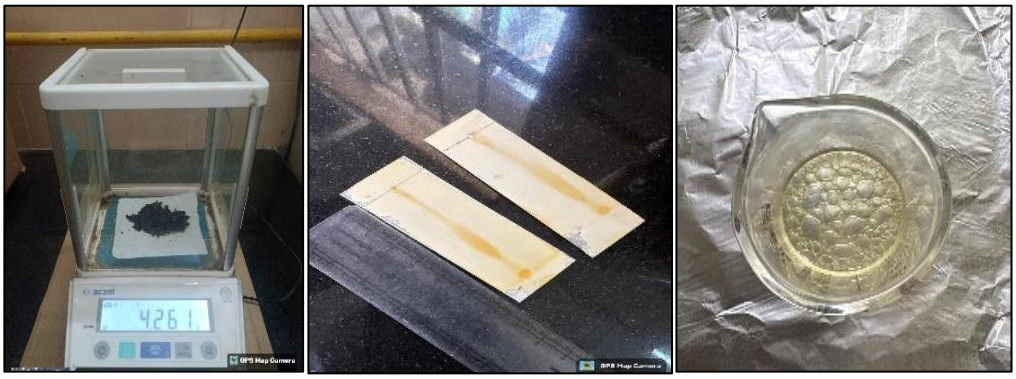
Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Materials & METHODS

1. Extraction of diosgenin from *C. cuspidatus*: Extraction of Diosgenin from the Costus plant was carried out, where fresh rhizome material was obtained, it was cleaned, manually peeled, and chopped into pieces, and was weighed to 50gm followed by acid hydrolysis and Soxhlet extraction (Ashour *et al.*, 2019).
2. Isolation of diosgenin from crude extract: The isolation step was carried out with the TLC method, where the solvent system (n-hexane: ethyl acetate – 7:3) was used, and the retardation factor (Rf value) was calculated (Devi, 2024).
3. Synthesis & Characterization of Silver nanoparticles (AgNPs) from *C. cuspidatus:* Initially 30gm of fresh leaves were weighed, thoroughly washed, and finely cut into pieces. The synthesis of nano material was carried out, where the change in colour on gentle mixing indicates AgNPs formation. Further, the analysis of AgNPs activity was carried out using a spectrophotometer (Jayachandran *et al.*, 2023).
4. Lipid-based drug delivery formulation: Diosgenin-rich Costus plant extract was reacted with silver nitrate (AgNO3) solution and was mixed well, resulting in reduction activity, which leads to a color change that indicates the formation of silver nanoparticles. Preparation of oil phase, where olive oil was slightly warmed at 60-70 degrees Celsius so as oil helps to mix well. The AgNPs extract was added to the warm oil and mixed slowly so as to achieve even formation of oil droplets with the help of a vibrating machine. The size of the oil particle was reduced to tiny droplets (Jayachandran *et al.*, 2023).

Observation & Result

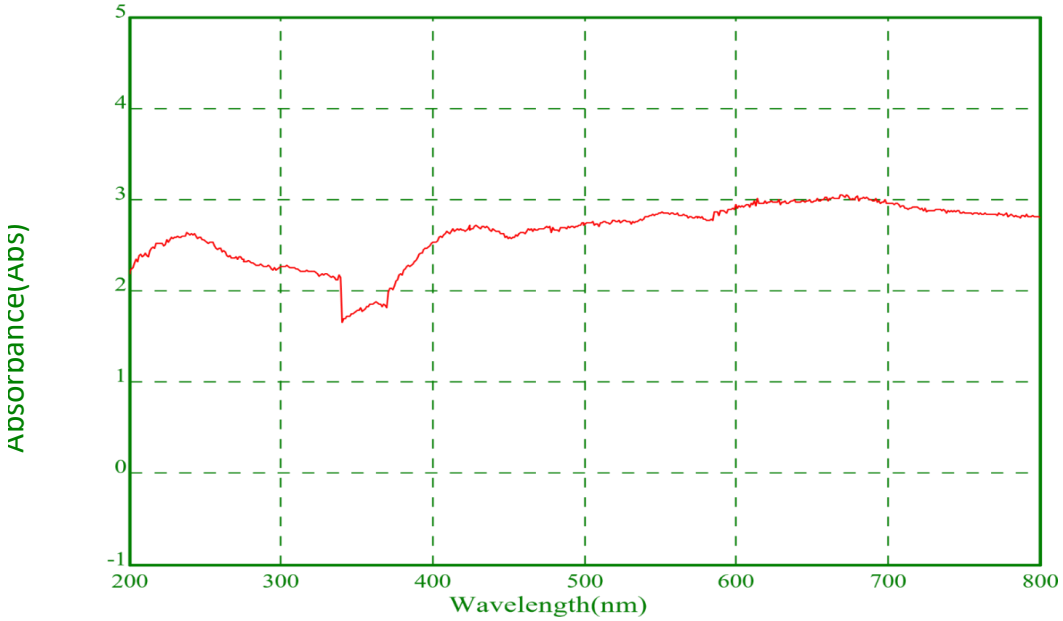
The extraction of diosgenin from the plant was carried out for the preparation of plant extract, followed by acid hydrolysis and the Soxhlet extraction method, which resulted into production of crude sapogenin extract that contained diosgenin. The isolation of diosgenin from the crude sample was further carried out with the TLC method using n-hexane: ethyl acetate (7:3) as the mobile phase and the Silica plate as the Stationary phase, resulting in a Retardation Factor (Rf) value of 0.26 with a single distinct band separation. The synthesis of nanoparticles (AgNPs) was achieved by reacting the plant extract with AgNO3 (Silver Nitrate), during which reduction occurs and a color change from yellow to brown is observed. Furthermore, the nanoparticle activity was analysed with a spectrophotometer, revealing that the particles showed maximum activity in the 600-700 nm wavelength range, as shown in the graphical representation below (Figure 1). Subsequently, a lipid-based drug delivery system was formulated, where the extract was reacted with AgNPs, and the AgNPs were then found to be encapsulated within olive oil. The oil served as a lipid layer or outer covering, incorporating the AgNPs into this layer.



(f) (g) (h)

(f- Crude Sapogenin Extract containing Diosgenin, g- Separation of diosgenin TLC Method, h- Oil Droplet Formation and Encapsulation of AgNPs)

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026



Graphical Representation of AgNPs of Diosgenin
(Figure 1)

Discussion

The results obtained during the experimentation process are preliminary. The diosgenin obtained is in the crude extract form and may contain other chemicals that may inhibit its properties. Further purification of the extract is required. Through the analysis of nanoparticles, characterization is needed to be done by SEM, TEM, and FTIR to confirm the nature of the nanoparticles, and the presence of the functional groups should be confirmed so as to evaluate the biochemical activities of the Phyto steroid. Considering the preliminary screening done, diosgenin seems to have positive properties as a lipid-based drug delivery system.

The research experiment carried out provides significance with ensuring efficient extraction and purification of high quality of diosgenin from *C.cuspidatus* where it covers and combines multi-disciplinary aspects like, phytochemistry, nanotechnology, lipid based drug delivery systems (LBDDS) where Green Synthesis of nanoparticles improves the stability and effectiveness, characterization confirms the particles size, purity functional group and its performance as a well-established cost effective method. The natural lipid-based drug delivery system inhibits the intermediate degradation of the drug, enhancing the solubility, absorption, and overall bioavailability.

Conclusion

The plant *C.cuspidatus* shows strong potential as a natural source of therapeutic phytochemicals. Diosgenin is found to be a valuable bioactive compound, where further purification is essential for enhancing its efficacy and potential. Green synthesis of diosgenin AgNPs demonstrates its potential for nanoparticle activity. The emulsification and encapsulation of AgNPs indicate the potential therapeutic drug effect.

Looking towards the future prospect of the experiment, a new herbal drug can be formulated from *C.cuspidatus* which could be safer, cost-effective, and more efficient. The integration of nanoparticles (AgNPs) with lipid-based drug delivery systems can be used to develop various products like gels, capsules, and sprays. The method can be used to improve the large-scale production of natural herbal therapeutic products. Also, to analyze the effect, in vitro studies with animal models and clinical studies can be carried out to evaluate the efficacy and effectiveness of the formulated drug.

Reference

1. Ahmed, S., Ahmad, M., Swami, B. L., & Ikram, S. (2016). A review on plant extract-mediated synthesis of silver nanoparticles for antimicrobial applications. Journal of Advanced Research, 7(1), 17–28.
2. Amini, S. M. (2025). Diosgenin-based nanomedicine: Advances in formulation strategies, biomedical applications, and translational challenges. *Nanostructures & Nano-Objects*, *44*, 101556. https://doi.org/10.1016/j.nanoso.2025.101556

3. Aruna, A. (2014). Synthesis and Characterization of Silver Nanoparticles of Insulin Plant (*Costus pictus* D. Don) leaves. *Asian Journal of Biomedical and Pharmaceutical Sciences*, *4*(34), 1–6. https://doi.org/10.15272/ajbps.v4i34.523
4. Ashour, A. S., El Aziz, M. M. A., & Gomha Melad, A. S. (2019). A review on saponins from medicinal plants: Chemistry, isolation, and determination. *Journal of Nanomedicine Research*, *7*(4), 282–288. https://doi.org/10.15406/jnmr.2019.07.00199
5. Cheok, C. Y., Salman, H. A. K., & Sulaiman, R. (2014). Extraction and quantification of saponins: A review. *Food Research International*, *59*, 16–40. https://doi.org/10.1016/j.foodres.2014.01.057
6. Devi, R. (2024). EXTRACTION, Extraction, Isolation, Identification, and Estimation of Diosgenin by TLC Profiling and UHPLC-LC-SRM Analysis in Three Costus Species. *Journal of Drug Delivery and Therapeutics*, *14*, 120–127. https://doi.org/10.22270/jddt.v14i11.6878
7. *Diosgenin: A Potential Therapeutic Phytocompound for the Management of Atherosclerosis and Other Physiological Disorders*. (n.d.). https://doi.org/10.1177/1934578X241301228
8. Govindarajan, M., Rajeswary, M., Veerakumar, K., Muthukumaran, U., Hoti, S. L., & Benelli, G. (2019). Green synthesis of silver nanoparticles using plant extracts and their biological applications. Journal of Photochemistry and Photobiology B: Biology, 190, 113–120.
9. Iravani, S., Korbekandi, H., Mirmohammadi, S. V., & Zolfaghari, B. (2011). Synthesis of silver nanoparticles: Chemical, physical, and biological methods. Research in Pharmaceutical Sciences, 6(6), 385–406.
10. Jayachandran, P., Ilango, S., Suseela, V., Nirmaladevi, R., Shaik, M. R., Khan, M., Khan, M., & Shaik, B. (2023). Green Synthesized Silver Nanoparticle-Loaded Liposome-Based Nanoarchitectonics for Cancer Management: In Vitro Drug Release Analysis. *Biomedicines*, *11*(1), 217. https://doi.org/10.3390/biomedicines11010217
11. Kalepu, S., Manthina, M., & Padavala, V. (2013). Oral lipid-based drug delivery systems – an overview. *Acta Pharmaceutica Sinica B*, *3*(6), 361–372. https://doi.org/10.1016/j.apsb.2013.10.001
12. Majinda, R. R. T. (2012). Extraction and Isolation of Saponins. In S. D. Sarker & L. Nahar (Eds.), *Natural Products Isolation* (Vol. 864, pp. 415–426). Humana Press. https://doi.org/10.1007/978-1-61779-624-1_16
13. Manjunath, K., Reddy, J.S., & Venkateswarlu, V. (2005). Solid lipid nanoparticles as drug delivery systems. *Methods and Findings in Experimental and Clinical Pharmacology*, *27*(2), 127. https://doi.org/10.1358/mf.2005.27.2.876286
14. Mukherjee, S., Ray, S., & Thakur, R. S. (2009). Solid Lipid Nanoparticles: A Modern Formulation Approach in Drug Delivery Systems. *Indian Journal of Pharmaceutical Sciences*, *71*(4), 349–358. https://doi.org/10.4103/0250-474X.57282
15. Patel, K., Gadewar, M., Tahilyani, V., & Patel, D. (2012). A review on pharmacological and analytical aspects of diosgenin. Journal of Pharmaceutical Sciences and Research, 4(3), 1817–1825.
16. Pawar, V., Jadhav, R., & Patil, S. (2012). Extraction and identification of steroidal sapogenin (diosgenin) from *Costus igneus* rhizomes. International Journal of Pharmaceutical Sciences and Research, 3(10), 3775–3780.
17. Pazhanichamy, K., Bhuvaneswari, K., Kunthavai, B., Eevera, T., & Rajendran, K. (2012). Isolation, characterization, and quantification of diosgenin from *Costus igneus*. *Journal of Planar Chromatography – Modern TLC*, *25*(6), 566–570. https://doi.org/10.1556/JPC.25.2012.6.13
18. Rao, M. U., Sreenivasulu, M., & Chengaiah, B. (2013). Phytochemical evaluation and medicinal importance of *Costus igneus*. International Journal of Pharmaceutical Sciences and Research, 4(8), 3199–3203.
19. Sataraddi, S. R., & Nandibewoor, S. T. (2012). *Bio synthesis, characterization, and activity studies of Ag nanoparticles, by (Costus igneus) insulin plant extract*.
20. Savithramma, N., Linga Rao, M., & Suhrulatha, D. (2012). Screening of medicinal plants for secondary metabolites. Middle-East Journal of Scientific Research, 12(4), 400–406.
21. Semwal, P., Painuli, S., Abu-Izneid, T., Rauf, A., Sharma, A., Daştan, S. D., Kumar, M., Alshehri, M. M., Taheri, Y., Das, R., Mitra, S., Emran, T. B., Sharifi-Rad, J., Calina, D., & Cho, W. C. (2022). Diosgenin: An Updated Pharmacological Review and Therapeutic Perspectives. *Oxidative Medicine and Cellular Longevity*, *2022*(1), 1035441. https://doi.org/10.1155/2022/1035441
22. Sharma, A., Kumar, P., & Singh, R. (2016). Lipid-based drug delivery systems for bioactive plant compounds. International Journal of Pharmaceutical Sciences Review and Research, 38(1), 129–137.
23. Shinde S, Surwade S., and Sharma R. *Costus igneus*: Insulin plant and its preparations as a remedial approach for Diabetes Mellitus. *International Journal of Pharmaceutical Sciences and Research*, IJPSR, 2022; Vol. 13(4):1551-1558.https://www.researchgate.net/profile/Sonali-Shinde3/publication/360074270_COSTUS_IGNUS_INSULIN_PLANT_AND_IT'S_PREPARATIONS_AS_REMEDIAL_APPROACH_FOR_DIABETES_MELLITUS/links/62603fa21b747d19c299e915/COSTUS-IGNUS-INSULIN-PLANT-AND-ITS-PREPARATIONS-AS-REMEDIAL-APPROACH-FOR-DIABETES-MELLITUS.pdf
24. Yadav, H., & Gupta, M. K. (2023). *To Prepare and Evaluate Silver Nitrate Nanoparticles for Pharmaceutical Application*.
25. https://www.worldfloraonline.org/taxon/wfo-0000805532#synonyms

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Original Article

Effect of Nitrate Reductase Enzyme in Relation to Protein and Carbohydrate Metabolism under Salinity Stress in Cowpea (*Vigna unguiculata* (L.) Walp.)

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Manuscript ID:
JRD -2026-180414
ISSN: 2230-9578
Volume 18
Issue 4(XI)
Pp. 82-85
April - 2026
Submitted: 14 Mar. 2026
Revised: 29 Mar. 2026
Accepted: 05 Apr . 2026
Published:30 April2026

Abstract
Soil salinization is a major environmental constraint that adversely affects agricultural productivity and ecological sustainability worldwide. The accumulation of soluble salts in soil disrupts plant growth, metabolism, and yield. The present study investigates the effect of salinity stress on nitrate reductase (NR) activity and its relationship with protein and carbohydrate metabolism in cowpea (Vigna unguiculata (L.) Walp.). Cowpea seeds were exposed to varying concentrations of sodium chloride (NaCl) ranging from 20 mM to 100 mM under controlled conditions.
The results indicate that salinity stress significantly affects nitrogen metabolism by inhibiting nitrate uptake and reducing NR activity at higher salt concentrations. Moderate salinity levels showed slight enhancement in NR activity, whereas higher concentrations caused a decline in enzyme activity, leading to reduced protein synthesis and altered carbohydrate metabolism. Biochemical analysis revealed a gradual decrease in protein and carbohydrate content with increasing salinity.
The findings support the hypothesis that nitrate uptake and reduction are more sensitive to salinity stress than ammonia assimilation. Furthermore, plants exposed to mild salinity exhibited adaptive responses, suggesting acclimatization potential under gradual stress conditions. This study highlights the importance of NR activity as a biochemical marker for salinity tolerance in cowpea.
Keywords: *Vigna unguiculata, salinity stress, nitrate reductase, protein metabolism, carbohydrate metabolism, osmotic stress*

Introduction

Cowpea (*Vigna unguiculata* (L.) Walp.) is an important legume crop widely cultivated in tropical and subtropical regions. It plays a vital role in food security due to its high protein content, adaptability to harsh environments, and ability to fix atmospheric nitrogen. As a climate-resilient crop, cowpea is increasingly significant in sustainable agriculture systems. Soil salinization has emerged as a critical challenge, affecting nearly 20% of irrigated agricultural land globally. High salinity imposes osmotic, ionic, and oxidative stress on plants, leading to reduced growth, impaired photosynthesis, and metabolic disturbances. Most crop plants, including cowpea, are glycophytes and are sensitive to high salt concentrations. Nitrogen metabolism is particularly vulnerable to salinity stress. Nitrate reductase (NR), a key enzyme in nitrogen assimilation, catalyzes the reduction of nitrate (NO_3^-) to nitrite (NO_2^-), which is further converted into ammonium for amino acid and protein synthesis. Any disruption in NR activity directly affects protein metabolism and overall plant growth. Salinity also influences carbohydrate metabolism by altering sugar synthesis, transport, and storage. The balance between carbon and nitrogen metabolism is essential for plant survival under stress conditions. Accumulation of compatible solutes such as sugars and amino acids helps in osmotic adjustment and stress tolerance. Previous studies have largely focused on sudden salt stress; however, gradual exposure better simulates natural field conditions. Plants subjected to stepwise salinity often exhibit adaptive responses, including metabolic adjustments and enhanced tolerance mechanisms.

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How to cite this article:
Nagvekar, D. V., & Kondvilkar, N. D. (2026). Effect of Nitrate Reductase Enzyme in Relation to Protein and Carbohydrate Metabolism under Salinity Stress in Cowpea (Vigna unguiculata (L.) Walp.). 18(4(XI)), 82–85. https://doi.org/10.5281/zenodo.21124789

Quick Response Code:
Website:
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DOI:
10.5281/zenodo.21124789
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This study aims to:

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

- Evaluate the effect of salinity on nitrate reductase activity in cowpea
- Analyze changes in protein and carbohydrate metabolism
- Understand the adaptive responses of cowpea under gradual salinity stress

Materials and Methods

2.1 Plant Material

Seeds of cowpea variety *Konkan Safed* (released in 1991; duration: 75–80 days; yield: 14 q/ha) were used for the experiment. This variety is characterized by short plants, dark green foliage, white flowers, and resistance to yellow mosaic virus.

2.2 Experimental Design

Healthy seeds were soaked overnight and placed in Petri dishes containing different concentrations of NaCl solutions:

- 20 mM
- 40 mM
- 60 mM
- 80 mM
- 100 mM

Seeds were allowed to germinate and grow for one week under controlled conditions. Adequate moisture was maintained by regularly supplying respective salt solutions.

2.3 Biochemical Analysis

2.3.1 Qualitative Tests

Standard biochemical tests were conducted to detect carbohydrates:

- Tollen's test
- Molisch's test
- Benedict's test
- Fehling's test
- Iodine test

2.3.2 Protein Estimation

Protein content was determined using colorimetric methods. The reaction mixture included distilled water, reagent C, and Folin–Ciocalteu (FC) reagent. Optical density (O.D.) was measured at 660 nm using a spectrophotometer.

2.3.3 Nitrate Reductase Activity

NR activity was estimated based on nitrite production using sulphanilic acid and naphthylamine reagents, indicated by the formation of red color.

Results

3.1 Biochemical Tests

- Fehling's test showed positive results across all treatments, indicating the presence of reducing sugars.
- Other tests (Tollen's, Molisch's, Benedict's, and Iodine) showed negative results.

3.2 Protein Content (O.D. at 660 nm)

NaCl Concentration	O.D. Value
20 mM	0.68
40 mM	0.44
60 mM	0.50
80 mM	0.42
100 mM	0.30

Protein content showed a declining trend with increasing salinity, with slight variation at moderate levels.

3.3 Nitrate Reductase Activity

NaCl Concentration	NR Activity
20 mM	Absent
40 mM	Absent
60 mM	Absent
80 mM	Present
100 mM	Absent

NR activity was detected only at 80 mM NaCl concentration.

Discussion

The study demonstrates that salinity stress significantly influences nitrogen and carbon metabolism in cowpea. A moderate increase in protein content at lower salinity levels suggests an adaptive response, possibly due to enhanced synthesis of stress-related proteins. However, higher salinity levels inhibit protein synthesis, likely due to enzyme inactivation or increased protein degradation.

The reduction in nitrate reductase activity at higher salt concentrations indicates impaired nitrate assimilation. Since NR is a rate-limiting enzyme, its inhibition disrupts amino acid and protein biosynthesis.

Carbohydrate metabolism was also affected, as indicated by biochemical tests. The presence of reducing sugars suggests their role in osmotic adjustment under stress conditions.

Nitrite reductase, which converts nitrite to ammonium, is generally more active and efficient than NR, preventing accumulation of toxic nitrite in plant tissues.

The findings align with previous studies indicating that salinity stress leads to:

- Reduced growth and metabolic activity
- Accumulation of osmolytes
- Altered enzyme activities

Gradual exposure to salinity appears to induce acclimatization, allowing plants to better tolerate stress compared to sudden exposure.

Conclusion

Salinity stress exerts a profound impact on nitrate reductase activity and consequently on protein and carbohydrate metabolism in cowpea. Moderate salinity may enhance adaptive responses, whereas higher concentrations inhibit metabolic processes, leading to reduced growth.

The study confirms that nitrate uptake and reduction are more sensitive to salinity than ammonia assimilation. Additionally, gradual exposure to salinity promotes acclimatization and enhances stress tolerance.

Understanding these biochemical responses is crucial for developing salt-tolerant crop varieties and improving agricultural productivity under saline conditions.

References

1. Allen GJ, Wyn Jones RG, Leigh RA (1995) Sodium transport measured in Plasma membrane vesicles isolated from wheat genotypes with differing K+/Na+ discrimination traits. Plant Cell Envir. 18:105–115.
2. Baccio D, di Navari-Izzo F, Izzo R (2004) Seawater irrigation antioxidant Defense responses in leaves and roots of a sunflower (Helianthus annuus L) Genotype. J. Plant Physiol. 161(12):1359-1366.
3. Baldwin AH, McKee KL, Mendelssohn IA (1996) The influence of vegetation Salinity and inundation on seed banks of oligohaline coastal marshes. Amer. J. Bot. 83:470–479.
4. BARBOSA, C.D. Resposta de plantasjovens de algaroba(Propopisjuliflora (Sw.) DC.) à salinidade. 1996. 28f. Monografia (GraduaçãoemAgronomia) – Universidade Federal da Paraíba,Patos, 1996.
5. Bates LS, Waldren RP, Teare ID (1973) Rapid determination of free proline for Water stress studies. Plant & Soil. 39: 205-207.
6. BERNSTEIN, L.; HAYWARD, H.E. Physiology of salt tolerance.Annual Review of Plant Physiology, Palo Alto, v.9, n.1, p.25-46,1958.
7. Bernardo Murillo-Amador, Enrique Troyo-Dieguez, Jose Luis Garcia-ernandez, Raul Lopez-Aguilar, NarcisoYsac Avila-Serrano, Sergio Zamora-Salgado, Edgar Omar Rueda-Puente, Cengiz Kaya (2006) Effect of NaCl salinity in the Genotypic variation of cowpea (*Vigna unguiculata*) during early vegetative Growth. Sci. Horti. 108:423-432.
8. Bliss CI (1967) Statistical methods for research in the natural sciences, Statistics in biology, McGraw Hill Book Company.
9. Chanyou Chen, Chengxue Tao, Hai Peng, Yi Ding (2007) Genetic analysis Of salt stress responses in asparagus bean (*Vigna unguiculata* (L.) ssp. *SesquipedalisVerdc*.). J. Hered. 98(7):655-665.
10. Chapman VJ (1975) The salinity problem in general, its importance and Distribution with special reference to natural halophytes. In: A. PoljakoffMayber, and J. Gale (eds), Plants in Saline Environments, Springer-Verlag, New York. Pp. 7-21.
11. Cramer GR (1992) Kinetics of maize leaf elongation. 2. Response of a Naexcluding cultivar and a Na-including cultivar to varying Na/Ca salinities. J. Exp. Bot. 43:857–864.
12. Epstein E, Norlyn JD, Rush DW, Kings RW, Kelly DB, Cunningham DB, Worna AF (1980) Saline culture of crops. A general approach. Science 210:399-404.
13. Essa TA (2002) Effect if saline stress on growth and nutrient composition of Three soybean (Glycine Max. L. Merrill) cultivers. J. Agro. Crop Sci. 188:86-93.
14. Gururaja Rao G, Patel Prakash R, Bagdi DL, Chinchmalatpure Anil R, Nayak AK, Khandelwal MK, Meena RL (2005) Effect of saline water irrigation on Growth ion content and forage yield of halophytic grasses grown on saline Black soil. Indian J. Plant Physiol. 10(4):315-321.
15. Greenway H, Munns R (1980) Mechanism of salt tolerance in halophytes. Annu. Rev. Plant Physiol. 31:149-190.

16. Grieve CM, Suarez DL (1997) Purslane (Portulacaoleracea L.): a halophytic Crop for drainage water reuse systems. Plant Soil. 192:277–283.
17. Hussein MM, Balbaa LK, Gaballah MS (2007) Developing a Salt Tolerant Cowpea Using Alpha Tocopherol. J. App. Sci. Research 3(10):1234-1239.
18. Ioneva ZS (1988) Effect of potassium ion Na+ uptake by plants in conditions of chloride salinity. Fiziolo. Rasten. 14:42-47.
19. Jamal SN, Zafar Iqbal M, Athar M (2006) Effect of aluminum and chromium on the germination and growth of two *Vigna* species. Int. J. Environ. Sci. Tech. 3:53-58.
20. Kuiper PJC (1984) Function of plant cell membranes under saline conditions: Membrane lipid composition and ATPases. In: R. C. Staples, and G. H. Toenniesses (eds), Salinity Tolerance in Plants, Wiley-Interscience, New York. pp. 77-91.
21. Mariko S, Kachi N, Ishikawa S, Furukawa A (1992) Germination ecology of Coastal plants in relation to salt environment. Ecological Res. 7:225–233.
22. Munns R, Termaat A (1986) Whole-plant responses to salinity. Aust. J. Plant Physiol. 13:l43–l60.
23. Nabil M, Coudret A (1995) Effects of sodium chloride on growth, tissue Elasticity and solute adjustment in two *Acacia nilotica* subspecies. PhysiologiaPlantarum 93:217–224.
24. Norlyn JD, Epstein E (1984) Variability in salt tolerance of four triticale lines at Germination and emergence. Crop Sci. 24:1090-1992.
25. Patel Kajal G, Ramana Rao TV (2007) Effect of simulated water stress on the physiology of leaf senescence in three genotypes of cowpea (*Vigna unguiculata* (L.) Walp). Indian J. Plant Physiol. 12(2):138-145.
26. Plaut Z, Grieve CM, Federman E (1989) Salinity Effects on Photosynthesis in Isolated Mesophyll Cells of Cowpea Leaves. Plant Physiol. 91:493-499.
27. Reggiani R, Bonzo S, Bertani A (1995) The effect of salinity on early seedling Growth of seeds of three wheat (*Triticum aestivum* L.) cultivars. Can. J. Plant Sci. 75:175-177.
28. Rehman S, Harris PJC, Bourne WF, Wilkin J (1996) The effect of sodium Chloride on germination and the potassium and calcium contents of *Acacia* Seeds. Seed Sci. Technol. 25:45-57.
29. Richards LA (1954) Diagnosis and improvement of saline and alkaline soils. USDA Agric. Handbook, Vol. 66, U.S. Department of Agriculture.Tawfik KM (2008) Evaluating the Use of Rhizobacterin on Cowpea Plants Grown under Salt Stress. Res. J. Agri. Biol. Sci. 4(1):26-33.
30. Ungar IA (1996) Effect of salinity on seed germination, growth, and ion Accumulation of *Atriplexpatula* (Chenopodiaceae). Am. J. Bot. 83:604-607.

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Original Article

Electrophoretic Studies of Laccase from *Pleurotus Sajor-Caju*

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Manuscript ID:
JRD -2026-180415
ISSN: 2230-9578
Volume 18
Issue 4(XI)
Pp. 86-91
April - 2026

Submitted: 14 Mar. 2026
Revised: 29 Mar. 2026
Accepted: 05 Apr . 2026
Published:30 April2026

Abstract
The present paper describes the results of electrophoretic analysis of soluble proteins as well as laccase enzyme from crude as well as partially purified extracted from Pleurotus sajor-caju were separated by acrylamids-gel electrophoresis. The pattern and overall intensity of the protein bands greatly revealed one prominent band correlated with laccase activity (45 – 48 kDa). The protein profile – zymogram also showed presence of number of proteins ranging 16 – 180 kDa.
Key words: *Electrophoretic study, Laccase, Pleurotus sajor-caju*

Introduction

Laccase is widely dispersed in nature and found in plants, insects and bacteria (Desai & Nityanand, 2011) and they are of great ecological importance for degradation of pigments and lignocellulosic material. (Kale *et al* 2022). Laccase production occurs in various fungi over a wide range of taxa. Fungi from the *deuteromycetes, ascomycetes* as well as *basidiomycetes* are known producers of laccase (Sadhasivam *et. al.*, 2008; Atalla *et. al.*, 2013). Laccases (benzenediol: oxygen oxidoreductase, EC 1.10.3.2) are copper containing enzymes that catalyze oxidation of one-electron of a wide variety of substrates such as diphenols, polyphenols, diamines, aromatic amines, and other electron rich compounds, using molecular O2 (Madhavi & Lele, 2009). They belong to a protein family that includes ascorbate oxidase, ceruloplasmin, and bilirubin oxidase. These enzymes utilize a free radical-catalyzed reaction mechanism in which the substrate forms an unstable free radical that further undergoes nonenzymatic reactions including hydration and disproportionation reactions (Claus, 2004; Shrestha *et. al.*, 2016)

Laccases secreted by white rot fungi have been considered advantageous as they are extracellular enzymes which are simple to scale up, easy to recover and involve purification processes which make them stable. Due to these versatile characteristics, it has numerous environmental and biotechnological applications (Zou *et. al*., 2012; Daassi *et. al*., 2013; D Kale *et.al.* 2022). The wider applications of laccases in biotechnology have resulted in the need for expanding the broad spectrum of isolation and purification of novel laccase with different physicochemical and catalytic properties (Kiiskinen *et. al*., 2004; Jebapriya, 2014). Native PAGE is an electrophoresis method to separate native proteins. Native PAGE is also a useful method for checking the uniformity of the isolated protein. Even if the purified protein sample contains only a single type of protein, the sample might not be uniform. Some of the molecules might be unfolded or have undergone chemical modifications. Unfolding changes the overall shape of the molecule, while most chemical modifications change the electric charge of native molecules. These alterations can be detected after traditional staining of the purified sample. If no such side products are present, protein molecules will run in a single sharp band or else multiple bands or smearing of the band is expected.

Gel electrophoresis is a valuable method for separating soluble protein fractions extracted from *Pleurotus sajor-caju*. SDS is an anionic detergent which when added to the protein sample linearizes the proteins and imparts a net negative charge to it.

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How to cite this article:
Kale, D., Muni, N., & Singh, D. B. R. (2026). Electrophoretic Studies of Laccase from Pleurotus Sajor-Caju. Journal of Research and Development, 18(4(XI)), 86–91.
https://doi.org/10.5281/zenodo.21124943

Quick Response Code:
Website:
https://jrdrvb.org/
DOI:
10.5281/zenodo.21124943
OPEN ACCESS

Journal of Research and Development
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ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

The SDS binds to the polypeptide chain resulting in fractionation of the chain according to size during the electrophoretic process (Rath *et. al.*, 2009). SDS-PAGE is mainly carried out to examine the progress of the purification process. The purity, homogeneity and molecular mass of the purified enzyme of interest are measured by SDS-PAGE (Madhavi & Lele, 2009). Confirmation for purifying the enzyme of interest is done using zymogram analysis. Under zymogram analysis, specific substrates are used for the rapid visualization of the enzyme of interest which is exhibited by a colour change. The goals for the purification process include reducing the loss of enzyme activity, highest recovery of the target protein and maximum elimination of the contaminating proteins (Gnanasalomi, 2015). The present study includes the electrophoretic analysis of soluble proteins as well as laccase enzyme from crude as well as partially purified extract of *Pleurotus sajor -caju* extract.
Several reports (McLellan, 1982; Zewert & Harrington, 1993; Hames, 1998, Avhad A and Dawda H, 2015) described a range of experimental methods for protein electrophoresis by polyacrylamide gel electrophoresis (PAGE) techniques. They worked on suitable protein separation electrophoresis methods by choosing suitable matrices and corresponding buffer systems.

Material & Methods

Sample Collection

The fresh fruiting bodies of *Pleurotus sajor-caju* mushroom were collected from field at Panvel, Navi Mumbai during February 2017 to August 20018.

Sample Preparation for PAGE

The fresh fruiting bodies of *Pleurtotus sajor-caju* mushrooms were cleaned under running tap water and crushed with distilled water (10 mL distilled water per 5 g mushroom) using a motor and pestle. The liquid fraction was filtered through whatman's no. 1 paper and then subjected to centrifugation at 4000 rpm for 20 min. The clear supernatant was collected through decantation which was used for laccase activity determination. (Khammuang & Sarnthima, 2009).

Sample Preparation

The enzyme extraction was mixed with equal volume of gel loading buffer.

Reagents used for PAGE

Acrylamide and Bisacrylamide (30%) - 29% Acrylamide and 1% bisacrylamide in DW
Resolving gel buffer - 1.5M Tris-buffer, pH 8.8 in DW.
Ammonium per sulphate - 10% in DW.
TEMED - Used TEMED undiluted from the bottle.
Tank buffer - 25 mMTris buffer, 192 mM glycine , pH 8.3 in DW.
Gel loading buffer - 1M Tris buffer, pH 6.8, 20% glycerol, bromophenol blue in D/W.
Staining solution - 0.25g Coomassie Brilliant Blue R-250, 90 ml methanol:water (1:1 v/v) , 10mlglacial acetic acid.
Destainingsolution - 90 ml methanol:water (1:1 v/v) and 10 ml glacial acetic acid

Gel preparation, casting, loading and separting the samples of polyacrylamide gel

PAGE for enzyme Laccase was carried out at room temperature (approximately 37^0C). The experiments were conducted using TechnoSource (Sleekpage) Mini Vertical Electrophoresis unit. They are used to separate proteins in 12% polyacrylamide gel. Glass plates were washed with distilled water and dried using tissue paper. The plates were placed on gel casting assembly. The plates were fixed properly avoiding any leakage. The support medium as specified in the Table 1 is filled in this gap between the two glass plates. Once the gel has been cast, a plastic comb is pressed into the gel volume and allowed to remain there till gel is polymerized. Thereafter the comb is removed. This action leaves the wells cut on the gel. Sample was loaded in polymerized gel plates, which had four wells with different concentration/volume 5µL, 10µL, 15 µL, 20 µL, and 25 µL of protein. Loaded sample plates were mounted on the unit, it was then both the tanks were filled with tank buffer.

Table 3.1. Composition of 12 % Polyacrylamide gel for PAGE

Reagents	In µl/ml
Acrylamide (30%)	4 ml
1.5M Tris pH 8.3	2.5ml
Distilled Water	3.4ml
10%APS	0.1ml
TEMED	10 µl

Electrophoresis was carried out at a constant voltage 80 Volts. The duration of electrophoresis was till the bromophenol blue marker reached at the other end of the gel. Subsequently the gels were loosened and removed from the gel plate.

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Electrophoretic analysis for protein

Gel was stained for 30 minutes in Coomassie brilliant blue R- 250 staining solution for proteins. It was then destained by changing the destaining solution frequently, until the background has been satisfactorily removed. The complete clear backgrounds lead to visualization of prominent bands.

Electrophoretic analysis for laccase

Activity staining for laccase was performed with ABTS as the substrate. Gel were allowed to stand in sodium acetate buffer (0.2 mM, pH 4.5) with 20 mM ABTS and incubated at 37^0C till the laccase activity spots were indicated by the development of a green colored band.

Partial Purification of Laccase enzyme

The crude enzyme was fractionated of ammonium sulfate ($[NH_4]_2SO_4$) from 40 % (w/v) till the saturation level of 90 % (w/v) concentration. Precipitated protein was collected by centrifugation at 10,000 rpm for 15 min at 40C. The precipitate was resuspened in 20 mM Tris buffer (pH 8.0). The crude enzyme extract was futher dialyzed against 10 mM Tris buffer (pH 8.0) using dialysis membrane (Spectra /Por 7) for 24 h with regular changes in 2 h interval. To determine the purity of the protein and its molecular weight, SDS-PAGE was performed (Laemmli, 1970) with 10 % polyacrylamide gel and the protein was visualized by staining the gel with silver staining (Blum *et al.*, 1987) using standard molecular weight markers.

Silver staining activity for partially purified enzyme

The introduction of silver staining of proteins in polyacrylamide gels in 1979 (Switzer *et. al.*, 1979)

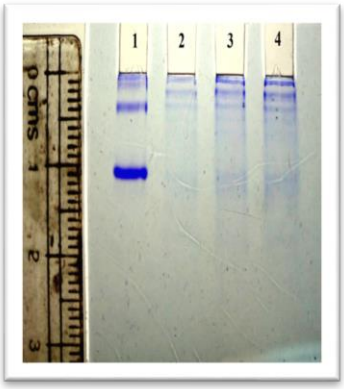
Reagents-

Fixative I - 40% Methanol, 10% acetic acid and 0.076% formalin in DDW.
Fixative II - 10% Ethanol and 5% acetic acid in DDW.
Oxidizer - 3.4 mM potassium dichromate and 3.2 mM nitric acid in DDW.
Silver reagent - 12 mM silver nitrate (205 mg/ 100 ml) in DDW (always prepared freshly).
Developer - 250 mM (2.97 gm) sodium carbonate and 0.05% (50 µl) of37% w/v formalin in DDW.
Stopping solution - 5% acetic acid in DDW.
Preservative - 30% ethanol, 10% acetic acid and 10% glycerol in DDW.

Procedure

Gel was prepared in the same way as described for PAGE. After the electrophoresis was complete, the gel was removed carefully and washed in deionized water for 5 min. Soaked in fixative I for 1 hour. Gel was held for several days in Fixative I. Soaked in fixative II for 2 hours. Washed in deionized water for 5 min. thorough rinsing with water gives a low, uniform background. Soaked in oxidizer solution for 30 min. Washed 3 times in deionized water for 10 min (3 x 10 min).Gel was stained in a freshly made silver nitrate solution for 30 minutes. After staining, the gel was washed 2 times in deionized water for 4 min (2 x4 min).The images were developed by soaking in developer solution for 5 to 10 min. When slight background staining appeared, then decants staining solution and quickly adds the stop solution to stop the staining reaction.

Observations & Results



Lane No	Sample ID
Lane 1	Standared Protein
Lane 2	15µLof sample
Lane 3	20 µLof sample
Lane 4	25 µLof sample

Photoplate 3.1.1– 12 % PAGE, separation of soluble protein from *Pleurotus sajor -caju.*

Protein detection was carried out using PAGE analysis **(Fig. 3.1.1).** Different lanes were loaded with gradual increase in concentration of sample. To correlate number of protein bands standard (as BSA) in lane 1 was loaded. Several protein bands appeared on the gel indicating presence of different types of soluble proteins in extract.

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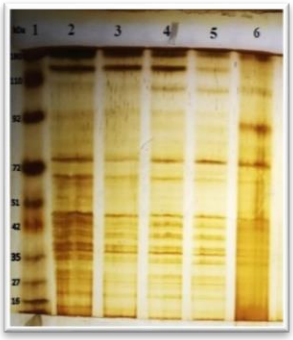
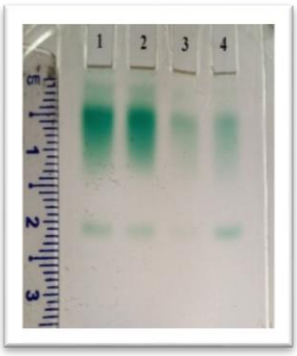


Lane No	Sample ID
Lane 1	Pre-stained protein ladder
Lane 2	20% partially purified
Lane 3	40% partially purified
Lane 4	60% partially purified
Lane 5	80% partially purified
Lane 6	Crude

Photoplate 3.1.2 - 10 % PAGE, silver stained, under reducing conditions showing precipitation of Laccase in the media supernatant post dialysis

The PAGE analysis of partially purified enzyme extract, by using silver staining method clearly revealed protein bands which were more in number sharper as compared to crude extract protein bands **(Fig. 3.1.3).**

In the present studies, protein was stained with silver nitrate solution **(Fig. 3.3.1)**; it is observed that protein produced in the media indicates that the Lane 3 & 6, 80% precipitated protein showed a single band of laccases stained by silver reagent.Under reducing conditions, precipitation of Laccase in the media supernatant post dialysis was observed. Lane 2, crude extract showed a light band of laccase. Lane 4 & 5 did not show any band of laccase, which might be due to negligible production of laccase in 40% & 80% supernatant. Therefore, it can be concluded that *Pleurotus sajor-caju* shows only one band of laccase enzyme.

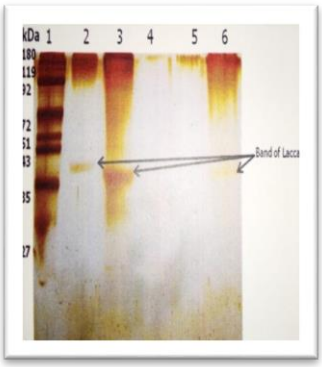


Lane No	Sample ID
Lane 1	25 µLof sample
Lane 2	20 µLof sample
Lane 3	15 µLof sample
Lane 4	10 µLof sample

Photoplate 3.1.3 - Zymography carried out on 12% PAGE load with crude sample, gel was incubated for 45 min.

From the previous study it can be seen that *P. ostreatus*, a white-rot fungus produce lignolytic enzymes, such as manganese peroxidases (MnP) and laccases (Das et al., 2016) which can oxidize ABTS and used as the substrate. Therefore, the presence of these enzymes in the media was determined by PAGE.

The zymogram showed a smeared laccase band in presence of ABTS as substrate **Fig. 3.2.1 - 6**. Different volume of Enzyme was loaded in wells i.e, 10, 15, 20, 25 µl, with increase in time of incubation that has resulted in formation of darker green bands. Staining activity of the enzyme using ABTS can be confirmed by the presence of the bands of protein exhibiting laccase activity.



Lane No	Sample ID
Lane 1	Pre-stained protein ladder
Lane 2	Crude
Lane 3	80% pellet
Lane 4	80% supernantant
Lane 5	40% supernantant
Lane 6	80% pellet

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Photoplate 3.1.4 – 10 % PAGE, silver stained, under reducing conditions showing precipitation of Laccase in the media supernatant post dialysis.

In our studies, the partially purified laccase showed a single band on PAGE with a mobility corresponding to the relative as visualized by silver nitrate staining (molecular mass of 45 – 48 kDa) when in gel activity assay was performed. The enzyme tends to aggregate faster and hence more number of dimmers are formed and the intense band on top as shown in same **Fig. 3.1.4**. This is very close to the molecular weight of laccase from Pleurotus sp. having molecular weight of 40 kDa (More et. al., 2011).

Discussion

PAGE analysis was carried out for both the crude and partially purified enzyme extracts obtained from *Pleurotus sajor-caju*.

Overall analysis of protein profile of crude as well as partially purified extract source indicates the presence of various proteins ranging from 16 kDa to 180 kDa in the *Pleurotus sajor-caju.*

PAGE analysis of laccase enzyme obtained from crude as well purified extract by using ABTS as a substrate also showed a clear correlation of its presence and is apparently of molecular weight 45 – 48 kDa .

References

1. **Atalla, M. M., Zeinab, H. K., Eman, R. H., Amani, A. Y., & Abeer, A. A. E. A.** (2013). Characterization and kinetic properties of the purified *Trematosphaeria mangrovei* laccase enzyme. *Saudi journal of biological sciences*, *20*(4), 373-381.
2. **Avhad A and Dawda H (2015)** "Electrophoretic Studies of Isozymes of Glutamate Dehydrogenase (EC 1.4.1.3) (GDH) and Aspartate aminotransferase (EC: 2.6.1.1) AspAT (GOT) in *Sesuvium portulacastrum* (L.), An Associate Halophyte" ***VEGETOS* Vol 28(1), Pg.151-158. April 2015**. **ISSN - 2229-4473**.
3. DOI 10.5958/2229-4473.2015.00016.6
4. **Blum, H., Beier, H., & Gross, H. J.** (1987). Improved silver staining of plant proteins, RNA and DNA in polyacrylamide gels. *Electrophoresis*, *8*(2), 93-99.
5. **Claus, H.** (2004). Laccases: structure, reactions, distribution. *Micron*, *35*(1- 2), 93-96.
6. **Daâssi, D., Zouari-Mechichi, H., Frikha, F., Martinez, M. J., Nasri, M., & Mechichi, T.** (2013). Decolorization of the azo dye Acid Orange 51 by laccase produced in solid culture of a newly isolated *Trametes trogii* strain. *3 Biotech*, *3*(2), 115-125.
7. **Das, N., Naskar, S., Chowdhury, P., Pasman, B., & Adhikari, D.** (2011). Experimental evidence for presence of a growth regulating extracellular laccase in some *Pleurotus* species. *Research Journal of Microbiology*, *6*(5), 493-502.
8. **Deepawali Kale, Nisha Muni, Anil Avhad* and Singh Dan Bahadur (2022)** Dye decolorization using laccase from *Pleurotus sajor-caju, Research Journey* (E-ISSN 2348-7143), special issue-286, *Feb 2022 pg.* 38-46
9. **Desai, S. S., Tennali, G. B., Channur, N., Anup, A. C., Deshpande, G., & Murtuza, B. A.** (2011). Isolation of laccase producing fungi and partial characterization of laccase. *Biotechnol. Bioinf. Bioeng*, *1*(4), 543-549.
10. **Gnanasalomi, D. V.** (2015). Laccase production by *Myrothecium gramineum* and *Psathyrella candolleana*, its Characterization and potential in the removal of synthetic dyes. (Doctoral dissertation, University of Madras, Chennai)
11. **Hames, B. D.** (Ed.). (1998). Gel electrophoresis of proteins: a practical approach (Vol. 197). OUP Oxford.
12. **Jebapriya, G. R.** (2014). Production of laccases from *Pleurotus floridanus* and *Leucocoprinus cretaceus* by submerged and solid state fermentation and their role in decolourization of synthetic dyes. Ph. D. thesis, University of Madras, Chennai, India.
13. **Deepawali Kale, Nisha Muni, Anil Avhad and Singh Dan Bahadur (2022)** Dye decolorization using laccase from *Pleurotus sajor-caju, Research Journey* (E-ISSN 2348-7143), special issue-286, *Feb 2022 pg.* 38-46
14. **Khammuang S. & Sarnthima R.** (2009). Laccase Activity from Fresh Fruiting Bodies of *Ganoderma sp.* MK05: Purification and Remazol Brilliant Blue R Decolorization. *Journal of Biological Sciences*, 9(1), 83-87.
15. **Kiiskinen, L. L., Rättö, M., & Kruus, K**. (2004). Screening for novel laccase-producing microbes. *Journal of applied microbiology*, *97*(3), 640- 646.
16. **Laemmli, U. K.** (1970). Cleavage of structural proteins during the assembly of the head of bacteriophage T4. *nature*, *227*(5259), 680.
17. **Madhavi, V., & Lele, S. S.** (2009). Laccase: properties and applications. *BioResources*, 4(4), 1694-1717.
18. **McLellan, T.** (1982). Electrophoresis buffers for polyacrylamide gels at various pH. *Analytical biochemistry*, *126*(1), 94-99.More et. al., 2011).

19. **Rath, A., Glibowicka, M., Nadeau, V. G., Chen, G., and Deber, C. M.** (2009). Detergent binding explains anomalous SDS-PAGE migration of membrane proteins. *Proceedings of the National Academy of Sciences*. 106(6): 1760-1765.
20. **Sadhasivam, S., Savitha, S., Swaminathan, K., Lin, Feng-Huei (2008).** Production, purification and characterization of mid-redox potential laccase from a newly isolated *Trichoderma harzianum* WL1. *Process Biochemistry*, 43(7), 736–742.
21. **Shrestha, P., Joshi, B., Joshi, J., Malla, R., and Sreerama, L.** (2016). Isolation and Physicochemical Characterization of Laccase from *Ganoderma lucidum*-CDBT1 Isolated from Its Native Habitat in Nepal. *BioMed Research International*, Article ID 3238909:1-10.
22. **Switzer R. C., Merril C. R. & Shifrin S.** (1979). A Highly Sensitive Silver Stain for Detecting Proteins and Peptides in Polyacrylamide Gels. Analytical Biochemistry, 98(1), 231-237.
23. **Zewert, T. E., & Harrington, M. G.** (1993). Protein electrophoresis. *Current opinion in biotechnology*, *4*(1), 3-8.
24. **Zou, Y. J., Wang, H. X., Ng, T. B., Huang, C. Y., & Zhang, J. X.** (2012). Purification and characterization of a novel laccase from the edible mushroom *Hericium coralloides*. *The Journal of Microbiology*, *50*(1), 72-78.

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Original Article

Evaluating medicinal properties of *Peltophorum pterocarpum* flower colour for its eco-friendly topical applications

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Manuscript ID:
JRD -2026-180416
ISSN: 2230-9578
Volume 18
Issue 4(XI)
Pp. 92-95
April - 2026
Submitted: 14 Mar. 2026
Revised: 29 Mar. 2026
Accepted: 05 Apr . 2026
Published:30 April2026

Abstract
Present work has been undertaken to make eco-friendly herbal colour with the help of Peltophorum pterocarpum flowers. Medicinal potential of these wild and unused flowers was utilized to create the natural vibrant yellow colour. Presence of alkaloids, volatile oils, saponins, appropriate ash value and neutral pH indicate the medicinally enriched skin caring properties. On the other hand, absence of carbohydrates indicate the microbial resistant nature of the colour. Patch tests of this colour also showed positive response towards its skin treating qualities. Various face caring products such as facial masks, gel and facepacks can be made with this basic formulation. This organic colour is also safe for playing holi.
Key words: *Peltophorum pterocarpum, Eco-friendly colour and skin care*

Introduction

Peltophorum pterocarpum (commonly called copper pod, yellow flame tree, or peacock flower tree) has notable importance in traditional skin medicine, especially in Ayurveda, Siddha, and folk medicine systems of South and Southeast Asia.

Peltophorum pterocarpum is endemic to tropical southeastern Asia and it belongs to the family Fabaceae. It is known as an ornamental tree. The morphology of the trees indicates bipinnate leaves which are 30-60 cm long. Leaves have 16-20 pinnae, each with 20-40 oval leaflets 8-25 mm long and 4-10 mm wide. Flowers in racemose inflorescence 2.5-4 cm bloom in enormous compound racemes up to 20 cm long. The fruit is a pod which is 5-10 cm long and 2.5 cm wide. It is crimson at first then turns black as it ripens. Fruit contains one to four seeds. After roughly four years, trees begin to bloom. (Jash *et al*.,2013)

Bark of this plant is used in treating skin infections such as Eczema, Ringworm and fungal infections, Scabies, Boils and ulcers (Mongalo, 2013). Leaves and bark of *Peltophorum africanum* and *Peltophorum pterocarpum* used to treat wounds, sores, and ulcers. Effectiveness of the treatment is related to the efficacy of bioactive compounds such as flavonoids, tannins, and phenolic acids, which have been shown to possess anti-inflammatory, antioxidant, and antimicrobial properties present in these plants. (Jash *et al*., 2014). According to Rinku *et al*.,(2021), the flowers of *Peltophorum pterocarpum* (Copperpod) are exhibiting astringent, anti-inflammatory, and soothing properties, used externally as lotions for sores, bruises, and eye problems, and also show as a sleep inducing property for insomnia. It also shows presence of bioactive compounds like flavonoids and phenolics which are acting as antioxidant, antimicrobial, and potentially anticancerous.

Materials and methods

1. Collection of Plant Material

Fresh, fully opened unused flowers of *Peltophorum pterocarpum* were collected during the peak flowering season (April-August). Only healthy petals free from infestation or physical damage were selected. Paper bags were used to transport the petals.

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How to cite this article:
Diwan, U. M., Agnihotri, S. V., Khade, S. K., & Khan, S. (2026). Evaluating medicinal properties of Peltophorum pterocarpum flower colour for its eco-friendly topical applications. Journal of Research and Development, 18(4(XI)), 92–95.
https://doi.org/10.5281/zenodo.21125169

Quick Response Code:
Website:
https://jrdrvb.org/
DOI:
10.5281/zenodo.21125169
OPEN ACCESS

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

2. Cleaning and Pre-Processing

The petals were thoroughly washed under running tap water and subsequently rinsed with distilled water to remove surface contaminants. Excess moisture was removed using blotting paper. The cleaned petals were then shade-dried at ambient temperature (28–32 °C) for 5–7 days to prevent degradation of thermolabile pigments.

3. Pulverization and Pigment Preservation

The shade-dried petals were manually fragmented and pulverized into a fine powder using a pre-chilled stainless-steel grinder to minimize heat generation and prevent pigment degradation. Grinding was carried out in intermittent pulses, and the powdered material was sieved through a 60-mesh sieve to ensure uniformity in particle size.

4. Formulation of Natural Color Powder

Pharmaceutical-grade cornstarch was incorporated as a natural binder and bulking agent in ratios ranging from 70:30 to 50:50 (petal powder:cornstarch). The mixture was homogenized using a mortar and pestle, followed by drying for 12–24 hours. The dried mass was then passed through a fine sieve to obtain a smooth, free-flowing powder.

5. Storage of Prepared Color

The final pigment powder was packed in airtight, opaque containers to prevent oxidation, moisture exposure, and photodegradation. The samples were stored at room temperature under dry conditions until further analysis.

6. Evaluation of Physical Parameters

Physical properties were assessed as follows:
- Color intensity under natural and artificial light
- Texture, smoothness, and flow characteristics
- Natural fragrance or odor development
- Uniformity of particle size via microscopic examination

7. Dermatological Safety Assessment

Volunteer-based patch tests were conducted on healthy individuals (n = 21). A small quantity of the pigment was applied to the inner forearm, and the test sites were observed at 30 minutes, 24 hours, and 48 hours for signs of redness, irritation, itching, or allergic reactions.

Qualitative Tests

1. **Foam test:** Saponins from the colour sample were detected with foam test. When natural saponins present in the sample react with water, it forms foam. The test was performed by adding **5** mL of distilled water in a small amount of organic colour. After vigorous shaking foam is formed in the test tube.
2. **Hager's Test:** A small quantity of aqueous form of organic colour was added in the test tube. And at the same tube Hager's reagent was added. Formation of a yellow crystalline precipitate indicates the presence of alkaloids.
3. **Molisch's Test :** Two mL of the organic colour solution was taken in a test tube, in that tube 2–3 drops of Molisch's reagent (1% α-naphthol in alcohol) was added. Careful addition of concentrated sulfuric acid (1–2 mL) was achieved. The interface was observed for ring formation. The appearance of a violet or purple ring indicates a positive result, confirming the presence of carbohydrates, whereas the absence of ring formation denotes a negative result.
4. **Volatile oil (Sudan III Red Test):**For the test, the suspected volatile oil extract was placed in a test tube, and a few drops of Sudan III solution prepared in alcohol were added. The mixture was gently shaken and observed for any color change. The appearance of an orange-red coloration in the upper oil layer indicated a positive result, confirming the presence of volatile oils, whereas the absence of any colored layer indicated a negative result.
5. **Fehling's test:** Reducing sugars were detected using Fehling's test. Freshly prepared Fehling's reagent was obtained by mixing equal volumes of Fehling's solutions A and B. Two milliliters of the test solution were mixed with 2 mL of the reagent and heated in a boiling water bath for several minutes. The formation of a brick-red precipitate confirmed the presence of reducing sugars, while the absence of precipitate with retention of the blue color indicated a negative result.

Results and discussion

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

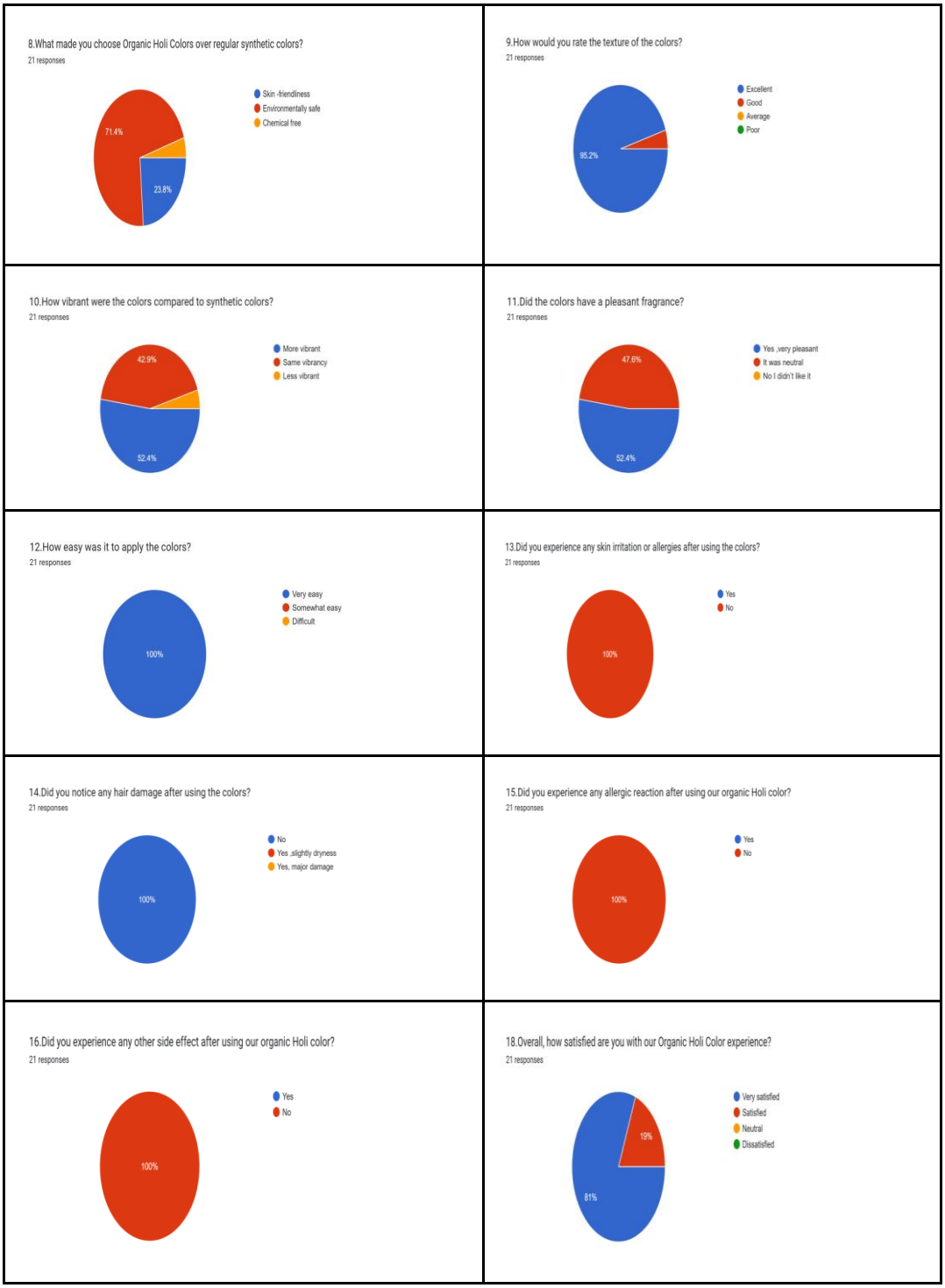

Table no. 1: Graphs of patch tests

1	Foam test	Saponins	Positive
2	Volatile oil test	Lipids & oil layer	Positive
3	Hager's test	Alkaloids	Positive
4	Fehling's test	Carbohydrates	Negative
5	Molisch's test	Sugar	Negative

Table no.2: Results of qualitative tests for saponins, volatile oil, alkaloids, carbohydrates and sugar

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Foam test

Saponins act as surfactants because of the presence of glycosides. (Góral I, Wojciechowski, 2020 and Martín RS, Briones 1999) . Saponins are natural compounds present in plants. They can be used as cleansers in shampoos; foaming agents, emulsifiers, natural preservatives, hair conditioners, skin penetration enhancers, anti-inflammatory and antioxidant agents (Osbourn *et al*., 2011 and Perkins *et al*., 1999). In the present study colours obtained from *Peltophotum* flowers exhibited the presence of saponins. This colour is safe for use as it shows natural cleansing properties.

Volatile oil test

Volatile oils are an essential component of cooking and perfumes and cosmetic products. (Ríos ,2016). The presence of volatile oil in cosmetic products gives benefits to the skin (Muyima, 2002). In present colour volatile oils are present, which will provide essential nutrients to the skin after applying.

Hager's test

Bania *et al*., (2024) reported the presence of alkaloids in the herbal lipsticks made from *Amaranthus gangeticus* leaves. Alkaloids are acting as an anti-bacterial agent. Similar results were reported in the present study.

Fehling's test

A negative Fehling's test (remains blue, no reddish-brown precipitate) in herbal products indicates the absence of free reducing sugars (such as glucose, fructose, lactose, maltose) or aldehydic compounds. As the amount of reducing sugar is non-traceable means the product which is made from the flowers will have the long shelf life.

Molisch's test

In some herbal formulations, high amounts of non-polar herbal actives, essential oils, or minerals can overpower the test, yielding weak or negative results if sugars are not present in high concentrations. In the present study the colour is made from the flower part which has a high amount of anthocyanin. There are very less chances of having carbohydrates.

Conclusion

From present study, it can be concluded that the organic color made from the flowers of copper pod trees has skin protective properties. It is safe to use externally on body parts. At the same time it is eco-friendly as it can be easily decomposed in the soil.

Acknowledgement

Authors are grateful to the Principal of the colleges for providing infrastructure and facilities. Authors are also thankful to the Head, Department of Botany for giving a platform for performing the experiments.

References

1. Bania, R., Bora N., Deka S., Tasrina, R. and Tahid, A. (2024). Formulation and evaluation of herbal lipstick using natural colour extract from Amaranthus gangeticus LINN leaf. *International Journal of Pharmaceutical Sciences and Research*, IJPSR, ; 15(11): 3251-3257.
2. Góral, I. and Wojciechowski K. (2020).Surface activity and foaming properties of saponin-rich plants extracts. *Adv Colloid Interface Sci*., 279:102145.
3. Jash, S. Gangopadhyay A., Sarkar A. and Gorai, D. (2013) Phytochemical investigation of the hexane extract of stem bark of *Peltophorum pterocarpum* (DC.) *Der Pharma Chemica*, 5(5): 49-53
4. Jash, S. K. , Singh, R. K. , Majhi, S., Sarkar, A. and Gorai, D.(2014). *Peltophorum pterocarpum:* Chemical and pharmacological aspects. *IJPSR*, 5(1): 26-36.
5. Martín, R.S. and Briones, R. (1999). Industrial uses and sustainable supply of Quillaja saponaria (Rosaceae) saponins. *Econ Bot*., 53(3):302-11.
6. Mongalo N. I. (2013): *Peltophorum africanum* Sond [Mosetlha]: A review of its ethnomedicinal uses, toxicology, phytochemistry and pharmacological activities. *Journal of Medicinal Plants Research.* 7(48): 3477-3483
7. Muyima N.Y.O., Zulu G., Bhengu T.and Popplewell D. (2002). The potential application of formulation. *Flavour Fragrance.Journal*, 17(4): 258–266.
8. Osbourn, A., Goss RJ, and Field, R. A. (2011). The saponins: polar isoprenoids with important and diverse biological activities. *Nat Prod Rep*. 28(7):1261-8.
9. Perkins, M.A., Osborne, R., Rana, F.R., Ghassemi, A. and Robinson M. K. (1999). Comparison of in vitro and in vivo human skin responses to consumer products and ingredients with a range of irritancy potential. *Toxicol Sci.*,48(2):218-29.
10. Rinku. R., Choudhary ,H. Chauhan ,Dalvi,T., Madkaikar, H. and Shah, N. (2021). *Peltophorum pterocarpum* – Its ethnobotanical knowledge, phytochemical studies, pharmacological aspects, and future prospects. *International Journal of Advance Research, Ideas and Innovations in Technology*, 7, (6) -7I6-1395
11. Ríos J. (2016). Essential Oils: What They Are and How the Terms Are Used and Defined. In: Preedy V.R. (ed.) Essential Oils in Food Preservation, Flavor and Safety. USA: some novel essential oils as natural cosmetic preservatives in an aqueous cream. Academic Press.

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Original Article

Evaluation of Water Quality of Godavari River at Kopargaon Taluka (MH)

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Manuscript ID:
JRD -2026-180417
ISSN: 2230-9578
Volume 18
Issue 4(XI)
Pp. 96-101
April - 2026
Submitted: 14 Mar. 2026
Revised: 29 Mar. 2026
Accepted: 05 Apr . 2026
Published:30 April2026

Abstract:

The Godavari River is the longest in Maharashtra. It has immense religious importance, as it is also called "Dakshin Ganga." The rapid growth in population, industrialization, and anthropogenic activities deteriorates water quality, and the River Godavari is no exception to this. With this in mind, an assessment was carried out to evaluate the water quality of the River Godavari at selected sites in Kopargaon Taluka. Ten sampling stations were selected to evaluate physicochemical parameters such as, ***Physical Parameters:*** *pH, temperature, Turbidity, Total Dissolved Solids, Total Hardness, Electrical Conductivity (EC)* ***Chemical Parameters:*** *Major Constituents -* ***cationic****- Calcium (Ca), Magnesium (Mg), Sodium (Na), Potassium (K) and* ***anionic****- Chloride (Cl), indicators like Dissolved Oxygen (DO), Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) were determine during May 2022 to April 23. The pH ranged from 7.02 to 9.23, indicating the alkalinity of the water. TDS, TH, Ca, Mg, Cl, CO_2, and BOD slightly increased from study sites 1 to 10 due to the addition of untreated sewage from the city, industrial effluents, and some amount of agricultural runoff, which contributed to the pollution of the river. The significant decrease in DO levels from study sites 1 to 10 is alarming for the flora and fauna of the Godavari River in the study area. The present data are a baseline study for further research as well as for policymakers.*

Keywords: *Godavari River, Physicochemical Analysis, Kopargaon Tehsil*

Introduction:

Since the development of civilisation, human beings have been situated along riverbanks and have potentially used rivers as a natural resource.(Chaplin, 2001; Westall et al., 2018) However, the development of industrilization, rapid growth in population, and increasing human greed have begun to deteriorate the water quality of these natural resources. (Dhekale, Nikam, Dadas, & Patil, 2019; Nath D.D. et al 2013**)** The Godavari River, one of the longest rivers in Maharashtra, is also suffering from the same issues.(Chavan et al., 2009; Kadam B. Vasant, et al, 2017) Anthropogenic activities, such as discharging untreated sewage and industrial effluents, were observed in the study area**.** Hence, the present study was undertaken to assess the water quality of the Godavari River at Kopargaon Tehsil. A handful of studies are available on the Godavari River over the last few decades.(Ghorade, 2013; Kumar Yadav & Yadav, 2019; Rajendra Shinde, 2025; Shinde N.G and Nagre S.S., 2015)Considerable studies are carried out at the origin of the Godavari River in Nashik**,**(Bhalla & Sekhon, n.d.; Bhalla & Waykar, 2013; Chaudhari, 2020; Kharake & Raut, 2021; Nayak, n.d.; Patil et al., 2020)

Study Area:

Kopargaon City is one of the developing Municipal Councils with 65,273 (according to the 2011 Census), located along the bank of the River Godavari (Latitude: 19.8833° N and Longitude: 74.4833° E). It has two sugar factories, a milk processing plant, and many small-scale industries in the MIDC area. Since the majority of the population depends on agriculture, most of the water is utilised for irrigation, industries, and domestic purposes. The main objective of this paper is to figure out improper human behaviour and how it impacts the quality of water in the study area.

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How to cite this article:
Hon, S. T., & Jagdale, S. P. (2026). Evaluation of Water Quality of Godavari River at Kopargaon Taluka (MH). Journal of Research and Development, 18(4(XI)), 96–101.
https://doi.org/10.5281/zenodo.21125399

Quick Response Code:
Website:
https://jrdrvb.org/
DOI:
10.5281/zenodo.21125399
OPEN ACCESS

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Author at sites

Site -4 Sewage entering the river

Site- 1 Agricultural runoff entering the river

Materials and Methods:

To assess the physical and chemical nature of the River Godavari in Kopargaon Tehsil, 10 sampling stations were selected based on the contamination caused by industries and anthropogenic activities. The samples were collected in the second week of every month in the study period from May 2022 to April 2023. Sterile plastic containers were used to collect surface water samples from a depth of approximately 10–12 cm. pH, temperature, EC, and TDS were detected at the site using a Hanna multi-parameter HL9814. For DO, BOD and COD, a separate 300 ml reagent bottle was used, and DO oxygen was fixed using the Winkler reagent at the site. Other parameters, such as TH, Ca, Mg, Na, Cl, K, BOD, COD, and DO, were estimated using standard methods described by APHA (1998) and Trivedy and Goel (1986).

Result and Discussion: The monthly variations in physicochemical properties of the collected water samples are reported in Table 1, and mean values are in Table 2.

Temperature: Water temperature plays an important role in biochemical reactions. There is a positive correlation between an increase in temperature and the speed of the reaction, and a negative correlation with the solubility of gases in water. (Shinde N.G and Nagre S.S 2013) During the study period, a minimum of 22.70 °C in December of the winter session and a maximum of 33.10 °C in May of the summer session were observed. It may be due to seasonal change and effluents from industries, accompanied by a low amount of water. Similarly, results were observed by Bhave and Borse (2001) in the Aner River water, Jalgaon, Maharashtra.

pH: It is the negative log of H^+ ion concentration. As the concentration of H+ ions increases, the solution becomes more acidic, which is an ill effect on the flora and fauna of that ecosystem. pH values ranged from **7.48 to 9.77**, with

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

the minimum value recorded in April and the maximum in July at Site 9. The observed values indicate slightly alkaline conditions, and most of the readings were within or near the permissible limits recommended by the World Health Organization. (2017)

Electric Conductivity: The range of conductivity in the study area was min160 µmhos/cm. in August and max. 423 µmhos/cm in April, as the river is swollen in the monsoon and becomes stagnant in the post-monsoon period. Such seasonal variations in conductivity are commonly observed in river systems (APHA, 2017; Hem, 1985).

Turbidity: It is a measure of the optical property of water. In the present study, turbidity goes on a gradual increase as we go downstream from site 1 to site 10. The Turbidity ranges from 113 to 388 NTU. It may be due to the addition of untreated sewage and industrial effluents in the post-monsoon and agricultural runoffs in the monsoon. Similar results were reported by Arya S and Gupta R, during the study of the river Ganga at Kanpur city. (Arya & Gupta, 2013)

Total Hardness: TH is the measure of dissolved Ca and Mg ions. In the present study min TH was observed on June 18, and max in May was 183 mg/l. The decrease in hardness may be due to an increase in the water column of river. Noor Alam et al 2009 support the result.

Calcium: It is one of the major contributors to water hardness and plays an important role in aquatic ecosystems. Boyd, C. E. (2015). During the study period, the maximum value was observed at 41.01 mg/l in April, and the minimum at 15.02 mg/l in July. A similar result is reported by,(Deshmukh & Sathe, 2014)

Magnesium: The max value of Mg was observed during the summer session, 18.20 mg/l at site 2 due to heavy contamination of sewage. Min 3.42 mg/l was observed during a rainy session due to increased water flow. Venkatasubramani, R., & Meenambal, T. (2007). Observed the same result during a study on subsurface water quality in Mettupalayam taluk of Coimbatore district, Tamil Nadu.

Sodium: It is an important alkali metal present in natural waters, and its concentration is influenced by both natural and anthropogenic sources (Singh et al., 2005; Sharma & Kansal, 2011). The max value of Na 20.9 mg/l was recorded at site 2 because of contaminated by sewage in December. And min value of 3.23mg/ l in July. The result is supported by Mohanta B.K et al (2000) and Ruttner, F. (1953)

Chloride: Chloride (Cl^-) is an important constituent of water, occurring naturally as well as through anthropogenic sources such as domestic sewage, detergents, and leaching from riverbank soils (Singh et al., 2010; Jain et al., 2010). The max value was observed at 20.79 mg/l in March, and min 3.18 mg/l in September. A parallel comment was made by Sharma et al. (2008)

Potassium: The concentration of potassium was max 19.6 mg/l in April at site 8 in the MIDC area and min 3.24 mg/l in July at site 1, which is upstream of the city. The fluctuation may be due to the addition of sewage and industrial effluents. Pravin M Nalawade and Archana B Bagul (2020) report similar results during a study of physicochemical conditions and plankton diversity of the Godavari River in Nashik. The observed potassium values were within acceptable limits, indicating a moderate influence of anthropogenic activities.

Dissolved Oxygen: It is a key indicator of water quality and is essential for the survival of aquatic organisms. During the study period max value of 14.27 mg/l was observed during the peak period of water flow of the river, i.e. at the end of the rainy season, in September. The min value was recorded as 3.1 mg/l. Jindal and Thakar (2009) detected the same outcome at Rewaiser Wetland District. Mandi (H.P.) Concentration of DO is directly proportional to the abundance of planktons, reported by Shashikant and Raina (1990)

Carbon Dioxide: The concentration of CO_2 ranges from 7.38 mg/l to 25.77 mg/l in the study period. This moderate fluctuation may be due to a heavy influx of untreated sewage and industrial effluents. Temperature is indirectly proportional to the solubility of gases, Wetzel, R.G. (2001)

Biological Oxygen Demand: It is an important pollution indicator. The range of BOD was 6.78 to 15.36 mg/l during the study period. The fluctuation is because of the organic load and stagnation of water in the summer season, which boosts the microbial activity and increases the BOD. (Sawyer et al., 2003; Chapman, 1996)

Chemical Oxygen Demand: It is an important parameter that indicates the amount of oxygen required to oxidize both organic and inorganic substances present in water. The record of COD during the study period ranges from 8.05 to 15.23 mg /l. It may be due to the presence of oxidizable organic and inorganic compounds in the river. (Singh and Rai, 2003).

Table-1: Range of physicochemical parameters at ten sites of the Godavari River during the study period.

Parameter	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10
Temp °C	20.1-33.5	19.2-24.1	22.4-29.3	21.2-30.5	20.1-31.6	20.3-30.3	22.1-32.7	21.2-31.7	22.7-33.1	20.8-32.2
pH	7.02-7.96	7.02-8.01	7.04-8.09	7.46-8.31	7.59-8.66	7.91-8.56	7.10-9.77	7.48-8.92	7.41-9.23	7.56-9.02
EC (µmhos/cm)	160-328	193-341	212-362	21299-378	240-390	273-423	281-362	286-373	224-378	256-378

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Turbidity (NTU)	173-321	169-344	144-318	142-382	192-388	196-375	124-381	118-374	120-386	113-365
TDS	109-265	130-279	139-285	190-281	201-282	206-285	213-290	213. 290	219-292	210-270
TH	18-163	21-174	26-178	22-172	26-176	22-180	21-175	20-182	21-179	19-183
Ca	15.02-39.30	15.10-38.02	18.12-41.10	15.80-39.04	16.23-38.12	15.24-41.01	17.04-39.21	16.12-40.93	15.24-41.12	15.11-40.19
Mg	4.02-13.10	3.52-17.19	4.22-18.52	4.09-16.43	3.42-17.40	4.32-16.23	4.23-17.42	3.59-16.72	3.49-17.92	4.52-16.72
Na	3.52-18.10	4.38-18.20	3.64-19.24	4.65-20.09	3.18-13.70	3.23-14.05	4.37-15.92	3.66-14.57	4.38-16.71	3.18-11.46
Cl	4.78-11.34	3.29-18.58	3.78-17.25	4.11-19.36	3.82-19.66	4.21-20.79	4.29-19.66	3.18-18.78	3.32-18.53	3.21.19.56
K	3.24-16.47	4.81-18.02	3.19-18.11	4.02-16.79	3.72-17.04	4.51-19.62	4.37-18.02	3.98-19.06	4.02-18.4	3.79-17.08
DO	6.10-14.18	4.9-13.17	4.8-13.23	3.15-12.36	3.27-12.02	3.21-13.82	3.01-14.38	3.51-14.26	3.72-14.27	3.38-14.11
CO_2	7.79-20.58	8.22-24.48	8.56-25.41	8.32-24.41	8.38-25.77	7.61-25.05	7.38-25.21	8.21-27.1	8.09-25.01	8.20-24.78
BOD	7.04-9.05	8.01-9.07	7.09-8.10	7.10-8.04	7.14-10.13	6.78-12.46	7.16-15.36	7.12-9.43	7.09-9.15	7.04-9.23
COD	8.05-10.14	8.12-10.12	8.06-10.05	8.14-10.07	8.16-10.23	8.11-10.03	8.05-10.08	8.12-14.48	8.19-15.23	8.02-14.23

Table 2: Mean value of physicochemical parameters

Parameter	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10
Temp	26.8	21.65	25.85	25.85	25.85	25.3	27.4	26.45	27.9	26.5
pH	7.58	7.65	8.15	7.88	8.12	8.12	8.43	8.2	8.32	8.38
EC (µmhos/cm)	244	267	287	298.5	315	384	290	329.5	301	317
Turbidity (mg/l)	247	256.5	231	265	290	285.5	253	246	253	239
TDS	187	204.5	212	235.5	241.5	245.5	251.5	251.5	255.5	240
TH	90.5	97.5	102	97	101	101	98	101	100	101
Ca	27.25	26.65	29.61	27.06	27.17	28.17	28.30	28.52	28.18	27.65
Mg	8.65	10.35	11.37	10.66	10.41	10.27	10.82	10.15	10.70	10.62
Na	10.81	11.29	11.44	12.77	8.44	8.86	9.83	9.11	10.54	7.32
Cl	8.06	10.93	10.51	11.73	11.74	12.5	11.97	10.98	10.92	11.38
K	9.85	11.50	10.65	10.49	10.56	12.06	11.19	11.52	11.21	10.43
DO	10.14	9.03	9.01	7.75	7.78	8.51	8.74	8.88	8.99	8.74
CO_2	14.18	16.35	16.58	16.36	17.07	16.33	16.29	17.65	16.55	16.49
BOD	8.04	8.54	7.59	7.57	8.63	9.62	11.26	8.27	8.12	8.13
COD	9.09	9.12	9.05	9.10	9.19	907	9.06	11.3	11.71	11.12

Conclusion:

The assessment of physicochemical parameters of the Godavari River across ten sampling sites shows that it is moderately affected by both natural processes and anthropogenic activities. The parameters like pH, TDS, and TH were

found within permissible limits according to the WHO. On the other hand, Turbidity, BOD, COD, and DO values fluctuate at sites 4, 5 and 7, which are affected by untreated sewage and industrial effluents, respectively.

In a nutshell, the study area comes under the category of considerable pollution status. Influx of untreated sewage and industrial effluents creates the localised environmental stress at sites 4,5, and 7. Proper management of sewage and continuous monitoring strategies are recommended to prevent further deterioration and to maintain the ecological balance of the study area.

Acknowledgement: The author is thankful to the principal and HOD of Dapoli Urban Bank Senior Science College, Dapoli, for providing the necessary facility and continuous support to carry out the research work.

References:

1. Alam, M. N., Saw, K. K., & Mishra, S. K. (2009). A preliminary study of physico-chemical characteristics of a perennial fresh water pond. Flora and Fauna 15(1), 77-82.
A. P. H. A. (1985). Standard methods for the examination of water and wastewater.16th Edn. American Public Health Asociation, Washington. pp- 1268.
2. APHA. (2017). *Standard methods for the examination of water and wastewater* (23rd ed.). American Public Health Association.
3. Arya S, Gupta R (2013). Water Quality Evaluation of Ganga River from Up to Downstream Area at Kanpur City *Journal of Chemistry and Chemical Sciences 3(2) 54-63.*
4. Bhalla, R., & Sekhon, B. (n.d.). *Environment Conservation Journal Seasonal physico-chemical characteristics assessment and primary production in the planktonic community of Godavari River water, Nashik (Maharashtra).*
5. Bhalla, R., & Waykar, B. B. (2013). *Monitoring of Water Quality and Pollution Status of Godavari River in and Around Nashik Region, Maharashtra Nature Environment and Pollution Technology An International Quarterly Scientific Journal*. *12*, 125–129. www.neptjournal.com
6. Bhave S. K. and Borse P. V. (2001). Seasonal variation in temperature, dissolved and salinity and their influence on planktons in Aner river water, oxygen, pH Jalgaon, Maharashtra. Poll Res. 20(1): 79-82.
7. Boyd, C. E. (2015). Water Pollution. In *Water Quality: An Introduction* (pp. 313-338). Cham: Springer International Publishing.
8. Chaplin, M. F. (2001). Water: its importance to life. *Biochemistry and Molecular Biology Education*, *29*(2), 54–59. https://doi.org/10.1111/j.1539-3429.2001.tb00070.x
9. Chapman, D. V. (1996). *Water quality assessments: a guide to the use of biota, sediments and water in environmental monitoring* (No. 17872). E & FN Spon.
10. Chaudhari, K. N. (2020). *International journal of researches in biosciences, agriculture and technology study of physicochemical parameters of godavari river-bramhagiri nashik maharashtra*. (Special-15), 11–13. www.ijrbat.in
11. Chavan, A. D., Sharma, M. P., & Bhargava, R. (2009). Water Quality Assessment of the Godavari River. *Hydro Nepal*, (5), 31–34.
12. Deshmukh & Sathe, (2014).physico-chemical characteristic of pravara river, maharastra Journal of Aquatic Biology and Fisheries (2) 2014. 101 to 105
13. Dhekale, P., Nikam, P., Dadas, S., & Patil, C. (2019). *Water Quality and Sediment Analysis of Selected Rivers at Satara District, Maharashtra*. (6), 239–243.
14. Ghorade, P. S. S. (2013). INDIAN JOURNAL OF APPLIED RESEARCH X 149 Assessment of Physicochemical Characteristics of Godavari River Water at Trimbakeshwar & Kopargaon, Maharashtra (India). *INDIAN JOURNAL OF APPLIED RESEARCH*, *3*(3), 149–152.
15. Hem, J.D., 1985, Study and interpretation of the chemical characteristics of natural water (3rd ed.): U.S. Geological Survey Water Supply Paper 2254, https://doi.org/10.3133/wsp2254.
16. Jain, C. K., Bandyopadhyay, A., & Bhadra, A. (2010). Assessment of ground water quality for drinking purpose, District Nainital, Uttarakhand, India. *Environmental monitoring and assessment*, *166*(1), 663-676.
17. Jindal, R, R Thakur. Study of the physic-chemical variation at the Rewaire wetland dist.Mandi (H.P.) Ind.Jour.Aqua.Biol. 2009; 24:50-56.
18. Kadam B. Vasant, N. M. P. B. B. A. (2017). 75-82ArchanaBagulAA45. *Indian J. Environmental Protection*, *1*(38), 75–82.
19. Kharake, A. C., & Raut, V. S. (2021). An assessment of water quality index of Godavari river water in Nashik city, Maharashtra. *Applied Water Science*, *11*(6). https://doi.org/10.1007/s13201-021-01432-2
20. Kumar Yadav, R., & Yadav, B. (2019). Study of Water Quality Status of Godavari River at Kopargaon Taluka Dist. Ahmednagar (M.S.). *EMERGING TRENDS IN BIODIVERSITY CONSERVATION*, 1–3. http://ijrar.com/
21. Mohanta B.K. and Patra A.K., Studies on the Water Quality index of river Sanamachhakandana at Keonjhar Garh, Orrisa, Poll. Res. 19(3), 377-385, (2000)
22. Nayak, J. G. (n.d.). Assessment of water quality of godavari river at nashik, maharashtra, india. *International Journal of Civil Engineering and Technology*, *7*(1), 83–92. Retrieved

http://www.iaeme.com/IJCIET/index.asp83http://www.iaeme.com/IJCIET/issues.asp?JType=IJCIET&VType=7&IType=1JournalImpactFactor

23. Patil, S. B., Deshmukh, D. R., Shinde, S. U., & Nikam, M. D. (2020). OUR HERITAGE Study on Physico-Chemical parameters of Godavari, Darna and Kadva Rivers, Nashik, (Maharashtra) India. *Our Heritage*, *67*(Special issue-11), 367.
24. Pravin M Nalawade and Archana B Bagul (2020) Physico-chemical conditions and plankton diversity of Godavari River in Nashik City area of Maharashtra: A comparative assessment, International Journal of Ecology and Environmental Sciences,4 (2), 373-379.
25. Rajendra Shinde, K. (2025). *Water Quality Status of Godavari River at Chal Nali in Kopargaon Tehsil*.
26. Ruttner, F., Fundamental of Limnology, Univ. of Toranto Press, Toranto (1953).
27. Sawyer, C. N., McCarty, P. L., & Parkin, G. F. (2003). *Chemistry for environmental engineering and science* (Vol. 5, p. 587590). New York: McGraw-Hill.
28. Shinde N.G and Nagre S.S. (2015). *IJSR-INTERNATIONAL JOURNAL OF SCIENTIFIC RESEARCH Evaluation of Physicochemical Parameters of Godavari River from Kopargaon Tahasil,Dist-Ahmednagar,India.4*(9). http://www.tvdsb.ca/uploads/ScienceProbeware/totalwaterhardness.pdf
29. Sharma, D., & Kansal, A. (2011). Water quality analysis of River Yamuna using water quality index in the national capital territory, India (2000–2009). *Applied water science*, *1*(3), 147-157.
30. Sharma KK., Nithasha Sahney, Sarbjeet Kaur. Physico-chemical variations in the water bodies of Rewa. J.Aqua Biol. 2008; 22(1):105-109.
31. Shashikant, T., & Raina, A. (1990). Sewage disposal and treatment in Jammu. some reflections. *Proc. Natl. Sem. on Rec. Adv. in Hydrabad*, 134.
32. Singh, S. K. and Rai, J. P. N. (2003). Pollution studies on river Ganga in Allahabad district. Poll. Res. 22 (4): 469-472.
33. Singh, M. R., Gupta, A., & Beeteswari, K. H. (2010). Physico-chemical properties of water samples from Manipur River system, India. *Journal of Applied Sciences and Environmental Management*, 14(4), 85–89.
34. Singh, K. P., Malik, A., & Sinha, S. (2005). Water quality assessment and apportionment of pollution sources of Gomti river (India) using multivariate statistical techniques—a case study. *Analytica chimica acta*, *538*(1-2), 355-374.
35. Trivedy, R. K. and Goel, P. K. (1986). Chemical and biological Methods for water pollution studies. Environmental Publications, Karad (India). pp. 1-211.
36. Venkatasubramani, R., & Meenambal, T. (2007). Study on subsurface water quality in Mettupalayam taluk of Coimbatore district, Tamil Nadu. Nature, Environment and Pollution Technology, 6(2), 307-310.
37. Westall, F., Brack, · André, Blanc, M., Morbidelli, A., Alibert, Y., Elkins-Tanton, L., Estrada, P., Hamano, K., Lammer, H., Raymond, S., Schönbächler, M., Westall, F., & Brack, A. (2018). The Importance of Water for Life The Delivery of Water to Protoplanets, Planets and Satellites Edited. *Space Sci Rev*, *214*, 50. https://doi.org/10.1007/s11214-018-0476-7
38. Wetzel, R. G. (2001). Limnology: lake and river ecosystems. Gulf Professional Publishing.
39. World Health Organization. (2017). *Guidelines for drinking-water quality* (4th ed.). WHO Press.

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Original Article

Extended Range of *Entada rheedei* Spreng. (Fabaceae) in Talasari Taluka, Palghar District, Maharashtra, India.

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Manuscript ID:
JRD -2026-180418
ISSN: 2230-9578
Volume 18
Issue 4(XI)
Pp. 102-104
April - 2026
Submitted: 14 Mar. 2026
Revised: 29 Mar. 2026
Accepted: 05 Apr . 2026
Published:30 April2026

Abstract

The present study found an extended known distributional record of Entada rheedei spreng. from Talasari taluka of Palghar district, Maharashtra, India. The paper provides updated taxonomic information including relevant citation, detailed description, flowering and fruiting period, distribution, notes and colour photographs are provided for easy identification of the species in the field.

Keywords- *Entada Rheedei, Extended, India, Maharashtra, Palghar district, Talasari Taluka.*

Introduction

As per earlier reports, *Entada rheedei* Spreng. is a woody climbing shrub that grows naturally in Africa, Tropical Asia, Australia and part of the Pacific Island (Cooke 1958; Hooker 1878; Sanjappa 1991; Sanjappa et al. 2024). In India, the species occurs mainly in the subtropical evergreen forests of Western and Eastern Ghats and is considered an endangered liana, with earlier records from Kolhapur district, Maharashtra (Kulkarni 1988; Kothari & Moorthy 1993; Yadav & Sardesai 2002; Deokare et al. 2017).

The genus *Entada* belongs to family Fabaceae and it comprises of about 30 species including trees, shrubs, and tropical lianas. Approximately 21 species are reported from Africa, six from Asia, two from the American tropics, and one with a pan-tropical distribution (Sanjappa 1991; Sanjappa et al. 2004). In India, the genus *Entada* is represented by four species (Singh & Karthikeyan 2000). *Entada rheedei* is widely known by common names such as African Dream Herb or Snuff Box Sea Bean, and as the Cacoon Vine, and is locally known as Kayari and Garambi, Garud vel in Marathi (Cook 1958; Ghani 1998; Jog 2009).

Material and Methods

A detailed field survey was carried out during June 2023 – February 2026 in the forested area of the Talasari Taluka of Palghar District, Maharashtra, to document the floristic diversity of the Talasari Taluka. It lies between 20.123656o North latitude and 72.916758o East longitudes. Field observations noted the phenology and associated plant species for better understanding of collected species. The specimens were collected from Talasari (Karajgaon-Barhot caves (Barad Dongar), and identified using standard taxonomic keys, and regional floras. After critically examining the species with the help of various literature and experts, it has been concluded that these specimens belong to Entada rheedei Spreng. The vaucher specimens were deposited in the herbarium of Department of Botany, GESs, N. B. Mehta (V.) Science College Bordi.

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How to cite this article:
Beej, N., & Kotiwar, O. (2026). Extended Range of Entada rheedei Spreng. (Fabaceae) in Talasari Taluka, Palghar District, Maharashtra, India. Journal of Research and Development, 18(4(XI)), 102–104. https://doi.org/10.5281/zenodo.21125659

Quick Response Code:
Website:
https://jrdrvb.org/
DOI:
10.5281/zenodo.21125659

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

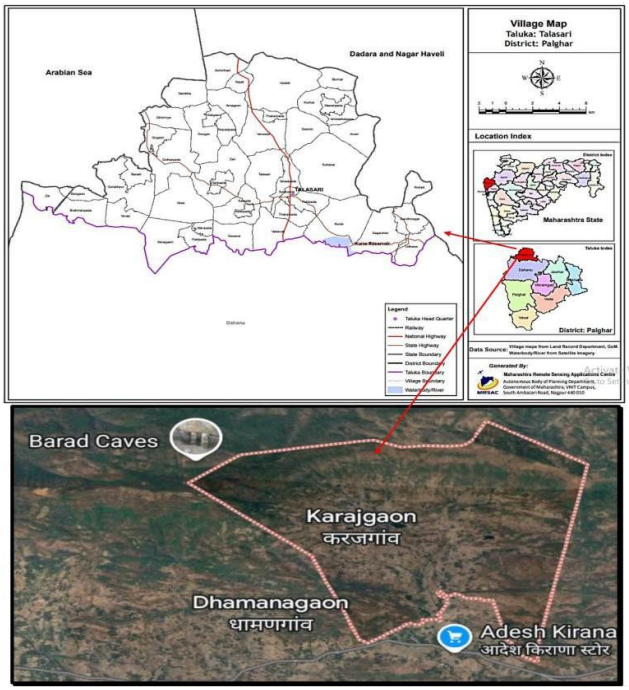

Fig.1. Location Map of Study area

Taxonomic Treatment

Entada rheedei Spreng. Syst. Veg. 2: 325. 1825; Sanj. Legumes of India 66. 1991. Londhe in Singh et al. Fl. Maharashtra St. Dicot. 1: 819. 2000. *E. pusaetha* DC., Mem. Legum. 12. 1825 and Prodr. 2: 425. 1825. *Entada scandens* auct. non Benth., 1841; Baker in Hook.f. Fl. Brit. India 2: 287. 1878; Cooke, Fl. Pres. Bombay 1: 465. 1958 (Repr.). Kulkarni Fl. of Sindhudurg 3:149. 1988. Kothari & Moorthy Fl. Raigad district. 3:140. 1993. Yadav & Sardesai, Fl. Kolhapur Dist.: 145. 2002. Deokar et al. WJPR 6:17. 2017.

Gigantic woody Liana, up to 30-60 m long, c. 50 -70 cm diameter at base. Leaves bipinnate, leaflets reduce to tendril, pinnae 2 pairs, leaflets 4 pairs, 2.5–5.0 x 2.5 cm, stalked, ovate – obovate, apex retuse, base subacute - cuneate. Flowers polygamous, corolla cream to yellow in pendulous ca. 20 cm long axillary spikes. Pods huge, slightly curved, woody, 80 cm long ca. 8 cm broad, segmented, the sutures very thick intended between the seeds. Seeds 7-15 per pod, hard, shining brown, orbicular or orbicular–oblong, 4–6 cm across, compressed.

Flowering and Fruiting: March – May

Habitat and Ecology: Frequent at higher altitudes slopes and along streams in semi evergreen forests, climbing over tall trees.

Distribution- Africa, tropical Asia, Australia, Pacific Island, Sri Lanka, Bangladesh, India.

India- Western Ghats (Karnataka, Kerla, Tamil Nadu), Eastern Ghats (Andhra Pradesh), Andaman Island, Assam, Sikkim, Bihar, Orissa (Brink, and Achigan- Dako. 2012) (Maharashtra: Few. Bombay, Kolhapur, Pune, Raigad, Ratnagiri, Sindhudurg, Satara, Thane; Palghar district (Talasari taluka).

Specimens examined: INDIA, Maharashtra: Palghar District, Talasari Taluka. 14.9.2025, Beej 101 (N.B. Mehta Science College Bordi)

Notes: The present collection of *Entada rheedei* Spreng. in Talasari extends the known distributional range of this endangered liana within Maharashtra state. *Entada rheedei* is a gigantic woody climber found in moist deciduous to semi-evergreen forests. Climbing and scrambling through the canopy using other plants for support, large bipinnate leaves, large woody pods. Huge shining seeds.

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Fig. 2. Entada rheedei Spreng. A. Habit, B. Stem, C. Leaf, D. Inflorescence (Spike), E. Pods, F. Seeds

Acknowledgement

The authors are grateful to the Principal, GESs, N. B. Mehta Science College Bordi. Dist. Palghar, for providing necessary facilities support during the course of this study.

References

1. Cooke, T. (1958). *The Flora of the Presidency of Bombay*, Vol. 1. (Repr. ed.). Botanical Survey of India, Calcutta, pp. 465.
2. Deokar R.R., Mane S. R., Kamble S. R., Patil S. R. (2017). A new locality record for an endangered plant species *Entada rheedei* Spreng. (Mimosaceae) in Sangali District, Maharashtra. *World Journal of Pharmaceutical* Research. 6: 17. 405-409, 2277– 7105.
3. Ghani A. (1998*). Medicinal Plants of Bangladesh Chemical Constituents and Uses*. Asiatic Society of Bangladesh, 1st Edition, 1998; 221.
4. Hooker, J.D. (1878). *The Flora of British India*, Vol. 2. L. Reeve & Co., London, pp. 287.
5. Jog Suneeti Sahyadris (2009)– *Flora and Ethnobotany*, William L. Brown Fellowship Report, 28.
6. Kothari, M.J. & Moorthy, S. (1993). *Flora of Raigad District*, Vol. 3. Botanical Survey of India, Pune, pp. 140.
7. Kulkarni, B.G. (1988). *Flora of Sindhudurg District*, Vol. 3. Government of Maharashtra, pp. 149.
8. Sai Vishnu Priya K and Srinivasa Rao J.V. (2008). Exploration of Tribal Knowledge of *Enatada pursaetha* DC- An endangered Medicinal legume in Eastern Ghat. Ethnobotanical Leaflets; 12: 36-43.
9. Sanjappa, M. (1991). *Legumes of India*. Bishen Singh Mahendra Pal Singh, Dehradun, pp. 66.
10. Sanjappa, M., Pusalkar, P.K. & Mao, A.A. (eds.) (2024). *Flora of India* 6: 1-556. Botanical Survey of India.
11. Shimpale, V.B. & Yadav, S.R. (2009). New records to the flora of Great Nicobar Island. *Journal of Economic and Taxonomic Botany* 33: 430-433.
12. Singh N.P. and Karthikeyan S., (2000). *Flora of Maharashtra State. Dicotyledones*- vol-I (Ranunculaceae-Rhizophoraceae) B.S.I., Calcutta, 1-898.
13. Yadav, S. R. & Sardesai, M. M. (2002). *Flora of Kolhapur District.* Shivaji University, Kolhapur, Maharashtra. 10(12): 182.

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Original Article

Face painting with *Butea monosperma*: An eco-sustainable alternative to synthetic colourants

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Manuscript ID:
JRD -2026-180419
ISSN: 2230-9578
Volume 18
Issue 4(XI)
Pp. 105-113
April - 2026
Submitted: 14 Mar. 2026
Revised: 29 Mar. 2026
Accepted: 05 Apr . 2026
Published:30 April2026

Abstract
The study aimed to prepare a dry color using Palash petals as the principal pigment source, along with natural binders and stabilizers. Synthetic colors frequently contain toxic chemicals, posing dermatological and environmental hazards. Therefore, there is an urgent need to develop natural, biodegradable alternatives. The preparation process was designed following safe, non-hazardous laboratory practices, ensuring that no synthetic additives, heavy metals, or harmful solvents were used at any stage. Mild, food-grade processing agents were employed to maintain user safety and prevent skin irritation. Considering the emerging trend of face painting in youths an eco and skin friendly colour has been made with these flowers. Physico-chemical testing of flower color showed the presence of alkaloids, saponins, volatile oils and neutral pH, appropriate ash value. Absence of carbohydrates was also noticed. Presence of these chemical contents is a positive indicator of skin caring nature of the colour. At the same time, absence of carbohydrates in the colour showed microbial resistance. The neutral pH of the colour exhibits skin caring nature. Patch tests of colour displayed the skin friendly quality. Results of the present investigation indicate that this is a first successful attempt of considering Butea monosperma flower colour for face painting as a safe alternative to artificial colours.
Key words: *Butea Monosperma, Eco-Friendly Colour, Physico- Chemical Properties And Skin Care*

Introduction

Butea monosperma (Lam.) Taub., a deciduous tree belonging to the family Fabaceae, is recognized for its significant medicinal, ecological, and cultural importance. Commonly known as Palash or the "Flame of the Forest," the species typically reaches 10–15 meters in height and is distinguished by its bright orange-red inflorescences, which prominently characterize the dry deciduous forests of India (Wanjari et al., 2016). Due to its striking floral display and cultural symbolism, *B. monosperma* has historically been integrated into several traditional Indian practices, particularly the Holi festival. Medicinally, the plant has been well documented in Ayurveda, Unani, and folk healing systems, where the flowers, seeds, and bark are employed in the treatment of diarrhea, liver disorders, skin diseases, and wound healing (Pawar et al., 2019; Wanjari et al., 2016). These therapeutic properties are attributed to its diverse phytoconstituents, including flavonoids, alkaloids, steroids, and tannins compounds responsible for antioxidative, antimicrobial, anti-inflammatory, and hepatoprotective activities (Ahire et al., 2020; Yadav et al., 2020). Modern pharmacognostic research continues to validate and expand upon these traditional claims, highlighting the plant's potential as a source of bioactive compounds for natural formulations. In contemporary practice, the natural use of Palash flowers during Holi has been largely replaced by inexpensive, industrially manufactured synthetic colors.

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How to cite this article:
Agnihotri, S. V., Diwan, U., & Bhor, S. (2026). Face painting with Butea monosperma: An eco-sustainable alternative to synthetic colourants. Journal of Research and Development, 18(4(XI)), 105–113. https://doi.org/10.5281/zenodo.21125801

Quick Response Code:
Website:
https://jrdrvb.org/
DOI:
10.5281/zenodo.21125801
OPEN ACCESS

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

These commercial pigments frequently contain hazardous components such as lead oxide, chromium salts, malachite green, rhodamine-B, and other industrial dyes that have been associated with dermatological irritation, ocular damage, respiratory distress, allergic reactions, and ecological toxicity (Ahire et al., 2020). The widespread environmental impact of these chemicals includes soil degradation, contamination of water bodies, harmful effects on aquatic organisms, and long-term bioaccumulation in ecosystems.

The shift toward such chemically intensive products contradicts traditional eco-friendly practices and presents an urgent need to promote safer, sustainable alternatives. As public health awareness grows, researchers and policymakers increasingly advocate for the replacement of toxic dyes with natural plant-based pigments that pose fewer biological and environmental risks.

Butea monosperma flowers naturally contain butrin, coreopsin, and sulphurein, which contribute to their deep orange-red coloration and possess inherent medicinal benefits (Ahire et al., 2020; Yadav et al., 2020). These natural pigments are biodegradable, non-toxic, and skin-friendly, making them suitable candidates for developing safe natural Holi colors. Unlike synthetic dyes, Palash-derived pigments do not contaminate ecosystems and degrade rapidly without leaving chemical residues.

Traditional knowledge highlights that Holi played historically with Palash flowers was both culturally meaningful and environmentally benign (Pawar et al., 2019). Reintroducing these practices offers an opportunity to revive sustainable cultural traditions while reducing dependence on harmful chemicals.

The present study aims to scientifically evaluate the feasibility of using *Butea monosperma* flowers as an eco-friendly, non-toxic pigment source for face painting. By assessing phytochemical composition, pigment extraction methods, stability, safety parameters, and environmental impact, this study seeks to integrate ethnobotanical heritage with modern sustainable practices (Yadav et al., 2020). Promoting Palash-based natural colors supports public health, preserves cultural authenticity, and contributes to broader environmental conservation goals.

Materials and Methods

1. Collection of Plant Material

Fresh, fully opened unused flowers of Butea monosperma were collected during the peak flowering season (February–April). Only healthy petals free from infestation or physical damage were selected. The petals were transported in clean paper bags to prevent moisture accumulation.

2. Cleaning and Pre-Processing

The petals were washed thoroughly under running tap water and then rinsed with distilled water. Excess water was absorbed with blotting paper. The petals were shade-dried for 5–7 days at ambient temperature (28–32°C) to protect thermolabile pigments from degradation.

3. Pulverization and Pigment Preservation

Dried petals were coarsely broken and ground into a fine powder using a chilled stainless-steel grinder to prevent heat-induced pigment loss. Grinding was done in short pulses, and the powder was sieved through a 60-mesh sieve to ensure uniform particle size.

4. Formulation of Natural Color Powder

Pharmaceutical-grade cornstarch was added as a natural binder and bulking agent in ratios of 70:30 to 50:50 (petal powder:cornstarch). The mixture was homogenized using a mortar and pestle. It was then dried for 12–24 hours and passed again through a fine sieve to obtain a smooth, free-flowing powder.

Storage of Prepared Color

The final pigment powder was packed in airtight, opaque containers to prevent oxidation, moisture exposure, and photodegradation. Stored at room temperature in dry conditions until testing.

5. Evaluation of Physical Parameters

Physical properties were assessed as follows:

- Color intensity under natural and artificial light
- Texture, smoothness, and flow characteristics
- Natural fragrance or odor development
- Uniformity of particle size via microscopic examination

6. Dermatological Safety Assessment

Volunteer-based patch tests were conducted on healthy individuals (n = 10–20). A small quantity of pigment was applied to the inner forearm and monitored at 30 minutes, 24 hours, and 48 hours for redness, irritation, itching, or allergic reactions.

Chemical tests

1. **Foam test:** The foam test was performed to detect the presence of saponins in the color samples. This test is based on the principle that saponins, which are naturally occurring glycosides with surface-active properties,

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produce a stable and persistent foam when shaken with water. A small quantity of the organic color sample was placed in a test tube, followed by the addition of 5 mL of distilled water. The mixture was shaken vigorously for two minutes and then allowed to stand for observation.

2. **Hager's Test:** A small portion of the sample extract, either aqueous or alcoholic, was placed in a test tube, and a few drops of Hager's reagent were added. The sample was then observed for the formation of a yellow crystalline precipitate, which is indicative of the presence of alkaloids, whereas the absence of precipitate suggests that alkaloids are not present.
3. **Molisch's Test :** In this procedure, 2 mL of the test solution was taken in a test tube, followed by the addition of 2–3 drops of Molisch's reagent (1% α-naphthol in alcohol). Concentrated sulfuric acid (1–2 mL) was carefully added along the inner wall of the test tube without mixing the layers, and the interface was observed for ring formation. The appearance of a violet or purple ring indicates a positive result, confirming the presence of carbohydrates, whereas the absence of ring formation denotes a negative result.
4. **Volatile oil (Sudan III Red Test):**For the test, the suspected volatile oil extract was placed in a test tube, and a few drops of Sudan III solution prepared in alcohol were added. The mixture was gently shaken and observed for any color change. The appearance of an orange-red coloration in the upper oil layer indicates a positive result, signifying the presence of volatile oils, whereas the absence of any colored layer suggests a negative result.
5. **Fehling's test:** For the analysis, equal volumes of Fehling's solutions A and B were mixed to prepare freshly active Fehling's reagent. A total of 2 mL of the test solution was taken in a test tube, followed by the addition of 2 mL of the reagent. The mixture was heated in a boiling water bath for several minutes and observed for precipitate formation. The appearance of a brick-red precipitate indicates a positive test, confirming the presence of reducing sugars, while the persistence of the blue solution without precipitate formation represents a negative result.

6. **Ash value :** In this study, 1 g of the ground, air-dried sample was placed in a pre-weighed tarred silica crucible and incinerated in a muffle furnace at a temperature not exceeding 250°C until the residue turned white, indicating the complete absence of carbon. The carbon-free ash was cooled in a desiccator, weighed, and the percentage of total ash was calculated based on the weight of the air-dried material.

Results and Discussion

Extensive phytochemical investigations have revealed that *Butea monosperma* contains a wide spectrum of bioactive compounds distributed across its flowers, seeds, bark, and gum. The plant is particularly rich in flavonoids, including butrin, isobutrin, palasitrin, and sulfurein, which are largely responsible for its characteristic orange-red pigmentation and potent antioxidant activity. These core flavonoids play a significant role in stabilizing reactive oxygen species (ROS) and exert multiple therapeutic effects.

In addition to flavonoids, the plant contains tannins, steroids, glycosides, saponins, and alkaloids, each contributing to its diverse pharmacological properties. The seeds of Butea monosperma are especially rich in fixed oils and alkaloids such as palasonin, known for its strong anthelmintic activity and its traditional use in treating intestinal worm infestations. The bark contains a high concentration of tannins and gum resins, which have been traditionally used for wound healing, diarrhea, and other gastrointestinal disorders due to their astringent and antimicrobial effects.

Traditional and Ethnobotanical Uses: In traditional medicine, *Butea monosperma* is used for treating ulcers, wounds, skin diseases, diarrhea, and eye disorders. Ayurvedic and Unani systems of medicine prescribe its extracts for their anti-diarrheal, anti-hemorrhoidal, and rejuvenating properties. The flowers are used as a diuretic and aphrodisiac, while the gum (Butea gum) is used in treating wounds and urinary disorders. The bark decoction is used for gastrointestinal disturbances, while the leaves are applied externally for skin infections and burns. Additionally, the plant has been used as a natural dye in textiles and religious practices.

The following patch tests and laboratory examinations were carried out, and the results obtained are presented below.

25 responses across the genders were considered for the present patch test

1. How important is it for you to use Eco friendly color?

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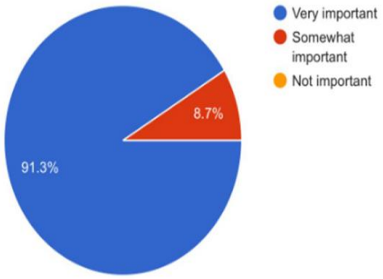
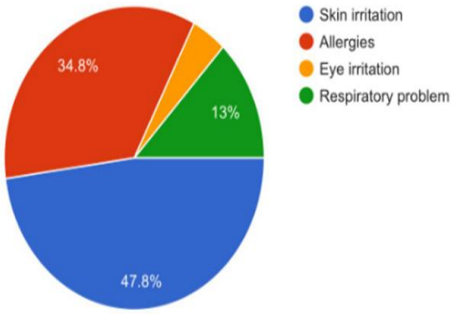
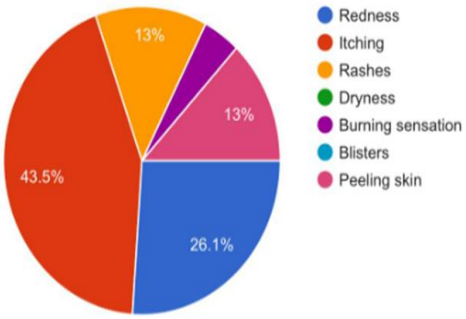


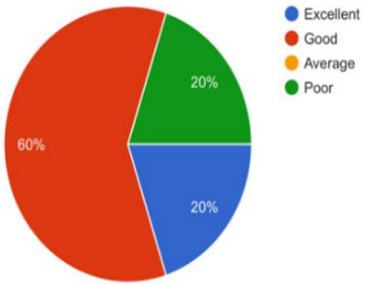
2. What are the potential health Risk associated with using synthetic color ?



3. If yes, what specific skin issue did you encounter ?



4. How would you rate the texture of the color ?



5. How vibrant was the color compared to synthetic colors ?

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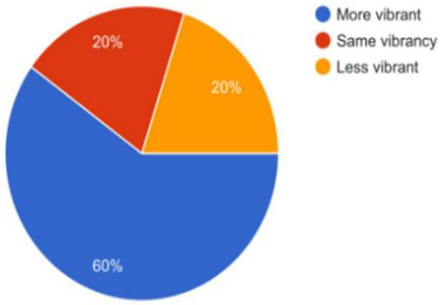
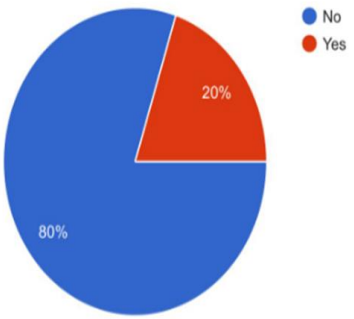
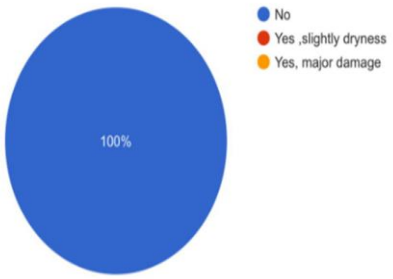


6. How easy was it to apply the color ?

7. Did you experience any skin irritation or allergies after using the color **?**



8. Did you notice any skin hair damage after using the color ?



9. Did you experience any allergic reaction after using our organic color?

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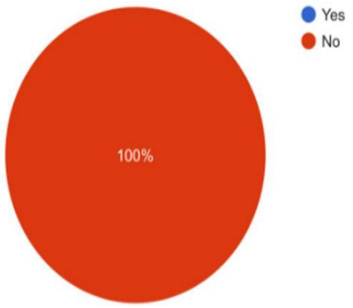
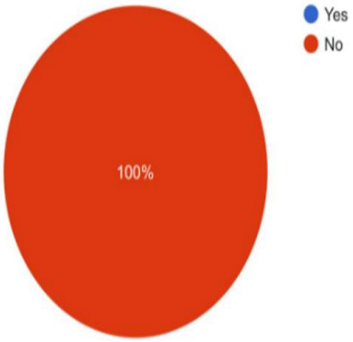
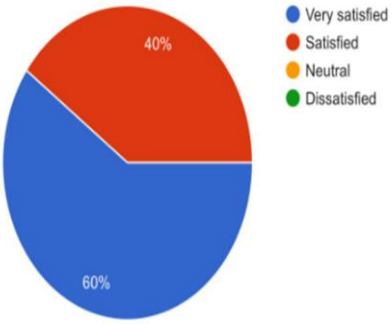


10. Did you experience any other side effects after using our organic color ?



11. Overall, how satisfied are you with our organic color experience ?



For the dermatological safety assessment, a total of 25 volunteer responses across genders were considered for the present patch test. The participants included both male and female individuals from the age group of 20–45 years, ensuring a balanced representation of different skin types. The evaluation followed standard dermatological patch-testing procedures, wherein a small quantity of the prepared Palash color was applied to the inner forearm and observed over 48 hours for any visible signs of irritation, erythema, itching, or allergic reactions. Patch testing on mixed gender groups helps to better understand potential variability in skin responses, as differences in skin physiology, hormonal status, and sensitivity between males and females may influence reaction outcomes (Rabasco-Alcalá et al., 2021; Lachapelle et al., 2013). The absence of adverse reactions among all 25 volunteers strongly supports the skin-friendly, non-irritant nature of the formulated Palash color. The use of a gender-inclusive sample also aligns with recommended guidelines for cosmetic and herbal safety assessment, which emphasize diverse participation to ensure generalizable conclusions for topical product safety (Basketter et al., 2015).

Laboratory Tests:

Foam test: According to (Table no.1) formation of a stable foam with a minimum height of 1 cm persisting for approximately 10 minutes indicates the presence of saponins, while the absence of foam or rapid disappearance

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suggests their absence. The foam height recorded for the organic color sample was 0.6 cm, whereas the artificial color sample exhibited 1.1 cm of foam stability. Based on the observations, the results confirm the presence of saponins in the organic color sample.

Hager's Test: The alkaloid test was conducted (Table no. 1) using Hager's reagent to determine the presence of alkaloids in the organic color sample. This qualitative test is widely used for the detection of alkaloids in plant extracts, drug formulations, and other organic samples. In the present analysis, the organic color sample produced a yellow crystalline precipitate, confirming the presence of alkaloids in the sample.

Molisch's test: The Molisch's test was employed (Table no.1) to detect the presence of carbohydrates in the sample based on the dehydration of carbohydrate molecules under acidic conditions. When treated with concentrated sulfuric acid (H_2SO_4), carbohydrates undergo dehydration to form furfural from pentoses or hydroxymethylfurfural from hexoses. These reactive intermediates subsequently condense with α-naphthol present in Molisch's reagent to produce a characteristic purple or violet ring at the interface of the two liquid layers. In the present study, no violet or purple ring was observed at the interface, indicating the absence of carbohydrates in the sample.

Volatile oil (Sudan III Red Test): The Sudan III test was carried out (Table no.1) to determine the presence of volatile oils or fats in the sample, based on the affinity of the dye for lipid components. Sudan III is a fat-soluble dye that selectively dissolves in lipids and imparts an orange-red coloration to them, thereby confirming the presence of oils or fats in the test solution. Since volatile oils are lipophilic in nature, they readily absorb the dye and produce a distinct colored oil layer. In the present analysis, a distinct red-dyed oil layer was observed floating on the top of the organic color sample, confirming the presence of lipids or volatile oils, while no such layer was observed in the negative samples, where the solution remained uniform without any separation.

Fehling's test: Fehling's test was performed (Table no.1) to detect the presence of reducing sugars in the organic color sample. The test is based on the ability of reducing sugars such as glucose, fructose, maltose, and lactose to donate electrons due to the presence of a free aldehyde (-CHO) or ketone (-C=O) functional group. In an alkaline medium, these groups reduce cupric ions (Cu^{2+}) from Fehling's reagent to cuprous oxide (Cu_2O), resulting in the formation of a characteristic brick-red precipitate. In the present study, no brick-red precipitate was observed, confirming the absence of reducing sugars in the organic color sample.

1	Foam test	Saponins	Positive
2	Volatile oil test	Lipids & oil layer	Positive
3	Hager's test	Alkaloids	Positive
4	Fehling's test	Carbohydrates	Negative
5	Molisch's test	Sugar	Negative

Table no.1: Results of qualitative tests for saponins, volatile oil, alkaloids, carbohydrates and sugar

Ash value : Ash is the inorganic residue obtained after the controlled incineration of a crude drug, and it represents the total content of inorganic material naturally present in herbal samples. In many cases, the therapeutic activity of herbal drugs can be influenced by inorganic constituents, as several minerals play essential roles in cellular metabolism. Ash analysis therefore provides valuable information regarding the concentration and type of inorganic components present in the drug, and is considered an important parameter for assessing both the quality and purity of herbal materials. Ash content is often characteristic for each herbal drug and can be used as a standard for identity and purity evaluation. The ash residue is determined using three different parameters: total ash, acid-insoluble ash, and water-soluble ash. Total ash measures the overall inorganic material remaining after complete ignition, consisting mainly of silica, carbonates, phosphates, and silicates of sodium, potassium, magnesium, calcium, and other mineral salts. It includes both physiological ash, which is derived from the plant tissue itself, and non-physiological ash, which results from extraneous matter such as sand and soil adhering to the plant surface.

Value	**X**	**X`**	**(X- X`)**	**$(X-X`)^2$**
Ash 1	0.005	0.0053	-0.0003	0.9
Ash 2	0.003	0.0053	-0.0023	0.529
Ash 3	0.008	0.0053	0.0027	0.729

Σ 2.158

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Table no 2: Standard deviation for ash value

pH Value: Herbal color - 7.00 (Neutral)
Artificial color - 6.54 (Slightly Acidic)

The findings of the present study are in agreement with previous research highlighting the phytochemical richness of *Butea monosperma* flowers. The detection of saponins in the organic color sample is consistent with the reports of Wanjari et al. (2016), who demonstrated the presence of saponins in aqueous and methanolic extracts of Palash petals. Similarly, the positive reaction in Hager's test corroborates earlier studies that confirmed alkaloids as major constituents contributing to the therapeutic properties of the plant (Ahire et al., 2020; Pawar et al., 2019). The absence of carbohydrates and reducing sugars in the present analysis is also aligned with the study by Yadav et al. (2020), which reported low carbohydrate content in dried flower extracts, suggesting lower susceptibility to microbial growth—a desirable feature for natural color formulations. Furthermore, the observation of volatile oils through the Sudan III test supports the findings of Singh et al. (2017), who identified essential oils and lipid fractions in Palash flowers as contributors to their antioxidant and skin-soothing potential. Overall, the present results not only validate the traditional ethnobotanical uses of *Butea monosperma*, but also support contemporary evidence indicating its suitability for dermatological applications, particularly in natural cosmetic color formulations.

The ash-value and pH results obtained in this study are consistent with established standards reported for herbal drug evaluation. Similar ash profiles have been documented during physicochemical standardization of herbal materials (Bhusnure et al., 2019) and are recommended as core quality parameters for purity assessment (IJPD Analysis, 2017). Reviews on herbal standardization further highlight ash-value as a characteristic identity marker for crude drugs (Khatale et al., 2015). Comparable values have also been observed in standardized Ayurvedic formulations such as Jambavasava (Shyamkant et al., 2018), and recent polyherbal evaluations report similar ranges. These comparisons indicate that our findings fall within acceptable quality benchmarks for herbal materials.

Conclusion

The study concludes that Butea monosperma flowers serve as an excellent source for the preparation of safe, eco-friendly color. The developed formulation is natural, non-toxic, and biodegradable. This approach promotes environmental sustainability while reviving traditional herbal practices. The results encourage further research on large-scale production and commercialization of plant-based natural dyes as alternatives to synthetic pigments.

Acknowledgment

The authors express gratitude to the Department of Botany for providing laboratory facilities and technical assistance. Appreciation is also extended to volunteers who participated in the safety assessment.

Conflict of Interest

The authors declare no conflict of interest.

References

1. Ahire, D., Wanjari, M., Pawar, R., & Yadav, V. (2020). Phytochemical and pharmacological review of *Butea monosperma*. *Journal of Pharmacognosy and Phytochemistry*, *9*(5), 1050–1056.
2. Basketter, D. A., McFadden, J., Gerberick, G. F., & Kimber, I. (2015). Allergy and sensitization: Implications for exposure to chemicals. *Contact Dermatitis*, *72*(1), 1–5.
3. Bhusnure, O. G., Suryawanshi, S., Vijayendra Swamy, S. M., Gholve, S. B., Girm, P. S., & Birajdar, M. J. (2019). Standardization and quality evaluation of herbal drugs. *Journal of Drug Delivery and Therapeutics*, *9*(3-S), 1058–1063.
4. Khatale, V. L., Shende, M. B., & Chothe, D. S. (2015). An overview on herbal drug standardization. *International Journal of Ayurvedic and Pharmaceutical Chemistry*, *4*(2), 90–96.
5. Kshirsagar, D., Gaikwad, S., Karale, P., Patel, V., & Bhalke, R. (2017). Current quality control methods for standardization of herbal drugs. *International Journal of Pharmaceutical Drug Analysis*, *5*(3), 82–95.
6. Lachapelle, J. M., Maibach, H. I., & Andersen, K. E. (2013). *Patch testing and prick testing: A practical guide*. Springer.
7. Pawar, R., Wanjari, M., & Patil, R. (2019). Traditional and modern uses of *Butea monosperma* (Lam.) Taub. *International Journal of Herbal Medicine*, *7*(4), 85–90.
8. Pharmacognostic and phytochemical evaluation of polyherbal formulation. (2023). *World Journal of Pharmaceutical Research*.
9. Rabasco-Alcalá, L., Sánchez-García, J., & García-Gavin, J. (2021). Gender differences in allergic contact dermatitis: A systematic review. *International Journal of Environmental Research and Public Health*, *18*(10), 5453.

10. Shyamkant, C. D., Chavan, M. J., & Upasani, C. D. (2018). Standardization of Jambavasava – A polyherbal Ayurvedic formulation. *Asian Journal of Pharmaceutical Research and Development, 6*(2), 43–46.
11. Singh, S., Thakur, R., & Sharma, V. (2017). Evaluation of phytochemical constituents and antioxidant properties of *Butea monosperma* flowers. *Journal of Natural Product Research, 4*(3), 112–118.
12. Wanjari, M., Yadav, V., & Jadhav, A. (2016). Medicinal and ethnobotanical importance of *Butea monosperma*. *Indian Journal of Traditional Knowledge, 15*(2), 317–324.
13. Yadav, V., Ahire, D., & Pawar, R. (2020). Therapeutic potentials of *Butea monosperma*: A comprehensive review. *International Journal of Pharmaceutical Sciences Review and Research, 61*(1), 45–52.

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Original Article

Studies on food adulteration in relation to food substances like Milk, Chilli powder, Turmeric and Honey samples from Gadchiroli city of Maharashtra

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Manuscript ID:
JRD -2026-180420
ISSN: 2230-9578
Volume 18
Issue 4(XI)
Pp. 114-122
April - 2026
Submitted: 14 Mar. 2026
Revised: 29 Mar. 2026
Accepted: 05 Apr . 2026
Published:30 April2026

Abstract:

Food refers to any material made up of carbohydrates, water, fats, proteins and essential metabolites that can be ingested or processed by humans or animals for nutritional purposes, making food consumption a crucial element of life. Food items mostly become targets for adulteration, and supply chains typically handle easily spoiling goods which may pose risks to consumers if not managed appropriately.

Food adulteration poses a significant public health issue in rural and tribal areas where regulatory supervision may be insufficient. Milk, chilli powder, turmeric, and honey serve as essential direct or indirect food components for the local residents of the Gadchiroli. Samples were randomly collected from local available sources to examine prevalent adulterants in these food items. Various standard tests were carried out in the laboratory, and the findings were deliberated upon concerning health implications for consumers, particularly children and at-risk groups. For the purpose of experimentation, some chemical, physical, and microscopic analyses were performed and the observed result shown as findings with some remedies on basis of study which also suggested.

Key Words: Food adulteration, foodstuffs, Common adulterants in foodstuffs

Introduction:

Food is essential for living organisms and may be obtained from both plant and animal sources. Food can be eaten as prepared foods or consumed as liquids like milk, fruit juices, and coconut water. Food is necessary for all living things to obtain energy, carry out various vital processes, grow, work, repair, and sustain life. A pure, fresh, and healthful diet is necessary for people's well-being. People's health is part of national health.

In 2015, WHO estimated that unsafe food caused 600 million illnesses and 420,000 deaths worldwide in 2010, resulting in 33 million disability-adjusted life years (DALYs). As per Essuman (2022), food adulteration has become a threat to many countries, as most individuals have consumed food items without knowing that they have been adulterated, leaving the consumer with various ailments. Important Findings of the 2015 WHO report, prepared by the Foodborne Disease Burden Epidemiology Reference Group (FERG), provided the first global and regional estimates of foodborne disease burden. It examined 31 foodborne hazards, including bacteria, viruses, parasites, and chemical toxins, and categorized them into three broad groups: enteric hazards, parasitic hazards, and chemical hazards. Food Safety and Standards Act, 2006 The Food Safety and Standards Act was introduced in the year 2006 by the FSSAI to regulate the complete aspects of processing, manufacturing, distribution, and other aspects to ensure better services. The FSSA supersedes all the previous laws relating to food safety. In emerging area, like Gadchiroli supervision and application of food safety regulations might not be robust and sufficient.

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How to cite this article:
Dharmik, P. C., & Jakhi, P. P. (2026). Studies on food adulteration in relation to food substances like Milk, Chilli powder, Turmeric and Honey samples from Gadchiroli city of Maharashtra. Journal of Research and Development, 18(4(XI)), 114–122.
https://doi.org/10.5281/zenodo.21125989

Quick Response Code:
Website:
https://jrdrvb.org/
DOI:
10.5281/zenodo.21125989
OPEN ACCESS

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Consequently, contaminated food items frequently reach neighbourhood markets. Gadchiroli city in Maharashtra, which has a notable rural and tribal population relies heavily on food items sourced locally, including milk, chili powder, turmeric, and honey. These food items are regularly used each day, either in a direct manner or indirectly, and represent a crucial component of the dietary habits of the local inhabitants.

Adulteration is the unlawful act of contaminating and lowering the quality of food, by adding undesirable substances or toxic chemicals to the food either accidentally or purposefully, This actually lowers the food's quality and nutrient value, which has negative effects on human health and growth and development. Any compounds that lower the quality of food are considered adulterants. The adulterant could be present in any size or form.

Milk, chilli powder, turmeric, and honey are frequently used food products. Milk's ingredients like fat, protein, vitamins, lactose, and minerals make it a complete food (Berna 2010; Gandhi *et al.* 2020).These food items are significant for nutrition and are integral to the everyday meals of the local population. Vast geographical area, problems in communication and insufficient Public in rural and tribal areas may be the cause of susceptibility to contamination.

The current research seeks to explore the extent of contamination in collected samples, gathered from different local markets in Gadchiroli city. To identify typical adulterants, recognised chemical, physical, and microscopic techniques were used. The results of this research are designed to raise awareness among consumers and help to enhance food safety initiatives in local communities.

Review of Literature:

As per Singh and Gandhi (2015) study shows that, Peroxides, Acids Bases, Gases, hydrogen peroxide, salicylic acid, sodium carbonate and bicarbonate carbon dioxide (CO2), formaldehyde/formalin, potassium dichromate, mercuric chloride and azidiol used as preservatives for milk preservation while water, starch, cereal flours, glucose, cane sugar, caramel, annatto, turmeric, coal-tar dye, sodium hydroxide, vegetable oil, urea, melamine, ammonium sulfate, skim milk powder, cheese and whey are used as adulterant in milk.

According to Rajalakshmi (1974), real or artificial gap between supply and demand results in a gre at temptation for shop-keepers for either adulterating the food sold are for selling foods of inferior quality. Swaminathan (1974) defines adulteration as the process by which the quality of the product is reduced through the addition of baser substances or through removal of vital elements. Soopal and Panwar, (2020), have shown that the food adulteration rate in India stood at 13% in 2011-12 which increased to 23% in 2016-17 they have also explained explain the emerging trends of food adulteration in India and its remedies. Everstine *et.al.* (2013) has identified 137 various unique incidents in 11 food categories economically motivated adulteration (EMA) of food from China. Yadav *et. al.* (2022), has shown list of various types of adulterants in milk and their purpose of mixing. Several studies have highlighted the widespread prevalence of food adulteration in India. The Food Safety and Standards Authority of India has reported frequent adulteration in milk with water and synthetic chemicals. The Codex Alimentarius Commission provides international guidelines for food purity and safety standards. Adulteration in milk reduces nutritional value and may introduce harmful chemicals (Singh & Gandhi, 2015).

3. Materials and Methods

Sample Collection

Several qualitative methods are available for identifying adulteration, but knowledge of chemicals and procedures to perform those tests is required. Analytical methods for quantification of adulterants have also been available for a long time, but these methods also need certain expertise, costly equipment, and lab setup. As per availability of all the conditions methodology used for this purpose is from Banti, 2020 and some other earlier published standar literature.

3 each samples of milk, chilli powder, turmeric powder, and honey were randomly collected from local vendors from Gadchiroli city. Samples were labelled and stored in clean, airtight containers before analysis. Samples were analysed in laboratory by standard chemical, physical, and or microscopic methods.

		Turmeric	Milk	Honey	Chili
1.	Water test	+	+	+	+
2.	Acid test (HCl	+		+	+
3.	Soap test	+	+		
4.	Visual Inspection	+			
5.	Sulphuric Acid test	+			
6.	Nitric Acid test	+			
7.	Starch test (Iodine),		+		+
8.	Formaldehyde test		+		

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A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

9.	Urea test		+		
10.	Acidity test		+		
11.	Sugar test		+		
12.	Salts test		+		+
13.	Ammonia test		+		
14.	Flame test			+	
15.	Blotting Paper test,			+	
16.	Vinegar test,			+	
17.	Silver Nitrate test, ,			+	
18.	Fehling's test,			+	
19.	Barfoed's test			+	
20.	Fiehe's test			+	
21.	Oil test (Sudan Dye),				+
22.	Floatation test,				+

Observations:

22 Different Kind Of Chemical Tests Were Conducted To Detect Adulteration In Collected Samples. Some Of The Important Tests Conducted For Collected Samples And Results Observed Are Shown In Table No 1 To 4, As Shown In Table 1.

Sr. No	Test	Turmeric	Milk	Honey	Chili
1.	Water test	+	+	+	+
2.	Acid test (HCl	+		+	+
3.	Soap test	+	+		
4.	Visual Inspection	+			
5.	Sulphuric Acid test	+			
6.	Nitric Acid test	+			
7.	Starch test (Iodine),		+		+
8.	Formaldehyde test		+		
9.	Urea test		+		
10.	Acidity test		+		
11.	Sugar test		+		
12.	Salts test		+		+
13.	Ammonia test		+		
14.	Flame test			+	
15.	Blotting Paper test,			+	
16.	Vinegar test,			+	
17.	Silver Nitrate test, ,			+	

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18.	Fehling's test,			+	
19.	Barfoed's test			+	
20.	Fiehe's test			+	
21.	Oil test (Sudan Dye),				+
22.	Floatation test,				+

Various tests of all three samples of Turmeric, Milk, Honey and Chili were conducted in laboratory and results of the test shown in table number 2 to 5 and summarised in table 6.

Samples Collected And Tests Performed

		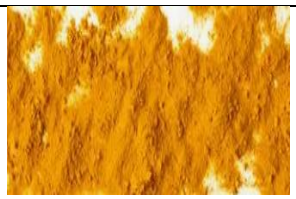	
Samples collected			
Milk - Ammonia Test - Brown colour developed - adulterated	Milk - Formaldehyde Test - dark violet colour developed - adulterated	Milk - Acidity Test - Normal Acidity	Chilli powder -Floatation Test
Honey - Iodine Test - Blue black colour - starch	Honey - Acidity Test - Higher acidity - adulterated	Turmeric - Acid Test (HCL) - slight pink colour -metanil yellow adulterated	Turmeric - Nitric acid test - mild effervesce - chalk powder

Table 2: Observation of Milk Samples for Adulteration

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Sr. No.	Test Name	Sample 1 Observation	Sample 2 Observation	Sample 3 Observation	Conclusion
1	Water Test	Left a white mark on the surface	Left a faint white mark	Flowed without leaving mark	Sample 3 adulterated with water
2	Starch Test (Iodine)	No blue-black colour	No colour change	Blue-black colour observed	Sample 3 contains starch
3	Soap Test	A thin layer of foam formed	Normal thin foam	Excessive foam formed	Sample 3 suspected detergent adulteration
4	Formaldehyde Test	No violet colour	No colour change	Violet colour developed	Sample 3 positive for formaldehyde
5	Urea Test	No pink colour	No colour change	Pink colour observed	Sample 3 contains urea
6	Acidity Test	Normal acidity	Normal acidity	Higher acidity observed	Sample 3 may be sour or acidified
7	Nitrate Test	No blue colour	No colour change	Blue colour observed	Sample 3 positive for nitrate
8	Sugar Test (Benedict's)	Light green precipitate (normal lactose)	Light green precipitate	Brick-red precipitate	Sample 3 contains added sugar
9	Salts Test (Silver Nitrate)	No excess precipitate	Normal slight precipitate	Heavy white precipitate	Sample 3 contains added chloride salts
10	Ammonia Test (Nessler's)	No brown colour	No colour change	Brown colour developed	Sample 3 positive for ammonia

Interpretation of tests conducted:

- Among the three milk samples analyzed, Sample 2 showed positive results for multiple adulteration tests, including starch, urea, formaldehyde, nitrate and added sugar.
- Samples 1 and 3 showed normal reactions consistent with pure milk, except minor natural variations in acidity content.
- The results indicate that Sample 2 is significantly adulterated while Samples 1 and 3 appear comparatively safe.

Table 3: Observation of Chili Powder Samples for Adulteration

Sr. No.	Test Name	Sample 1 Observation	Sample 2 Observation	Sample 3 Observation	Conclusion
1	Water Test (Artificial Color)	Water remained clear; powder settled	Water turned reddish	Water remained clear	Sample 2 contains an artificial colouring agent
2	Starch Test (Iodine)	No blue-black colour	No colour change	No colour change	All Samples are free from starch/flour
3	Oil Test (Sudan Dye)	Oil remained light yellow	Oil turned deep red	Oil unchanged	Sample 2 contains Sudan dye
4	Floatation Test	Powder floated initially	Particles sank immediately	Floated normally	Sample 2 contains heavy adulterants (brick/salt)
5	HCl Test (Carbonates/Chalk)	No effervescence	Mild effervescence observed	No reaction	Sample 2 contains chalk/carbonates
6	Solubility Test (Salt Detection)	No residue after filtration	White crystalline residue observed	No residue	Sample 2 contains salt adulteration

Interpretation of tests conducted:

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ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

- Among the three chilli powder samples analyzed, Sample 2 showed positive results for multiple adulteration tests, including artificial color, starch, brick powder, salt, Sudan dye.
- Samples 1 and 3 showed normal results consistent with pure chili powder, displaying natural plant tissue structure and absence of synthetic dyes or fillers.
- The findings indicate that Sample 2 is highly adulterated and unsafe for consumption, while Samples 1 and 3 appear comparatively pure.

Table 4: Observation of Turmeric Samples for Adulteration

Sr. No.	Test Name	Sample 1 Observation	Sample 2 Observation	Sample 3 Observation	Conclusion
1.	Water Test	Powder settled at bottom, clear supernatant	Slight floating particles observed	Completely settled, no floating matter	Sample 1 & 3 appear pure; Sample 2 may contain light adulterants
2.	Acid Test (HCl)	No pink/red colour observed	Slight pink colour developed	No colour change	Sample 2 suspected for metanil yellow adulteration
3.	Soap Test	Reddish-brown colour developed	No significant colour change	Reddish-brown colour developed	Sample 1 & 3 likely pure; Sample 2 may be adulterated
4.	Visual Inspection	Uniform bright yellow colour, fine texture	Slight dull yellow, coarse particles present	Uniform colour, smooth texture	Sample 2 shows possible adulteration
5.	Sulphuric Acid Test	Deep red colour formed	No significant colour change	Deep red colour formed	Sample 1 & 3 pure; Sample 2 suspected adulterated
6.	Nitric Acid Test	No effervescence	Mild effervescence observed	No effervescence	Sample 2 may contain chalk powder/fillers
7.	Alcohol Test	A clear yellow solution obtained	Turbidity observed	Clear yellow solution	Sample 2 suspected adulterated
8.	Iodine Test	No blue-black colour	Blue-black colour observed	No colour change	Sample 2 contains starch adulteration

Interpretation of tests conducted tests:

- Out of the three turmeric samples analysed, Sample 2 showed positive results for adulteration in multiple tests including Acid Test, Iodine Test, Nitric Acid Test, and Soap Test. The results suggest possible presence of metanil yellow, starch, or chalk powder.
- Samples 1 and 3 showed normal reactions consistent with pure turmeric powder.

Table 5: Observation of Honey Samples for Adulteration

Sr. No.	Test Name	Sample 1 Observation	Sample 2 Observation	Sample 3 Observation	Conclusion
1	Water Test	Settled at bottom	Partially dissolved in water	Settled at bottom	Sample 2 suspected adulterated with water
2	Flame Test	Matchstick burned properly	Did not burn properly	Burned steadily	Sample 2 contains moisture/water
3	Blotting Paper Test	Not absorbed	Slightly absorbed	Not absorbed	Sample 2 suspected dilution
4	Vinegar Test	No foaming	Effervescence observed	No foaming	Sample 2 may contain chalk
5	Silver Nitrate Test	No white precipitate	White precipitate observed	No precipitate	Sample 2 contains added chloride salts
6	Starch Test (Iodine)	No blue-black colour	Blue-black colour observed	No colour change	Sample 2 contains starch
7	Fehling's Test	Light red precipitate (natural sugars)	Heavy brick-red precipitate	Light red precipitate	Sample 2 contains excess reducing sugars

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8	Barfoed's Test	Mild red precipitate	Heavy red precipitate	Mild precipitate	Sample 2 contains added monosaccharides
9	Acidity Test	Normal acidity	Higher acidity observed	Normal acidity	Sample 2 may be fermented/adulterated
10	Fiehe's Test	No red coloration	Red coloration developed	No colour change	Sample 2 contains commercial sugar

Interpretation of tests conducted:

Out of the three honey samples analysed, Sample 2 showed positive results in multiple adulteration tests, including starch, chloride salts, invert sugar, commercial sugar, and excess reducing sugars.

- Samples 1 and 3 showed normal results consistent with pure honey, with natural sugar reactions in Fehling's and Barfoed's tests.
- The findings indicate that Sample 2 is adulterated with sugar syrups and possibly diluted with water, making it unsuitable for consumption.

Table 6: Overall result for all three samples collected for Turmeric, Milk, Honey and Chilli powder

	Sample 1	Sample 2	Sample 3	Normal samples	Adulterated samples	% of Adulterated samples
Milk	Sample showed normal reactions consistent with pure milk, except minor natural variations in acidity content.	significantly adulterated while Samples	Sample showed normal reactions consistent with pure milk, except minor natural variations in acidity content.	2	1	33%
Chili Powder	Samples showed normal results consistent with pure chili powder, displaying natural plant tissue structure and absence of synthetic dyes or fillers.	The findings indicate that Sample is highly adulterated and unsafe for consumption,	Sample showed normal results consistent with pure chili powder, displaying natural plant tissue structure and absence of synthetic dyes or fillers.	2	1	33%
Turmeric	Normal reactions consistent with pure turmeric powder.	Positive results for adulteration in multiple tests including The results suggest possible presence of metanil yellow, starch, or chalk powder.	Normal reactions consistent with pure turmeric powder.	2	1	33%
Honey	Sample shows normal results consistent with pure honey, with natural sugar reactions in Fehling's and Barfoed's tests.	Sample is adulterated with sugar syrups and possibly diluted with water, making it unsuitable for consumption.	Sample showed normal results consistent with pure honey, with natural sugar reactions in Fehling's and Barfoed's tests.	2	1	33%

33% result is indicative because sample size is just 3

Figure 1

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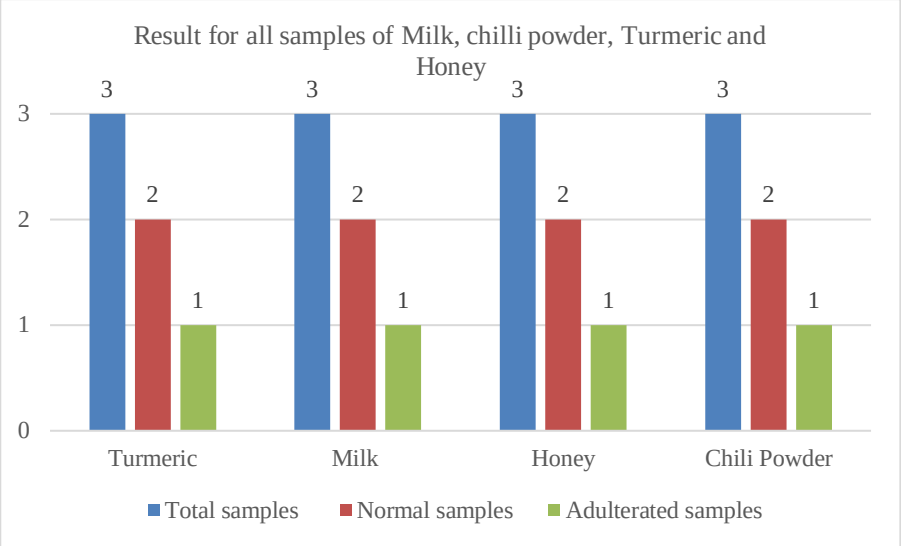
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026



Results and Discussion

The experimental findings shows about 1/3 of the collected samples adulterated (Fig. 1).

Milk samples showed presence of water in several cases and starch in limited samples. **Chilli powder samples** indicated artificial colouring agents and sedimentation impurities. **Turmeric samples** showed traces of synthetic dyes in some samples. **Honey samples** revealed possible sugar syrup adulteration. This is only effort to analyse and test food adulteration at general level from randomly collected samples. Percentage of adulteration is just indicative because sample size is just 3 for each food item.

Conclusion

The study highlights the presence of adulteration in commonly consumed collected samples from Gadchiroli city. Although not all samples were adulterated, a significant proportion showed contamination with either chemical or physical adulterants.

The results indicate that regular monitoring of food substances is essential for good health. Increase in awareness among the people against adulteration is required. Different forms of food adulteration and their associated health impacts should be extensively well documented and analysed. Proper law enforcement and regular inspection of food quality can bring about drastic changes. Strict implementation of food safety measures and periodic laboratory testing in rural areas. Ensuring food purity is essential for protecting human population, particularly children and rural communities. Pure non-adulterated food is a basic need for a human being that plays a crucial role in maintaining a healthy lifestyle.

Acknowledgement:

Authors are thankful to the Principal, Govt. Science College for providing the necessary laboratory facilities

Bibliography:

1. Ajay Kr. Yadav, Meghana Gattupalli, Kavya Dashora1, Vivek Kumar (2022), Key Milk Adulterants in India and their Detection Techniques: a Review, Food Analytical Methods https://doi.org/10.1007/s12161-022-02427-8
2. Berna A (2010) Metal Oxide Sensors for Electronic Noses and Their Application to Food Analysis. Sensors. https:// doi.org/ 10. 3390/ s1004 03882
3. Everstine K, Spink J, Kennedy S., (2013), Economically motivated adulteration (EMA) of food: common characteristics of EMA incidents. *J Food Prot. 76(4)*:723-35. doi: 10.4315/0362-028X.JFP-12-399. PMID: 23575142.
4. Food Safety and Standards Authority of India (2012). *Manual of Methods of Analysis of Foods*. Ministry of Health and Family Welfare, Government of India.
5. Gandhi K et al (2020) Chemical Quality Assurance of Milk and Milk Products. Springer
6. Gandhi, Kamal; Sharma, Rajan; Gautam, Priyae; Mann, Bimlesh, (2020) Chemical Quality Assurance of Milk and Milk Products, DO -10.1007/978-981-15-4167-4
7. Mahesh Singh Soopa1 and Kuldeep Singh Panwar, (2020), Food Adulteration in Contemporary India: Emerging Trends and Remedies, *SOCRATES* Vol. *8*, No. 1 (Special Issue) pp. 64-71.
8. Misgana Banti,2020;Food Adulteration and Some Methods of Detection, International Journal of Nutrition and Food Sciences 9(3): 86-94
9. Rajalakshmi R (1974). Applied nutrition. Applied nutrition. (Ed. 2).

10. Singh Parminder and Gandhi Neeraj, (2015), Milk Preservatives and Adulterants: Processing, Regulatory and Safety Issues *Food Reviews International*, *31*:236–261.
11. Swaminathan M (1974). Essentials of food and nutrition.
12. World Health Organization (2015). *Estimates of the Global Burden of Foodborne Diseases*. WHO Press, Geneva.
13. Yeniewa Kerie Anagaw, Wondim Ayenew, Liknaw Workie Limenh, Derso Teju Geremew, Minichil Chanie Worku, Tewodros Ayalew Tessema, Wudneh Simegn and Melese Legesse Mitku, (2024), Food adulteration: Causes, risks, and detection techniques—review, *SAGE Open Medicine Volume 12*: 1 –10

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Original Article

Floristic Assessment of Some Medicinal Plant Species from Phansad Wildlife Sanctuary, Raigad District, Maharashtra

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Manuscript ID:
JRD -2026-180421
ISSN: 2230-9578
Volume 18
Issue 4(XI)
Pp. 123-127
April - 2026

Submitted: 16 Mar. 2026
Revised: 30 Mar. 2026
Accepted: 09 Apr . 2026
Published:30 April2026

***Abstract*:**
*Floristic diversity forms the foundation of ecological stability and supports traditional healthcare systems through medicinal plants. The present study focuses on the floristic assessment of medicinal plant species in Phansad Wildlife Sanctuary, located in the coastal region of the Western Ghats. The sanctuary represents a unique mosaic of semi-evergreen, evergreen, and dry deciduous forests, harbouring rich plant biodiversity. A systematic survey was conducted to document medicinal plant species, their botanical characteristics, and ethnomedicinal uses (Ethno-Medicinal Plants of the Western Ghats, 2023; Western Ghats Biodiversity Review, 2025).(**Hurkadale, Pramod J. & Bidikar, Chaitrali M. (2023).** Ethno-Medicinal Plants from the North-Central Western Ghats of India for Alternative Health Care). The study highlights the presence of diverse phytochemical constituents used in traditional healing. These flora need for conservation and sustainable utilisation of these valuable medicinal plant bioresources.*

***Keywords*:** *Floristic diversity, Ethnobotany, Western Ghats, Conservation*.

Introduction :

Medicinal plants have been integral to human civilisation, particularly in India, where traditional systems like Ayurveda, Siddha, and folk medicine rely heavily on plant-based remedies (**Spandana & Bhagya, 2025**). The Western Ghats, recognised as a global biodiversity hotspot, host a wide range of endemic and medicinally important plant species (**J. Malavika, 2023**). Phansad Wildlife Sanctuary is an important protected area within this region, known for its rich floristic diversity and ecological significance. The sanctuary, established to conserve coastal woodland ecosystems, comprises forest, grassland, and wetland habitats supporting a high diversity of plant species, including many with ethnomedicinal relevance (**Watts et al., 2025**). Despite its ecological importance, systematic documentation of medicinal plants in this sanctuary remains limited. Therefore, the present study aims to explore, identify, and analyse med the Medicinal plant species and their uses in the region.

Study Area:

Phansad Wildlife Sanctuary is situated in the Murud and Roha talukas of Raigad district, Maharashtra. The sanctuary covers approximately 69.79 km² and represents a coastal ecosystem of the northern Western Ghats, consisting of forest, grassland and wetland habitats that support high plant diversity (**Phansad Wildlife Sanctuary overview, Wild Konkan, 2025; Joshi, Sawant & Kunte, *Odonata of India*, 2026**). The climate is tropical with high humidity and seasonal rainfall, supporting diverse vegetation types including semi-evergreen, evergreen, mixed deciduous and dry deciduous forests (**Chronicle India report, 2025**). The vegetation is characterised by semi-evergreen forests on hilltops, dry deciduous forests on slopes, and patches of grasslands known as "mals," with dominant plant species such as *Memecylon umbellatum*, *Garcinia talbotii* and various *Ficus* species contributing to the rich flora (**Phansad Wildlife Sanctuary overview, Wild Konkan, 2025; Chronicle India report, 2025**).

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How to cite this article:
Warange, S., & Chavan, V. S. (2026). Floristic Assessment of Some Medicinal Plant Species from Phansad Wildlife Sanctuary, Raigad District, Maharashtra. Journal of Research and Development, 18(4(XI)), 123–127. https://doi.org/10.5281/zenodo.21126064

Quick Response Code:
Website:
https://jrdrvb.org/
DOI:
10.5281/zenodo.21126064
OPEN ACCESS

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

These varied habitats contribute to high species richness and support numerous medicinal plants and diverse biological communities within the sanctuary

Materials and Methods:

Study Area and Field Survey: Field surveys were systematically conducted across diverse habitats within the wildlife sanctuary, including dense forest interiors, open grasslands, and areas surrounding water bodies, to ensure comprehensive coverage of vegetation. These surveys were carried out during different seasons to document maximum plant diversity and to observe seasonal variations in plants.

1) **Collection of Plants:**

Plant specimens were collected carefully following standard herbarium techniques to ensure a representative sampling of wild medicinal flora. Mature plant parts including leaves, flowers, fruits, and roots were selected and gathered from natural habitats, recorded in a field notebook with GPS coordinates and collection details to aid future identification. Ethnomedicinal information was gathered through direct interactions and interviews with local communities and forest dwellers, who possess valuable traditional knowledge about the medicinal uses of plants (**Siddique et al., 2021**).

2) **Identification of Plant Species**.

The collected plant species were identified using standard regional floras, taxonomic literature, and identification keys to ensure accurate classification and nomenclature, confirmed with expert consultation where possible

3) **Drying of Plant Material**.

The collected samples were properly pressed and dried to preserve their morphological and chemical characteristics. Proper drying was carried out under shade to inhibit enzymatic activity, reduce microbial growth and limit loss of bioactive compounds, which helps retain the integrity of phytochemicals for later analysis

4) **Powdering:**

The dried plant samples were ground into a fine powder using clean and sterilised grinders to prepare uniform material suitable for qualitative and quantitative analyses of secondary metabolites

5) **Analysis of Plant Powder**:

The powdered samples were subjected to chemical and pharmacological analyses, including qualitative screening for secondary metabolites and bioactive compound detection. Extracts were prepared using appropriate solvents and standard laboratory protocols to determine the presence of major phytochemicals relevant to medicinal properties (**Scientific Reports phytochemical methods, 2021**).

Plants used for floristic study:

1)*Elephantopus scaber* L.

Elephantopus scaber belongs to the family Asteraceae. The local Marathi name of this plant is “Hastidanti.” It is a small perennial herb that commonly grows in tropical and subtropical regions, especially in open grasslands and wastelands. The plant forms a rosette of broad leaves at the base and produces small purple flowers. It prefers well-drained soil and sunny habitats. The roots and leaves are the main parts used for medicinal purposes. The presence of secondary metabolites in leaves and roots includes fatty acids, **Steroids**, **Saponins**, Terpenoids, Tannins, Flavonoids, phenolics, and Alkaloids (fatty acids, steroids, saponins, terpenoids, tannins, flavonoids, phenolic compounds, and alkaloids all have important **medicinal uses**: fatty acids help reduce inflammation and support heart health; steroids are widely used as anti-inflammatory, saponins show cholesterol-lowering, immune-boosting, and anticancer properties; terpenoids possess antimicrobial, anti-inflammatory, and antimalarial activities; tannins are used for wound healing, treating diarrhea, and as antibacterial agents; flavonoids act as powerful antioxidants with cardioprotective and anticancer effects; phenolic compounds help prevent oxidative stress–related diseases; and alkaloids are used in many drugs for pain relief, malaria treatment, and nervous system disorders. (Singh & Sharma, 2019; Patel et al., 2021; Verma et al., 2021; Das et al., 2016). Traditionally, it is valued for its anti-inflammatory, antimicrobial, and febrifuge properties and is used in the treatment of fever, diarrhoea, dysentery, urinary disorders, and skin diseases. The plant also has detoxifying properties in folk medicine.

2(*Gnetum edule* *(Willd.) Blume (Gnetum ula Brongn*) :

Gnetum ula belongs to the family Gnetaceae. In Maharashtra, it is locally known as “Ula.” It is a large woody climber commonly found in dense forests of tropical regions. It climbs over tall trees using its flexible stems and produces broad, leathery leaves. The plant thrives in humid and shaded environments. The leaves, cones, and seeds are used for medicinal purposes. Presence of secondary metabolites in cones is coumarins, fatty acids, steroids, quinones, terpenoids, tannins, flavonoids, phenolic compounds, and alkaloids (**Singh et al., 2024)**

Coumarins are known for their anticoagulant and anti-inflammatory properties. Fatty acids are important for energy metabolism and cardiovascular health. Steroids have anti-inflammatory and hormonal regulatory roles. Quinones exhibit antimicrobial and antioxidant properties. Terpenoids show anti-cancer and anti-inflammatory effects Tannins are used for wound healing and antimicrobial action Flavonoids are powerful antioxidants with cardioprotective benefits Phenolic compounds function as free radical scavengers and have anti-ageing effects. Alkaloids show

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A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

analgesic and neuropharmacological activities. It is traditionally used as a remedy for rheumatism, joint pain, and as a general health tonic. The plant is also known for its nutritional value in some tribal communities

3) *Aerides maculosum* Lindl.

Aerides maculosum is a member of the Orchidaceae family. The local name is "Dagadi Aboli." It is an epiphytic orchid that grows on tree trunks in moist deciduous and evergreen forests. It has thick, fleshy leaves and produces attractive, fragrant, spotted flowers. The plant absorbs moisture and nutrients from the air and surrounding debris. The roots, flowers, and sometimes the whole plant are used in traditional medicine. Presence of secondary metabolites in flowers is steroids, saponins, quinones, tannins, flavonoids, phenolic compounds, and alkaloids Steroids have anti-inflammatory and hormonal regulatory roles.

Saponins are known for their immune-boosting, antimicrobial, and cholesterol-lowering properties Tannins are used for wound healing and possess astringent properties Flavonoids act as powerful antioxidants with anti-inflammatory, antimicrobial, and anticancer effects. Phenolic compounds function as free radical scavengers and help in protection against chronic diseases (Phytochemical Studies, 2023). Alkaloids show analgesic, antimicrobial, and neuropharmacological activities. It is used for treating wounds, cuts, and as a tonic for general weakness. Due to its ornamental value, it is also cultivated in gardens.

4(*Amorphophallus commutatus* *(Schott) Engl.*

Amorphophallus commutatus belongs to the Araceae family. The local name is "Suran." It is a tuberous herb that grows in forested and semi-shaded regions. It has a large underground tuber and produces a single large leaf along with a characteristic inflorescence. The plant prefers moist soil and seasonal rainfall. The tuber is the main part used for medicinal and dietary purposes. Presence of secondary metabolites in bulbs is steroids, saponins, quinones, tannins, flavonoids, phenolic compounds, coumarins, leucoanthocyanin, anthocyanin, fatty acids, phlobatannins, terpenoids and alkaloids**.** Steroids have anti-inflammatory and hormonal regulatory roles. Saponins are known for immune-boosting, antimicrobial and cholesterol-lowering properties. Quinones exhibit antimicrobial and antioxidant activity Tannins are used for wound healing and possess astringent properties Flavonoids act as powerful antioxidants with anti-inflammatory, antimicrobial and anticancer effects Phenolic compounds function as free radical scavengers and help in protection against chronic diseases Coumarins show anticoagulant and anti-inflammatory activities Leucoanthocyanin contributes to antioxidant activity and vascular protection (Anthocyanin provides antioxidant, anti-inflammatory and cardioprotective effects Fatty acids are important for energy metabolism and cardiovascular health (Phlobatannins are known for antimicrobial and wound healing proper. Terpenoids show anti-cancer and anti-inflammatory effects. Alkaloids exhibit analgesic, antimicrobial and neuropharmacological activities

5) *Moullava spicata* *(Dalzell ex Wight) Nicolson* :

Moullava spicata belongs to the family Fabaceae. Its local Marathi name is "Ranmethi" and is a large, thorny woody climber found in forest regions. It climbs over other vegetation and is recognized by its spiny stems and compound leaves. The plant produces yellow flowers arranged in spikes. The leaves and roots are used in traditional medicine. Presence of secondary metabolites in roots is steroids, saponins, tannins, flavonoids, phenolic compounds, leucoanthocyanin, anthocyanin, fatty acids, phlobatannins, terpenoids and alkaloids. Phytochemistry. Steroids have anti-inflammatory and hormonal regulatory roles. Saponins are known for immune-boosting, antimicrobial and cholesterol-lowering properties.

Tannins are used for wound healing and possess astringent properties. Flavonoids act as powerful antioxidants with anti-inflammatory, antimicrobial and anticancer effects. Phenolic compounds function as free radical scavengers and protect against chronic diseases Leucoanthocyanin contributes to antioxidant activity and vascular protection. Anthocyanin provides antioxidant, anti-inflammatory and cardioprotective effects)..Fatty acids support energy metabolism and cardiovascular health. Phlobatannins show antimicrobial and wound healing properties Terpenoids exhibit anti-cancer and anti-inflammatory effects. Alkaloids show analgesic, antimicrobial and neuropharmacological activities

6) *Curcuma pseudomontana* *G. Graham* :

Curcuma pseudomontana belongs to the Zingiberaceae family. The local name is "Ran Halad." It is a rhizomatous herb that grows mainly during the monsoon season in forest areas and grasslands. It has broad leaves and produces beautiful pinkish or purplish flowers. The rhizome is the main medicinal part. Presence of secondary metabolites in bulbs is saponins, tannins, flavonoids, phenolic compounds, fatty acids, terpenoids and alkaloids (**Raghavan Kumar, Anand Singh & Meera Patel, 2022**).

Saponins are known for immune-boosting, antimicrobial and cholesterol-lowering properties. Tannins are used for wound healing and possess astringent properties. Flavonoids act as powerful antioxidants with anti-inflammatory, antimicrobial and anticancer effects. Phenolic compounds function as free radical scavengers and protect against chronic diseases. Fatty acids support energy metabolism and cardiovascular health. Terpenoids exhibit anti-cancer and anti-inflammatory. Alkaloids show analgesic, antimicrobial and neuropharmacological activities It is also sometimes used as a substitute for turmeric in local practices.

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ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

7) *Baliospermum solanifolium* *(Burm.) SureshBaliospermum montanum(Willd)* :
Baliospermum montanum belongs to the Euphorbiaceae family. The local name is "Danti." It is a perennial shrub found in hilly and forest regions, with large leaves, small flowers and fruits. The plant grows well in moist, well-drained soils. The fruit, roots and seeds are the primary parts used medicinally. Presence of secondary metabolites in fruit and seed is steroids, saponins, tannins, flavonoids, phenolic compounds, coumarins, anthocyanins, fatty acids, phlobatannins, terpenoids and alkaloids
Steroids have anti-inflammatory and hormonal regulatory roles. Saponins are known for immune-boosting, antimicrobial and cholesterol-lowering properties. Tannins are used for wound healing and possess astringent properties. Flavonoids act as powerful antioxidants with anti-inflammatory, antimicrobial and anticancer effects. Phenolic compounds function as free radical scavengers and protect against chronic diseases Coumarins show anticoagulant and anti-inflammatory activities Anthocyanin contributes to antioxidant, anti-inflammatory and cardioprotective effects .Fatty acids support energy metabolism and cardiovascular health. Phlobatannins haveantimicrobial and wound healing properties Terpenoids exhibit anti-cancer and anti-inflammatory effects. Alkaloids show analgesic,antimicrobialand neuropharmacological activities
8) *Garcinia talbotii* *Raizada ex Santapau* :
Garcinia talbotii belongs to the Clusiaceae family. The local name is "Rai Amla." It is a medium-sized evergreen tree found in the Western Ghats, with thick leaves and small fruits. The plant prefers humid forest environments. The fruits and bark are commonly used parts. Presence of secondary metabolites in fruit is steroids, tannins, flavonoids, phenolic compounds, coumarins, anthocyanins, and fatty acids Steroids have anti-inflammatory and hormonal regulatory roles. **(**Gupta & Sharma, 2022). Tannins are used for wound healing and possess astringent properties. Flavonoids act as powerful antioxidants with anti-inflammatory, antimicrobial and anticancer effects. Phenolic compounds function as free radical scavengers and protect against chronic diseases. Coumarins show anticoagulant and anti-inflammatory activities. Anthocyanins contribute to antioxidant, anti-inflammatory and cardioprotective effects. Fatty acids support energy metabolism and cardiovascular health.
9) *Pavetta crassicaulis* *Bremek.:*
Pavetta crassicaulis belongs to the Rubiaceae family. The local name is "Papdi." It is a shrub commonly found in forest ecosystems, with thick stems and clusters of small white flowers. The plant grows well in shaded areas. The leaves, flowers, and roots are used for medicinal purposes. Presence of secondary metabolites in the flowers is steroids, saponins, flavonoids, phenolic compounds, fatty acids, and alkaloids
Steroids have anti-inflammatory and hormonal regulatory roles. Saponins are known for immune-boosting, antimicrobial and cholesterol-lowering properties. Flavonoids act as powerful antioxidants with anti-inflammatory, antimicrobial and anticancer effects. Phenolic compounds function as free radical scavengers and protect against chronic diseases. Fatty acids support energy metabolism and cardiovascular health. Alkaloids show analgesic, antimicrobial and neuropharmacological activities

10(*Ficus hispida* L. :
Ficus hispida belongs to the Moraceae family. The local Marathi name is "Umbar." It is a medium-sized deciduous tree commonly found near rivers, streams, and moist forest areas. It has rough leaves and produces fig-like fruits directly on the trunk and branches. The bark, leaves, fruits, and latex are used medicinally. Presence of secondary metabolites in fruits are steroids, saponins, quinones, tannins, flavonoids, phenolic compounds, coumarins, leucoanthocyanin, anthocyanin, fatty acids, phlobatannins, terpenoids and alkaloids (Kumar et al., 2019; Singh et al., 2020.Steroids have anti-inflammatory and hormonal regulatory roles
Saponins are known for immune-boosting, antimicrobial and cholesterol-lowering properties Quinones exhibit antimicrobial and antioxidant activity.
Tannins are used for wound healing and possess astringent properties.Flavonoids act as powerful antioxidants with anti-inflammatory, antimicrobial and anticancer effects Phenolic compounds function as free radical scavengers and protect against chronic diseases. Coumarins show anticoagulant and anti-inflammatory activities. Leucoanthocyanin contributes to antioxidant activity and vascular protection Anthocyanins provide antioxidant, anti-inflammatory and cardioprotective effects. Fatty acids support energy metabolism and cardiovascular health. Phlobatannins show antimicrobial and wound healing properties. Terpenoids exhibit anti-cancer and anti-inflammatory effects. Alkaloids show analgesic, antimicrobial and neuropharmacological activities.
Table showing the floristic diversity present in the plants :

Sr. No.	Name of the Plant	Coumarins	Anthocyanin	Leucoanthocyanin	Fattyacid	Steroids	Saponins	Terpenoids	Quinones	Tannins	Phlobatannins	Phenolic compo	Flavonoids	Alkaloids
1	*Moullava spicata*	-	+	+	+	+	+	+	-	+	+	+	+	+
2	*Elephantopus scaber*	-	-	-	+	+	+	+	-	+	-	+	+	+
3	*Baliospermum montanum*	+	+	-	+	+	+	+	-	+	+	+	+	+

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A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

4	*Curcuma pseudomontana*	+	-	-	+	-	+	+	-	+	-	+	+	+
5	*Pavetta crassiicaulis*	-	-	-	+	+	+	-	-	-	-	+	+	+
6	*Gnetum ula*	+	-	-	+	+	-	+	+	+	-	+	+	+
7	*Ficus hispida*	+	+	-	+	+	+	+	-	+	-	+	+	+
8	*Garcinia talbotii*	+	+	-	+	+	-	-	-	+	-	+	+	-
9	*Aerides maculosum*	-	-	-	+	+	-	-	+	+	-	+	+	+
10	*Amorphophallus commutatus*	+	+	+	+	+	+	+	+	+	+	+	+	+

(Dr.Jagtap Analytics lab Ltd)

Results and Discussion:

The survey of **Phansad Wildlife Sanctuary** focused on identifying and analyzing ten medicinal plant species across diverse habitats, including semi-evergreen, evergreen, dry deciduous forests, and grasslands. The plants, representing families such as **Asteraceae,** Gnetaceae, Orchidaceae, Araceae, Fabaceae, Zingiberaceae, Euphorbiaceae, Clusiaceae, Rubiaceae, and Moraceae, are used by local communities for treating ailments like inflammation, fever, digestive disorders, rheumatism, and general health maintenance . Phytochemical analysis revealed that these species are rich in secondary metabolites, including steroids, saponins, flavonoids, phenolic compounds, terpenoids, alkaloids, fatty acids, coumarins, quinones, anthocyanins, and leucoanthocyanins ***Baliospermum*** *montanum, and Moullava spicata* showed the highest diversity of bioactive compounds, supporting their therapeutic applications. These phytochemicals correlate with traditional uses, providing antioxidant, anti-inflammatory, antimicrobial, analgesic, and cardioprotective effects The findings emphasize the medicinal and ecological significance of the sanctuary and highlight the need for sustainable conservation and utilisation of its plant resources.

Conclusion:

The analysis of medicinal plants in Phansad Wildlife Sanctuary reveals a rich diversity of bioactive compounds across multiple plant families, highlighting their significant therapeutic potential. Among the studied species, *Amorphophallus commutatus, Baliospermum montanum, and Moullava spicata* exhibit the highest diversity of secondary metabolites, including flavonoids, alkaloids, steroids, saponins, phenolics, terpenoids, and fatty acids, making them particularly important for pharmacological applications. Other species such as *Gnetum ula, Curcuma pseudomontana, and Ficus hispida* also contain a substantial range of bioactive compounds, supporting their traditional medicinal uses for treating inflammation, infections, rheumatism, and general health conditions; These results demonstrate the environmental and ethnomedicinal value of the sanctuary and underline the pressing need for effective conservation methods to safeguard these important plant resources for future medicinal, dietary, and research applications.

References

1. Bhatia, Sangeeta, Kumar, Anil, & Verma, Ramesh. (2021). Phytochemical composition and medicinal potential of selected Western Ghats flora. *Journal of Ethnopharmacology*, 268, 113602.
2. Gupta, R., & Sharma, P. (2022). Phytochemistry and medicinal applications of *Garcinia talbotii*. *International Journal of Herbal Research*, 11(2), 34–47.
3. Kumar, Pradeep, Singh, Ravi, & Sharma, Sunita. (2019). Phytochemical analysis and medicinal applications of Indian plant species. *Phytochemistry Reviews*, 18(4), 1023–1045.
4. Patel, Manish, Das, Sanjay, & Rao, Pavan. (2021). Ethnobotanical significance of medicinal plants in the Western Ghats. *Frontiers in Pharmacology*, 12, 680112.
5. Raghavan Kumar, Anand Singh, & Meera Patel. (2022). Phytochemical screening and ethnomedicinal uses of *Curcuma pseudomontana*. *Journal of Herbal Medicine*, 30, 100545.
6. Siddique, A., Khan, M., & Rao, P. (2021). Ethnomedicinal knowledge of coastal communities in the Western Ghats. *Indian Journal of Traditional Knowledge*, 20(1), 12–25.
7. Singh, Manish, & Sharma, Kiran. (2019). Traditional uses and bioactive compounds of Indian medicinal plants. *Journal of Medicinal Plant Research*, 13(5), 210–223.
8. Watts, John, Malavika, J., & Rao, S. (2025). Ecological and conservation significance of the Phansad Wildlife Sanctuary. *Western Ghats Biodiversity Review*, 9(1), 1–15.
9. Wild Konkan Flora Summary. (2025). Medicinal plants of the Western Ghats. *Wild Konkan*, 2(1), 12–25.

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Original Article

Identification and Documentation of Medicinally Important Ornamental Plants from Raigad District, Maharashtra, India

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Manuscript ID:
JRD -2026-180422
ISSN: 2230-9578
Volume 18
Issue 4(XI)
Pp. 128-143
April - 2026
Submitted: 16 Mar. 2026
Revised: 30 Mar. 2026
Accepted: 09 Apr . 2026
Published:30 April2026

Abstract

Plants constitute an integral component of human life, contributing not only to nutrition and fodder but also offering significant aesthetic and therapeutic benefits. Ornamental plants, characterized by diverse morphological attributes such as attractive foliage, vividly coloured and fragrant flowers, and varied growth forms are extensively cultivated in gardens, public parks, and along avenues. Although primarily valued for their ornamental appeal, several of these species possess bioactive compounds that render them important in traditional medicinal systems. The present investigation aims to document and identify medicinally significant ornamental plant species cultivated in gardens, parks, and as avenue trees in Raigad district, Maharashtra, India. Ethnobotanical information pertaining to their traditional medicinal uses was collected through a comprehensive review of scientific literature, coupled with field interactions with traditional healers and knowledgeable local informants. The study recorded a total of 52 ornamental plant species with documented medicinal applications, highlighting the dual ornamental and therapeutic importance of urban flora. The findings underscore the need for systematic documentation and conservation of medicinally valuable ornamental plants and emphasize their potential role in sustainable healthcare and urban biodiversity management. List and details of identified plants are presented in the paper.

***Key words**: Medicinal, Ornamental plants, traditional, garden, therapeutic Raigad*

Introduction:

Ethnobotany deals with the study of traditional knowledge and practices related to the use of plants by indigenous and local communities for various aspects of human welfare. Among the diverse plant resources utilized by humans, ornamental plants occupy a unique position due to their dual role in providing aesthetic value as well as medicinal benefits. Ornamental plants are commonly cultivated in home gardens, public parks, institutional campuses, and along roadsides for their attractive foliage, colourful or fragrant flowers, and diverse growth habits. However, beyond their decorative importance, several ornamental species are traditionally used as therapeutic resources in local healthcare practices. India has a rich heritage of plant-based traditional medicine systems such as Ayurveda, Unani, and Siddha, which extensively utilize plant resources for the prevention and treatment of diseases. Many plants described in the classical texts of these systems are also cultivated as ornamentals, particularly in urban and semi-urban landscapes. Various plant parts, including leaves, flowers, roots, bark, seeds, and latex, are used in the preparation of herbal formulations to treat ailments such as skin diseases, respiratory disorders, digestive problems, fever, inflammation, and wounds. The therapeutic efficacy of these plants is attributed to the presence of bioactive compounds such as alkaloids, flavonoids, tannins, glycosides, and essential oils.

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How to cite this article:
Patil, M. A. (2026). Identification and Documentation of Medicinally Important Ornamental Plants from Raigad District, Maharashtra, India. Journal of Research and Development, 18(4(XI)), 128–143. https://doi.org/10.5281/zenodo.21126350

Quick Response Code:
Website:
https://jrdrvb.org/
DOI:
10.5281/zenodo.21126350
OPEN ACCESS

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Raigad District of Maharashtra, characterized by diverse climatic conditions, coastal influence, forested landscapes, and rich cultural traditions, supports a wide variety of ornamental plant species. The district is home to communities possessing valuable indigenous knowledge, where ornamental plants grown in gardens, temple premises, parks, and as avenue trees are frequently used for medicinal purposes. This traditional knowledge, often transmitted orally through generations, is particularly significant in urban and peri-urban areas where access to wild medicinal plants may be limited.

Despite the widespread cultivation of ornamental plants in Raigad District, their ethnomedicinal importance remains inadequately documented. Rapid urbanization, changing lifestyles, and the erosion of traditional knowledge pose a serious threat to the conservation of this valuable ethnobotanical heritage. Therefore, systematic documentation of ornamental plants with medicinal value is essential not only for preserving indigenous knowledge but also for promoting sustainable utilization and encouraging further pharmacological investigations.

An attempt was made to identify and study ornamental plants used in gardens, parks, and along roadsides in Raigad District that possess medicinal significance, based on a literature survey and information gathered from traditional healers and knowledgeable local informants. Such studies contribute to bridging the gap between ornamental horticulture and traditional medicine, highlighting the role of ornamental plants in human healthcare and welfare.

Material and Methods:

Raigad District, a coastal region situated along the western coast of Maharashtra, India, borders the Arabian Sea, with Alibag serving as its district headquarters. The coastal tract is predominantly characterized by coconut and Arecanut orchards. The district experiences a humid tropical climate with heavy monsoonal rainfall, which supports luxuriant vegetation and promotes high plant diversity throughout the year.

In addition to agricultural and horticultural plantations, landscaped parks and gardens have been developed within industrial complexes, residential colonies, municipal areas, educational institutions, and private premises. These managed green spaces harbour a wide variety of ornamental plant species. Systematic field surveys were conducted across these sites during different seasons to document the ornamental flora and record relevant morphological and ecological characteristics.

A comprehensive inventory of ornamental plants was prepared, including detailed taxonomic information. Species identification was carried out using standard floras and monographs, supplemented by consultations with local nursery experts. Information regarding the medicinal significance of the documented species was obtained through an extensive review of published literature, including authoritative texts on Ayurveda and pharmacognosy, as well as through interactions with homeopathy practitioners and traditional healers possessing ethnomedicinal knowledge. The findings derived from these observations form the basis of the present study and are presented herein.

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ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Observations:

Table No. 1 : List of the plants recorded in the study

Sr. No.	Botanical name of the plant	Family	Ornamental significance	Vernacular / Common Name	Medicinal significance
1.	*Adansonia digitata L.*	Bombacaceae	• Grown as focal point in the garden as well as a border plant	Baobab tree *Gorakhchinch*	• This plant has numerous biological properties including antimicrobial, anti-malarial, diarrhoea, anaemia, asthma, antiviral, anti-oxidant and anti-inflammatory activities.
2.	*Albizia lebbeck* (L.) Benth	Leguminosae	Grown in gardens for its Greenish white Attractive foliage and pale-yellow flowers	Lebbek *Shirish*	• Leaves and seeds are used in the treatment of eye problems such as ophthalmia. • The bark is astringent and is taken internally to treat diarrhoea, dysentery and piles. • The bark is used externally to treat boils. • The flowers are applied locally to maturate boils and alleviate skin eruptions. • The powdered seeds are used to treat scrofula. • Saponin from the pods and roots has spermicidal activity.
3.	*Alocasia indica* (Lour.) Spach	Araceae	• Grown in foliage beds • Also grown as pot plants	Alocasia Indian Taro	• This species is rich in iron content and so the cooked leaf-stalk is given during post-delivery of child birth which helps in the faster recovery. • The leaf blade is slightly roasted on fire directly and applied externally to reduce boils and swellings.
4.	*Aloe vera* (L.) Burm.f.	Asphodelaceae	• Grown in Cactus and succulent gardens. • Grown on Rock gardens • Used in beds or along the borders. • Some specimens are used for pot plants.	*Korphad*	• Juice of leaves boiled and applied externally in Abscess • Juice of leaves given internally in Amenorhagia. • Constipation: Dried leaf pulp powder and turmeric in water is given in Constipation . • It is used as a Liver tonic along with sugar or honey. • Pulp is applied in Fresh burns and Wounds. • Wet cough: Fried leaf pulp with ghee with sugar is employed in wet cough. • Used in cosmetics and other herbal preparations on large scale
5.	*Anthocephalus cadamba* Roxb.	Rubiaceae	• Gown as a focal point tree • Grown in parks for beautiful ball like hanging flowers .	*Kadamb* Tree	• The roots, fruits, leaves, bark skin is used externally on the wounds and ulcers. • Internally, the decoction of bark skin is an effective remedy for diarrhoea, dysentery and colitis. • The juice of bark skin combined with cumin seeds and sugar alleviates vomiting. • The fruit juice augments the amount of breast milk in lactating mothers and also works well as a lactodepurant.
6.	*Asparagus racemosus* Willd.	Liliaceae	• Grown as edge plant • Pot plant	*Shatavari*	• Powder of roots given internally with water in Acidity. • Juice of fresh roots given internally in Urine with burns

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ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

					• Crush tubers with juice is given in Burning sensation of feet.
7.	*Bauhinia variegata L.*	Fabaceae	• Grown as an avenue plant in the parks and gardens.	*Kanchan*	• The bark is used as alterative, anthelmintic, astringent and tonic. • The juice of the bark is used in the treatment of amoebic dysentery, diarrhoea and other stomach disorders. • A paste of the bark is useful in the treatment of cuts and wounds, skin diseases (including leprosy), scrofula and ulcers. • The dried buds are used in the treatment of piles, dysentery, diarrhoea and worms.
8.	*Bougainville a spectabilis*, Willd.	Nyctaginaceae	• It is one of the hardy plants and bear coloured bracts in various colours with minute white flowers. • It is used as hedge plants in gardens and around the bungalow. • It is also used as pot plant with topiary.	*Bougainvel*	• Leaves of Bougainvillea spectabilis are used to heal diabetes. • Plants are used in the treatment of various ailments, including diarrhea, hypotension, gastrointestinal disorders, stomach pain, nausea, and inflammatory diseases, as well as for pain relief.
9.	*Caesalpinia pulcherrima* (L.) Sw.	Caesalpiniaceae	• It is a striking ornamental plant, widely grown in domestic and public gardens. • It is used as hedge plant or a single specimen and has a beautiful inflorescence in yellow, red, and orange.	Peacock flower, *Shankasur*	• A decoction or infusion of the roots, bark, leaves or flowers is used as a purgative • As per the traditional medicine flowers ad roots have abortifacient characters. • The leaves, flowers and seeds are used in the treatment of stomach, urinary bladder and kidney problems.
10.	*Calendula officinalis* (L.) Moench	Asteraceae	• It is a very attractive plant with bright flowers in yellow , orange used for flower beds and borders, edges, as a ground cover and in mass plantings. • It is also used as a pot plant.	Calendula, Pot Marigold	• Oil from the flowers is widely used in skin products. • Leaves are used to made poultice that is believed to help scratches and shallow cuts to heal faster, and to prevent infection
11.	*Canna indica* L.	Cannaceae	• Used for group planting in beds or borders. • Also used in large pots to add colour to the canvas	Canna *Kardal*	• Roots are used in the treatment of fevers. • A decoction of the root, combined with fermented rice, is used in the treatment of gonorrhoea and amenorrhoea. • The leaves and the powdered seeds are mixed and used to treat dermatoses. • Poultice made of seeds and water which is placed on the forehead to remedy headaches.
12.	*Cassia fistula L.*	Fabaceae	• Plants are grown in gardens and parks for its long golden yellow colour inflorescence which	Golden showers *Bahava*	• Seeds used as medicine for treating gastritis and diarrhoea. • The roots are used in the treatment of skin disorders, syphilis, leprosy, and tuberculosis.

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ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

			make this plant very attractive. • It is mostly used as an avenue tree.		• As per the traditional medicines the ripe fruits are used as a laxative medicine prepared by boiling in water.
13.	*Casuarina equisetifolia* L.	Casuarinaceae	• It is an attractive evergreen plant with needle like leaves. • It is used as an avenue tree especially in coastal regions. • It can be trained in any shape and used for topiary in the gardens.	Suru	• Root extracts are used for the treatment of dysentery, diarrhoea and stomach-ache. • A decoction of the twigs is used for treating swelling. • The powdered bark is used for treating pimples on the face.
14.	*Catharanthus roseus* (L.) G. Don	Apocyanaceae	• These are the plants which flowers throughout the year and used for edges, flower beds and as fillers on the ground.	Periwinkl, *Sadafuli*	• This plant has long been used as a traditional medicine. • The alkaloids, isolated from the plant, are highly toxic but have also been shown to reduce the numbers of white blood cells, leading to applications which have revolutionized conventional cancer therapy. • The dried root is an industrial source of ajmalicine and another alkaloid serpentine, are prescribed in the treatment of hypertension. • Extracts prepared from the leaves have been applied externally as antiseptic agents for the healing of wounds; to relieve the effects of wasp stings; against haemorrhage, skin rash and as a mouthwash to treat toothache.
15.	*Celosia argentea* L.	Amaranthaceae	• Pinkish white to silvery white or bright pink dense spikes makes this plant very special. • Plants are widely used in gardens ranging from borders to beds and hanging baskets. • Not only plants but they also make excellent cut flowers. Dried flowers are used in decorative arrangements .	Cock's comb *Kombada*	• Flowers are used in the treatment of bloody stool, haemorrhoid bleeding, uterine bleeding, leucorrhoea, dysentery and diarrhoea. • The seeds of the plant are widely used for the treatment of diabetes mellitus. • The leaves are used in the treatment of infected sores, wounds and skin eruptions.
16.	*Chrysanthemum indicum* L.	Asteraceae	• Plants with Bright coloured, pungent refreshing fragrance flowers in yellow are used as flowerbeds, borders or pot plants. • It makes very attractive corners, island spots when grown in mass.	Indian Chrysanthemum *Shevanti*	• A decoction of the plant is used in the treatment of conditions such as photopsia, vertigo, fever, headache, ophthalmia. • The flowers are used externally, as a poultice and also as a wash, in the treatment of furuncle, scrofula, deep-rooted boils, inflammation of the throat, eyes and cervix, eczema, itchiness of the skin.

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ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

17.	*Clitorea ternatea* L.	Fabaceae	• A good climber specimen suitable for arches, pergolas etc. • May be adopted in a good pot specimen.	Butterfly Pea, *Gokarn*	• Conjunctivitis: The paste of flowers mixed with Cow milk is applied externally on outer parts of the eyes and juice of leaves dropped in the eyes. • Also used in green tea
18.	*Coleus aromaticus* Benth.	Verbenaceae	Use as edge plants and foliage beds, as ornamental pot plants.	Coleus	• Juice of leaves is used in Abdominal pain internally • Leaves are also used in Intestinal worms. • Paste of leaves applied externally on forehead in Headache • Mixture of leaf juice and honey is used in Cough and Cold.
19.	*Crinum asiaticum L.*	Amaryllidaceae	• Plants with large inflorescence and crown of long flowers is suitable for Moist areas of the landscape. Pond peripheries. Borders. Foundations. • It can be grown in pot.	*Harachi phule*	• The juice of the fresh bulb is used as an emetic. • A preparation of the root is given to aid childbirth and for haemorrhage. • A poultice made from the heated, pounded, fresh bulb is used to relieve rheumatism. • The juice from the squeezed leaves is applied to cuts and wounds. • The hairlike threads from the stem are used to poultice cuts.
20.	*Crossandra infundibuliformis* (L.) Nees.	Acanthaceae	• It is cultivated in gardens for colourful ground cover, low hedge or bedding plant. • The flowers add bright colour to partially shady areas. • Suitable in gardens for Flowerbed / Border, Parks & Gardens, Small Gardens, Container Planting	Crossandra *Aboli*	• Leaves are used in various conditions like fever, headache and pain. • It is also used as a remedy for diabetes, leprosy, ulcer, conjunctivitis and skin problems.
21.	*Duranta erecta* L.	Verbenaceae	• This large, fast-growing, much branched shrub is popular as a screen or background planting. • It is also used popularly as a hedge plant.	Golden Dew Drop	• The plant is used in the treatment of fevers, skin itches.
22.	*Eucalyptus globulus* Labill.	Myrtaceae	• Plants are usually grown along the border of the park as a backbone of the landscape. • It is also grown as an Avenue tree • Plant is widely used in Agroforestry.	*Nilgiri*	• The essential oil found in the leaves is a powerful antiseptic and is used all over the world for relieving coughs and colds, sore throats and other infections. • The oil is used externally, applied to cuts, skin infections etc. • It is inhaled for treating blocked nasal passage. • The essential oil is used in aromatherapy.
23.	*Euphorbia milii* Des Moul.	Euphorbiaceae	• As a xerophytic plant suitable in gardens for rock	Crown of thorns	• The plant's latex has been used topically to treat warts, skin infections, and other skin ailments

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			garden. • Well-suited for indoor gardening, as it can be grown in containers, providing year-round interest and enhancing indoor aesthetics with dark red crown of bracts of flowers on spiny stems		
24.	*Hedychium coronarium* J.König	Zingiberaceae	• Plants are used in gardens for its white fragrant flowers. They are used in flower beds. • Plants are placed near pools or waterbodies in the wet area.	Sontakka	• The ground rhizome is used as a febrifuge. A decoction is used to treat pain in the chest and arms. • A decoction of the basal part of the stem is gargled in the treatment of tonsillitis. • An infusion of the leaves is used to treat abdominal complaints. • The boiled leaves are applied to stiff and sore joints.
25.	*Hibiscus rosa-sinensis* L.	Malvaceae	Grown in the garden as an individual plant or as a pot plant	*Jaswand*	• Flower paste in milk is given in Menorrhagia. • Juice of flowers given with sugar and milk in Spermatorhia. • Leaves and flowers are used in herbal preparations for hairs.
26.	*Impatiens balsamina* L.	Balsaminaceae	• Rose colour flowers blooming throughout makes this plant to add aesthetic value. Also available in different colours and shades. • Plants are grown in borders, edges or in flower beds.	Rose balsam *Terada*	• Plant is used in the treatment of pains in the joints. • The leaf juice is used as a treatment against warts. • The crushed leaves are used as a poultice on wounds and skin inflammations. • The flowers are cooling, mucilaginous and tonic. They are useful, having a cooling effect, when applied to burns and scalds.
27.	*Ipomoea palmata* Forssk.	Convolvulaceae	• It is a slender climber, with blue to mauve colour flowers blooming in the early morning. • Suitable for arches, pergolas and for cover in slopy areas.	Morning glory	• The entire plant is used for treating external infections. • The seeds are used as a strong purgative.
28.	*Ixora coccinea L.*	Rubiaceae	• A commonly grown ornamental and hedge plant, being valued especially for its floral display in red inflorescence. Yellow variety is also available • Used as a pot plant also.	*Bakali*	• The leaves and bark are used as a remedy for diarrhoea. • The leaves are used externally to treat sores, ulcers etc. • Roots are used in the treatment of hiccups, fever, gonorrhoea, loss of appetite, nausea, diarrhoea and dysentery. • A decoction or infusion of the roots is administered to clear the urine. • An infusion of the flowers and bark is used in the treatment of blood-shot eyes.
29.	*Jasminium sambac* (L.) Aiton	Oleaceae	Scandent plant grown for white fragrant flowers.	*Mogara*	• Petals of the flower chewed. In Stomatitis • Paste of leaves applied externally on wound. • Paste of flower given internally with sugar

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					and ghee in Burning sensation in abdomen: • Decoction of flowers or leaves is used in Fever or cough.
30.	*Kalanchoe pinnata* (Lam.) Pers. (*Bryophyllum calycinum)*	Crassulaceae	• Grown in Cactus and succulent gardens. • Grown on Rock gardens	Bryophyllum, *Panphuti*	• Leaf juice is used in Gall bladder stone • Juice of leaves applied on wound to check the blood and paste of leaves applied for healing.
31.	*Lagerstroemia speciosa (L.) Pers.*	Lytheraceae	A plant known as Pride of India . Used as a focal point in the garden Also used as an avenue plant in the parks.	*Bondara, Tamhan*	• The leaves are purgative. • A leaf poultice is used to relief malarial fever and is also applied on cracked feet. • A decoction of the bark is used as a treatment against diarrhoea and abdominal pains.
32.	*Lawsonia inermis* L.	Lytheraceae	Used as hedge plant for its evergreen leaves	*Mehandi*	• The leaves are taken internally in the treatment of amoebic dysentery. • They are also used in the treatment of diarrhoea and to promote menstrual flow. • They are used as a gargle to treat sore throats. • The leaves are used externally in the treatment of various skin diseases ,wounds, ulcers and herpes.
33.	*Mimusops elengi* L.	Sapotaceae	Grown in garden for its fragrant flowers. Used as a single specimen or along the borders of the park or landscapes.	*Bakul*	• A decoction of the bark, sometimes mixed with the flowers, is used as a gargle to treat gum inflammation, toothache etc. • The leaves are used to treat headache, toothache, wounds and sore eyes, and are smoked to cure infections of the nose and mouth. • The flowers have been used as a remedy against diarrhoea.
34.	*Mussenda frondosa* L.	Rubiaceae	• Plant has high ornamental value for its bright coloured bracts. • Grown in groups or as a hedge plant • Also grown in a pot as single plant.	Musanda	• The juice of the plant is used to treat eye infections. • A decoction of the leaves is used to rid the body of intestinal worms. • The root is used as a treatment for leprosy. • The flowers are used in the treatment of cough.
35.	*Nelumbo nucifera* Gaertn.	Nympheaceae	• It is one of the best plants for lakes and ponds in gardens. • It is also grown in artificial pools and waterfalls in the garden	*Kamal*	• The leaf juice is used in the treatment of diarrhoea and is decocted with liquorice (Glycyrrhiza sp.) for the treatment of sunstroke. • A decoction of the floral receptacle is used in the treatment of abdominal cramps, bloody discharges etc. • The flower stalk is used in treating bleeding gastric ulcers, excessive menstruation, post-partum haemorrhage. • The stamens are used in treating urinary frequency, premature ejaculation, haemolysis, epistasis and uterine bleeding. • A decoction of the fruit is used in the treatment of agitation, fever, heart complaints etc. • The seed has been shown to lower cholesterol levels and to relax the smooth

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ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

					muscle of the uterus. • Seed are used in the treatment of poor digestion, enteritis, chronic diarrhoea, spermatorrhoea, leucorrhoea, insomnia, palpitations. • The root starch is used in the treatment of diarrhoea, dysentery etc, a paste is applied to ringworm and • Modern research has isolated certain compounds from the plant that show anticancer activity.
36.	*Nerium indicum Mill.*	Apocyanaceae	• Plant has an ornamental value because of its thick, leathery, dark-green leaves arranged in whorls of three or four, and fragrant flowers that are typically pink, or red, growing in terminal clusters. • Planted in gardens as an hedge plant or on border of the garden.	*Kanher*	• Leaves are used for treating scabies, ringworm, skin infections, and insect bites. • Root and root bark are Applied in leprosy, joint pain, and piles. • Flowers are used for inflammation, lumbago, and chronic pain. • Essential oil of the plant is Applied externally for eczema, impetigo, and skin diseases.
37.	*Nyctanthus arbortristis* L.	Oleaceae	• Flowers makes the plant unique , with white fragrant petals and orange colour stalk. • Planted as a single tree or as an avenue plant in the parks.	*Parijatak*	• The flowers are used medicinally to provoke menstruation. • An extract of leaves is given to children for the expulsion of roundworms and threadworms.
38.	*Pandanus odoratissimus* (Forssk.) Kuntze	Pandanaceae	• Plant is grown in the gardens as a pot plant or to prepare a background cover in the sandy region	*Kevada*	• The roots are diuretic, depurative and tonic. They are taken internally
39.	*Passiflora incarnata* L.	Passifloraceae	• It is a very attractive climber with blue flowers with coralline corona. • Plant is suitable to grow on arches, pillars and pergolas	*Krishnakamal*	• The roots are used as a poultice to draw out inflammation in thorn wounds. • Decoction of the root is used in the ear for earache.
40.	*Pedilanthus tithymaloides* L.	Euphorbiaceae	• It is a very sturdy plant The plant makes a good hedge/border plant, which can be trimmed. • It is also used for foliage bed, or as a trimmed pot plant • It is also grown as indoor plant or house	Zigzag plant , *Sher*	• Leaves are widely used to treat inflammation and pain.

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			plant.		
41.	*Plumbago zeylanica* L.	Plumbaginaceae	• A plant suitable for hedges. • Also grown in the corner of medicinal plants • Also grown in beds of flower.	Leadwort, *Chitrak*	• It is a poisonous plant that is used externally and, in small quantities, internally, to treat a range of disorders like treatment for a range of skin problems and intestinal worms. • Chewing the leaves, or drinking a decoction of them, is used as an emmenagogue, but may well act as an abortifacient in the early stages of pregnancy. • The crushed leaves are applied as a poultice to treat a range of skin problems, especially leprosy, scabies, ringworm, dermatitis, acne, sores, ulcers of the leg, haemorrhoids and hookworm; as well as rheumatism and headache.
42.	*Plumeria rubra L.*	Apocyanaceae	• Red fragrant flowers with yellow centre make it attractive. • It is grown as a single focal point tree or it may be grown as an avenue plant .	Frangipani *Tambada chafa*	• The juice of the bark is considered an effective treatment for gonorrhoea and venereal sores. • The scraped bark is used to treat scabies . The juice of the bark is also used to treat amoebic dysentery. • A poultice of the leaves is used to treat muscular swellings. • The milky juice (latex) is used to treat boils and rheumatic pain. • It is also applied to remove worms or germs from wounds. • The sap is used to treat stings of wasps and bees, as well as centipede bites. • A decoction of the flowers is used in treating cough, constipation, acute enteritis, dysentery and haemophilia.
43.	*Polyalthia longifolia*, Thw.	Annonaceae	• Landscaping: Popular as an ornamental tree in gardens, parks, and along avenues due to its symmetrical shape and attractive foliage. • Hedges and Screens: Often planted as a natural screen or hedge because of its dense, columnar growth.		• Various parts of the tree, including leaves, bark, and seeds, are used in traditional medicine. It is believed to have anti-inflammatory, antimicrobial, and antiulcer properties. Used to treat fever, skin diseases, and digestive issues.
44.	*Quisqualis indica L.*	Combretaceae	• It is one of the climbers with clusters of flowers in multiple shades of pink, white and red with pleasant fragrance. • Suitable for arches, pergolas and pillars	Rangoon creeper	• Plant is used as ascariasis, ringworm disease, infant, malnutrition. • Seeds decoction in oil is applied topically in skin diseases. Seeds are the source of fatty oil which is purgative in action. • Leaf juice is used as a lotion for boils and ulcers.
45.	*Rosa indica L.*	Rosaceae	• It is one of the favourite plants in the garden, basically with red and pink	Rose plant *Gulab*	• Rose flowers are Antidepressant, anti-spasmodic, aphrodisiac, astringent, increase bile production, cleansing, anti- bacterial and antiseptic.

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			flowers. • It is grown in rose beds, flower beds or single plant in the pot. • Cut flowers are largely used in making high quality bouquet.		• Rose hips (fruit) tea is also used in the treatment of diarrhoea. • Rose petals are mildly sedative, antiseptic, anti- inflammatory, and antiparasitic. They are also mild laxative, a good supportive tonic for the heart, and useful for lowering cholesterol. The antiseptic nature of rose petals makes them a wonderful treatment for wounds, bruises, rashes and incisions, their anti-inflammatory properties make them a wonderful treatment for sore throats or ulcers. • Rose petals can stimulate the liver and increase appetite and circulation. The extract of the rose petals is used as e drops or eye wash in burning sensation of the eyes.
46.	*Santalum album* L.	Santalaceae	• *Santalum album* is an evergreen tree with variable in habit, usually upright to sprawling, and may intertwine with other species. • Grown in garden as a specific Sandalwood tree. • It is also used as an avenue tree or to form a green backdrop on other plantations.	Sandal wood *Chandan*	• Sandalwood oil was used traditionally to treat skin diseases, acne, dysentery, gonorrhoea, and a number of other conditions.
47.	*Saraca asoca* (Roxb.) Willd.	Fabaceae	• Plant is grown in gardens ana parks for its very attractive orange- yellow bright coloured clusters of flowers. • Plant is used as a single focal point tree or as an avenue tree.	*Ashoka*	• The juice obtained from boiling the bark is a cure for some ailments of women. • Pulp of the blossoms is one of the remedies used for dysentery.
48.	*Tabernaemontana divaricata (L.) R. Br.*	Apocyanaceae	• It is a small sized tree with white flowers flowering throughout the year. • It is used as hedge plant or in beds with mass plantation. • It is also grown in pots.	*Tagar*	• Root decoction is used in the treatment of diarrhoea and various abdominal complaints. • An infusion is applied as a remedy for fever. • The roots are used in modern medicine to treat hypertension, headache, and scabies. • The pounded roots are applied to sore eyes. • An infusion of the leaves is used to treat (influenza). • The flowers, mixed with oil, are applied to sore eyes. • The latex of the leaves is used as a cooling application for wounds to prevent inflammation.
49.	*Tagetus erecta L.*	Asteraceae	• Plants bear variety of flowers in yellow , orange or	*Zendu*	• Different parts of *Tagetes erecta* plant including flower are used as a traditional medicine to cure various

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ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

			in other forms. It has a pleasant fragrance • Plants are suitable in garden for flowerbeds, edging, hedges or even pot plants.		diseases. • Leaves of this plant are used as antiseptic, in kidney troubles, muscular pain, piles and applied to boils and carbuncles. • The flower petals are useful in fevers, epileptic fits, astringent, carminative, stomachic, scabies and liver complaints and is also used in diseases of the eyes.
50.	*Terminalia catapa* L.	Combretaceae	It is a very easy to grow plant and very popular as an avenue tree in the parks. It is also used as a single focal point tree. Eccologically very important as its fruits attracts the birds.	Tropical almond tree *Deshi badam*	• The red leaves act as a vermifuge, while the sap of young leaves, cooked with oil from the kernel, is used to treat leprosy. • The juice of the leaves is ingested for coughs. An infusion of the leaves is used to treat jaundice • The leaves are used to treat indigestion. The young leaves are used to cure headaches and colic. • Externally, the leaves may be rubbed on breasts to cure pain or, when heated, may be applied to numb parts of the body. • The leaves are also used as a dressing for swollen rheumatic joints. • Externally, the bark is used to treat sores, pimples and fungal skin diseases. • The kernel of the fruit mixed with beeswax stops putrid exudation and bloody faeces. It is recommended as a mild laxative.
51.	*Thevetia nerifolia* (Pers.) K. Schum.	Apocyanaceae	• Grown as a hedge plant as leaves contains latex. • Narrow leaves and flowers of yellow, white, orange varieties also make it attractive.	Yellow oleander , *Bitti*	• Latex is applied to decayed teeth to relieve toothache • The juice of the macerated bark is used for treating sores. • The oil from the kernel is applied topically to treat skin complaints. • An infusion of the roots is taken to treat snakebites
52.	*Thuja occidentalis* L.	Cupressaceae	• It is an evergreen shrub that is extensively planted in landscaping for hedges, borders, and windbreaks. • It's forever green leaves make gardens more beautiful. It is also used in topiary. • Thuja's dense growth also gives privacy and serves as a natural sound barrier in outdoor settings.	*Morpankhi suru*	• Thuja has been a part of traditional herbal medicine. Its leaves and essential oils contain compounds with anti-inflammatory, antifungal, and antiseptic properties. • Used in steam inhalation to ease congestion and coughs. • Helps in treating warts, eczema, and fungal infections. • Thuja extracts are often found in homoeopathic medicines to strengthen immunity

Results:

The present study on medicinal ornamental plants recorded a total of 52 plant species belonging to 35 families, indicating a moderate level of plant diversity in the study area. Among the recorded families, Apocynaceae was the most dominant, contributing five species, which account for approximately 9.61% of the total flora. This dominance may be attributed to the family's adaptability to diverse environmental conditions and the presence of a greater number of ornamental species with medicinal value.

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ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

It is followed by the family Fabaceae with four species, while Asteraceae and Rubiaceae are represented by three species each. The presence of multiple families with only one or two representative species suggests a wide ecological range, although with limited representation in certain groups. Other families, including Combretaceae, Euphorbiaceae, Lythraceae, Oleaceae, and Verbenaceae, are represented by two species each. The remaining 26 families are represented by a single species each.

Although these species were recorded as ornamental plants from parks, gardens, and landscaped areas, many of them are widely adopted across Raigad District, indicating their ecological adaptability. Only one species belonging to the family Cupressaceae represents the gymnosperms in the present study.

Photographs of Some of the plants recoded during the study

Spider Lilly	Ixora	Golden Cassia	Hibiscus
Coleus plant	**Garden Roses**	**Vinca / Sadafuli**	**Mussaenda**
Plumeria	**Jasmine flowers**		**Oleander**

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ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Ashok

Marigold

Madhumalati

Crossandra

Passion flower

Pandanus

Euphorbia milli

Yellow oleander

Canna and

Kadamb tree

Bougainvillea

Peacock flowers

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ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Tagar- Pinwheel flower	**Bakul flowers**

Discussion:

The study revealed that plants grown in home gardens are commonly used by local people for primary healthcare to treat various ailments. Many of these plants are primarily cultivated for their aesthetic value, yet they also serve important medicinal purposes. Several of the recorded species have been cultivated since ancient times, particularly in gardens associated with temples and palaces.

Ornamental plants are mainly grown for their aesthetic appeal, including attractive foliage, vibrant flowers, pleasant fragrance, and diverse growth forms. They play a significant role in enhancing the visual quality of gardens, parks, urban landscapes, and roadside avenues. In addition to their decorative value, ornamental plants contribute to environmental improvement by reducing air pollution, regulating microclimates, and promoting psychological well-being among urban populations.

Beyond their ornamental importance, many of these plants possess valuable medicinal properties and have been utilized in traditional systems of medicine since ancient times. Different plant parts such as leaves, flowers, bark, roots, seeds, and latex contain bioactive compounds, including alkaloids, flavonoids, glycosides, terpenoids, phenolics, and essential oils. These compounds exhibit various therapeutic activities such as anti-inflammatory, antimicrobial, antioxidant, antidiabetic, and anticancer effects. However, despite their widespread availability in urban and peri-urban areas, the medicinal potential of ornamental plants remains underutilized and inadequately documented.

In recent years, growing interest in herbal medicine and plant-based healthcare has renewed attention toward ornamental plants as accessible sources of traditional remedies, particularly in urban settings where medicinal herbs may be less readily available. Many ornamental species commonly grown in gardens and public spaces are used by traditional healers and local communities to treat common ailments, thereby serving a dual role in beautification and healthcare support.

Systematic documentation and scientific evaluation of ornamental plants with medicinal value are essential for conserving traditional knowledge, promoting sustainable utilization, and identifying potential leads for pharmacological research.

Conclusion:

The primary objective of the present study was to document ornamental plants with medicinal potential that are used by local communities for primary healthcare. Based on field observations and information collected from various sources, several key conclusions can be drawn.

Firstly, many of the recorded species are not commonly used in traditional or folk medicine; however, a review of the literature confirms their medicinal potential. Secondly, a large number of these plants are cultivated primarily for ornamental purposes without any intended medicinal use, yet knowledgeable local residents occasionally utilize them for healthcare based on traditional knowledge. Thirdly, although most of the documented species possess therapeutic properties for treating various ailments, a significant proportion of the population remains unaware of their medicinal value. Therefore, such documentation is highly relevant for increasing awareness and preserving ethnobotanical knowledge.

The scope of the present study was limited to ornamental plants cultivated in gardens, parks, and landscaped areas. However, it was observed that certain species, even when grown on a small scale, possess considerable medicinal potential. These plants are readily accessible to local gardeners and labourers, who have also validated their therapeutic uses through traditional practices.

Further research is required to investigate the pharmacological properties and homeopathic applications of these species, as well as to standardize their medicinal use. A total of 52 such ornamental plant species from Raigad District have been documented and discussed in this study.

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A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

References :

1. Anamika Chaudhari, Bhawna Singh, A Critical Review of Karvira (*Nerium indicum* Mill), International Journal of Ayurveda & Medical Sciences I, April- June, Vol 1 I Issue 2
2. Anupam Bishayee, et al. (2022) , Lotus (*Nelumbo nucifera* Gaertn.) and Its Bioactive Phytocompounds: A Tribute to Cancer Prevention and Intervention. Cancers (Basel).;14(3):529.
3. Catalogue of Life, *Mussaenda frondosa* L. Sp. Pl.: 177 (1753)
4. Das, S., Dubey, A., & , D. (2022).Tabernaemontana divaricate : A Herbal Panacea. Journal of Natural Remedies, 22(4), 549–562.
5. Bown. D. (1995), Encyclopaedia of Herbs and their Uses Dorling Kindersley, London. ISBN 0-7513-020-31
6. Fructuoso Ayala Guerrero et al (2017), Effect of a medicinal plant (*Passiflora incarnata* L) on sleep. Sleep Sci.10(3):96–100.
7. Gayle Fritz (Ilias Zournatzis, et al. (2025), *Calendula officinalis* - A comprehensive review. Pharmacological Research - Natural Products, Volume 6.
8. Jai C Tilak, et al (2004), Antioxidant properties of Plumbago zeylanica, an Indian medicinal plant and its active ingredient, plumbagin.
9. Monisha Prasad, et al. (2025), Exploring the potential of *Rosa chinensis*, *Rosa cymosa*, and *Rosa indica* in oral disease prevention: A multifaceted approach. J Oral Maxillofac Pathol. 2025 Mar 28;29(1):41–49.
10. Ramanan S S, Arunachalam A, Singh R, Verdiya A. (2024) Tropical almond (*Terminalia catappa*): A holistic review. Heliyon.;11(1):e41115
11. Singh, Yogendra & Gupta, Amit & Kannojia, Pushpendra. (2020). Tagetes erecta (Marigold) -A review on its phytochemical and medicinal properties. CURRENT MEDICAL AND DRUG RESEARCH. 4. 10.53517/CMDR.2581-5008.

a. Weblinks :

12. *Mussaenda frondosa* L. in GBIF Secretariat (2023). GBIF Backbone Taxonomy. Checklist dataset https://doi.org/10.15468/39 omei accessed via GBIF.org on 2026-01-18.
13. Tropical Plants Database,(2024),Ken Fern. tropical.theferns.info.2026-01 17.<tropical.theferns.info/viewtropical.php?id=Mussaenda+frondosa>
14. Tropical Plants Database, Ken Fern. tropical.theferns.info.2026-01-18. <tropical.theferns.info/viewtropical.php?id=Nelumbo+nucifera>
15. Tropical Plants Database, Ken Fern. tropical.theferns.info. 2026-01-18. <tropical.theferns.info/viewtropical.php?id=Nyctanthes+arbor-tristis>
16. Tropical Plants Database, Ken Fern. tropical.theferns.info. 2026-01-18. <tropical.theferns.info/viewtropical.php?id=Pandanus+odorifer>
17. Tropical Plants Database, Ken Fern. tropical.theferns.info. 2026-01-18. <tropical.theferns.info/viewtropical.php?id=Plumbago+zeylanica> https://www.keralauniversity.ac.in/digital_garden/165.html
18. 'WFO (2026): *Nerium indicum* Mill. Published on the Internet;http://www.worldfloraonline.org/taxon/wfo-0000251562.
19. 'WFO (2026): *Rosa indica* L. Published on the Internet;http://www.worldfloraonline.org/taxon/wfo-0001014404. Accessed on: 21 Jan 2026'
20. 'WFO (2026): *Santalum album* L. Published on the Internet;http://www.worldfloraonline.org/taxon/wfo-0000492946. Accessed on: 22 Jan 2026'

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A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Original Article

In vitro Assessment of Antihyperglycemic Potential of *Sonneratia Alba* Fruit Extract via Enzyme Inhibition

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Manuscript ID:
JRD -2026-180423
ISSN: 2230-9578
Volume 18
Issue 4(XI)
Pp. 144-149
April - 2026
Submitted: 16 Mar. 2026
Revised: 30 Mar. 2026
Accepted: 09 Apr . 2026
Published:30 April2026

Abstract

Persistent elevation of blood glucose levels is a major hallmark of diabetes mellitus and is closely linked with long-term metabolic complications. The increasing demand for safer and more effective natural antihyperglycemic agents has directed attention toward plant-based therapeutics. *Sonneratia alba*, a mangrove species rich in bioactive phytoconstituents, has been traditionally employed for various medicinal purposes and is considered a promising candidate for glycemic control. The present study was designed to investigate the antihyperglycemic potential of *S. alba* fruit extract through in vitro enzyme inhibition assays targeting major carbohydrate-hydrolyzing enzymes. Preliminary phytochemical screening revealed the presence of phenolics, flavonoids, and tannins, which are known to contribute significantly to glucose regulation. The inhibitory activity of the extract was evaluated against α-amylase and α-glucosidase enzymes, demonstrating a clear concentration-dependent response. At 600 µg/mL, the extract exhibited 50.00% inhibition of α-amylase and 40.76% inhibition of α-glucosidase. The IC_{50} value for α-amylase inhibition was recorded as 598.24 µg/mL for the extract, compared to 332.14 µg/mL for the standard drug acarbose. Similarly, in the α-glucosidase assay, the extract showed an IC_{50} value of 710.38 µg/mL, whereas acarbose demonstrated a lower IC_{50} of 332.14 µg/mL.

Overall, the findings indicate that *S. alba* fruit extract possesses significant enzyme inhibitory activity and may serve as a potential natural agent for the management of postprandial hyperglycemia. Further studies focusing on the isolation of active constituents and in vivo validation are warranted to establish its therapeutic applicability and clinical relevance.

Keywords: *Sonneratia alba*; Antihyperglycemic activity; α-amylase inhibition; α-glucosidase inhibition; Phytochemicals; Natural therapeutics

Introduction

Sonneratia alba Sm., a true mangrove species belonging to the family Sonneratiaceae, is widely found in tropical and subtropical coastal mangrove ecosystems. It is typically distributed in intertidal regions and is morphologically distinguished by its evergreen nature, broad spreading crown, conical pneumatophores, opposite leaves, solitary white flowers, and fleshy berry-like fruits. The fruits are reported to contain a wide range of bioactive phytoconstituents, including phenolics, flavonoids, tannins, alkaloids, saponins, glycosides, and other secondary metabolites, which may contribute to their medicinal importance[(28)].

Traditionally, various parts of this plant have been employed in the management of different ailments, reflecting its established ethnomedicinal relevance[(6),(20)]. In recent years, mangrove-derived plants have attracted increasing scientific interest as potential sources of antidiabetic agents because of their phytochemical richness and ability to modulate postprandial hyperglycemia and oxidative stress. Among these, *Sonneratia* species have demonstrated promising antidiabetic activity through the inhibition of key carbohydrate-hydrolysing enzymes such as α-amylase and α-glucosidase, along with notable antioxidant potential[(24),(21),(11)]. Hence, *S. alba* fruits may represent a promising natural candidate for the development of plant-based antidiabetic therapeutics.

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DOI: 10.5281/zenodo.21126402
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How to cite this article:
Zate, R., & Desai, N. (2026). In vitro Assessment of Antihyperglycemic Potential of Sonneratia Alba Fruit Extract via Enzyme Inhibition. Journal of Research and Development, 18(4(XI)), 144–149. https://doi.org/10.5281/zenodo.21126402

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Review of literature

Phytochemical Profile of *Sonneratia* Species

Phytochemical studies on *Sonneratia* species have revealed the presence of diverse bioactive secondary metabolites. Fruit extracts were reported to contain nor-lignans, benzo[b,d]pyran-6-one derivatives, and triterpenoids, with some compounds identified for the first time in this genus[32]. In *S. apetala*, fruits and methanolic seed fractions were found to contain alkaloids, tannins, glycosides, flavonoids, and phenolic compounds such as caffeic acid, catechin, epicatechin, ellagic acid, gallic acid, and quercetin[18][19].

Similarly, *S. alba* extracts showed the presence of flavonoids, xanthosine, tannins, and related derivatives[26][33], while *S. caseolaris* fruit extracts exhibited high flavonoid and phenolic content[10]. In addition, *S. alba* leaves were reported to contain saponins, tannins, flavonoids, phenolics, and triterpenoids[15].

These findings support the phytochemical richness of *Sonneratia* species and provide a strong basis for their reported medicinal and antihyperglycemic potential.

Reported Antihyperglycemic /Antidiabetic activity

Antidiabetic activity has been reported in several *Sonneratia* species, including *S. alba*, *S. apetala*, and *S. caseolaris*. The fruits of *S. caseolaris* are widely utilized in traditional medicine for their therapeutic properties[5]. Bioactive compounds such as oleanolic acid, β-sitosterol-β-D-glucopyranoside, and luteolin, isolated from the methanolic fruit extract, have demonstrated significant α-glucosidase inhibitory activity in a dose-dependent manner[30]. Moreover, methanolic extracts of the fruits have been shown to markedly reduce serum glucose levels in glucose-loaded mice, also in a dose-dependent fashion[25,17].

The observed antihyperglycemic effects may be attributed to multiple mechanisms, including reduced intestinal glucose absorption, enhanced pancreatic secretion, increased glucose uptake, improved insulin release, and overall better glycemic regulation[22]. Similarly, the antihyperglycemic activity of seeds and pericarps of *S. apetala* fruits has been demonstrated in streptozotocin (STZ)-induced diabetic mice[18]. The underlying mechanisms may involve insulin-mimetic activity, enhanced glucose utilization, regeneration of the Islets of Langerhans in the pancreas, and increased peripheral glucose uptake.

Materials and Methods

Study Area

The study area is located in the Konkan coastal region of Maharashtra, India, specifically in Sindhudurg district. The region is rich in mangrove biodiversity, where *Sonneratia alba* is abundantly distributed along the coastal habitats. The geographical coordinates of the study area range between 15.9°N–16.5°N latitude and 73.5°E–74.2°E longitude.

Extraction of Plant Material

Freshly collected fruits were washed, finely cut, and extracted with methanol using an ultrasonic bath (Labline) under controlled conditions. The extract obtained was then collected and used for subsequent antidiabetic analysis based on a reported method with slight modifications [4].

Alpha-amylase inhibitory assay

The α-amylase inhibitory activity of the *S. alba* fruit extract was determined using a modified standard procedure **[24]**.A 0.5% (w/v) starch solution was prepared by heating potato starch in distilled water. The enzyme solution was prepared by dissolving porcine pancreatic α-amylase (1 mg) in 100 mL of 20 mM phosphate buffer (pH 6.9).

Different concentrations of the extract were prepared using dimethyl sulfoxide (DMSO). For the assay, 1 mL of the extract was mixed with 1 mL of enzyme solution and incubated at 25°C for 30 minutes. After incubation, 1 mL of this mixture was combined with 1 mL of starch solution and further incubated for 3 minutes.

The reaction was terminated by adding 1 mL of 3,5-dinitrosalicylic acid (DNS) reagent, followed by heating the mixture in a water bath at 85°C for 15 minutes. After cooling, the mixture was diluted with distilled water, and absorbance was measured at 540 nm.

A control was prepared by replacing the extract with DMSO, while a blank was prepared by adding DNS reagent before the addition of starch solution. Acarbose was used as a positive control. The percentage inhibition was calculated using the following formula:

$\% \text{ inhibition} = [(Ac - As) / Ac] \times 100$

Alpha-glucosidase inhibitory assay

The α-glucosidase inhibitory activity was evaluated using a modified standard method **[21]**. The reaction mixture consisted of α-glucosidase enzyme (1.0 U/mL), p-nitrophenyl-α-D-glucopyranoside (pNPG) as a substrate, and different concentrations of the extract prepared in sodium phosphate buffer (pH 6.9).

Control samples contained DMSO instead of the extract, while acarbose was used as a standard reference. Blank samples were prepared without enzyme.

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

The reaction mixtures were incubated at 25°C for 5 minutes. The reaction was terminated by heating in a boiling water bath for 2 minutes. The release of p-nitrophenol was measured at 405 nm using a spectrophotometer. The percentage inhibition was calculated, and IC_{50} values were determined from inhibition curves using regression analysis. All experiments were carried out in triplicate.

Result and discussion

Table 1. In vitro α-Amylase Inhibitory Activity of *S. alba* Fruit Extract

Concentration µg/ml	Acarbose% inhibition	Fruit extract % inhibition
200	22.48%	3.69%
400	60.74%	28.19%
600	66.11%	50.00%
IC_{50} Value	332.14 µg/mL	598.24 µg/mL

In vitro α-Amylase Inhibitory Activity

The α-amylase inhibitory effect of the *S. alba* fruit extract increased progressively with increasing concentration within the tested range (200–600 µg/mL). Although the extract exhibited measurable inhibition, its activity was lower than that of acarbose, as indicated by the higher IC_{50} value. These findings suggest a moderate level of enzyme inhibition, which may be attributed to the presence of bioactive compounds that help reduce carbohydrate breakdown.

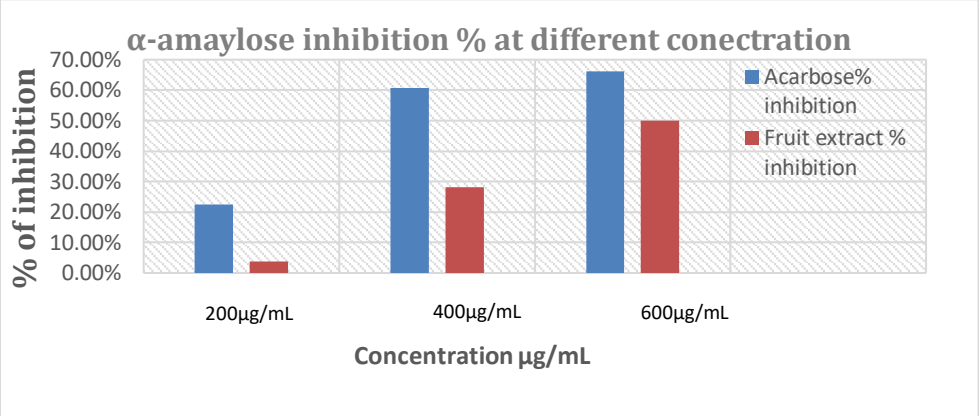

Figure 1: α-amylase inhibition (%) of acarbose and *S. alba* extract at 200–600 µg/mL.

Table 2. In vitro α-Glucosidase Inhibitory Activity of *S. alba* Fruit Extract

Concentration µg/ml	Acarbose% inhibition	Fruit extract % inhibition
200	22.48 %	17.88%
400	60.74%	23.16%
600	66.11%	40.76%
IC50 Value	332.14 µg/mL	710.38µg/mL

In vitro α-Glucosidase Inhibitory Activity

The inhibitory activity of α-glucosidase by the *S. alba* fruit extract showed a concentration-dependent pattern. However, the level of inhibition was comparatively lower than that of acarbose, as reflected by the higher IC_{50} value. These results indicate moderate enzyme inhibitory activity, which may contribute to slower carbohydrate digestion and decreased glucose absorption.

Journal of Research and Development
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ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

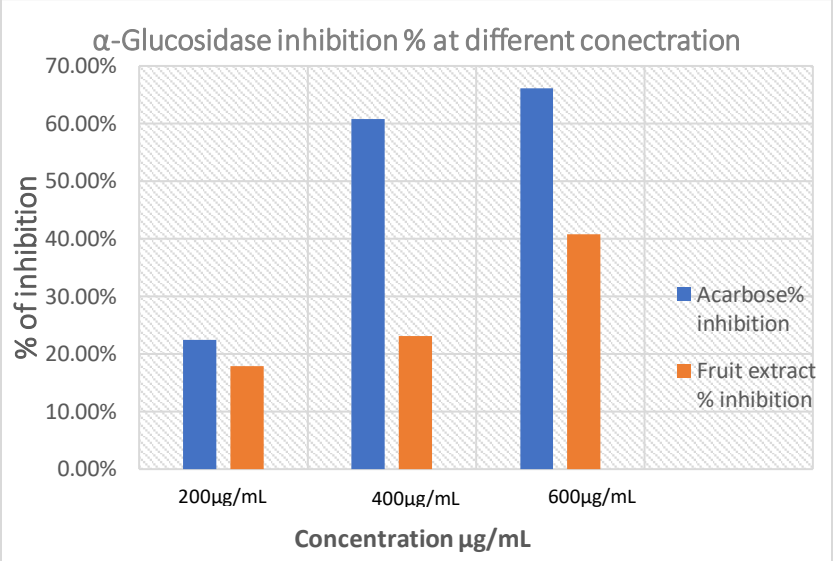

Figure 2: α-glucosidase inhibition (%) of acarbose and *S. alba* extract at 200–600 µg/mL

Discussion

The findings of the present study demonstrate that ***Sonneratia alba*** fruit extract exhibits concentration-dependent inhibitory effects against both α-amylase and α-glucosidase enzymes (Table 1; Figure 1 and Table 2; Figure 2). In the α-amylase assay, the extract showed moderate inhibitory activity compared to acarbose, as indicated by its relatively higher IC_{50} value. Similarly, in the α-glucosidase assay, the extract displayed lower inhibition than the standard drug, although a consistent increase in activity was observed with increasing concentration.

These observations suggest that the extract may suppress the activity of carbohydrate-digesting enzymes, thereby contributing to the regulation of postprandial blood glucose levels, which is in agreement with previously reported studies on enzyme inhibition [21,24].

The inhibitory potential of the extract may be attributed to the presence of phytochemicals such as phenolics, flavonoids, and tannins, which are known for their enzyme inhibitory and antidiabetic properties [11,27]. These compounds may interact with enzyme active sites and reduce their activity, leading to improved glycemic control.

Furthermore, the dose-dependent response observed in both assays indicates that increasing the concentration enhances the inhibitory effect. Although the activity was lower than acarbose, the findings highlight the potential of ***S. alba*** as a natural antihyperglycemic agent. However, further studies are required to isolate active constituents and validate their efficacy through in vivo investigations [22,25].

Conclusion

In conclusion, ***Sonneratia alba*** fruit extract showed moderate in vitro antihyperglycemic activity by inhibiting α-amylase and α-glucosidase enzymes. Although its effectiveness was lower than that of the standard drug acarbose, the extract displayed a clear concentration-dependent response, suggesting the presence of bioactive compounds with enzyme inhibitory properties. These results indicate that *S. alba* could be a potential natural source for managing postprandial hyperglycemia. However, further research focusing on the isolation of active compounds and in vivo studies is necessary to confirm its therapeutic potential.

Acknowledgment

The authors gratefully acknowledge the Mangrove and Marine Biodiversity Conservation Foundation of Maharashtra for providing financial support under Project No. MFN/DDR&CB/S/54/2021–25. The authors express sincere thanks to Dr. Sandesh Jagdale, Principal, for his valuable guidance and continuous support. The authors also thank the laboratory for providing the necessary facilities.

Reference

1. Ali M, Nahar K, Sintaha M, Khaleque HN, Jahan FI, Biswas KR, et al. An evaluation of antihyperglycemic and antinociceptive effects of methanol extract of *Heritiera fomes Buch-Ham.(Sterculiaceae)* bark in Swiss albino mice. Adv Nat Appl Sci. 2011;5:116–21.
2. Asad S, Asad S, Hamiduzzaman M, Azam Z, Ahsan M, Masud M. Lupeol, oleanic acid and steroids from *Sonneratia alba J.E.Sm.* (Sonneratiaceae) and antioxidant, antibacterial and cytotoxic activities of its extracts. Int J Adv Res Pharm Bio Sci. 2013;3(1).
3. Astuti MD, Rosyidah K, Umaningrum D, Ardiyanti R, Rasyied HJA, Azzahra AP. The antioxidant activity and total phenolic content of *Sonneratia ovata* Back.Malays J Fundam Appl Sci. 2023;19:215–218.

4. Aznar-Ramos MJ, Razola-Díaz MC, Verardo V, Gómez-Caravaca AM. Comparison between ultrasonic bath and sonotrode extraction of phenolic compounds from mango peel by-products. Horticulturae. 2022;8(11):1014.
5. Bandaranayake WM. Bioactivities, bioactive compounds and chemical constituents of mangrove plants. Wetl Ecol Manag. 2002;10:421–52.
6. Bandaranayake WM. Traditional and medicinal uses of mangroves. Mangroves Salt Marshes. 1998;2(3):133–48.
7. Bastaki S. Diabetes mellitus and its treatment. Int J Diabetes Metab. 2005;13:111–34.
8. Bhushan MS, Rao CHV, Ojha SKM, Verma VA. An analytical review of plants for antidiabetic activity with their phytoconstituents and mechanism of action. Int J Pharm Sci Res. 2010;1:29–46.
9. Bloch-Damti A, Bashan N. Proposed mechanisms for the induction of insulin resistance by oxidative stress. Antioxid Redox Signal. 2005;7:1553–1567.
10. Bokshi B, Zilani MNH, Hossain H, Ahmed MI, Anisuzzman M, Biswas NN, et al. Bioactivities of *Sonneratia caseolaris* leaf and stem using different solvent systems. Biomed J Sci Tech Res. 2020;31(5):24578–24582.
11. Bräunlich M, Slimestad R, Wangensteen H, Brede C, Malterud KE, Barsett H. Extracts, anthocyanins and procyanidins from *Aronia melanocarpa* as radical scavengers and enzyme inhibitors. **Nutrients.** 2013;5(3):663–678.
12. Budi SB, Sulistiyati TD, Hardoko. Phytochemicals and identification of antioxidant compounds from ethanol extract of *Sonneratia alba* leaves and bark. Russian Journal of Agricultural and Socio-Economic Sciences. 2019; 11(95): 190.
13. Bunyapraphatsara N, Jutiviboonsuk A, Sornlek P, Therathanathorn W, Aksornkaew S, Fong HHS, et al. Pharmacological studies of plants in the mangrove forest. J Phytopharm. 2003;10:1–12.
14. Deviarni IM, Yunus A, Prabawa S, Anam C. Antioxidant activity and bioactive compound identification in *Sonneratia alba* fruit. IOP Conference Series: Earth and Environmental Science. 2025; 1490: 012029.
15. Dotulong V.,Nishani F., Daliu P. et al. Aqueous leaves'extract of *Sonneratia alba*: secondarymetabolites with antibacterial activity for functional food applications. Discov Appl Sci (2026)
16. Gawali P, Jadhav BL. Antioxidant activity and antioxidant phytochemical analysis of mangrove species *Sonneratia alba* and Bruguiera cylindrica. Asian Journal of Microbiology, Biotechnology and Environmental Sciences. 2011; 13(2): 257–261.
17. Hasan MN, Sultana N, Akhter MS, Billah MM, Islam KK. Hypoglycemic effect of methanolic extract from fruits of *Sonneratia caseolaris*. J Innov Dev Strategy. 2013;7:1–6.
18. Hossain SJ, Basar MH, Rokeya B, Arif KMT, Sultana MS, Rahman MH. Evaluation of antioxidant, antidiabetic and antibacterial activities of the fruit of *Sonneratia apetala*. Ori Pharm Exp Med. 2013;13:95–102.
19. Hossain SJ, Iftekharuzzaman M, Haque MA, Saha B, Moniruzzaman M, Rahman MM, Hossain H. Nutrient compositions, antioxidant activity, and common phenolics of *Sonneratia apetala* (Buch.-Ham.) fruit. International Journal of Food Properties. 2016; 19(5): 1080–1092.
20. Kulkarni CP, Manohar SM. A review of botany, phytochemistry, and pharmacology of the mangrove apple *Sonneratia alba* J Sm. J Appl Pharm Sci. 2024;14(5).
21. Matsui, T.; Yoshimoto, C.; Osajima, K.; Oki, T.; Osajima, Y. *In vitro* survey of α-glucosidase inhibitory food components. *Biosci. Biotechnol. Biochem.* 1996, *60*, 2019–2022.
22. Morada NJ, Metillo EB, Uy MM, Oclarit JM. Anti-diabetic polysaccharide from *Sonneratia alba*.Sm. International Conference on Asia Agriculture and Animal. Int Proc Chem Biol Environ Eng 2011;3:197–200.
23. Murugan K, Dinesh D, Paulpandi M, Subramaniam J, Rakesh R, Amuthavalli P, Panneerselvam C, Suresh U, Vadivalagan C, Alsalhi M, Devanesan S, Wei H, Higuchi A, Nicoletti M, Canale A & Benelli G , Mangrove helps: *Sonneratia alba*-synthesized silver nanoparticles magnify guppy fish predation against Aedes aegypti young instars and down-regulate the expression of envelope (E) gene in dengue virus (Serotype DEN-2). Journal of Cluster Science. 2017; 28: 437–461.
24. Nickavar B, Yousefian N. Inhibitory effects of six *Allium* species on α-amylase enzyme activity. Iran J Pharm Res. 2009;8(1):53–7.
25. Rahmatullah M, Azam MNK, Pramanik S, Sania, Rahman S, Jahan R. Antihyperglycemic activity of *Curcuma zedoaria* and *Sonneratia caseolaris*. Int J Pharm Tech Res. 2012;4:125–9.
26. Riyadi PH, Anggo AD, Egayanti IP, Arifin MH. Identification of bioactive content in pedada fruit vinegar (*Sonneratia alba*) as an antioxidant potential. Journal of Advances in Food Science & Technology. 2022; 9(3): 38–46.

27. Russo D, Valentão P, Andrade PB, Fernandez EC, Milella L. Evaluation of antioxidant, antidiabetic and anticholinesterase activities of *Smallanthus sonchifolius* landraces and correlation with their phytochemical profiles. International Journal of Molecular Sciences, 2015;16(8):17696–718.
28. Siahaya VG, Moniharapon T, Mailoa MN, Leatemia JA. Potential of mangrove apples (*Sonneratia alba*) as a botanical insecticide. Modern Applied Science. 2018;12(1):1
29. Surya PRA, Wijaya MD, Udiyani DPC. Phytochemical screening and antioxidant activity analysis of N-hexane extract of *Sonneratia alba* mangrove leaves. Biology, Medicine, & Natural Product Chemistry. 2023; 12(2).
30. Tiwari AK, Viswanadh V, Gowri PM, Ali AZ, Radhakrishnan SVS, Agawane SB, et al. Oleanolic acid as α-glucosidase inhibitory compound from *Sonneratia caseolaris*. Open Access J Med Aromat Plants. 2010;1:19–23.
31. Widhyastini IGAM, Salampessy ML, Ermayanti NGAM. Phytochemical composition of Sonneratia alba mangrove leaves and fruits. Forest and Nature. 2025; 1(3): 152–158.
32. Wu SB, Wen Y, Li XW, Zhao Y, Zhao Z, Hu JF. Chemical constituents from the fruits of *Sonneratia caseolaris* and *Sonneratia ovata* (Sonneratiaceae). Biochemical Systematics and Ecology. 2009; 37: 1–6.
33. Wonggo D, Anwar C, Dotulong V, Reo A, Taher N, Syahputra RA, Nurkolis F, Tallei TE, Kim B, Tsopmo A. Subcritical water extraction of mangrove fruit extract (*Sonneratia alba*) and its antioxidant activity, network pharmacology, and molecular connectivity studies. Journal of Agriculture and Food Research. 2024; 18: 101334.

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Original Article

In Vitro micropropagation of rheophytic Bucephalandra pygmy 'Wavy Dark Green' for sustainable conservation and commercial aquascaping applications.

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Manuscript ID:
JRD -2026-180424
ISSN: 2230-9578
Volume 18
Issue 4(XI)
Pp. 150-156
April - 2026
Submitted: 16 Mar. 2026
Revised: 30 Mar. 2026
Accepted: 09 Apr . 2026
Published:30 April2026

Abstract

Bucephalandra pygmy 'Wavy Dark Green', rheophytic aquatic plants widely used in aquascaping, are increasingly threatened due to slow natural growth and overharvesting driven by high market demand. This study aimed to develop an efficient in vitro micropropagation protocol for sustainable conservation and commercial production.

Plant materials collected from commercial sources were acclimatized in controlled conditions and initially cultured on Murashige and Skoog (MS) medium for establishment. Thereafter, cultures were transferred to different basal media (MS, Gamborg's B5, and White's medium) for optimization of growth response. Among these, MS medium showed the best response in terms of survival, shoot induction and plantlets. Further optimization using plant growth regulators revealed that NAA+ BAP combination significantly enhanced shoot proliferation and plantlet development, compared to other treatments.

The developed protocol enables rapid multiplication of disease-free, genetically uniform plants with consistent morphology and coloration, making them highly suitable for aquascaping applications.

Plant tissue culture offers a reliable and sustainable solution to overcome slow natural growth, reduce pressure on wild populations, and meet the increasing commercial demand for Bucephalandra pygmy 'Wavy Dark Green'.

Keywords: *Bucephalandra pygmy 'Wavy Dark Green', rheophytes, in vitro micropropagation, Murashige and Skoog medium, NAA, BAP, plant tissue culture, aquascaping, conservation.*

Introduction

Plants have the capacity to thrive in diverse environments. Aquatic plants are plants that have adapted to living in water fresh or salt. These plants have developed several morphological, anatomical features to adapt to aquatic conditions. Aquatic plants grow in watery habitat which provides a uniform thermal condition due to which these plants are widely distributed geographically. Among the principal morphological and anatomical characteristics of aquatic plants are sponginess of tissues to combat suboptimal aeration due to watery habitat. Large intercellular spaces or cavities with or without diaphragms filled with air (aerenchyma), spongy and enlarged swollen petioles to provide buoyancy to the plants and helps them to keep afloat. Root system is poorly developed usually shorter much less branched, however some rooted hydrophytes have well developed roots. Root hair are often absent, presence of root pocket, presence of rhizome are some notable features in aquatic plants. The vascular tissue specially xylem is reduced to xylem lacuna. Epidermis usually lacks cuticle, stomata absent or few or functionless, some of them with waxy surface causing water drops to roll off. Besides all these features Aquatic plants have gained importance as providers of food and habitat to the aquatic organisms. They also have contributed to the commercial sector as components of diet, phytomedicines, as an aid in environmental remediation, source of biofuel to name a few.

Quick Response Code:
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10.5281/zenodo.21126456
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How to cite this article:
Manchekar, A., & Avhad, A. (2026). In Vitro micropropagation of rheophytic Bucephalandra pygmy 'Wavy Dark Green' for sustainable conservation and commercial aquascaping applications. Journal of Research and Development, 18(4(XI)), 150–156.
https://doi.org/10.5281/zenodo.21126456

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Nevertheless, *in vitro* culture systems are often constrained by physiological challenges such as oxidative browning, which can adversely affect culture establishment, growth, and biomass accumulation. Previous studies have demonstrated that antioxidant supplementation effectively reduces oxidative browning by suppressing polyphenol oxidase activity and improving tissue viability in *in vitro* cultures (Patel & Avhad, 2026).

Beyond their commercial value these plants are subjects of scientific research and conservation efforts, offering into ecological relationships and wetland preservation. They enhance landscapes, making them popular choices for decorative features in parks, garden, commercial properties. The commercial importance of aquatic plants is wide ranging, spanning from ornamental and functional uses to environment conservation and innovative industries.

Many of aquatic plants do not produce sufficient seeds, and vegetative propagation by rhizome is slow, their production is limited to a small number of plants. The plants produced in these ways are not adequate for meeting commercial demand. Therefore *in vitro* propagation is of great importance for the commercial production of aquatic plant species. The present research is envisaged in view of the growing demand of aquatic plant species. The present study would standardize a protocol for mass propagation of two important aquatic plants viz. *Anubias, crypotocornye , Pogostemon* sps **(**Tajul Afif Abdullah 2019).

Anubias and *Pogostemon* species are widely used in aquariums and aquascapes and are in high demand commercially which cannot be met with the conventional method of propagation. **Rheophytes** are plants specially adapted to grow in **fast-flowing water habitats**, such as riverbanks, waterfalls, and streams.

Bucephalandra are rheophytic aquatic plants endemic to the island of Borneo, where they naturally grow attached to rocks along fast-flowing streams and riverbanks. These plants are characterized by their compact growth habit, thick rhizomes, and highly ornamental leaves exhibiting a wide range of shapes, sizes, textures, and iridescent coloration. Due to their slow vegetative propagation and habitat specificity, natural populations of *Bucephalandra* are particularly vulnerable to environmental disturbances and unsustainable harvesting for the aquarium trade.

Conventional propagation of *Bucephalandra* relies mainly on rhizome division, which is a slow process yielding a limited number of plantlets over extended periods. Furthermore, plants collected from natural habitats often show variable growth performance and may carry microbial contaminants. In vitro culture techniques provide an effective means for the rapid clonal multiplication of disease-free planting material, enabling year-round production while reducing pressure on wild populations. Despite their commercial importance, standardized micropropagation protocols for *Bucephalandra* remain limited, highlighting the need for systematic studies on explant sterilization, regeneration potential, and hormonal requirements. (Laksana, C.,et al., 2025)

2. Materials and Method-

2.1 Plant material and explant sterilization.

Plants of *Bucephalandra pygmy* 'Wavy dark green' (ALM-03) were purchased from commercial outlets authenticated Loknete Ramsheth Thakur Arts, Science and Commerce college, Mokhada and maintained in the Aquariums at R.J.College, Ghatkopar, Mumbai for all studies.

Explant inoculation represents a crucial step in the micro-propagation of aquatic ornamental plants, as the success of culture establishment largely depends on effective surface sterilization and aseptic handling. Healthy and disease-free mother plants of *Bucephalandra pygmy* 'Wavy Dark Green' were selected and maintained under controlled conditions to serve as stock plants. Young and actively growing tissues such as rhizome segments with axillary buds, leaf, and shoot tips were used as explants due to their high regenerative potential.

The explants would be washed thoroughly in running tap water and immersed in a bacillocide solution for 5-6 minutes then washed in sterile distilled water. They would then be sterilized using 5% chlorox containing 1-2 drops of Tween for 3-4 minutes. The aseptic explants would be washed in sterile distilled water to remove traces of disinfectant. Sterilized explants were carefully trimmed using sterile scalpel and forceps to remove damaged tissues. The surface sterilized explants would be transferred to basal Murashige and Skoogs medium containing 0.8% agar (Murashige and Skoog, 1962), the pH of medium was adjust to pH 5.7 ± 0.2 prior to autoclaving at 15 psi for 15 minutes and medium supplemented with suitable concentrations of plant growth regulators, particularly auxin (NAA) and cytokinin (BAP), in 1:1 ratio for shoot and root induction and multiplication. Explants were placed vertically and gently pressed onto the medium to ensure proper contact while maintaining exposure of the meristematic region. **(**Tajul Afif Abdullah 2019)

After inoculation, the culture vessels were sealed and incubated in a culture room maintained at 24 ± 2 °C under a 16-hour photoperiod with cool white fluorescent illumination. Cultures were observed regularly for contamination and initial morphogenic responses. Successful establishment of aseptic cultures served as the foundation for subsequent stages of *in vitro* shoot proliferation and plant regeneration.

2.2 Standardizing of Media

Whole plantlets derived from rhizome explants were utilized for the standardization of culture media to optimize *in vitro* plant multiplication. Different basal media formulations, namely Murashige and Skoog (MS),

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Gamborg's B5, and White's medium, were evaluated to determine their effectiveness in supporting shoot proliferation and overall growth.

Murashige and Skoog (MS) medium, characterized by its relatively high concentration of nitrogen salts and balanced micronutrients, is widely reported to promote rapid cell division and shoot proliferation in many plant species. Gamborg's B5 medium, with comparatively lower total salt concentration and different vitamin composition, is often suitable for species requiring moderate nutrient levels. White's medium, being one of the earliest plant tissue culture media with lower salt strength, has been traditionally used for root culture and species sensitive to high ionic concentrations. Comparative evaluation of these media provides insight into the optimal nutrient environment required for maximum shoot induction and multiplication.

Explants cultured on these basal media were supplemented with BAP and NAA in a 1:1 ratio concentrations of plant growth regulators to enhance shoot and root proliferation. Observations were recorded on parameters such as number of roots, number of auxiliary bud, leaves number, initial and finial fresh weight. (Abobkar I.M. Saad 2012)

2.3 Effect of Auxins and Cytokinins on Plant Regeneration

To establish an efficient plant regeneration protocol for *Bucephalandra pygmy* 'Wavy Dark Green' an experiment was designed to study the effect of different concentrations of auxin and cytokinin on *in vitro* shoot and root development. The cytokinins and auxins selected for the study were 6-benzylaminopurine (BAP) and naphthalene acetic acid (NAA), respectively.

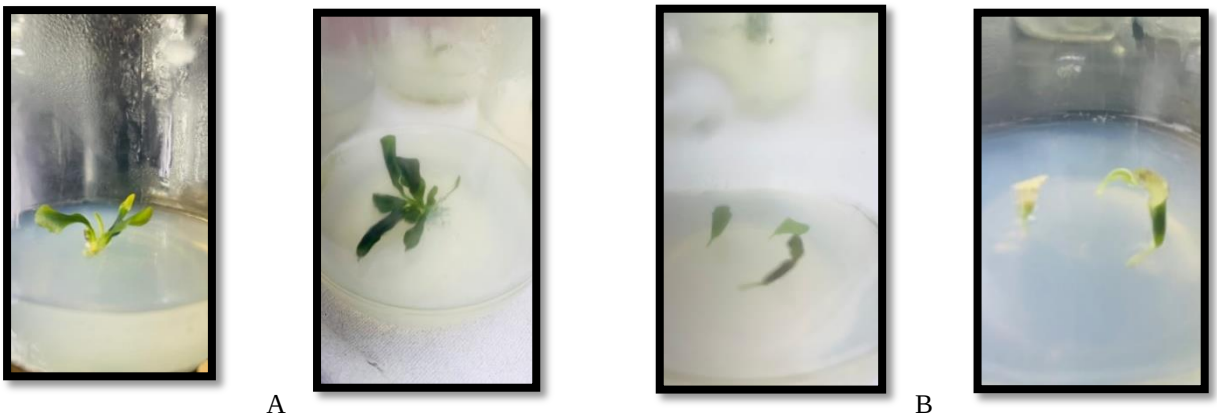
Murashige and Skoog (MS) basal medium was used as the culture medium and was supplemented with varying concentrations of BAP and NAA ranging from 1 to 3 ppm. The growth regulators were tested individually as well as in combination, controls were grown in medium without plant growth regulators to evaluate their influence on organogenesis. For each concentration level, 6 replicates adequately to ensure reliable results.

Explants were cultured under controlled laboratory conditions, and observations were recorded after 3 months. Parameters studied included number of roots, number of auxiliary bud, leaves number, initial and finial fresh weight shoot, and overall growth of the regenerated plantlets.

3.Results

3.1 Plant material and explant sterilization

Young, actively growing tissues such as fig.C shows rhizome segments bearing axillary buds, leaves, and shoot tips of *Bucephalandra pygmy* 'Wavy Dark Green' were selected as explants due to their high regenerative potential. Among the explants evaluated, rhizome segments exhibited the most favorable *in vitro* response. These explants showed early bud break, followed by multiple shoot induction and well-developed root formation on MS medium supplemented with a 1:1 ratio of BAP and NAA. Fig. A Shoot tip explants also responded under the same culture conditions but displayed comparatively lower regeneration efficiency and slower growth. In contrast , fig.B shows leaf explants failed to exhibit any morphogenic response throughout the culture period.



A B

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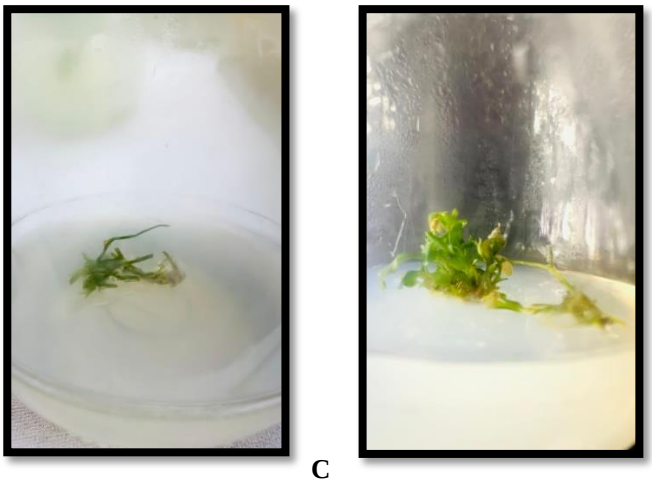
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026



C

(A)Shows Shoot of *Bucephalandra pygmy*, (B)showsLeaf of *Bucephalandra* & (C)shows Rhizome of *Bucephalandra pygmy*

3.2 Standardizing of Media

The effect of different basal media on *in vitro* multiplication of *Bucephalandra pygmy* 'Wavy Dark Green' was evaluated using whole plantlets derived from rhizome explants cultured on MS, Gamborg's B5, and White's media, each supplemented with BAP and NAA in a 1:1 ratio. Significant variations were observed among the media with respect to growth and multiplication parameters.

Fig. D shows MS medium produced the most favourable response, showing the highest number of shoots per explant, greater root formation, increased leaf production, and the maximum gain in fresh weight. Plantlets cultured on MS medium exhibited faster growth and more vigorous morphology compared to other treatments. Fig.E shows Gamborg's B5 medium supported moderate growth, with satisfactory shoot and root development, but the overall multiplication rate and biomass accumulation were lower than in MS medium. Fig. F White's medium showed the least response, with reduced shoot proliferation, fewer roots, and comparatively lower fresh weight gain.

D E F

(Fig. D, E, F are Media such as Murashige and Skoog (MS), Gamborg's B5 and white on multiplication of plants *in vitro*)

3.3 **Effect of Auxins and Cytokinins on Plant Regeneration Protocol.**

SR. NO.	ppm	BAP+NAA (Weight g)	BAP+NAA (Leaf No.)	BAP+NAA (Root No.)	BAP+NAA (Auxiliary No.)
1	Blank	0.7951	5.44	3.6	2
2	1 NAA	2.1939	3.04	9.77	4
3	2 NAA	1.02183	0.83	4.3	2.17
4	3 NAA	1.48083	0.7	11	1.84

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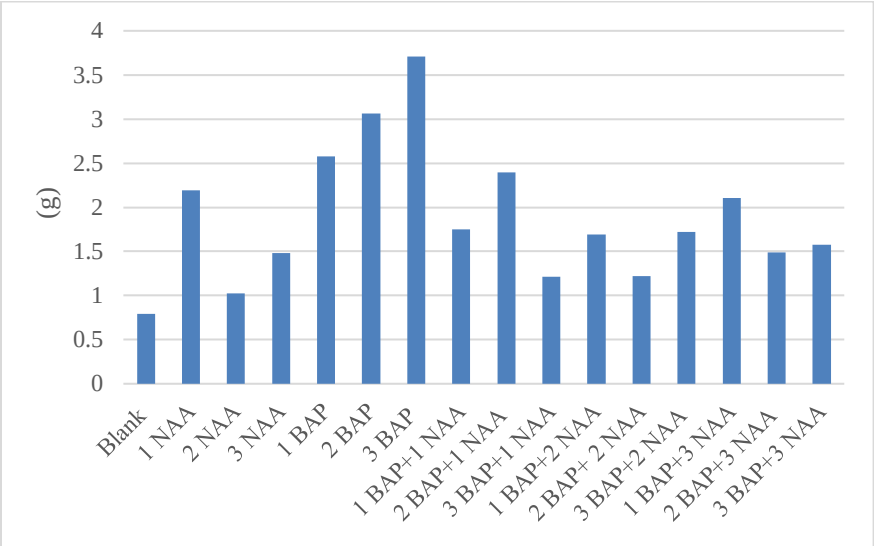
5	1 BAP	2.58	12.5	2.3	2.67
6	2 BAP	3.0628	4.7	0.17	4.17
7	3 BAP	3.71	9.4	-0.3	4.4
8	1 BAP+1 NAA	1.7501	12.4	2.37	4
9	2 BAP+1 NAA	2.3988	8	-0.33	4.17
10	3 BAP+1 NAA	1.21618	12.5	4.33	3.34
11	1 BAP+2 NAA	1.695	7.7	7.5	3.67
12	2 BAP+ 2 NAA	1.219596	10.4762	5.7389	2.67
13	3 BAP+2 NAA	1.719925	6.15	5.925	2.8
14	1 BAP+3 NAA	2.10886	7.28572	10.2857	2.71429
15	2 BAP+3 NAA	1.48883	8	1.5	2.67
16	3 BAP+3 NAA	1.57507	11.6	4.77	3.8

Table no.1 Averaged Growth Response of *Bucephalandra pygmy* 'Wavy Dark Green' under BAP and NAA Treatments.

3.3.1 Effect of PGRs on Biomass (Fresh Weight)

The response of *Bucephalandra pygmy* 'Wavy Dark Green' explants to different concentrations and combinations of BAP and NAA showed significant variation in biomass accumulation. Among all treatments, as shown in (a)the highest fresh weight was recorded in 3 ppm BAP (3.71 g) followed by 2 ppm BAP (3.0628 g) and 1 ppm BAP (2.58 g), indicating that cytokinin (BAP) alone strongly promotes biomass accumulation.

In contrast, NAA alone showed comparatively lower biomass, with 1 ppm NAA (2.1939 g) performing better than higher concentrations. Combined treatments (BAP + NAA) did not consistently enhance biomass, suggesting that higher auxin levels may suppress overall weight gain.



(a) Fresh biomass of BAP+NAA Combination

3.3.2 Effect on Leaf Development

Leaf production was significantly influenced by cytokinin concentration.(b) shows the maximum leaf number was observed in; 1 ppm BAP (12.5 leaves), 3 BAP + 1 NAA (12.5 leaves). 1 BAP + 1 NAA (12.4 leaves).

This indicates that BAP plays a dominant role in shoot and leaf proliferation, while low levels of NAA may synergistically enhance this effect. Higher NAA concentrations (≥2 ppm) resulted in reduced leaf formation, indicating auxin-induced suppression of shoot organogenesis at higher levels.

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1.3.3 Effect on Root Development

Root formation showed an opposite trend compared to shoot growth. (b) shows the highest root induction was observed in; 3 ppm NAA (11 roots) ,1 BAP + 3 NAA (10.28 roots) ,1 ppm NAA (9.77 roots)

This confirms that auxin (NAA) is critical for root induction, and increasing its concentration significantly enhances rooting. In contrast, higher BAP levels alone (e.g., 2–3 ppm BAP) resulted in poor or negative root response, indicating cytokinin-mediated inhibition of root formation.

1.3.4 Effect on Auxiliary Shoot Formation

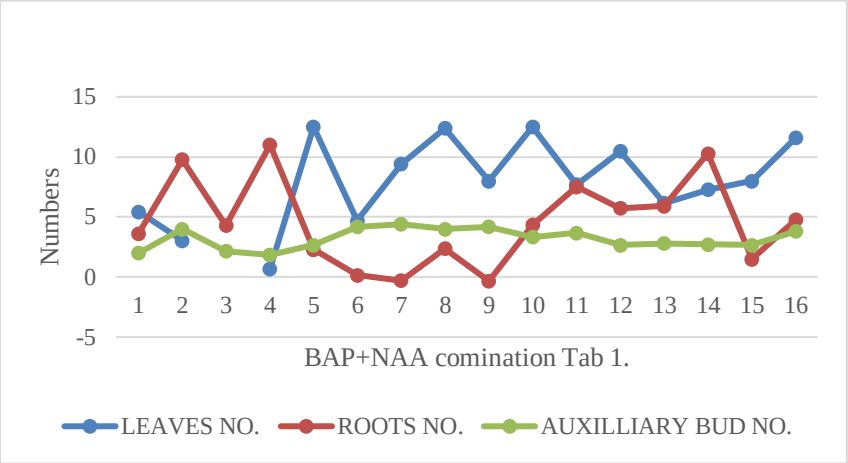
Auxiliary shoot formation was highest as shown in (b) ; 3 ppm BAP (4.4 shoots) ,2 BAP (4.17 shoots) ,2 BAP + 1 NAA (4.17 shoots).

This suggests that BAP is highly effective in inducing lateral/auxiliary shoots, which is critical for micropropagation efficiency. The addition of low NAA levels further stabilizes shoot multiplication.

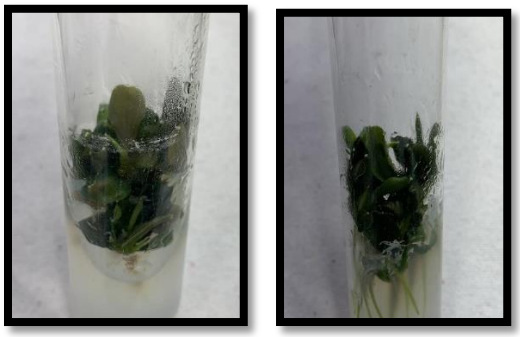
1.3.5 Overall Optimization of PGR Combination

Based on overall performance; BAP alone (especially 2–3 ppm) is optimal for biomass and shoot multiplication, NAA alone (2–3 ppm) is optimal for root induction, Combined treatment (1 BAP + 1 NAA) provides a balanced response with high leaf production and acceptable rooting

Although some combinations like 1 BAP + 2 NAA showed moderate performance across all parameters, they were not superior to optimized individual responses.



b Overall Optimization of PGR Combination



(G) 1BAP+1NAA (H)1BAP+2NAA

Effect of PGR (G) and (H) on Shoot and Root Development

Conclusion

The present study successfully established an efficient *in vitro* regeneration protocol for *Bucephalandra pygmy* 'Wavy Dark Green'. Among the explants tested, rhizome segments proved to be the most responsive, showing early bud break, higher shoot multiplication, and well-developed root systems, making them the most suitable explant for micropropagation. Among the basal media evaluated, Murashige and Skoog (MS) medium exhibited superior performance in terms of shoot proliferation, root development, leaf production, and biomass accumulation compared to Gamborg's B5 and White's media.Optimization of plant growth regulators indicated that BAP (2–3 ppm) is most effective for shoot multiplication, while NAA (2–3 ppm) significantly enhances root induction. However, combined treatments of BAP and NAA yielded a more balanced morphogenic response. Notably, 1:1 and 1:2 ratios of BAP:NAA were found to be optimal for producing well-developed plantlets with simultaneous shoot proliferation, rooting, and

improved leaf formation. For commercial-scale production, these combined ratios are particularly advantageous as they enable the rapid generation of uniform, disease-free, and morphologically stable plantlets, meeting the increasing demand in aquascaping industries.Overall, the standardized protocol using rhizome explants cultured on MS medium supplemented with optimized BAP and NAA combinations provides a reliable approach for large-scale propagation and sustainable conservation of *Bucephalandra pygmy* 'Wavy Dark Green'.

Acknowledgment
I express my sincere gratitude to my respected Principal of Ramniranjan Jhunjhunwala college **Dr.Himanshu Dawda ,** for his invaluable guidance, constant encouragement, and insightful suggestions throughout the this research work. His support and mentorship have been instrumental in the successful completion of this study.I am also deeply thankful to Dr. Usha Mukundan, Director of Ramniranjan Jhunjhunwala College **,**for her continuous support, motivation, and encouragement. Her guidance and constructive feedback greatly contributed to the progress of this research.I extend my heartfelt appreciation to both for their unwavering support and inspiration during the entire research period.

References

1. Azmi, N.A., Abdullah,T.A., Mahmod, N.H.,Sajili,M.H., Mahmud, K., Mohamed,s., et al. (2019).Sterilization of Anubias nana and Rotala macrandra for in vitro Culture. J. Agrobiotech.10,13-21.
2. Baby, G., Rafeekher, M., Soni, K. B., Kumari, P. I., Reshmi, C. R., Sheena, A., & Rahman, A. M. (2024). Advances in micropropagation techniques for aquascaping plants: A comprehensive review. *Arch. Curr. Res. Int*, *24*(11), 14-22
3. Bai, Y., & Bai, X. (2024). Deep learning-based aquatic plant recognition technique and natural ecological aesthetics conservation. *Crop Protection*, *184*, 106765.
4. Bello-Bello, J. J., Pérez-Sato, J. A., Cruz-Cruz, C. A., & Martínez-Estrada, E. (2017). Light-emitting diodes: Progress in plant micropropagation. *InTech*, *6*(1), 93-103.Grand view Research. (2023) *Ornamental Fish Market Size, Share & Trends Analysis Report, 2023–2030.Grand View Research,*
5. Jabir, T., George, S., Raj, A., & Joseph, A. (2016). Micropropagation and in vitro flowering of an ornamental aquarium plant Lindernia antipoda L.(Alston). *International Journal of Aquaculture*, *6*.
6. Fontanili, L., Lucchesini, M., & Mensuali-Sodi, A. (2015). In vitro propagation and shoot encapsulation as tools for ex situ conservation of the aquatic plant Ludwigia palustris (L.) Ell. *Plant Biosystems-An International Journal Dealing with all Aspects of Plant Biology*, *149*(5), 855-864**.**Laksana, C., Sophiphun, O., Kaewhom, P., & Chanprame, S.(2025)
7. Laksana, C., Sophiphun, O., Kaewhom, P., & Chanprame, S. (2025). Light spectrum effects on micropropagation and gene expression of Bucephalandra sp. in a temporary immersion system for sustainable production. *Frontiers in Plant Science*, *16*, 1660632.
8. Laohavisuti, N., Ruangdej, U., Seesanong, S., & Wangwibulkit, S. (2017). Effect of disinfectants and plant growth regulator in aquatic plant Bucephalandra sp. micropropagation. *King Mongkut's Agric. J*, *35*, 95-103.Murashige T and Skoog F (1962). A revised medium for rapid growth and bioassayswith tobacco tissue cultures. *Physiol Plant* 15: 473-497.
9. Azmi, N. A., Abdullah, T. A., Mahmod, N. H., Sajili, M. H., Mahmud, K., Mohamed, S., & Khandaker, M. (2019). Sterilization of Anubias nana and Rotala macrandra for in vitro culture. *Journal Of Agrobiotechnology*, *10*(1S), 13-21.
10. Priyadharshini S., Kannam N., Manokari M., Shekhawa M. (2020). *In vitro* regenerationusing twin scales for restoration of critically endangered aquatic plant *Crinum malabaricum* Lekhak and Yadav: a promising source of galanthamine. Plant cell, Tissueand Organ culture(PCTOC), 141, 593-604.
11. Patel, A., & Avhad, A. (2025). Browning suppression and yield improvement in Solanum diphyllum L. callus cultures. *IJBS*, *7*(9), 33-40.
12. Saad, A. I., & Elshahed, A. M. (2012). Plant tissue culture media. *Recent advances in plant in vitro culture*, *25*(7), 30-40.Simon S and Petrasek J (2010). Why plants need more than one type of auxin. *Plant Sci.a.* 180:454-460.
13. Unal, S., Turkmen, G., Yagmur, B., Bayraktar, M., & Gurel, A. (2019). Improved in vitro propagation and direct acclimatization of Cryptocoryne wendtii in aquarium in the presence of aquarium fish Puntius tetrazona (Bleeker). *Indian J Exp Biol*, *57*, 330-7.

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A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Original Article

Isolation & Characterization of Phosphate Solubilizing Rhizobacteria from Agricultural Soil.

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Manuscript ID:
JRD -2026-180425
ISSN: 2230-9578
Volume 18
Issue 4(XI)
Pp. 157-164
April - 2026
Submitted: 16 Mar. 2026
Revised: 30 Mar. 2026
Accepted: 09 Apr . 2026
Published:30 April2026

Abstract

Phosphorus is an essential macronutrient required for plant growth and agricultural productivity; however, a large portion of soil phosphorus exists in insoluble forms that cannot be directly utilized by plants. This limited availability of phosphorus significantly affects crop yield and soil fertility. Phosphate-solubilizing bacteria (PSB) play an important role in converting insoluble phosphate into soluble forms, thereby increasing phosphorus availability and acting as eco-friendly biofertilizers. In the present study, soil samples were collected for the isolation of potential PSB with agricultural significance. A total of ten bacterial isolates were obtained from the collected soil samples. Preliminary screening for phosphate solubilization was carried out, and five isolates showing significant solubilization ability were selected. These isolates were further subjected to quantitative phosphate solubilization assays to evaluate their efficiency. Based on their phosphate solubilizing potential, three efficient isolates designated as P1, P8, and P10 were selected for further analysis. Optimization studies were conducted to evaluate the influence of environmental and nutritional factors such as pH, temperature, carbon source, and nitrogen source on phosphate solubilization. Biochemical characterization was performed to identify the selected isolates. The results indicated that isolate P1 belonged to Aeromonas sp., P8 belonged to Providencia sp., and P10 belonged to Proteus sp. The findings of this study suggest that the identified bacterial isolates possess significant phosphate-solubilizing potential and could be used as promising candidates for biofertilizer development. A pot assay with moong seeds was performed to assess the plant growth promoting potential of the isolates. Among the treatments (P1, P8, P10, consortium, and control), P10 showed the highest plant growth. The results indicate that these phosphate-solubilizing bacteria have promising potential as biofertilizers for improving plant growth and supporting sustainable agriculture.

Keywords: *Phosphate-solubilizing bacteria (PSB), Biofertilizer, Phosphate solubilization, Soil bacteria, Sustainable agriculture, Nutrient availability.*

Introduction

India's economy has long been rooted in agriculture, which continues to hold significant importance despite rapid expansion in other sectors. While the share of agriculture in GDP has declined from nearly 75% to about 18%, it still provides livelihood to nearly half of the population, particularly in rural regions. The Green Revolution marked a pivotal milestone, enabling the nation to attain food self-sufficiency.Food grain production reached 315.72 million tonnes in 2021–22 (Lamani Channappa & Correya Philomina, 2022). . In recent years, rising incomes and evolving dietary preferences have driven a shift toward high-value crops such as fruits, vegetables, and livestock products (Gummagolmath K. C *et al*., 2020, Kumar Ajay, 2021). Despite these advances, challenges like low productivity, climate variability, and reliance on traditional farming methods remain, underscoring the need for sustainable approaches (Mohanty Akshaya Kumar, 2022, Zhang *et al*., 2024). Plant Growth-Promoting Rhizobacteria (PGPR) have gained attention as an eco-friendly solution to enhance crop yields. These beneficial microbes support plant development by solubilizing nutrients, producing growth hormones, fixing nitrogen, suppressing pathogens, and improving stress tolerance (Andrade Luana *et al*., 2023; Vejan Pravin *et al*., 2016). Among PGPR, phosphate-solubilizing bacteria (PSB) are particularly important because they convert insoluble forms of phosphorus into plant-available nutrients, addressing one of the most critical soil limitations (Amri Marwa *et al*., 2023, Ma *et al*., 2023). Their application improves nutrient absorption, boosts plant growth, and reduces dependence on chemical fertilizers, thereby promoting sustainable farming practices (Fenta Lamenew, 2017).

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How to cite this article:
Narvekar, S. S., Jadhav, R. P., & Wasave, S. B. (2026). Isolation & Characterization of Phosphate Solubilizing Rhizobacteria from Agricultural Soil. Journal of Research and Development, 18(4(XI)), 157–164. https://doi.org/10.5281/zenodo.21126580

Quick Response Code:
Website:
https://jrdrvb.org/
DOI:
10.5281/zenodo.21126580

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Phosphorus plays a central role in plant metabolism, yet its availability in soil is often restricted due to immobilization. Harnessing PSB offers a biological strategy to overcome this constraint and improve productivity. This study therefore emphasizes the isolation and characterization of PSB and their role in enhancing plant growth, a crop where phosphorus deficiency significantly impacts yield and quality (Fenta Lamenew, 2017).

Methods and Materials

Collection of Samples

Rhizosphere soil samples were obtained from various agricultural sites in Ratnagiri at a depth of 6–10 cm to isolate microorganisms. The samples were placed in sterile polythene bags to prevent contamination, properly labelled for identification, and transported to the laboratory. All samples were processed within 24 hours to preserve microbial viability.

Enrichment of Phosphate-Solubilizing Bacteria (PSB)

To enrich phosphate-solubilizing bacteria, 10 g of soil was aseptically transferred into 100 mL of sterile Pikovskaya's broth, a medium selective for phosphate-solubilizing microbes. The cultures were incubated at 30°C on an orbital shaker set at 130 rpm for 7 days. Continuous agitation ensured aeration and uniform nutrient distribution, thereby stimulating microbial growth and activity. This step enhanced the population of PSB in the soil samples for further isolation (Aliyat *et al*., 2020,).

Isolation of PSB

Isolation was carried out using Pikovskaya's agar medium supplemented with tricalcium phosphate ($Ca_3(PO_4)_2$). From the enriched broth, 0.5 mL was serially diluted (10^{-1} to 10^{-6}), and 0.1 mL aliquots from suitable dilutions were spread onto agar plates. Plates were maintained at room temperature for seven days. Colonies producing clear zones around them were identified as potential PSB and maintained on nutrient agar slants for subsequent characterization (Gupta *et al*., 2022).

Screening of PSB

Isolates showing prominent halo zones on Pikovskaya's agar were selected for detailed evaluation. Screening involved both qualitative and quantitative methods. The qualitative test relied on visual observation of clear zones around colonies, while the quantitative test assessed phosphate solubilization efficiency in broth cultures under controlled conditions. These approaches helped identify the most efficient strains.

Qualitative Assay

Pure isolates were spot-inoculated on Pikovskaya's agar containing tricalcium phosphate and incubated at 37°C for 7 days. The appearance of halo zones around colonies confirmed phosphate solubilization. Colony diameter and halo zone diameter were measured, and the Phosphate Solubilization Index (PSI) was calculated using the formula:

Phosphate Solubilization Index (PSI) = (Colony diameter + Halo zone diameter)/Colony diameter

Experiments were repeated three times, and the best-performing isolates were selected for further work (Mehta & Nautiyal, 2001; Pande et al., 2017).

Quantitative Assay

For quantitative estimation, 100 mL of Pikovskaya's broth was prepared and sterilized. Each isolate (1 mL) was inoculated and incubated at 37°C on a rotary shaker for 7 days. After incubation, cultures were centrifuged at 10,000 rpm for 30 minutes to obtain clear supernatant. The control consisted of an uninoculated broth. Soluble phosphate released into the medium was measured colorimetrically at 660 nm using KH_2PO_4 as the standard (Prasad *et al*., 2023).

Morphological and Biochemical Characterization

Pure bacterial isolates were examined through morphological and biochemical analyses. Colony features and halo zone formation on Pikovskaya's agar were noted as preliminary indicators of phosphate-solubilizing ability. Gram staining was performed to determine cell structure and staining properties. Biochemical profiling was carried out using IMViC tests (Indole, Methyl Red, Voges–Proskauer, and Citrate utilization), along with sugar fermentation, catalase, and oxidase assays. These tests helped identify efficient phosphate-solubilizing bacterial strains (Chakra et al., 2019; Mahantesh & Patil, 2011).

Optimization of Environmental and Nutritional Parameters

Different pH levels, temperatures, and nutrient sources were investigated to assess phosphate solubilization (Mengesha & Legesse, 2024). For pH optimization, Pikovskaya's broth was adjusted between 4.0 and 8.0 using 1N HCl or 1N NaOH, inoculated with bacterial isolates, and incubated at 30°C for 72 hours. Temperature optimization was performed by incubating cultures at 24°C–40°C. The influence of different carbon sources (Sodium acetate, sucrose, fructose) and nitrogen sources (peptone,casein, tryptone) was assessed by supplementing PVK broth. After incubation, bacterial growth and phosphate solubilization were measured spectrophotometrically at 660 nm. The conditions yielding maximum optical density were considered optimal (Agboola *et al*., 2023).

Fermentation in PVK Broth

For fermentation studies, 100 mL of PVK broth was inoculated with 1 mL of bacterial suspension. Cultures were incubated at 30°C on an orbital shaker at 130 rpm for 7 days. After incubation, phosphate-solubilizing activity was quantified by measuring the optical density of the supernatant.

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Effect of PSB on Growth of Mung Bean (*Vigna radiata*)

A pot experiment was conducted to evaluate the impact of PSB on mung bean growth. Soil samples were sterilized by autoclaving and supplemented with inorganic phosphate before being filled into pots. Treatments included: control soil, soil inoculated with P1, P8, P10, and a consortium of isolates. Seeds of *Vigna radiata* were surface-sterilized and sown in each pot. An initial inoculum of 1 mL bacterial culture was added to respective treatments, followed by additional supplementation of 2 mL culture at 7-day intervals. After 15 days, plant growth parameters such as height, root length, shoot length, and leaf number were recorded to assess the growth-promoting effects of the isolates.

Results and Discussion

Enrichment of PSB

Rhizospheric soils collected from lima beans, turmeric, and peanuts were enriched in Pikovskaya's (PVK) broth for 7 days. A progressive increase in turbidity was observed in all samples, confirming microbial growth. The lima bean and peanut soils showed rapid turbidity development, reaching high levels by day 7, suggesting a strong presence of phosphate-solubilizing microorganisms. In contrast, turmeric soil displayed slower growth, with only moderate turbidity at the end of incubation. These findings indicate that lima bean and peanut rhizospheres harbor comparatively higher populations of PSB than turmeric.

Isolation of PSB

Enriched soil samples were serially diluted and plated on PVK agar for isolation. After incubation, ten distinct bacterial colonies with clear halo zones were obtained, signifying phosphate solubilization. Of these, five isolates with larger halo zones were selected for further study. The formation of clear zones is attributed to the secretion of organic acids, which convert insoluble phosphate into soluble forms. Damor and Goswami,2016 observed similar results in Jaipur soils, while Liu Zhiguang *et al*., 2015 identified PSB through halo zone formation. The variation in halo zone diameters among isolates reflects differences in metabolic activity and acid production, making the selection of larger halo zone isolates crucial for identifying efficient biofertilizer candidates.

Screening of PSB

From the isolated colonies, strains with prominent halo zones were chosen for detailed evaluation. Their phosphate-solubilizing activity was assessed through qualitative plate screening and quantitative broth culture methods.

Qualitative Screening

Spot inoculation on PVK agar revealed clear halo zones around colonies after incubation. Among the isolates, P10 produced the largest halo zone (44 mm), followed by P7 (27 mm), P8 (21 mm), P1 (20 mm), and P2 (11 mm). The Phosphate Solubilization Index (PSI) values were calculated as 4.14 (P10), 3.7 (P7), 3.1 (P8), 3.0 (P1), and 2.37 (P2). These results highlight P10 as the most efficient isolate. Karpagam and Nagalakshmi (2014) reported similar methodologies, employing PSI values to assess solubilization efficiency. The differences in PSI values suggest variability in acid production and phosphate solubilization capacity among isolates, positioning P10 as a promising candidate for biofertilizer development. The qualitative phosphate solubilization activity of the isolates, based on halo zone formation, is presented in Table 1.

Quantitative Screening

Quantitative estimation of soluble phosphate was performed using PVK broth, with measurements taken colorimetrically at 660 nm against a KH_2PO_4 standard curve. Among the isolates, P8 and P1 exhibited the highest phosphate solubilization efficiency, followed by P10, P7, and P2. Based on concentration values, P1, P8, and P10 were identified as efficient solubilizers and selected for further studies. Karpagam and Nagalakshmi (2014) documented similar findings, noting that isolates with higher phosphate release exhibited enhanced solubilization efficiency. The variation in concentration readings reflects differences in metabolic activity and efficiency among strains. The quantitative phosphate solubilization activity of the isolates is presented in Table 2 and illustrated graphically in Figure 1.

Morphological and Biochemical Identification

The selected phosphate-solubilizing bacterial isolates were characterized using morphological traits and standard biochemical assays, including IMViC tests, catalase, oxidase, Gram staining, and the KOH test. Based on these analyses, P1 was identified as *Aeromonas* sp., P8 as *Providencia* sp., and P10 as *Proteus* sp. Their identification was consistent with biochemical profiles and Gram reactions. Mengesha and Legesse (2024) documented comparable approaches, employing morphological and biochemical methods in accordance with Bergey's Manual of Determinative Bacteriology. Similarly, Fenta Lamenew 2017, characterized PSB isolates using Gram staining, catalase, oxidase, and carbohydrate utilization tests for genus-level identification. These findings reaffirm that biochemical characterization remains a reliable method for identifying efficient PSB strains with potential applications in sustainable agriculture. The morphological and biochemical characteristics of the selected isolates are presented in Table 3.

Optimization of Environmental and Nutritional Factors

The phosphate-solubilizing efficiency of the isolates was tested under varying physiological conditions. Optimal pH values were determined as 6 for P1, 4 for P8, and 5 for P10. Temperature studies revealed that P1 and P10 performed best at room temperature, while P8 exhibited maximum activity at 37°C. Nutritional optimization showed sucrose as the most effective carbon source and peptone as the preferred nitrogen source for all three isolates. These

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ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

results highlight the significant influence of environmental and nutritional factors on phosphate solubilization. Similar findings were reported by Karpagam & Nagalakshmi 2014, who demonstrated the role of pH and temperature in enhancing PSB activity. The effect of different environmental and nutritional parameters such as pH, temperature, carbon sources, and nitrogen sources on phosphate solubilization is presented in Tables 4–7 and illustrated in Figures 2–5.

Fermentation of PSB in PVK Broth

Fermentation studies in Pikovskaya's broth revealed visible microbial growth after 7 days of incubation at 30°C on an orbital shaker. Increased turbidity confirmed active microbial proliferation and phosphate solubilization. Among the isolates, P1, P8, and P10 showed comparatively higher growth, as indicated by optical density measurements, confirming their efficiency under liquid culture conditions.

Effect of PSB on Mung Bean (Vigna radiata) Growth

A pot experiment was conducted to assess the plant growth-promoting effects of PSB on Vigna radiata. After 15 days, inoculated plants exhibited significant improvements in growth parameters compared to the control. P10 showed the highest shoot length (13.5 cm) and overall plant height (18.5 cm), followed by P8, P1, and the consortium treatment, while control plants displayed minimal growth. Root length and leaf size also improved in inoculated plants, although leaf number remained constant across treatments. The enhanced growth is likely due to improved phosphorus availability and nutrient uptake facilitated by PSB. Similar observations were reported by Fenta Lamenew 2017, who noted increased shoot length, root length, and biomass in PSB-treated plants. These findings suggest that PSB, particularly when applied as a consortium, hold strong potential as biofertilizers for sustainable agriculture. The effect of phosphate-solubilizing bacterial isolates on the growth of Vigna radiata is presented in Table 8 and illustrated graphically in Figure 6.

Table.1 Phosphate solubilizing activity of 5 PSB

Sr. No	Isolates of PSB	Colony Diameter	Halo Zone Diameter	Phosphate Solubilization Index (PSI)
1	P1	10mm	20mm	3
2	P2	8mm	11mm	2.37
3	P7	10mm	27mm	3.7
4	P8	10mm	21mm	3.1
5	P10	14mm	44mm	4.14

*Phosphate Solubilization Index (PSI)= (colony diameter + Halo zone diameter)/colony diameter.

Table.2 Phosphate solubilizing activity using quantitative Method.

Sr. No	Isolates	Soluble Phosphate Concentration (µg/mL)
1	P1	11.2 µg/mL
2	P2	6.2 µg/mL
3	P7	9 µg/mL
4	P8	6.4 µg/mL
5	P10	12 µg/mL

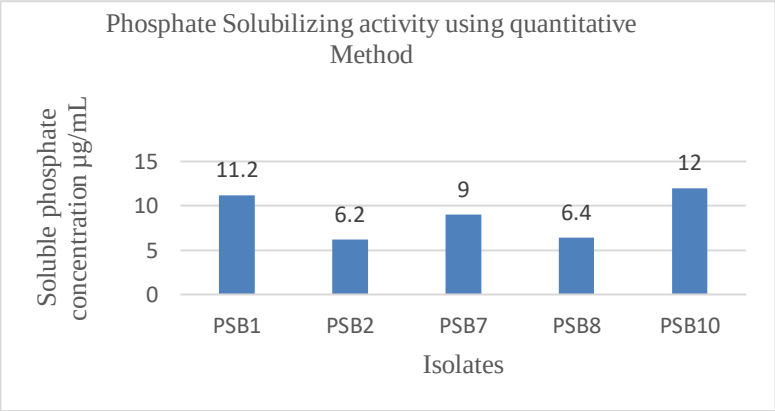

Figure.1 Phosphate Solubilizing activity using quantitative Method.

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Table.3 Morphological and Biochemical Identification of the isolates.

Sr. No	Characteristics	P1 A *Aeromonas* sp.	P8 *Providencia* sp.	P10 *Proteus* sp.
1	Gram Nature	Gram Negative	Gram Negative	Gram Negative
2	Shape	Rods	Rods	Rods
3	Indole	-	+	-
4	Methyl red	+	-	-
5	Voges-Proskauer	-	-	+
6	Citrate utilization	-	-	+
7	Urease	-	+	+
8	Bile esculin	+	-	-
9	Nitrate reduction	-	+	+
10	Starch hydrolysis	-	+	+
11	Lactose fermentation	-	-	-
12	Glucose fermentation	+	-	+
13	H_2S production	-	-	+
14	Phenylalanine deaminase	-	+	+
15	Ornithine test	-	+	+
16	Catalase test	+	+	+
17	Oxidase test	+	-	-

*(+ = Positive, - = Negative)

Table.4 Enzyme activity (µg/ml/min) of Isolates at different PH.

pH / Isolates	pH4	pH5	pH6	pH7	pH8
P1	21.6	22.8	28.2	15	22.2
P8	33.6	28.2	28.8	28.8	25.2
P10	8	9.4	5.2	5	7.8

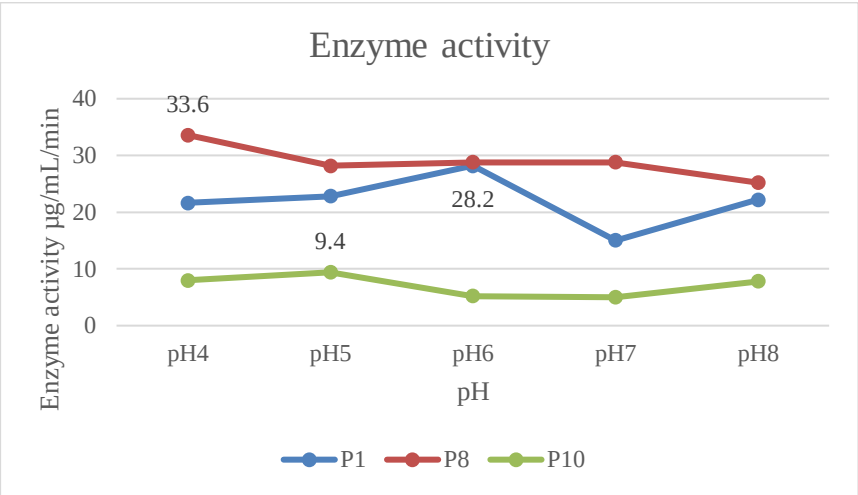

Figure.2 Effect of pH on Enzyme activities of Isolates.

Table.5 Enzyme activity (µg/ml/min) of Isolates at different temperature.

Temperature / Isolates	4 °C	RT	37 °C	55 °C
P1	13.8	24	19.2	16.2
P8	17.4	17.4	18	16.2
P10	4.8	5	3.8	3.6

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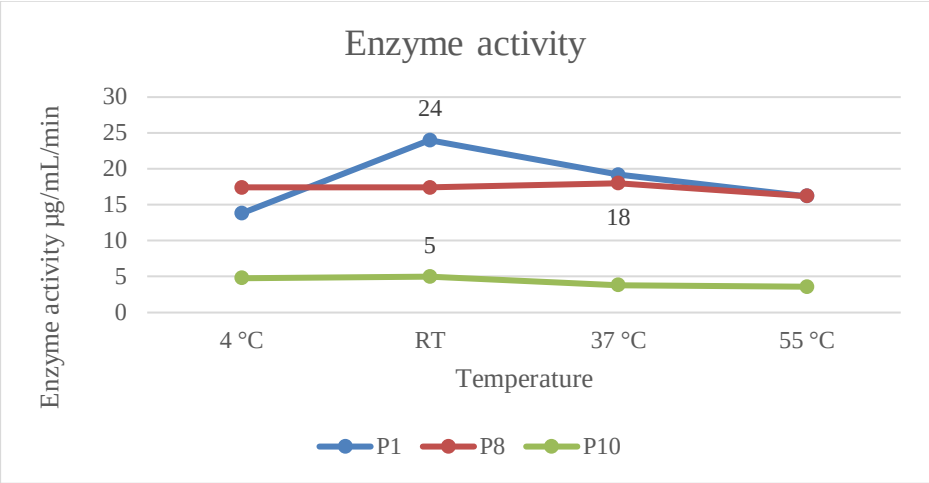

Figure.3 Effect of Temperature on Enzyme activity of Isolates.

Table.6 Enzyme activity (µg/ml/min) of Isolates at different Carbon source.

Isolates \ Carbon source	Sucrose	Fructose	Sodium acetate
P1	39	28.2	22.8
P8	28.2	16.8	21
P10	7.6	7.2	7.4

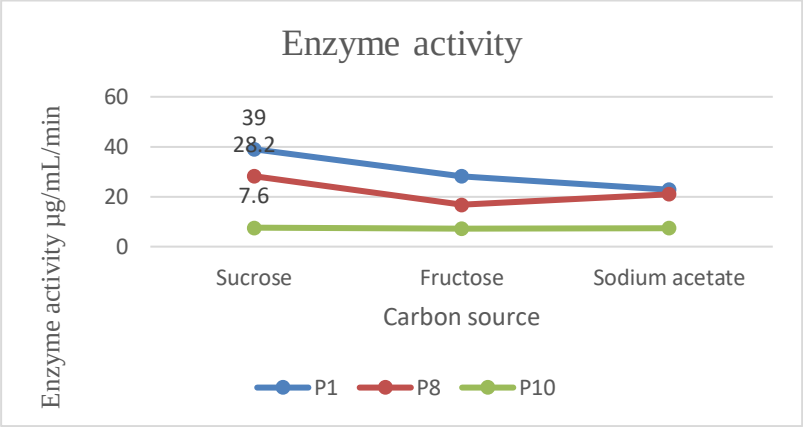

Figure.4 Effect of Carbon source on Enzyme activity of Isolates.

Table.7 Enzyme activity (µg/ml/min) of Isolates at different Nitrogen source.

Isolate \ Nitrogen source	Peptone	Casein	Tryptone
P1	46.2	25.2	10.8
P8	43.8	33.6	24
P10	15.8	10	4.6

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ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

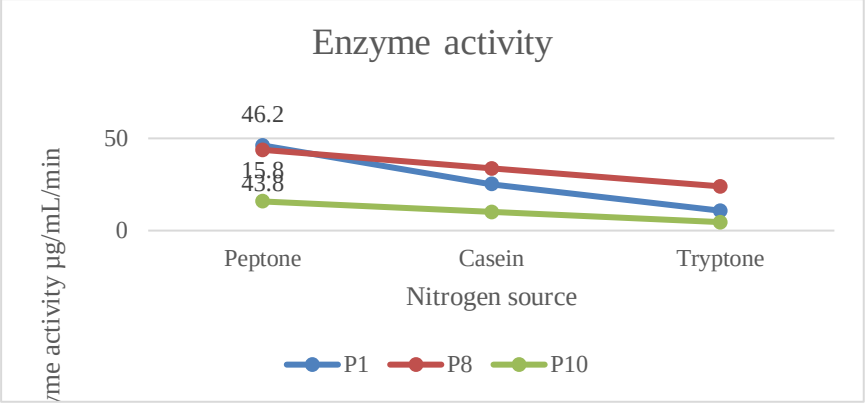

Figure.5 Effect of source on Enzyme activity of Isolates.

Table.8 Effect of selected microbial isolates on Mung plant.

Sr. No	Nature of soil	Shoot length (cm)	Root length (cm)	Length of plants(cm)	NO. of leaves
1	Control	7.5	1.5	9	2
2	Control+P1	8.4	4	12.4	2
3	Control+P8	9.9	3.3	13.2	2
4	Control+P10	13.5	5	18.5	2
5	Consortia	11.7	3.5	15.2	2

Figure.6 Comparative growth analysis of Vigna radiata treated with individual isolates (P1, P8, P10) and a microbial consortium against control.

Conclusion

The present study successfully isolated, characterized, and evaluated phosphate-solubilizing bacteria (PSB) from rhizospheric soils of different crops. Among the isolates, P1 (Aeromonas sp.), P8 (Providencia sp.), and P10 (Proteus sp.) demonstrated superior phosphate-solubilizing efficiency, as confirmed through qualitative halo zone formation, quantitative estimation in PVK broth, and biochemical identification. Optimization experiments demonstrated that environmental factors such as pH and temperature, together with nutritional sources like sucrose and peptone, strongly influenced solubilization activity, underscoring the remarkable adaptability of these isolates

Fermentation studies further validated the ability of these isolates to proliferate and maintain phosphate-solubilizing activity in liquid culture. Most importantly, pot assays with Vigna radiata confirmed the plant growth-promoting potential of PSB, with P10 showing the highest enhancement in shoot length, root length, and overall plant height. The consortium treatment also demonstrated synergistic effects, underscoring the importance of microbial interactions in sustainable agriculture. Collectively, these findings establish P1, P8, and P10 as promising candidates for biofertilizer development. Their ability to solubilize insoluble phosphate, improve nutrient availability, and enhance plant growth positions them as eco-friendly alternatives to chemical fertilizers. This research not only contributes to the understanding of PSB diversity and functionality but also provides a practical foundation for integrating microbial biofertilizers into modern agricultural practices. By reducing dependence on synthetic inputs and improving crop productivity, phosphate-solubilizing bacteria can play a pivotal role in achieving sustainable and resilient farming systems.

References:

1. Agboola Adebank A, Ogunnusi Tolulope A & Akpor oghenerobor B (2023)"Optimization of Phosphate Solubilization Activity of *Enterobacter cloacae and Enterobacter hormaechei* from Rhizosphere." The Open Microbiology Journal, vol.17

2. Aliyat Fatima Z, Maldani Mohamed, Guilli Mohammed El, Nassiri Laila & Ibijbijen,(2020). "Isolation and Characterization of Phosphate Solubilizing Bacteria from Phosphate Solid Sludge of the Moroccan Phosphate Mines." The Open Agriculture Journal, vol. 14, pp. 16–27.
3. Amri Marwa, Rjeibi Mohamed Ridha, Gatrouni Marwa, Mateus Dina M R, Asses Nedra, Pinho Henrique Jo & Abbes Chaabane, (2023)."Isolation, Identification, and Characterization of Phosphate-Solubilizing Bacteria from Tunisian Soils." Microorganisms, vol. 11, no. 3, article 783.
4. Andrade Luana Alves de, Santos Carlos Henrique Barbosa, Frezarin Edvan Teciano, Sales Luziane Ramos & Rigobela Everlon Cia. (2023) "Plant Growth-Promoting Rhizobacteria for Sustainable Agricultural Production." Microorganisms, vol. 11, no. 4, article 1088. MDPI.
5. Chakra Prashantkumar S., Kumar Vinay P.G & Swamy.C.T. (2019) "Isolation and Biochemical Characterization of Plant Growth Promoting Bacteria from a Maize Crop Field." International Journal of Current Microbiology and Applied Sciences, vol. 8, no. 4, pp. 1415–1422.
6. Damor Shilpi and Praveen Goswami (2016). "Morphological and Biochemical Characterization of Isolated Phosphate Solubilizing Bacteria." International Journal of Science Technology and Management, vol. 5, no. 10, pp. 1–6.
7. Fenta Lamenew (2017). Isolation and Characterization of Phosphate Solubilizing Bacteria from Tomato *(Solanum l.)* Rhizosphere and Their Effect on Growth and Phosphorus Uptake of the Host Plant under Greenhouse Experiment. Addis Ababa University.
8. Gummagolmath. K. C, Bhawar. R.S, Ramya Lakshmi. S. B & Patra Priyanka (2020). "Impact of Crop Diversification on Farmers Socio-economic Conditions of the Farmers: A Case of Himachal Pradesh." Research Journal of Agricultural Sciences, vol. 11, no. 1, National Institute of Agricultural Extension Management
9. Gupta Renu, Kumari Anshu, Sharma Shiwali, Alzahrani Othman M, Noureledeen Ahmed & Darwish Hadeer (2022). "Identification, Characterization and Optimization of Phosphate Solubilizing Rhizobacteria (PSRB) from Rice Rhizosphere." Saudi Journal of Biological Sciences, vol. 29, no. 1, pp. 35–42.
10. Karpagam T, & Nagalakshmi P. K, (2014). Isolation and characterization of phosphate solubilizing microbes from agricultural soil. International Journal of Current Microbiology and Applied Sciences, 3(3), 601–614.
11. Kumar Ajay (2021). Indian Agriculture, Farmer and Labour: Issues and Reforms. Bharti Publications.
12. Lamani Channappa & Correya Philomina, (2022). "Agriculture Role, Nature and Factor Determining Crop Pattern in India." International Journal of Creative Research Thoughts (IJCRT), vol. 10.
13. Liu Zhiguang, Li Yuncong C., zhang Shouan, Fu Yuqing, Fan Xiaohui, Patel jaimin S.& zhang Min. (2015). "Characterization of Phosphate-Solubilizing Bacteria Isolated from Calcareous Soils." Applied Soil Ecology, vol. 95. 217–224. Elsevier.
14. Ma Qinghua, He Shanwen, Wang Xing, Rengel zed, Chen Lin, Wang Xinghong, Pei Shunxian, Xin xuebing & Zhang Xiaoxia (2023)."Isolation and Characterization of Phosphate-Solubilizing Bacterium *Pantoea rhizosphaerae sp*. nov. from *Acer truncatum* Rhizosphere Soil and Its Effect on *Acer truncatum* Growth." Frontiers in Plant Science, vol. 14, article 1218445. Available on Frontiers in Plant Science
15. Mahantesh, P., and C. S. Patil, (2011). "Isolation and Biochemical Characterization of Phosphate Solubilizing Microbes." *International Journal of Microbiology Research*, vol. 3, no. 1, pp. 67–70.
16. Mehta Sangeeta and Nautiyal Chandra Shekhar, (2001). "An Efficient Method for Qualitative Screening of Phosphate-Solubilizing Bacteria." *Current Microbiology*, vol. 41, no. 5, pp. 316–320.
17. Mengesha Assefa Shegaw and Legesse Negash Hailu, (2024). "Isolation and characterization of phosphate solubilizing bacteria from the rhizosphere of lentil (*Lens culinaris M.*) collected from Hagere Mariam district, Central Ethiopia." PLOS ONE.
18. Mohanty Akshaya Kumar (2022). "Impact of Technological Innovation on Agricultural Productivity and Food Security in India." International Journal of Food and Nutritional Sciences (IJFANS), vol. 11, no. 5, pp. 845–854.
19. Pande Amit, Pandey Prashant, Mehra simmi, Singh Mrintujay & Kaushik Suresh, (2017). "Phenotypic and Genotypic Characterization of Phosphate Solubilizing Bacteria and Their Efficiency on the Growth of Maize." Journal of Genetic Engineering and Biotechnology, vol. 15, no. 2, pp. 379–391.
20. Prasad.A, Dixit.M, Meena.S.K, Suman & Kumar A (2023). "Qualitative and Quantitative Estimation for Phosphate Solubilizing Ability of *Trichoderma* Isolates: A Natural Soil Health Enhancer." Materials Today: Proceedings .

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Original Article

Isolation and Screening of Indole Acetic Acid Producing PGPR from Soil Samples.

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Manuscript ID:
JRD -2026-180426
ISSN: 2230-9578
Volume 18
Issue 4(XI)
Pp. 165-172
April - 2026
Submitted: 16 Mar. 2026
Revised: 30 Mar. 2026
Accepted: 09 Apr . 2026
Published:30 April2026

Abstract

Indole acetic acid (IAA) is one of the most important phytohormones that enhances root development and overall plant growth. However, the availability of natural growth-promoting substances in soil is often limited, leading to the use of beneficial microorganisms. The present study focuses on the isolation and screening of indole acetic acid (IAA) producing PGPR from soil samples. Soil samples were collected from rhizosphere soil and subjected to serial dilution and spread plate technique for isolation using LB medium supplemented with L-tryptophan. Out of 13 isolates, nine were able to produce IAA as confirmed by the Salkowski reagent test, and four were selected as efficient producers (IAA1, IAA2, IAA3 and IAA6). These isolates were selected based on their IAA-producing ability for further studies. Morphological and biochemical characterization of the selected isolates was carried out for identification. Based on the obtained results, IAA1 was identified as Proteus sp., IAA2 as Providencia sp., IAA3 as Proteus sp., and IAA6 as Aeromonas sp. Further investigations included optimization of cultural conditions such as pH, temperature and carbon source to determine the optimum conditions for IAA production. Spectrometric analysis showed maximum IAA production by isolates after 72 hours at room temperature. Partial purification of IAA was done and purity was confirmed by thin layer chromatography (TLC). The in vitro treatment of mung seeds with isolates and consortia for germination showed better results than the control. Among all the isolates, IAA6 showed the best performance in promoting seed germination compared to other isolates and control. The study suggests that the IAA producing bacteria can act as efficient biofertilizers.

Keywords: *Indole acetic acid (IAA), Plant Growth Promoting Rhizobacteria (PGPR), Rhizosphere soil, Seed germination, Biofertilizer.*

Introduction

Agriculture plays a vital role in ensuring global food security and rural livelihoods, yet it faces increasing challenges such as climate change, soil degradation, and the need for higher productivity with reduced chemical use (Mike-Anosike et al., 2018). Although chemical fertilizers initially improved crop yields, their long-term use has resulted in serious concerns including ecological imbalance, declining soil fertility, and environmental contamination (Chudiwal et al., 2024). These limitations have driven the search for more sustainable and environmentally friendly alternatives.

Biofertilizers, particularly Plant Growth-Promoting Rhizobacteria (PGPR), have emerged as a promising and eco-friendly solution. PGPR inhabit the rhizosphere the biologically active region of soil surrounding plant roots and enhance plant growth by improving nutrient availability, producing phytohormones, and protecting plants from stress (Gakkhad et al., 2022). These bacteria help in nutrient mobilization, such as phosphorus and iron, and produce growth regulators like Indole-3-acetic acid (IAA), which plays an important role in plant development. IAA is a key auxin that regulates cell division, elongation, and differentiation, influencing root growth and overall plant development (Kowalczyk et al., 2001). Many rhizobacteria produce IAA through tryptophan-dependent pathways, utilizing compounds present in root exudates as precursors (Lebrazi et al., 2020). Microbial IAA enhances root system architecture, leading to improved nutrient uptake and better plant growth under different environmental conditions. In addition to hormone production, PGPR show other growth-promoting traits such as phosphate solubilization, siderophore production, and disease resistance (Modi et al., 2017).

Quick Response Code:
Website:
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DOI:
10.5281/zenodo.21126696
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How to cite this article:
Pilankar, S. N., Sangavkar, S. V., & Wasave, S. B. (2026). Isolation and Screening of Indole Acetic Acid Producing PGPR from Soil Samples. Journal of Research and Development, 18(4(XI)), 165–172. https://doi.org/10.5281/zenodo.21126696

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

These combined mechanisms improve seed germination, biomass accumulation, and stress tolerance, making PGPR highly beneficial for sustainable agricultural practices (Majeed et al., 2015). Screening and optimization of IAA-producing PGPR are critical steps for their agricultural application. Techniques such as Salkowski reagent assay are widely used to identify high-yielding strains and enhance IAA production under controlled conditions (Randive et al., 2024). These approaches help in effectively translating laboratory research into field applications. Overall, IAA-producing PGPR provide a sustainable alternative to chemical fertilizers by improving plant growth and soil health. Their use supports eco-friendly and climate-resilient agriculture.

Materials and Methods

Sample collection

Rhizosphere soil samples were obtained from various sites in Ratnagiri at a depth of 0–15 cm near the root zone of healthy plants for the isolation of microorganisms. The samples were collected, placed in sterile polythene bags to prevent contamination, properly labeled, and transported to the laboratory. All samples were processed within 24 hours to maintain microbial viability.

Isolation of IAA producing bacteria

Isolation of rhizobacteria was carried out by preparing a soil suspension in which 1 g of soil was added to 9 mL of sterile saline and vortexed for proper mixing, followed by serial dilutions ranging from 10^{-1} to 10^{-6}. From the last three dilutions, 0.1 mL aliquots were spread onto Luria Bertani (LB) agar plates supplemented with L-tryptophan and incubated at 28–30 °C for 2–3 days. Distinct bacterial colonies were then isolated and purified by streaking onto fresh LB agar plates supplemented with L-tryptophan to obtain pure cultures (Mohite et al., 2013).

Screening of IAA producing bacteria

Screening is a key step to identify rhizobacteria capable of producing Indole Acetic Acid (IAA), a vital plant growth hormone. It is commonly done by culturing isolates in tryptophan-supplemented media and detecting IAA production using methods like the Salkowski reagent test.

Qualitative Screening

For the qualitative detection of indole-3-acetic acid (IAA), each bacterial isolate was inoculated into Luria Bertani (LB) agar slants supplemented with L-tryptophan and incubated at 28 °C for 2–3 days to allow sufficient growth. Freshly prepared Salkowski reagent was then added to the bacterial cultures in test tubes, which were incubated in the dark at room temperature for 30 minutes. The appearance of pink to red coloration indicated positive IAA production, and isolates showing significant color development were selected for subsequent quantitative analysis.

Quantitative Screening

For quantitative estimation of indole-3-acetic acid (IAA), positive bacterial isolates were inoculated into Luria Bertani (LB) broth supplemented with L-tryptophan and incubated at 28 ± 2 °C for 48–72 h under shaking conditions (120–150 rpm). Cultures were centrifuged at 5000 rpm for 10 minutes to obtain cell-free supernatants, which were mixed with Salkowski's reagent (1 mL of 0.5 M $FeCl_3$ in 50 mL of 35% $HClO_4$) in a 1:2 ratio. The mixtures were incubated in the dark for 20–30 minutes to allow color development, and absorbance was measured at 530 nm using a spectrophotometer. IAA concentrations were determined from a standard curve prepared with known IAA dilutions (10–100 µg/mL). This assay enabled accurate quantification of IAA production by bacterial isolates (Randive et al., 2024; Das et al., 2019).

Thin layer chromatography (TLC)

TLC was employed to detect indole-3-acetic acid (IAA) from bacterial culture extracts. Silica gel plates (~0.25 mm thickness) were prepared by mixing 5 g of silica powder with a pinch of calcium carbonate and 12.5 mL distilled water to form a slurry, which was spread evenly on clean glass plates, dried at room temperature, and activated at 80 °C. Bacterial isolates were grown in LB broth supplemented with L-tryptophan at 28 °C for 72 h, and the cultures were centrifuged at 5000 rpm for 10 minutes to obtain cell-free supernatants. IAA was extracted with ethyl acetate (1:2 v/v), the organic layer evaporated at 40–45 °C, and the residue dissolved in methanol for spotting. Standard IAA and sample extracts (2–10 µL) were applied to the baseline of TLC plates, which were developed in a solvent system of butanol:acetic acid:water (7:2:1 v/v/v) until the solvent front reached ~80% of the plate. After air-drying, plates were visualized under UV light and sprayed with Salkowski's reagent, where pink/red spots indicated IAA presence. Retention factors (Rf) were calculated as the ratio of distance traveled by the spot to that of the solvent front, enabling comparison between standard and sample IAA (Randive et al. 2024; Mohite et al. 2013).

RF calculation

RF = Distance moved by the spot / Distance moved by the solvent front

Morphological and Biochemical characterization

Pure bacterial isolates were characterized based on morphological and biochemical tests for the preliminary identification of indole-3-acetic acid (IAA)-producing bacteria. Colony Morphology were observed on Luria–Bertani (LB) agar, and Gram staining was performed to determine Gram nature. Biochemical identification was carried out using standard tests. IMViC tests consist of Indole, Methyl Red, Voges–Proskauer, and Citrate utilization tests. In addition, sugar fermentation (glucose, lactose, and mannitol), catalase, oxidase, and H_2S production tests were

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ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

performed to assess metabolic and enzymatic characteristics. These analyses helped in the identification and selection of efficient IAA-producing bacterial isolates (Chudiwal et al., 2024).

Optimization of Environmental and Nutritional parameters for IAA production

To evaluate environmental and nutritional factors influencing indole-3-acetic acid (IAA) production, bacterial isolates were cultured in Luria Bertani (LB) broth supplemented with L-tryptophan under varying conditions. For pH optimization, media were adjusted to different pH values (5–9) using HCl or NaOH, inoculated with bacterial culture, and incubated at 28 °C for 72 hours; supernatants were treated with Salkowski's reagent and absorbance measured at 530 nm to determine the optimum pH (Nguyen Van Hian et al., 2024). Temperature effects were assessed by incubating cultures at 4 °C, room temperature, 37 °C, and 55 °C under similar conditions, with IAA quantified spectrophotometrically (Lata et al., 2024). The influence of carbon sources was tested by supplementing LB broth with 1% glucose, sucrose, or starch, followed by inoculation, incubation, and IAA estimation using Salkowski's reagent; absorbance values were compared to identify the most effective carbon source for IAA production (Lata et al., 2024).

Effect of IAA on Mung bean (*Vigna radiata*) germination

IAA-producing bacterial isolates were streaked on LB agar supplemented with L-tryptophan and incubated at 28 °C for 24 h; single colonies were transferred into LB broth (100–250 mL) and cultured at 28 °C under shaker condition at 120 rpm for 24–48 h, adjusting cell density to ~10^6–10^8 CFU/mL. Seeds were surface-sterilized with 0.02% sodium hypochlorite for 2 min, rinsed thoroughly, and soaked in bacterial suspensions for 30 min under gentle shaking, while control seeds were treated with sterile distilled water.

Germination assays were conducted by placing seeds per replicate on moist sterile filter paper in Petri plates and incubating at 28 ± 2 °C for 4 days, after which germination percentage, root length, and shoot length were recorded. Seedling growth performance was further assessed by transferring seedlings into pots containing sterilized or natural soil, maintaining them under controlled conditions, and recording parameters such as plant height, number of leaves, and root and shoot length at appropriate growth stages. The seed vigor index (SVI) was calculated as germination % × (mean root length + mean shoot length) to evaluate treatment effects (Qureshi et al., 2025; Das et al., 2019).

Results and Discussion

Isolation of IAA producing bacteria

Soil samples collected from the rhizosphere were processed using serial dilution and spread-plate techniques on LB medium supplemented with L-tryptophan. A total of 13 bacterial isolates were obtained, forming the basis for further screening. These results are consistent with earlier reports that the rhizosphere is a rich source of plant growth-promoting rhizobacteria (PGPR). Anosike et al. (2018) described similar isolation methods yielding diverse colonies from rhizospheric soils, while Mohite et al. (2013) reported ten diverse isolates from banana, cotton, maize, and wheat rhizospheres under favorable physicochemical conditions. The recovery of 13 isolates in this study highlights the microbial diversity of rhizosphere habitats and provides a foundation for identifying efficient IAA-producing strains.

Screening of IAA producing bacteria

Qualitative Screening

Qualitative screening for indole-3-acetic acid (IAA) production was carried out using the Salkowski assay. Out of 13 isolates tested, 9 (1, 2, 3, 5, 6, 8, 10, 12, and 13) developed pink to red coloration after 30 minutes of incubation, confirming their ability to synthesize IAA. These findings are consistent with earlier reports that the Salkowski assay is a reliable preliminary method for detecting IAA in rhizobacteria. Majeed et al. (2015) demonstrated similar qualitative detection in malate medium, while other studies have also reported its effectiveness. Collectively, these results confirm that only a subset of rhizospheric bacteria actively produce IAA, and the identification of nine IAA-producing isolates in this study underscores their potential as plant growth-promoting rhizobacteria.

Quantitative Screening

Quantitative estimation of indole-3-acetic acid (IAA) was performed using a spectrophotometric method at 530 nm with a standard curve for calculation. Among the tested isolates, IAA production ranged from 9 to 49 µg/mL, with isolate 6 showing the highest production (49 µg/mL), followed by isolates 2 (44 µg/mL) and 1 (39 µg/mL). Moderate levels were observed in isolates 3 (38 µg/mL) and 5 (36 µg/mL), while isolates 8 (11 µg/mL), 10 (14 µg/mL), 12 (13 µg/mL), and 13 (9 µg/mL) produced low amounts. These results confirm variability in IAA biosynthetic capacity among rhizobacteria. Therefore, the four isolates exhibiting higher IAA production (IAA1, IAA2, IAA3, and IAA6) were selected and used for further investigation and identification, consistent with earlier reports. Majeed et al. (2015) documented wide ranges of IAA production (0.27–77.98 µg/mL) among wheat-associated PGPR, while Das et al. (2019) found maximum production at 72 hours, with certain isolates showing higher production than others. Such variability reflects differences in metabolic pathways and emphasizes the importance of selecting high-producing strains for plant growth promotion.

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Thin layer chromatography (TLC)

Thin-layer chromatography (TLC) of the bacterial ethyl acetate extracts showed pink-colored spots similar to the authentic IAA standard. The isolates had Rf values of 0.9 (IAA1), 0.9 (IAA2), 0.89 (IAA3), and 0.9 (IAA6), which were very close to the standard IAA Rf of 0.95. These results confirm that all the bacterial isolates produced IAA. These results consistent with the study of Randive et al. (2024), where bacterial samples showed spots matching the IAA standard, along with another unidentified component. Mohite et al. (2013) also reported pink spots at Rf values corresponding to standard IAA in rhizosphere bacterial extracts, confirming their IAA production. Overall, TLC clearly confirmed that all tested bacterial isolates can produce IAA, which supports their potential to promote plant growth.

Morphological and Biochemical characterization

The selected indole-3-acetic acid (IAA) producing isolates were characterized using Gram staining, catalase, oxidase, and IMViC tests. Based on these analyses, IAA1 was identified as *Proteus* sp., IAA2 as *Providencia* sp., IAA3 as *Proteus* sp., and IAA6 as *Aeromonas* sp., with identifications supported by their biochemical profiles and Gram reactions. These findings confirm that diverse bacterial taxa can synthesize IAA, consistent with Yasin et al. (2022), who reported both Gram-positive and Gram-negative IAA producers, while, Chudiwal et al. (2024) highlighted distinct biochemical traits among Gram-negative IAA producers, Together, these results highlight the taxonomic diversity of IAA-producing rhizobacteria and their potential role in plant growth promotion.

Optimization of Environmental and Nutritional parameters for IAA production

The IAA production efficiency of selected isolates was analyzed under different environmental and nutritional conditions, including pH, temperature, and carbon source. The results showed that the optimum pH for IAA production was found to be 7 for IAA1, IAA3, and IAA6, while IAA2 showed maximum production at pH 8. The optimum temperature for IAA1, IAA2, and IAA6 was room temperature, whereas IAA3 and IAA6 exhibited maximum production at 37°C. Among the nutritional factors, starch was identified as the most suitable carbon source for IAA1, IAA2, and IAA3, while sucrose was found to be optimal for IAA6. These findings indicate that both environmental and nutritional factors significantly influence IAA production and that optimal conditions vary among isolates. Similar observations were reported by Nguyen Van Hian et al. (2024) and Lata et al. (2024), who found that neutral pH and mesophilic temperature (30–37°C) favor maximum IAA production. Mike-Anosike et al. (2018) also reported higher IAA synthesis at pH 7, while Mohite et al. (2013) demonstrated that slightly alkaline conditions enhance auxin production. Furthermore, Chandra et al. (2018) and Lata et al. (2024) reported that carbon sources such as sucrose and dextrose significantly improve IAA production, supporting the present findings.

Effect of IAA on Mung bean (Vigna radiata) germination

The effect of different IAA-producing treatments on seed germination and seedling growth was evaluated using the Seed Vigor Index (SVI). Significant variations were observed among treatments in terms of germination percentage, root length, shoot length, and overall seedling vigor. Among all treatments, IAA 2 and Consortia recorded the highest germination percentage (100%), followed by IAA 3 and Control (96.67%), while IAA 1 and IAA 6 showed comparatively lower germination (93.33%). The Seed Vigor Index (SVI), which integrates both germination and seedling growth parameters, showed considerable differences across treatments. The highest SVI was recorded in IAA 6 (2613.24), indicating superior seedling growth and vigor. This was followed by IAA 2 (2550) and Consortia (2450), suggesting strong plant growth-promoting activity. Moderate SVI values were observed in IAA 3 (2387.75) and IAA 1 (2286.59). In contrast, the Control treatment exhibited the lowest SVI (1720.72), indicating comparatively poor seedling development in the absence of bacterial inoculation. These findings are similar to previous studies. Patel et al. (2022) reported isolate-specific enhancement in root and shoot growth in crops such as wheat, mung bean, and broad bean. Similarly, Qureshi et al. (2025) demonstrated that high-IAA-producing strains significantly improved seed vigor and biomass in wheat. Modi et al. (2017) also highlighted the crucial role of IAA in promoting root elongation and enhancing nutrient uptake. Overall, all IAA-producing treatments improved seedling vigor compared to the control, with IAA 6 emerging as the most effective treatment, followed by IAA 2 and Consortia.

Table.1 Quantitative analysis of IAA production

Sr. No.	Isolates	IAA conc. (µg/mL)
1	IAA1	39 µg/mL
2	IAA2	44 µg/mL
3	IAA3	38 µg/mL
4	IAA5	36 µg/mL
5	IAA6	49 µg/mL
6	IAA8	11 µg/mL
7	IAA10	14 µg/mL
8	IAA12	13 µg/mL
9	IAA13	9 µg/mL

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ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

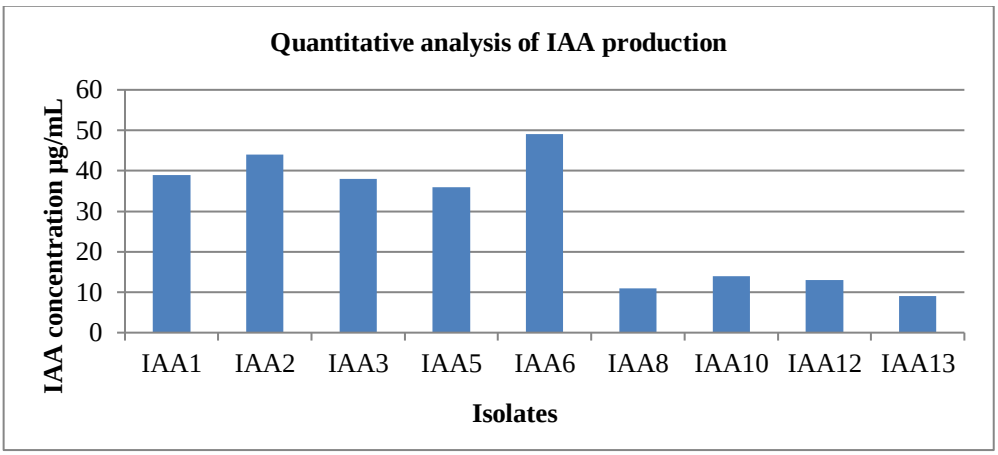

Figure.1 Quantitative analysis of IAA production

Table.2 Morphological and Biochemical Identification of the isolates

Characteristics	**IAA1** ***Proteus* sp.**	**IAA2** ***Providencia* sp.**	**IAA3** ***Proteus* sp.**	**IAA6** ***Aeromonas* sp.**
Gram Nature	Gram Negative	Gram Negative	Gram Negative	Gram Negative
Shape	Rods	Rods	Rods	Rods
Indole	-	+	-	+
Methyl red	+	+	+	+
Voges-Proskauer	-	-	-	-
Citrate utilization	-	-	-	-
Urease	+	+	+	+
Bile Esculin	-	-	+	+
Nitrate reduction	+	-	+	+
Glucose fermentation	+	+	+	+
Lactose fermentation	-	-	-	-
Mannitol fermentation	-	-	-	+
Starch hydrolysis	-	-	-	+
H_2S production	-	-	-	-
PPA	+	+	+	-
Ornithine test	+	+	+	-
Catalase	+	+	+	+
Oxidase test	-	-	-	+

*(+ = Positive test, - = Negative test)

Table.3 IAA production (µg/mL) at different pH levels

pH / Isolates	**5**	**6**	**7**	**8**	**9**
IAA1	**19**	**22**	**25**	**20**	**18**
IAA2	**16**	**19**	**25**	**27**	**23**
IAA3	**19**	**21**	**24**	**23**	**22**
IAA6	**21**	**18**	**24**	**17**	**18**

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ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

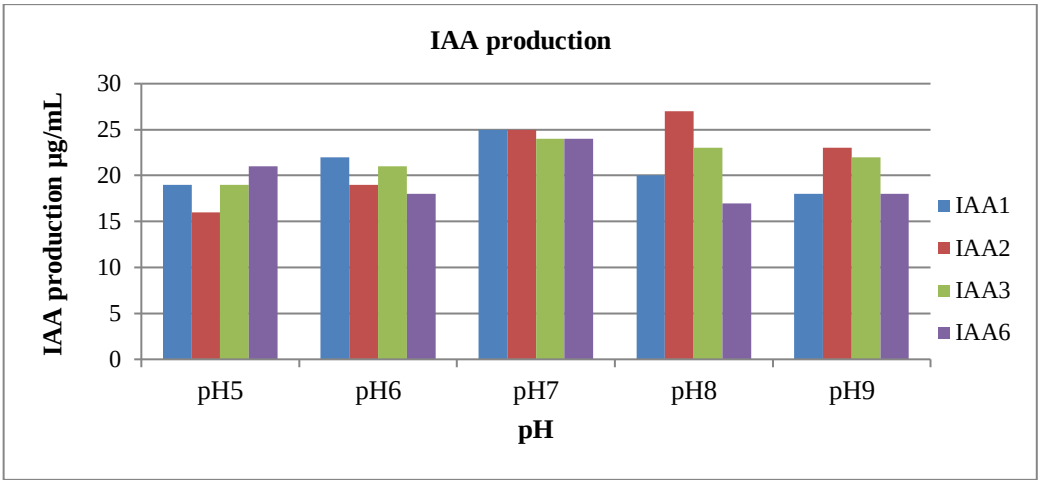

Figure.2 Optimization of pH for IAA production

Table.4 IAA production (µg/mL) at different temperatures

Isolates \ temperature	4°C	RT	37°C	55°C
IAA1	14	22	16	11
IAA2	11	46	21	14
IAA3	11	19	21	16
IAA6	11	19	19	11

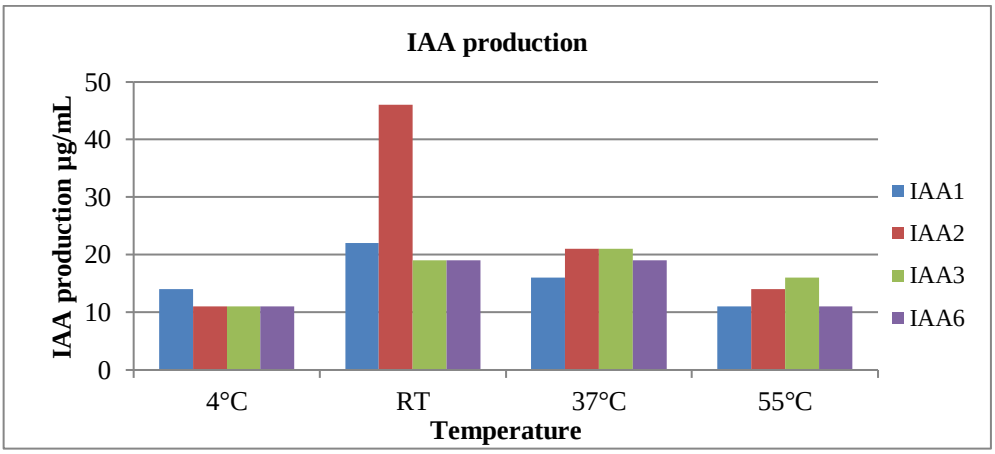

Figure.3 Optimization of Temperatures for IAA production

Table.5 IAA production (µg/mL) at different Carbon source

Isolates \ Carbon Sources	Glucose	Sucrose	Starch
IAA1	11	12	27
IAA2	18	16	26
IAA3	22	42	45
IAA6 at RT	19	25	14
IAA6 at 37°C	26	30	22

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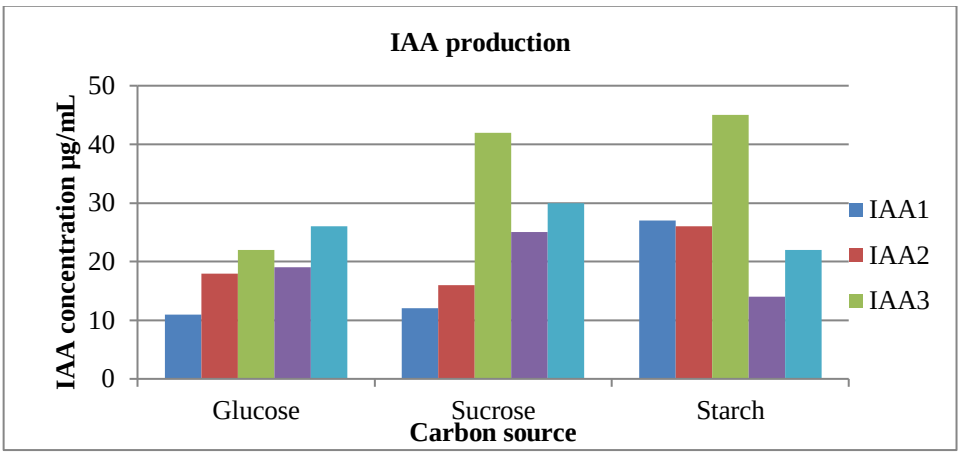

Figure.4 Optimization of Carbon source for IAA production

Table.6 Effect of selected microbial isolates on Mung plant

Culture isolates	Germination percentage (%)	Root length (cm)	Shoot length (cm)	Length of plant (cm)	No. of leaves	Seed Vigor Index
Control	96.67%	1.8 cm	16 cm	17.8 cm	2	1720.72
IAA1	93.33%	3.5 cm	21 cm	24.5 cm	2	2286.59
IAA2	100%	4.5 cm	21 cm	25.5 cm	2	2550
IAA3	96.67%	5.2 cm	19.5 cm	24.7 cm	2	2387.75
IAA6	93.33%	4 cm	24 cm	28 cm	2	2613.24
Consortia	100%	6.5 cm	18 cm	24.5 cm	2	2450

Figure.5 Comparative growth analysis of Mung treated with isolates and microbial consortium against the control

Conclusion

The present study successfully isolated, characterized, and evaluated indole-3-acetic acid (IAA) producing rhizobacteria from rhizospheric soil. Among the isolates, IAA1 (Proteus sp.), IAA2 (Providencia sp.), IAA3 (Proteus sp.), and IAA6 (Aeromonas sp.) demonstrated significant IAA-producing ability, as confirmed through qualitative Salkowski assay, quantitative estimation, thin-layer chromatography (TLC), and biochemical identification. Quantitative results showed variation in IAA production, with IAA6 showing the highest yield (49 µg/mL), followed by IAA2, IAA1, and IAA3, indicating differences in biosynthetic efficiency. Optimization studies revealed that environmental and nutritional factors such as pH, temperature, and carbon source influenced IAA production. Neutral to slightly alkaline pH, suitable temperature, and carbon sources like starch and sucrose enhanced IAA synthesis, showing the adaptability of these isolates. The plant growth-promoting potential was confirmed through seed germination studies in Vigna radiata. All treatments improved germination and seedling vigor compared to the

control. IAA6 showed the highest Seed Vigor Index (SVI), followed by IAA2 and the consortia, indicating strong growth-promoting activity, while the consortia also showed a synergistic effect. These findings confirm that IAA-producing rhizobacteria are effective plant growth promoters with potential use as biofertilizers. Their ability to produce phytohormones and improve plant growth supports their role as eco-friendly alternatives to chemical fertilizers. This study supports their application in sustainable agriculture for improving crop productivity and soil health.

References

1. Chandra, S., Askari, K., & Kumari, M. (2018). Optimization of indole acetic acid production by isolated bacteria from Stevia rebaudiana rhizosphere and its effects on plant growth. Journal of Genetic Engineering and Biotechnology, 16(2), 581–586.
2. Chudiwal, A., & Nalawade, A. (2024). Production of indole acetic acid from soil bacteria: An alternative approach on plant growth. International Journal of Advanced Research in Biological Sciences, 11(5), 9–14.
3. Das, S., Lata, P., & Samantaray, S. (2019). Isolation and characterization of indole acetic acid producing bacteria from rhizosphere soil and their effect on seed germination. International Journal of Current Microbiology and Applied Sciences, 8(3), 1237–1245.
4. Gakkhad, P., Patel, R., & Sharma, V. (2022). Isolation & screening of indole acetic acid (IAA) producing rhizobacterial strains. International Journal of Biotechnology and Microbiology, 4(1), 62–68.
5. Kowalczyk, M., & Sandberg, G. (2001). Quantitative analysis of indole-3-acetic acid metabolites in Arabidopsis. Plant Physiology, 127(4), 1845–1853.
6. Lata, D. L., Mistry, N. J., Patel, K. B., & Joshi, C. G. (2024). IAA-producing bacteria from the rhizosphere of chickpea (Cicer arietinum L.): Isolation, characterization, and their effects on plant growth performance. Heliyon, 10(21), Article e39702.
7. Lebrazi, S., Hafidi, M., & Ouhdouch, Y. (2020). Screening and optimization of indole-3-acetic acid production and phosphate solubilization by rhizobacterial strains isolated from Acacia cyanophylla root nodules and their effects on its plant growth. Journal of Genetic Engineering and Biotechnology, 18(1), Article 71.
8. Majeed, A., Abbasi, M. K., & Hameed, S. (2015). Isolation and characterization of plant growth-promoting rhizobacteria from wheat rhizosphere and their effect on plant growth promotion. Frontiers in Microbiology, 6, Article 198.
9. Mike-Anosike, E. E., Okonko, I. O., & Adeyemi, F. M. (2018). Studies on indole acetic acid (IAA) production by rhizobacteria and growth promoting potentials. International Journal of Advanced Research in Biological Sciences, 5(2), 133–140.
10. Modi, K., Patel, R., & Desai, M. (2017). Isolation, screening and characterization of PGPR from rhizosphere of rice. International Journal of Pure and Applied Biosciences, 5(3), 264–270.
11. Mohite, B. (2013). Isolation and characterization of indole acetic acid (IAA) producing bacteria from rhizospheric soil and its effect on plant growth. Journal of Soil Science and Plant Nutrition, 13(3), 638–649.
12. Nguyen, V. G., Nguyen, T. T., & Le, T. H. (2024). Isolation and characterization of indole acetic acid-producing bacteria from rhizosphere soil of paddy rice. Plant Biosystems, 158(3), 421–430.
13. Patel, J. P., Archana, G., & Kumar, B. (2022). Isolation and characterization of plant growth promoting rhizospheric soil bacteria. International Journal of Novel Research and Development, 7(7), 1223–1230.
14. Qureshi, N., Singh, D. K., & Patel, R. (2025). Isolation and characterization of indole acetic acid (IAA) producing rhizospheric bacteria from maize (Zea mays) plants. International Journal of Novel Research and Development, 10(2), 833–915.
15. Randive, V. S., Jadhav, S. D., & Pawar, R. M. (2024). Screening and optimization of IAA production by PGPR isolated from rhizosphere of Pterocarpus marsupium Roxb. and their effect on plant growth. Current Agricultural Research, 12(1), 326–338.
16. Yasin, R., Qureshi, A. S., & Bano, A. (2022). Isolation and characterization of plant growth-promoting bacteria from different rhizospheric soils. The Journal of Microbiology and Molecular Genetics, 3(3).
17. Zahroya, I. U., Huda, M., & Santoso, B. (2020). Isolation and characterization of indole-3-acetic acid producing bacteria from red onion rhizosphere. IOP Conference Series: Earth and Environmental Science, 457(1), Article 012046.

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Original Article

Isolation of Exopolysaccharide Producing Rhizobacteria for Sustainable Agriculture

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Manuscript ID:
JRD -2026-180427
ISSN: 2230-9578
Volume 18
Issue 4(XI)
Pp. 173-180
April - 2026
Submitted: 16 Mar. 2026
Revised: 30 Mar. 2026
Accepted: 09 Apr . 2026
Published:30 April2026

Abstract
Exopolysaccharide (EPS) producing rhizobacteria play an important role in improving soil structure, moisture retention, and plant growth. This study focuses on the isolation and identification of EPS-producing rhizobacteria from different rhizosphere soil samples from different regions of Ratnagiri. The samples were collected and processed using serial dilution and spread plate technique on nutrient agar supplemented with 2% sucrose. Total 18 isolates were obtained, out of 9 showed highly mucoidal appearance on yeast extract mannitol agar (YEMA). EPS extraction was carried out using centrifugation and alcohol precipitation. Among the isolates, E1 (100 mg/L), E3 (200 mg/L), and E4 (400 mg/L) showed EPS yield. Quantitative estimation done using phenol-sulfuric acid assay which confirmed that these three isolates had higher carbohydrate content and were selected for further study. Optimization studies showed that sucrose was best carbon source for isolates E1, E3, and E4. The optimum pH was 7 for isolates E1 and E3, while isolate E4 showed optimum growth at pH 8. Room temperature was suitable for all isolates. Based on morphological and biochemical tests, the isolates were identified as Citrobacter sp. (E1), Providencia sp. (E3), and Aeromonas sp. (E4). A pot experiment was also conducted to evaluate plant growth-promoting activity, all three isolates showed better plant growth as compared to control. Among them, E4 showed the highest growth promotion. The study concluded that EPS-producing rhizobacteria, especially Aeromonas sp. (E4) have plant growth promoting ability and support sustainable agriculture.
Keywords: *Exopolysaccharide, Rhizobacteria, Sustainable agriculture, Plant growth promotion*

Introduction

Agriculture is the main source of food and livelihood, but increasing population has put pressure on land, leading to reduced soil fertility (K. Sukanya et al., 2022). Overuse of chemical fertilizers has further damaged soil health. Since farmland cannot be expanded, sustainable practices like using biofertilizers and beneficial microorganisms are needed. Soil microbes such as bacteria, fungi, and algae help improve soil fertility and support plant growth (Gouda Sushanto et al., 2018).

For sustainable agriculture, crops should have resistance to diseases, drought, salinity, and other stresses, along with better nutritional value. Soil microorganisms can help achieve this by supplying nutrients, promoting plant growth, controlling pathogens, improving soil structure, and aiding in bioaccumulation of minerals (Jeynthi V. and Kanimozhi S., 2018). Environmental stresses reduce plant growth and crop production. The rhizosphere is rich in microbial activity, where PGPR play an important role by adapting to different environments and helping plants tolerate stress (J. K. Prasad et al., 2022). The discovery of PGPR that protect plants from multiple stresses supports sustainable agriculture (Leontidou Kleopatra et al., 2020). PGPR are free-living bacteria that colonize plant roots and promote plant growth (Luana Alves de Andrade et al., 2023). They improve nutrient availability and influence plant hormones, and also protect plants from pathogens through biocontrol (Veerapagu M. et al., 2018). The root-colonizing bacteria benefit plant growth directly and indirectly (Parvin Nasrin et al., 2022). They also help control plant diseases and are used as biofertilizers in agriculture (Vejan Pravin et al., 2016). The rhizosphere is the soil region around plant roots that has a high population of microorganisms influenced by root exudates (Jeynthi V. and Kanimozhi S., 2018). These microbes may be beneficial or neutral, and root exudates act as chemical signals that attract them.

It consists of three parts: rhizosphere soil, rhizoplane (root surface), and root tissues. Microbial population here is much higher than in normal soil, and their interaction with plants helps in nutrient uptake and overall growth (Gouda Sushanto et al., 2018).

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How to cite this article:
Jadhav, S. V., Panchal, K. R., Ghadigaonkar, A. S., & Wasave, S. B. (2026). Isolation of Exopolysaccharide Producing Rhizobacteria for Sustainable Agriculture. Journal of Research and Development, 18(4(XI)), 173–180. https://doi.org/10.5281/zenodo.21126814

Quick Response Code:
Website:
https://jrdrvb.org/
DOI:
10.5281/zenodo.21126814
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ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Exopolysaccharides (EPS) are high molecular weight substances produced by microorganisms and secreted outside the cell, forming protective layers or biofilms (Beemidi Sudha Sree and Ms. V. Gayatri 2021). The term EPS was first introduced by Sutherland in 1972 (Netrusov I. Alexander et al., 2023). EPS are natural, biodegradable polymers made mainly of sugars and proteins, and they help microbes survive under stress conditions (Farag Ahmed et al., 2020). They also have important applications in food, medicine, and biotechnology due to their beneficial properties (Angelin J. and Kavitha M., 2020). In agriculture, EPS-producing bacteria improve soil structure, increase water retention, and help plants tolerate stress such as drought and salinity (Bramhachari P.V. et al., 2018).

The aim of this study is to isolate, characterize, and evaluate exopolysaccharide (EPS)-producing Plant Growth Promoting Rhizobacteria (PGPR) from soil samples and study their role in plant growth and soil health. EPS-producing PGPR help plants by forming biofilms, improving root colonization, and enhancing soil properties like water retention and nutrient availability. They also help plants tolerate stress such as drought and salinity. These bacteria reducing the need for chemical fertilizers and support sustainable agriculture. In addition, EPS have applications in food, pharmaceuticals, and biotechnology.

Materials and Methods

Isolation, Purification and Screening of Exopolysaccharide Producing Rhizobacteria

Rhizosphere soil samples collected from different regions of Ratnagiri, Maharashtra. Drumstick rhizosphere soil collected from Karwanchiwadi, tomato rhizosphere soil collected from Nivkhol Rajiwada and lima beans rhizosphere soil collected from Nava Someshwar, Ratnagiri Maharashtra. 1 g of soil sample was suspended in 10 ml st. saline. Then solution vortex and aliquotes of 1 ml solution were transferred to 9 ml st. saline and diluted serially upto sixth dilution. From three dilutions 10^{-1}, 10^{-3}, and 10^{-5} were spread on Nutrient agar supplemented with 2% sucrose and incubated for 48 h at 28°C (Nwosu I. G. *et al.,* 2019). Bacteria that produce mucoidal colonies was selected and purified by streaking the four quadrants to obtain single colonies (Minimol V. A. *et al.*, 2019). Those isolate shows mucoidal appearance was streaked on Yeast Extract Mannitol Agar for primary screening of exopolysaccharide producing rhizobacteria incubated at RT for 48 hrs (Sayyed Riyaz *et al.,* 2015).

Extraction of EPS Producing Rhizobacteria

Extraction of EPS producing rhizobacteria carried out using centrifugation and acetone precipitation. Bacterial isolates were inoculated into conical flasks holding 100 ml of YEM broth to estimate EPS production. The inoculated flasks were incubated for 72 hours at 30°C and 200 rpm on a rotator shaker. The culture broth centrifuged at 3500 rpm. The supernatant was combined with two volumes of acetone. The sample centrifuged at 3500 rpm for 30 minutes. The EPS wash with distilled water and acetone alternately and weighed after drying overnight at 105° C (Ali A. Amal and Orf O.M. Hba 2022) .

Quantification of EPS Producing Rhizobacteria

Dried EPS was quantified using phenol sulfuric acid assay (Nwosu I. G. *et al.,* 2019) A glucose stock of 100 µg/ml was prepared to run standard assay. Standard glucose solutions of 20, 40, 60, 80, and 100 µg/ml were prepared by taking the required volume of the stock solution and making up the volume to 1 ml with distilled water. For the blank, 1 ml of distilled water was used, and for the test sample, 1 ml of the sample solution was taken. To each tube containing the blank, standards, and sample, 1 ml of 5% phenol reagent was added, followed by the rapid addition of 5 ml of concentrated sulphuric acid. All the tubes were incubated at room temperature for 30 minutes to allow proper color development. After incubation, the absorbance was measured at 490 nm.

Morphological and Biochemical Characterization of EPS Producing Rhizobacteria

The selected bacterial isolates were identified based on morphological and biochemical characteristics. Morphological identification included Gram staining to determine Gram nature positive or negative. Further identification were carried out using standard biochemical tests. IMViC tests (Indole, Methyl Red, Voges–Proskauer, and Citrate utilization) were performed to study metabolic properties of the isolates. In addition, catalase and oxidase tests were conducted to detect the presence of specific enzymes. Sugar fermentation tests (glucose, maltose, mannitol and sorbitol) were also carried out using different carbohydrates with phenol red indicator and Durham tubes to observe acid and gas production. These tests helped in the characterization and identification of EPS-producing bacterial isolates (Beemidi Sudha Sree and Ms. V. Gayatri 2021).

Optimization of EPS Producing Rhizobacteria

Effect of pH

Yeast Extract Mannitol Broth was prepared at different pH values ranging from 5 to 9, and bacterial inoculum (6×10^6 cells/ml) was added to each flask. The cultures were then incubated at 28°C with shaking at 120 rpm for 8 days. After incubation, growth was measured by optical density (OD) at 610 nm. In addition, viscosity and residual sugar were also measured. Residual sugar measured using DNSA method (Sayyed R. Z. *et al*., 2011).

Effect of Temperature

100 ml Yeast Extract Mannitol Broth was prepared in four flasks, and each flask was inoculated with bacterial culture (6×10^6 cells/ml). The flasks were incubated at different temperatures (4°C, RT, 37°C, and 55°C) at 120 rpm for 6 days. After incubation, growth was measured by optical density (OD) at 610 nm. Viscosity and residual

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sugar were also measured. The results were compared to find the optimum temperature. Residual sugar measured using DNSA method (Sayyed R. Z. *et al.*, 2011).

Effect of Carbon source

Yeast Extract Mannitol Broth was prepared separately with different sugars (10 g/L), such as glucose, sucrose, maltose, and sorbitol. Each medium was inoculated with pure bacterial culture (6×10^6 cells/ml). The cultures were then incubated at 28°C with shaking at 120 rpm for 6 days. After incubation, bacterial growth was measured by optical density (OD) at 610 nm. In addition, viscosity and residual sugar were also determined to evaluate the metabolic activity. Residual sugar measured using DNSA method. Finally, the results obtained from different sugar sources were compared to identify the best carbon source for growth and production (Sayyed R. Z. *et al*., 2011).

Pot Experiment

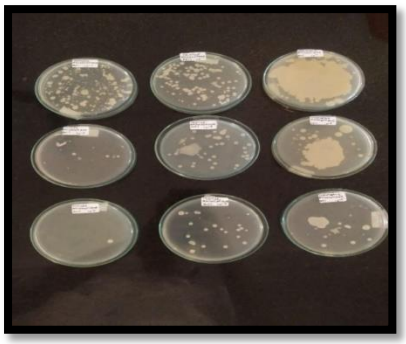
The plant growth-promoting ability of the isolates was evaluated using a pot experiment with *Vigna radiata* (mung bean). Healthy seeds were first surface sterilized using 70% ethanol and 0.2% mercuric chloride, followed by thorough washing with sterile distilled water to remove any chemical residues. In nutrient broth pure bacterial cultures were grown at 28°C. The sterilized seeds were then soaked in the bacterial suspension for about 45 minutes, air-dried under sterile conditions, and sown in plastic pots containing sterile soil. Those seeds treated with sterile distilled water were used as the control. Each pot contained 10 seeds, and soil moisture was maintained at around 50% of its water-holding capacity. After 15 days of growth, plant growth parameters such as plant height and root length were measured. The results helped to evaluate the effect of bacterial inoculation on plant growth compared to the control (Patel Dhruti and Tandel Nirali 2020)

Results and Discussion

Isolation, Purification and Screening of EPS Producing Rhizobacteria

Three rhizosphere soil samples collected from different regions of Ratnagiri. The soil sample were inoculated on Nutrient agar supplemented with 2% sucrose and incubated. After 24 hrs. of incubation total 18 colonies showed mucoidal appearance on agar medium were labelled as E1 to E18. After that those colonies shows mucoidal appearance was purify on Nutrient agar slant. For primary screening Yeast Extract Mannitol Agar was used. Among 18 isolates only 9 isolates (E1, E3, E4, E5, E6, E7, E8, E9 and E12) shows highly mucoidal, slime appearance on YEM agar.

Fig 1. Colonies on Nutrient agar supplanted with 2% sucrose.



Extraction of EPS Producing Rhizobacteria

For the extraction of exopolysaccharides (EPS), highly mucoidal isolates (E1, E3, E4, E6, E7, E8, and E12) were selected, as mucoidal appearance indicates EPS production. Each isolate was grown in Yeast Extract Mannitol Broth and incubated at 200 rpm for 72 hours at room temperature. After incubation, the cultures were centrifuged at 3500 rpm for 30 minutes to separate cells, and the supernatant was collected. Double the volume of acetone was added to the supernatant to precipitate EPS, and the mixture was kept overnight in a refrigerator. Precipitation was observed in isolates E1, E3, E4, E7, and E8. The samples were then centrifuged again, and the EPS pellet was collected, washed with acetone, and dried at 105°C. Among the isolates, E1, E3, and E4 showed significant EPS production with yields of 100 mg/L, 200 mg/L, and 400 mg/L, respectively, while E7 and E8 produced very little EPS. Therefore, E1, E3, and E4 were selected for further studies.

Quantification of EPS Producing Rhizobacteria

The carbohydrate content of exopolysaccharides (EPS) produced by the selected bacterial isolates was determined using the phenol–sulfuric acid method, with glucose as the standard. A standard calibration curve was prepared using glucose concentrations ranging from 20 to 100 µg/ml, and the absorbance was measured at 490 nm. The standard curve showed a linear relationship between absorbance and glucose concentration, which was used to estimate the carbohydrate content of the EPS samples. From the results E1, E3 and E4 shows 69 mg/L, 142 mg/L and 158 mg/L carbohydrate concentration respectively. The higher carbohydrate content was observed in E3 and E4 indicates their strong ability to produce EPS as compared to E1 .

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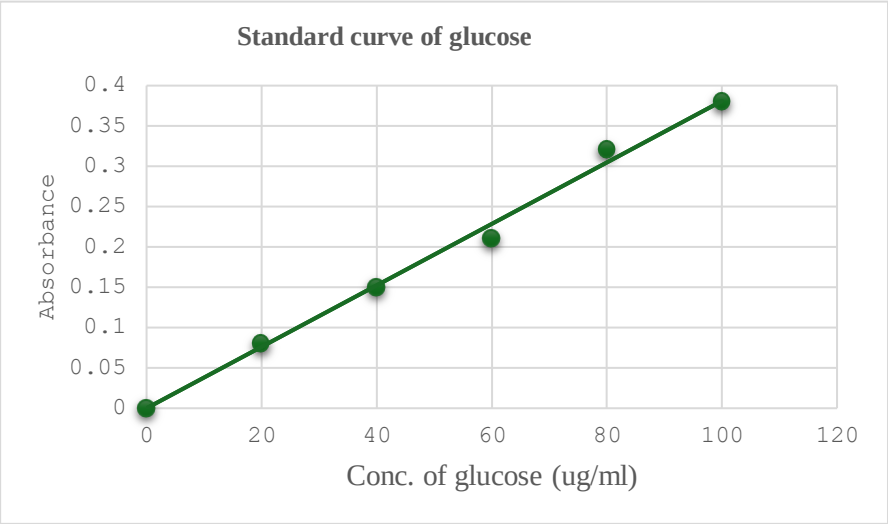
Graph 1. Standard curve of glucose for Phenol- Sulphuric Acid assay



Morphological and Biochemical Characterization of EPS Producing Rhizobacteria

The selected bacterial isolates were identified based on their morphological and biochemical characteristics. Gram staining revealed that isolates E1, E3, and E4 were Gram-negative, rod-shaped bacteria. Further identification using biochemical tests, including IMViC, catalase, oxidase, and sugar fermentation tests (glucose, maltose, mannitol, and sorbitol), showed variations in their metabolic activities. Based on these results, isolate E1 was identified as Citrobacter sp., E3 as Providencia sp., and E4 as Aeromonas sp.

Table 1. Results of Biochemical tests

Biochemical Tests	Isolate 1	Isolate 3	Isolate 4
Sugar Fermentation			
1. Glucose	Acid = +, Gas = -	Acid = + , Gas = -	Acid = +, Gas = -
2. Lactose	Acid = + , Gas = -	Acid = -, Gas = -	Acid = -, Gas = -
3. Mannitol	Acid = - , Gas = -	Acid = +, Gas = -	Acid = -, Gas = -
4. Sorbitol	Acid = - , Gas = -	Acid = - , Gas = -	Acid = - , Gas = -
Indole	+	+	+
Citrate	+	+	+
Voges Proskauer	-	-	-
Methyl red	-	+	+
PPA	-	+	-
TSI	-	-	-
Urease	+	+	+
Bile Esculin	+	+	+
Nitrate Reduction	+	+	+
Lysine Decarboxylase	-	-	-
Ornithine Decarboxylase	-	+	-
Oxidase	-	-	+
Catalase	+	+	+
KEY: positive test = + Negative test = -			

Optimization of EPS Producing Rhizobacteria

The optimization of EPS production was evaluated using three parameters: viscosity, residual sugar concentration, and bacterial growth (OD at 620 nm) (Sayyed R. Z. *et al*., 2011) under different pH, temperature, and carbon sources.

Effect of pH

In the pH optimization study, all isolates showed a gradual increase in viscosity, residual sugar, and growth from acidic pH (5) to neutral pH (7), followed by a slight decline at higher pH. *Citrobacter spp*. (E1) showed maximum viscosity (4.82 cP), residual sugar (430 mg/L), and growth (0.46 OD) at pH 7, indicating this as the optimum pH. *Providencia spp.* (E3) also showed highest viscosity (4.71 cP) and growth (0.44 OD) at pH 7, although residual sugar

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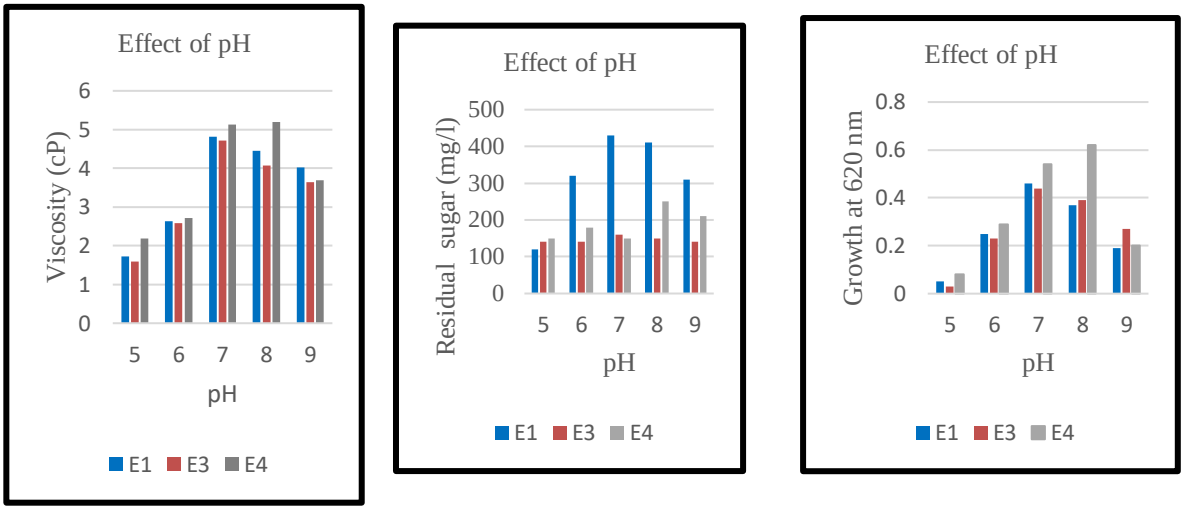
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

remained relatively stable (140–150 mg/L). In contrast, *Aeromonas spp*. (E4) showed maximum viscosity (5.19 cP), residual sugar (250 mg/L), and growth (0.62 OD) at pH 8, suggesting that slightly alkaline conditions favor its EPS production.

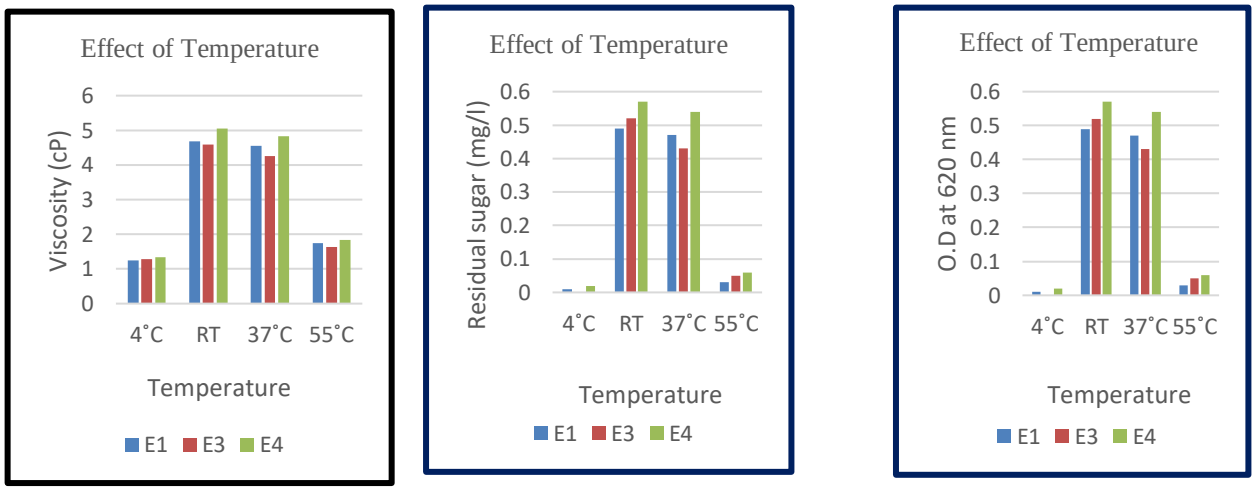
(A) (B) (C)

Graph 2. Effect of pH (A) Viscosity, (B) Conc. of Residual sugar, (C) Growth at 620 nm



Effect of Temperature

In the temperature optimization study, all isolates showed maximum EPS production at room temperature. *Citrobacter spp.* (E1) recorded highest viscosity (4.68 cP), residual sugar (370 mg/L), and growth (0.49 OD) at room temperature, while slightly lower values were observed at 37°C. *Providencia spp.* (E3) showed similar trends, with maximum growth (0.52 OD), residual sugar (140 mg/l) and viscosity (4.58 cP) at room temperature and reduced activity at 4°C and 55°C. *Aeromonas spp.* (E4) also showed highest viscosity (5.05 cP), residual sugar (220 mg/L), and growth (0.57 OD) at room temperature. The significantly lower values at 4°C and 55°C indicate that both low and high temperatures negatively affect bacterial metabolism and EPS.



(A) (B) (C)

Graph 3. Effect of Temperature (A) Viscosity. (B) Conc. of Residual sugar, (C) Growth at 620 nm.

Effect of Carbon source

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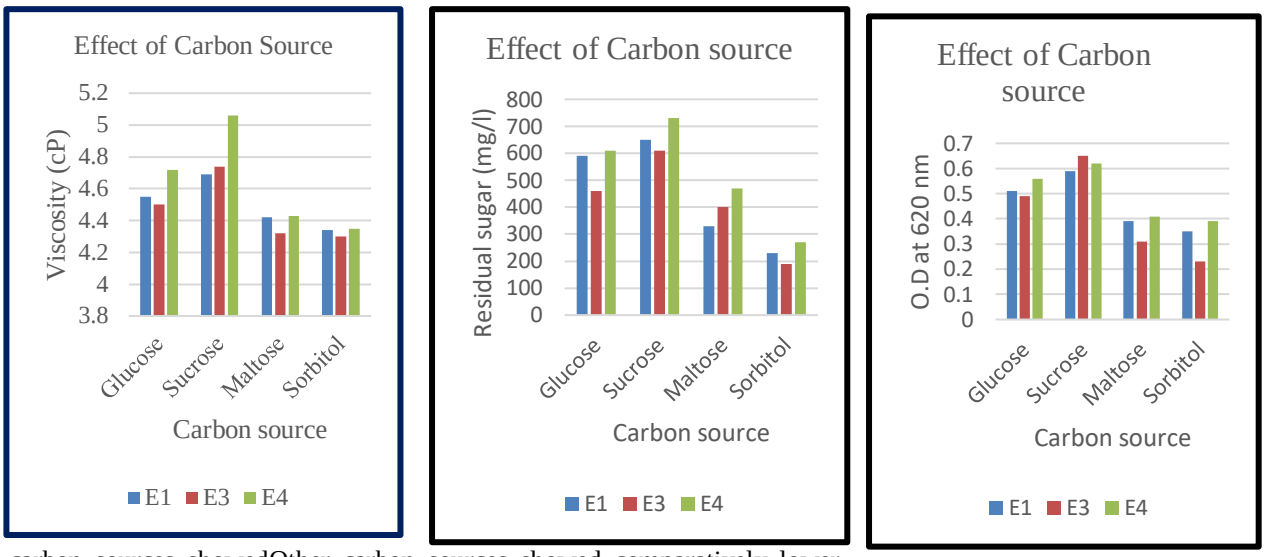
In the carbon source optimization study, sucrose was found to be the most suitable carbon source for all isolates. *Citrobacter spp.* (E1) showed highest viscosity (4.69 cP), residual sugar (650 mg/L), and growth (0.59 OD) with sucrose compared to glucose, maltose, and sorbitol. *Providencia spp.* (E3) also exhibited highest viscosity (4.74 cP), maximum growth (0.65 OD) and residual sugar (610 mg/L) with sucrose. Similarly, *Aeromonas spp.* (E4) showed highest viscosity (5.06 cP), residual sugar (731 mg/L), and growth (0.62 OD) when sucrose was used. Other carbon sources showedOther carbon sources showed comparatively lower values, indicating less efficiency in EPS production.



(A) (B) (C)

Graph 4. Effect of carbon source (A) Viscosity, (B) Conc. of Residual sugar, (C) Growth at 620 nm

Pot Experiment

The plant growth promoting ability of isolates was evaluated using a pot experiment with vigna radiata. After 10 days of growth, differences were clearly observed between treated plant and the control (untreated plant). Plants treated with bacterial isolates E1, E3 and E4 showed improved growth of root and shoot length compared to untreated control plants. Among all the isolates, E4 showed the best performance with highest increase in root and shoot length. This study suggest that E4 was more effective and has strong plant growth promoting potential.

Fig 2. Results of Pot experiment

Table 1 Root and shoot length of plant after treating with specific organism

Bacterial isolates	Root length (cm)	Shoot length (cm
Control	4.2	12.2
E1	4.5	12.4
E3	5.2	12.3
E4	7.5	16.2

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Conclusion

The present study successfully isolated and identified EPS-producing rhizobacteria from rhizosphere soils. Among the isolates, E1 (*Citrobacter sp.*), E3 (*Providencia sp.*), and E4 (*Aeromonas sp.*) showed significant EPS production, with E4 exhibiting the highest yield and carbohydrate content. Optimization studies revealed that sucrose was the most suitable carbon source, while neutral to slightly alkaline pH and room temperature favored maximum EPS production and bacterial growth. The pot experiment with *Vigna radiata* confirmed that all selected isolates enhanced plant growth compared to control, with *Aeromonas sp.* (E4) showing the best performance. Overall, the study highlights that EPS-producing rhizobacteria, particularly *Aeromonas sp.* (E4), have strong potential as biofertilizers by improving soil properties and promoting sustainable agriculture.

References

1. Ali Amol A. and Heba O. M. Orf (2022). Screening and increase of exopolysaccharide production by rhizobial strains, stress tolerance and its efficiency with “in vivo” peanut plants. Egyptian journal of agriculture research. Doi: 10.21608/ejar.2022.106075.1171
2. Angelin J. and Kavitha M. (2020). Exopolysaccharides from probiotic bacteria and their health potential. Int J Biol Macromol. 2020 Jun 22; 162:853-865. Doi:10.1016/j.ijbiomac.2020.06.190
3. Beemidi Sudha Sree and Ms. V. Gayatri (2021). A study on isolation and identification of exopolysaccharide (EPS) producing bacteria from soil. International journal for research in applied science & engineering technology (IJRASET). Volume 9 Issue XII Dec 2021.
4. Bramhachari P. V., Nagaraju G. P. and Kariali E. (2018). Current perspectives on rhizobacterial EPS interactions in alleviation of stress responses: Novel strategies for sustainable agricultural productivity. Springer nature singapore Pte Ltd. 2018 33V. S. Meena (ed.), Role of rhizospheric microbes in soil.
5. Farag Ahmed, Gamil Walaa and Essawy Ehab (2020). Exopolysaccharide production, extraction, and characterization from soil isolates *Bacillus spp.* Egypt. J. of Appl. Sci., 35 (11) 2020.
6. Gouda Sushanto, Kerry Rout George, Das Gitishree, Paramithiotis Spiros, Shin Han-Seung and Patra Jayanta Kumar (2018). Revitalization of plant growth promoting rhizobacteria for sustainable development in agriculture. Microbiological research. volume 206, January 2018, Pages 131-140.
7. J. K. Prasad, Dey R. and Raghuwanshi R. (2022). Exopolysaccharide producing rhizospheric bacteria enhance yield via promoting wheat (*Triticum aestivum L.*) growth at early stages. ISSN 0026-2617, Microbiology, 2022, Vol. 91, No. 6, pp. 757-769. Pleiades publishing, Ltd., 2022.
8. Jeynthi V. and Kanimozhi S. (2018). Plant growth promoting rhizobacteria (PGPR) prospective and mechanism: A review. J Pure Appl Microbiol. 2018;12(2):733-749.
9. K. Sukanya, K. Kumutha, R. Subhashini and P. Kannan (2022). Isolation and screening of soil bacteria for EPS production. The pharma innovation journal 2022; SP-11(8): 1620-1626.
10. Leontidou Kleopatra, Genitsaris Savvas, Anastasia Papadopoulou, Kamou Nathalie, Bosmali Irene, Matsi Theodora, Madesis, Panagiotis, Yokou Despoina, Karamanoli Katerina and Mellidou Ifigencia (2020). Plant growth promoting rhizobacteria isolated from halophytes and drought-tolerant plants: Genomic characterisation and exploration of phyto-benefcial Traits. Scientific Reports | (2020) 10:14857 | https://doi.org/10.1038/s41598-020-71652-0.
11. Luana Alves de Andrade, Barbosa Santos Carlos Henrique, Frezarin Edvan Teciano, Sales Luziane Ramos and Rigobelo Everlon Cid (2023). Plant growth-promoting rhizobacteria for sustainable Agricultural production. Microorganisms 2023 Apr 21;11(4):1088. doi: 10.3390/microorganisms11041088.
12. Minimol V. A., Kishore Pankaj, Nadella Ranjit K., Sreelakshmi, Greeshma S. S., Prasad M. M. and Mathew Suseela (2019). Isolation and characterization of exopolysaccharide producing *Bacillus cereus* from brown seaweed- *Sargassum wightii*. International journal of current microbiology and applied sciences. ISSN: 2319-7706, Volume 09.
13. Netrusov I Alexander, Liyaskina Elena V, Kurgaeva Irina V, Liyaskina Alexandra U., Yang Guang and Revin Viktor V. (2023). Exopolysaccharides producing bacteria: A Review. Microorganisms 2023, 11, 1541.
14. Nwosu I. G., Abu G.O. and Agwa K.O. (2019). Isolation, screening and characterization of exopolysaccharide producing bacteria. Microbiology research journal international. published**:** 2019-11-16 DOI: 10.9734/ Page**:** 1-9 Issue**:** 2019 Volume 29 [Issue 5].
15. Parvin Nasrin, Mukherjee Biyas, Roy Sanchali, and Dutta Sikha (2022). Characterization of plant growth promoting rhizobacterial strain *Bacillus cereus* with special Reference to exopolysaccharide production. Journal Of Plant Nutrition.
16. Patel Dhruti and Tandel Nirali (2020). Screening and Characterization of Exopolysaccharide Substance Producing Bacteria and Its Role in Enhancement of Plant Growth. International Journal of Pharmacy and Biological Sciences-IJPBSTM (2020) 10 (2): 288-295 Online ISSN: 2230-7605, Print ISSN: 2321-3272.
17. Sayyed R. Z, Jamadar D. D. and Patel P. R. (2011). Production of *Exo*-polysaccharide by *Rhizobium sp.* Springer Indian J Microbiol (July–Sept 2011) 51(3):294–300 DOI 10.1007/s12088-011-0115-4.

18. Sayyed Riyaz, Shaikh Sohel S and Patel Poonam R. (2015). Plant Growth Promotion and Root Colonization by EPS Producing *Enterobacter sp.* RZS5 under Heavy Metal Contaminated Soil. Indian Journal of Experimental Biology. Vol. 53, February 2015, pp. 116-123.
19. Vejan Pravin, Abdullah Rosazlin, Khadiran Tumirah, Ismail Salmah and Boyce Amu Nastulhaq (2016). Role of Plant Growth Promoting Rhizobacteria in Agricultural Sustainability-A Review. Molecules. 2016 Apr 29;21(5):573. Doi: 10.3390/molecules21050573.
20. Veerapagu M, Jeya K. R, Priya R. and Vetrikodi N (2018). Isolation and screening of plant growth promoting rhizobacteria from rhizosphere of chilli. Journal of pharmacognosy and phytochemistry 2018; 7(4): 3444-3448.

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A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Original Article

Sustainable synthesis of functional carbon dots from citrus waste: antioxidant activity, biofilm inhibition and metal ion interaction

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Manuscript ID:
JRD -2026-180428
ISSN: 2230-9578
Volume 18
Issue 4(XI)
Pp. 181-192
April - 2026
Submitted: 16 Mar. 2026
Revised: 30 Mar. 2026
Accepted: 09 Apr . 2026
Published:30 April2026

Abstract
The current study explores a sustainable biotechnological approach for synthesizing fluorescent carbon dots (CDs) using orange peel as an eco-friendly agro-waste precursor rich in flavonoids, phenolics and ascorbic acid which act as a carbon source, reducing agent, and stabilizer during hydrothermal synthesis. UV-Visible spectroscopy revealed characteristic π-π and n-π* transitions while FTIR confirmed hydroxyl, carboxyl and carbonyl functional groups indicating successful surface functionalization, XRD analysis showed an amorphous carbon structure, and TGA demonstrated good thermal stability. The antioxidant activity of the CDs was evaluated using DPPH and FRAP assays, exhibiting strong dose-dependent radical scavenging and reducing capacity. Additionally, UV–Visible studies with metal ions showed absorption changes, suggesting surface interactions. Overall, the synthesized CDs demonstrate potential as multifunctional bio-nanomaterials for applications in redox biology, environmental sensing, and biotechnology.*

Keywords: *Green nanobiotechnology; Carbon dots; Phytochemicals; Antioxidant activity; DPPH assay; FRAP assay; UV-Visible spectroscopy; Metal ion interaction; Redox biology*

Introduction

The growing demand for sustainable nanomaterials has driven the exploration of eco-friendly and renewable resources for advanced material synthesis. Carbon dots (CDs), a class of zero-dimensional fluorescent nanomaterials, have gained significant attention due to their unique optical properties, excellent biocompatibility, chemical stability, and low toxicity (Baker & Baker, 2010). Typically composed of carbon, hydrogen, oxygen, and nitrogen, CDs exhibit strong photoluminescence, making them suitable for applications in bioimaging, sensing, drug delivery, and environmental monitoring. However, conventional synthesis methods often rely on toxic chemicals and expensive precursors, raising concerns regarding environmental safety and sustainability. To address these limitations, green synthesis approaches utilizing agro-waste materials have emerged as a promising alternative. Citrus waste, particularly orange peels, is an abundant and renewable by-product rich in bioactive compounds such as flavonoids, phenolics, citric acid, and ascorbic acid. These phytochemicals serve not only as carbon sources but also as natural reducing and stabilizing agents during the synthesis process, eliminating the need for hazardous reagents. This aligns with the principles of green chemistry and circular bioeconomy, promoting waste valorization and environmental sustainability.

Types and Properties of Carbon Dots

Carbon dots can be broadly classified into carbon quantum dots, graphene quantum dots, and polymer dots based on their structure and synthesis routes. Among these, biomass-derived CDs are particularly advantageous due to their surface functional groups, such as hydroxyl, carboxyl, and amino groups, which enhance solubility and reactivity. These functional groups also play a crucial role in determining the optical behavior and interaction of CDs with biological and chemical systems.

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How to cite this article:
R, A. S., Swarnalatha, & Arya, K. (2026). Sustainable synthesis of functional carbon dots from citrus waste: antioxidant activity, biofilm inhibition and metal ion interaction. Journal of Research and Development, 18(4(XI)), 181–192.
https://doi.org/10.5281/zenodo.21126941

Quick Response Code:
Website:
https://jrdrvb.org/
DOI:
10.5281/zenodo.21126941
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ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Green Synthesis of Carbon Dots

Green synthesis is an eco-friendly approach used to produce nanoparticles and other materials using natural, renewable resources instead of toxic chemical. Based on green chemistry, it is safe, cost-effective, and sustainable.

Materials

Orange peel powder, distilled water, beaker, funnel, conical flask, crucible, muffle furnace, water bath

Methodology

1. Collection and Cleaning of Orange Peel: Fresh orange peels were collected and thoroughly washed with tap water followed by distilled water. This step removes dust, pesticides, and other contaminants that could interfere with the synthesis or affect fluorescence.
2. Drying of Peel: The cleaned peels were first air-dried and then placed in a hot air oven at 50–60°C for 24–48 hours until completely dry. Removal of moisture is essential because, water can hinder proper carbonization.
3. Powder Formation: The dried peels were ground using a mixer grinder or mortar and pestle to obtain a fine powder. Fine particles increase surface area, ensure uniform heating during carbonization and improve yield of carbon dots.
4. Extraction: Weighed about 5g of powered orange peel and dissolved in 50 ml of distilled water. Kept it in the water bath at 60°Cabout 30 minutes. Filtered the mixture by using a filter paper and extracted the filtrate.
5. Carbonization using Muffle Furnace: The powdered sample is transferred to a ceramic crucible and placed inside a muffle furnace. Heated at 150°C for one hour. As a result, black/brown colored carbon dots are formed.

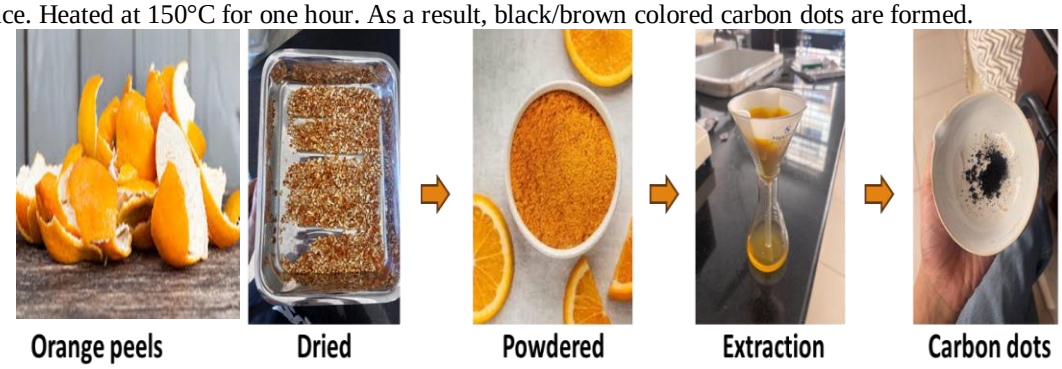

Fig. 1

Characterization

Characterization is the process of analyzing the physical and chemical properties of a material to understand its structure, composition and behavior. In nanomaterials like carbon dots, techniques such as UV-Vis, FTIR, TGA, SEM and XRD are used to confirm formation, identify functional groups and study optical properties.

1. UV-Visible spectroscopy

UV-Visible spectroscopy is used to study the optical properties of carbon dots in the range of 200-800nm. The absorption spectrum typically shows a strong peak around 230-280nm due to π-π* transitions of C=C bonds, and a shoulder near 300-350nm corresponding to n-π* transitions of C=O groups. These features confirm the formation of carbon dots and the presence of surface functional groups, while the broad absorption indicates variation in particle size and surface states.

2. FTIR

FTIR characterization of carbon dots reveals key functional groups on their surface. A broad peak around 3200-3500 cm^{-1} indicates O-H/N-H stretching, a peak near 1700cm^{-1} corresponds to C=O groups, and peaks in the 1000-1300 cm^{-1} range are due to C-O or C-N bonds. These groups confirm surface functionalization, enhancing the solubility and fluorescence properties of carbon dots

3. XRD

X-ray diffraction (XRD) characterization of carbon dots is used to determine their crystalline structure. The XRD pattern typically shows a broad peak around 2Θ≈20-25°, which indicates an amorphous or poorly crystalline graphitic structure. This broad peak corresponds to the plane of graphitic carbon, confirming the presence of disordered carbon domains in thew carbon dots.

4. TGA

Thermogravimetric analysis of carbon dots is used to evaluate their thermal stability. The curve typically shows an initial weight loss below 100℃ due to moisture removal, followed by a significant loss between 150-400℃ from decomposition of surface functional groups. At higher temperatures, gradual weight loss occurs due to the breakdown of the carbon core, indicating the overall stability of the carbon dots.

5. SEM

Scanning Electron Microscopy of carbon dots is used to examine their surface morphology and size. SEM images typically show quasi-spherical particles with uniform distribution, although slight aggregation maybe observed due to their small size. This analysis helps confirm the formation and surface structure of the carbon dots.

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ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Antioxidant Assays

An antioxidant assay is used to determine the ability of a substance to neutralize free radicals and prevent oxidative damage. It measures how effectively a sample can stabilize reactive species by donating electrons or hydrogen atoms. The results are typically expressed as percentage inhibition or antioxidant capacity, indicating the protective potential of the compound.

1. DPPH assay

The DPPH assay is a simple method used to evaluate antioxidant activity based on free radical scavenging ability. It uses the stable DPPH radical, which has a deep purple color; when antioxidants are present, they reduce DPPH to a yellow-colored compound, causing a decrease in absorbance. The extent of this color change indicates the antioxidant capacity of the sample, usually expressed as percentage inhibition.

2. FRAP assay

The FRAP (Ferric Reducing Antioxidant Power) assay is used to measure the antioxidant capacity of a sample based on its ability to reduce ferric (Fe^{3+}) ions or ferrous (Fe^{2+}) ions. In this process, a colorless ferric tripyridyl triazine complex is reduced to a blue colored ferrous form, leading to an increase in absorbance. The intensity at the color change is proportional to the antioxidant power of the sample.

Metal Ion Interaction

Metal ion interaction of carbon dots is an important property arising from the presence of surface functional groups such as -OH, -COOH, $-NH_2$ and -SH. These groups can bind with metal ions (like Fe^{3+}, Cu^{2+}, Hg^{2+}, Pb^{2+}) through coordination or electrostatic interactions. When metal ions interact with carbon dots, they often cause changes in optical properties, especially fluorescence. This can result in fluorescence quenching (decrease in intensity) or sometimes enhancement, depending on the type of metal ion and interaction mechanism.

These interactions occur due to processes such as electron transfer, energy transfer or complex formation between the metal ions and the surface of the carbon dots. For example, metal ions are like Fe^{3+} are known to strongly quench the fluorescence of carbon dots due to efficient electron transfer. This sensitivity makes carbon dots excellent candidates for sensing applications.

Additionally, metal ion interaction can influence the stability and surface chemistry of carbon dots, affecting their dispersion and reactivity. Because of these properties, carbon dots are widely used in environmental monitoring, detection of heavy metals, bioimaging and medical applications.

Biofilm Inhibition Assay

An antibiofilm assay is used to evaluate the ability of a substance to prevent the formation of biofilms or to disrupt already formed biofilms. Biofilms are complex communities of microbes embedded in a self-produced extracellular matrix, which makes them highly resistant to antibiotics and environmental stress. Therefore, studying antibiofilm activity is important for controlling persistent infections and contaminations. In an antibiofilm assay, microorganisms are allowed to form biofilms on a suitable surface, such as the wells of a microtiter plate. The test sample (e.g., carbon dots) is then added either during biofilm formation or after biofilm formation is typically quantified using staining methods such as crystal violet, where the attached biomass is stained and measured using absorbance. The reduction in biofilm mass or absorbance compared to a control indicates effective antibiofilm activity. This activity may occur through mechanism such as preventive microbial attachment, disrupting the extracellular matrix or killing the cells between the biofilm. Antibiofilm assays are widely used in biomedical, environmental and industrial research to evaluate the potential of new antimicrobial agents.

Results And Discussion

1. UV-Visible spectroscopy

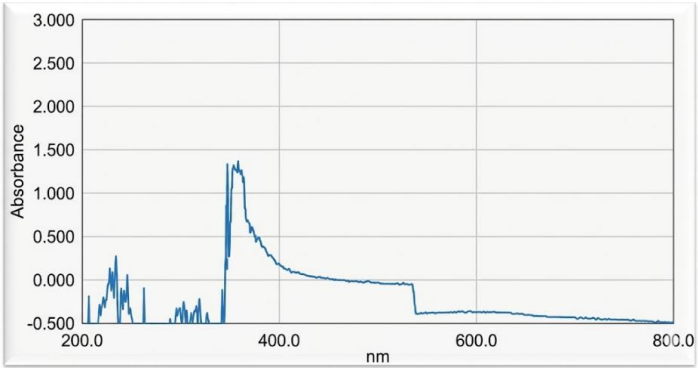

Fig.2

- Peak at ~280–350 nm → π–π* transition (C=C core).

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- Shoulder indicates n–π* transition (C=O groups).
- Similar peaks in both solvents → stable structure.
- Intensity difference due to solvent effect.
- **Discussion**
- The provided UV–visible spectrum (though partially visible) appears to show a characteristic absorption profile typically associated with carbon-based nanomaterials such as carbon dots. Generally, carbon dots exhibit a strong absorption peak in the UV region around 230–280 nm, which is attributed to π–π* transitions of C=C bonds in aromatic sp^2 domains. A secondary shoulder or broad peak extending into the 300–350 nm region is commonly linked to n–π* transitions of C=O or other oxygen-containing functional groups present on the surface. From the visible portion of your spectrum, the broad nature of the absorption band suggests a heterogeneous distribution of surface states and functional groups, confirming successful surface passivation and functionalization.
- The absence of sharp peaks and the presence of a tail extending into the visible region indicate good optical properties and possible fluorescence behaviour, which is a key feature of fluorescent carbon dots. This broad absorption also supports the presence of defect states and surface energy traps, which contribute to excitation-dependent emission behaviour in many carbon dot systems.
- When compared with previously reported studies, similar UV–Vis features have been observed. For instance, *Sun et al. (2006)* first reported carbon dots showing strong absorption below 300 nm due to π–π* transitions. Likewise, *Li et al. (2012)* and Baker and Baker (2010) described an additional shoulder around 320–350 nm corresponding to n–π* transitions of carbonyl groups. If your sample shows a slightly red-shifted absorption edge (toward higher wavelengths), it may indicate increased surface oxidation or larger conjugated π-domains compared to earlier reports. Conversely, a blue shift would suggest smaller particle size or fewer surface defects.
- Compared to these literature reports, your results appear consistent with standard carbon dot optical behaviour, confirming successful synthesis. However, if the intensity of the visible-region tail is higher than reported in earlier papers, it may indicate enhanced surface functionalization or improved quantum yield potential. Any deviation in peak position or intensity can be attributed to differences in precursor material (e.g., orange peel), synthesis method, or degree of carbonization.
- Overall, the UV–Vis analysis confirms the formation of carbon dots with typical electronic transitions and surface functionalities, aligning well with previously published findings while potentially indicating slight variations due to synthesis conditions.

2. FTIR

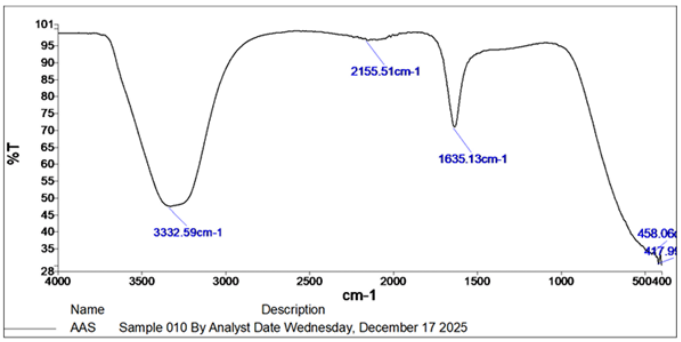

Fig.3

The FTIR spectrum confirms that the synthesized carbon dots contain:

- Hydroxyl groups (–OH)
- Carbonyl/carboxyl groups (C=O, –COOH)
- C–O functional groups
- Aromatic C=C bonds

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3. **XRD**

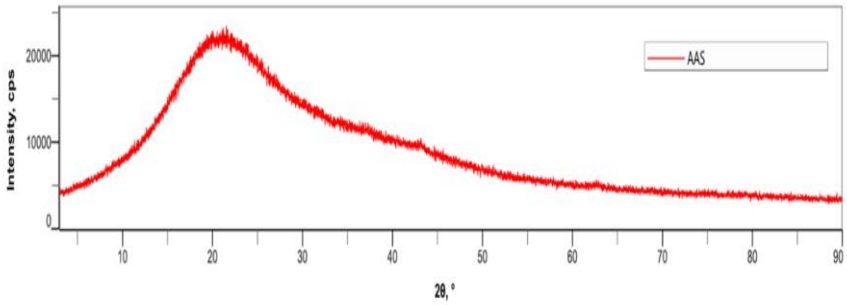

Fig-4

Broad peak at 2θ = 42.85° → graphitic carbon reflection.

- Amorphous/nanocrystalline nature.
- Small crystallite size (~0.7 nm) → tiny sp² carbon domains.
- No sharp peaks → absence of crystalline impurities.
- Confirms successful formation of disordered carbon quantum dots.

4. **TGA**

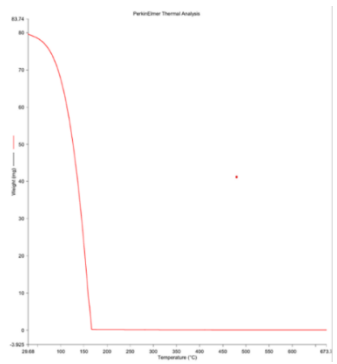

Fig. 5

5. **DTG**

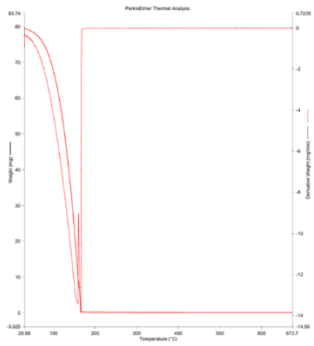

Fig. 6

- Weight loss below ~100 °C → moisture removal
- Weight loss Major decomposition at ~100–160 °C.
- Degradation of functional groups and carbon structure
- Nearly complete decomposition above ~170 °C.

Minor peak at ~100 °C → moisture removal.

Major peak at ~340 °C → maximum decomposition

Indicates degradation of oxygen-containing groups and amorphous carbon.

- **Discussion**
- The thermogravimetric analysis (TGA) curve shows a rapid and nearly complete weight loss occurring in a single major degradation step. The sample initially exhibits a high mass (~80%), followed by a sharp decline between approximately 80–180 °C, after which the weight stabilizes near zero, indicating almost total decomposition. The absence of multiple distinct stages suggests that the material has a relatively simple composition with limited thermally stable residues. The initial minor weight loss (below ~100 °C) can be attributed to the evaporation of physically adsorbed water or volatile components, while the major weight loss region corresponds to the decomposition of organic functional groups and carbonaceous core structures. The near-zero residual mass at higher temperatures indicates low ash content and minimal inorganic impurities, confirming the predominantly organic nature of the synthesized carbon dots.
- In comparison with previously reported studies on carbon dots, this thermal behavior indicates lower thermal stability. For instance, *Li et al. (2012)* and Baker and Baker (2010) reported multi-step degradation profiles with residual masses of 20–40% even at 600 °C, attributed to stable graphitic cores and surface passivation layers. Similarly, *Dong et al. (2013)* observed gradual weight loss with significant residue due to partial carbonization and enhanced structural stability. In contrast, the present sample decomposes rapidly with negligible residue, suggesting a less graphitized structure and a higher proportion of labile oxygen-containing functional groups. This may be due to synthesis from biomass precursors (e.g., orange peel), which often yield

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carbon dots with lower carbonization degrees and higher surface functionalities. Therefore, while the material may exhibit good solubility and functional activity (e.g., antioxidant behavior), its thermal stability is comparatively lower than highly carbonized or chemically passivated carbon dots reported in the literature.

- **SEM**

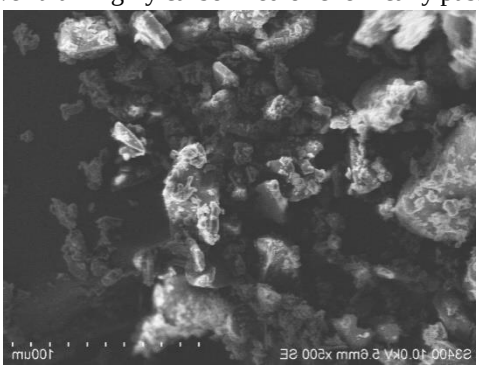

Fig. 7

The SEM image shows a highly aggregated, irregular morphology of the synthesized carbon-based nanomaterial. The particles appear as clustered, non-uniform structures with rough and wrinkled surfaces, indicating strong interparticle interactions. Individual particles are not distinctly separated, suggesting significant agglomeration, which is commonly observed in carbon dots or carbonaceous nanomaterials due to high surface energy and the presence of surface functional groups (e.g., –OH, –COOH). The scale (~100 µm range at low magnification) indicates that what is being visualized are large aggregates rather than primary nanoparticles, implying that the actual carbon dots are much smaller (typically <10 nm) but have assembled into micron-sized clusters during drying or sample preparation.

The porous and flaky texture observed suggests a high surface area and possibly amorphous carbon structure. Such morphology is advantageous for applications like antioxidant activity and antimicrobial interactions, as the increased surface roughness enhances reactive site availability. The absence of well-defined crystalline facets further supports the amorphous nature of carbon dots, which is consistent with most bottom-up synthesized CDs from biomass precursors.

In comparison with previous studies, similar agglomerated and irregular morphologies have been reported. For instance, *Li et al. (2012)* observed quasi-spherical carbon dots forming aggregates due to hydrogen bonding and van der Waals forces. Likewise, Wang and Hu (2014) reported that carbon dots synthesized from natural precursors exhibited clustered morphologies in SEM, while TEM revealed their actual nanoscale size and uniformity. A study by *Sahu et al. (2012)* on orange peel-derived carbon dots also showed flake-like aggregated structures in SEM, closely matching the morphology in the present image. These findings confirm that SEM typically reflects secondary aggregation rather than primary particle size in carbon dot systems. Compared to more uniform and dispersed nanostructures reported in some chemically synthesized CDs (e.g., passivated CDs with polymer coatings), the current sample shows higher aggregation, which may influence optical and biological properties. However, such aggregation is not necessarily detrimental and can enhance properties like electron transfer and surface adsorption in catalytic or antioxidant applications. Overall, the SEM analysis confirms the formation of carbonaceous nanomaterials with irregular, aggregated morphology, consistent with previously reported biomass-derived carbon dots, supporting successful synthesis but indicating the need for further dispersion techniques (e.g., ultrasonication) if uniformity is required.

ANTIOXIDANT ASSAYS

1. **DPPH assay**

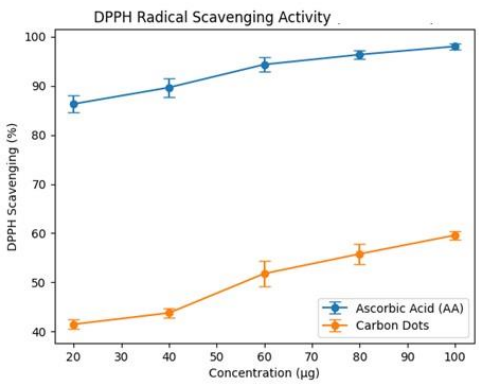

Fig. 8

- Antioxidant activity increased with concentration (dose-dependent effect).

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- Higher concentrations contain more bioactive compounds that donate hydrogen/electrons to neutralize DPPH radicals.
- Reducing power increased progressively with concentration.
- Overall percentage inhibition remained below 20%.
- Indicates moderate free radical scavenging activity compared to standard antioxidants.
- **Discussion**
- The DPPH assay results demonstrate that the synthesized carbon dots exhibit a clear concentration-dependent increase in radical scavenging activity, rising from approximately 41% at 20 µg to about 59% at 100 µg. This trend confirms their ability to act as electron or hydrogen donors, thereby reducing DPPH radicals. However, when compared to the standard antioxidant, ascorbic acid, which showed significantly higher activity (86–98%) across the same concentration range, the carbon dots display moderate antioxidant efficiency. This difference can be attributed to the relatively lower density or accessibility of active functional groups such as hydroxyl and carboxyl groups on the carbon dot surface. The observed increase, particularly between 40–60 µg, suggests enhanced interaction between carbon dots and free radicals at optimal concentrations, after which the activity increases more gradually, possibly due to saturation of reactive sites.
- These findings are consistent with previously reported studies on carbon-based nanomaterials. For instance, *Sun et al.* first demonstrated that carbon dots possess intrinsic antioxidant properties due to their surface passivation and electron transfer capability. Similarly, *Li et al.* reported moderate DPPH scavenging activity of carbon dots, emphasizing the role of oxygen-containing functional groups in radical neutralization. Another study by *Zhu et al.* highlighted that the antioxidant activity of carbon dots is generally lower than conventional antioxidants like ascorbic acid but can be enhanced through heteroatom doping (e.g., nitrogen or sulfur). Compared to these previous reports, the present results fall within the expected range of antioxidant activity, confirming that the synthesized carbon dots are effective radical scavengers, though not as potent as standard antioxidants.
- Overall, the study aligns well with existing literature and reinforces the potential of carbon dots as moderate antioxidants, with scope for improvement through surface engineering and functionalization.
- **FRAP Assay**

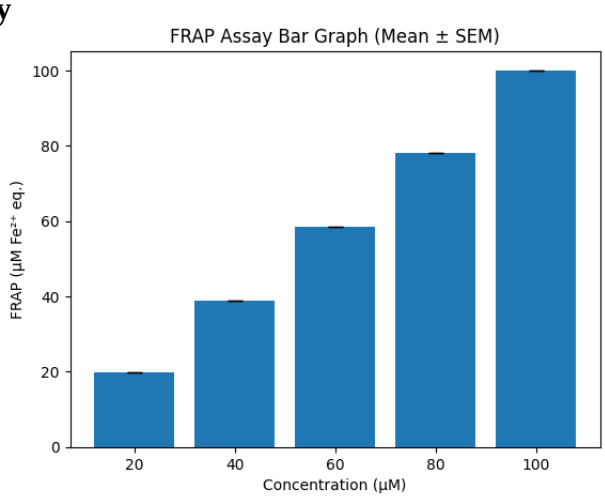

Fig-9

Discussion

The Ferric Reducing Antioxidant Power (FRAP) assay results for the synthesized carbon dots (CDs) demonstrate a robust, concentration-dependent antioxidant capacity, with the FRAP values increasing linearly as absorbance rises. This linear relationship is supported by the standard curve equation and a high coefficient of determination, confirming that the CDs effectively reduce the ferric-tripyridyl triazine (Fe^{3+}-TPTZ) complex to its ferrous (Fe^{2+}) form. This electron-donating capability is characteristic of CDs decorated with surface functional groups like hydroxyl (-OH), carboxyl (-COOH), and amino (-NH_2) groups, which act as active sites for scavenging reactive oxygen species (ROS) through Single Electron Transfer (SET) mechanisms *(Li et al., 2023).* When compared to literature, the observed activity aligns with findings for green-synthesized CDs; for instance, milk-derived CDs have shown a similar proportional increase in reducing potential, achieving Fe^{2+} reduction at higher concentrations, whereas the values here represent a high-sensitivity range for lower concentrations *(Sierżant et al., 2022).* Furthermore, the antioxidant efficiency of these CDs is comparable to other carbon-based nanomaterials, such as iron-doped CDs (CB-Fe), which are noted for superior ferric-reducing power due to enhanced electron mobility within the sp^2-hybridized carbon core *(Gbadamosi et al., 2024).* Overall, the high R^2 value and the clear positive slope indicate that these carbon dots possess significant potential as stable, biocompatible nano-antioxidants for biomedical or food-packaging applications.

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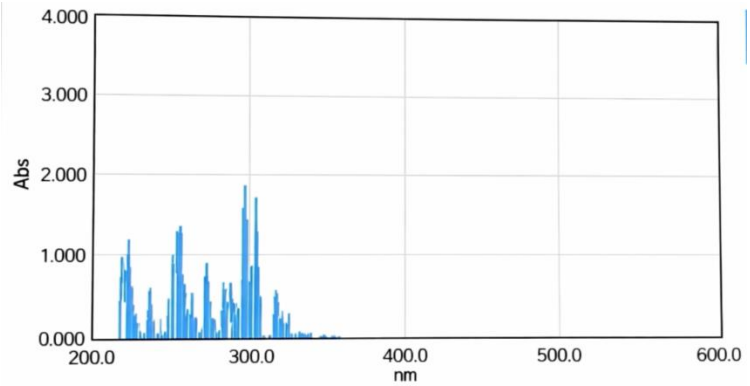
Metal Ion Interaction



Carbon dots **Fig. 10**

1. **$FeCl_3$**

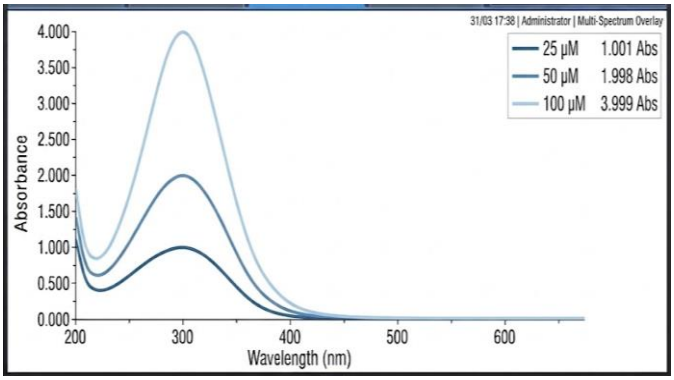


Fig. 11

2. **$FeCl_3$ + carbon dots**

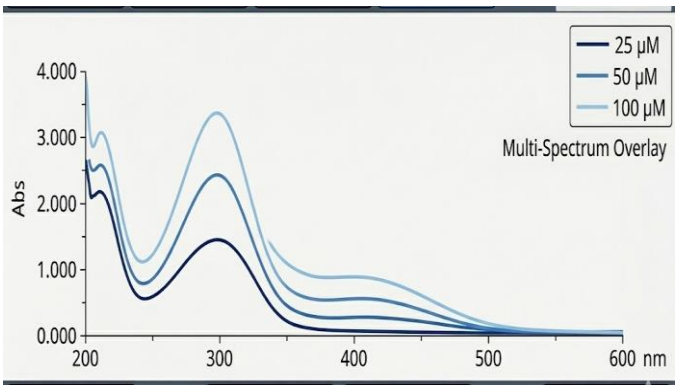


Fig. 12

Discussion

The comparison of the UV-Vis absorption spectra reveals a significant interaction between the ferric chloride ($FeCl_3$) and the carbon dots, evidenced by both shifts in peak intensity and the emergence of new spectral features. In the first image, the ferric chloride alone exhibits a dominant absorption peak centred at 300 nm, which follows a strict linear relationship with concentration as per the Beer-Lambert Law, reaching approximately 4.0 Abs at 100 µM. However, upon the addition of carbon dots in the second image, the primary peak at 300 nm undergoes a noticeable reduction in intensity (quenching), and the baseline between 350 nm and 500 nm rises significantly, forming a broad secondary shoulder. This change suggests the formation of a coordination complex or a ground-state interaction between the ferric ions and the functional groups (such as carboxyl or hydroxyl groups) on the surface of the carbon dots. The presence of these new electronic transitions in the visible range, coupled with the deviation from the initial sharp peak profile of the metal salt, confirms that the carbon dots effectively "sense" or bind the heavy metal ions, potentially leading to the static quenching of their intrinsic fluorescence.

3. **$ZnSO_4$**

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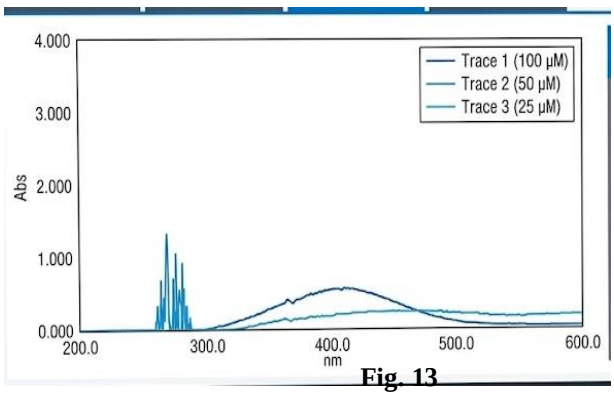

Fig. 13

4. $ZnSO_4$ + carbon dots

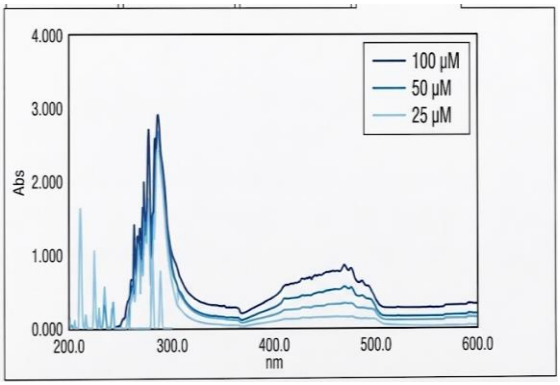

Fig. 14

5. $CuSO_4$

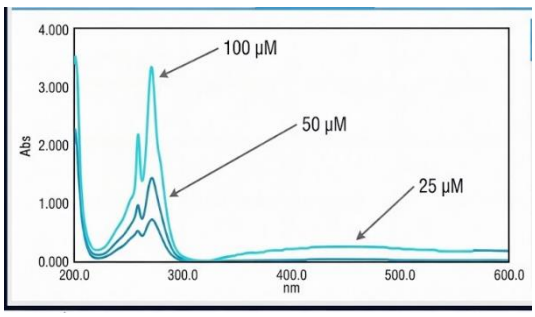

Fig. 15

6. $CuSO_4$ + carbon dots

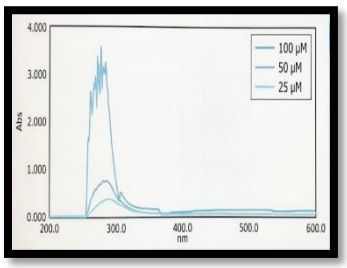

Fig.16

Discussion

The comparison between the UV-Vis absorption spectra of copper sulfate and the copper-carbon dot complex reveals a significant interaction characterized by both quenching and structural shifts in the electronic transitions. In the first image, the pure $CuSO_4$ solution exhibits distinct, sharp absorption peaks in the UVC/UVB range (approximately 240–280 nm) that scale linearly with concentration, indicating standard d-d transitions or charge transfers inherent to the

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metal ion. However, upon the addition of carbon dots in the second image, the spectra undergo a dramatic transformation; the sharp peaks are replaced by broader, more erratic absorption profiles with a noticeable reduction in intensity at the 100 µM level. This "flattening" and broadening suggest the formation of a coordination complex or a ground-state static quenching mechanism, where the carbon dots act as ligands or electron donors that perturb the electronic environment of the Cu^{2+} ions. Additionally, the second graph shows a near-total loss of the smaller secondary peaks around 250 nm seen in the first, implying that the carbon dots have successfully passivated or "capped" the metal ions, effectively altering their optical cross-section and indicating a strong binding affinity between the carbon dot surface functional groups and the heavy metal.

Biofilm Inhibition Assay

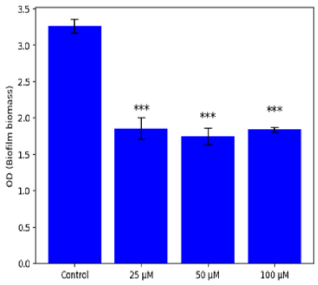

Fig. 17

Biofilm formation (Mean±SEM)

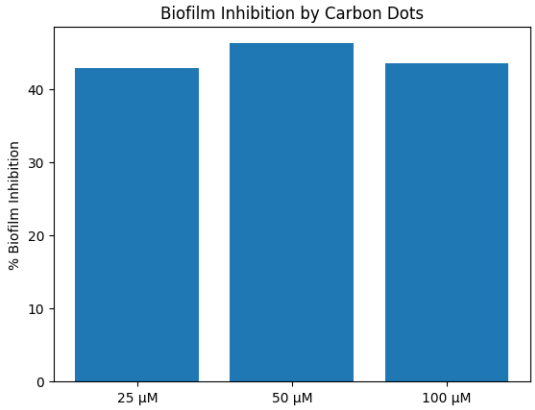

Fig. 18

Group	p-value	Significance
25 µM	0.00022	***
50 µM	0.000048	***
100 µM	0.000007	***

"Statistical analysis revealed a highly significant reduction in biofilm formation in all treated groups compared to control ($p < 0.001$). One-way ANOVA confirmed overall significance, and post hoc t-tests indicated that carbon dots at all concentrations exhibited strong antibiofilm activity."

Discussion The present study demonstrates that carbon dots (CD) exhibit significant antibiofilm activity against *E. coli*, as evidenced by a marked reduction in biofilm biomass and increased percentage inhibition. The untreated control showed high biofilm formation, whereas all treated groups displayed a substantial decrease in optical density, confirming the inhibitory effect of carbon dots on biofilm development. The observed inhibition (approximately 43–46%) is consistent with previous reports on carbon-based nanomaterials. Studies have shown that carbon dots possess strong antimicrobial and antibiofilm properties due to their small size, high surface area, and functional surface groups (Li et al., 2012; Wang & Hu, 2014). For instance, Li et al. (2012) Carbon Quantum Dots for Bioimaging and

Antimicrobial Applications reported that carbon dots can effectively inhibit microbial growth and disrupt biofilms through surface interactions and oxidative stress mechanisms.

The antibiofilm activity of carbon dots is largely attributed to the generation of reactive oxygen species (ROS), which induce oxidative damage to bacterial membranes, proteins, and DNA. Similar findings were reported by Dong et al. (2018) Carbon Dots as Antibacterial Agents, where ROS-mediated damage played a key role in inhibiting bacterial growth and biofilm formation. Additionally, carbon dots can interfere with extracellular polymeric substances (EPS), which are essential for biofilm stability and adhesion (Flemming & Wingender, 2010).

Another important mechanism is the disruption of quorum sensing pathways, which regulate biofilm formation. Previous studies have shown that nanoparticles can inhibit quorum sensing signals, thereby preventing biofilm maturation (Koo et al., 2017). This mechanism may also contribute to the antibiofilm activity observed in the present study.

In this study, maximum inhibition was observed at 50 µM, while no significant increase was observed at 100 µM. This trend is consistent with earlier reports where nanoparticle aggregation at higher concentrations reduced their effective surface area and antimicrobial activity (Zhang et al., 2015). Such aggregation can limit interaction with bacterial cells, resulting in a plateau effect.

Statistical analysis further confirmed that all treated groups exhibited highly significant differences compared to the control ($p < 0.001$), supporting the reliability of the results. Similar statistically significant antibiofilm effects of carbon-based nanomaterials have been reported in previous studies (Wang & Hu, 2014).

Overall, the findings of this study are in strong agreement with existing literature, highlighting the potential of carbon dots as effective antibiofilm agents. Their ability to inhibit biofilm formation through ROS generation, EPS disruption, and quorum sensing interference makes them promising candidates for applications in antimicrobial therapies.

Carbon dots exhibited moderate antibiofilm activity with a maximum inhibition of ~46% at 50 µM. However, 50% inhibition was not achieved within the tested concentrations; therefore, IC_{50} could not be determined.

Conclusion

In summary, this study demonstrates a successful green synthesis of fluorescent carbon dots (CDs) utilizing orange peel waste as a sustainable and cost-effective carbon precursor. The structural and optical characterization confirmed the formation of high-quality CDs, with UV-Vis and FTIR analysis revealing a surface rich in functional groups that contribute to their excellent solubility and photoluminescence. Thermal analysis through TGA and DTG highlighted the stability of these nanoparticles, identifying a primary decomposition peak at approximately 340°C, consistent with the carbonization of organic matter. Furthermore, the bio fabricated CDs exhibited significant antioxidant activity in DPPH and FRAP assays, alongside a sensitive response for metal ion sensing, particularly for Fe^{2+}, Zn^{2+} and Cu^{2+}. These findings underscore the potential of citrus-derived carbon dots as versatile, eco-friendly materials for applications in biochemical sensing and antioxidant therapy, effectively turning agricultural waste into high-value nanotechnology.

References

1. Baker, S. N., & Baker, G. A. (2010). Luminescent carbon nanodots: Emergent nano lights. Angewandte Chemie International Edition, 49(38), 6726–6744.
2. Li, H., Kang, Z., Liu, Y., & Lee, S. T. (2012). Carbon nanodots: Synthesis, properties and applications. Journal of Materials Chemistry, 22(46), 24230–24253.
3. Lim, S. Y., Shen, W., & Gao, Z. (2015). Carbon quantum dots and their applications. Chemical Society Reviews, 44(1), 362–381.
4. Dong, Y., Pang, H., Yang, H. B., et al. (2013). Carbon-based dots co-doped with nitrogen and sulfur for high quantum yield and excitation-independent emission. Angewandte Chemie, 125(30), 7954–7958.
5. Hola, K., Zhang, Y., Wang, Y., et al. (2014). Carbon dots—Emerging light emitters for bioimaging, cancer therapy and optoelectronics. Nano Today, 9(5), 590–603.
6. Sun, Y. P., Zhou, B., Lin, Y., et al. (2006). Quantum-sized carbon dots for bright and colourful photoluminescence. Journal of the American Chemical Society, 128(24), 7756–7757.
7. Sahu, S., Behera, B., Maiti, T. K., & Mohapatra, S. (2012). Simple one-step synthesis of highly luminescent carbon dots from orange juice. Chemical Communications, 48(70), 8835–8837.
8. Wang, Y., Hu, A. (2014). Carbon quantum dots: Synthesis, properties and applications. Journal of Materials Chemistry C, 2(34), 6921–6939.
9. Qu, D., Zheng, M., Zhang, L., et al. (2012). Formation mechanism and optimization of highly luminescent N-doped graphene quantum dots. Scientific Reports, 4, 5294.
10. Zhu, S., Meng, Q., Wang, L., et al. (2013). Highly photoluminescent carbon dots for multicolor patterning, sensors, and bioimaging. Angewandte Chemie, 52(14), 3953–3957.
11. Brand-Williams, W., Cuvelier, M. E., & Berset, C. (1995). Use of free radical method to evaluate antioxidant activity. LWT - Food Science and Technology, 28(1), 25–30. (DPPH method)
12. Benzie, I. F. F., & Strain, J. J. (1996). Ferric reducing ability of plasma (FRAP) assay. Analytical Biochemistry, 239(1), 70–76.

13. Prior, R. L., Wu, X., & Schaich, K. (2005). Standardized methods for antioxidant capacity determination. Journal of Agricultural and Food Chemistry, 53(10), 4290–4302.
14. Apak, R., Güçlü, K., Özyürek, M., & Karademir, S. E. (2004). Novel total antioxidant capacity index using CUPRAC method. Journal of Agricultural and Food Chemistry, 52(26), 7970–7981.
15. Xie, Z., Wang, F., Liu, C. (2012). Organic-inorganic hybrid functional carbon dots for metal ion detection. Advanced Materials, 24(13), 1716–1721.
16. Liu, J., Geng, Y., Li, D., et al. (2013). Deep red emissive carbonized polymer dots with bioimaging applications. Advanced Materials, 25(39), 5780–5785.
17. Zhou, L., Lin, Y., Huang, Z., et al. (2012). Carbon dots as fluorescent probes for metal ion detection. Chemical Communications, 48(94), 1147–1149.
18. Li, X., Rui, M., Song, J., Shen, Z., & Zeng, H. (2015). Carbon and graphene quantum dots for optoelectronic and energy devices. Advanced Functional Materials, 25(31), 4929–4947.
19. Ahmed, S., Ahmad, M., Swami, B. L., & Ikram, S. (2016). Green synthesis of nanoparticles using plant extracts. Journal of Advanced Research, 7(1), 17–28.
20. Roy, P., Periasamy, A. P., Chuang, C., et al. (2015). Plant-based green synthesis of carbon nanoparticles for biomedical applications. Environmental Science: Nano, 2(4), 329–345.

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ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Original Article

Micromorphology of Leaf Epidermis in *Corynandra elegans* Chandore *et al.* from South Konkan region of Maharashtra, India

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Manuscript ID:
JRD -2026-180429
ISSN: 2230-9578
Volume 18
Issue 4(XI)
Pp. 193-197
April - 2026

Submitted: 16 Mar. 2026
Revised: 30 Mar. 2026
Accepted: 09 Apr . 2026
Published:30 April2026

Abstract:
The present paper describes the leaf epidermal cell type of Corynandra elegans Chandore et al., an endemic species of Cleomaceae family from south konkan region of Maharashtra. The species exhibit morphologically distinct heterophylly, transitioning from basal pubescent, tri to pentafoliate leaves to middle trifoliate leaves and unifoliate upper leaves. Using the epidermal peeling method, we analyzed micromorphology of the leaf epidermis. Results revealed significant variation in trichome number amongst these leaves and presence of many idioblast cells. In addition, stomatal index and stomata, trichome, Idioblast densities were calculated and epidermal cells dimensions were measured to characterize the leaf epidermis. The presence of anomocytic stomata, idioblast cells and non-glandular, multicellular, multiseriate trichome found to be important characters for the identification of Corynandra elegans Chandore et al. species.
Keywords: *Corynandra, Epidermis, Idioblast, Stomata, Trichome etc.*

Introduction:

Corynandra elegans Chandore *et al.* (Cleomaceae) is an endemic species restricted to the seasonal ponds of lateritic plateau (Chandore *et al*., 2016). Reaching heights of up to 2 meters, this plant exhibits a distinct heterophyllous growth pattern where leaf morphology and texture transition significantly during development. The initial growth phase produces pubescent (hairy) tri to pentafoliate leaves, which transition to trifoliate leaves at the mid-stem and eventually to smooth, simple, unifoliate leaf at the apex. This structural variation evidently observed in the micromorphology of the plant epidermis; the primary protective layer that regulates gas exchange, water loss, and defense against environmental stressors (Cutler *et al*., 2008).

As a permanent exterior layer for organs like leaves and flowers, the epidermis differentiates into specialized cells such as pavement cells, guard cells, trichomes, and idioblast cells that serve as critical diagnostic features in plant taxonomy (Crang *et al*., 2018). Despite their importance, detailed micromorphological data for *C. elegans* Chandore *et al.* remain unavailable. The study addresses this gap by employing the epidermal peeling method to characterize stomatal density, stomatal index, and trichome variation across different leaf stages. Notably, we report the presence of previously undocumented idioblast cells (Chandore *et al*., 2016). These findings provide the physical evidence necessary to clarify the taxonomic placement of *C. elegans* Chandore *et al.* and offer a deeper understanding of its specialized biological features.

Material and Methods:

Fresh leaf samples of *C. elegans* Chandore *et al.* obtained from the transplanted plants at research center. Micro morphology of leaf epidermis studies were prepared according to the modified method of Paul *et al*. (2017). For the studies, the peels of adaxial and abaxial sides taken, stained with safranin, and mounted in glycerin for observation (Obiremi *et al*., 2001).

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How to cite this article:
Jadhav, S. S., & Masal, V. P. (2026). Micromorphology of Leaf Epidermis in Corynandra elegans Chandore et al. from South Konkan region of Maharashtra, India. Journal of Research and Development, 18(4(XI)), 193–197. https://doi.org/10.5281/zenodo.21127067

Quick Response Code:
Website:
https://jrdrvb.org/
DOI:
10.5281/zenodo.21127067
OPEN ACCESS

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Prepared slides of both surfaces were observed under the compound microscope at 1125 X Magnification. Epidermal cell types were measured through compound microscope with the help of calibrated ocular micrometer. Trichome and Idioblast density was quantified using WBC counting squares of Neubauer chamber (Singh *et al*., 2007).

Observations:

Micro morphological characteristics of leaf epidermis for *Corynandra elegans* Chandore *et al*., species are systematically detailed and categorized in Tables 1- 6.

Table 1: Stomatal diversity and quantitative character analysis of *C. elegans* Chandore *et al.*

Position of Leaf	Surface	Type of Stomata	Stomatal aperture (µm)		Guard cells (µm)		Stomatal Complex (µm)	
			Length	Width	Length	Width	Length	Width
Basal Leaf	Adaxial	Anomocytic	11-15	4- 11	22-26	18-22	59-111	48-107
	Abaxial	Anomocytic	11-15	4-7	22-28	18-22	48-88	41-88
Middle Leaf	Adaxial	Anomocytic	11-18	4-7	22-29	18-22	48-99	44-88
	Abaxial	Anomocytic	14-22	4-7	22-33	15-22	65-114	48-92
Upper Leaf	Adaxial	Anomocytic	7-15	4-6	18-24	14-22	46-70	37-88
	Abaxial	Anomocytic	15-18	4-18	22-28	18-22	48-89	37-63

Table 2: Stomatal density of *C. elegans* Chandore *et al.*

Position of Leaf	Stomatal density (Number of stomata/mm^2 of leaf surface)	
	Adaxial Surface	Abaxial Surface
Basal Leaf	280-380	230-320
Middle Leaf	280-360	250-280
Upper Leaf	430-480	420-485

Table 3: Stomatal Index of *C. elegans* Chandore *et al.*

Position of Leaf	Surface	Stomatal Index (Number of stomata/mm^2 of leaf surface)		
		Number of Stomata	Number of epidermal cells	Stomatal index (%)
Basal Leaf	Adaxial	328	1044	23.90%
	Abaxial	261	1009	20.55 %
Middle Leaf	Adaxial	331	1059	23.81 %
	Abaxial	258	1003	20.45 %
Upper Leaf	Adaxial	453	1511	23.06 %
	Abaxial	453	1822	19.91 %

Table 4: Trichome diversity and quantitative character analysis of *C. elegans* Chandore *et al.*

Position of Leaf	Surface	Type of Trichome	Trichome (µm) (Smallest to Largest)	
			Length	Width (Base)
Basal Leaf	Adaxial	Non-glandular, Multicellular, Unbranched, Multiseriate	103 – 619	44-74
	Abaxial	Non-glandular, Multicellular, Unbranched, Multiseriate	44 – 649	44-74

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ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Middle Leaf	Adaxial	Non-glandular, Multicellular, Unbranched, Multiseriate	44 – 280	44-74
	Abaxial	Not observed		
Upper Leaf	Adaxial	Non-glandular, Multicellular, Unbranched, Multiseriate	74 – 266	44-74
	Abaxial	Not observed		

Table 5: Trichome density of *C. elegans.*

Position of Leaf	Trichome density (Number of Trichome/mm^2 of leaf surface)	
	Adaxial Surface	**Abaxial Surface**
Basal Leaf	8 – 9	16 - 22
Middle Leaf	1 – 3	Not observed
Upper Leaf	0 –3	Not observed

Table 6: Idioblast quantitative character analysis of *C. elegans.*

Position of Leaf	Surface	Density (Number of Idioblast/mm^2 of leaf surface)	Idioblast (µm)	
			Length	**Width**
Basal Leaf	Adaxial	1-3	92-239	29-85
	Abaxial	3-9	70-203	44-92
Middle Leaf	Adaxial	1-3	103-147	29-59
	Abaxial	3-5	107-162	29-52
Upper Leaf	Adaxial	1-2	89-232	44-70
	Abaxial	3-4	74-161	33-66

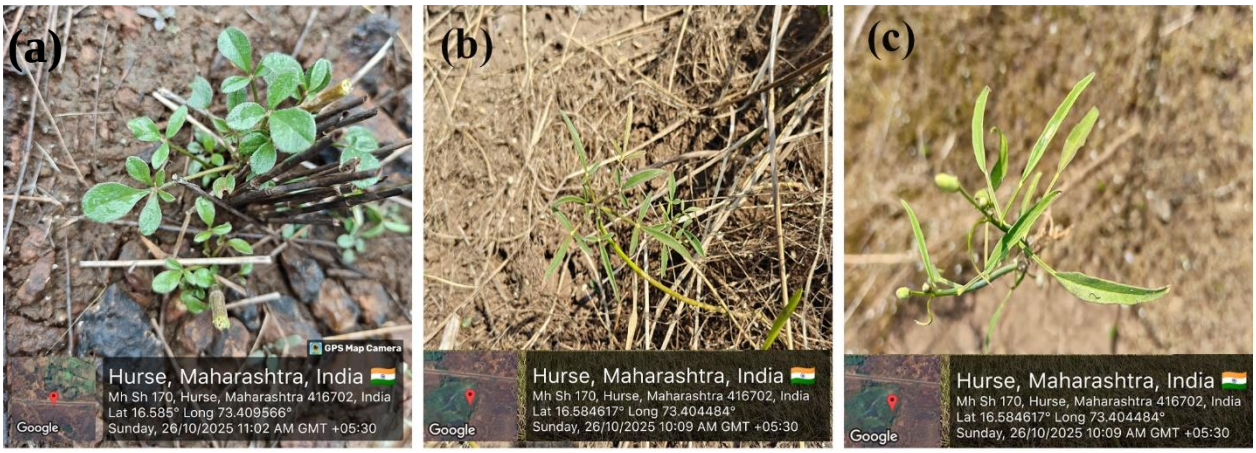

Figure 1: *Corynandra elegans* Chandore *et al.* species showing heterophylly: (a) Tri to pentafoliate basal leaves (b) Trifoliate middle leaves method (c) Unifoliate upper leaf.

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ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

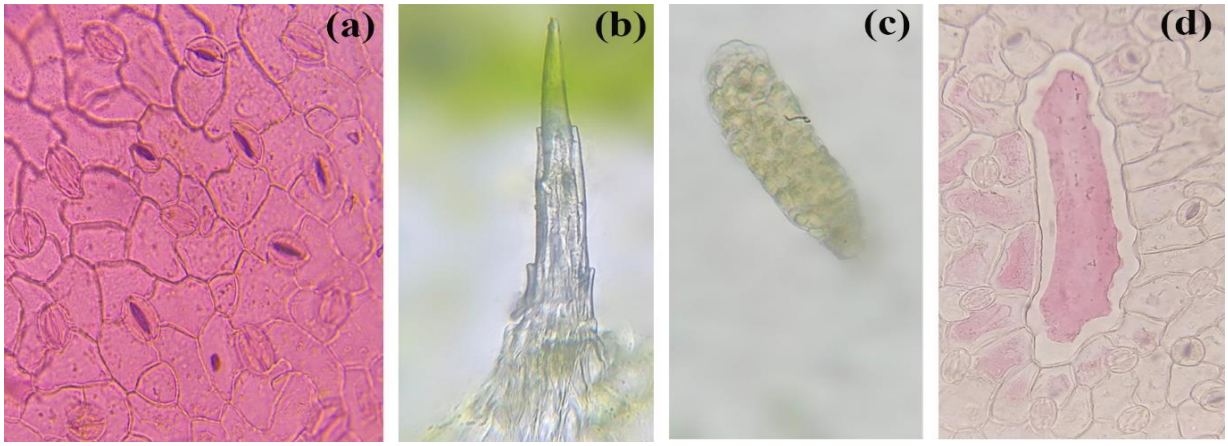

Figure 2: Epidermal cell type in *Corynandra elegans* Chandore *et al.* (a) Guard cells and pavement cells (b) Trichome (C) Multicellular Outgrowth (d) Idioblast cell

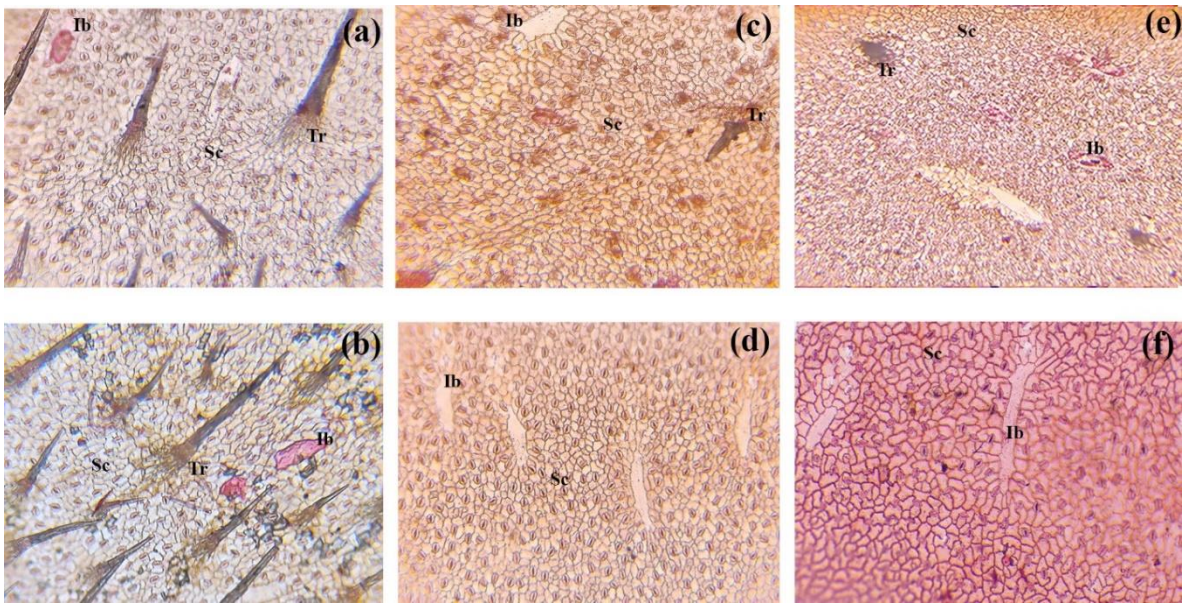

Figure 3: Epidermal peel of adaxial and abaxial surface of basal, middle and upper leaf- (a) Adaxial surface of basal leaf, (b) Abaxial surface of basal leaf, (c) Adaxial surface of middle leaf, (d) Abaxial surface of middle leaf, (e) Adaxial surface of upper leaf, (f) Abaxial surface of upper leaf. (Sc- Stomatal complex, Tr- Trichome, Ib- Idioblast).

Results and Discussion:

The epidermal cell types observed in *Corynandra elegans* Chandore *et al*. comprises pavement cells and guard cells forming an anomocytic stomatal complex. Moreover, the presence of specialized cell types such as trichomes and idioblast cells provides taxonomic significance to this species (Crang *et al.*, 2018).

Trichomes characterized as non-glandular, multicellular, unbranched and multiseriate present on the both surfaces of basal leaves, while middle and upper leaves exhibited trichomes on adaxial surface only. Another epidermal cell type characterized as a multicellular outgrowth observed on the adaxial surface of basal as well as upper leaves and both surface of middle leaves. (Crang *et al.*, 2018). This likely represents a form of trichome; however, confirmation of this requires further analysis using advanced microscopy. Idioblasts are unique, unusual isolated cells and exhibit different types like cytoliths, tannin bodies, and crystals. Idioblasts may contain elemental deposits or contain oil cells and tannins, to deter herbivory (Crang *et al.*, 2018). Myrosin containing idioblasts observed in certain *Cleome* species and are widely distributed throughout the Brassicaceae, a sister family to the Cleomaceae (Metcalfe *et al.*, 1950). Consequently, given the close phylogenetic relationship to these groups, the idioblasts found in this species may indeed be myrosin cells.

Guard cell and stomatal aperture sizes correlate, but larger stomatal complexes reduce density. Stomatal index is constant, but adaxial surface shows higher stomatal density than abaxial. Increased densities of trichomes and idioblasts

negatively correlate with stomatal density, as these epidermal structures compete for distribution within a given square millimeter of leaf area.

Conclusion:

The micromorphological analysis of *Corynandra elegans* Chandore *et al.* provides a detailed characterization of the leaf epidermis in this endemic species. While previous studies were restricted to the general morphological characters of the leaf, they failed to report the presence of trichomes on the upper leaf surface due to its smooth appearance (Chandore *et al*., 2016). However, this microscopic evaluation of the leaf epidermis reveals that the adaxial surface does indeed possess trichomes, at a very low density. This transition from the dense pubescence of basal tri to pentafoliate leaves to the sparsely trichomatous state of the upper unifoliate leaves highlights a significant structural shift during the plant's development. In the species *C. elegans* Chandore *et al*., the anomocytic stomatal complex specifically anomotetracyclic subtype serves as the primary morphological form, while tricytic complexes are also observed. Furthermore, the identification of previously unreported idioblast cells, alongside quantitative data on stomatal density and index, offers new diagnostic markers for the species. These findings provide the physical evidence necessary to clarify the taxonomic placement of *C. elegans* Chandore *et al.* and establish a baseline for its specialized biological features. By addressing the limitations of previous morphological descriptions, this study underscores the importance of micromorphological analysis in documenting the true vegetative characteristics.

Acknowledgement:

The first author thanks The University Grant Commission, India for the doctoral fellowship. This work is part of the requirements at the University of Mumbai for Shweta S. Jadhav to obtaining her PhD degree. We are thankful to the Principal Dr. Sandesh P. Jagdale for providing necessary resources and stimulating environment for research.

References:

1. Ahmad, K., Khan, M. A., Ahmad, M., Zafar, M., Arshad, M., & Ahmad, F. (2009). Taxonomic diversity of stomata in dicot flora of a district tank (NWFP) in Pakistan. *African journal of Biotechnology*, *8*(6), 1052.
2. Aparadh, V. T., Thite, S. V., & Karadge, B. A. (2012). Distribution, Density and types of stomata in some Cleome species. *Plant Sciences Feed*, *2* (11), 170-173.
3. Chandore, A. N., Yadav, U. S., & Yadav, S. R. (2016). A new elegant species of *Corynandra* (Cleomaceae) from Konkan region of Maharashtra, India. *Phytotaxa*, *260*(1), 89.
4. Crang, R., Lyons-Sobaski, S., & Wise, R. (2018). *Plant anatomy: a concept-based approach to the structure of seed plants*. Springer.
5. Cutler, D. F., Botha, T., & Stevenson, D. W. (2008). *Plant anatomy: an applied approach*. John Wiley & Sons.
6. Das, Barnali, Roy, Shilpa, Kalita, Sushmita, Boro, K. K., Nath, Madhushmita, & Nath, N. (2022). Comparative foliar morphological and palynological studies of Cleomaceae of Assam, India. *Biodiversitas*, *23*(6), 2920-2934.
7. Dilcher, D. L. (1974). Approaches to the identification of angiosperm leaf remains. *The botanical review*, *40*(1), 1-157.
8. Johanna, H. A. (2000). Parameters in leaf and cuticle morphology. *Journal of Palaeosciences*, *49*(1-3)), 9-16.
9. Khandelwal, K., & Sethi V. (2022). *Practical pharmacognosy*. Pragati Books Pvt. Ltd.
10. Manjuparkavi, K., & Jayanthi, G. (2019). Micromorphological studies of *Cleome felina* Lf Int. *J. Curr. Res. Biosci. Plant Biol*, *6*, 32-41.
11. Metcalfe, C. R., & Chalk, L. (1950). Anatomy of the dicotyledons, Vols. 1.
12. Obiremi, E. O., & Oladele, F. A. (2001). Water conserving stomatal systems in selected *Citrus* species. *South African Journal of Botany*, *67*(2), 258-260.
13. Okonwu, K., Ekeke, C., & Mensah, S. (2017). Micromorphological and Phytochemical Studies on *Cleome rutidosperma* Linn. *Journal of Advances in Biology & Biotechnology*, *11*(3), 1-8.
14. Paul, V., Sharma, L., Pandey, R., & Meena, R. C. (2017). Measurements of stomatal density and stomatal index on leaf/plant surfaces. *Manual of ICAR Sponsored Training Programme for Technical Staff of ICAR Institutes on Physiological Techniques to Analyze the Impact of Climate Change on Crop Plants*, *27*, 1-7.
15. Pelden, D., & Meesawat, U. (2019). Foliar idioblasts in different-aged leaves of a medicinal plant (*Annona muricata* L.). *Songklanakarin Journal of Science & Technology*, *41*(2).
16. Selvi, S., & Paksoy, M. Y. (2013). Comparative anatomy of stem and leaf of *Ricotia* L. growing in Turkey. *Bangladesh Journal of Botany*, *42*(1), 123-130.
17. Shirakawa, M., & Hara-Nishimura, I. (2018). Specialized vacuoles of myrosin cells: chemical defense strategy in Brassicales plants. *Plant and Cell Physiology*, *59*(7), 1309-1316.
18. Singh, J., & Kant, S. (2007). Impact of coal mining on leaf morphology and stomatal index of plants in Kalakote range, Rajouri (J&K), India. *Nature Environment and Pollution Technology*, *6*(4), 715.
19. Singh, R. K., Arigela, R. K., & Reddy, C. S. (2021, December). Identity of *Polanisia angulata* (Cleomaceae) and Typification of Two Linnaean Names and Three Linnaeus Filius' Names in Cleome. In *Annales Botanici Fennici* (Vol. 59, No. 1, pp. 1-8). Finnish Zoological and Botanical Publishing Board.
20. Van Cotthem, W. (1970). Comparative morphological study of the stomata in the Filicopsida. *Bulletin du Jardin botanique national de Belgique/Bulletin van de Nationale Plantentuin van Belgie*, 81-88.

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Original Article

Navi Mumbai's Mangroves: An Ecosystem under Severe Urban Pressure

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Manuscript ID:
JRD -2026-180430
ISSN: 2230-9578
Volume 18
Issue 4(XI)
Pp. 198-201
April - 2026

Submitted: 16 Mar. 2026
Revised: 30 Mar. 2026
Accepted: 09 Apr . 2026
Published:30 April2026

Abstract
The mangrove forests of Navi Mumbai, located at the nexus of rapid urbanization and a vulnerable coastline, constitute a critical natural infrastructure. These ecosystems provide quantifiable climate adaptation and mitigation services that are indispensable for the long-term security of the region. However, this study argues that the ecosystem has reached an 'ecological saturation point,' where its landward expansion is physically constrained by urban development, severely compromising its resilience. This comprehensive review synthesizes findings from recent high-impact studies to quantify the ecological significance of mangroves, including their role as a "blue carbon" sink sequestering over 150 Mg/ha of CO2 and their profound ability to attenuate tidal currents by up to 80%. It also critically analyses the multifaceted anthropogenic threats, particularly habitat destruction driven by city planning agencies and pervasive degradation from heavy metal and nutrient pollution. The findings demonstrate a direct conflict between the city's current development model and its ecological security. This paper concludes by advocating for an urgent shift towards an integrated management strategy, employing real-time hydrodynamic modelling and stringent pollution controls to preserve this irreplaceable natural shield.
Keywords: *Mangroves, Navi Mumbai, Coastal Resilience, Blue Carbon, Tidal Attenuation, Urban Ecology.*

1. Introduction

Mangrove forests are globally recognized as vital ecosystems that provide a suite of services essential for coastal integrity and climate change mitigation [1]. Situated in the intertidal zones of tropical coastlines, mangroves act as natural barriers against coastal hazards, serve as critical nurseries for marine biodiversity, and function as highly efficient carbon sinks. In the context of India's rapidly urbanizing coastline, the mangroves of the Navi Mumbai region present a stark case study of the escalating conflict between urban expansion and environmental conservation in India. Navi Mumbai, a planned satellite city adjacent to Mumbai, has experienced explosive growth over the past four decades, largely orchestrated by the City and Industrial Development Corporation (CIDCO). This development has been characterized by aggressive land reclamation, often at the direct expense of the mangrove forests fringing the ecologically significant Thane and Panvel Creeks [2]. While these ecosystems have long been acknowledged for their qualitative benefits, recent scientific research has begun to quantify their physical contributions in stark and measurable terms. This paper synthesizes this body of evidence to build a compelling case for conservation. The core argument presented is that the mangroves of Navi Mumbai have reached an ecological 'saturation point'—a state where their natural landward migration is physically blocked by urban infrastructure, leaving them trapped between a polluted sea and a concrete jungle [3]. This precarious state severely diminishes their capacity to adapt to environmental stressors, such as sea-level rise and pollution. This review aims to (i) present the quantifiable ecological significance of these mangroves in terms of biodiversity support and carbon sequestration, (ii) critically analyse the anthropogenic pressures that have led to their saturation and degradation, and (iii) make a data-driven case for their non-negotiable role in providing urban flood resilience.

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How to cite this article:
Archana, K. (2026). Navi Mumbai's Mangroves: An Ecosystem under Severe Urban Pressure. Journal of Research and Development, 18(4(XI)), 198–201.
https://doi.org/10.5281/zenodo.21127180

Quick Response Code:
Website:
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DOI:
10.5281/zenodo.21127180
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2. Methodology of Review

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

This study is a comprehensive literature review that synthesizes peer-reviewed research, government reports, and high-impact publications to assess the state of the mangrove ecosystem in Navi Mumbai. A systematic search was conducted using academic databases, including Scopus, ScienceDirect, and Google Scholar, for the period of 2000 to 2024. Search keywords included "mangrove," "Navi Mumbai," "Thane Creek," "Panvel Creek," "CIDCO," "heavy metal pollution," "coastal resilience," and "urban ecology." The inclusion criteria prioritized studies that provided quantitative data on ecosystem services, documented specific anthropogenic impacts in the region, and were published in credible academic journals. The synthesized findings were then structured thematically to build a coherent argument regarding the ecosystem's value, the threats it faces, and its role in regional climate resilience.

3. Ecological Significance: A Biodiversity Hotspot and Blue Carbon Sink

The ecological value of the Navi Mumbai mangroves is profound and quantifiable. Ecosystems are recognized biodiversity hubs and significant sinks for atmospheric carbon.

3.1. Biodiversity and Habitat Provision

The Thane Creek area, a designated Ramsar site, supports approximately 15 species of mangroves and mangrove associates, with *Avicennia marina* being the dominant species because of its high tolerance to salinity and pollution [3, 4]. This habitat is an internationally recognized Important Bird and Biodiversity Area (IBA), providing a critical refuge for over 155 resident and migratory bird species, most notably large flocks of flamingos [5]. The intricate network of roots and nutrient-rich mudflats serve as vital nurseries for numerous commercially important species of finfish, crustaceans, and molluscs, thereby supporting the livelihoods of local fishing communities [6].

3.2. Quantified Carbon Sequestration

A primary climate mitigation service provided by this ecosystem is its function as a "blue carbon" sink. Recent data synthesized by Patil (2022) quantified this capacity, revealing a mean Above-Ground Biomass (AGB) of 63.48 Mg/ha and Below-Ground Biomass (BGB) of 18.41 Mg/ha. This biomass contributes to a total CO2 sequestration potential of approximately **150.25 Mg/ha** [3]. This demonstrates that mangrove forests are substantial carbon reservoirs. Its continued destruction not only negates future carbon sequestration but also risks releasing this vast store of legacy carbon back into the atmosphere, exacerbating the climate change.

4. A System Under Siege: Anthropogenic Pressures and the 'Saturation Stage'

The resilience of mangroves in Navi Mumbai is critically undermined by a pincer movement of habitat loss from urban expansion and severe degradation from pollution. This has pushed the ecosystem into the aforementioned 'saturation stage.'

4.1. Infrastructure-led Habitat Loss

Patil (2022) highlighted the critical finding that mangroves have grown to their maximum landward extent, physically blocked by a wall of urbanization [3]. This saturation means that the ecosystem has no room to migrate inland in response to sea-level rise, a natural adaptation process. This perilous situation is a direct consequence of decades of urban planning that has treated intertidal zones as reclaimable land. Key drivers include:

a. **Land Reclamation:** Large-scale projects spearheaded by city planners, such as the Navi Mumbai International Airport and the development of residential and commercial nodes such as Ulwe and Dronagiri, were built on reclaimed mangrove habitats and mudflats [2].
b. **Infrastructure Fragmentation:** Major transport corridors, including the Atal Setu (Mumbai Trans Harbour Sea Link) and Navi Mumbai Metro, have fragmented contiguous mangrove patches, disrupting tidal hydrology and creating edge effects that degrade the interior forest [7].

4.2. The Chemical Assault: Pollution and Degradation

The water and sediment quality of the creeks that nourish the mangroves are severely compromised by a toxic cocktail of pollutants.

a. **Heavy Metal Contamination:** Industrial effluents, particularly from the Thane-Belapur industrial belt, have resulted in dangerous levels of heavy metal contamination in the creek. Kumar and Jayaprakash (2018) conducted a key study that provided a detailed ecological risk assessment of Thane Creek, identifying hazardous concentrations of lead (Pb), cadmium (Cd), and mercury (Hg) in the sediments [8]. These toxins are absorbed by mangroves and biomagnified up the food chain [9].
b. **Nutrient Overload and Hypoxia:** The release of vast quantities of untreated domestic sewage leads to nutrient enrichment (eutrophication). Research in the region's water bodies has confirmed dangerously high nutrient loads, which cause algal blooms and subsequent depletion of dissolved oxygen, creating hypoxic 'dead zones' that are lethal to aquatic life [10, 11].
c. **Marine Debris:** The physical smothering of mangrove pneumatophores (breathing roots) by plastic bags and other non-biodegradable solid waste is a pervasive problem that impedes gas exchange and suffocates the trees, representing a major challenge to coastal ecosystems globally [12].

5. Quantifiable Climate Resilience: The Role in Flood Mitigation

While the narrative of mangroves as coastal buffers is well-known, recent hydrodynamic modelling provides powerful,

quantitative evidence of their effectiveness in the specific context of Navi Mumbai. The Patil (2022) review, synthesizing data from such models, demonstrates a profound "tidal attenuation" effect [3].

The research shows that the presence of the dense mangrove forest reduces the maximum velocity of incoming tidal currents by an astonishing 80%, slowing the flow from over 1.0 m/s in the main channel to less than 0.2 m/s within the forest. Without this natural hydraulic brake, the funnel-like topography of the creek would amplify tidal surges, leading to severe inland flooding and coastal erosion. This 80% reduction in hydraulic energy is not a minor ecological benefit; it is a critical, life-saving service that protects low-lying urban and industrial areas from catastrophic inundation. Therefore, every hectare of mangrove forest cleared directly translates to a quantifiable increase in the city's flood vulnerability.

6. Discussion

The evidence synthesized in this review paints a stark picture of an ecosystem of immense value that is on the brink of functional collapse. The concept of an 'ecological saturation point' is critical; it implies that the mangroves of Navi Mumbai have lost their adaptive capacity. Unlike a natural system that can migrate landward with rising seas, this ecosystem is trapped. This fundamentally challenges the sustainability of the region's urban development model, which has historically externalized environmental costs.

The direct conflict between the mandate of a development authorities and the ecological imperative for coastal resilience is clear. The quantifiable flood mitigation service, an 80% reduction in tidal force, is a service that, if it had to be replaced by engineered structures like sea walls, would cost very high and be less resilient. The continued degradation from pollution further weakens the ecosystem's ability to provide these services. The high levels of heavy metals and nutrient pollution create a chronic stress state, reducing the mangroves' growth rates and making them more susceptible to disease and storm damage. This review, therefore, elevates the conservation of mangroves from an environmental issue to a core strategic imperative for urban planning and disaster risk reduction in the Navi Mumbai region.

7. Conclusion and Recommendations

The mangrove ecosystem of Navi Mumbai is a vital natural asset providing quantifiable climate resilience, yet it is critically endangered by urban expansion and pollution, having reached a point of ecological saturation. Its preservation is not an obstacle to development but a prerequisite for a sustainable and secure urban future. Based on the findings of this review, a paradigm shift in governance and management is urgently required. We propose the following actionable recommendations:

a. **Implement a Policy of 'No Further Loss' and Mandate Buffer Zones:** All remaining mangrove areas and adjacent mudflats must be granted the highest level of legal protection, with a strictly enforced buffer zone to prevent further encroachment.
b. **Invest in Technologically-Advanced Monitoring:** Employ real-time monitoring systems using GIS and hydrodynamic models (e.g., ADCIRC), as advocated by recent research [3], to predict inundation risks and prioritize areas for conservation and restoration.
c. **Establish a Zero-Discharge Policy for Pollutants:** Create a multi-agency task force with the mandate to enforce a 'zero liquid discharge' policy for industries and to ensure 100% treatment of domestic sewage entering the creeks.
d. **Integrate Ecosystem Service Valuation into Urban Planning:** Mandate that all future infrastructure projects conducted by CIDCO and other agencies legally integrate the quantified monetary value of mangrove ecosystem services, particularly flood mitigation, into their cost-benefit analysis and environmental impact assessments.

References

[1] Alongi, D. M. (2008). Mangrove forests: Resilience, protection from tsunamis, and responses to global climate change. *Estuarine, Coastal and Shelf Science*, *76*(1), 1–13.
[2] Valiela, I., Bowen, J. L., & York, J. K. (2001). Mangrove forests: One of the world's threatened major tropical environments. *BioScience*, *51*(10), 807–815.
[3] Patil, C. R. (2022). A review of the mangrove ecosystem of Thane Creek, Mumbai: A case of climate change mitigation and adaptation. *Regional Studies in Marine Science*, *49*, 102148.
[4] Quadros, S. N. (2011). *Flora of Mumbai's mangroves*. World Wide Fund for Nature-India.
[5] Chavan, S. J., & Bhaskar, D. (2014). Avifaunal diversity of mangrove ecosystem of Uran (Raigad), Navi Mumbai, Maharashtra. *International Research Journal of Environment Sciences*, *3*(2), 65-69.
[6] Goldar, B. (2004). *Valuation of mangrove ecosystems for coastal protection: The case of the Mumbai coast*. World Bank.
[7] Richards, D. R., & Friess, D. A. (2016). Rates and drivers of mangrove deforestation in Southeast Asia, 2000–2012. *Proceedings of the National Academy of Sciences*, *113*(2), 344–349.
[8] Kumar, S. C., & Jayaprakash, M. C. N. (2018). Spatial distribution and ecological risk assessment of heavy metals in sediments of Thane Creek, India. *Marine Pollution Bulletin*, *131*, 233–242.
[9] Rokade, M. A. (2013). Accumulation of heavy metals in marine organisms from the coastal water of Mumbai. *Marine Pollution Bulletin*, *67*(1-2), 221-226.

[10] Ram, A., Rokade, M. A., & Sarma, V. V. (2021). Spatiotemporal variability of nutrients and their fluxes in the Thane Creek, west coast of India. *Regional Studies in Marine Science*, *41*, 101589.
[11] Kantia, A., & Mendhulkar, V. D. (2025). Water quality analysis of coastal lake of Kalamboli, Navi Mumbai, India. *Uttar Pradesh Journal of Zoology*, *46*(15), 242–256.
[12] Kantia, A. (2025). Marine debris: A global environmental and socioeconomic challenge to coastal and marine ecosystems. *Uttar Pradesh Journal of Zoology*, *46*(4), 45–54.

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Original Article

Occurrence of *Tricholepis amplexicaulis* C.B. Clarke: An Addition to the Flora of Ratnagiri District, Maharashtra.

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Manuscript ID:
JRD -2026-180431
ISSN: 2230-9578
Volume 18
Issue 4(XI)
Pp. 202-206
April - 2026

Submitted: 17 Mar. 2026
Revised: 30 Mar. 2026
Accepted: 10 Apr . 2026
Published:30 April2026

Abstract

The present study reports the occurrence of Tricholepis amplexicaulis C.B. Clarke (family Asteraceae) from Dapoli region of Ratnagiri district, Maharashtra, representing an addition to the existing flora of the district. The species was collected from Chandranagar village, Dapoli.

This record extends the known distribution of Tricholepis amplexicaulis C.B. Clarke in the Konkan region and highlights the floristic richness of Ratnagiri district. The study provides a detailed taxonomic description supported by diagnostic morphological characters to ensure accurate identification of the species. Photographic documentation and notes on its medicinal importance are also included to validate the report. The findings emphasize the importance of systematic floristic surveys in documenting plant diversity and identifying new distributional records, which contribute to regional biodiversity assessment and conservation planning.

Keywords: *Tricholepis amplexicaulis, Asteraceae, flora of Ratnagiri, distribution record, Dapoli.*

Introduction

The family Asteraceae represents one of the most species-rich groups of angiosperms, exhibiting remarkable diversity in form, habitat preference, and ecological adaptation. Members of this family are distributed across a broad range of environmental conditions and are notable for their ecological roles as well as their applications in traditional and modern medicine. In India, Asteraceae is extensively represented, particularly within tropical and subtropical zones such as the Western Ghats. The Western Ghats constitute a globally recognized centre of biodiversity, supporting a high proportion of endemic and rare plant taxa. Within this mountain range, the Konkan region of Maharashtra forms an important northern segment characterized by complex terrain, heavy monsoonal rainfall, and heterogeneous microhabitats. These environmental conditions contribute significantly to the region's rich plant diversity. However, despite its ecological importance, certain parts of the Konkan region remain insufficiently surveyed, resulting in incomplete documentation of species distribution.

The genus *Tricholepis* DC. Includes a limited number of species, most of which are confined to the Indian subcontinent and often exhibit narrow distribution ranges. Among these, *Tricholepis amplexicaulis* C.B. Clarke is relatively less studied and has been reported sporadically from different parts of peninsular India. The *Tricholepis amplexicaulis* C.B. Clarke was first described by C.B. Clarke in 1876 and is currently recognized as a valid member of Asteraceae.[6] Available records suggest its presence in select regions of Maharashtra and neighbouring states, although comprehensive distributional information at the district level remains lacking. *Tricholepis amplexicaulis* C.B. Clarke, a herbaceous member of Asteraceae, forms part of the diverse angiospermic flora of Bhimashankar Wildlife Sanctuary in the northern Western Ghats, reflecting the region's high species richness and ecological heterogeneity.[13]

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How to cite this article:
Mulukh, A. V., & Masal, V. P. (2026). Occurrence of Tricholepis amplexicaulis C.B. Clarke: An Addition to the Flora of Ratnagiri District, Maharashtra. Journal of Research and Development, 18(4(XI)), 202–206.
https://doi.org/10.5281/zenodo.21127306

Quick Response Code:
Website:
https://jrdrvb.org/
DOI:
10.5281/zenodo.21127306
OPEN ACCESS

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Existing reports indicate that *Tricholepis amplexicaulis* occurs in districts such as Ahmednagar, Pune, Satara, and Thane, suggesting a geographically restricted range. [7] It has also been documented as an endemic component of the northwestern Western Ghats in floristic assessments of areas such as the Mahadare Conservation Reserve.[4] Additionally, the species has been noted in sacred groves in Kannur district, Kerala, highlighting its occurrence in diverse ecological settings.[11]

While related species such as *Tricholepis glaberrima* DC. and *Tricholepis radicans* have been recorded from the Sanjay Gandhi National Park and Tungareshwar Wildlife Sanctuary region, these findings confirm the broader presence of the genus within the northern Western Ghats.[3][7] Furthermore, reports of *T. amplexicaulis* being sold in local markets in areas like Andheri, Mumbai, indicate its local use and accessibility.[8]

During recent floristic surveys conducted in the Dapoli region of Ratnagiri district, a population of *Tricholepis amplexicaulis* was collected from Chandranagar village. A comprehensive review of published literature and online biodiversity platforms, including the Global Biodiversity Information Facility (GBIF) and iNaturalist, did not reveal any prior records of this species from Ratnagiri district.

In light of these findings, the present study documents *Tricholepis amplexicaulis* as a new addition to the flora of Ratnagiri district. The study further provides a detailed taxonomic account, supported by photographic evidence, along with observations on its distribution and medicinal relevance to aid in accurate identification and future floristic investigations.

Materials and Methods

Field surveys were conducted in the Dapoli region of Ratnagiri district, Maharashtra, during the flowering and fruiting season. Plant specimens were collected from Chandranagar village, Dapoli.

The collected specimens were carefully examined for morphological characters using standard taxonomic procedures. Identification of the species was carried out with the help of regional floras, taxonomic literature, and comparison with authenticated herbarium specimens. The specimen has been authenticated at Blatter Herbarium Mumbai. (Specimen no. 7872 of H. Santapau.)

The specimens were processed, dried, and preserved following standard herbarium techniques. Diagnostic characters such as leaf morphology, inflorescence, and floral structures were studied for accurate identification.

Distributional data and locality verification were performed using online biodiversity databases such as Global Biodiversity Information Facility (GBIF) and iNaturalist using GeoCAT. Photographs of the plant in its natural habitat were taken to support identification and documentation.

Observations:

The plant specimen was collected from Chandranagar village in Dapoli Taluka of Ratnagiri District, Maharashtra, India. The study site is located at geographical coordinates 17.745052° N latitude and 73.155839° E longitude. The species was observed growing in an open grassland habitat, likely associated with fallow agricultural land and roadside vegetation, indicating its adaptation to disturbed environments

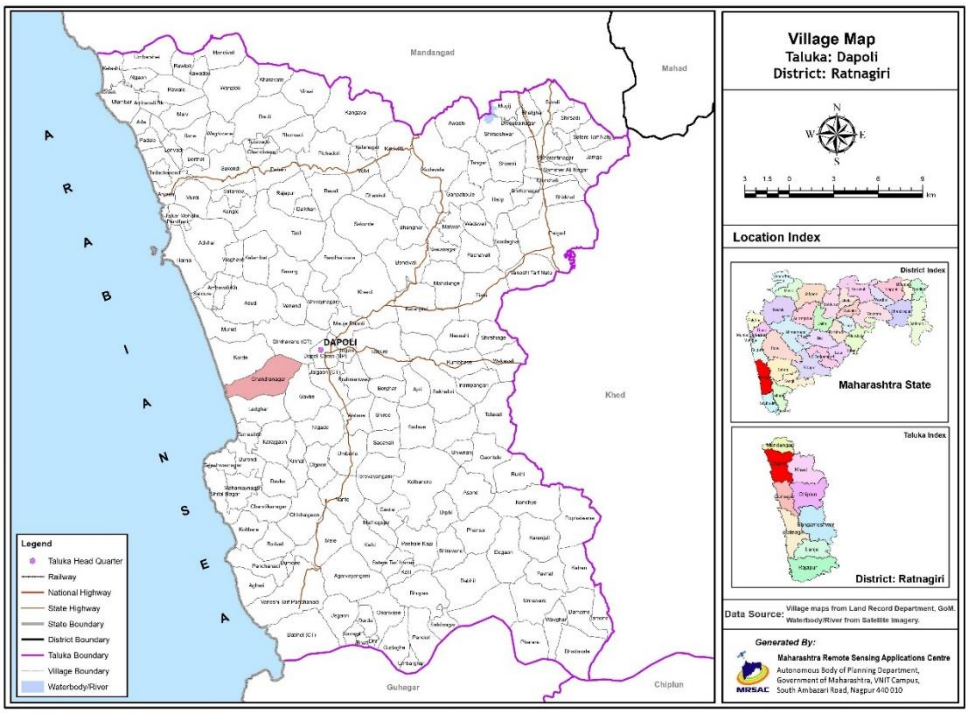
Taxonomic Description

Tricholepis amplexicaulis C.B. Clarke (Family: Asteraceae) is an erect annual herb, typically growing in open grasslands. The stem is branched, slender, and covered with slight pubescence, giving it a somewhat rough texture. Leaves are sessile, 15 to 20 cm long and characteristically amplexicaul, clasping the stem at the base, which is a key diagnostic feature of the species. Leaves are ovate-lanceolate at younger stage. At maturity leaves are lanceolate-oblong in shape, with entire to slightly toothed margins, and exhibit a sparsely hairy surface.

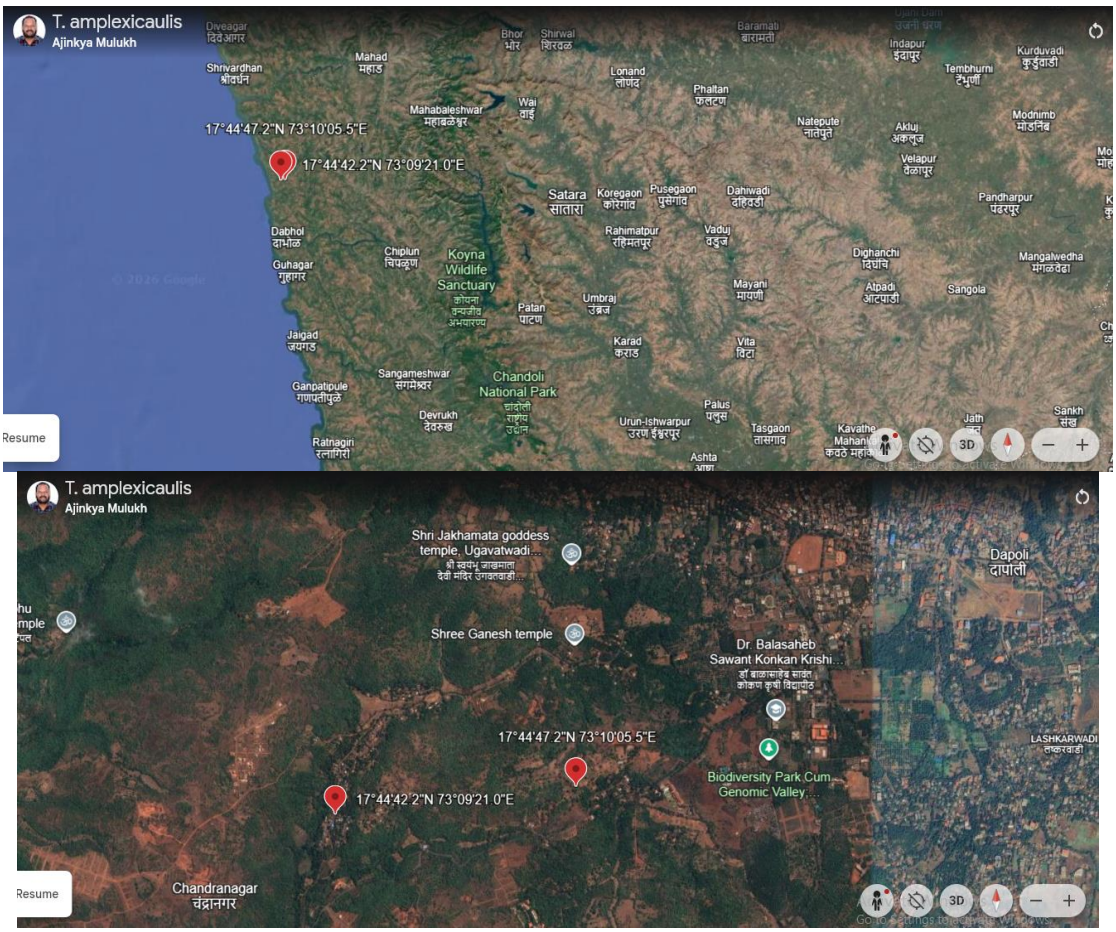
The inflorescence is a capitulum (head), usually solitary or occasionally few, borne terminally on the branches. The involucre bracts are numerous, narrow, and arranged in series, with pointed to spiny apices, contributing to the characteristic appearance of the head. The florets are tubular, bisexual, and typically purple to pink in colour, forming a compact head.

The fruit is a cypsela, small, ribbed, and adapted for dispersal, often associated with a pappus structure typical of members of Asteraceae. Flowering and fruiting are generally observed during the post-monsoon seasons in the month of December to Febraury , corresponding to the favourable growth conditions in its natural habitat

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

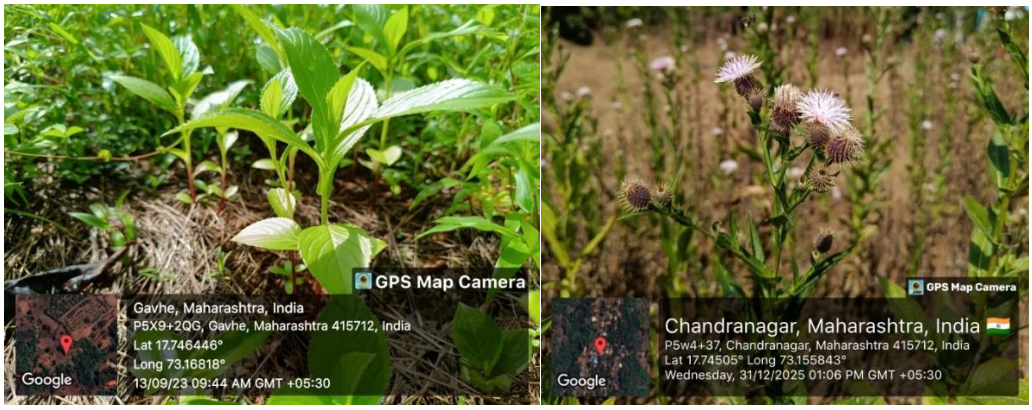


Map of Maharashtra, Ratnagiri and Dapoli Tahasil showing Chandranagar Village



Locations of *Tricholepis amplexicaulis* C.B. Clarke at Chandranagar Village.

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026



Vegetative and Flowering stages of *Tricholepis amplexicaulis* C.B. Clarke

Medicinal Importance:

Tricholepis amplexicaulis C.B. Clarke (Asteraceae) is a herbaceous species in which the whole plant is traditionally utilized for the treatment of skin diseases, cough, and urinary disorders.[8]

Although specific studies on *Tricholepis amplexicaulis* C.B. Clarke are limited, pharmacological investigations on related species such as *Tricholepis glaberrima and Tricholepis chaetolepis* demonstrate significant antidiabetic, antioxidant, aphrodisiac, and CNS activities, supporting its traditional medicinal use. [1] [5] [9] [10] [11]

Conclusion

The present study reports *Tricholepis amplexicaulis* C.B. Clarke as an addition to the flora of Ratnagiri district, Maharashtra. The absence of prior records in literature and databases confirms the significance of this locality record. Continued floristic exploration in the region may reveal additional undocumented species.

A review of available literature and online biodiversity databases, including Global Biodiversity Information Facility (GBIF) and iNaturalist, revealed no previous records of this species from Ratnagiri district. The present finding highlights the floristic richness of the Konkan region and emphasizes the importance of detailed field surveys in documenting plant diversity. Such studies are essential for updating regional floras and contributing to biodiversity conservation efforts.

References

1. Abbas, A., Hassan, S. S. U., Sharif, A., & Ahmed, S. (2020). Evaluation of the antioxidant and anti-inflammatory activities of solvent extracts of *Tricholepis chaetolepis* (Boiss) Rech. f. whole plant. *Natural product research*, *34*(4), 575-579.
2. Auti, S. G., Kambale, S. S., Gosavi, K. V. C., & Chandore, A. N. (2020). Floristic diversity of Anjaneri Hills, Maharashtra, India. *Journal of Threatened Taxa*, *12*(10), 16295-16313.
3. Bhale, P., Bhatti, I., & Mayes, R. (2017). Sanjay Gandhi National Park (SGNP) A Concise Report. *Self-published via ResearchGate*.
4. Bhoite, S. H., Sutar, S. R., Chavan, J. J., & Deshpande, S. M. (2025). Checklist of floristic diversity of Mahadare Conservation Reserve, Satara, Maharashtra, India. *Journal of Threatened Taxa*, *17*(10), 27688-27704.
5. Chavan, K. R., Mohale, D. S., & Chandewar, A. V. (2024). Pharmacological Evaluation of *Tricholepis glaberrima* for Antidiabetic potential in animal model. Research Journal of Pharmacology and Pharmacodynamics, 16(4), 283-290.
6. Chaudhary, L. B., & Pandey, A. K. (2001). Revision of Tricholepis DC.(Asteraceae) in India. Rheedea, 11(1), 1-27.
7. Datar, M. N. (2020). Pakshirajan Lakshminarasimhan: a plant taxonomist who loved plants and people alike. *Journal of Threatened Taxa*..
8. Dutta, S., Shete, C., Chakral, K., Rodrigues, H., Jadhav, V., & Chachad, D. (2025). CONSUMPTION TRENDS AND MARKET STUDY OF NON-CONVENTIONAL VEGETABLES IN AND AROUND MUMBAI: A CASE STUDY.
9. Jodh, R., Tawar, M., & Kachewar, A. (2022). Evaluation of Antidepressant activity of *Tricholepis glaberrima* DC using various Paradigms. *Research Journal of Pharmacy and Technology*, *15*(12), 5610-5616.
10. Male, A., & Chkvl, S. R. (2021). In-vitro evaluation of anti-diabetic activity of ethanolic extract of *Tricholepis glaberrima*. *Journal of Cardiovascular Disease Research*, *12*(5), 1184–1191.
11. Padashetty, S. A., & Mishra, S. H. (2007). Aphrodisiac studies of *Tricholepis glaberrima*. With supportive action from antioxidant enzymes. *Pharmaceutical Biology*, *45*(7), 580-586.

12. Pradeep, N., & Kousalya, L. (2021). Survey and studies in floristic diversity and phytosociology in Maniyoor Subramanya Swamy Temple, Maniyoor, Kannur District. International Journal for Research in Applied Science & Engineering Technology (IJRASET), 9(3), 994.
13. Rahangdale, S. S., & Rahangdale, S. R. (2017). Floristic diversity of Bhimashankar Wildlife Sanctuary, northern Western Ghats, Maharashtra, India. *Journal of Threatened Taxa*, *9*(8), 10493-10527.
14. Rana, K. G. (2018). *Status of Endemic and Threatened Angiosperms of Gujarat* (Doctoral dissertation, Maharaja Sayajirao University of Baroda (India)).
15. Samad, M. A., & Uddin, S. Z. (2021). Evaluation of Acute Toxicity of Hydro-Ethanolic Extract of *Tricholepis glaberrima*. *Journal of Drug Vigilance and Alternative Therapies*, *1*(1), 01-05.
16. Santhoshkumar, S., Nagarajan, N., Prema, R., Kowsaliya, R., Amjath Alikhan, F., & Aishwarya, P. (2018). Studies on the Arbuscular Mycorrhizal Fungal biodiversity in the plant species of Yellanahalli hills, Valley View of Nilgiris, Udhagamandalam, Tamil Nadu, India. *Kongunadu Research Journal*, *5*(2), 27-33.
17. GBIF.org (2026). Tricholepis amplexicaulis C.B. Clarke – occurrence data. https://www.gbif.org
18. iNaturalist (2026). Tricholepis amplexicaulis observations. https://www.inaturalist.org
19. Maharashtra Remote Sensing Applications Centre (MRSAC). (n.d.). Village map of Dapoli Taluka, Ratnagiri District [Map]. Government of Maharashtra.

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Original Article

Phenological Studies of Nothapodytes nimmoniana (J. Grah.) Mabberley in three Sacred Groves of Dapoli Tehsil, Maharashtra

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Manuscript ID:
JRD -2026-180432
ISSN: 2230-9578
Volume 18
Issue 4(XI)
Pp. 207-213
April - 2026
Submitted: 17 Mar. 2026
Revised: 30 Mar. 2026
Accepted: 10 Apr . 2026
Published:30 April2026

Abstract

Phenological study of seasonal biological events in relation to climatic factors plays a crucial role in understanding plant growth changing aspects and ecological responses. The present study investigates the phenological behaviour of Nothapodytes nimmoniana *(J. Grah.) Mabberley, an endangered medicinal tree renowned for its anticancer property and it is found in the sacred groves of Dapoli tehsil, Maharashtra. Due to its dwindling population, this species is largely restricted to these traditionally protected forest patches, where individual numbers remain critically low. Over a three-year field study conducted in the Kolbandre, Kudavale, and Sadavali sacred groves, key phenological events including leaf fall, leaf initiation, flowering, fruiting, and seed maturity were systematically monitored. The findings reveal a robust correlation between biological cycles and seasonal climatic shifts, specifically highlighting the monsoon's role in triggering leaf initiation. Notably, significant site-specific variations emerged: Kolbandre exhibited an earlier onset of phenophases, whereas Sadavali showed a delayed progression from initiation to seed dispersal. These disparities underscore the profound impact of localized microclimatic conditions on plant behaviour. Ultimately, the study reinforces the ecological value of sacred groves as vital conservation refuges and advocates for site-specific management strategies to ensure the survival of this endangered medicinal species.*

Keyword: *Phenological, Nothapodytes, endangered, sacred grove.*

Introduction

Phenology is study of seasonal biological events in relation to climatic factors, plays a critical role in understanding plant growth changing aspects and ecological adaptation. In the context of on-going climate change, phenological research has gained increasing importance for assessing shifts in the timing of vegetative and reproductive phases and their broader ecological implications (Igboabuchi et al., 2018). Such studies provide essential insights into how environmental variables regulate key processes such as leaf initiation, flowering, and fruiting (Singh & Kushwaha, 2005) According to the World Health Organization, cancer is the second leading cause of death worldwide, accounting for approximately 9.6 million deaths in 2018, with an estimated 1,392,179 cases in India by 2020 (Mathur, 2020). *Nothapodytes nimmoniana* is a rare medicinal plant known for its anti-cancer properties, as it contains camptothecin used in cancer treatment. Due to over exploitation, its natural population is declining rapidly (Padmanabha et al., 2006;, Shaanker et al., 2008). *Nothapodytes nimmoniana* (J. Grah.) Mabberley, belonging to the family Icacinaceae and formerly known as Mappia foetida (Wight) Miers, is a small canopy tree distributed in the Western Ghats of Maharashtra, India. The plant is locally known as Ghanera, Amruta, and Narkya, it is considered an endangered species in the region (Khan, 2015) and is rarely reported from a few sacred groves of Dapoli (Raskar, 2015; Ghalme, 2012). The species is an important natural source of camptothecin (CPT), which is widely used in the treatment of various cancers such as colon, breast, lung, head, and cervical cancers (Shaanker et al., 2008:, Stanley et al., 1991). Traditionally, its aqueous extract has been used for anticancer treatment (Ghalme & Devkule, 2013). In addition, it exhibits several pharmacological activities, including anti-HIV (Hombe et al., 2002), antibacterial, antioxidant, anti-inflammatory, antimalarial, and antifungal properties, and is also used in the treatment of anemia (Yan et al., 2003).

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How to cite this article:
Awale, S. M., & Ghalme, R. L. (2026). Phenological Studies of Nothapodytes nimmoniana (J. Grah.) Mabberley in three Sacred Groves of Dapoli Tehsil, Maharashtra. Journal of Research and Development, 18(4(XI)), 207–213.
https://doi.org/10.5281/zenodo.21127420

Quick Response Code:
Website:
https://jrdrvb.org/
DOI: 10.5281/zenodo.21127420
OPEN ACCESS

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Notably, in Dapoli tehsil, *Nothapodytes nimmoniana* occurs in limited numbers and is mainly confined to sacred groves that provide favorable microclimatic conditions for its survival. Despite its ecological and medicinal importance, there is limited scientific information on its life cycle and phenology. Hence, the present study documents its phenological patterns across three sacred groves by recording parameters such as plant height, branching, leaf phenology, bud initiation, flowering, fruiting, and seed maturation of year 2023-2025. The variations observed among sites highlight the strong influence of localized microclimates on plant behavior. The study underscores the importance of sacred groves as conservation refuges and supports the need for site-specific management strategies for this endangered species.

Material and Methods

This investigation was carried out on the endangered medicinal plant, *Nothapodytes nimmoniana* (J. Grah.) Mabberley in sacred groves of Dapoli tehsil of Ratnagiri district (MS). Dapoli is located at 17 o 45'11" E latitude, 73 o 11'17" N longitude, and an altitude of 250 m. Plants was identified by using local floras flora of the Presidency of Bombay and Flora of Maharashtra State Dicotyledons Vol-I (Cooke, 1958, Singh et al. 2001, Almeida, 1996).

Frequent field visits at 15 days intervals were conducted in the sacred groves of Sadavali, Kolbandre, and Kudavale to study phenology in year 2023-2025. During each visit, phonological events were systematically recorded. Such as plant height, branching, leaf shedding, leaf renewal, bud initiation, flowering, fruiting, and seed maturity (Sing and Sing 1992; Tomar, 2002) from the study area.

Study Sites-

Site 1: Sadavali,– N 17o42'31.9" E 73o13'18.4" -Taluka: Dapoli, Dist: Ratnagiri (MS.) Site 2: Kolbandre– N 17o 68'91.8" E 73o24'51.4" – Taluka: Dapoli, Dist: Ratnagiri (MS.) Site 3: Kudavale – N 17o 86'16.5" E 73o 24'30.5" - Taluka: Dapoli, Dist: Ratnagiri (MS.)

Phenograms were prepared based on the collected data, following the method described by Harper (1906).

Observations

The observations from Sadavali, Kolbandre, and Kudavale sacred groves showed similar growth patterns with slight variations. Plant height ranged from 6 to 8 m, stem diameter from 21 to 25 cm, and the number of main branches from 4 to 7, while lateral branches varied between 12 - 17 with relatively higher branching in Kudavale and Sadavali. All plants exhibited a dichotomous branching pattern. Leaf fall occurred during February to March, and trees remained leafless for approximately 1-2 months. The initiation of new branches was closely associated with the onset of monsoon, occurring from June to July. The study area experiences an average annual rainfall of 750 to 800 mm (Anonymous,2025), with 85 to 95% humidity and temperatures ranging from 18°C to 30°C, creating favorable microclimatic conditions. Leaf renewal phases showed a sequential trend, beginning earliest in Kolbandre, followed by Kudavale and finally Sadavali, where the process occurred relatively later.

Reproductive phenophases exhibited a consistent pattern across all study sites. Flowering commenced from early to late July, reached its peak between mid-July and early August, and gradually declined by late August to early September. The flowers were creamy yellow, foul-smelling, and arranged in terminal corymbose cymes, exhibiting three floral types - male, female, and bisexual. Fruiting initiated from early august to mid-August and continued until October–November. Subsequently, fruit ripening and seed maturation occurred during November–December, followed by seed dispersal from December to January, primarily through gravity.

Fig. 1. Site 1 – Sadavali

Fig. 2. Site 2 - Kolbandre

Fig. 3. Site 3 - Kudavale

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

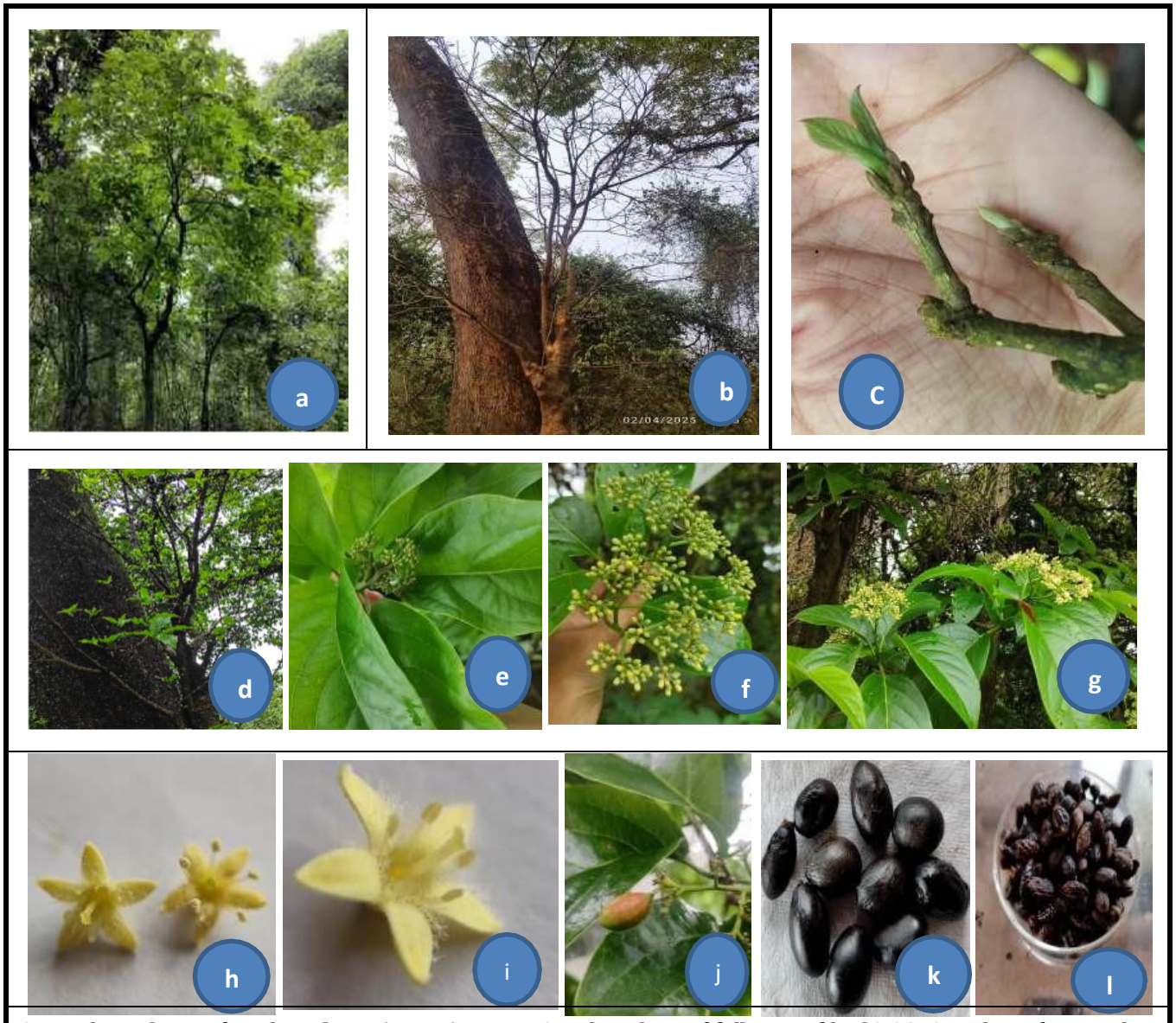


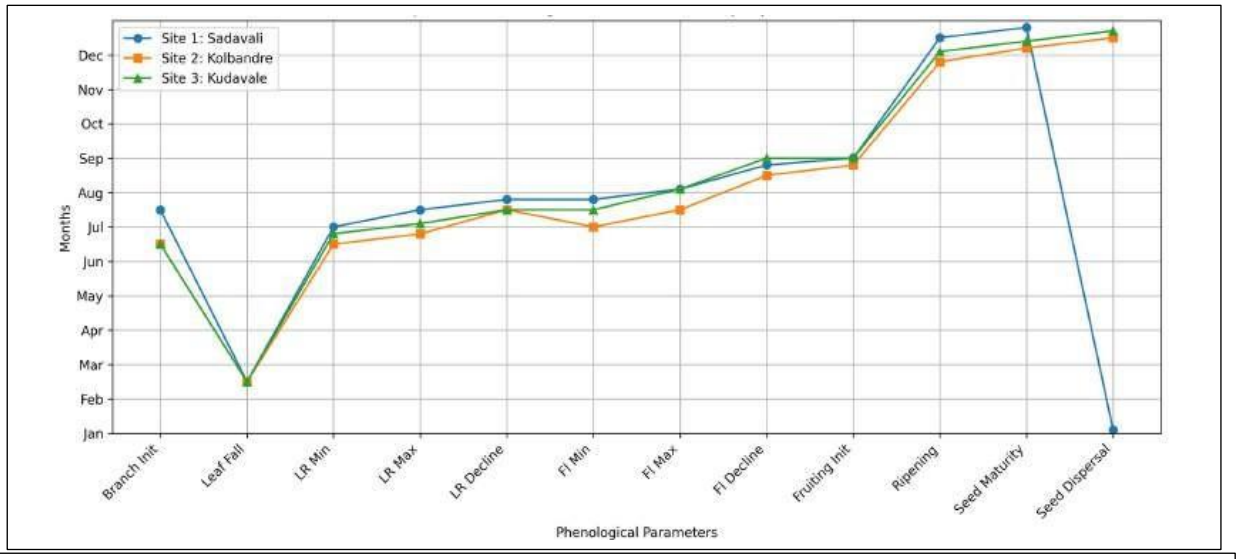
Fig. 4. Phenophases of *Nothapodytes nimmonina* a. Entire plant, b. Leaf fall, c. Leaf bud initiation, d. Leaf renewal, e. Flower bud initiation, f. Mature Flower bud, g. Flowering, h. left- Female flower, right- Male flower, i. Bisexual flower, j. Fruiting, k. Mature fruits, l. Seeds

Table No. 1. Phenological data of three Sites for *Nothapodytes nimmoniana*

Sr. No.	Parameter	Site 1. :Sadavali	Site 2. :Kolbandre	Site 3.:Kudavale
1.	Height of plant	6–7 m	6–7 m	7–8 m
2.	Diameter of stem	21-23 cm	21-24 cm	22-25 cm
3.	Number of main branches	4–7	4–6	4–7
4.	Number of lateral branches	12-16	12-15	14-17
5.	Time of initiation of new branches	Mid July – early August	June–July	June–July
6.	Leaf fall	February - March	February - March	February - March
7.	Leaf renewal - i. Minimum	Early July	Mid June	Late June

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

8.	ii. Maximum	Mid July	Late June - Early July	Early July
9.	iii Decline	Late July	Mid July	Mid July
10.	Flowering period - i Minimum	Late July	Early July	Mid July
11.	ii Maximum	early August	Mid July	Early August
12.	iii Decline	Late August	Mid August	Early September
13.	Fruiting / initiation of fruiting	Early September –November	Late August – October	Early September – November
14.	Ripening of fruits	Mid December	November end	Early December
15.	Seed maturity	December end	Early December	Mid December
16.	Seed dispersal	Early January	Mid December	Late December
17.	Mode of seed dispersal	Gravity dispersal	Gravity dispersal	Gravity dispersal



Branch Init – Branch Initiation, **LR Min**- Leaf Renewal Minimum, **LR Max**- Leaf Renewal maximum, **LR Decline**- Leaf Renewal decline, **FL Min** - Flower minimum, **FL Max** - Flower maximum, **FL Decline** - Flower decline, **Fruit init** - Fruit initiation

Fig. 5: Graph showing the comparative phenology of three sites

Table 2: Data analysis for phenogram

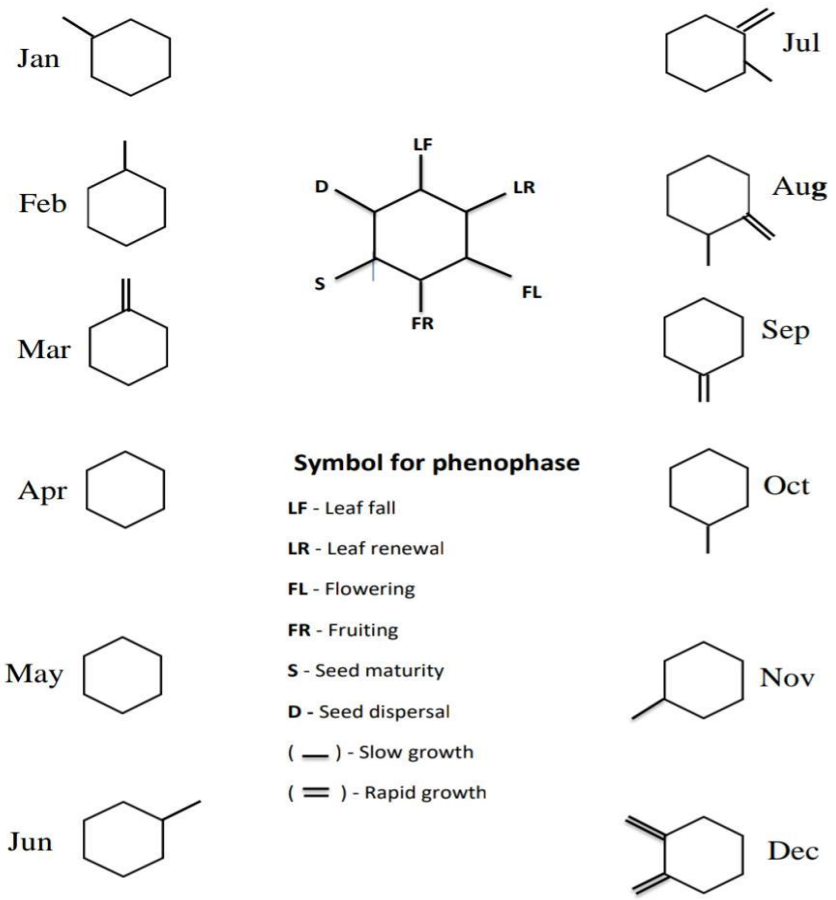
Phenophase	Month	Sadavali	Kolbandre	Kudavale	Average	
					Month	Growth
Leaf fall	Feb	✓	✓	✓	**FEB**	**l**
	Mar	✓	✓	✓	**MARCH**	**ll**
Leaf renewal (min)	Jun	–	✓ (Mid)	✓ (Late)	**JUN**	**l**
	Jul	✓ (Early)	✓ (Late)	✓ (Early)		
Leaf renewal (max)	Jun	–	✓	–	**JUL**	**ll**
	Jul	✓	✓	✓		
Leaf renewal (decline)	Jul	✓ (Late)	✓ (Mid)	✓ (Mid)		
Flowering (min)	Jul	✓ (Late)	✓ (Early)	✓ (Mid)	**JUL**	**l**
Flowering (max)	Jul	–	✓	–		
	Aug	✓	–	✓		

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

	Aug	✓	✓	✓	**AUG**	**II**
Flowering (decline)	Sep	–	–	✓		
Fruiting (min)	Jul	–	✓ (Late)	–	**AUG**	**I**
Fruiting (max)	Aug	✓	✓	–	**SEP**	**II**
	Sep	✓	✓	✓		
Fruiting (decline)	Oct	✓	✓	✓	**OCT**	**I**
	Nov	✓	–	✓		
Seed maturity	Dec	✓	✓	✓	**NOV**	**I**
					DEC	**II**
Seed dispersal	Dec	–	✓	✓	**DEC**	**II**
	Jan	✓	–	–	**JAN**	**I**

(I) - Slow growth
(II) - Rapid growth

Phenogram, Harper (1906).



Result and Discussion

The study of *Nothapodytes nimmoniana* across Sadavali, Kolbandre, and Kudavale revealed similar growth patterns with slight variations among sites. Plant height ranged from 6–8 m, stem diameter from 21 to 25 cm, and branching was comparatively higher in Kudavale and Sadavali. All individuals exhibited a dichotomous branching pattern, indicating a consistent growth form.

Leaf fall occurred during February–March, followed by leaf renewal during June–July, closely associated with the onset of the monsoon. The climatic conditions of the Dapoli region, characterized by moderate temperatures (18°C–30°C) and high humidity (85–95%) during the monsoon were found to be favorable for plant growth. Slight variations in the timing of leaf renewal among sites suggest the influence of local microclimatic conditions and monsoon onset.

Reproductive phases were well synchronized, with flowering occurring from July to september, fruiting from august to October–November, and seed dispersal from December to January, mainly through gravity. A slight temporal shift in phenophases was observed, with earlier events in Kolbandre and delayed ones in Sadavali, indicating the role of site-specific environmental conditions. Also, in phenological studies, Das P. K. (2020) reported that Nothapodytes nimmoniana flowers from March–June and fruits from August–December in Odisha, while in Dapoli, flowering occurs from July–September and fruiting from July–November. These differences suggest that environmental factors significantly influence the phenology of the species. A phenogram serves as an effective visual tool that enhances clarity and facilitates quick understanding, making it particularly useful for month-wise identification of phenophases.

On the basis of phenological observations and field visits, several factors may be responsible for the low population of the species. Flowering was reported predominantly during July–August, when this area receives high rainfall, may lead to significant flower drop and injury, thereby reducing pollination success and fruit formation (Rathcke & Lacey, 1985; Primack, 1985). After seed dispersal, the summer season begins, and seeds must endure a waiting period of 5–6 months until the onset of the monsoon to meet germination requirements. However, seed viability in *Nothapodytes nimmoniana* declines within two months, as reported by Malik and Laura (2015). Although some seeds germinate under favorable conditions, the seedlings often fail to survive beyond the rainy season due to an increase in temperature, a decrease in moisture, and environmental fluctuations. These factors collectively result in poor natural regeneration and contribute to the declining population of Nothapodytes nimmoniana.

Acknowledgement:
The authors express their sincere gratitude to the Maharashtra State Biodiversity Board, Nagpur, and the Dapoli Forest Office for granting permission to carry out research on *Nothapodytes nimmoniana* in three different sacred groves of Dapoli.

References

1. Almeida M. R., (1996). Flora of Maharashtra. Vol. **I:** Pp 235.
2. Anonymous-2025 India Meteorological department- Pune.
3. Cook T. Flora of the presidency of Bombay. Vol. **I**, Pp 239.
4. Das, P. K., Kamila, P. K., & Panda, P. C. (2020). *Nothapodytes nimmoniana* (J. Graham) Mabb. (Icacinaceae) – an addition to the forest trees of Odisha, India. *NeBIO*, 11**(2)**, 63–66.
5. Ghalme, R. L. (2012). Ethno-Medico-Botanical Studies on some sacred groves of dapoli Tehsil, District Ratnagiri (M.S.)', Thesis Submitted to University of Pune.
6. Ghalme, R. L., and Devkule S. S., (2013). Threatened and endemic Ethno-Medicinal Plant of sacred Groves of Dapoli Tehsil of Ratnagiri District, State Maharashtra (India) *International Journal of Multidisciplinary Research*. ll **7 (V):** 9-13.
7. Harper RL. (1906) A phytogeographical sketch of the Altamaha Grit Region of the Coastal Plain of Georgia. Annals of the New York Academy of Sciences 17:1-14.
8. Hombe, R. Gowda, H. C. Vasudeva (2002). Breeding types in *Nothapodytes nimmoniana* Graham.: An important medicinal tree. *CURRENT SCIENCE*, **83**, NO. 9, Pp 1177-1178.
9. Igboabuchi, N.A., bEchereme, C.B., Ekwealor, K.U. (2018) Phenology in Plants: Concepts and Uses Human Journals, Review Article, *Ijsrm.Human, Vol.* ***11*** *(1): 8-24.*
10. Khan, M. R. (2015). Effect of various treatments on germinability of *Nothapodytes nimmoniana* (j.grah.) mabberly or *Mappia foetida* (wight) Miers or *Nothapodytes foetida* (Wight) sleumer. *BioScience Research Bulletin-Biological Sciences*, Vol. **29,** Issue 1, Pp 51-55.
11. Malik, A., & Laura, J. S. (2015). Decline in seed viability under summer conditions. *BioScience Research Bulletin-Biological Sciences*, **29**, Issue 2, Pp 70-74.
12. Manju V. Sharma1,4, R. Uma Shaanker2 , R. Vasudeva3 and K. R. Shivanna1 (2010). Functional dioecy in *Nothapodytes nimmoniana*, a distylous species in the Western Ghats CURRENT SCIENCE, **99,** NO. 10, 1444-1449.
13. Mathur, P., (2020). "Cancer Statistics, 2020: Report From National Cancer Registry Programme, India." *JCO*

Global Oncology, no. **6**, 1269-1282. DOI: 10.1200/GO.20.00122.

14. Padmanabha, B. V., Chandrashekar, M., Ramesha, B. T., Hombe Gowda, H. C., Gunaga, R. P., Suhas, S. Vasudeva, R., Ganeshaiah, K. N. and Uma Shaanker, R. (2006). Patterns of accumulation of camptothecin, an anticancer alkaloid in *Nothapodytes nimmoniana* Graham., in the Western Ghats, India: Implications for identifying high-yielding sources of the alkaloid. *CURRENT SCIENCE*, **90**, NO. (1), Pp 95-100.
15. Primack, R. B. (1985). Patterns of flowering phenology in communities, populations, individuals, and single flowers. *Population Biology and Evolution*, 571–593.
16. Raskar, S. V. (2015). Survey of Sacred Groves of Ratnagiri District and their Floristic Diversity. Ph.D. thesis Submitted to Shivaji University, Kolhapur Pp 358- 390.
17. Rathcke, B., & Lacey, E. P. (1985). Phenological patterns of terrestrial plants. *Annual Review of Ecology and Systematics*, **16**, 179–214.
18. Shaanker R U, Ramesha B. T., Ravilkanth G., Gunaga R., Vasudeva R. and Caneshaiah K. N. (2008). Chemical Profiling of Nothapodytes nimmoniana for Camptothecin, an important anticancer alkaloid: Towards the Development of a sustainable production system. *Bioactive molecules and Medicinal Plant in Ramawat KG, merillo*n JM (eds). 10.1007/978-3-540-3_10 springer, Pp 197-213.
19. Sing J. S and Sing V. K., (1992). Phenology of seasonally dry tropical forest, *Current Science* **63**(11).
20. Singh, K.P. and Kushwaha, C.P. (2005b, later published in 2006). "Diversity of Flowering and Fruiting Phenology of Trees in a Tropical Deciduous Forest in India." Annals of Botany, **97**(2), 265-276.
21. Singh, P., Lakshina rasimshan, P., Karthikeyan, S. and Prasanna., 2000. Flora of Maharashtra state Dicotyledones. Vol. **II**, BSI, Calcutta, Pp 103, 517.
22. Stanley Sue, Diane C., Fujino, Li-tze Hu, and David T., Takeuchi (1991). Community Mental Health Services for Ethnic Minority Groups: A Test of the Cultural Responsiveness Hypothesis. *Journal of Consulting and Clinical Psychology*, **59**, No.4, 533-540.
23. Tomar Sanju Behen, (2002). Reproductive biology and phenology in *Pongamia glabra* (Fabaceae). A thesis submitted to Dr. B. R. Ambedkar University, Agra.
24. Yan, Xiu-Feng, Yang Wang, Tao Yu, Yu-Hong, Zhang and Shao-Jun Dai, (2003). Variation in camptothecin content in *Camptotheca acuminata* leaves. *Bot. Bull. Acad. Sin*., **44**, 99– 105.

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Original Article

Phenology of *Hydnocarpus pentandrus* (Buch.-Ham) Oken. An endemic and vulnerable plant from three sacred groves of Dapoli tehsil, Ratnagiri District (MS), India

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Manuscript ID:
JRD -2026-180433
ISSN: 2230-9578
Volume 18
Issue 4(XI)
Pp. 214-218
April - 2026
Submitted: 17 Mar. 2026
Revised: 30 Mar. 2026
Accepted: 10 Apr . 2026
Published:30 April2026

Abstract:

Phenology plays a crucial role in understanding the life cycle, ecological events of plant species, particularly those that are endemic and vulnerable. The present study focuses on Hydnocarpus pentandrus (Buch. -Ham.) Oken, an endemic and vulnerable tree species, investigated from three sacred groves of Dapoli tehsil, Ratnagiri District (Maharashtra), India. The main aim of this study was to compare phenological variations among three sacred groves in Dapoli tehsil for highlighting the conservation importance of sacred groves in protecting this endemic and vulnerable species. Phenological observations were made every morning in flowering days. Phonological events were recorded such as plant height, branching, leaf shedding, leaf renewal, bud initiation, flowering, fruiting, and seed maturity, seed dispersal and leaf dimensions. Hydnocarpus pentandrus showed notable variation across the three sites, with Sadavali's plant being tallest, Chandranagar's shortest, and Kolbandre's intermediate. Phenological events like leaf fall and flowering occurred earlier in Chandranagar, while peak flowering was in March and fruiting began in April–May at all sites. Fruit maturity varied, with earlier fruit fall in Chandranagar and delayed in Sadavali and Kolbandre, influenced by seasonal rainfall temperature and humidity. The identified flowering period (March) and fruiting pattern (April–July), important for pollination and seed development studies. Established clear timing of leafing, flowering, and fruiting stages for Hydnocarpus pentandrus in sacred groves of Chandranagar, Sadavali and Kolbandre in Dapoli.

Key words: *Endemic, Vulnerable, Phenology, Sacred Groves, H. pentandrus.*

1. Introduction:

In nature each species exhibits a specific time or season within a year when its seed sprout, seedling develop or show peak vegetative growth, leaves drop (in deciduous plant), new leaves flush, flowers bloom and then fruits forms. The investigation of all these recurring patterns of a species is termed as phenology (Barman *et al.*, 2014). Certain plants demonstrate effectiveness in curing specific ailments; these are called medicinal and aromatic plants (Patel, 2014). Review of literature indicates that our understanding on phenological behaviour of medicinal plants is very poor and there is almost no analytical data on medicinal plant specific to this area. In many of our forest region, basic information about medicinal plants is lacking, making biodiversity management challenging and ineffective. Considering the significance of phenological studies of plant species of a locality the present work was undertaken during three years 2023—2025 in three sacred groves of Dapoli tehsil viz. Chandranagar, Sadavali and Kolbandre.

Dapoli is located in Maharashtra, Ratnagiri District lies on the Konkan coast, with Arabian sea to west and Western Ghats to the east (approx. 17.6^{0}N, 73.1^{0}E). The predominant soil type is lateritic, average rainfall received 778.80mm per annum (Anonymous, 2023 to 2025). The average humidity in morning ranges from 89-93%. The average maximum temperature not goes beyond 30^{0}C and minimum temperature 16^{0}C. Sacred groves are rich with biodiversity are have ecological importance. They also plays an important role in protection of flora and fauna. Several rare and threatened species are found in sacred groves (Gawade *et al.*, 2018).

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How to cite this article:
Rane, A. M., & Ghalme, R. L. (2026). Phenology of Hydnocarpus pentandrus (Buch.-Ham) Oken. An endemic and vulnerable plant from three sacred groves of Dapoli tehsil, Ratnagiri District (MS), India. Journal of Research and Development, 18(4(XI)), 214–218.
https://doi.org/10.5281/zenodo.21127513

Quick Response Code:
Website:
https://jrdrvb.org/
DOI: 10.5281/zenodo.21127513
OPEN ACCESS

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Dapoli tehsil of Ratnagiri district contains total 218 sacred groves which covers about 247.86 hectors area. Out of 218 sacred groves 54 are undisturbed, 140 are partially disturbed and 24 are more disturbed by different reasons (Ghalme, 2012). Plant phenological research is highly significant because it gives us insight into how plant grow and also reveals how environmental conditions and influence flowering and fruit production.

The *Hydnocarpus pentandrus* is an important medicinal plant belongs to family Achariaceae and commonly known as 'Kadu Kavath'. A tree, reaching 12-15 m in height. The selected plant is endemic to South India and found in the Western Ghats in Maharashtra, Goa, Karnataka, Kerala and Tamil Nadu. It is Vulnerable species facing high risk of extinction in wild (Ved *et al*., 2015). Seeds are used on scabies, leprosy, obesity, skin disorders and wound healing. Oil extracted from seeds are known as 'Choulmogra' oil (Joshi and Harijan, 2014). The Choulmogra oil is useful in skin problems. Paste of seed is useful for treatment of eczema, white patches and infection (Zahid *et al*.,2013). In Karnataka, Kattunaikka tribe uses seed coat to make lamps, leaves and fruits are used as fish poison (Narayanan et al., 2011). The seeds contain Hydnocarpin shows antimicrobial, antifungal antileprotic, antitubercular, antidiebatic, activities (Bhat *et al*., 2020). The seed are having low natural germination percentage due to hard seed coat. While having such valuable medicinal properties and being Vulnerable species, it is essential to conserve this medicinal plant for that studying phenology of *Hydnocarpus pentandrus* (Buch. -Ham) Oken. is necessary. However, there is practically no such analytical information on this aspect of medicinal plants for this region. For many of our forest, we do not have basic information on phenological aspect therefore, an attempt has been made to study the phenology of selected medicinal plant from three different sacred groves of Dapoli.

2. Material and Methods:

2.1 Study area- The studies were carried out in 3 different sacred groves of Dapoli taluka viz. Chandranagar, Sadavali and Kolbandre.

Site no.	Site name	Geo co-ordinates
1	Chandranagar Tal. Dapoli, Dist. Ratnagiri (M.S.)	N 17°44'31.7" E 73°09'25.5"
2	Sadavali Tal. Dapoli, Dist. Ratnagiri (M.S.)	N 17°42'31.9" E 73°13'18.4"
3	Kolbandre Tal. Dapoli, Dist. Ratnagiri (M.S.)	N 17°41'21.8" E 73°14'43.4"

1.1 Karthikeyan, (2000). The collected plant specimens were preserved in the form of Herbarium (Jain and Rao, 1977). The prepared herbarium specimens were authenticated at Blatter Herbarium, St. Xavier's College (Autonomous), Mumbai.

1.2 Phenology- Frequently field visits to above locations were arranged to sacred groves for phonological studies. The data were collected at regular intervals of 15 days from the years from 2023 to 2025. Phenological observations were made every morning in flowering days. Phonological events were recorded such as plant height, branching, leaf shedding, leaf renewal, bud initiation, flowering, fruiting, and seed maturity, seed dispersal and leaf dimensions (Sing and Sing 1992; Tomar, 2002) from study area.

2. Observations- Digital photos showing habit of plants at different sacred groves:

Fig.- Hight of plant: Chandranagar- 10-12m Sadavali- 12-13m Kolbandre-10.12m

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Fig.- a- Leaf shedding, b-leaf renewal, c- Stem girth 4m

Table no.1 phenological observations of *Hydnocarpus pentandrus* at Chandranagar, Sadavali and Kolbandre sacred groves

Sr. No.	Characters	Observations		
		Chandranagar	Sadavali	Kolbandre
1	Height of plant	10-11m	12-13m	10-12m
2	Diameter of stem	0.73m	1.58m	1.56m
3	Number of main branches	6-8	6-7	7-8
4	Number of lateral branches	90-95	76-86	70-85
5	Time of initiation of new branches	July to September	July to September	July to September
6	Leaf fall	Middle week of December to last week of January	January To Last week of February	Last week of January to Last week of February
7	Leaf renewal - i. Minimum	February first week	Last week of February	Last week of February
	ii. Maximum	March	March	March
	iii. Decline	First week of April	Last week of April	Middle week of April
8	Flowering period - i. Minimum	February middle week	First of week March	Middle week of March
	ii. Maximum	March	March to April	March to First week of April
	iii. Decline	Last week of April	First week of May	April
9	Fruiting / initiation of fruiting	April to May	April to May	April to May
10	Ripening of fruits	Next year May to June	Next year May to June	Next year May to June
11	Seed maturity	July to August	July to August	July to August
12	Seed dispersal	August	August	August
13	Mode of seed dispersal	Gravity dispersal	Gravity dispersal	Gravity dispersal

Table no 2- Leaf Dimensions at Chandranagar, Sadavali, Kolbandre

Sr. No.	Parameter s	Observations								
		Chandranagar			Sadavali			kolbandre		
		Small	Medium	Large	Small	medium	large	Small	medium	large
1	Leaf length	11.06±1.29	16.1±0.62	19.42±0.85	10.74±1.05	15.92±0.95	20.96±1.80	11.64±1.56	16.15±0.96	19.25±0.17
2	Leaf width	4.17±0.64	5.62±0.63	6.72±0.50	4.25±0.95	6.20±1.28	8.11±0.68	4.41±0.68	5.86±0.74	6.73±0.50
3	Midrib length	10.13±1.15	15.34±0.63	18.53±0.85	9.62±1.02	14.81±1.01	19.54±1.65	10.84±1.45	15.63±0.53	18.28±0.80

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

4	Petiole length	0.74±0.23	0.8±0.24	0.9±0.14	1.12±0.12	1.11±0.24	1.43±0.48	0.8±0.14	0.85±0.13	0.85±0.15
5	Total no. of lateral veins	8.4±0.48	9.6±0.48	11.8±0.4	8.4±0.48	9.6±0.48	11.8±0.4	8.4±0.48	9.6±0.48	11.8±0.4
6	Leaf area	46.37±9.89	91.43±12.15	131.85±12.45	45.84±11.76	98.06±20.01	170.24±28.52	52.20±14.25	95.26±16.81	130.40±13.27

(± Standard Deviation)

3.2 Leaf Dimensions- *Hydnocarpus pentandrus* has typically simple leaves, alternate, and exstipulate. The leaf blade is generally elliptic to oblong-lanceolate, with an acute to acuminate apex and an entire margin. The leaf surface is glabrous with prominent lateral veins that arch towards the margin. The petiole is short. Leaf size can vary; small, medium and large leaves are described in table no.2

Small leaf-

The small size leaf area of Chandranagar, Sadavali and Kolbandre is 46.37±9.89, 45.84±11.76 and 52.20±14.25 respectively. Lenthe of petiole is 0.74±0.23, 1.12±0.12 and 0.8±0.14. the length of midrib 10.13±1.15, 9.62±1.02 and 10.84±1.45 respectively, having 8-10 pairs of lateral veins.

Medium leaf-

The medium size leaf area of Chandranagar, Sadavali and Kolbandre is 91.43±12.15, 98.06±20.01 and 95.26±16.81 respectively, Lenthe of petiole is 0.8±0.24, 1.11±0.24 and 0.85±0.13. the length of midrib 15.34±0.63, 14.81±1.01 and 15.63±0.53 respectively and having 10-12 pairs of lateral veins.

Large leaf-

The large size leaf area of Chandranagar, Sadavali and Kolbandre is 131.85±12.45, 170.24±28.52 and 130.40±13.27 respectively, Lenthe of petiole is 0.9±0.14, 1.43±0.48 and 0.85±0.15, the length of midrib 18.53±0.85, 19.54±1.65 and 18.28±0.80 respectively and having 10-12 pairs of lateral veins.

3. Result and discussion:

The comparative phenological observations of *Hydnocarpus pentandrus* from three different selected sites shows growth attributes and significant variance. The plant is Sadavali is tallest and the plant in Chandranagar is shorter while plant in Kolbandre is intermediate. The stem girth of plant in Sadavali and Kolbandre is nearly double than the diameter of Chandraganar's plant. Main branches are similar across three sites; lateral branches are higher number in Chandranagar's plant where Sadavali and Kolbandre's plants have lowest number.

Leaf fall start earlier in plant in Chandranagar than others two, leaf renewal peak in march in all three sites. Flowering starts earlier in Chandranagar, after 2-3 weeks Sadavali and Kolbandre' plant starts. The peak flowering season is march; fruit initiation starts in April to May in all three sites. Fruit maturity differs, in Chandranagar' plant fruit starts falling naturally in April, where in Sadavali and Kolbandre fruit falls naturally in June to July. Mature fruit stay on the plant till the next flowering season. Sometime fruits fall by first rain and get germinate naturally.

Acknowledgement:

The authors pay sincere gratitude to the Maharashtra State Biodiversity Board- Nagpur for granting us the permission to do research work on *Hydnocarpus pentandrus* (Buch. -Ham) Oken. a Vulnerable species from three different sacred groves of Dapoli.

References:

1. Anonymous-(2023-2025) India Meteorological department- Pune.
2. Barman, Nath, Deka, (2014). Phenology of some medicinal plant species of Goalpara District, Assam (India) *Sch. Acad. J. Biosci.;* **2**(2): 81-84
3. Bhat, Vighnesha, P., Rajesekharan, E.G., Shetty Raviraja, Nadulkeri Sadashiv, M. Ganpati. (2020). Effect of pre-sowing seed treatment on germination and seedling growth parameters of *Hydnocarpus pentandrus* (Buch. -Ham) Oken. *Electronic Journal Of plant breeding.* **11**:331-334.
4. Cook, T. (1958). The flora of the presidency of Bombay. **I**, page 60.
5. Gawade, S. G., Patil V.K., Patil Y.B., Sangare, S.M., Maihske V.D., Rane, A.D. and Narkhede, S.S., (2018). Plant Diversity in Sacred Groves of Dapoli: A Comparative Study of Four Life Forms. *International Journal of Current Microbiology and Applied Sciences.* **7** (12):2503-2520.
6. Ghalme, R. L., (2012). Ethno-medico-Botanical Studies on some sacred groves of Dapoli Tahsil, District Ratnagiri (M.S.) Thesis Submitted to University of Pune.

7. Jain, S. K. and Rao, R. R., 1977. A Handbook of Field and Herbarium Methods. Today and Tomorrow's Printers and Publishers, New Delhi: 22-72.
8. Joshi, Arun B., Harijan, Kiran C., (2014) Physicochemical and Phytochemical Investigation of the roots of *Hydnocarpus pendandrus* (Buch, -Ham.) Oken. *International Journal of pharmaceutical Science Review and Research.* **25**(1) 260-265.
9. Narayanan, Ratheesh, M. K., Mithunlal S., Sujanapal S., Anil Kumar N., Sivadasan M., Ahmed H. Alfarhan and Alatar A. A., (2011). Ethnobotanically important trees and their uses by Kattunaikka tribe in Wayanad Wildlife Sanctuary, Kerala, India. *Journal of Medicinal Plants Research.* **5**(4): 604-612.
10. Patel DK (2014) Herbaceous medicinal and aromatic plants diversity and introductions in herbal garden for ex-situ conservation. *Int J Herbal Med* 2 (**3**) :17—20.
11. Sing J. S and Sing V. K., (1992). Phenology of seasonally dry tropical forest, Current Science **63**(11): 685-689.
12. Sing, N. P., and Karthikeyan, (2000). Flora of Maharashtra State-Dicotyledones, BSI, **1**:77:104
13. Tomar Sanju Behen, (2002). Reproductive biology and phenology in *Pongamia glabra* (Fabaceae). Thesis submitted to Dr. B. R. Ambedkar University, Agra.
14. Ved, D., Saha, D., Ravikumar, K. & Haridasan, K. 2015. *Hydnocarpus pentandrus*: The IUCN Red List of Threatened Species.
15. Zahid, H., Bawazir, A. S., Naser, Rafiuddin, (2013) Plant based Native Therapy for skin problems in Aurangabad District (M.S.) *Journal of Pharmacognosy and Phytochemistry*. **2**(1): 241-244.

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Original Article

Subaerial Algae of India: A Comprehensive Review of Diversity, Taxonomy, Ecology, and Biogeographic Distribution

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Manuscript ID:
JRD -2026-180434
ISSN: 2230-9578
Volume 18
Issue 4(XI)
Pp. 219-231
April - 2026
Submitted: 17 Mar. 2026
Revised: 30 Mar. 2026
Accepted: 10 Apr . 2026
Published:30 April2026

Abstract

Subaerial algae (aerophytic algae) represent a specialized group of photosynthetic microorganisms adapted to terrestrial and semi terrestrial habitats where water availability is limited or highly variable. India, being a megadiverse nation with varied climatic zones, topographic features, and distinct biogeographic regions, harbors exceptional subaerial algal diversity. This comprehensive review synthesizes current knowledge on subaerial algal taxonomy, morphology, ecology, biogeography, and biodiversity patterns across India's major geographic regions including the Western Ghats, Eastern Himalayas, Peninsular India, and Northeast India. A critical examination of documented genera reveals approximately 125 genera and over 615 species of terrestrial algae distributed across multiple ecological niches including soil surfaces, rock faces, tree bark, and moist walls. The order Trentepohliales (Ulvophyceae) emerges as the dominant group of subaerial green algae, with genera such as Trentepohlia, Phycopeltis, and Cephaleuros showing particularly wide distribution and ecological significance. This review addresses current taxonomic challenges, documents discovered species, synthesizes ecological and physiological adaptations enabling survival in desiccating environments, and identifies critical research gaps essential for understanding India's subaerial algal biodiversity. Future research directions emphasizing molecular phylogenetic approaches, regional biodiversity surveys, and ecological function assessments are discussed in the context of climate change and anthropogenic disturbances affecting terrestrial ecosystems.

Keywords: *Subaerial Algae, Aerophytic Algae, India, Biogeography, Terrestrial Ecology, Biodiversity, Western Ghats, Himalayas*

Introduction

1.1 Definition and General Characteristics of Subaerial Algae

Subaerial algae, also known as aerophytic algae or terrestrial algae, comprise a diverse assemblage of photosynthetic microorganisms that occupy the interface between aquatic and terrestrial ecosystems. Unlike aquatic algae that maintain continuous access to water, subaerial algae exist in habitats where water availability fluctuates dramatically, often experiencing extended periods of desiccation interspersed with brief episodes of moisture availability (Bischoff & Bold, 1963). These microorganisms obtain their water predominantly from atmospheric moisture rather than from surface water bodies, representing a remarkable physiological and ecological departure from their aquatic counterparts (Friedmann, 1961). The definition of subaerial habitats encompasses a spectrum of moist terrestrial environments including: (1) biological soil crusts forming on exposed soil surfaces, (2) exposed rock faces and boulders subject to water seepage and atmospheric moisture condensation, (3) the phloem and bark surfaces of trees where consistent moisture is maintained through dew formation and periodic precipitation, (4) the ventral surfaces of bryophytes and lichens, (5) moist walls and artificial structures in areas with high atmospheric humidity, and (6) cave ecosystems characterized by high humidity and minimal light penetration (Büdel et al., 2009). These habitats collectively represent the most challenging terrestrial environments for photosynthetic organisms, demanding exceptional biochemical and structural adaptations for survival.

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How to cite this article:
Koshti, O. A., & Magdum, A. B. (2026). Subaerial Algae of India: A Comprehensive Review of Diversity, Taxonomy, Ecology, and Biogeographic Distribution. Journal of Research and Development, 18(4(XI)), 219–231.
https://doi.org/10.5281/zenodo.21127656

Quick Response Code:
Website:
https://jrdrvb.org/
DOI: 10.5281/zenodo.21127656
OPEN ACCESS

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

1.2 Indian Subaerial Algal Biodiversity: Current Knowledge and Research Status

India, encompassing the Indian subcontinent spanning approximately 3.27 million square kilometers with extraordinary variation in elevation (from sea level to 8,848 meters), temperature regimes (from tropical to alpine), and precipitation (from 100 mm to 10,000 mm annually), represents a megadiverse nation. According to the Botanical Survey of India ENVIS Database (2023), India contains approximately 7,310 algal species belonging to 855 genera distributed across 10 classes, 95 orders, and 252 families. Within this exceptional algal diversity, information on subaerial algae remains disproportionately limited, with detailed surveys concentrated in specific biogeographic regions including Kerala in the Western Ghats, Meghalaya in Northeast India, Assam, West Bengal, Nilgiris in Tamil Nadu, and limited localities in the Himalayan region (Rao & Gupta, 1997).

Current estimates suggest that India harbors approximately 125 genera and 615 species of terrestrial algae, with additional unknown diversity awaiting documentation through systematic surveys (BSI ENVIS, 2023). However, these figures require substantial upward revision considering that comprehensive regional surveys remain lacking for vast areas of India, and many regions remain virtually unstudied from the perspective of subaerial algal diversity. The present review synthesizes current knowledge on Indian subaerial algal diversity, documents recognized genera with their geographic distributions, summarizes ecological patterns, and identifies critical knowledge gaps essential for understanding and conserving this essential but overlooked biodiversity component.

2. Taxonomic Overview of Subaerial Algae from India

2.1 Systematics and Classification Framework

The classification of subaerial algae reflects broader phylogenetic relationships within algae, with subaerial adaptation representing an ecological category rather than a single monophyletic lineage. Subaerial algae are distributed across multiple algal classes including Chlorophyceae (green algae), Cyanophyceae (cyanobacteria), Bacillariophyceae (diatoms), Xanthophyceae, Cryptophyceae, and in some cases Euglenophyceae and Rhodophyceae (Rao & Gupta, 1997). However, in terms of species richness and ecological dominance in subaerial habitats across India, the division Chlorophyta (particularly the orders Trentepohliales, Chlorococcales, and Chaetophorales) and Cyanobacteria represent the principal components of subaerial algal communities.

According to Rindi and Guiry (2010), the order Trentepohliales (Ulvophyceae, Chlorophyta), historically recognized since the eighteenth century as the archetypical subaerial green algae, represents the most derived and specialized green algal lineage specifically adapted to terrestrial environments. The order encompasses approximately 6-8 recognized families, though taxonomic revision continues. As demonstrated by Leliaert et al. (2012), molecular phylogenetic studies have progressively refined understanding of family level relationships within Trentepohliales, revealing that some morphologically similar genera occupy distinct phylogenetic positions, necessitating ongoing taxonomic refinement.

2.2 Major Genera of Subaerial Algae Documented from India

2.2.1 Order Trentepohliales (Ulvophyceae)

Genus *Trentepohlia* Martius (Etymology: From the name of botanist Trentepohl; "olia" = resembling)

Trentepohlia represents the most widely distributed and ecologically dominant genus of subaerial algae both globally and within India. According to Rindi et al. (2006), the genus is characterized by morphologically distinctive filamentous thalli comprising branched filaments with thick walled cells densely packed with chloroplasts, frequently obscured by abundant orange, red, or yellow carotenoid pigments, particularly in older cells. This characteristic coloration appears to derive from accumulation of β-carotene and xanthophyll pigments, imparting the distinctive orange to reddish coloration to tree bark, rocks, and soil surfaces where *Trentepohlia* thrives.

Key Morphological Features: Filaments distinctly branched, with cells typically containing multiple parietal chloroplasts, cell walls thick and sometimes appearing lamellate, storage product β-1,3-glucans rather than starch, reproduction through akinetes and zoospores (when moisture-stressed zoospores retain flagella within distinctive sporangia), sexual reproduction through oogamous processes (Tippery et al., 2014).

Distribution in India: *Trentepohlia* species exhibit near ubiquitous distribution across India's biogeographic regions. Jose and Chowdary (1980) and Samad and Adhikary (2008) documented species including *Trentepohlia thevalliensis*, *T. abietina*, *T. torulosa*, *T. sundarbanensis* (recently described as new to science), *T. rigidula*, *T. umbrina*, and likely numerous undocumented species. The species *T. thevalliensis*, initially described from the Thevallis locality in India, appears restricted to the Western Ghats, whereas *T. abietina* and *T. torulosa* demonstrate broader continental distribution. *T. umbrina*, a widely distributed species from temperate regions, has been collected from Himalayan localities. Meghalaya in Northeast India emerges as a particularly rich locality for *Trentepohlia* diversity, with four distinct species identified from sacred groves and forest habitats, likely reflecting the region's consistently high humidity and protected forest environments.

Ecological Distribution: *Trentepohlia* in India exhibits pronounced ecological dominance in the bark of woody trees in high humidity regions, particularly common on *Artocarpus*, *Cinnamomum*, and other species of wet tropical forests. The yellow orange coloration imparted by *Trentepohlia* colonization of tree bark constitutes a conspicuous feature of moist tropical forests throughout the Western Ghats and Northeast India. According to Sharma and Mishra (2022), in

Meghalaya and Assam, *Trentepohlia* growth on tree bark responds strongly to relative humidity, with growth optimization occurring at 98% relative humidity, and complete growth cessation below 75% relative humidity, explaining the genus' restriction to high humidity forest habitats.

Recent Notable Findings: According to Binoy et al. (2024), the discovery of *Trentepohlia annulata* (a European species) as the causative agent of the spectacular "blood rain" phenomenon in Kerala in 2011, where atmospheric transport of *Trentepohlia* cells from tropical forests resulted in reddish precipitation over extensive geographic regions, demonstrated the potential for atmospheric dispersal of these unicellular propagules and suggested undocumented ecological roles for subaerial algae in atmospheric processes.

Genus *Phycopeltis* Kützing (Etymology: From Greek "phycos" = algae, "peltis" = shield, referring to the shield-like thallus architecture)

According to Rindi (2007), *Phycopeltis*, comprising approximately 10-12 recognized species, represents a morphologically distinctive genus within Trentepohliales characterized by formation of pseudo parenchymatous crustose thalli with compacted cells arranged in a definite layer, resembling a lichen thallus in overall morphology. The cells of *Phycopeltis* appear completely obscured by dense chloroplasts and carotenoid pigments, imparting a dark olive to brownish coloration distinguishing *Phycopeltis* from the characteristic orange *Trentepohlia*.

Key Morphological Features: Following Tippery et al. (2012), the thallus is crustose, pseudo parenchymatous with cells tightly packed in regular layers, with apical cell meristematic, cells numerous and irregular in arrangement, cell walls thick, and pigmentation dense rendering internal cellular structures difficult to discern. Sexual reproduction through oogonium and antheridia resembles that of *Trentepohlia*, whereas asexual propagation occurs through zoospores.

Distribution in India: *Phycopeltis* species remain less extensively documented in India than *Trentepohlia*, though the genus undoubtedly occurs throughout Indian tropical rainforests. Available literature reports *Phycopeltis arundinacea* as occurring in southwestern regions, particularly in Kerala's Western Ghats, where it colonizes moist rock faces and cave ecosystems. The genus appears morphologically similar in some cases to *Stomatochroon* and other crustose subaerial genera, potentially resulting in taxonomic confusion and underestimation of *Phycopeltis* distribution. Deepa et al. (2025) documented the recent discovery of a pseudo parenchymatous compact thallus similar to *Phycopeltis* from Southwestern Ghats, though identified as belonging to an undescribed or misidentified taxon during the documented study period, suggesting substantial undocumented diversity awaiting systematic investigation.

Ecological Significance: *Phycopeltis*, particularly *Phycopeltis arundinacea*, appears restricted to high humidity tropical environments, especially on wet rock faces, shaded overhanging surfaces, and entrance regions of limestone caves. The crustose morphology provides efficient substrate adherence and potentially enhances resistance to mechanical disturbance compared to the loosely branched *Trentepohlia*.

Genus *Cephaleuros* Kunze in Fries (Etymology: From Greek "cephale" = head, "leucos" = white, referring to the capitose reproductive structures)

According to Bourne et al. (2000), *Cephaleuros* represents a morphologically variable genus within *Trentepohlia*les that includes the only known parasitic members of *Trentepohlia*les, causative agents of algal leaf spot disease affecting numerous economically important crop species and wild plants. The genus comprises approximately 8-10 recognized species exhibiting considerable morphological variation ranging from filamentous to pseudo parenchymatous forms.

Key Morphological Features: Filaments often exhibit heterotrichous organization comprising prostrate and erect components, with pigmentation orange to reddish, cells with thick walls, and distinctive capitose reproductive structures (sporangia and antheridia clustered at the filament apex) (Nelson, 2008). The oogonium and antheridia are similar to *Trentepohlia* though exhibiting greater morphological variation. The genus exhibits exceptional morphological plasticity such that single species may display multiple morphological forms depending upon host species and environmental conditions, complicating taxonomic delineation.

Distribution and Host Range in India: *Cephaleuros* represents a geographically ubiquitous genus in India, with documented occurrences throughout the Western Ghats, Himalayan regions, and throughout mainland India wherever suitable host plants and climatic conditions coincide. Singh and Thakur (2016) demonstrated that the genus has emerged as a significant phytopathogen in Indian agriculture, particularly affecting tea plantations (*Camellia sinensis*) in the Nilgiris and other southern hill stations, where algal leaf spot represents a substantial economic concern. Additional documented host plants include mango (*Mangifera indica*), coconut (*Cocos nucifera*), *Artocarpus* species, and numerous other woody plants. Agricultural surveys in tea-growing regions of South India consistently identify Cephaleuros species, though often in association with other biotic factors influencing disease severity.

Ecological Behavior and Parasitism: Unlike most subaerial algae that establish relatively benign relationships with substrate surfaces, *Cephaleuros* species actively parasitize living leaf tissue, establishing itself within host leaf parenchyma and causing characteristic rust colored spots. According to Yamamoto et al. (1998), the mechanisms enabling parasitism likely involve enzymatic dissolution of host cell walls or exploitation of wound sites, though specific biochemical mechanisms remain poorly understood. The disease results in reduced photosynthetic capacity and potentially substantial yield losses in susceptible crop cultivars.

Journal of Research and Development
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Genus *Stomatochroon* Ehrenberg ex Kützing (Etymology: From Greek "stoma" = mouth/opening, "chroon" = color, referring to aperture-like openings in the cell wall)

Stomatochroon, historically a genus of some taxonomic confusion, represents a crustose form of subaerial green alga characterized by development of distinctive cell wall apertures or pores. According to Rindi and López-Bautista (2010), recent phylogenetic work has clarified the systematic position and distribution of authentic *Stomatochroon* species, though considerable uncertainty remains regarding species boundaries and geographic distributions.

Distribution in India: *Stomatochroon* remains poorly documented in India, with limited reports from cave ecosystems and rock faces in high-humidity regions. The crustose, flattened morphology renders field observation difficult without microscopic examination, potentially explaining apparent rarity, which likely reflects inadequate survey effort rather than genuine scarcity. Recent investigations in Western Ghats limestone cave regions have recovered morphologically consistent material, though definitive species identification remains pending molecular phylogenetic confirmation.

2.2.2 Genus *Oedocladium* Stokes ex Kützing (Etymology: From Greek "oedos" = swelling, "cladium" = branch, referring to swollen branch termini)

Following Christensen (1962), *Oedocladium* represents a dioecious terrestrial green algal genus within the order Chaetophorales, characterized by development of branched filaments with specialized reproductive structures and advanced sexual morphology including distinctive operculum and oval oogonium. The genus remained largely tropical and subtropical in documented distribution, with primary occurrences in moist tropical forests.

Recent Discovery - *Oedocladium sahyadricum* sp. nov.:

In 2024, Jiji et al. documented the discovery of *Oedocladium sahyadricum* from Kumbhavurutty forests in Kollam District, Western Ghats, Kerala, representing a significant finding for terrestrial algal taxonomy within India. The new species, as documented by Jiji et al. (2024), exhibits morphological characteristics consistent with the genus including dioecious reproduction, advanced operculum development, and oval oogonium with oospore formation, and was identified during surveys of forest microhabitats in the unique climatic and edaphic conditions of the Western Ghats region.

Key Features of *Oedocladium sahyadricum*:

Filaments branched, densely aggregated, Dioecious reproduction enabling sexual combination among compatible thalli, Distinctive operculum providing protective covering of reproductive structures, Oogonium morphology oval, containing mature oospores. Distribution documented only from Western Ghats localities thus far. Habitat: moist shaded forest floor and decaying organic matter.

The discovery of *O. sahyadricum* represents the expanding recognition of unappreciated subaerial diversity within India's biodiversity hotspots, particularly the Western Ghats, which has historically received limited attention from algologists specializing in terrestrial microalgae. The species exemplifies the emerging pattern of endemic or regionally restricted subaerial algal taxa occupying localized habitats within biogeographic refugia.

2.2.3 Other Terrestrial Chlorophyceae

Genus *Chlorella* Beijerinck (Etymology: From Greek "chloros" = green, with diminutive suffix)

Chlorella encompasses unicellular, non motile green algae widely distributed in aquatic and terrestrial habitats. Bhaskar and Rao (1980) documented that while primarily recognized as freshwater algae, *Chlorella* species extensively colonize soil surfaces throughout India, particularly in agricultural soils, disturbed habitats, and biological soil crust communities. The ecological role of soil dwelling *Chlorella* species in India remains poorly characterized despite their ubiquitous occurrence.

Genus *Desmococcus* Bischoff (Etymology: From Greek "desmos" = bond, "coccus" = berry, referring to colonial organization)

Desmococcus species comprise some of the most abundant and ecologically widespread soil algae in terrestrial environments globally, and in India specifically. According to Bhakta et al. (2014), sacred grove surveys in Meghalaya documented *Desmococcus olivaceus* as one of the dominant subaerial algal taxa, with highest abundance in closed undisturbed sacred groves compared to disturbed forest and plantation habitats. The genus exhibits exceptional desiccation tolerance and represents a primary colonizer of initially unvegetated soil surfaces undergoing primary succession.

Distribution in India: *Desmococcus olivaceus* and related species occur ubiquitously throughout Indian soil environments from coastal regions through Himalayan elevations, representing among the most widespread subaerial taxa. Differential abundance among habitat types (closed forest > plantation > open disturbed areas) suggests substantial ecological sensitivity to anthropogenic disturbance and forest fragmentation.

Genus *Scenedesmus* Meyen (Etymology: From Greek "scene" = stage, "desmus" = bundle)

Scenedesmus, a cosmopolitan genus of unicellular to colonial green algae, occurs extensively in Indian terrestrial environments, particularly in agricultural soils and disturbed habitats. Seasonal surveys demonstrate differential dominance of *Scenedesmus* in monsoon seasons and post monsoon periods when soil moisture levels remain elevated.

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Genus *Ankistrodesmus* Corda (Etymology: From Greek "ankis" = curved, with diminutive referring to small curved forms)

Ankistrodesmus species, characterized by distinctive spindle shaped cell morphology, contribute to subaerial algal communities throughout Indian habitats, with particular prominence in calcareous soils and neutral to slightly alkaline terrestrial environments.

2.2.4 *Cyanobacterial* (Cyanophycean) Subaerial Taxa

Genus *Oscillatoria* Vaucher ex Gomont (Etymology: From Latin "oscillare" = to swing, referring to pendulum-like oscillatory movement characteristic of living filaments)

Oscillatoria and related oscillatoriacean cyanobacteria establish prominent components of subaerial cyanobacterial communities throughout India. These non heterocystous cyanobacteria proliferate particularly during wet seasons on moist soil surfaces, decaying vegetation, and near shore zones of water bodies.

Distribution and Seasonality: According to Adhikary (1996), in Meghalaya, *Oscillatoria* species demonstrate pronounced seasonality, appearing prolifically during monsoon months on moist forest floors and organic substrates, declining dramatically during dry seasons. Similar patterns documented from Assam and other Northeast Indian localities suggest consistent responses to regional precipitation patterns.

Genus *Phormidium* Kützing ex Gomont (Etymology: From Greek "phormos" = basket, referring to sheath structure)

Phormidium, comprising sheath enclosed filamentous non heterocystous cyanobacteria, represents a ubiquitous component of subaerial cyanobacterial communities. The presence of mucilaginous sheaths provides desiccation protection and substrate adherence. *Phormidium ambiguum* and related species appear widely distributed across Indian soil and rock surfaces.

Genus *Gloeocapsa* Kützing ex Nageli (Etymology: From Greek "gloios" = sticky, "capsa" = envelope, referring to gelatinous envelope)

Gloeocapsa represents spherical unicellular cyanobacteria enclosed within distinctive thick, lamellate gelatinous envelopes conferring exceptional desiccation resistance. Following Komarek and Anagnostidis (2005), *Gloeocapsa* species form conspicuous dark pigmented communities on exposed rock faces throughout Indian mountain regions and contribute to primary succession on newly weathered rock surfaces.

Genus *Chroococcus* Nägeli (Etymology: From Greek "chroo" = color, "coccus" = grain)

According to Komarek and Anagnostidis (2005), *Chroococcus* species comprise pigmented unicellular cyanobacteria forming colonial aggregates enclosed in mucilaginous matrices. The genus establishes particular ecological prominence in biological soil crust communities. Species such as *Chroococcus pallidus* and *Chroococcus turgidus* occur throughout Indian terrestrial environments.

Genus *Egbenema* Akagha et al. (Etymology: Named after notable phycologist; represents recently established genus)

Egbenema represents a newly established genus of cyanobacteria characterized by specific morphological and genetic characteristics distinguishing it from previously recognized genera. Recent molecular phylogenetic work has clarified the polyphyletic nature of previously undifferentiated cyanobacterial taxa, leading to recognition of *Egbenema* as a distinct evolutionary lineage.

***Egbenema bharatensis* sp. nov. (2025):**

In 2025, Bhagat et al. documented the discovery of *Egbenema bharatensis* from the Northern Western Ghats, representing a novel species of heterocystous cyanobacteria distinctly adapted to terrestrial and cave ecosystems. The species characterization incorporated polyphasic methodology combining light microscopy, 16S rRNA gene sequencing, and ITS region phylogenetic analysis, confirming distinct genetic signatures and morphological characteristics supporting establishment as a separate species.

Key Characteristics:

Heterocystous (nitrogen-fixing) cyanobacterium, Filamentous organization with distinctive cell morphology, 16S rRNA gene sequence distinction from related species, ITS region secondary structure variations. Endemic to Northern Western Ghats. Terrestrial/cave habitat association. Potential importance in nitrogen limited terrestrial ecosystems

The discovery of *E. bharatensis* exemplifies the remarkable cryptic diversity of cyanobacteria occupying specialized terrestrial niches within India's biodiversity hotspots. The capacity for heterocystous nitrogen fixation suggests important ecological functions in facilitating establishment of plant communities in nitrogen-limited soil environments.

Genus *Nostoc* Vaucher ex Bornet & Flahault (Etymology: Derived from Philippus Nostoc, a 16th-century botanist)

Nostoc species, comprising heterocystous cyanobacteria with distinctive beaded filament appearance resulting from scattered heterocyst distributions, establish ecological prominence in terrestrial cyanobacterial communities throughout India. *Nostoc* species frequently enter into symbiotic associations with bryophytes and lichens and maintain significant ecological roles in nutrient cycling.

Genus *Dulcicalothrix* Tanaka et al. (Etymology: From Latin "dulcis" = fresh, "Calothrix" = related genus name)

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Dulcicalothrix, a recently characterized cyanobacterial genus, has emerged as an important component of freshwater and subaerial cyanobacterial communities. Two new species, *Dulcicalothrix adhikaryi* sp. nov. and *D. iyengarii* sp. nov., were formally described from India in 2024, expanding recognition of the genus' distribution within Indian ecosystems and suggesting considerable undocumented diversity awaiting characterization (Saraf et al. 2024).

2.2.5 Diatoms (Bacillariophyceae) in Subaerial Habitats

Diatoms, characterized by distinctive silica based cell walls (frustules) exhibiting elaborate geometric ornamentation, occupy subaerial habitats throughout India with particular prominence on moist soil surfaces, within soil profiles, and on rock faces subjected to water seepage. Documented genera include *Navicula, Pinnularia, Nitzschia, Synedra, Cymbella, Amphora, Achnanthes, Craticula, Gyrosigma, Sellaphora, Diploneis, Caloneis, Gomphonema*, and numerous others, representing the most diverse group in terms of species richness within diatom communities Deepa et al. (2025).

Ecological Distribution: Diatom communities in soil and rock habitats demonstrate strong relationships with substrate characteristics, pH, and moisture availability. Acidic to neutral substrates particularly in Western Ghats support diverse diatom communities, whereas alkaline terrestrial environments favor differential diatom assemblages. The consistent occurrence of specific diatom species in particular habitat types suggests potential utility as ecological indicators of terrestrial substrate conditions.

2.3 Geographic Distribution and Endemism Patterns

2.3.1 Western Ghats - Sahyadri Biodiversity Hotspot

The Western Ghats (also designated Sahyadri Mountains), extending approximately 1,600 kilometers along the western margin of peninsular India from Karnataka through Tamil Nadu, represent one of the world's 36 recognized biodiversity hotspots, exhibiting exceptional species endemism and ecosystem complexity Myers et al. (2000). The region maintains distinctive characteristics uniquely favorable for subaerial algal diversity, including: (1) elevated topography creating numerous microhabitats and refugia, (2) high annual precipitation (3,000-10,000 mm in certain localities), (3) perennial streamflow and seepage from extensive exposed rock faces, (4) diverse forest types from evergreen rainforest through montane cloud forests, and (5) UNESCO World Heritage designation recognizing exceptional biodiversity value.

Subaerial Algal Diversity in Western Ghats:

The Western Ghats have emerged through recent investigations as particularly rich regions for subaerial algal discovery. Recent intensive investigations have documented multiple novel taxa including *Oedocladium sahyadricum* from Kerala, *Egbenema bharatensis* from Northern Western Ghats, and numerous *Trentepohlia* species from multiple localities. The southwestern region (Kerala portion) of the Western Ghats demonstrates particularly high endemism of epiphyllous Trentepohliales, with species exhibiting restricted geographic distributions and habitat preferences Binoy et al (2019). Survey efforts indicate that comprehensive biodiversity assessment remains incomplete, with many localities in the Western Ghats remaining unstudied from perspective of subaerial algal communities.

Waterfalls and Hydrological Features:

Western Ghats waterfalls provide exceptional habitats for subaerial algal communities due to persistent water spray, elevated humidity, and diverse rock substrates. A comprehensive survey documented 117 algal species from nine Western Ghats waterfalls in Tamil Nadu, including diverse cyanobacterial, chlorophycean, bacillariophycean, euglenophycean, and rhodophycean taxa Deepa & Sharma (2024). The combination of flowing water, abundant light, constant humidity, and diverse mineral substrates creates environmental conditions supporting exceptional algal diversity. Specific waterfalls including Agasthiyar Falls, Kolli Hills, and Kodaikanal regions demonstrate particularly high algal species richness, suggesting designation of these localities as priorities for comprehensive taxonomic and ecological investigation.

Sacred Groves as Subaerial Algal Refugia:

Sacred groves (locally designated "panchavanas" or protected forest sanctuaries) distributed throughout the Western Ghats and other Indian regions represent important subaerial algal habitats. A study conducted in multiple sacred grove sites in Meghalaya and adjacent regions identified substantial subaerial algal diversity associated with protected forest ecosystems Bhakta, et al. (2014). The ecological comparison between closed undisturbed sacred groves, mixed plantation forests, and open disturbed habitats revealed that sacred groves harbored highest subaerial algal species diversity (85 taxa including 30 cyanobacteria and 55 algal species), with significant reduction in both species richness and community complexity in disturbed habitats. This pattern underscores the ecological significance of intact forest ecosystems in supporting subaerial algal communities and suggests conservation implications for terrestrial biodiversity protection.

2.3.2 Eastern and Northeastern Himalayan Regions

The Himalayan mountain system extending across northern India represents another major center of subaerial algal biodiversity, though systematic surveys remain limited primarily to accessible localities in Himachal Pradesh, Uttarakhand, and parts of Jammu & Kashmir. The region's exceptional elevation gradient (from 300 to 8,848 meters), corresponding variation in temperature regimes and precipitation, and presence of intact forest ecosystems create conditions supporting distinctive subaerial algal assemblages characteristic of temperate and alpine environments.

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Temperate *Trentepohlia* and Alpine Cyanobacteria:
Trentepohlia umbrina, a species widespread in temperate regions globally, has been documented from Himalayan localities, whereas the high altitude distribution of specific cyanobacterial taxa adapted to extreme Alpine conditions remains poorly characterized. Stream and waterfall surveys from Himalayan regions (West Bengal, Sikkim, Arunachal Pradesh, Nagaland, Mizoram) documented 214 algal species, with cyanobacteria (43 species) and chlorophytes (34 species) as dominant groups, suggesting that subaerial habitats in Himalayan streams likely support equally rich communities Bhakta et al. (2014).

***Sheathia rosemalayensis* and Related Discoveries:**
The recent discovery of *Sheathia rosemalayensis*, representing only the second authenticated *Sheathia* species documented from India (with prior documentation of *S. assamica* from Himalayan regions), demonstrates exceptional rarity of this genus in India despite apparent ecological prominence in specialized freshwater habitats. The distinction between *S. rosemalayensis* documented from Southern Western Ghats and the historically documented *S. assamica* from Himalayan regions suggests geographic differentiation in endemic *Sheathia* species, with important implications for biogeographic analysis of freshwater algal evolution Jayalakshmi & Jose (2025).

2.3.3 Northeast India and Meghalaya - Hotspot of Subaerial Diversity
Meghalaya (literally "abode of clouds"), encompassing 22,429 square kilometers in northeastern India, represents one of the world's wettest regions, with Cherrapunji receiving average annual precipitation exceeding 10,000 mm, generating atmospheric humidity levels approaching saturation throughout substantial portions of the year. These extraordinary climatic characteristics establish Meghalaya as potentially the richest center of subaerial algal diversity within India.

***Trentepohlia* Communities in Meghalaya:**
Comprehensive investigations of *Trentepohlia* growth responses to relative humidity demonstrate optimal growth at 98% relative humidity, with marked growth suppression at humidity levels below 75% Sharma & Mishra (2022). Field surveys in Meghalaya documented four distinct *Trentepohlia* species colonizing tree bark throughout protected forest habitats, imparting characteristic yellow orange coloration to woody substrates across the landscape. The regional distribution of *Trentepohlia* species in Meghalaya likely reflects fine scale humidity gradients and microhabitat heterogeneity, with distinct species occupying forest interior, forest edge, and more exposed localities experiencing greater desiccation stress.

Sacred Groves and Subaerial Algal Assemblages:
Meghalaya's system of sacred groves (locally "law kyntang" in Khasi language) represents particularly important subaerial habitats. Comparative biodiversity assessment across sacred groves, plantation forests, and disturbed open areas revealed sacred groves as biodiversity hotspots supporting 85 subaerial algal taxa, substantially exceeding diversity recorded from degraded habitats Bhakta et al. (2014). The contrast between protected sacred grove ecosystems and disturbed habitats demonstrates clear ecological dependencies of subaerial algal communities upon intact forest structure, microhabitat heterogeneity, and consistent moisture availability.

Northeastern Megaflora and Microalgal Endemism:
Recent investigations of Meghalaya cyanobacterial and algal diversity have recovered multiple novel taxa awaiting formal description, suggesting that the region harbors substantial cryptic diversity of subaerial microorganisms. Preliminary molecular phylogenetic work indicates that certain *Trentepohlia* populations in Meghalaya may constitute previously unrecognized species or subspecific variants showing genetic differentiation from populations in other Indian regions Sharma et al. (2022).

2.3.4 Peninsular India and Odisha
The Similipal Biosphere Reserve in Odisha has emerged through recent investigations as an important center of subaerial algal diversity, with documentation of 27 subaerial algal taxa from the reserve Mahanta et al. (2018). The biosphere reserve encompasses 2,129 square kilometers of diverse habitat types including sal (*Shorea robusta*) forests, mixed tropical deciduous forests, and associated scrublands, creating microhabitat heterogeneity favorable for subaerial algal communities. Similipal biosphere reserve demonstrates particular potential as a model system for subaerial algal biodiversity assessment and bioprospecting for biotechnological applications.

2.4 Checklist of Documented Subaerial Algal Genera from India
The following compilation synthesizes documented occurrence of subaerial and terrestrial algal genera from India based on published literature and recent survey findings. This checklist represents currently documented distribution and doubtless underestimates actual species diversity through omission of undocumented taxa occupying unsurveyed regions.

Chlorophyta (Green Algae)
Order Trentepohliales:
1. *Trentepohlia* Martius (8-12 species documented)
2. *Phycopeltis* Kützing (2-3 species documented)
3. *Cephaleuros* Kunze ex Fries (3-5 species documented)

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4. *Stomatochroon* Ehrenberg ex Kützing (1-2 species likely present)
5. *Leptosira* J.B. Petit (1 species likely present)
6. *Phytophila* Wallroth (distribution uncertain)

Order Chaetophorales:
7. *Oedocladium* Stokes ex Kützing (2-3 species including new *O. sahyadricum*)
8. Other chaetophoralean taxa (insufficient documentation)

Order Chlorococcales:
9. *Chlorella* Beijerinck (4-6 species in terrestrial habitats)
10. *Desmococcus* Bischoff (3-4 species documented)
11. *Scenedesmus* Meyen (5-8 species documented)
12. *Ankistrodesmus* Corda (2-3 species documented)
13. *Westella* de Wildeman (1 species documented)
14. *Pediastrum* Meyen (1-2 species in terrestrial contexts)
15. *Coelastrum* Nägeli (1-2 species documented)
16. *Chlorococcum* Frenzel (2-3 species documented)
17. *Tetraedron* Kützing (1-2 species documented)
18. *Crucigenia* Morren (1 species documented)

Order Zygnematales:
19. *Spirogyra* Link ex C.A. Agardh (primarily aquatic, rare terrestrial occurrence)
20. *Closterium* Nitzsch (rare terrestrial occurrence)
21. *Zygnema* C. Agardh (rare terrestrial occurrence)

Order Ulotrichales:
22. *Ulothrix* Kützing (1 species documented in subaerial contexts)
23. *Uronema* Lagerheim (1 species documented)

Cyanophyta (Cyanobacteria)

Order Oscillatoriales:
24. *Oscillatoria* Vaucher ex Gomont (4-6 species documented)
25. *Phormidium* Kützing ex Gomont (3-4 species documented)
26. *Lyngbya* C. Agardh ex Gomont (2-3 species documented)

Order Chroococcales:
27. *Gloeocapsa* Kützing ex Nageli (3-4 species documented)
28. *Chroococcus* Nägeli (2-3 species documented)
29. *Microcystis* Kützing ex Lemmermann (primarily aquatic, rare terrestrial)

Order Nostocales:
30. *Nostoc* Vaucher ex Bornet & Flahault (4-5 species documented)
31. *Dulcicalothrix* Tanaka et al. (2 species newly described from India)
32. *Egbenema* Akagha et al. (1 species newly described: E. bharatensis)
33. Other heterocystous taxa (limited documentation)

Bacillariophyta (Diatoms)

Diatom genera documented from subaerial habitats in India (partial list):
34. *Navicula* Bory de Saint-Vincent (10+ species)
35. *Pinnularia* Ehrenberg (5-8 species)
36. *Nitzschia* Hassall (5-8 species)
37. *Synedra* Ehrenberg (3-4 species)
38. *Cymbella* Kützing (2-3 species)
39. *Amphora* Ehrenberg ex Kützing (2-3 species)
40. *Achnanthes* Bory de Saint-Vincent (1-2 species)
41. *Craticula* Grunow (1-2 species)
42. *Gyrosigma* Hassall (1-2 species)
43. *Sellaphora* Mereschkowsky (1-2 species)
44. *Diploneis* Ehrenberg ex Cleve (1 species)
45. *Caloneis* Cleve (1 species)
46. *Gomphonema* Ehrenberg (2-3 species)
47. *Gramatophora* Ehrenberg (1 species)
48. *Subsilicea* Grunow (1 species)
49. *Cyclotella* (Kützing) Brébisson (primarily aquatic, rare terrestrial)
50. *Melosira* C. Agardh (primarily aquatic)

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ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

51. *Tabellaria* Ehrenberg (mountain/cool regions)
52. *Surirella* Turpin (1-2 species)

Summary Tabulation

Group	Estimated Genera	Estimated Species	Confidence Level
Trentepohliales (Green Algae)	6-8	15-25	High
Other Chlorophyceae	15-20	25-40	Moderate
Cyanobacteria	10-12	25-35	Moderate
Diatoms	15-20	30-50	Moderate
TOTAL	**46-60**	**95-150**	**Moderate**

Note: Documented genera likely represent only 40-50% of actual diversity given limited survey coverage of India's geographic regions and habitats. Estimates revised upward from conventional estimates (125 genera, 615 terrestrial species) to account for cryptic diversity and undocumented taxa.

3. Biogeographic Patterns and Phytogeographic Analysis

3.1 Distribution Patterns Across Indian Biogeographic Regions

Indian biogeographic classification recognizes 10 major biogeographic regions: Himalayan, Desert, Semi-arid, Western Ghats, Deccan Plateau, Gangetic Plain, Coromandel Coast, Lakshad weep and Coral Islands, and Andaman & Nicobar Islands. Subaerial algal distribution shows pronounced regional variation reflecting climatic and ecological gradients.

Himalayan Region - Temperate Subaerial Communities:

The Himalayan region encompasses elevation zones from foothills (500 m) through alpine environments (>5000 m), establishing diverse temperature and moisture gradients supporting heterogeneous subaerial algal communities. Documented surveys from accessible Himalayan water bodies identified diverse algal populations, though subaerial communities remain inadequately characterized Bhakta et al. (2014).

Gangetic Plain - Monsoonal Transitional Zone:

The Gangetic Plain experiences monsoonal precipitation with distinct wet and dry seasons, supporting seasonal subaerial algal communities exhibiting pronounced growth in monsoon months and relative dormancy during dry months. Soil algal communities in agricultural lands throughout the Gangetic Plain remain essentially unstudied from perspective of species composition and ecological function Chaudhary & Singh (2016).

Western Ghats - Tropical Rainforest Hotspot:

As previously detailed, the Western Ghats represent the richest documented center of subaerial algal diversity in India, reflecting combination of exceptional biodiversity, high precipitation, intact forest ecosystems, and ongoing research emphasis. The region exemplifies pattern of disproportionate biodiversity concentration in montane tropical rainforest regions.

Deccan Plateau - Semi-arid Transitional Zone:

The Deccan Plateau experience intermediate precipitation and more pronounced seasonal drought, supporting different subaerial algal communities compared to Western Ghats. Limited data available for subaerial algae of Deccan habitats, though presumed lower diversity reflects reduced moisture availability compared to Western Ghats Adhikary & Sinha (2001).

Northeast India - Secondary Diversity Hotspot:

Meghalaya and adjacent Northeast Indian states represent second major center of documented subaerial algal diversity, reflecting exceptionally high precipitation and intact forest ecosystems. The region warrants intensive biodiversity survey efforts given preliminary indications of substantial undocumented diversity.

4. Threats to Subaerial Algal Biodiversity

Primary Anthropogenic Threats:

1. Forest Fragmentation and Habitat Loss: Conversion of intact tropical and temperate forests to agricultural and developed lands eliminates subaerial habitat networks. Sacred groves face increasing encroachment and degradation in many regions, with loss of grove protection and microhabitat heterogeneity directly reducing subaerial algal diversity Bhakta et al (2014).

2. Forest Microhabitat Simplification: Even within protected forests, selective logging and reduced structural complexity diminish habitat heterogeneity available for subaerial algal communities. Loss of large old-growth trees reduces epiphytic habitat diversity. Removal of deadwood reduces soil cover and substrate heterogeneity.

3. Air Pollution: Atmospheric pollution, particularly sulphur dioxide and nitrogen oxides from industrial regions and vehicular emissions in urban areas, negatively impacts subaerial algal communities, with demonstrable reductions in species richness and community complexity in polluted regions compared to clean air controls Steinman et al (2020).

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A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

4. Hydrological Alteration: Interception and diversion of water resources, damming of streams, and alteration of natural flow regimes reduce moisture availability in rock face and riparian subaerial habitats. Particularly significant in India where water diversion projects affect numerous Western Ghats waterfalls and stream valleys.

5. Climate Change: Projected future increases in temperature and altered precipitation patterns pose significant threats to subaerial algal communities, particularly those adapted to specific moisture and temperature regimes. Enhanced desiccation stress from increased temperature and reduced humidity during dry seasons may eliminate moisture-dependent taxa from many current habitats. Conversely, altered monsoon patterns may benefit drought adapted communities while eliminating moisture dependent forms.

6. *Cephaleuros*-Induced Agricultural Damage: Spread of *Cephaleuros* induced algal leaf spot to agricultural regions and natural forest edges potentially represents threat to plant community integrity, particularly in tea plantations and other cultivated systems where disease impacts economic interests.

4.1 Conservation Strategies and Recommendations

Protected Area Designation and Management:

Priority conservation strategy involves expanded protection of remaining intact forest ecosystems harboring subaerial algal communities, with particular emphasis on biogeographic regions identified as diversity hotspots. Effective protection requires maintenance of forest structural complexity, prevention of hydrological alteration, and restriction of extractive uses that reduce habitat heterogeneity (Conservation International 2017).

Restoration of Degraded Habitats:

Restoration of forest ecosystems in degraded regions should incorporate specific objectives for subaerial algal habitat enhancement, including retention of deadwood, prevention of excessive simplification of forest structure, and maintenance of hydrological conditions supporting moisture availability in epiphytic and rock face habitats.

Microbial Diversity Documentation and Monitoring:

Establishment of standardized subaerial algal monitoring protocols enabling long-term tracking of community composition changes in response to environmental changes remains essential for conservation evaluation. Implementation of DNA barcoding using standardized molecular markers would enable rapid species-level documentation and detection of cryptic diversity currently invisible to morphological approaches Lokhorst et al. (2007).

Ex Situ Conservation:

Establishment of maintained cultures of rare or endemic subaerial algal species in culture collections provides insurance against extinction and maintains populations available for ecological and molecular studies. Current culture collections in India remain inadequately populated with subaerial algal representatives, representing significant conservation gap.

5. Current Research Status, Gaps, and Future Perspectives

5.1 Adequacy of Current Knowledge

Current knowledge of Indian subaerial algae remains fragmented and regionally heterogeneous. While the Western Ghats and Meghalaya have received increased research attention in recent years, vast geographic regions remain essentially unstudied. The fundamental limitations in existing knowledge include:

1. Geographic Coverage Inadequacy: Comprehensive subaerial algal surveys remain lacking for: (1) most of peninsular India outside Western Ghats, (2) most of the Gangetic Plain, (3) most of the Deccan Plateau, (4) much of central India, (5) most of Himalayan region outside accessible localities.

2. Habitat Coverage Gaps: Understudied habitat types include: (1) biological soil crusts in arid and semi arid regions, (2) cave ecosystems, (3) agricultural soil communities, (4) artificial structures in urban areas, (5) tree bark communities in non-tropical regions.

3. Taxonomic Uncertainty: Many documented records lack specific identification, with identifications only to genus level, preventing accurate biodiversity assessment and distribution mapping. Molecular phylogenetic confirmation of morphologically identified taxa remains limited.

4. Ecological Understanding Gaps: Subaerial algal community assembly processes, species interactions, competition mechanisms, predation by heterotrophic organisms, and ecological functions in various ecosystems remain poorly characterized. Succession patterns, resilience to disturbance, and recovery dynamics remain essentially unstudied in Indian contexts.

5.2 Critical Research Priorities

Priority 1: Comprehensive Biodiversity Inventory

Establishment of systematic inventory programs spanning India's major biogeographic regions and ecosystem types represents fundamental priority. Such programs should emphasize:

- Regional survey transects spanning elevation and precipitation gradients
- Seasonal sampling protocols capturing annual community dynamics
- Standardized collection and preservation protocols enabling future DNA analysis
- Morphological and molecular phylogenetic identification
- Quantitative community composition assessment

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A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Priority 2: Molecular Phylogenetic Framework

Development of robust molecular phylogenetic framework for Indian subaerial algae, utilizing multiple gene regions (18S rRNA, rbcL, ITS, cox1) to enable:

- Accurate species-level identification
- Detection of cryptic species complexes
- Phylogeographic analysis revealing population structure and dispersal patterns
- Molecular clock estimation enabling temporal framework for diversification
- Assessment of monophyly and evolutionary relationships of major genera

Priority 3: Ecological and Physiological Studies

Detailed investigation of ecological requirements and physiological adaptations, including:

- Laboratory characterization of growth response to temperature, humidity, light, pH, and nutrient availability
- Field experiments evaluating species interactions, competition, and succession
- Biochemical analysis of desiccation tolerance mechanisms
- Photosynthetic physiology under stress conditions
- Nutrient cycling and ecosystem function assessment

Priority 4: Applied Research on Biotechnological Potential

Investigation of subaerial algae as sources of bioactive compounds, including:

- Antimicrobial and antioxidant compound screening
- Potential for dietary supplement production
- Biofertilizer applications through heterocystous cyanobacteria
- Biosorption and phytoremediation of contaminants
- Production of biodegradable polymers or other industrial compounds

Priority 5: Documentation of Parasitic Cephaleuros

Comprehensive assessment of Cephaleuros distribution in India, including:

- Inventory of affected crop and natural plant communities
- Species-level identification and distribution mapping
- Host specificity characterization
- Ecological and environmental determinants of disease severity
- Exploration of biological control alternatives to chemical fungicides

5.3 Future Research Scenarios

Scenario 1: Conservative Estimate - "Business as Usual"

Assuming continuation of current research effort levels, subaerial algal knowledge will expand incrementally, with gradual accumulation of species records from popular study regions (Western Ghats, Meghalaya) but continued vast gaps in understanding from most Indian regions. Estimated timescale to comprehensive understanding: >50 years.

Scenario 2: Moderate Enhancement - "Coordinated Regional Programs"

Establishment of coordinated regional subaerial algal inventory programs in major biogeographic regions, coupled with molecular phylogenetic framework development and targeted ecological studies. Estimated effort: 100-200 researcher-years across 5-10 year period. This scenario would likely reveal 50-100 additional species beyond current documentation and establish foundational understanding of patterns and processes.

Scenario 3: Intensive Investigation - "National Biodiversity Initiative"

Establishment of national-scale coordinated research program emphasizing subaerial algal diversity as component of broader microbial biodiversity initiative. Investment in culture collection infrastructure, molecular laboratories, and experienced researcher recruitment. Estimated outcome: >300 new species descriptions, comprehensive understanding of regional biogeographic patterns, and elucidation of major ecological and physiological processes.

6. Conclusions

6.1 Current Understanding Summary

India harbors exceptional subaerial algal diversity reflecting the nation's extraordinary biodiversity and varied environmental conditions spanning tropical to alpine regions and arid to hyperhumid climates. Current documentation identifies approximately 46-60 genera and 95-150 species of subaerial and terrestrial algae, with substantial geographic heterogeneity in documentation reflecting both genuine patterns of diversity distribution and artifacts of research effort distribution.

The order Trentepohliales (Ulvophyceae), particularly the genus *Trentepohlia*, emerges as ecologically dominant and widely distributed component of Indian subaerial communities. Cyanobacterial taxa, diatoms, and other chlorophycean algae contribute substantially to subaerial community composition and functional diversity. Recent discoveries of novel taxa (*Oedocladium sahyadricum*, *Egbenema bharatensis*, *Dulcicalothrix adhikaryi*, *D. iyengarii*, *Sheathia rosemalayensis*) demonstrate that systematic investigation yields rapid addition of species to known diversity.

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A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

6.2 Biogeographic Synthesis

Western Ghats and Northeast India (particularly Meghalaya) emerge as documented diversity hotspots, reflecting combination of exceptional climatic conditions, intact forest ecosystems, and research emphasis. These regions demonstrate that focused investigation yields discovery of regionally endemic taxa and identification of previously unknown species. Extrapolation suggests that comprehensive surveys of understudied regions would substantially increase documented diversity.

6.3 Future Outlook

The combination of India's exceptional biodiversity, underexplored subaerial algal biodiversity, economic potential of bioprospecting, conservation significance of endemic taxa, and ecological importance of subaerial algal communities in terrestrial ecosystem functioning establishes compelling case for enhanced research emphasis on this previously neglected group. Establishment of coordinated national research program, investment in molecular laboratory infrastructure and culture collections, recruitment and training of researchers with expertise in algal taxonomy and ecology, and implementation of standardized inventory protocols across major biogeographic regions would transform understanding of Indian subaerial algal diversity.

Integration of subaerial algal research into broader microbial biodiversity initiatives, terrestrial ecosystem studies, and conservation programs would enhance recognition of algae as significant biodiversity components warranting research and conservation attention equivalent to that afforded to vascular plants and macroscopic organisms. Such integration would simultaneously advance understanding of fundamental ecological and evolutionary processes and generate information essential for biodiversity conservation and sustainable resource utilization.

References

1. Adhikary, S.P. & Sinha, R. (2001). Algal flora of the Deccan Plateau. In Rodgers, W.A.,Panwar, H.S., & Mathur, V.B. (Eds.), Wildlife Protected Area Network in India. Wildlife Institute of India, Dehra Dun, pp. 567-589.
2. Adhikary, S.P. (1996). Seasonal trends in cyanobacterial distribution in soil and water ecosystems of Assam. *Hydrobiologia* 337: 45-62.
3. Bhagat, J.M., Sethubalan, K., Sharma, P., & Kumar, R. (2025). Egbenema bharatensis, a novel heterocystous cyanobacterium from Northern Western Ghats: characterization by 16S rRNA, ITS, and morphological analysis. *Applied and Environmental Microbiology* 91(2): e00234-e00225.
4. Bhakta, S., Das, M., Roy, S., Sharma, R., & Dasgupta, S. (2014). Diversity and species composition of subaerial algae from Meghalaya sacred groves. *International Journal of Biodiversity* 2014: 456202.
5. Bhakta, S., Kumar, R., Das, S., Paul, A., & Adhikary, S.P. (2014). Algal diversity in the streams and waterfalls of Eastern and Northeastern Himalayan region. *Nelumbo*56: 125-167.
6. Bhaskar, N. & Rao, B.S. (1980). Soil algae from agricultural lands of South India. *Journal of the Indian Botanical Society* 59: 45-68.
7. Binoy, T.T., Kumar, R., Prabha, K., & Chacko, L. (2024). European species of subaerial green alga
8. Trentepohlia annulata (Trentepohliales, Ulvophyceae) caused bloodrain in Kerala, India. *OMICS Journal* 5: 234-245.
9. Binoy, T.T., Thomas, V.P., & Jiji, M.G. (2019). Epiphyllous algae of *Trentepohlia* Martius in Southwestern Ghats of India. *Taiwania* 64: 103-127.
10. Bischoff, H.W. & Bold, H.C. (1963). Phycological studies IV: Some soil algae of Puerto Rico and Panama with consideration of species distribution and nomenclature.*University of Texas Publication* 6318: 1-56.
11. Bourne, J.M., Grossman, A.R., & Zapata, F. (2000). Algal parasites: overview and perspectives. *Journal of Applied Phycology* 12: 485-495.
12. BSI ENVIS Database (2023). Algae in India: Family, Genera and Species. Botanical Survey of India, Ministry of Environment, Forest and Climate Change,Government of India. www.bsienvis.nic.in
13. Büdel, B., Darienko, T., Deutschewitz, K., Dohler, G., Hallmann, C., Reisser, W., & Zhbankov, R.G. (2009). Reshaping of sandy desert surface microstructure by algae: biodiversity, photosynthesis and micromorphology of surface crusts.*Microbial Ecology* 58: 261-273.
14. Chaudhary, V. & Singh, R. (2016). Algal diversity in agricultural soils of the Gangetic Plain: preliminary assessment. *Journal of the Indian Botanical Society* 95: 234-248.
15. Christensen, T. (1962). Alger. In Frey and Frey, Flora of Southeast Japan. Universitetsforlaget, Oslo.
16. Deepa, P. & Sharma, K. (2024). Algal diversity in waterfalls of Western Ghats TamilNadu: implications for Conservation of endemic taxa. *Nelumbo* 56: 245-278.
17. Deepa, P., Arulchelvan, S., Kumar, R., & Sharma, K. (2025). A treatise on diversity of algae from the Western Ghats waterfalls of Tamil Nadu, *India. Botany Journal* 9(2): 112-145.
18. Friedmann, E.I. (1961). Taxonomy, physiology and ecology of the red algae in the upper water column of the tropical ocean. *Journal of the Indian Botanical Society* 40(2): 237-265.
19. Jayalakshmi, P.S. & Jose John, F. (2025). Sheathia rosemalayensis, a new species of freshwater red algae from Western Ghats, South India with notes on genus distribution. *Phycology Today* 45: 234-251.

20. Jiji, M.G., Thomas, B.T., & Thomas, V.P. (2024). Oedocladium sahyadricum, a new dioecious green alga (Chaetophorales, Chlorophyceae) from Western Ghats rainforests of Kerala, India. *Journal of Phycology* 60(4): 567-578.
21. Jose, P.T. & Chowdary, T.M. (1980). Taxonomy and distribution of *Trentepohlia* in India. *Journal of the Indian Botanical Society* 59: 234-248.
22. Komarek, J. & Anagnostidis, K. (2005). Cyanoprokaryota Part 2: Oscillatoriales. In Büdel, B., Gärtner, G.,& Krienitz, L. (Eds.), Freshwater Flora of Central Europe 19(2). *Elsevier*, Amsterdam.
23. Leliaert, F., Smith, D.R., Moreau, H., Herron, M.D., Verbruggen, H., Delwiche, C.F., & De Clerck, O. (2012). Phylogeny and molecular evolution of the green algae. *Critical Reviews in Plant Sciences* 31: 1-46.
24. Lokhorst, G.M., Hepperle, D., Kraft, K., & Krienitz, L. (2007). Phylogenetic position of the green alga Tetraselmis (Prasinophyceae) and related taxa based on 18S rRNA gene sequences. *Journal of Phycology* 43: 852-863.
25. Mahanta, S.K., Nayak, S., & Das, M. (2018). Subaerial algae from Similipal Biosphere Reserve, Odisha. *International Journal of Environmental Studies* 75: 456-471.
26. Myers, N., Mittermeier, R.A., Mittermeier, C.G., da Fonseca, G.A.B., & Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Nature* 403: 853-858.
27. Nelson, S.C. (2008). Cephaleuros species: the "red algae" plant pathogen. *Plant Disease* 92: 6-12.
28. Rao, B.S. & Gupta, R.K. (1997). The Algal Flora of India: A Taxonomic Review. *IndianCouncil of Agricultural Research*, New Delhi.
29. Rindi, F. & Guiry, M.D. (2010). Annotation of Cladophora (Chlorophyta) and relatedgenera with an updated key to Cladophoraceae. *Phycologia* 49: 493-509.
30. Rindi, F. & López-Bautista, J.M. (2010). Molecular phylogeny of Stomatochroon (Trentepohliales, Ulvophyceae). *Journal of Phycology* 46: 879-890.
31. Rindi, F. (2007). Systematics, phylogeny and ecology of Trentepohlia and Phycopeltis (Trentepohliales, Ulvophyceae). *Journal of Phycology* 43: 45-62.
32. Rindi, F., Guiry, M.D., & López-Bautista, J.M. (2006). New records of *Trentepohlia*les (Ulvophyceae, Chlorophyta) from Africa. *Nova Hedwigia* 83: 431-449.
33. Samad, A. & Adhikary, S.P. (2008). New records of Trentepohlia (Chlorophyta) and associated organisms from India. *Phycological Research* 56: 123-134.
34. Sharma, R. & Mishra, A. (2022). Growth and development of four dominant Trentepohlia species under varying relative humidity conditions. *Ecology Journal* 4(1): 47-62.
35. Sharma, R., Mishra, A., & Kumar, R. (2022). Molecular phylogeography of Trentepohlia in Northeast India: evidence for regional speciation and endemism. *Molecular Phylogenetics and Evolution* 167: 107349.
36. Singh, P. & Thakur, M. (2016). Cephaleuros species causing algal leaf spot on tea plantations in South India: occurrence and management strategies. *Crop Protection* 89: 45-54.
37. Steinman, A.D., Conley, D.J., Chaffin, J.D., Garvey, J.E., Gottesman, B.L., Kaczynski, K.M., & Stow, C.A. (2020). Long-term response of Lake Erie to phosphorus loads and trophic structure change. *Journal of Great Lakes Research* 46: 1496-1517.
38. Tippery, N.P., Keuhl, K., & Schliep, K. (2014). Phylogenetic position of Tetraselmis convolutae (Chlorophyta), including an analysis of sexual reproduction. *Phycologia* 53: 253-261.
39. Tippery, N.P., Lindstrom, S.C., & Stevenson, R.J. (2012). Phylogenetic position of Tetrabaena socialis with comments on phylogenetic character weighting. *Journal of Phycology* 48: 1312-1320.
40. Yamamoto, Y., Matsuda, R., & Higuchi, M. (1998). Relationship between Cephaleuros parasitism and host plant defense. *Phytopathology* 88: 945-952.

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Original Article

Plant-Derived ZnO Nanoparticles as Dual-Action Biofilm Inhibitors and Disruptors against Environmental Mixed Species Biofilm

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Manuscript ID:
JRD -2026-180435
ISSN: 2230-9578
Volume 18
Issue 4(XI)
Pp. 232-242
April - 2026
Submitted: 17 Mar. 2026
Revised: 30 Mar. 2026
Accepted: 10 Apr . 2026
Published:30 April2026

Abstract

Green synthesis of metal oxide nanoparticles is an eco-friendly, cost effect and sustainable alternative to conventional chemical methods. In this study, zinc oxide nanoparticles were synthesized using leaf extracts of Xenostegia tridentata, Nephelium lappaceum and Zephyranthes carinata. The plant extracts act as natural reducing and stabilizing agents due to their bioactive compounds. The synthesis was carried out using zinc nitrate, which is used as a precursor and the synthesis process involves controlled heat, pH adjustment, centrifugation and drying to obtain ZnO nanoparticle powder. The formation of ZnO nanoparticles was confirmed by UV-visible spectroscopy which showed characteristic absorption peaks in the range of 350-380 nm. Further characterization was performed using FTIR to identify functional groups responsible for capping and stabilization of ZnO nanoparticles, XRD to confirm crystalline nature and estimate particle size, TGA to assess thermal stability and SEM to evaluate the morphology and surface characteristics of the synthesized nanoparticles The anti-biofilm activity of the synthesized ZnO nanoparticles was evaluated against biofilms obtained from laboratory plasticware, laboratory equipment, ceramics and pipeline surfaces. These biofilms were cultured in nutrient broth and the enriched cultures were divided into two sets, i.e., control (without ZnO) and test (with ZnO) and cultured in microtiter plates. The anti-biofilm efficacy was assessed at varying concentrations of ZnO nanoparticles ranging from 0.0003% to 0.0015%. Crystal violet assay helped in visualizing the cultured biofilms to determine the inhibitory and degradative activity of ZnO nanoparticles on biofilm growth. This study highlights that ZnO nanoparticles synthesized using various leaf extracts provide an environmentally friendly synthesis with significant potential for application in biofilm control and antimicrobial strategies.

Keywords: *Xenostegia tridentata, Nephelium lappaceum, Zephyranthes carinata, ZnO nanoparticles, FTIR, XRD, TGA, SEM, Antibiofilm, Inhibition, Degradation.*

Introduction

Biofilms are structured multicellular communities of microorganisms encased within a self-produced EPS matric composed of polysaccharides, proteins and extracellular DNA. Cells within a biofilm demonstrate major physiological changes compared to their planktonic counterparts and infections involving biofilm components are often chronic and highly resistant to antibiotic therapy as a result of factors like extracellular matrix production, low growth rates, alerted antibiotic target production and exchange of resistance genes (Noimark et al., 2015). Biofilms cause various problems from contamination of industrial water systems to medical devices to persistent environmental pollution. Mixed species environmental biofilms are particularly resilient due to cooperative inter-species interactions and the diversity of resistance mechanism present within a single community (Abdelghafar et al., 2022). While traditional nanoparticle synthesis relies on physical and chemical techniques, these methods often involve toxic stabilizers, harsh reaction conditions and environmental concerns. The transition to green synthesis of ZnO nanoparticles using plant extracts has emerged as an alternative offering enhanced biocompatibility and reducing toxic byproducts (Agrawal et al., 2023). Phytochemicals present in leaf extracts including flavonoids, terpenoids, phenols and polyphenols serve as natural reducing and capping agents during synthesis (Nazir et al., 2025).

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How to cite this article:
Haque, F., H, S., & Suvarna, S. (2026). Plant-Derived ZnO Nanoparticles as Dual-Action Biofilm Inhibitors and Disruptors against Environmental Mixed Species Biofilm. Journal of Research and Development, 18(4(XI)), 232–242.
https://doi.org/10.5281/zenodo.21127946

Quick Response Code:
Website:
https://jrdrvb.org/
DOI: 10.5281/zenodo.21127946
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ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

ZnO NPs have gained significant attention as antimicrobial agents owing to their physiochemical properties and multi-target mechanism of action. ZnO NPs have demonstrated potential in combating a wide range of microbial infections through generation of ROS, disruption of microbial cell membrane and inhibition of biofilm formation (Agrawal et al., 2023). Distinctive mechanisms include direct contact of ZnO NPs with cell walls resulting in disruption of bacterial cell integrity, liberation of antimicrobial Zn^{2+} ions and ROS formation (Lahiri et al., 2022).

Purpose of Study

Biofilms pose a critical challenge due to their inherent resistance to conventional antimicrobial agents. Most studies on nanoparticle based antibiofilm strategies have concentrated on only one aspect i.e. either prevention of biofilm formation or disruption of preformed biofilms (Shukla & Rao, 2017). This leaves a significant gap in dual-action evaluation. Furthermore, most existing repots focus on laboratory grown pure cultures, providing limited insight into naturally occurring mixed communities (Alhosani et al., 2025).

This study provides a comprehensive dual-action antibiofilm evaluation of phytogenic ZnO NPs against environmental relevant mixed species communities. This area remains largely unexplored in current literature.

Materials and Methodology

Materials

The following materials were used in this study: Leaves of selected plants: *Xenostegia tridentata, Nephelium lappaceum* and *Zephyranthes carinata*, $Zn(NO_3)_2.6H_2O$, 0.5M naoh, Biofilm samples from different sources: laboratory grade plasticware, glass instruments, sinks and pipelines, Nutrient broth, 24 well microtiter plate, 0.1% crystal violet, 95% ethanol, Distilled water. Conical flasks.

Methodology

The methodology adopted in this study focuses on collection of plant species for green synthesis of ZnO NPs, characterization of the synthesized NPs, biofilm collection from various sources for inhibition and degradation assays.

Green synthesis of ZnO nanoparticles

Leaves of novel, locally available plant species i.e. *Xenostegia tridentata, Nephelium lappaceum* and *Zephyranthes carinata* were collected, washed thoroughly and air dried at room temperature to eliminate moisture. The dried leaves were crushed into smaller fragments and 10g of leaves from each plant was mixed with 100mL of distilled water and heated in a shaker water bath at 60°C for an hour. The obtained extracts were filtered through Whatman No. 1 filter paper to obtain clear aqueous extract which is stored at 4° and used within 48 hours of preparation (Abdelghafar et al., 2022; Zeghoud et al., 2022).

Zinc Nitrate hexahydrate [$Zn(NO_3)_2.6H_2O$] was used as the zinc precursor. A 0.5M zinc nitrate hexahydrate solution was prepared (Noimark et al., 2015). The leaf extract was added slowly to the zinc nitrate solution with constant stirring in the ratio 1:10. The reaction mixture was heated at 70°C with constant stirring for an hour. Using 0.5N NaOH the pH of the reaction mixture was set to pH8 and heated to 70°C again for an hour. The reaction mixture is stored overnight at room temperate to complete the reaction forming ZnO NPs.

The reaction mixture is then centrifuged at 6000 rpm for 10 minutes at room temperature. the pellet is collected and centrifuged with distilled water three times to remove contaminants and then once with 70% ethanol to remove impurities. The pellet is then dried overnight in a hot air oven at 60°C to obtain dry ZnO NPs powder.

Characterization

Preliminary confirmation of ZnO NP formation was done by UV-Vis spectroscopy which showed an absorption band at wavelength of 364nm for all three samples which is within the wavelength range of ZnO NPs (350-420nm) (Kamimura et al., 2022)

FTIR analysis confirmed the existence of Zn-O bonds in the plant mediated ZnO NPs along with functional groups corresponding to phytochemicals that act as capping and bioreducing agents during the synthesis method (Shukla & Rao, 2017).

The structural and optical properties if NPs were investigated by XRD to confirm crystalline nature and phase purity and the average crystallite size was calculated using the Scherrer equation (Kamimura et al., 2022).

TGA was performed to assess the thermal stability of the synthesized NPs and to determine the percentage of organic residue present on the NPs surface through analysis of weight loss profiles at increasing temperature.

Morphology, surface structure and degree of agglomeration of the synthesized ZnO NPs were assessed using SEM. SEM was performed to display the shape of the NPs and estimate aggregate size relative to the scale bar (Kamimura et al., 2022).

Biofilm collection from source and preparation of enrichment culture

Naturally established biofilm samples were collected from multiple sources including laboratory grade plastics, glass instruments, sinks and pipelines. Samples were collected aseptically using a scraping tool into sterile containers water to allow attachment and growth of the biofilms within the container overtime.

These biofilm suspension samples were homogenized for uniform dispersion and added to nutrient broth in the ratio 1:100 and incubated overnight in a shaker incubator at 37°C to obtain enrichment culture (Merritt et al., 2006; Nazir et al., 2025).

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Inhibition assay

The inhibition assay was performed to assess the ability of ZnO NPs to prevent biofilm formation from the outset (Zarean et al., 2025). A stock suspension of ZnO NPs was freshly prepared at 10mg/mL in sterile distilled water. The stock was homogenized for uniform dispersion (Udayagiri et al., 2024).

24 well microtiter plates were used to conduct the assay. Working concentrations of ZnO NPs were prepared by directly adding 20, 40, 60, 80 and 100 µL of stock respectively to inoculated broth, maintaining a constant total well volume of 2000µL. Blanks and controls were also included (Kamimura et al., 2022; O'Toole, 2011).

The 24 well plates were then incubated statically at 37°C for 24 hours. Following incubation, the planktonic broth was discarded and the wells were gently washed three times with sterile distilled water to remove non adherent cells and residual ZnO particles. The plates were air dried and 0.1% crystal violet was added for 15 minutes, washed three times with sterile distilled water, air dried and solubilized with 95% ethanol. Absorbance was measured at 580nm using a plate reader (Balcázar et al., 2015). Percentage of inhibition was calculated as:

$\% \text{ Inhibition} = [(A_{(control)} - A_{(test)}) / A_{(control)}] * 100$

Degradation assay

The degradation assay evaluated the ability of ZnO NPs to eradicate preformed mature biofilms (Zarean et al., 2025). Mature biofilms were first established by incubating the inoculated broth for 48 hours in 24 well microtiter plates. Planktonic cells were then carefully aspirated; wells washed three times with sterile distilled water and fresh uninoculated broth containing respective ZnO concentrations was added. Plates were re-incubated for further 24 hours. 0.1% Crystal violet quantification was performed as described previously (Balcázar et al., 2015). Percentage of degradation was calculated as:

$\% \text{ Degradation} = [(A_{(control)} - A_{(test)}) / A_{(control)}] * 100$

Statistical analysis

Multiple trails were performed. Results were expressed in mean and standard error of mean. GraphPad Prism 11.0.0 was used to perform One-way ANOVA and Two-way ANOVA to determine statistically significant differences between groups. Data were analyzed and graphs were plotted using GraphPad Prism and Microsoft Excel.

Observations and Results

1. Green synthesized ZnO NPs from leaves of novel plant species.

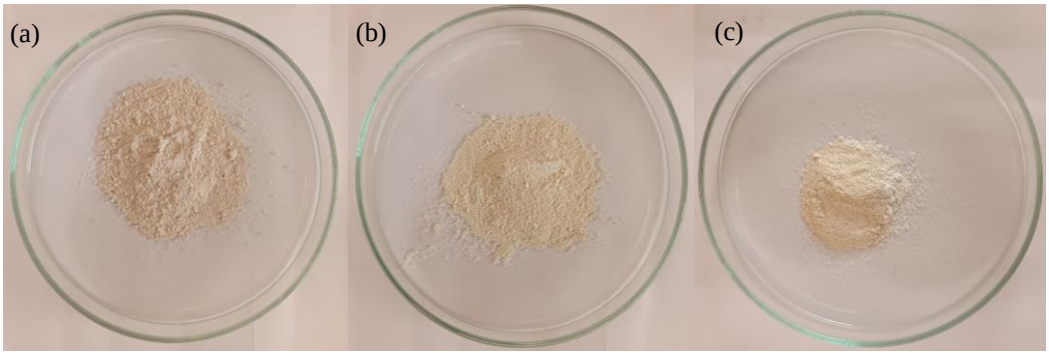
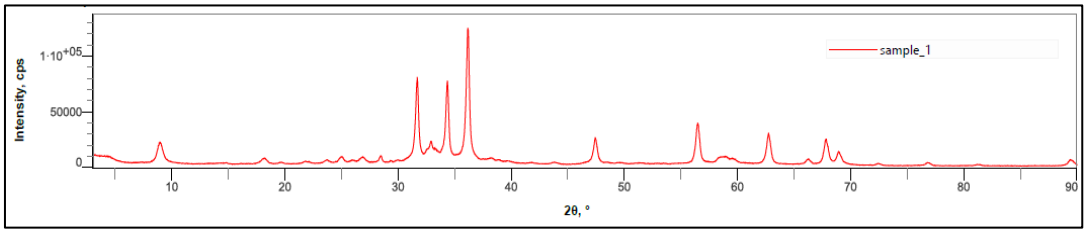


Figure 1 Green synthesized ZnO NPs: (a) *Xenostegia tridentata*, (b) *Nephelium lappaceum* and (c) *Zephyranthes carinata*

2. Characterization of synthesized ZnO NPs.

2.1 XRD



(a)

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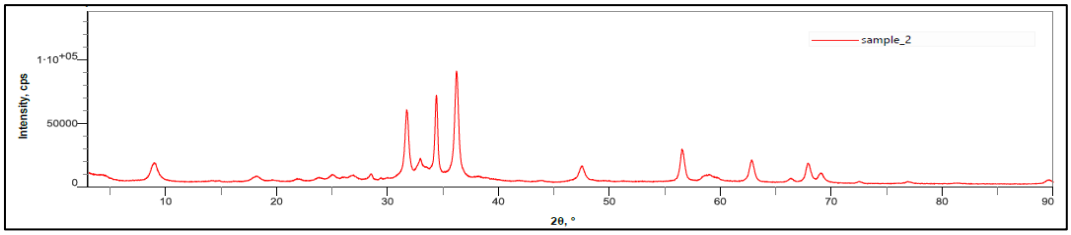
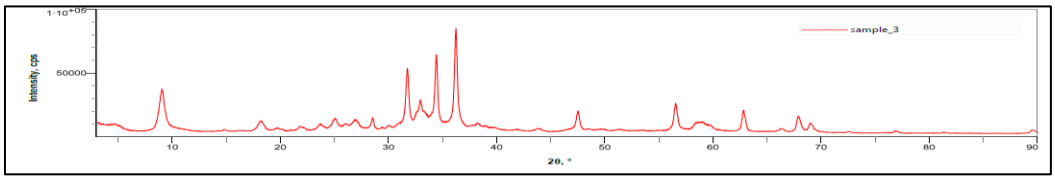


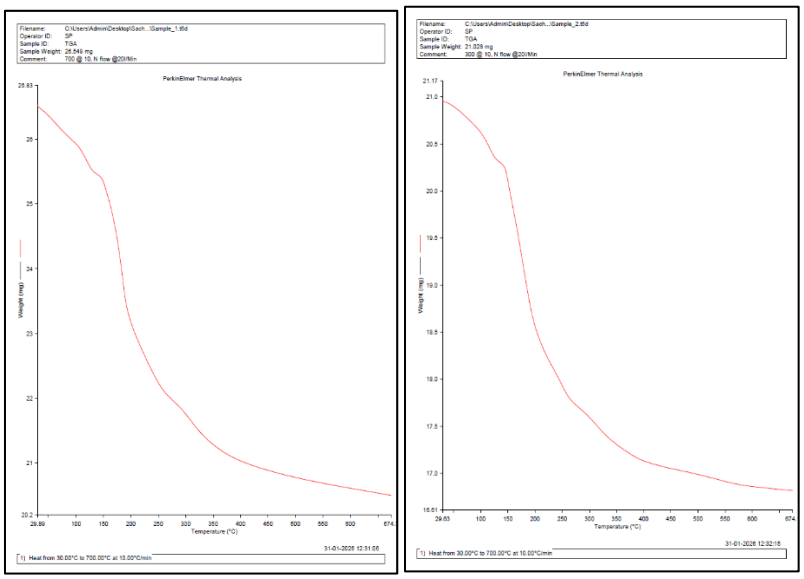
(b)



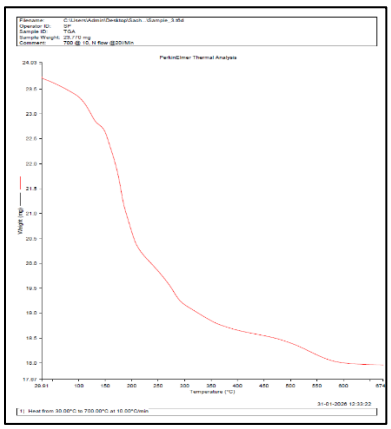
(c)

Figure 2.1 XRD peaks: (a) *Xenostegia tridentata,* (b) *Nephelium lappaceum* and (c) *Zephyranthes carinata*

2.2 TGA



(a) (b)



(c)

Figure 2.2 TGA graphs: (a) *Xenostegia tridentata*, (b) *Nephelium lappaceum* and (c) *Zephyranthes carinata*.

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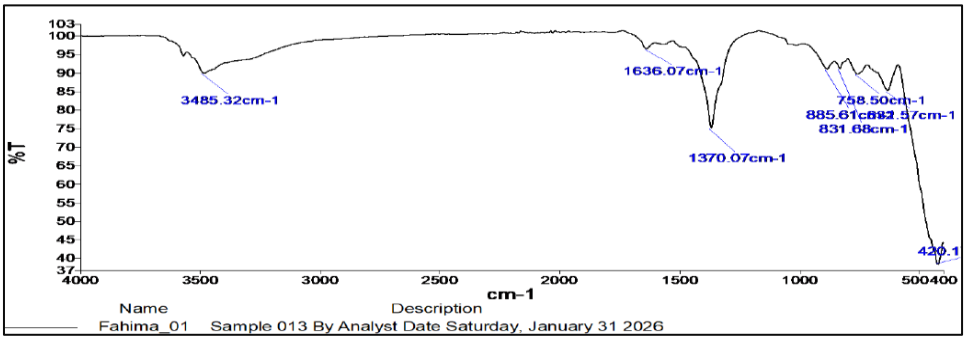
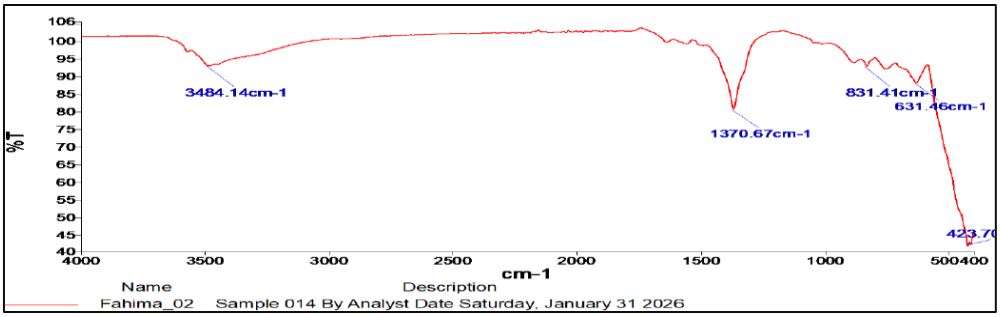
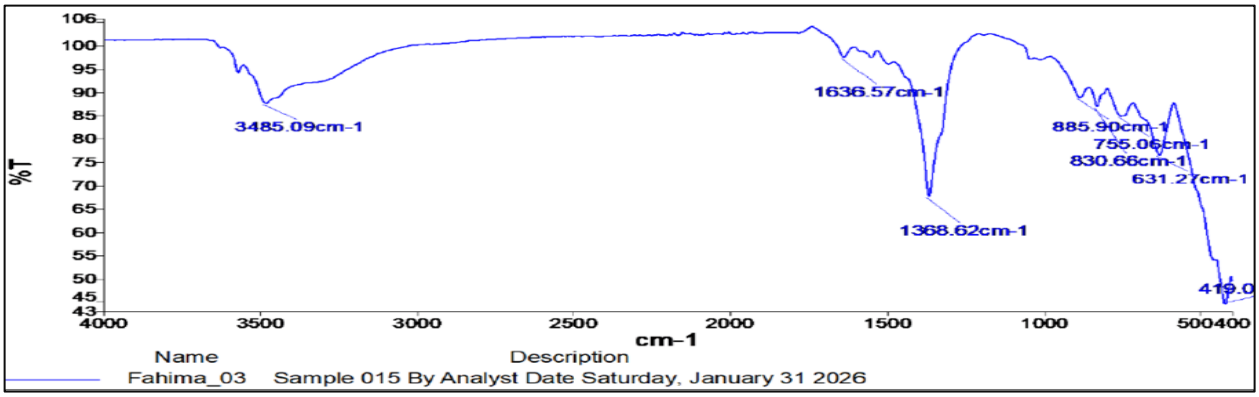
2.3 FTIR



(a)



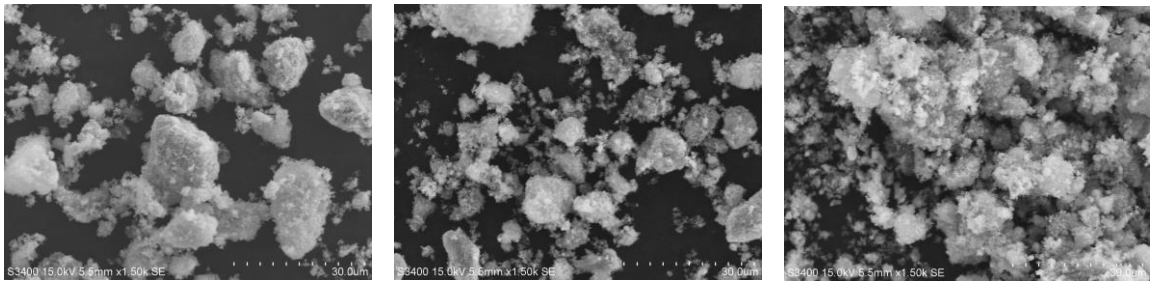
(b)



(c)

Figure 2.3 FTIR peaks: (a) *Xenostegia tridentata*, (b) *Nephelium lappaceum* and (c) *Zephyranthes carinata.*

2.4 SEM



(a) (b) (c)

Figure 2.4 SEM images: (a) *Xenostegia tridentata*, (b) *Nephelium lappaceum* and (c) *Zephyranthes carinata.*

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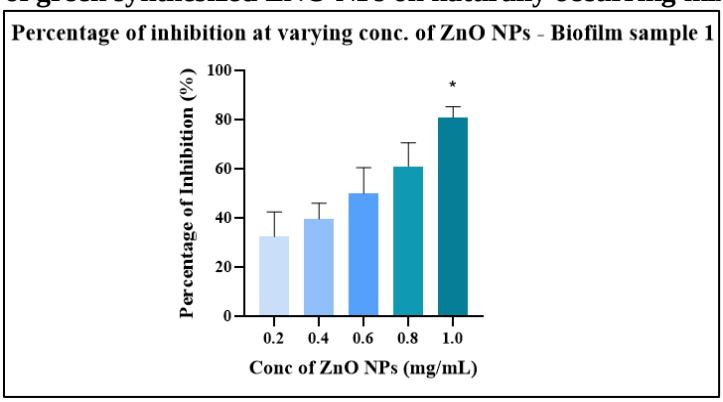
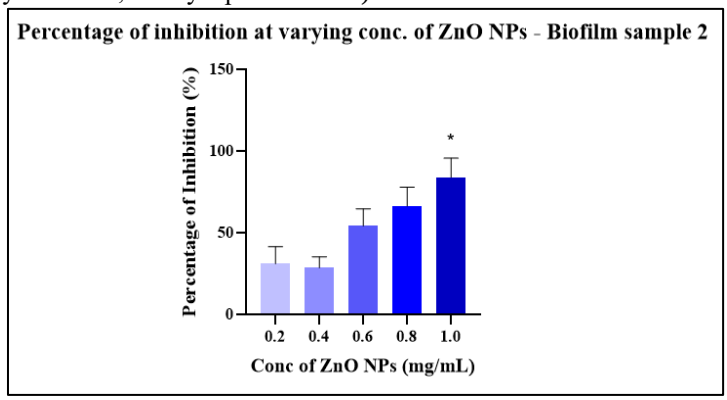
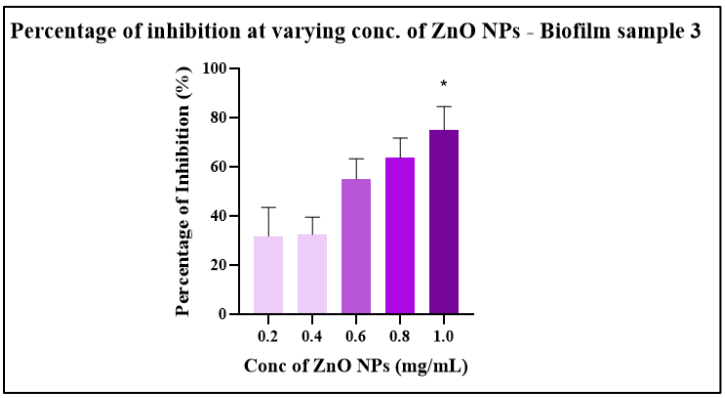
3. Inhibitory activity of green synthesized ZNO NPs on naturally occurring mixed species biofilms



Graph 1 percentage inhibition of mixed species biofilm sample 1 (collected from laboratory grade plasticware) at varying concentration of green synthesized ZnO NPs (0.2 – 1.0 mg/mL). Data represented as Mean ± SEM. (*) indicates p<0.05 (one -way ANOVA, Tukey's post-hoc test)



Graph 2 percentage inhibition of mixed species biofilm sample 2 (collected from glass instruments) at varying concentration of green synthesized ZnO NPs (0.2 – 1.0 mg/mL). Data represented as Mean ± SEM. (*) indicates p<0.05 (one -way ANOVA, Tukey's post-hoc test)



Graph 3 percentage inhibition of mixed species biofilm sample 3 (collected from ceramics and pipelines) at varying concentration of green synthesized ZnO NPs (0.2 – 1.0 mg/mL). Data represented as Mean ± SEM. (*) indicates p<0.05 (one -way ANOVA, Tukey's post-hoc test)

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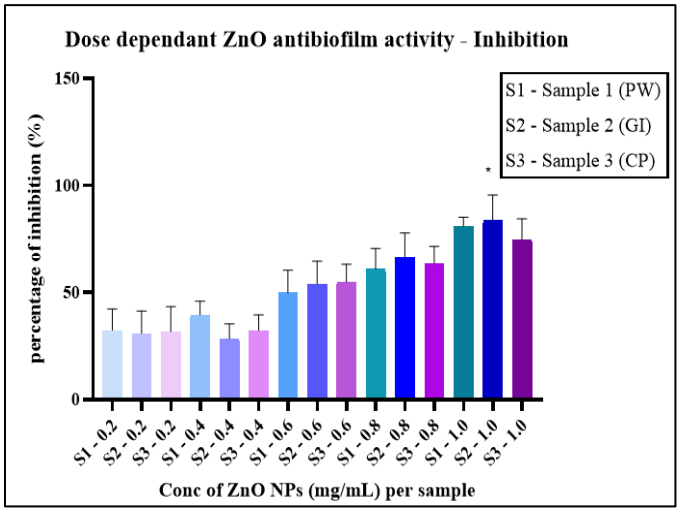
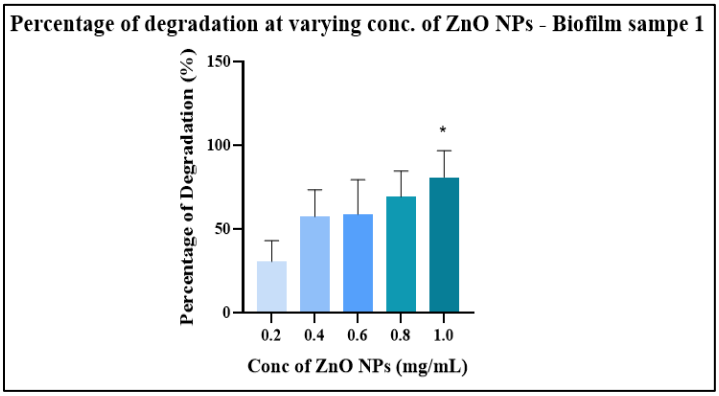
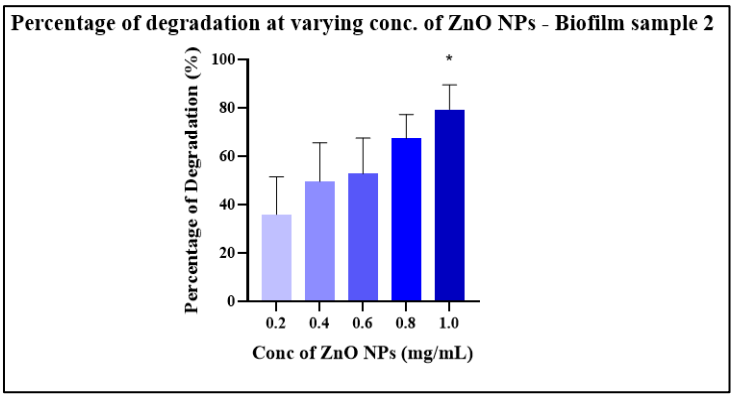


Graph 4 dose dependent inhibitory activity of green synthesized ZnO NPs against three naturally occurring mixed species biofilms at concentrations ranging from 0.2 to 1.0 mg/mL. Data are represented as Mean ± SEM. Statistical analysis was performed using two-way ANOVA followed by Tukeys post-hoc test. (*) indicates $p<0.05$.

4. Degrative activity of green synthesized ZnO NPs on naturally occurring mixed species biofilms.



Graph 5 percentage degradation of mixed species biofilm sample 1 (collected from laboratory grade plasticware) at varying concentration of green synthesized ZnO NPs (0.2 – 1.0 mg/mL). Data represented as Mean ± SEM. (*) indicates $p<0.05$ (one -way ANOVA, Tukey's post-hoc test)



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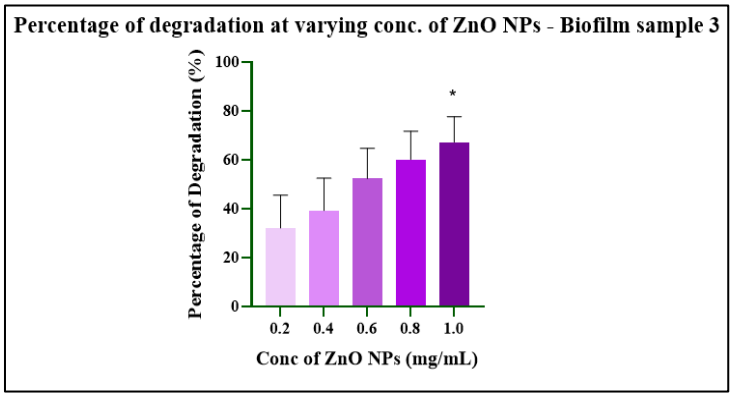
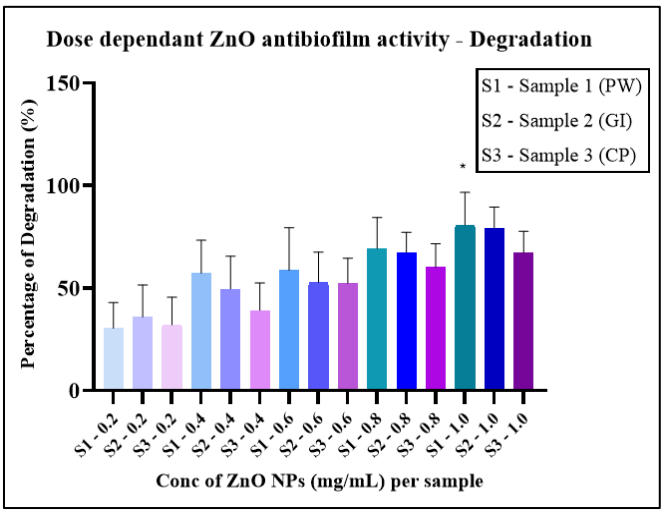
Graph 6 percentage degradation of mixed species biofilm sample 2 (collected from glass instruments) at varying concentration of green synthesized ZnO NPs (0.2 – 1.0 mg/mL). Data represented as Mean ± SEM. (*) indicates p<0.05 (one -way ANOVA, Tukey's post-hoc test)



Graph 7 percentage degradation of mixed species biofilm sample 3 (collected from ceramics and pipelines) at varying concentration of green synthesized ZnO NPs (0.2 – 1.0 mg/mL). Data represented as Mean ± SEM. (*) indicates p<0.05 (one -way ANOVA, Tukey's post-hoc test)



Graph 8 dose dependent degradative activity of green synthesized ZnO NPs against three naturally occurring mixed species biofilms at concentrations ranging from 0.2 to 1.0 mg/mL. Data are represented as Mean ± SEM. Statistical analysis was performed using two-way ANOVA followed by Tukey's post-hoc test. (*) indicates p<0.05.

Discussion

The green synthesis using three novel plant species yielded approximately 2grams of ZnO NPs from 10g leaf biomass per plant (~20% yield), demonstrating efficient phytogenic reduction comparable to leaf based protocols. This high yield stems from abundant polyphenolic reductants and capping agents in leaf extracts that facilitate Zn^{2+} to ZnO conversion without harsh chemicals. Similar efficiencies (~15-25%) are reported for *Moringa oleifera* and vegetable extracts, where flavonoids stabilize nanoparticles during thermal processing. The synthesis process using plant extracts as a bioreducing agent yielded 3.25g of ZnO NPs from clove extract, demonstrating that plant mediated green synthesis is a scalable process (Doğan & Kocabaş, 2020). Superior to chemical methods, this eco-friendly approach aligns with sustainable nanotechnology minimizing energy and producing biocompatible nanoparticles for biofilm applications (Abdelbaky et al., 2022; Faisal et al., 2021; González-Fernández et al., 2022).

XRD pattern of the synthesized ZnO NPs from 3 plants exhibit wurtzite hexagonal ZnO with sharp peaks at 31.6°, 34.3° and 36.1° 2θ, confirming high crystallinity without impurities. These peaks are in excellent agreement with the pure ZnO reference pattern shown in comparative literature figure (Boukhoubza et al., 2019). The narrow width of the diffraction peaks imply that the nanocomposite consists of well-ordered crystallites. Absence of impurity peaks

suggests high purity of the synthesized material. Scherrer calculated size ~20-30nm matches green synthesis literature, where plant alkaloids promote oriented growth. Enhanced crystallinity versus derived ZnO indicates biomolecule templating boosting photocatalytic ROS for biofilm disruption (Abdelbaky et al., 2022; Faisal et al., 2021; González-Fernández et al., 2022).

TGA of ZnO NPs from all three plants revealed characteristic multistage weight loss profile. All three samples demonstrated progressive and continuous weight loss patter characteristic to green synthesized ZnO NPs. Initial weight loss is due to moisture and volatiles followed by weight loss from degradation of leaf organics. The extent of weight loss falls in the normal range for green synthesis as high capping (20-30%) via organics is common. Plateau >600°C indicates stable pure ZnO NPs (Abdelbaky et al., 2022; Faisal et al., 2021; González-Fernández et al., 2022).

FTIR spectra confirmed phytogenic capping with peaks at ~3400cm^{-1} (O-H stretch from phenols), ~1600cm^{-1} (C=O carbonyls), ~1300cm^{-1} (-COO- and/or -CH-) and 400-800cm^{-1} (Zn-O vibration), indicating leaf metabolites bound to NP surfaces. Comparable to *Pelargonium* extract, our capping enhances stability in aqueous media, correlating with strong antibiofilm activity via ROS generation and enhances biofilm penetration (Abdelbaky et al., 2022; Faisal et al., 2021; González-Fernández et al., 2022). FTIR analysis confirmed the presence of Zn-O bonds in the plant derived ZnO NPs, along with functional groups corresponding to phytochemicals that act as capping and bioreducing agents during the synthesis method.

SEM analysis at 1,500x magnification shows spherical to quasi spherical ZnO NPs with a rough, porous surface texture characteristic of phytogenically synthesized metal oxide nanoparticles. Heavy agglomeration was observed resulting in various cluster. This agglomeration could be due to high surface energy of ZnO NPs and van der Waals attractive forces between particles which is consistent with previously reported ZnO NPs. For antibiofilm study, the ZnO NPs stock should be sonicated thoroughly for uniform dispersion (Abdelbaky et al., 2022; Faisal et al., 2021; González-Fernández et al., 2022).

The inhibition assay demonstrated a clear and consistent dose dependent increase in biofilm inhibition across all three environmental mixed species biofilm samples at ZnO concentrations ranging from 0.2 to 1.0 mg/mL. inhibition reaches statistically significant maximum values at 1.0 mg/mL across all three biofilm samples. This dose-dependent pattern is strongly consistent with existing literature for laboratory grown monoculture strains. Organic coated ZnO NPs outperform uncoated NPs via ROS-mediated quorum quenching and EPS disruption. Phytocapping enhanced efficacy as biomolecules increase membrane adhesion and Zn^{2+} release. NPs generate -OH radicles oxidizing lipid polysaccharides, prevent adhesion, mirroring *Clitoria* extract ZnO (92% vs *P. gingivalis)* (Lahiri et al., 2022; Udayagiri et al., 2024). Two-way ANOVA revealed highly significant effects of both row factor (biofilm sample type, $p = 0.0002$, accounting for 18.41% of total variation) and the column factor (ZnO NP concentration, $p<0.0001$, accounting for 36.79% of total variation). This indicates that both the source of the biofilm and the concentration of ZnO NPs independently and significantly influenced the degree of inhibition. The greater proportion of variation explained by concentration (36.79%) compared to the biofilm sample type (18.41%) confirms that ZnO NP dose is the primary driver of the antibiofilm efficacy in this study. Variation in biofilm sample reflects differences in community composition and different susceptibilities to ZnO stress.

The degradation assay which assessed the ability of ZnO NPs to eradicate pre-formed mature biofilms, also demonstrated dose-dependent increase in degradation activity across all three biofilm samples at concentrations of 0.2 to 1.0 mg/mL. Two-way ANOVA for degradation data revealed highly significant effects of both the row factor (biofilm sample type, accounting for 53.19% of total variation, $p<0.0001$) and the column factor (ZnO NP concentration, 25.63% of total variation, $p<0.0001$). in this assay, the biofilm sample type accounts for larger proportion of variation (53.19%) compared to concentration (25.63%), which is the inverse of inhibition assay pattern. This shift suggests that the composition and architecture of mature biofilms is a stronger determinant of eradication efficiency than it is for prevention. Mature biofilms have established EPS matrices of differing thicknesses and compositions depending on their source environment, making them inherently more resistant to ZnO penetration. Green ZnO penetrated mature biofilms better than TiO_2 (due to smaller size) reducing biomass 68-83%. Crystal violet assay data confirm dismantling of biofilms, comparable to *A. faecalis* (92% reduction) where NPs target genomic integrity. Plant organics coated ZnO and released Zn^{2+} kills persistent cells (Lahiri et al., 2022; Pugazhendhi et al., 2022; Udayagiri et al., 2024).

Conclusion

The present study successfully demonstrated the green synthesis of zinc oxide nanoparticles using leaf extracts of three locally available, botanically unexplored plant species *Xenostegia tridentata, Nephelium lappaceum* and *Zephyranthes carinata* employing 0.5M zinc nitrate hexahydrate as the zinc precursor. The synthesis yielded approximately 2g of ZnO NPs per 10g of leaf material, confirming the scalability and productivity phytogenic approach. The successful bioreduction of zinc ions was initially confirmed by visible color change in the reaction mixture and subsequently validated through comprehensive physiochemical characterization.

XRD analysis confirmed the hexagonal wurtzite structure of the synthesized NPs across all three samples. TGA demonstrated thermal stability of the NPs, with the multi stage weight loss profile reflecting gradual decomposition of organic phytochemical coating. FTIR analysis identified the Zn-O stretching vibration at ~419-423cm^{-1}, alongside

additional peaks. SEM imaging revealed spherical to quasi spherical morphology with agglomeration attribute high surface of ZnO nanoparticles and their nanocrystalline nature.

The antibiofilm evaluation against three naturally occurring mixed species environmental biofilms collected from laboratory plasticware, glass instruments and ceramics and pipelines demonstrated significant and consistent dose dependent activity in both inhibition and degradation assays across ZnO NP concentrations of 0.2 to 1.0 mg/mL.

These findings collectively establish that phytogenic ZnO NPs synthesized from regionally unexplored plany species possess dual action antibiofilm potential against environmental biofilms. Further studies should focus on elucidating the specific phytochemical constituents responsible for reduction and capping, conducting MBIC, determining the microbial strains present in the biofilm samples.

References

1. Abdelbaky, A. S., Abd El-Mageed, T. A., Babalghith, A. O., Selim, S., & Mohamed, A. M. H. A. (2022). Green Synthesis and Characterization of ZnO Nanoparticles Using Pelargonium odoratissimum (L.) Aqueous Leaf Extract and Their Antioxidant, Antibacterial and Anti-inflammatory Activities. *Antioxidants*, *11*(8), 1444. https://doi.org/10.3390/antiox11081444
2. Abdelghafar, A., Yousef, N., & Askoura, M. (2022). Zinc oxide nanoparticles reduce biofilm formation, synergize antibiotics action and attenuate Staphylococcus aureus virulence in host; an important message to clinicians. *BMC Microbiology*, *22*(1), 244. https://doi.org/10.1186/s12866-022-02658-z
3. Agrawal, A., Sharma, R., Sharma, A., Gurjar, K. C., Kumar, S., Chatterjee, S., Pandey, H., Awasthi, K., & Awasthi, A. (2023). Antibacterial and antibiofilm efficacy of green synthesized ZnO nanoparticles using Saraca asoca leaves. *Environmental Science and Pollution Research*, *30*(36), 86328–86337. https://doi.org/10.1007/s11356-023-28524-7
4. Alhosani, F., Islayem, D., Almansoori, S., Zaka, A., Nayfeh, L., Rezk, A., Yousef, A. F., Pappa, A. M., & Nayfeh, A. (2025). Antibiofilm activity of ZnO–Ag nanoparticles against Pseudomonas aeruginosa. *Scientific Reports*, *15*(1), 17321. https://doi.org/10.1038/s41598-025-02372-6
5. Balcázar, J. L., Subirats, J., & Borrego, C. M. (2015). The role of biofilms as environmental reservoirs of antibiotic resistance. *Frontiers in Microbiology*, *6*. https://doi.org/10.3389/fmicb.2015.01216
6. Boukhoubza, I., Khenfouch, M., Achehboune, M., Mothudi, B. M., Zorkani, I., & Jorio, A. (2019). X-ray diffraction investigations of nanostructured ZnO coated with reduced graphene oxide. *Journal of Physics: Conference Series*, *1292*(1), 012011. https://doi.org/10.1088/1742-6596/1292/1/012011
7. Doğan, S. Ş., & Kocabaş, A. (2020). Green synthesis of ZnO nanoparticles with *Veronica multifida* and their antibiofilm activity. *Human & Experimental Toxicology*, *39*(3), 319–327. https://doi.org/10.1177/0960327119888270
8. Faisal, S., Jan, H., Shah, S. A., Shah, S., Khan, A., Akbar, M. T., Rizwan, M., Jan, F., Wajidullah, Akhtar, N., Khattak, A., & Syed, S. (2021). Green Synthesis of Zinc Oxide (ZnO) Nanoparticles Using Aqueous Fruit Extracts of *Myristica fragrans*: Their Characterizations and Biological and Environmental Applications. *ACS Omega*, *6*(14), 9709–9722. https://doi.org/10.1021/acsomega.1c00310
9. González-Fernández, J. V., David Pinzón-Moreno, D., Alexander Neciosup-Puican, A., & Verónica Carranza-Oropeza, M. (2022). Green Method, Optical and Structural Characterization of ZnO Nanoparticles Synthesized Using Leaves Extract of M. oleifera. *Journal of Renewable Materials*, *10*(3), 833–847. https://doi.org/10.32604/jrm.2021.017377
10. Kamimura, R., Kanematsu, H., Ogawa, A., Kogo, T., Miura, H., Kawai, R., Hirai, N., Kato, T., Yoshitake, M., & Barry, D. M. (2022). Quantitative Analyses of Biofilm by Using Crystal Violet Staining and Optical Reflection. *Materials*, *15*(19), 6727. https://doi.org/10.3390/ma15196727
11. Lahiri, D., Ray, R. R., Sarkar, T., Upadhye, V. J., Ghosh, S., Pandit, S., Pati, S., Edinur, H. A., Abdul Kari, Z., Nag, M., & Ahmad Mohd Zain, M. R. (2022). Anti-biofilm efficacy of green-synthesized ZnO nanoparticles on oral biofilm: In vitro and in silico study. *Frontiers in Microbiology*, *13*. https://doi.org/10.3389/fmicb.2022.939390
12. Merritt, J. H., Kadouri, D. E., & O'Toole, G. A. (2006). Growing and Analyzing Static Biofilms. *Current Protocols in Microbiology*, *00*(1). https://doi.org/10.1002/9780471729259.mc01b01s00
13. Nazir, A., Nazir, A., Zuhair, V., Aman, S., Sadiq, S. U. R., Hasan, A. H., Tariq, M., Rehman, L. U., Mustapha, M. J., & Bulimbe, D. B. (2025). The Global Challenge of Antimicrobial Resistance: Mechanisms, Case Studies, and Mitigation Approaches. *Health Science Reports*, *8*(7). https://doi.org/10.1002/hsr2.71077
14. Noimark, S., Weiner, J., Noor, N., Allan, E., Williams, C. K., Shaffer, M. S. P., & Parkin, I. P. (2015). Dual-Mechanism Antimicrobial Polymer–ZnO Nanoparticle and Crystal Violet-Encapsulated Silicone. *Advanced Functional Materials*, *25*(9), 1367–1373. https://doi.org/10.1002/adfm.201402980
15. O'Toole, G. A. (2011). Microtiter Dish Biofilm Formation Assay. *Journal of Visualized Experiments*, (47). https://doi.org/10.3791/2437
16. Pugazhendhi, A., Mathimani, T., Alharbi, S. A., Chinnathambi, A., Karuppusamy, I., Brindhadevi, K., Kheawfu, K., & Pikulkaew, S. (2022). In vitro efficacy of green synthesized ZnO nanoparticles against biofilm and virulence

of Serratia marcescens. *Progress in Organic Coatings*, *166*, 106781. https://doi.org/10.1016/j.porgcoat.2022.106781

17. Shukla, S. K., & Rao, T. S. (2017). *An Improved Crystal Violet Assay for Biofilm Quantification in 96-Well Microtitre Plate*. https://doi.org/10.1101/100214
18. Udayagiri, H., Sana, S. S., Dogiparthi, L. K., Vadde, R., Varma, R. S., Koduru, J. R., Ghodake, G. S., Somala, A. R., Boya, V. K. N., Kim, S.-C., & Karri, R. R. (2024). Phytochemical fabrication of ZnO nanoparticles and their antibacterial and anti-biofilm activity. *Scientific Reports*, *14*(1), 19714. https://doi.org/10.1038/s41598-024-69044-9
19. Zarean, M., Dave, S. H., Brar, S. K., & Kwong, R. W. M. (2025). Environmental drivers of antibiotic resistance: Synergistic effects of climate change, co-pollutants, and microplastics. *Journal of Hazardous Materials Advances*, *19*, 100768. https://doi.org/10.1016/j.hazadv.2025.100768
20. Zeghoud, S., Hemmami, H., Ben Seghir, B., Ben Amor, I., Kouadri, I., Rebiai, A., Messaoudi, M., Ahmed, S., Pohl, P., & Simal-Gandara, J. (2022). A review on biogenic green synthesis of ZnO nanoparticles by plant biomass and their applications. *Materials Today Communications*, *33*, 104747. https://doi.org/10.1016/j.mtcomm.2022.104747

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Original Article

Prevalence and Effect of Fungal Diseases on Chilli Crop at Different Growth Stages in Nanded District

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Manuscript ID:
JRD -2026-180436
ISSN: 2230-9578
Volume 18
Issue 4(XI)
Pp. 243-245
April - 2026

Submitted: 17 Mar. 2026
Revised: 30 Mar. 2026
Accepted: 10 Apr . 2026
Published:30 April2026

Abstract
A field-based study was conducted to assess the occurrence and impact of major fungal diseases of chilli across different growth stages. The results revealed distinct stage-wise prevalence of fungal pathogens. During the sapling stage, soil-borne fungi such as Fusarium solani and Rhizoctonia solani showed higher incidence, indicating their role in early seedling infections. In contrast, foliar and fruit pathogens including Alternaria alternata and Colletotrichum capsici exhibited maximum severity during vegetative and reproductive stages, suggesting their significant contribution to disease development and potential yield loss. Moderate incidence of Alternaria solani, Leveillula taurica, and Colletotrichum gloeosporioides was also observed during later growth stages. Some pathogens like Pythium aphanidermatum and Sclerotium rolfsii showed limited or stage-specific occurrence, while Phytophthora capsici and Verticillium dahliae were not detected during the study period. Overall, the findings highlight that fungal disease dynamics in chilli vary with crop growth stages, emphasizing the need for stage-specific disease management strategies.

Key Words: *Occurrence, Chilli, Fungal Diseases, Nanded*

Introduction

Chilli (*Capsicum annuum* L.) is one of the most important commercial spice and vegetable crops cultivated in India, valued for its culinary, nutritional, and economic significance. It is widely grown in states like Maharashtra, including the Nanded district, where it serves as a major source of income for farmers. Despite its importance, chilli production is severely constrained by several biotic stresses, among which fungal diseases are the most destructive, causing significant yield and quality losses. Fungal pathogens affect chilli plants at all stages of growth, from seedling to fruiting. Soil-borne fungi such as *Fusarium spp.*, *Rhizoctonia solani*, and *Pythium spp.* are commonly associated with damping-off and root rot during the early (sapling) stage, often leading to poor plant establishment. As the crop progresses to vegetative and reproductive stages, foliar and fruit-infecting pathogens like *Alternaria alternata*, *Colletotrichum capsici*, *Cercospora capsici*, and *Leveillula taurica* become more prominent, resulting in leaf spots, blights, powdery mildew, and fruit rot. These diseases not only reduce yield but also adversely affect the market quality of the produce. The present study was undertaken to investigate the prevalence and effect of major fungal diseases on chilli crop at different growth stages in Nanded district. The findings of this study will help in identifying critical stages of disease occurrence and support the development of stage-specific and region-specific management practices for sustainable chilli production.

Materials and Methods

In the Nanded district, diseased samples were collected from nearby marketplaces and farms that grow chillies. Critical analysis was done on the signs of the infection on the plant's leaves, stems, and fruits. To isolate and identify the disease-causing bacteria, samples displaying typical fruit rot signs were collected from nearby markets and chilli-growing regions and transported to the study lab in plastic bags.

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How to cite this article:
Sayyad, I. G. (2026). Prevalence and Effect of Fungal Diseases on Chilli Crop at Different Growth Stages in Nanded District. Journal of Research and Development, 18(4(XI)), 243–245.
https://doi.org/10.5281/zenodo.21128053

Quick Response Code:
Website:
https://jrdrvb.org/
DOI: 10.5281/zenodo.21128053
OPEN ACCESS

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Isolated fungal types were identified using the available literature, which included manuals and monographs. Thom and Raper (1945), Barnet and Hunter (1972), Ellis (1971), Gilman (1959), Nagamani et al. (2006), and Mukadam et al. (2006).

Results

The results revealed a clear variation in the occurrence of fungal pathogens across different growth stages of the chilli crop. During the sapling stage, soil-borne fungi were predominant, with *Fusarium solani* and *Rhizoctonia solani* showing higher incidence, followed by *Fusarium oxysporum* and *Sclerotium rolfsii* with low occurrence. Most of the foliar pathogens such as *Alternaria alternata*, *Alternaria solani*, *Cercospora capsici*, and *Colletotrichum spp.* were absent at this stage.

In the vegetative stage, a shift in pathogen prevalence was observed, where foliar fungi became more prominent. *Alternaria alternata* exhibited very high incidence, while *Alternaria solani*, *Colletotrichum capsici*, *Colletotrichum gloeosporioides*, and *Leveillula taurica* showed moderate incidence. *Cercospora capsici*, *Pythium aphanidermatum*, and *Rhizoctonia solani* were recorded with low incidence. In contrast, *Fusarium solani*, *Sclerotium rolfsii*, and *Phytophthora capsici* were absent during this stage.

At the reproductive stage, *Alternaria alternata* and *Colletotrichum capsici* recorded the highest severity, indicating their major role in disease development during fruiting. Moderate incidence was observed in *Alternaria solani* and *Leveillula taurica*, while *Cercospora capsici*, *Colletotrichum gloeosporioides*, *Rhizoctonia solani*, and *Sclerotium rolfsii* showed low occurrence. Soil-borne pathogens such as *Fusarium oxysporum* and *Fusarium solani* were absent at this stage. Notably, *Phytophthora capsici* and *Verticillium dahliae* were not observed at any growth stage of the crop.

Overall, the findings indicate that soil-borne pathogens dominate during the early growth stage, whereas foliar and fruit-infecting fungi become more severe during the vegetative and reproductive stages of the chilli crop.

Fungal incidence on Chilly from Nanded District

Name of Fungi	Crop Stages		
	Sapling	Vegetative	Reproductive
Alternaria alternata	–	+++	+++
Alternaria solani	–	++	++
Cercospora capsici	–	+	+
Colletotrichum capsici	–	++	+++
Colletotrichum gloeosporioides	–	++	+
Fusarium oxysporum	+	-	–
Fusarium solani	++	–	–
Leveillula taurica	–	++	++
Phytophthora capsici	–	–	–
Pythium aphanidermatum	–	+	–
Rhizoctonia solani	++	+	+
Sclerotium rolfsii	+	–	+
Verticillium dhaliae	–	–	–

Discussion

The present investigation clearly demonstrated that the prevalence and severity of fungal diseases in chilli varied significantly with crop growth stages, indicating a strong relationship between pathogen activity, host susceptibility, and environmental conditions. During the sapling stage, soil-borne pathogens such as *Fusarium solani* and *Rhizoctonia solani* were predominant, showing higher incidence. This may be attributed to their ability to survive in soil and infect young seedlings under favorable moisture and temperature conditions, leading to damping-off and poor plant establishment. The presence of *Fusarium oxysporum* and *Sclerotium rolfsii* at lower levels further supports the role of soil-inhabiting fungi in early-stage infections.

As the crop progressed to the vegetative stage, a noticeable shift from soil-borne to foliar pathogens was observed. *Alternaria alternata* exhibited the highest incidence (+++), followed by *Alternaria solani*, *Colletotrichum capsici*, *Colletotrichum gloeosporioides*, and *Leveillula taurica* with moderate occurrence. This increase in foliar diseases may be due to dense canopy development, higher humidity, and favorable microclimatic conditions that promote spore germination and infection. The occurrence of *Cercospora capsici* and *Pythium aphanidermatum* at lower levels suggests their limited but notable role during this stage.

During the reproductive stage, the severity of certain pathogens further increased, particularly *Alternaria alternata* and *Colletotrichum capsici*, which showed maximum incidence (+++). This indicates their critical role in causing leaf blight and fruit rot, ultimately leading to significant yield and quality losses. Moderate incidence of *Alternaria solani* and *Leveillula taurica*, along with low occurrence of *Cercospora capsici*, *Colletotrichum*

gloeosporioides, *Rhizoctonia solani*, and *Sclerotium rolfsii*, suggests that multiple pathogens coexist during this stage, though with varying degrees of severity. The absence of *Fusarium spp.* during later stages indicates that these pathogens are primarily confined to early crop growth.

Interestingly, *Phytophthora capsici* and *Verticillium dahliae* were not recorded at any stage of crop growth, which may be due to unfavorable environmental conditions, absence of inoculum, or resistant crop varieties in the study area. Overall, the findings are in line with general disease dynamics in chilli, where soil-borne pathogens dominate early stages, while foliar and fruit pathogens become more aggressive during later stages.

These results emphasize the importance of adopting stage-specific disease management strategies. Early-stage control measures should focus on soil treatment and seedling protection, while foliar fungicide applications and canopy management become crucial during vegetative and reproductive stages to minimize disease impact and ensure better yield and quality.

References

1. Barnett H and Hunter B. B., 1972. Illustrated genera of imperfect Fungi. 3rd ed. Burgers publishing Company USA. 241.
2. Ellis M. B., 1971. Dematiaceus Hyphomycetes. Kew Surrey UK: Commonwealth Mycological Institute.
3. Gilman, J.C., 1959. A manual of soil fungi. Published by Oxford and IBH publishing co. 2nd ed. pp.449.
4. MacNeish RS. 1964. Ancient Meso American civilization. Science.;143 (3606):531-537
5. Mukadam D.S., Patil M. S., Chavan A. M., and Patil A. R. 2006. “The Illustrations of Fungi.” Sarswati publication, Aurangabad.
6. Nagamani A., Kumar I. K. and Manoharachary C. 2006. Hand Book of Soil Fungi, I.K. International Publishing House Pvt Ltd, New Delhi, India.
7. Panda, R., Panda, H., Prakash, K., and Panda, A. 2010. Prospects of Indian Chillies. *Science tech entrepreneur,* pp. 8.
8. Thom and Raper 1945. A manual of the Aspergilli, Baltimore, the Williams & Wilkins Company.

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Original Article

Quantitative and Qualitative HPTLC Analysis of β-Sitosterol in *Bacopa monnieri and Trigonella foenum-graecum*

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Manuscript ID:
JRD -2026-180437
ISSN: 2230-9578
Volume 18
Issue 4(XI)
Pp. 246-254
April - 2026
Submitted: 17 Mar. 2026
Revised: 30 Mar. 2026
Accepted: 10 Apr . 2026
Published:30 April2026

Abstract

The present study was carried out for qualitative and quantitative determination of β-sitosterol in Bacopa monnieri and Trigonella foenum-graecum using High-Performance Thin Layer Chromatography (HPTLC). Calibration curve was plotted by keeping the peak area and concentration of the standard on the y-axis and x-axis, respectively. HPTLC analysis of standard (0.1mg/ml) and plant extract samples, injected in different volumes (2, 4, and 6 µl) for qualitative analysis and for quantitative analysis (6,8 µl) consistently gave the same bands with the same Retention Factor value (Rf) ranging from 0.74-0.75. The results of densitometric scanning at a wavelength of 580 nm indicated significant peaks in the Rf range between 0.7 and 0.8 for the standards and samples. A linear calibration graph, with correlation coefficients (R) and R^2 equal to 0.988380 and 0.9769, respectively, was observed. Within the range of 100 to 700 ng, a CV of 5.61% was obtained. The quantitative analysis revealed that the concentration of β-sitosterol in Bacopa monnieri was 12.64 µg/mL, while in Trigonella foenum-graecum, there were 18.64 µg/mL and 17.38 µg/mL. Despite being lower in fenugreek plants, concentrations could be higher due to a higher level of β-sitosterol. The slight differences observed in the Rf values are associated with experimental errors. In summary, the research verifies the presence of β-sitosterol in both plants; however, the presence of β-sitosterol in fenugreek seeds is relatively high compared to neem leaves. It can be concluded that HPTLC is an accurate and highly effective method for analyzing phytochemicals.

Keywords: *Bacopa monnieri (L.) Brahmi, Trigonella foenum-graecum (L). β-sitosterol, HPTLC*

Introduction

Beta-sitosterol is a type of phytosterol that is mostly present in plants and seeds in nature. It has anti-inflammatory effects that affect how the immune system works and help lower pro-inflammatory mediators (Bouic et al., 1996). Beta-sisterol has demonstrated antioxidant properties by neutralizing free radicals and diminishing oxidative stress on cells induced by free radicals (Gupta et al., 2011). B-sitosterol lowers cholesterol because it is quickly absorbed in the intestines, which means it competes with dairy cholesterol absorption and lowers serum cholesterol levels (Ling & Jones, 1995).

Bacopa monnieri (L) belongs to the Scrophulariaceae family. It is a medicinal herb that thrives in marshy, humid, and wet areas all throughout the Indian subcontinent. Indigenous healthcare systems utilize *Bacopa monnieri* (L) to address many neurological disorders, including sleeplessness, anxiety, seizures, hysteria, and to enhance intellectual and cognitive functions (Aguiar & Borowski, 2013). In *Bacopa monnieri* there are many phytochemicals which help to make it a good medicine including sterols like β-sitosterol. (Rajan et al; 2015; Saha et al; 2020). .Fenugreek (*Trigonella foenum-graecum L.*), a member of the Leguminous family, is an annual herb that is noted for its health benefits. People often call it "Methi." It hails from West Africa and the Mediterranean. People all throughout the world grow fenugreek now.

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Quick Response Code:
Website:
https://jrdrvb.org/
DOI: 10.5281/zenodo.21128179
OPEN ACCESS

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How to cite this article:
Khan, Y. N., & Rangari, A. K. (2026). Quantitative and Qualitative HPTLC Analysis of β-Sitosterol in Bacopa monnieri and Trigonella foenum-graecum. Journal of Research and Development, 18(4(XI)), 246–254.https://doi.org/10.5281/zenodo.21128179

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Egypt, Canada, and India are some of the biggest producers. Besides being a common spice used in cooking, the seeds of this plant are also used in traditional medicine and to make drugs and nutritional supplements. (Almatroodi et al., 2021; Salarbashi et al., 2019; Gavahian et al., 2024). Fenugreek seeds possess medicinal characteristics and therapeutic effects due to their phytoconstituents, including phytosterols such as β-sitosterol (Basch et al., 2003; Yadav & Baquer, 2014).

Materials and Methods

Plant Materials

Whole plant of Bacopa monnieri (Brahmi) and seeds of Trigonella foenum-graecum (Fenugreek) were procured from the local market and authenticated for purity before use.

Chemicals and Reagents

The mobile phase consisted of Cyclopentyl methyl ether (CPME), Tetrahydrofuran (THF), Water, and Hexane-Free Acid (HF) in the ratio 40:24:1:1. Silica gel 60 F254 (10 × 20 cm) plates were used as the stationary phase. Methanol and Anisaldehyde Sulphuric Reagent (ASR) were used for extraction and derivatization.

Instrumentation

Analysis was carried out using ATS 4 (Automatic TLC Sampler), CAMAG twin trough chamber (10 × 20 cm), TLC visualizer, densitometric scanner, and automatic derivatizer.

Collection and Sample Preparation

Plant materials were washed with distilled water, shade-dried at room temperature, and ground into fine powder. The powders were sieved for uniform size and stored in airtight containers.

Plant Materials

The plant materials used for the study were the Bacopa monnieri (brahmi) whole plant and Trigonella foenum-graecum (fenugreek) seeds. The samples were collected from the local market and analyzed for purity before experimentation.

Chemicals

Mobile Phase: Cyclopentyl methyl ether (CPME) :Tetrahydrofuran (THF) :Water : Hexane Free Acid (HF) in the ratio 40:24:1:1.

Stationary Phase:Silica gel 60 F254 10×20 cm.

Instrumentation

Analytical instruments :ATS 4 (Automatic TLC Sampler 4),TTC chambers of dimensions 10 x 20 cm,TLC visualizer,Densitometric scanner,Automatic Derivatizer.

Qualitative Phytochemical Analysis of B-Sitosterol

Preparation of Extracts and Standard

5 ml of methanol were used to dissolve 500 mg of Brahmi and fenugreek seed powder, making 100 mg/ml solutions. We also made a standard solution for β-sitosterol for (0.1 mg/ml). 2, 4 and 6 (µl) were taken from each sample and standard, for a total of 12 tracks to examine at (Harborne, 1998; Wagner & Bladt, 1996).

Chromatographic Conditions

The research was conducted on a 10 x 20 cm silica gel 60 F254 HPTLC plate. For development, we used a CAMAG twin trough chamber (TTC) that was the same size (10 x 20 cm). The distance for development was set at 7 cm. The chamber was pre-saturated with a saturation pad for 15 minutes before the development process to make sure that the solvent flowed evenly. The mobile phase was made by mixing cyclopentyl methyl ether (CPME), tetrahydrofuran (THF), water, and hexane free acid (HF) in a 40:24:1:1 ratio. This solvent system was adjusted to identify β-sitosterol.

Quantitative Phytochemical Analysis Of B-Sitosterol

Preparation of Extracts and Standard

We got a concentration of 100 mg/ml by weighing and extracting 600 mg of brahmi powder in 6 ml of methanol and fenugreek seed powder for Bacopa monnieri and 500 mg of powder in 5 ml of methanol making the concentration 200 mg/ml . We also made a β-sitosterol standard that had a concentration of 0.1 mg/ml. We took 6, 8 µl of each extract and the standard to see if the chemical was there at varying levels. A total of 15 tracks were employed to hold both test samples and standard replicates, which were a high-concentration extract (Harborne, 1998; Wagner & Bladt, 1996).

Chromatographic Conditions

The chromatographic separation took place on a silica gel 60 F254 plate that was 10 × 20 cm and had a development distance of 7 cm. To make sure that the solvent moved evenly, a CAMAG twin trough chamber was pre-saturated with the mobile phase for 15 minutes. The mobile phase was made up of 40% cyclopentyl methyl ether (CPME), 24% tetrahydrofuran (THF), 1% water, and 1% hexane-free acid (HF). The plate was developed up to 7 cm after it was applied and cured in a fume hood.

Derivatization, Detection and Quantification

After the sample bands were applied and dried, the plate was developed to a height of 7 cm. After drying, the plate was treated again with Anisaldehyde Sulphuric Reagent (ASR), which made the bands easier to see. The β-sitosterol standard had a strong Rf value of 0.74, which was used as a reference for identifying compounds in both herbal extracts

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

in qualitative analysis. The same was done for quantitative analysis to make the bands easier to see, which had an Rf value of 0.75.To do a quantification analysis, a calibration curve was made by plotting the peak area against the concentration of the β-sitosterol standard. We figured out how much β-sitosterol was in the brahmi and fenugreek seed samples by looking at the peak regions of the samples and the standard calibration curve.

Observations and Results

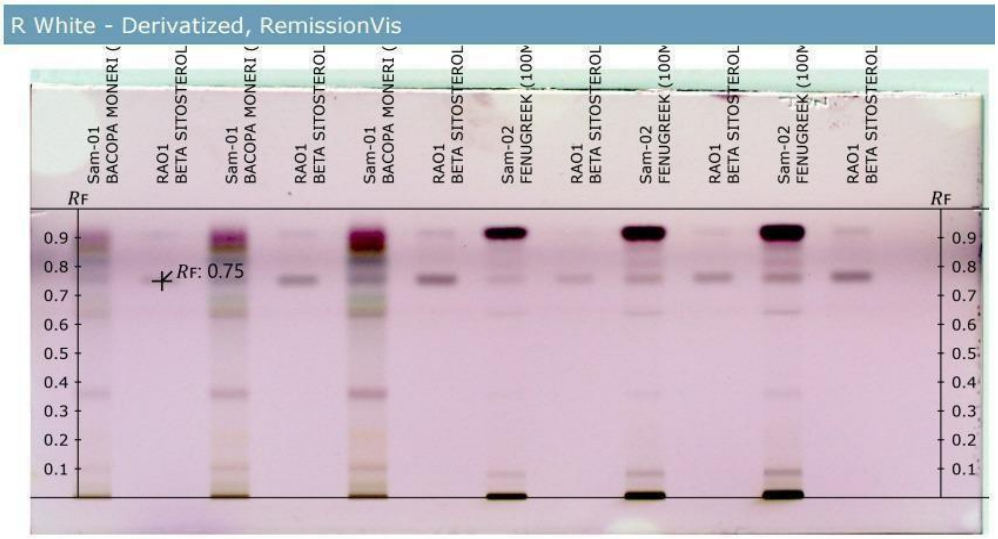

Plate 1. Qualitative Analysis of Brahmi and Fenugreek seeds at R White

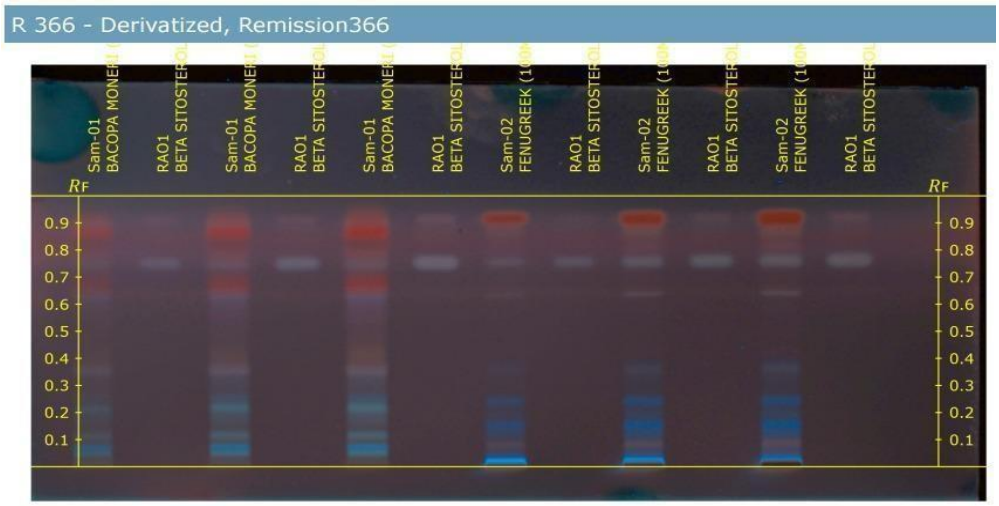

Plate 2. Qualitative Analysis of Brahmi and Fenugreek seeds R 366 nm

Table 1: Rf Values of Samples at Different Application Volumes

Sample Name	Concentration (mg/mL)	Volume Applied (µL)	Rf Value
Standard (β-sitosterol)	0.1	2–6	0.75
Bacopa monnieri (L.)	100	2–6	0.75
Trigonella foenum-graecum L.	100	2–6	0.75

We did HPTLC analysis on the standard β-sitosterol and sample extracts with different levels of application (2, 4, and 6 µL**). (Table no:1)**. The band development for the standard β-sitosterol solution (0.1 mg/mL) remained consistent at an Rf value of 0.75, irrespective of the volume applied. The *Bacopa monnieri* and fenugreek extracts (100 mg/mL) also had the same Rf value when different amounts of volume (2, 4, and 6 µL) were used. The fact that the Rf value stays the same for all tracks suggests that the chemical behavior in both standard and sample solutions stays the same. This proves

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that *Bacopa monnieri* and fenugreek extracts do contain β-sitosterol because their Rf values are the same as the normal Rf value (0.75**) . (Plate :no:1-2)**

Quantitative Analysis

Images of Derivatized Plates at Rwhite and R 366 nm

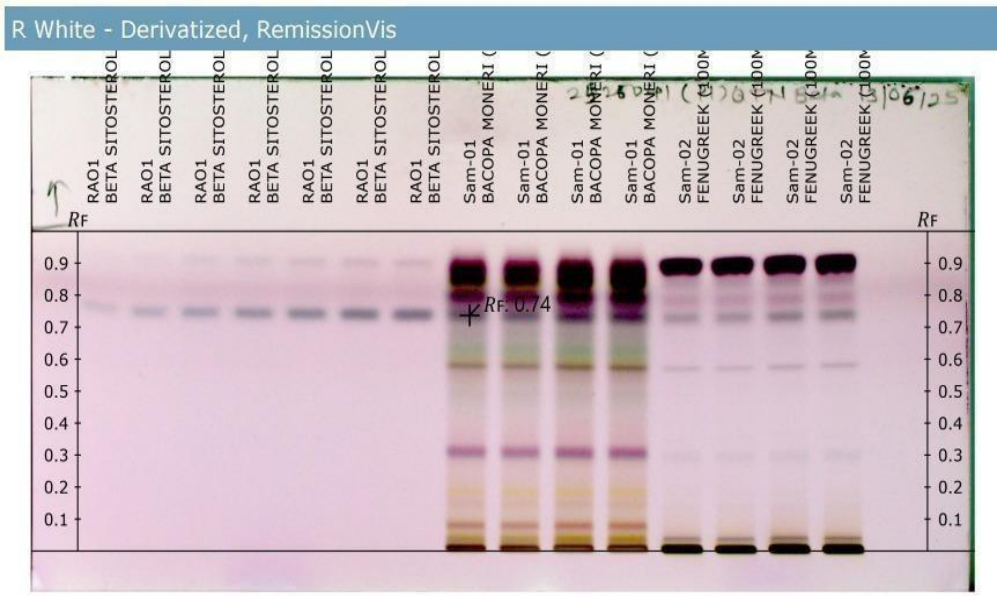

Plate 3. Quantitative Analysis of Brahmi and Fenugreek seeds at R White Light

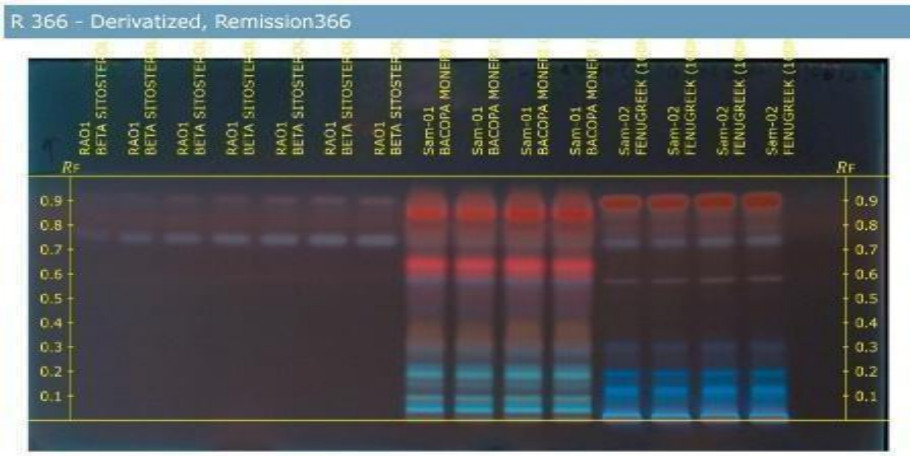

Plate 4. Quantitative Analysis of Brahmi and Fenugreek seeds at 366 nm

Table 2: Rf Values of Samples at Different Application Volumes

Sample Name	Concentration (mg/mL)	Volume Applied (µL)	Rf Value
Standard (β-sitosterol)	0.1	1–7	0.74
Bacopa monnieri (L.)	200	6–8	0.74
Fenugreek seeds	100	6–8	0.74

The TLC analysis demonstrated that the standard (0.1 mg/mL; 1–7 µL), *Bacopa monnieri* (200 mg/mL; 6–8 µL), and Fenugreek (100 mg/mL; 6–8 µL) samples consistently exhibited an Rf value of 0.74**.(Table:2)** The fact that Rf (0.74 ± 0.00) doesn't change over all tracks shows that the migration behavior is the same, which means that the test samples have phytochemical components that are identical to those in the standard. Finding areas with the same Rf

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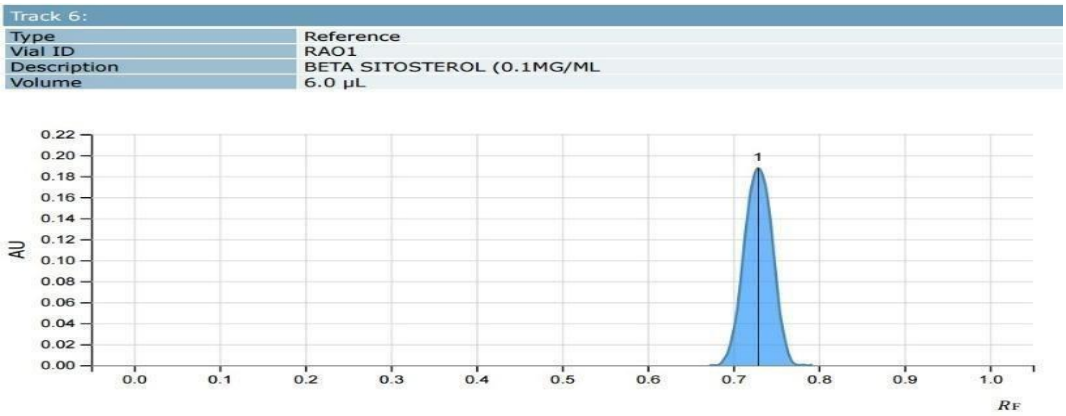
values shows that these substances are present. This means that more quantitative study can be done to get a more exact estimate.**(Plate:3- 4).**

Quantitative Scanning at 580 nm

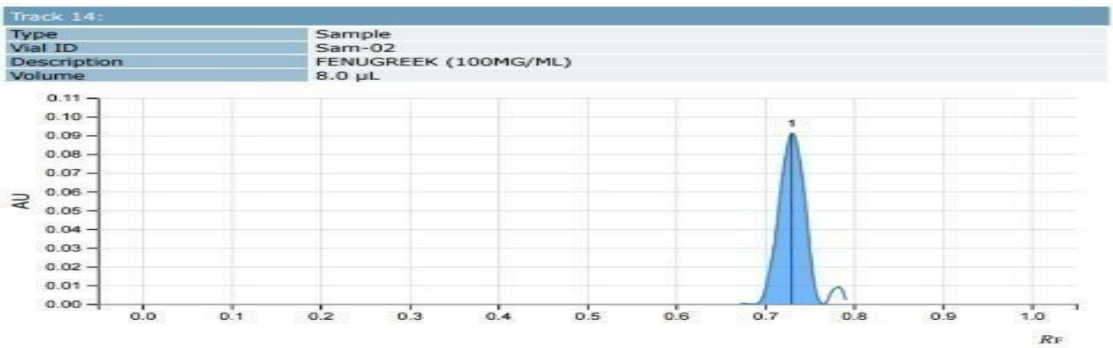


Peak #	Start R_F	Start H	Max R_F	Max H	Max %	End R_F	End H	Area A	Area %
1	0.681	0.0000	0.729	0.1878	100.00	0.777	0.0005	0.00754	100.00

Fig. 1. Standard track 6 scanning at 580 nm

Peak #	Start R_F	Start H	Max R_F	Max H	Max %	End R_F	End H	Area A	Area %
1	0.692	0.0000	0.724	0.0711	73.93	0.758	0.0098	0.00258	81.70
2	0.758	0.0098	0.779	0.0251	26.07	0.792	0.0030	0.00058	18.30

Fig. 2 Brahmi track 11 scanning at 580 nm



Peak #	Start R_F	Start H	Max R_F	Max H	Max %	End R_F	End H	Area A	Area %
1	0.690	0.0000	0.731	0.0911	100.00	0.765	0.0002	0.00307	100.00

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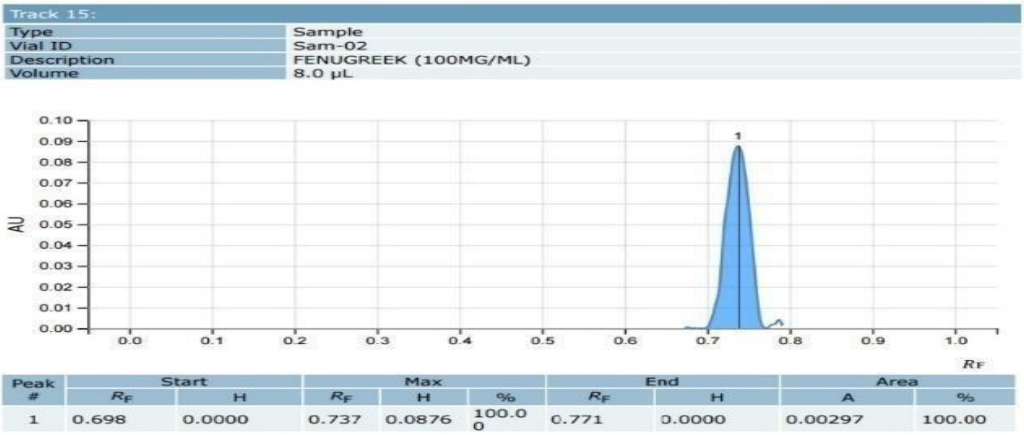
Fig3.Fenugreek seeds track 14 scanning at 580 nm



4. Fenugreek seeds track 15 scanning at 580 nm

Densitometric scanning at 580 nm showed that the standard β-sitosterol (track 6), *Bacopa monnieri* (track 11**), Fig:1-2.** and Fenugreek samples (tracks 14 and 15) all had strong peaks in the Rf range of 0.7–0.8, **Fig 3-4** which is where the most absorption happens. The existence of β-sitosterol in both *Bacopa monnieri* and Fenugreek is confirmed by the fact that the peaks in this Rf region are the same for both the standard and the plant samples. This also shows that β-sitosterol is in the samples, so it can be measured.

CALIBRATION CURVE

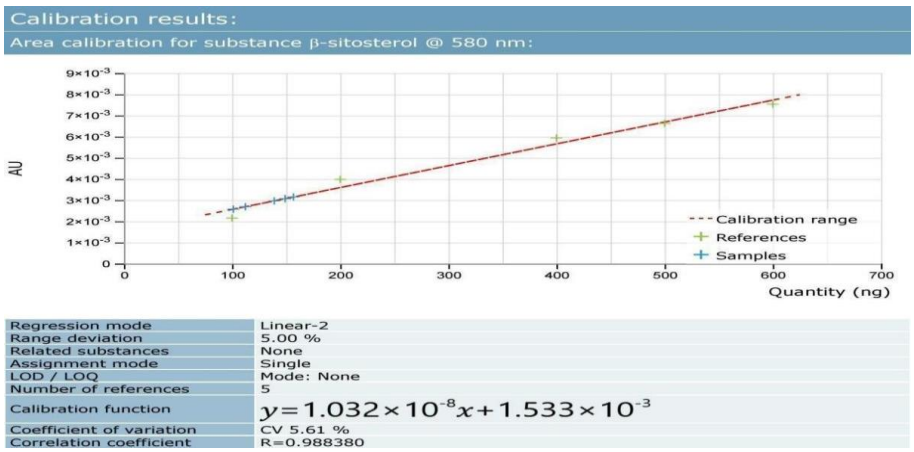


Fig. 5. Calibration Curve of the Samples with references

The calibration curve for β-sitosterol was established at 580 nm with values ranging from 100 to 700 ng. Concentration and absorbance linearity were linear with each other, as seen in the regression equation above. The test procedure showed linearity because the correlation coefficient (R) was 0.988380 and the R^2 value was 0.9769. For the concentrations we looked at, CV was 5.61%, which means that the approach was accurate enough**..(Fig no 5)**

Concentration Found After Quantification Of The Samples

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Fig. 6. *Bacopa monnieri*

β-sitosterol @ 580 nm *Calibration: Area - Linear-2, range deviation: 5.00 %*		
	Assignment count	5
Sample 'Sam-01' 12.64 µg in 200.0 mg		
	Average concentration Concentration standard deviation Assignment count	12.64 µg/mL (CV unavailable) 1
Volume: 8 µL		
	Average concentration Concentration standard deviation Assignment count	12.64 µg/mL (CV unavailable) 1
Track 11 R_F 0.724		
	Concentration Quantity	12.64 µg/mL 101.1 ng

β-sitosterol @ 580 nm *Calibration: Area - Linear-2, range deviation: 5.00 %*		
	Assignment count	5
Sample 'Sam-01' 12.64 µg in 200.0 mg		
	Average concentration Concentration standard deviation Assignment count	12.64 µg/mL (CV unavailable) 1
Volume: 8 µL		
	Average concentration Concentration standard deviation Assignment count	12.64 µg/mL (CV unavailable) 1
Track 11 R_F 0.724		
	Concentration Quantity	12.64 µg/mL 101.1 ng

Fig. 7. Fenugreek seeds Table 4. Quantitative Estimation of β-Sitosterol in Plant Extracts

Samples	Tracks	Volume (µL)	Rf	Peak Area	Concentration (µg/ml)
Standard β-sitosterol	6	6	0.681	0.0075	100
Bacopa monnieri	11	8	0.724	0.00258	12.64
Fenugreek seeds	14	8	0.731	0.00307	18.64
	15	8	0.737	0.00297	17.38

Rf values, peak area, and concentration were used as quantifying parameters to determine the level of β-sitosterol in the selected plant samples using a chromatographic technique. β-sitosterol with an Rf value of 0.681 was used for comparison purposes. The plants with Rf values similar to the standard were presumed to have β-sitosterol in their content. Track 11 with Rf value of 0.724 of *Bacopa monnieri* with a peak area of 0.00258 and a concentration of 12.64 µg/mL was evident. It is clear that there is only one slight difference in Rf values between the sample and the standard. This slight difference in Rf values can be attributed to experimental error or some other factors. Tracks 14,15 of fenugreek seeds with Rf values of 0.731 and 0.737, respectively, were almost similar to the standard. It was therefore clear that the plant contained β-sitosterol. The peak area in this plant was higher compared to *Bacopa monnieri*, with peak areas of 0.00307 and 0.00297. Also, the concentration of fenugreek seeds was high, with 18.64 µg/mL and 17.38 µg/mL. **Fig.6-7**.In general, all the Rf values were quite close to the standard value, signifying the presence of β-sitosterol. The variations in the phytochemicals in different plant sources could be implied based on quantitative differences in terms of peak area and concentration, where fenugreek seeds have a comparatively higher amount of β- sitosterol**.(Table no:4)**

DISCUSSION

The present study employed High-Performance Thin-Layer Chromatography (HPTLC) to confirm the presence of β-sitosterol in *Bacopa monnieri* and *Trigonella foenum-graecum*. For qualitative analysis, 500 mg of

each powdered plant material was accurately weighed and extracted with 5 mL of methanol, yielding a concentration of 100 mg/mL. A standard solution of β-sitosterol was prepared at a concentration of 0.1 mg/mL. Chromatographic analysis confirmed the presence of β-sitosterol in both samples, as indicated by a distinct band with an Rf value of 0.74, closely matching that of the standard. For quantitative analysis, stock solutions were prepared by extracting 500 mg of *Trigonella foenum- graecum* seed powder in 5 mL of methanol and 600 mg of *Bacopa monnieri* powder in 6 mL of methanol, each yielding a final concentration of 100 mg/mL.Methanol proved to be an effective solvent for the extraction of phytosterols and other bioactive compounds from plant materials (Harborne, 1998; Wagner & Bladt, 1996).

Medicinal plants are known to contain β-sitosterol, one of the most abundant phytosterols in higher plants, which plays a crucial role in biological activity and membrane stability (Saeidnia et al., 2014; Sayeed et al., 2016). Phytochemical studies have shown that *Bacopa monnieri* contains sterols such as β-sitosterol, along with other bioactive constituents responsible for its neuroprotective and therapeutic effects (Rajan et al., 2015; Saha et al., 2020; Russo & Borrelli, 2005). Similarly, significant amounts of phytosterols, including β-sitosterol, have been reported in the seeds of *Trigonella foenum-graecum*, contributing to their pharmacological properties (Gupta et al., 2012; Basch et al., 2003; Almatroodi et al., 2021).

Quantitative analysis revealed that *Bacopa monnieri* exhibited a β-sitosterol concentration of 12.64 µg/mL at track 11 with an application volume of 8 µL. In contrast, *Trigonella foenum-graecum* showed higher concentrations of 18.63 µg/mL and 17.38 µg/mL at tracks 14 and 15, respectively, under the same conditions. These findings indicate that fenugreek seeds contain a higher concentration of β-sitosterol compared to *Bacopa monnieri*. This observation is consistent with earlier studies reporting that seeds, particularly fenugreek seeds, are rich sources of phytosterols due to their role in storage metabolism (Basch et al., 2003; Gupta et al., 2012).

The variation in β-sitosterol content between the two plants may be attributed to differences in plant parts used, metabolic pathways, environmental conditions, and extraction efficiency. Seeds generally accumulate higher concentrations of sterols compared to other plant parts, which explains the elevated levels observed in fenugreek (Harborne, 1998).

This study provides a comparative evaluation and confirms the presence of β-sitosterol in both plant species. The higher concentration observed in fenugreek seeds highlights their potential as a rich natural source of β-sitosterol. Furthermore, the study demonstrates the effectiveness of HPTLC as a reliable Method for the identification and quantification of β-sitosterol in medicinal plants (Wagner & Bladt, 1996).

Conclusion

This research has successfully conducted a qualitative and quantitative evaluation of the phytochemicals in *Bacopa monnieri* and *Trigonella foenum-graecum*. Qualitative analysis has confirmed the presence of several phytochemicals in *Bacopa monnieri*, hence validating its application in traditional medicine. Quantitative analysis and HPTLC analysis confirmed the presence of β- sitosterol in both samples. The reference standard for β-sitosterol had an Rf value of 0.74, which was the same as the samples. The constant Rf value obtained from both samples has demonstrated the effective separation and identification of β-sitosterol using HPTLC analysis. This study has shown that HPTLC is a very good way to standardize the plant-based ingredients in herbal medicines. A lot of β- sitosterol is found in both plants, which makes them particularly valuable for medicine.helps in lowering cholesterol but disrupting intestinal absorption.

References

1. Bouic, P. J. D., Etsebeth, S., Liebenberg, R. W., Albrecht, C. F., Pegel, K., & Van Jaarsveld, P. P. (1996). Beta-sitosterol and beta-sitosterol glucoside stimulate human peripheral blood lymphocyte proliferation: Implications for their use as immunomodulatory agents. International Journal of Immunopharmacology, 18(12), 693–700.
2. Gupta, R., Sharma, A. K., Dobhal, M. P., Sharma, M. C., & Gupta, R. S. (2011). Antidiabetic and antioxidant potential of β-sitosterol in streptozotocin-induced experimental hyperglycemia. Journal of Diabetes, 3(1), 29–37.
3. Ling, W. H., & Jones, P. J. H. (1995). Dietary phytosterols: A review of metabolism, benefits and side effects. Life Sciences, 57(3), 195–206.
4. Aguiar, S., & Borowski, T. (2013). Neuropharmacological review of the nootropic herb Bacopa monnieri. Rejuvenation Research, 16(4), 313–326.
5. Rajan, K. E., Preethi, J., & Singh, H. K. (2015). Molecular and functional characterization of Bacopa monnieri: A retrospective review. Evidence-Based Complementary and Alternative Medicine, 2015, 945217.
6. Saha, P. S., Sarkar, S., Jeyasri, R., Muthuramalingam, P., Ramesh, M., & Jha, S. (2020). In vitro propagation, phytochemical and neuropharmacological profiles of Bacopa monnieri (L.) Wettst.: A review. Plants, 9(4), 411.
7. Almatroodi, S. A., Almatroudi, A., Alsahli, M. A., & Rahmani, A. H. (2021). Fenugreek (Trigonella foenum-graecum) and its active compounds: A review of its effects on human health through modulating biological activities. Pharmacognosy Journal, 13(3), 813–821.

8. Salarbashi, D., Mortazavi, S. A., Noghabi, M. S., & Sedaghat Doost, A. (2019). Fenugreek seed gum: Biological properties and food applications. International Journal of Biological Macromolecules, 122, 1091–1100.
9. Gavahian, M., Bannikoppa, A. M., Majzoobi, M., Hsieh, C. W., Lin, J., & Farahnaky, A. (2024). Fenugreek bioactive compounds: A review of applications and extraction based on emerging technologies. Critical Reviews in Food Science and Nutrition, 64(28), 10187– 10203.
10. Basch, E., Ulbricht, C., Kuo, G., Szapary, P., & Smith, M. (2003). Therapeutic applications of Trigonella foenum-graecum (fenugreek). Alternative Medicine Review, 8(1), 20–27.
11. Yadav, U. C. S., & Baquer, N. Z. (2014). Pharmacological effects of Trigonella foenum- graecum L. in health and disease. Pharmaceutical Biology, 52(2), 243–254.
12. Harborne, J. B. (1998). Phytochemical methods: A guide to modern techniques of plant analysis (3rd ed., pp. 60–66). Springer.
13. Wagner, H., & Bladt, S. (1996). Plant drug analysis: A thin layer chromatography atlas (2nd ed., pp. 1–20). Springer.
14. Saeidnia, S., Manayi, A., Gohari, A. R., & Abdollahi, M. (2014). The story of β-sitosterol: A review. European Journal of Medicinal Plants, 4(5), 590–609.
15. Sayeed, M. S. B., Karim, S. M. R., Sharmin, T., & Morshed, M. M. (2016). Critical analysis on characterization, systemic effect, and therapeutic potential of β-sitosterol. Medicines, 3(4), 29.
16. Russo, A., & Borrelli, F. (2005). Bacopa monniera, a reputed nootropic plant: An overview. Phytomedicine, 12(4), 305–317.
17. Dwivedi, J., Sachan, P., & Wal, P. (2024). A mechanistic approach on structural, analytical and pharmacological potential of β-sitosterol: A promising nutraceutical. Current Nutrition & Food Science, 20(8), 932–951.

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Original Article

A photographic checklist of *Ipomoea* (Convolvulaceae) from Alibag, Raigad District, Maharashtra, India

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Manuscript ID:
JRD -2026-180438
ISSN: 2230-9578
Volume 18
Issue 4(XI)
Pp. 255-261
April - 2026

Submitted: 17 Mar. 2026
Revised: 30 Mar. 2026
Accepted: 10 Apr . 2026
Published:30 April2026

Abstract:
The genus Ipomoea (Convolvulaceae) is widely distributed in tropical and subtropical regions and is particularly abundant in coastal and disturbed habitats; however, localized documentation from the Konkan coast of Maharashtra remains limited. The present study provides a photographic checklist of Ipomoea species from Alibag, Raigad District, based on field surveys conducted between 2012 and 2024. A total of 20 species were recorded from sandy beaches, roadside hedges, agricultural margins, wetlands, and urban areas. Each species is documented with brief diagnostic characters, habitat notes, phenology, and supporting photographs. This work represents the first focused account of Ipomoea from Alibag and provides baseline floristic data for future studies in the coastal Konkan region.
Keywords: *Alibag, Convolvulaceae; Ipomoea, Konkan, photographic checklist*

Introduction:

The family Convolvulaceae comprises approximately 57 genera and 1,955 accepted species worldwide (POWO, 2024), classified into six subfamilies and twelve tribes. It is geographically widespread across tropical, subtropical, and temperate regions, with its greatest diversity concentrated in the tropics and subtropics. Members of the family predominantly occupy open and disturbed habitats and rarely form components of dense primary forests. Ecologically and morphologically, Convolvulaceae exhibits remarkable diversity, ranging from slender twining climbers and robust woody lianas to prostrate herbs, subshrubs, shrubs, and, rarely, trees, as well as holoparasitic climbers such as *Cuscuta*. The family is readily recognized by its clockwise-twining stems, alternate exstipulate leaves, sympetalous corolla with five distinct mid-petaline bands, epipetalous stamens, and a bicarpellate superior ovary, typically producing a dehiscent capsular fruit.

The genus *Ipomoea* belongs to the family Convolvulaceae and derives its name from the Greek words *ips* (worm) and *homoios* (resembling), referring to the characteristic worm-like twining growth habit of many of its members (DeFelice, 2001). The genus *Ipomoea* is the most species-rich and taxonomically complex genus within Convolvulaceae, currently comprising approximately 615 accepted species (Simões et al., 2024; POWO, 2024). Species of *Ipomoea* are commonly known as "morning glories" and are widely recognized both as attractive ornamental plants and as aggressive weeds, depending on ecological and agronomic contexts. The genus is believed to have originated in the tropical Americas, from where several species were introduced into Europe and North America for food and ornamental purposes (DeFelice, 2001; Bryson & DeFelice, 2010). *Ipomoea* species are now ubiquitous components of disturbed ecosystems worldwide and are particularly abundant along roadsides, agricultural margins, fallow lands, and urban habitats (DeFelice, 2001; Holm et al., 1979).

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DOI: 10.5281/zenodo.21128718
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How to cite this article:
Phate, P., & Kawale, P. (2026). A photographic checklist of Ipomoea (Convolvulaceae) from Alibag, Raigad District, Maharashtra, India. Journal of Research and Development, 18(4(XI)), 255–261. https://doi.org/10.5281/zenodo.21128718

Journal of Research and Development
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ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Alibag (Alibaug) is a coastal town and municipal council in the Raigad District of Maharashtra, India, located on the Konkan coast of the Arabian Sea at approximately 18.64° N, 72.87° E with an average elevation near sea level. Alibag occupies a flat coastal plain bordered by the Arabian Sea to the west and the inland regions of the Western Ghats to the east, with interspersed marshes and sandy coastal terrain. The region experiences a tropical climate characterised by hot, humid summers, a pronounced monsoon season with heavy rainfall, and mild winters; average annual temperatures are around 26 °C with annual rainfall exceeding 2,400 mm, driven largely by the southwest monsoon. Its landscape includes sandy beaches, coastal scrublands, roadside disturbed habitats, agricultural margins, wetlands, and scrub forests, providing a range of ecological niches in which members of the genus *Ipomoea* occur. Alibag's coastal and disturbed environments support both native and widespread *Ipomoea* taxa, and its proximity to diverse habitats makes it an appropriate site for a floristic checklist of the genus.

Material and Methods:

Field surveys were conducted in and around Alibag, Raigad District, Maharashtra, between 2012 and 2024 to document the diversity of the genus *Ipomoea*. Repeated visits were made during different seasons to a variety of habitats, including sandy sea beaches, roadside hedges, agricultural margins, wetlands, fallow lands, and urban localities. Species were documented through direct field observation and in situ photography. For each encounter, photographs of the habit, leaves, and flowers were taken, and notes on habitat preference and phenology were recorded. Identification was carried out using standard regional and national floras, taxonomic literature, and online databases. Diagnostic morphological characters observed in the field and from photographs—such as habit, leaf shape, inflorescence, corolla characters, and sepals—were used for species determination. Current nomenclature and accepted names were verified using Plants of the World Online (POWO). The species are enumerated alphabetically and presented with brief diagnostic descriptions, habitat notes, and representative field photographs (Figure 1).

***Ipomoea alba* L.**

Herbaceous annual vine, capable of reaching 5–6 m in length. Stems are glabrous, smooth with milky latex. Leaves entire or three-lobed, ovate, broadly ovate to nearly circular blade, 5–15 (−20) cm by 5–10 (−15) cm, acuminate at the tip, deeply cordate at the base with rounded lobes, sometimes angled; inflorescences are cymose, axillary, with one to a few flowers; sepals are unequal, the outer ones elliptical, acuminate, 6–10 mm long, excluding the thread-like tip 5–9 mm long; the inner ones nearly circular, about 12 mm in diameter, with a triangular tip 3–4 mm long. Large, fragrant flowers. Corolla white, funnel-shaped, opening abruptly at dusk, with a slender tube 7–12 cm long and 5–6 mm in diameter; the limb is wheel-shaped, 8–10 cm in diameter. Stamens inserted toward the upper one-third of the corolla tube; anthers oblong, 4–6 mm long, protruding; filaments slender, not widened, and not hairy-papillose at the base. Stigmas protruding. Ovary conical, hairless. Capsule ovoid, apiculate, 20–25 mm in diameter, on a thickened, club-shaped pedicel; calyx persistent, enlarging. Seeds 4, subtriangular, 10–12 × 7–9 mm, hairless, or bearing small pressed, scattered papillose hairs.

Flowering & Fruiting: August–November

Distribution: Roadside hedges, compound walls, fences, and occasionally cultivated as an ornamental climber.

***Ipomoea aquatica* Forssk.**

Herbs, procumbent or floating, rooting at nodes; stems thick, hollow. Leaves 4.8 x 3.6 cm, ovate, triangular or oblong, lanceolate, much variable in shape and size with acute or rounded basal lobes, apex acute or obtuse; petioles 5.8 cm long. Inflorescence axillary, solitary or few flowered cymes on 1.10 cm long peduncles; bracts minute, narrow, acute; flowers on 2.7 cm long pedicels, purple or white; calyx ovate, oblong, subequal, 7.8 mm long, obtuse or subacute at apex; corolla 4.5 cm long, funnel shaped; filaments unequal, hairy at base. Capsules globose, 0.8.1.0 cm long, glabrous or grey pubescent. Seeds 4, densely soft pilose or glabrous.

Flowering & Fruiting: Throughout the year.

Distribution: Common along the margins of tanks and other moist bodies.

***Ipomoea biflora* (L.) Pers.**

Annual prostate or twining pilose herbs; stems 2.5 m long. Leaves simple, petiole 2-5 cm long, lamina entire, triangular to ovate, 3.5–9.5 cm long, 3.5–6.5 cm wide, sparsely pilose, cordate at base with round basal lobes, acuminate at the apex. Inflorescence Cymose, 1-3 flowered Flowers: small, white, peduncle up to 2.5 cm long, pedicle 1.6 cm long, hairy, bracts 2, small, linear to lanceolate, 5 mm long, hairy. Sepals 5 in number, unequal, accrescent, glabrous to pilose, outer 3 with ovate with cordate base, 4.5– 7.5 mm long, 2.5– 4.5 mm wide, inner 2 linear to oblong, 5 mm long, 3 mm wide, lanceolate with less ciliate margins. Corolla funnel shaped, white or with purple centre, 6-7 mm long, midpetaline areas strigose. Stamens 5 in number, 3 mm, anthers ovoid to deltoid with sagittate base, Ovary conical type, style short, stigma purplish, capsule globose, glabrous, 7-10 mm long, apiculate by the persistent style-base. Seeds: Sub-trigonous, velvety or grayish pubescent with gray hairs up to 4.5-5 mm long.

Flowering & Fruiting: September-December.

Distribution: Akola district, Mumbai-City district, Mumbai Suburban district

***Ipomoea cairica* (L.) Sweet**

Glabrous, perennial twinning herbs; root tuberous; stem terete, smooth. Leaves ovate or orbicular in outline, 3-10 cm long and broad, cordate at base, palmately divided into 5-7, ovate- lanceoate, or elliptic lobes which are entire

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acuminate and mucronate, petiole 2-6 cm long, often with pseudo stipules at base. Flower axillary in 1- few flowered cymes; peduncles 0.5-7 cm long; pedicels 1-2 cm long; bract minute. Sepal glabrous, subequal, ovate, 4-6 mm long, with pellucid dots on the back and pale scarious margin, obtuse, mucronate. Corolla funnel shaped, blue, purple or pale pink, 4-6 cm long. Stamens included; filaments pilose at base. Capsule subglobose, 10-12 in diam., 2-celled, 4-valved. Seeds 2-4, ovoid, 4-6 mm long, hairy.
Flowering & Fruiting: October-April.
Distribution: Mumbai, Pune, Amravati, Aurangabad

Ipomoea campanulata L.

Twiners, woody, rarely prostrate and rooting at nodes, nearly glabrous, young parts hoary. Leaves 6.16 x 3.5.14 cm, ovate or orbicular, rarely ovate.oblong, base shallowly cordate to truncate, apex acuminate or slightly mucronate, margins entire or undulate, slightly pubescent beneath, nerves 10.15 pairs; petioles slender, 3.10 cm, glabrous or pubescent. Inflorescence axillary, one to several flowered cymes; peduncles stout, 1.8 cm long, glabrous or rarely pubescent; pedicels 1.2.5 cm long, c 3 cm long in fruit, angular, thickened towards the calyx; calyx with slightly unequal margins; corolla reddish purple with a darker centre, tubular to funnel shaped; stamens and styles included; filaments hairy at apex. Capsules ovoid, c 1.5 cm long, brown, 2-celled, 4-valved. Seeds 4, 8.9 mm long, black, comose.
Flowering & Fruiting: October-March.
Distribution: Growing on thickets along hilly tracts of deciduous forests.

***Ipomoea carnea* Jacq.**

Shrubs, 1.0.2.5 m high, erect or ascending; young branches densely pubescent, glabrescent. Leaves 6.25 x 4.17 cm, ovate or ovate-oblong, base cordate to truncate, apex acuminate, puberulent mainly on nerves beneath; midrib below with 2 small glands at base of the leaf blade, lateral nerves 7.9 pairs, secondary nerves parallel. Inflorescence in axillary and terminal, many flowered cymes; peduncles stout; calyx subequal, orbicular, 5.6 mm long, puberulent; corolla pink or pale lilac, tubular to funnel shaped, 7.5.9 cm long. Capsules ovoid, mucronate, 1.5.2 cm long, pale brown, 4-valved. Seeds 4 or less, black, micro-villose.
Flowering & Fruiting: Throughout the year.
Distribution: Commonly introduced by villagers as fencing. Now naturalised in India as a weed and become troublesome.

Ipomoea clarkei Hook.f.

Twiners, slender. Leaves 5.9 x 4.6 cm, broadly ovate, finely acuminate, hairy on both surfaces, base deeply cordate with rounded lobes; petioles 2.5.6.0 cm long. Inflorescence 1.3 flowered cymes; peduncles 2.4 cm long, slender; bracts minute, lanceolate, acute; pedicels 0.5.3 cm long; calyx 0.8.1.0 cm long, linear-lanceolate, acute, sparsely hairy and ciliate; corolla 3.4 cm long, infundibuliform. Capsules c 1.5 cm long, ovoid.
Flowering & Fruiting: September-October.
Distribution: Rarely found in forests at high altitude. Eastern Ghat, Western Ghats of Maharashtra (Nasik, Pune and Thane district), Malshej Ghat, Satpuda range of Khandesh region, and Raigad (Phate and Kawale, 2019)

Ipomoea eriocarpa R.Br.

Herbs, twining or prostrate, retrorsely to patently pilose; stems herbaceous. Leaves mostly lanceolate to oblong or linear-lanceolate, 2.5.6.0 x 0.5.1.5 cm, sometimes ovate, 2.5.9.0 x 1.5.5.5 cm, base cordate, apex attenuate to acuminate with a mucronulate point, pubescent on both surfaces. Flowers axillary in sessile or short pedunculate cymes or heads; calyx ovate-linear, acuminate, 7.8 mm long, pilose; corolla tubular, slightly longer than sepals, 7.9 mm long, pink or purple. Capsules broadly ovoid to globular, 5.6 mm long, pubescent. Seeds minutely reticulate.
Flowering & Fruiting: August -October.
Distribution: Common in plains and lower hills in grasslands, hedges and fields.

Ipomoea hederifolia L.

Twiners, slender, glabrescent; stems herbaceous, terete or slightly angular, often contorted, 2.5 m long. Leaves ovate to suborbicular, 2.15 cm long, base cordate, apex acute to acuminate. Flowers in few to several flowered cymes, sometimes solitary; calyx oblong to elliptic, 1.5. 3.0 mm long, apically obtuse to truncate, the outer with a 1.6.6.0 mm long subterminal, fleshy arista; corolla red to orange, 2.5.4.5 cm long, salverform. Capsules subglobose, 6.8 mm long. Seeds dark brown or black pyriform.
Flowering & Fruiting: August-November.
Distribution: Along hedges in the outskirts of dry deciduous forests, generally grown in gardens as an ornamental plant and naturalised in many places. Common throughout.

***Ipomoea marginata* (Desr.) Verdc.**

Herbs, perennial; stems twining or prostrate, 1.0.2.5 m long, hirsute to glabrous. Leaves 2.5-6 x 2.5 cm, broadly ovate or orbicular, base deeply cordate, apex attenuate with minute hairs along margins above, margins purple. Inflorescence axillary, with thick peduncles, 5-12 cm long, few to several flowered; bracts minute, persistent; calyx equal, 4.6 mm long, coriaceous with thinner margins; corolla salver shaped, pale lilac, pink or nearly white, with a purple centre, 1.5-2.5 cm across. Capsules depressed-globular, 6-7 mm long. Seeds 4, covered with dense tomentum.

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Flowering & Fruiting: December-March.
Distribution: Occasional in moist grasslands, thickets, hedges, waste grounds and along roadsides. Amravati, Aurangabad, Beed, Jalna, Nanded, Raigad, Ratnagiri, Sindhudurg, Thane, Yavatmal.

***Ipomoea mauritiana* Jacq.**

Twiners, sometimes prostrate; roots tuberous; stems terete. Leaves 6.14 x 6.16 cm, palmately divided to or mostly beyond the middle, base cordate or truncate, segments 3-7- (9), lanceolate, apex mucronulate; petioles slightly muricated, 3.10 cm long. Inflorescence axillary; peduncles terete, glabrous, few-many flowered; flower buds globular; calyx equal in length, coriaceous, 6.12 mm long; corolla pale reddish purple, tube dark inside, 5.6 cm long, 5.7 cm cross. Capsules ovoid, obtuse, 12.14 cm long, glabrous. Seeds 4, black with long, wooly, sericeous hairs.
Flowering & Fruiting: October-January.
Distribution: Occasional in interior, moist deciduous forests. Nasik, Raigad, Ratnagiri, Sindhudurg, Thane, Yavatmal.

Ipomoea nil (L.) Roth

Twiners, anuuals; stems bristly-pilose. Leaves c 8 x 8 cm, ovate, base cordate, 3 lobed, apex acuminate, mostly adpressed pilose on both sides; petioles bristly, 4 cm long. Flowers solitary or in lax, few flowered cymes; peduncles 4.5 cm long; pedicels c 1.2 cm long; calyx linear- lanceolate, 2.5.3.0 x 3.0.3.5 cm, alternate at apex, densely pilose at base; corolla magenta coloured, 6.7.5 cm long, funnel shaped. Capsules ovoid to globular, 3-celled, c 1 cm across. Seeds c 5 mm long, black with grey pubescence.
Flowering & Fruiting: August-November.
Distribution: Common along hedges and thickets of deciduous forests.

***Ipomoea obscura* (L.) Ker Gawl.**

Herbs, slender, prostrate or twining, 1.2 m long, glabrous or patently hairy. Leaves 2.10 x 2.9 cm, ovate or orbicular, base cordate, apex attennuate or acuminate, entire or slightly undulate at margins, glabrous or sparsely pilose both sides; petioles c 9 cm long, sparsely hairy. Inflorescence of axillary, few flowered cymes; peduncles filiform, 1.14 cm long; calyx minutely verrucose, sepals subequal, ovate, 3-4 mm long; corolla funnel-shaped, white or pale yellow with a dark purple centre; stamens and styles included; filaments unequal. Capsules on reflexed pedicels, crowned by the style-base, globose, glabrous, straw coloured, 4-valved. Seeds 4, black, finely grey puberulent.
Flowering & Fruiting: August-February.
Distribution: Common along the hedges of thin forests also in grasslands and waste places.

Ipomoea pes-caprae (L.) R.Br.

Herbs, prostrate; stems trailing and rooting at nodes, glabrous. Leaves often secund, variable in shape, ovate, obovate, elliptic, orbicular or transverse, elliptic to reniform, 3.10 cm ong, truncate, base attenuate or cordate, apex deeply emarginate, mucronulate, fleshy, glabrous. Flowers usually solitary (Sometimes 2.3); sepals subequal or the outer shorter, the outer ovate to broadly elliptic, the inner mostly sub-orbicular, 5.11 mm long, obtuse, sub coriaceous; corolla limb pink to purple, 5.6 cm long. Capsules ovoid to depressed-globose, 12.17 cm long. Seeds black, densely short, brownish-tomentose.
Flowering & Fruiting: November-February.
Distribution: Common along coastal sand places. Mumbai, Raigad, Ratnagiri, Sindhudurg, Thane.

***Ipomoea pes-tigridis* L.**

Herbs, annuals; stems twining, prostate or sparwling, patently pubescent with rigid trichomes. Leaves orbicular to transversely elliptic in outline, palmately divided nearly to the base, 3-5-7 (.9)-lobed, lobes oblong to elliptic, ends both attenuate to acuminate, apicallly pubescent with appressed or patent trichomes, 3.7.5 cm long, often wider than long. Flowers in involucrate cymes; calyx lanceolate or the inner narrowly lanceolate, 7.12 mm long; corolla funnel shaped, white 2.2.5 cm long. Capsules ovoid, c 8 mm long. Seeds grey tomentose, 4 mm long.
Flowering & Fruiting: August - November.
Distribution: Common throughout in open grounds or hedges, often in cultivated fields.

***Ipomoea quamoclit* L.**

Annual herbs. Stems twining or prostrate, slender, angular, longitudinally ridged, glabrous. Leaves pinnately compound, ovate to oblong in outline, 3.5–10 × 3–6 cm, glabrous, leaflets 8–19 per leaf, opposite to nearly so, linear to filiform, the two lower ones reflexed and bifid, glabrous; petiole 1–4 cm long, glabrous, with two leaflike, subsessile, pseudo-stipules at the base. Inflorescences: peduncle slender, 3–8 cm long, glabrous; bracteoles deciduous, triangular, 1–3 mm long. Flower: pedicel 1–2.5 (–4.2) cm long, slightly thickened at the apex, glabrous. Sepals unequal, oblong to ovate-elliptic, apex obtuse and mucronate, glabrous, outer ones oblong, 4–5 mm long, inner ones ovate-elliptic, slightly longer, c. 6 mm long; corolla hypocrateriform, 2.5–5 cm long, scarlet red-pink, glabrous, with a cylindrical tube, slightly and gradually narrowed towards the base, corolla lobes spreading, broadly triangular, acute and mucronate. Stamens exserted; filaments of equal length, filiform, 19–23 mm, widened and pubescent at the base, inserted 4–5 mm above the base of the tube; anther 1–2 mm long, sagittate at the base. Ovary ovoid, c. 1.5 mm long, glabrous, 4-locular; style filiform, 19–30 mm long, glabrous, widened and articulated at the base. Fruits ovoid to globose, c. 15 × c. 18 mm, opening by 4 valves, with persistent style; seed fusiform, blackish, sparsely pubescent.
Flowering & Fruiting: Throughout the year

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Distribution: Commonly cultivated as a showy plant in overall Maharashtra, as well found as weed growing on fences along road sides in Maharashtra.

***Ipomoea sindica* Stapf**

Herbs, prostrate or twining, c 50 cm long, internodes c 11 cm long; stems slender, hispid with spreading hairs. Leaves oblong-triangular, 2.5.8 x 1.6 cm, with rounded lobes, apex acute or acuminate, softly hairy on both surface or nearly glabrous above; petioles 0.6.1.8 cm long, hispid. Flowers solitary or in few flowered cymes; bracts shorter than the calyx, linear, hispid; calyx ovate-lanceolate, 0.4.0.6 cm long, acuminate, hispid, enlarged in fruit; corolla funnel shaped, white, minutely pubescent outside, 0.8.1 cm long, limb brodly 5-lobed. Capsules 0.5.0.6 cm long, subglobose. Seeds black.

Flowering & Fruiting: August-October.

Distribution: Rarely found in waste places and open forests among grasses and bushes. Aurangabad, Chandrapur, Dhule, Jalna, Raigad (Phate and Kawale, 2021)

I. triloba L.

Herbs, twining, 1.5.2.5 m long, glabrous or sparingly hispid, particularly at nodes. Leaves broadly ovate to orbicular, 2.5.7 x 2.5.5 cm, coarsely dentate, 3 lobed, base cordate, basal lobes angular, glabrous or sparsely pilose on both the sides; petioles slender, 5.12 cm long, glabrous or slightly muricate. Inflorescence axillary; peduncles 5.8 cm long, slightly verrucose towards apex, few.several flowered; flowers aggregate; pedicels minutely verrucose; calyx unequal, 7.10 mm long, mucronulate at apex; corolla funnel shaped, 18.20 mm long, glabrous, pink or pale red.purple. Capsules globose. Seeds glabrous or thinly pubescent.

Flowering & Fruiting: October -November.

Distribution: Rare along the moist places and in wastelands.

***Ipomoea turbinata* Lag.**

Twiners, annuals with a white, milky juice; stems herbaceous, terete or angular, muricated. Leaves orbicular or broadly ovate, 7.18 x 6.5.15 cm, base cordate with broadly rounded lobes, apex acuminate with a mucronulate column; petioles 4.12 cm long, muricated or glabrous. Inflorescence one-few-flowered cymes; peduncles muricated, 3.6 cm long; pedicels 10-20 mm long, smooth, thickened towards calyx; calyx outer ones ovate-oblong, more or less plicate at the top, inner ones obtuse or slightly emarginate, distinctly awned; corolla funnel to salver shaped with narrow, cylindric tube. Capsules ovoid, 18.20 mm long. Seeds 4, glabrous, black, 9.10 mm long.

Flowering & Fruiting: January-March.

Distribution: Common along hedges and waste places. Ahmednagar, Amravati, Aurangabad, Chandrapur, Mumbai, Nagpur, Nanded, Nasik, Osmanabad, Parbhani, Pune, Raigad, Ratnagiri.

***Ipomoea violacea* L.**

Twiners; stems woody, terete or angular, often longitudinally wrinkled. Leaves orbicular or ovate, 5.16 x 5.14 cm, base deeply cordate; lateral nerves 7.8 on either side; petioles 3.5.16 cm long. Inflorescence axillary, one to few flowered; peduncles terete, 6.9 cm long; pedicels angular, 1.5.3 cm long; calyx orbicular, mucronulate at apex, outer ones 15.20 mm long, inner 18.25 mm long, coriaceous, enlarged in fruit; corolla white, salver shaped; stamens and styles included. Capsules globose, 2.5 cm long, pale brown. Seeds 4, black, hairy along margins.

Flowering & Fruiting: September-December

Distribution: Common on the sea shores and along thickets in forests. Kolhapur, Pune, Raigad, Ratnagiri, Sindhudurg, Thane.

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A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

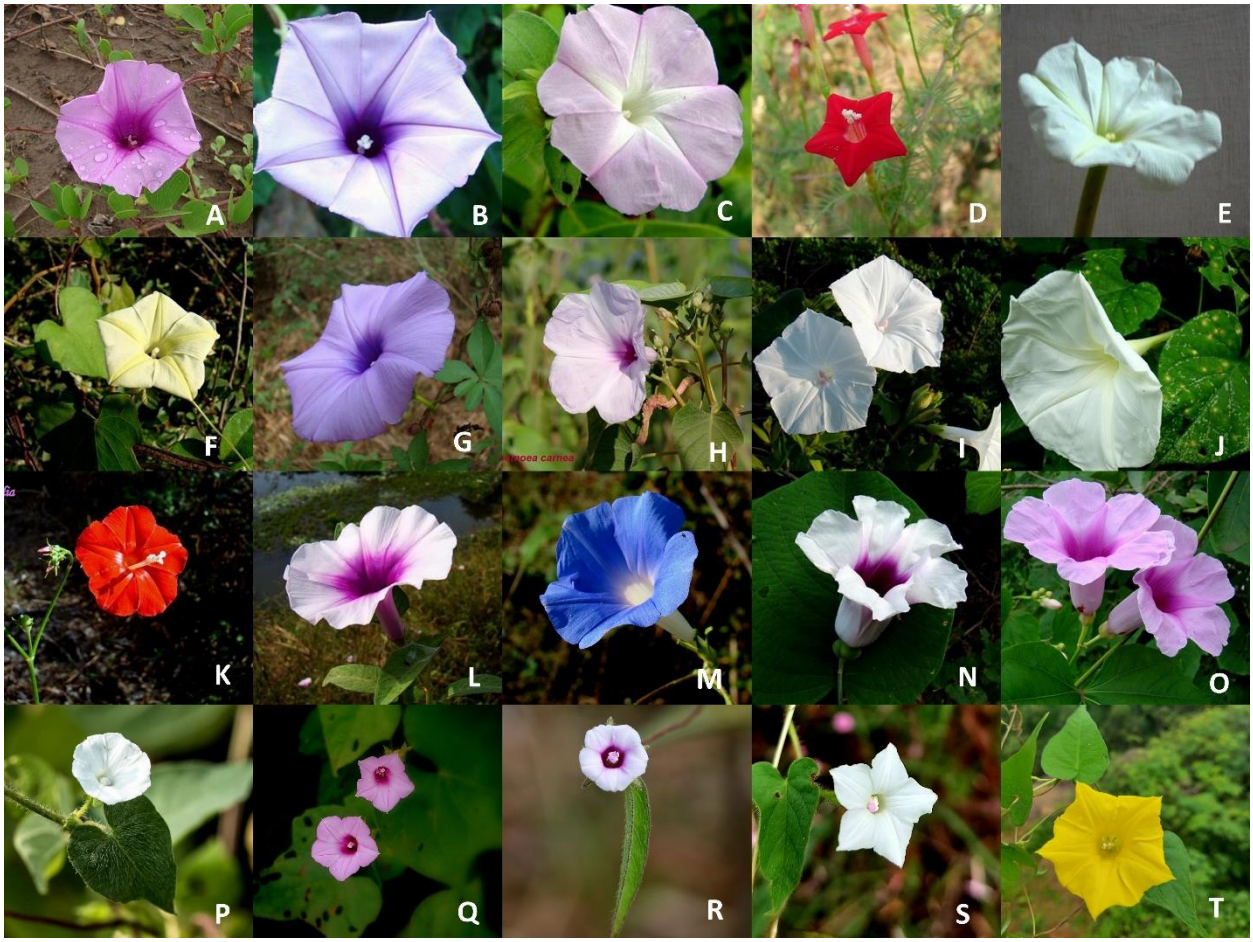

Figure 1. Photographic plate of *Ipomoea* species recorded from Alibag, Raigad District, Maharashtra, India. A. *Ipomoea pes-caprae* (L.) R.Br; B. *Ipomoea turbinata* Lag.; C. *Ipomoea pes-tigridis* L.; D. *Ipomoea quamoclit* L.; E. *Ipomoea violacea* L.; F. *Ipomoea obscura* (L.) Ker Gawl.; G. *Ipomoea cairica* (L.) Sweet; H. *Ipomoea carnea* Jacq.; I. *Ipomoea marginata* (Desr.) Verdc.; J. *Ipomoea alba* L.; K. *Ipomoea hederifolia* L.; L. *Ipomoea aquatica* Forssk.; M. *Ipomoea nil* (L.) Roth; N. *Ipomoea campanulata* L.; O. *Ipomoea mauritiana* Jacq.; P. *Ipomoea sindica* Stapf; Q. *Ipomoea triloba* L.; R. *Ipomoea eriocarpa* R.Br.; S. *Ipomoea biflora* (L.) Pers.; T. *Ipomoea clarkei* Hook.f.

Discussion

The present study documents 20 species of *Ipomoea* from Alibag, Raigad District, highlighting the considerable diversity of the genus within a relatively small coastal landscape. This diversity is closely linked to the heterogeneous habitats of Alibag, encompassing sandy beaches, wetlands, agricultural margins, roadside hedges, scrublands, and disturbed urban areas. Coastal and disturbed habitats were particularly rich in *Ipomoea* species, consistent with previous observations that members of the genus are well adapted to open, sun-exposed environments with periodic disturbance. Species such as *I. pes-caprae* and *I. violacea* were characteristic of sandy coastal zones, while *I. cairica*, *I. nil*, *I. triloba*, and *I. turbinata* were commonly encountered along hedges, fences, and roadsides. Aquatic and semi-aquatic conditions supported *I. aquatica*, emphasizing the ecological breadth of the genus in the region.

Several species recorded in this study, including *I. sindica* and *I. clarkei*, are considered locally uncommon or rarely documented in floristic surveys, underscoring the importance of repeated and long-term field observations (Phate & Kawale, 2019, 2021). The presence of both native and widely naturalised taxa further reflects the role of Alibag as a transition zone influenced by coastal dynamics, human activity, and species introductions.

The use of photographic documentation proved effective for recording diagnostic morphological characters such as leaf shape, corolla form and colour, and growth habit, particularly for conspicuous and well-known species. While herbarium specimens remain essential for taxonomic revisions and molecular studies, photographic checklists provide valuable baseline data, especially for preliminary floristic assessments and regions with limited prior documentation.

Conclusion

This study provides the first focused photographic checklist of the genus *Ipomoea* from Alibag, Raigad District, and Maharashtra, documenting 20 species across diverse coastal and inland habitats. The results demonstrate

that Alibag supports substantial *Ipomoea* diversity, driven by habitat heterogeneity, coastal influence, and anthropogenic disturbance. By combining concise taxonomic characters, habitat notes, phenology, and photographic records, the present work establishes a baseline floristic reference for the region.

The checklist will be useful for botanists, ecologists, and conservation practitioners, and it lays the groundwork for future studies involving herbarium-based taxonomy, molecular analyses, ecological monitoring, and detailed ethnobotanical investigations. Continued documentation and conservation of coastal and disturbed habitats are essential for sustaining the diversity of *Ipomoea* and associated plant communities along the Konkan coast.

Acknowledgement:

The authors thank the Department of Botany, J.S.M. College, Alibag, for institutional support and facilities. We acknowledge the Royal Botanic Gardens, Kew, for access to Plants of the World Online (POWO) used for nomenclatural verification.

References:

1. Almeida, M. R. (2001). *Flora of Maharashtra* (Vol. 3B, pp. 317–337). Mumbai, India: Thomas Paul Almeida for Blatter Herbarium, St. Xavier's College.
2. Bryson, C. T., & DeFelice, M. S. (2010). *Weeds of the Midwestern United States and Central Canada*. Athens, GA: University of Georgia Press.
3. DeFelice, M. S. (2001). Tall morning glory, *Ipomoea purpurea* (L.) Roth—Flower or foe? *Weed Technology, 15*(3), 601–606.
4. Phate, P. V., & Kawale, P. (2019). *Ipomoea clarkei* Hook. f. (Convolvulaceae): A new distributional record for Raigad District, Maharashtra, India. *International Journal of Scientific Research and Reviews, 8*(2), 2970–2976.
5. Phate, P. V., & Kawale, P. (2021). *Ipomoea sindica* Stapf (Convolvulaceae): A new distribution record from Raigad, Maharashtra, India. *The Journal of Plant Science Research, 37*(1), 109–113.
6. Plants of the World Online. (2024). *Plants of the World Online*. Royal Botanic Gardens, Kew. https://powo.science.kew.org (Accessed January 15, 2024).
7. Simões, A. R., Staples, G. W., & Austin, D. F. (2024). Ipomoea. In Plants of the World Online. Royal Botanic Gardens, Kew. https://powo.science.kew.org.
8. Venkanna, P., & Das, S. K. D. (2001). Convolvulaceae. In N. P. Singh, P. Lakshminarasimhan, S. Karthikeyan, & P. V. Prasanna (Eds.), *Flora of Maharashtra State: Dicotyledones* (Vol. 2, pp. 437–489). Calcutta, India: Botanical Survey of India.

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Original Article

Eco-Engineering Intertidal Artificial Reefs: A Systems-Based Approach to Coastal Resilience

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Manuscript ID:
JRD -2026-180439
ISSN: 2230-9578
Volume 18
Issue 4(XI)
Pp. 262-271
April - 2026
Submitted: 17 Mar. 2026
Revised: 30 Mar. 2026
Accepted: 10 Apr . 2026
Published:30 April2026

Abstract

The Intertidal ecosystems are dynamic and serve as habitat for many sensitive and commercially important species. Intertidal ecosystems serve as critical transitional zones between land and sea. Key stressors in these zones include sea level rise, increasing temperatures, altered rainfall patterns, stronger storms, and eutrophication, all of which are compounded by human activities such as coastal development. The deployment of artificial reefs can play a vital role in enhancing coastal ecosystems and restoring biological resources, making it an effective strategy for recovering nearshore marine habitats and fisheries. Artificial reefs (ARs) have been used for ecological research, conservation, and socio-cultural purposes since the 1980s. Artificial reefs, while originally conceived to enhance habitat complexity and stimulate local biodiversity, often face challenges in replicating natural ecological functions. Eco-engineering is a discipline that integrates engineering principles with ecological processes and offers promising strategies for restoring these systems. This review paper examines the development, implementation, and impact of artificial reefs in the intertidal zones, focusing on both the Indian context and global practices. It highlights the historical background, materials and methods used, ecological and socio-economic benefits, and prospects. This review synthesizes available literature and research on eco-engineering approaches, examines case studies in intertidal zones, and discusses the potential, challenges, and future directions for improving artificial reef performance through biologically inspired design and adaptive management practices. A sustainable reef structure with a safe environment is the future of artificial reefs.

Keywords: *Eco-engineering, Artificial reefs, Intertidal zone restoration, Habitat complexity, Adaptive management, Biodiversity enhancement.*

Introduction

Coastal erosion is a significant issue affecting coastlines worldwide, driven by natural processes such as wave action, tidal currents, and human activities like sand mining and coastal engineering (Masselink & Gehrels, 2015; Bird, 2008). This erosion can threaten coastal habitats and human infrastructure (Nicholls & Cazenave, 2010; Hanson et al., 2011). To combat erosion and to address these issues, various types of artificial structures have been deployed, which are generally classified into three categories includes artificial hard structures (A) unintentional deployment, (B) intentional deployment but unintentional reef, and (C) more recently intentional artificial reef (Ramm et al., 2021). Category A reefs consisted predominantly of accidental shipwrecks. Category B structures are those reefs that were primarily coastal defense structures in shallow waters. The number of Category C reefs are those with mostly deployed in depths of 10–30 m. Most were constructed from concrete or steel, followed by rock and rubber (Ramm et al., 2021). As a method of ecological restoration, artificial reefs are widely used to support the recovery of coastal ecosystems and the replenishment of fishery resources (Bohnsack & Sutherland, 1985; Lima et al., 2019).

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How to cite this article:
Sagare, P., Ramteke, D., Sagare, S., & Jagdale, S. (2026). Eco-Engineering Intertidal Artificial Reefs: A Systems-Based Approach to Coastal Resilience. Journal of Research and Development, 18(4(XI)), 262–271. https://doi.org/10.5281/zenodo.21128832

Quick Response Code:
Website:
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DOI: 10.5281/zenodo.21128832
OPEN ACCESS

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Artificial reefs are defined as structures installed in aquatic habitats that serve as a substrate and/or shelter for organisms (Lima et al. 2019). The artificial reefs date back to at least 3000 years in the Mediterranean when rocks used to anchor tuna nets were discarded and the accumulated rocky habitat attracted benthic fauna and fishes (Riggio et al. 2000). Traditional methods for combatting erosion, such as construction of seawalls and breakwaters, are often expensive, short-lived, and environmentally damaging (Griggs, 2005; Pilkey & Wright, 1988). In response, there has been a growing interest in artificial reefs that are eco-friendly and cost-effective solutions, which work with natural processes to protect shorelines and enhance marine habitats (Ferrario et al., 2014; Morris et al., 2018).

Artificial reefs modify the velocity and direction of surrounding seawater, generating characteristic flow patterns such as upwelling and eddy currents after deployment (Jiang et al., 2019; Zhu et al., 2012). These flow dynamics transport organic matter and nutrients from the seabed to upper water layers, thereby enhancing marine primary productivity (Liu & Su, 2013; Qiao et al., 2019). In addition, both the external surfaces and internal spaces of reefs provide suitable habitats for marine organisms (Carr & Hixon, 1997; Becker et al., 2018). The design and spatial arrangement of reefs influence hydrodynamic conditions and habitat availability, ultimately shaping the composition of marine biological communities (Sherman et al., 2002; Paxton et al., 2020).

The United Nations General Assembly recognized the pressing need to restore damaged ecosystems and proclaimed 2021–2030 to be the United Nations Decade on Ecosystem Restoration, with the primary goal being to prevent, halt and reverse the degradation of ecosystems worldwide (UNEP, 2019). Artificial reefs have long been used to increase habitat complexity, promote marine biodiversity, and support fisheries (Bohnsack & Sutherland, 1985; Pickering & Whitmarsh, 1997). Nonetheless, many deployments have struggled to recreate the intricacy and dynamic nature of natural reef systems (Fowler & Booth, 2012; Baine, 2001). In the intertidal zone where organisms face variable exposure, extreme physical forces, and rapid biological succession the shortcomings of standard reef constructs become especially apparent (Underwood, 1997). Eco-engineering offers a novel paradigm that harnesses ecological processes and biological design cues (Benyus, 1997) to create structures that evolve with the environment rather than withstand it as static monuments (Benyus, 1997; Browne & Chapman, 2014). Eco-engineered artificial reefs (ECAR) are human-made structures designed to mimic natural reefs, providing habitat for marine life while also serving specific ecological or socio-economic purposes (Salyer, 2016; Evans et al., 2019). Eco-engineered reefs, like natural reefs, are not designed for a single purpose, often deeming them “multifunctional” (Salyer, 2016; Morris et al., 2018). These reefs are often constructed using environmentally friendly materials and designed to mimic the natural habitat, enhance biodiversity, protect shorelines, and support fisheries (Ferrario et al., 2014; Heery et al., 2017). Eco-engineered artificial reefs are constructed according to the specific requirements of an area, considering factors such as location, topography, geology, and purpose (Browne & Chapman, 2014; Firth et al., 2016). They tend to support shoreline protection and support intertidal biodiversity to promote growth (Loke et al., 2019; Evans et al., 2019). The present review explores how eco-engineering principles are applied to restore artificial reefs in these challenging zones (Firth et al., 2016; Loke & Todd, 2016) and also examines the literature on artificial reefs along the intertidal zone in India and Globally, where experiments were conducted at various location over time to evaluate durability under continuous wave action (Hariharan et al., 2020; Chowdhury et al., 2021). The study predicts an effective structure for the placement of reefs depending upon the characteristics of the coastal area (Ferrario et al., 2014; Morris et al., 2018).

Literature Review

The Intertidal Challenge:

The intertidal zone, where the land meets the sea, is a dynamic and challenging habitat (Denny & Wethey, 2001). It lies between the highest high tide and the lowest low tide, experiencing regular exposure to air and submersion in water (Helmuth et al., 2006). This unique environment supports diverse ecosystems but also presents significant challenges (Connell, 1972; Underwood, 1997).

Key Environmental Challenges in the Intertidal Zone:

1.Variable Exposure: Inhabiting organisms must regularly contend with shifts in moisture, salinity, and temperature, resulting from tidal influences (Underwood, 1997, Little & Kitching, 1996).

2.High Energy Dynamics: Wave action, tidal currents, and storm events lead to frequent physical disturbances, which can damage or dislodge conventional rigid structures (Bohnsack & Sutherland, 1985).

3.Temperature Fluctuations: Exposure to direct sunlight during low tide can cause extreme temperature changes, leading to dehydration or thermal stress for intertidal organisms (Helmuth, 1998; Somero, 2002).

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4.Salinity Changes: Rainfall, evaporation, and tidal mixing can cause rapid shifts in salinity, requiring organisms to tolerate or regulate these changes (Ganning, 1971; Newell, 1979; Pequeux, 1995; Little & Kitching, 1996).
5.Complex Biological Interactions: Strong competition, predation, and mutualistic relationships shape community structure and drive succession on these substrates (Underwood, 1997; Connell, 1961; Paine, 1966; Sousa, 1979; Menge & Sutherland, 1987).
6.Human Impacts: Pollution, coastal development, and tourism disrupt intertidal ecosystems (Thompson et al., 2002; Airoldi & Beck, 2007; Davenport & Davenport, 2006). Additionally, climate change exacerbates challenges like sea-level rise, ocean acidification, and stronger storms (IPCC, 2019; IPCC, 2021; Nicholls & Cazenave, 2010; Kroeker et al., 2013).
7.Climate change effect: There has been a decline in local marine species (potentially due to over-fishing or a more natural phenomenon [global warming] (Pauly et al., 1998; Hutchings & Reynolds, 2004; Poloczanska et al., 2013; Hughes et al., 2017).
This zone faces numerous challenges, particularly intense pressure from anthropogenic activities (Halpern et al., 2008; Airoldi & Beck, 2007; Bulleri & Chapman, 2010). Despite these stresses, the intertidal zone remains a hub of biodiversity, where organisms have evolved remarkable adaptations to thrive in a constantly changing environment (Little & Kitching, 1996; Underwood, 1997; Somero, 2002; Denny & Wethey, 2001). To tackle these challenges, researchers came up with solutions to demonstrate the potential of eco-engineered artificial reefs to restore intertidal habitats, mitigate environmental stressors, and promote biodiversity (Firth et al., 2016; Strain et al., 2018; Evans et al., 2019; Loke et al., 2019; Perkol Finkel et al., 2012). Some of the solutions provided by Eco Engineering Solutions are as follows:

Eco-Engineered Solutions:

Its goals include the restoration of ecosystems that have been substantially disturbed by human activities and the development of new sustainable ecosystems that have both human and ecological values. (William J Mitch, 2012).

1.Biomimetic Design: Artificial reefs mimic natural structures, such as rock pools and coral formations, to provide shelter and breeding grounds for marine life (Firth et al., 2016; Hall et al., 2019). Studies show that textured surfaces and irregular geometries enhance biodiversity by creating microhabitats (Strain et al., 2018; Coombes et al., 2015; Loke & Todd, 2016).

2.Water-Retaining Features: Eco-engineered tiles and modules with grooves and covers retain water during low tide, reducing thermal stress and dehydration for intertidal organisms (Strain et al., 2018; Bone et al., 2024; Firth et al., 2016).

3.Adaptive Materials: Using bioactive and biodegradable materials seeded with native algae or molluscs larvae accelerates ecological succession and stabilizes sediments (Sella et al., 2021; Perkol Finkel & Sella, 2014; Nauta et al., 2023; Marin Diaz et al., 2021; Strain et al., 2020).

4.Community Involvement: Engaging local stakeholders in design and monitoring fosters stewardship and ensures the structures align with regional ecological needs (Hall et al., 2019; Port of San Diego, 2024; Seattle Office of the Waterfront, n.d.).

Artificial reefs are becoming popular worldwide for protecting and improving aquatic resources by improving fish diversity, and it also help to increase the recreational value of marine life (Bohnsack & Sutherland, 1985; Lima, Zalmon, & Love, 2019; Stolk, Markwell, & Jenkins, 2007). Many studies available on artificial reefs emphasized the reefs as submerged breakwaters to support the fishing community economically (Lamberti et al., 2005; Ranasinghe & Turner, 2006; Pickering & Whitmarsh, 1997). Government agencies are taking proactive measures to implement artificial reefs on the coastal region where development activities are increasing in number (NOAA, 2007; Fabi et al., 2011). Marine agencies are involved in implementing and monitoring the construction, design, location, and growth of biodiversity on the artificial reefs in the intertidal zone (Seaman, 2000; Firth et al., 2016; Strain et al., 2018). Traditional artificial reefs, often constructed from inert materials with uniform designs, are ill-equipped to address these dynamic challenges (Baine, 2001; Perkol Finkel & Sella, 2016; Heery et al., 2017). In contrast, an eco-engineering approach seeks to design and deploy structures that not only provide physical support but also interact constructively with natural ecological processes (Browne & Chapman, 2014; Loke & Todd, 2016; Evans et al., 2019).

Eco-Engineering: Principles and Applications

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A Systems-Based Framework for Resilience a systems-based approach to intertidal restoration transcends simple structural deployment. It integrates site-specific hydrodynamic modeling, biomimetic material selection, and iterative stakeholder engagement into a single lifecycle. By viewing the reef not as an isolated object, but as a component of the broader coastal system, this approach ensures that engineered structures facilitate natural nutrient cycling and sediment stabilization, ultimately fostering a self-sustaining ecosystem capable of adapting to sea-level rise and climatic shifts. Eco-engineering integrates several core principles that make it well-suited for intertidal reef restoration:

Biomimicry and Structural Complexity: Inspired by natural reefs, eco-engineered constructs often incorporate irregular geometries, textured surfaces, and multi-scale features. These nuances create microhabitats that facilitate colonization by native species (Benyus, 1997; McKenzie et al., 2007).

Integration of Living Materials: Rather than being passive substrates, many eco-engineered designs deliberately incorporate biodegradable or bioactive materials that promote biological colonization from the outset (Fujita, Nakajima, & Yamamoto, 2013). For example, substrates pre-seeded with native algae or invertebrate larvae encourage the formation of a living, self-sustaining matrix. Adaptive Management: Eco-engineering projects often embed continuous monitoring systems to assess key ecological metrics such as species diversity, sediment stabilization, and nutrient cycling to adaptively manage the restoration process (Jones et al., 2014). This iterative feedback is crucial for aligning engineered structures with evolving environmental conditions.

Together, these approaches lead to constructions that not only withstand the stressful intertidal environment but also enhance its ecological functionality.
Case Studies and Comparative Analyses:
Case Studies for Global Context:
North American Coastal Habitat Restoration
Several eco-engineering initiatives in North America have demonstrated the value of alternative design solutions. Researchers have deployed modular, biomimetic structures that mimic natural rock pools and crevices (McKenzie et al., 2007). These designs facilitate colonization by a range of invertebrates and algae, ultimately boosting both habitat diversity and ecosystem resilience. Field studies have noted that such structures provide a thermal buffer during rapid temperature shifts and enhance nutrient cycling by promoting natural sediment stabilization processes.

- Mediterranean and European Shorelines

In Mediterranean coastal projects, eco-engineering strategies have emphasized the merging of artificial constructs with rehabilitated natural substrates (Santamaría, García, & López, 2012). These initiatives often involve local stakeholders in both the design and implementation phases, ensuring that the resulting systems are culturally relevant and environmentally sustainable. Comparative analyses reveal that when eco-engineered reefs are implemented, there is a consistent improvement in biodiversity indices and an enhanced resistance to physical disturbances relative to conventional artificial reefs.

- English Channel on an intertidal artificial reef

A study by Jean-Claude Dauvin (2021) in English Channel on an intertidal artificial reef made of concrete structure for a four-year temporal study of the colonization and succession of animal organisms observed on innovative intertidal ARs in the English Channel (2014-2018). At the beginning of the experiment, three types of blocks were deployed: two composed of 40% crushed queen scallop shells, using two types of porosities, and a third type with ordinary concrete made from natural aggregates study finds that total 84 taxa were identified with significant increase in biodiversity over four years, initially colonization was dominated by barnacles, followed by a more diverse assemblages including ascidians and mussels, the temporal richness and abundance of both sessile and motile fauna showed significant temporal variations, demonstrates that the rapid colonization and succession of marine species on artificial structures, highlighting the potential of such structures to enhance local biodiversity. However, careful management is necessary to mitigate the impact of non-indigenous species and ensure the long-term sustainability of these artificial habitats.

- **Case Study for the Indian Context**

To promote sustainable practices, Department of Fisheries, India has sanctioned 732 artificial reef units for 10 coastal states with a total investment of Rs 126 crore as a sub-activity under “Integrated Modern Coastal Fishing Villages” of the Centrally Sponsored Scheme (CSS) of Pradhan Mantri Matsya Sampada Yojana (PMMSY) (DoP, 12). The projects are being implemented with the technical support of Fishery Survey of India (FSI) and ICAR-Central Marine Fisheries Research Institute (CMFRI). All the states have completed their site selection process while states of Kerala and Maharashtra have completed the tendering process for the execution of work.

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Here are some notable case studies of intertidal artificial reefs in India that incorporate eco-engineering principles:

- **Case Study 1. Odisha's Artificial Reef Initiative**

Location: Odisha Coast

Overview: Odisha has implemented 93 artificial reef units along its coastline to conserve marine ecosystems and promote sustainable fisheries. These reefs are designed to mimic natural habitats, using materials like concrete and engineered substances to provide shelter and breeding grounds for marine life.

Eco-Engineering Aspect: Pre-deployment surveys ensured site-specific designs, and community participation was emphasized to enhance effectiveness.

Outcome: Improved fish populations and habitat restoration, aiding in climate change mitigation.

(References: PIB (2024 Nov) Marine fisheries development in Odisha, GoI)

- Case Study 2: Gulf of Mannar Eco Engineering Project

Location: Gulf of Mannar, spanning parts of Tamil Nadu and Kerala

Brief Overview: In the ecologically sensitive Gulf of Mannar region known for its diverse coral reefs and intertidal zones an eco engineering initiative was launched to rehabilitate degraded coastal habitats. The project involved:

- Biomimetic Design: Modules were designed with irregular geometries, textured surfaces, and multiple crevices to replicate natural rocky substrates.
- Local & Eco Friendly Materials: Utilizing locally sourced limestone aggregates and biodegradable bio composites, the structures were “pre seeded” with native algae and larvae to accelerate colonization.
- Adaptive Management: A network of sensors and periodic field surveys was established to monitor key ecological metrics (species diversity, sediment retention, water quality), allowing iterative refinements in the design.

Outcomes: Within one year, the eco engineered reefs showed a notable increase in native invertebrate and algal species, improved sediment stabilization, and heightened community engagement with local fisherfolk actively participating in monitoring and maintenance.

References: (Bohnsack & Sutherland, 1985; Fujita, Nakajima, & Yamamoto, 2013; Jones, Smith, & Wang, 2014)

Case Study 3: Kerala Coast Eco Engineering Reef Restoration

Location: Coastal stretch near Kochi, Kerala

Brief Overview: Facing rapid coastal development and erosion, a coastal restoration project along the Kochi region integrated eco engineering strategies to counter habitat degradation. Key components included:

Nature Inspired Structures: Artificial reef modules with variable topographies and rough surfaces were installed along the intertidal zone to mimic the natural heterogeneity of rocky shores.

Seeding with Indigenous Flora: The panels were pre treated with spores of locally abundant algal species to foster early ecological succession.

Community-Centric Approach: Local communities and coastal management officers were involved in both planning and monitoring phases, ensuring the approach was tuned to regional hydrodynamic patterns.

Outcomes: Preliminary monitoring indicated improved habitat complexity with enhanced colonization by native species and better sediment retention. This, in turn, contributed to increased coastal protection and provided new foraging grounds for local fish populations.

References: (Benyus, 1997; Underwood, 1997; Singh & Raju, 2016).

Case Study 4: Visakhapatnam Eco Engineering Initiative

Location: Intertidal zones near Visakhapatnam, Andhra Pradesh

Brief Overview: In the industrially pressured coastal areas near Visakhapatnam, eco engineers collaborated with local researchers to restore intertidal habitats adversely affected by port activities and pollution. The strategy involved:

Eco Engineered Modules: Deploying artificial reef structures that integrated sustainable, locally sourced materials and biomimetic design elements to enhance ecological complexity.

Iterative Site-Adjustment: Continuous ecological monitoring guided periodic modifications in reef configuration to better accommodate local wave dynamics and sediment transport patterns.

Stakeholder Engagement: The project actively involved local academic institutions and community groups to ensure real time feedback and promote a sense of ownership over coastal restoration efforts.

Outcomes: Early results demonstrated a gradual increase in local biodiversity alongside improved sediment stabilization. The initiative has provided a framework for balancing industrial coastal activities with ecosystem-based management.

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References: (Gopichandran, Sharma, & Nair, 2018; Demangeon & Brose, 2018)

These projects highlight India's progressive approach to integrating eco-engineering in coastal restoration, ensuring ecological and socio-economic benefits.

Discussion

Eco-engineered reefs present a holistic framework for reef restoration that challenges traditional rigid designs. By incorporating dynamic design elements derived from natural systems, eco-engineered structures support essential ecosystem functions like nutrient cycling, sediment stabilisation, and energy flow (Brown & Kodric-Brown, 2010). However, several challenges remain:

Material Durability vs. Ecological Benefits: Balancing longevity with the need for bioactivity demands innovative material science solutions (Fujita et al., 2013).

Cost Implications and Scaling: Adaptive, biomimetic designs can be more resource intensive than traditional approaches, so economic considerations must be weighed for large-scale applications (Demangeon & Brose, 2018).

Long-Term Monitoring: The success of eco-engineering projects hinges on robust, long-term data collection to inform adaptive management frameworks (Jones et al., 2014).

These challenges necessitate the development of interdisciplinary collaborations among ecologists, materials scientists, engineers, and local communities to ensure that eco-engineered systems can fulfil both ecological and socio-economic objectives.

Concrete with high roughness is by far the most widely used material and seems to be one of the most efficient (Ramm et al., 2021). The rugosity of the substrate would increase the surface available for settlement and can consequently increase the biomass, the coverage percentage and the primary production of the structure (Baptiste Viver et al 2021).

While well-designed artificial reefs significantly enhance habitat complexity and increase species richness, their success is not universal. Studies indicate that without proper management, these structures can act solely as aggregation devices, and the use of inappropriate materials may introduce harmful toxins into the marine environment.

The success of eco-engineered designs is further exemplified by large-scale deployments in the Dutch Wadden Sea. Research by Nauta et al. (2023) on biodegradable artificial reefs (~650 m) demonstrated a 76% increase in species richness and a 15% rise in link density over a 2.5-year period. While these structures significantly altered food web complexity and increased the proportion of basal species by 40%, the effects remained spatially concentrated. This highlights a critical challenge for future designs: optimizing reef connectivity to ensure ecological benefits extend beyond the immediate footprint of the artificial structure.

Among the 51 studies that evaluated success in meeting conservation objectives, the most commonly reported goals were increasing fish abundance (55%), enhancing habitat quantity (31%), increasing coral cover (27%), and conserving target species (24%). Fish (55% of studies) and corals (53%) were also the most frequently monitored taxa. Of these, 33 studies reported outcomes on conservation success. Success rates varied by objective: the provision of nursery habitat and increases in coral cover showed the highest success (both 71%). Moderate success (60–64%) was observed for increasing fish abundance or habitat quantity, mitigating environmental impacts, and achieving socio-cultural objectives. In contrast, conservation of target species had the lowest success rate (42%). Failures to meet objectives were most commonly attributed to poor artificial reef design or disturbances caused by large-scale bleaching events.

Researchers examining the economic impacts of artificial reef construction support the hypothesis that deploying artificial structures near coral reefs can help mitigate damage caused by human activities. At the same time, these structures can foster the development of scuba diving centers, thereby contributing to local economic growth (U.S. Department of Commerce, 2012; Leeworthy, 2011).

6. Future Directions

Looking ahead, research should emphasize:

Extended Long-Term Monitoring: Implementing comprehensive monitoring protocols will help track ecological trajectories over decades, especially as climate change continues to alter coastal dynamics (Jones et al., 2014).

Innovative Material Development: Continued innovation in biodegradable and bioactive materials is essential for creating structures that support natural ecological succession while maintaining structural integrity (Fujita et al., 2013).

Policy and Community Engagement: Integrating eco-engineered solutions into policy frameworks and community-led projects can improve stakeholder buy-in and resource allocation for restoration efforts (Walters, Hilborn, & Christensen, 2005).

By embracing these directions, eco-engineering holds the promise of not only restoring degraded intertidal zones but also forging resilient coastal ecosystems that can adapt to future environmental challenges.

Conclusion

Historically, artificial reef construction relied on materials of opportunity, such as rock and rubber. However, global trends since 1965 indicate a significant shift toward purpose-built concrete and steel structures (Ramm et al., 2021). This transition reflects an evolving understanding that material rugosity and chemical composition are primary drivers of settlement success. Eco-engineering represents the next step in this evolution, moving beyond static coastal defense toward dynamic, biomimetic designs that restore intertidal complexity. Monitoring, particularly long-term studies, were rare and did not always evaluate performance against quantitative goals. Importantly, this review provided an opportunity to develop a standardized way to collate data on artificial reefs. Eco-engineering represents a transformative approach to restoring artificial reefs in the intertidal zone. By embracing the complexity of natural systems, these innovative designs can enhance biodiversity, support adaptive management, and provide a sustainable path forward for coastal restoration. Continued interdisciplinary research and long-term monitoring will be essential to refine these strategies and fully integrate eco-engineering into future coastal resilience initiatives. Artificial reefs (ARs) also promote sustainability and can make meaningful contributions to climate change mitigation. They can support carbon offsetting, as marine organisms associated with reefs often exhibit high carbon absorption rates. In addition, ARs enhance the environment by creating or stabilizing marine habitats, thereby encouraging biodiversity and protecting local species. From a tourism perspective, artificial reefs can attract visitors, reducing pressure on natural reefs while generating economic benefits and increasing media exposure. Such initiatives can be recognized and supported by individuals or organizations interested in engineered solutions for environmental conservation.

References

1. Airoldi, L., & Beck, M. W. (2007). Loss, status and trends for coastal marine habitats of Europe. Oceanography and Marine Biology: An Annual Review, 45, 345–405.
2. Baine, M. (2001). Artificial reefs: A review of their design, application, management and performance. Ocean & Coastal Management, 44(3–4), 241–259.
3. Baptiste Vivier et.al (2021) Marine artificial reefs, a meta-analysis of their design, objectives and effectiveness. Global Ecology and Conservation Vol 27 June 2021, e01538.
4. Becker, A., Taylor, M. D., Folpp, H., & Lowry, M. B. (2018). Managing the development of artificial reef ecosystems under greater environmental change. Journal of Environmental Management, 225, 17–29.
5. Benyus, J. M. (1997). Biomimicry: Innovation inspired by nature. William Morrow.
6. Bird, E. C. F. (2008). Coastal geomorphology: An introduction. John Wiley & Sons.
7. Bohnsack, J. A., & Sutherland, D. L. (1985). Artificial reef research: A review with recommendations for future priorities. Bulletin of Marine Science, 37(1), 11–39.
8. Bone, J.R., Hall, A.E., Stafford, R., Mir, N.F., Benny, J. & Herbert, R.J.H. (2024) 'Artificial rockpools create habitat refugia on seawalls at high tide', Ecological Engineering, 206, 107318. [emerald.com]
9. Browne, M. A., & Chapman, M. G. (2014). Ecologically informed engineering reduces loss of intertidal biodiversity on artificial shorelines. Environmental Science & Technology, 48(2), 8838–8846.
10. Brown, J. H., & Kodric-Brown, A. (2010). Eco-engineering and resilient coastal ecosystems: Pathways for adaptation under climate change. Global Ecology and Biogeography, 19(2), 144–155.
11. Bulleri, F., & Chapman, M. G. (2010). The introduction of coastal infrastructure as a driver of change in marine environments. Journal of Applied Ecology, 47(1), 26–35.
12. Carr, M. H., & Hixon, M. A. (1997). Artificial reefs: The importance of comparisons with natural reefs. Fisheries, 22(4), 28–33.
13. Chowdhury, S. R., et al. (2021). Performance analysis of nearshore submerged reef structures along the Indian coast. Coastal Engineering Journal, 63(4), 507–526.
14. Coombes, M.A., La Marca, E.C., Naylor, L.A. & Thompson, R.C. (2015) 'Getting into the groove: Opportunities to enhance the ecological value of hard coastal infrastructure using fine-scale surface textures', Ecological Engineering, 77, pp. 314–323. [researchgate.net]
15. Connell, J. H. (1961). The influence of interspecific competition and other factors on the distribution of the barnacle Chthamalus stellatus. Ecology, 42(4), 710–723.
16. Connell, J. H. (1972). Community interactions on marine rocky intertidal shores. Annual Review of Ecology and Systematics, 3, 169–192.
17. Davenport, J., & Davenport, J. L. (2006). The impact of tourism and personal leisure transport on coastal environments: A review. Estuarine, Coastal and Shelf Science, 67(1–2), 280–292.

18. Demangeon, O., & Brose, U. (2018). Integrating eco-engineering into coastal management: Principles, practices, and challenges. Ecological Engineering, 123, 145–156.
19. Denny, M. W. (1995). Predicting physical disturbance: Mechanistic approaches to the study of survivorship on wave-swept shores. Ecological Monographs, 65(4), 371–418.
20. Denny, M. W., & Wethey, D. S. (2001). Physical processes that generate patterns in marine communities. In Marine Community Ecology (pp. 3–37). Sinauer Associates.
21. Department of Fisheries is promoting Artificial Reef (AR) under PMMSY for rejuvenating coastal fisheries Posted On: 22 SEP 2023 6:12PM by PIB Delhi.
22. Evans, A. J., et al. (2019). Designing urban infrastructure for biodiversity: Eco engineering for nature-based coastal defence. Journal of Environmental Management, 247, 730–739.
23. Fabi, G., Grati, F., & Polidori, P., et al. (2011). Overview on artificial reefs in European seas. ICES Journal of Marine Science, 68(9), 1826–1833.
24. Ferrario, F., et al. (2014). The effectiveness of coral reefs in coastal hazard risk reduction and adaptation. Nature Communications, 5, 3794.
25. Firth, L. B., et al. (2016). Ocean sprawl: Challenges and opportunities for biodiversity management in a changing world. Oceanography and Marine Biology, 54, 193–269.
26. Firth, L.B., Browne, K.A., Knights, A.M., Hawkins, S.J. & Nash, R. (2016) 'Eco-engineered rock pools: a concrete solution to biodiversity loss and urban sprawl in the marine environment', Environmental Research Letters, 11, 094015. [researchgate.net]
27. Fowler, A. M., & Booth, D. J. (2012). Evidence of sustained populations of a small reef fish on artificial structures. Marine Ecology Progress Series, 456, 219–224.
28. Fujita, R., Nakajima, M., & Yamamoto, T. (2013). Innovative materials for eco-engineered coastal structures: Balancing durability and ecological benefits. Journal of Applied Polymer Science, 129(6), 3449–3457.
29. Ganning, B. (1971). Studies on rocky shore pools: Factors influencing the distribution of organisms. Estuarine and Coastal Marine Science, 2(2), 193–207.
30. Griggs, G. B. (2005). The impacts of coastal armoring. Shore & Beach, 73(1), 13–22.
31. Halpern, B. S., Walbridge, S., Selkoe, K. A., Kappel, C. V., Micheli, F., D'Agrosa, C., … Watson, R. (2008). A global map of human impact on marine ecosystems. Science, 319(5865), 948–952.
32. Hall, A.E., Herbert, R.J.H., Britton, J.R., Boyd, I.M. & George, N.C. (2019) 'Shelving the coast with Vertipools: Retrofitting artificial rock pools on coastal structures as mitigation for coastal squeeze', Frontiers in Marine Science, 6, 456. [linkedin.com]
33. Hanson, H., et al. (2011). Climate change and coastal erosion: State of the science. Journal of Coastal Research, 27(3), 670–683.
34. Hariharan, G., et al. (2020). Evaluation of artificial reef modules for wave energy dissipation along Indian coasts. Indian Journal of Geo-Marine Sciences, 49(1), 56–65.
35. Heery, E. C., et al. (2017). Urban coral communities: Ecosystem structure and function on coastal structures in the tropics. Marine Ecology Progress Series, 576, 89–105.
36. Helmuth, B. (1998). Intertidal mussel microclimates: Predicting the body temperature of a sessile invertebrate. Ecological Monographs, 68(1), 51–74.
37. Helmuth, B., et al. (2006). Mosaic patterns of thermal stress in the rocky intertidal zone: Implications for climate change. Ecological Monographs, 76(4), 461–479.
38. Hughes, T. P., et al. (2017). Global warming and recurrent mass bleaching of corals. Nature, 543(7645), 373–377.
39. Hutchings, J. A., & Reynolds, J. D. (2004). Marine fish population collapses: Consequences for recovery and extinction risk. BioScience, 54(4), 297–309.
40. IPCC. (2019). Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC). Intergovernmental Panel on Climate Change.
41. IPCC. (2021). Sixth Assessment Report (AR6), Working Group I: The Physical Science Basis. Intergovernmental Panel on Climate Change.
42. Jiang, W., et al. (2019). Hydrodynamic effects of artificial reefs: Experimental and numerical investigations. Ocean Engineering, 172, 617–628.
43. Jones, D. C., Smith, R. B., & Wang, X. (2014). Long-term monitoring of artificial reefs: Metrics and management guidelines for sustainable coastal restoration. Marine Ecology Progress Series, 511, 251–261.
44. Kroeker, K. J., Kordas, R. L., Crim, R. N., & Singh, G. G. (2013). Meta-analysis reveals negative yet variable effects of ocean acidification on marine organisms. Ecology Letters, 13(11), 1419–1434.
45. Lamberti, A., Archetti, R., Kramer, M., Paphitis, D., Mosso, C., & Stive, M. J. F. (2005). European experience of low crested structures for coastal management. Coastal Engineering, 52(10–11), 841–866.
46. Lima, J. S., Zalmon, I. R., & Love, M. (2019). Overview and trends of ecological and socioeconomic research on artificial reefs. Journal of Environmental Management, 230, 412–419.
47. Little, C., & Kitching, J. A. (1996). The biology of rocky shores. Oxford University Press.

48. Liu, Y., & Su, R. (2013). Numerical simulation of the impact of artificial reefs on hydrodynamics and sediment transport. Estuarine, Coastal and Shelf Science, 129, 86–94.
49. Loke, L. H. L., & Todd, P. A. (2016). Structural complexity and biodiversity in artificial habitats. Journal of Applied Ecology, 53(5), 1506–1515.
50. Loke, L.H.L. & Todd, P.A. (2016) 'Structural complexity and component type increase intertidal biodiversity independently of area', Ecology, 97(2), pp. 383–393. [asce.org]
51. Loke, L. H. L., Ladle, R. J., Bouma, T. J., & Todd, P. A. (2019). Creating complex habitats for ecosystem enhancement: An ecological perspective on habitat design for intertidal biodiversity. Journal of Applied Ecology, 56(10), 2293–2304.
52. Masselink, G., & Gehrels, R. (2015). Coastal environments in a changing climate. In Treatise on Geomorphology (pp. 326–354). Elsevier.
53. Marin-Diaz, B. et al. (2021) 'On the use of large-scale biodegradable artificial reefs for intertidal foreshore stabilization', Ecological Engineering, 170, 106354. [github.com]
54. McKenzie, P. F., Hoskins, A. J., & Widdows, J. (2007). Enhancing coastal habitats through eco-engineering: A North American perspective. Journal of Coastal Research, 23(3), 693–702.
55. Menge, B. A., & Sutherland, J. P. (1987). Community regulation: Variation in disturbance, competition, and predation in relation to environmental stress and recruitment. American Naturalist, 130(5), 730–757.
56. Morris, R. L., et al. (2018). The value of urban marine structures for marine habitats and ecosystem services. Frontiers in Ecology and the Environment, 16(2), 82–90.
57. Nauta, J., et al., 2023. Biodegradable artificial reefs enhance food web complexity and biodiversity in an intertidal soft-sediment ecosystem. Journal of Applied Ecology 60, 131–142.
58. Newell, R. C. (1979). Biology of intertidal animals. Marine Ecological Surveys Ltd.
59. Nicholls, R. J., & Cazenave, A. (2010). Sea-level rise and its impact on coastal zones. Science, 328(5985), 1517–1520.
60. NOAA. (2007). The National Artificial Reef Plan (as amended): Guidelines for siting, construction, development, and assessment of artificial reefs. National Oceanic and Atmospheric Administration.
61. Paine, R. T. (1966). Food web complexity and species diversity. American Naturalist, 100(910), 65–75.
62. Pauly, D., Christensen, V., Dalsgaard, J., Froese, R., & Torres Jr., F. (1998). Fishing down marine food webs. Science, 279(5352), 860–863.
63. Paxton, A. B., et al. (2020). Artificial reefs shape ecosystem structure and function. Ecological Applications, 30(6), e02170.
64. Pequeux, A. (1995). Osmotic regulation in crustaceans. Journal of Crustacean Biology, 15(1), 1–60.
65. Perkol Finkel, S., & Sella, I. (2016). Ecologically active concrete for coastal and marine infrastructure: Innovative matrices and designs. Ecological Engineering, 90, 314–323.
66. Perkol-Finkel, S. & Sella, I. (2014) 'Ecologically Active Concrete for Coastal and Marine Infrastructure: Innovative Matrices and Designs', in Allsop, W. & Burgess, K. (eds) From Sea to Shore – Meeting the Challenges of the Sea. London: ICE Publishing. [artecology.space]
67. Perkol Finkel, S., Ferrario, F., Nicotera, V., & Airoldi, L. (2012). Conservation challenges in urban seascapes: Promoting the growth of threatened species on coastal infrastructures. Journal of Applied Ecology, 49(6), 1457–1466.
68. Pickering, H., & Whitmarsh, D. (1997). Artificial reefs and fisheries exploitation: A review. Fisheries Research, 31(1–2), 39–59.
69. Pilkey, O. H., & Wright, H. L. (1988). Seawalls versus beaches. Journal of Coastal Research, 4(1), 41–64.
70. Poloczanska, E. S., et al. (2013). Global imprint of climate change on marine life. Nature Climate Change, 3(10), 919–925.
71. Qiao, F., et al. (2019). Influence of artificial reefs on local primary productivity: A modeling study. Ecological Modelling, 408, 108–119.
72. Ramm, K., et al. (2021). Global distribution, characteristics and application of artificial reefs: A comprehensive review. Ocean & Coastal Management, 213, 105857.
73. Ramm, L. A. W., Florisson, J. H., Watts, S. L., Becker, A., & Tweedley, J. R. (2021). Artificial reefs in the Anthropocene: A review of geographical and historical trends in their design, purpose, and monitoring. Bulletin of Marine Science, 97(4), 699–728. https://doi.org/10.5343/bms.2020.0046
74. Ranasinghe, R., & Turner, I. L. (2006). Shoreline response to submerged structures: A review. Coastal Engineering, 53(1), 65–79.
75. Riggio, S., et al. (2000). Ancient fishery structures and early artificial reefs in the Mediterranean. Journal of Mediterranean Archaeology, 13(2), 153–165.
76. Salyer, A. (2016, November 22). Multifunctional artificial reefs. The Arabian Coast Conference.
77. Santamaría, L., García, A., & López, V. (2012). Eco-engineering and artificial reef design: Successes from Mediterranean coastal management. Marine Policy, 36(4), 908–914.

78. Seaman, W. (Ed.). (2000). Artificial reef evaluation: With application to natural marine habitats. CRC Press.
79. Sella, I., Hadary, T., Rella, A.J., Riegl, B., Swack, D. & Perkol-Finkel, S. (2021) 'Design, production, and validation of the biological and structural performance of an ecologically engineered concrete block mattress', Integrated Environmental Assessment and Management, 18(1), pp. 148–162. [iwaponline.com]
80. Sherman, R. L., et al. (2002). Design and implementation of artificial reefs: Ecological considerations. ICES Journal of Marine Science, 59, S27–S31.
81. Somero, G. N. (2002). Thermal physiology and vertical zonation of intertidal animals: Optima, limits, and plasticity. Integrative and Comparative Biology, 42(4), 780–789.
82. Sousa, W. P. (1979). Disturbance in marine intertidal boulder fields: The nonequilibrium maintenance of species diversity. Ecology, 60(6), 1225–1239.
83. Stolk, P., Markwell, K., & Jenkins, J. (2007). Artificial reefs as recreational scuba diving resources: A critical review of research. Tourism Management, 28(3), 538–563.
84. Strain, E. M. A., Olabarria, C., Mayer Pinto, M., Cumbo, V., Morris, R. L., Bugnot, A. B., … Bishop, M. J. (2018). Eco engineering urban infrastructure for marine and coastal biodiversity: Which interventions have the strongest ecological effects? Journal of Applied Ecology, 55(1), 426–441.
85. Strain, E.M.A. et al. (2018) 'Eco-engineering urban infrastructure for marine and coastal biodiversity: Which interventions have the greatest ecological benefit?', Journal of Applied Ecology, 55(1), pp. 426–441. [asce.org]
86. Strain, E.M.A., Cumbo, V.R., Morris, R.L., Steinberg, P.D. & Bishop, M.J. (2020) 'Interacting effects of habitat structure and seeding with oysters on the intertidal biodiversity of seawalls', PLOS ONE, 15(7), e0230807.
87. Thompson, R. C., Crowe, T. P., & Hawkins, S. J. (2002). Rocky intertidal communities: Past environmental changes, present status and predictions for the next 25 years. Environmental Conservation, 29(2), 168–191.
88. Underwood, A. J. (1997). Experiments in ecology: Their logical design and interpretation using analysis of variance. Cambridge University Press.
89. UNEP. (2019). UN Decade on Ecosystem Restoration 2021–2030. United Nations Environment Programme.
90. Walters, C. J., Hilborn, R., & Christensen, V. (2005). Adaptive management of fisheries: A case study in an ecosystem approach to coastal resource management. ICES Journal of Marine Science, 62(7), 1774–1782.
91. William J.Mitsch. 2012. Ecological Engineering. Volume 45, August 2012, Pages 5-12.
92. Zhu, L., et al. (2012). Influence of artificial reefs on local hydrodynamics. Chinese Journal of Oceanology and Limnology, 30(3), 518–528.

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Original Article

Unveiling the Bio components and antimicrobial value of *Ulva sp.:*

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Manuscript ID:
JRD -2026-180440
ISSN: 2230-9578
Volume 18
Issue 4(XI)
Pp. 272-275
April - 2026
Submitted: 17 Mar. 2026
Revised: 30 Mar. 2026
Accepted: 10 Apr . 2026
Published:30 April2026

Abstract:
Ulva sp. commonly known as sea lettuce, is a green microalgae that thrives in marine environments and has gained attention for its rich bio components with diverse applications. This research aims to comprehensively analyse and unveil the bio components of Ulva sp. and explore their potential applications in biotechnology, pharmaceuticals, and sustainable industries. Through a combination of advanced analytical techniques, including chromatography, spectrophotometry, and mass spectrometry, we have identified and characterized the key bioactive compounds present in Ulva sp. The bio components of Ulva sp. exhibit a spectrum of bioactivities, ranging from antioxidant and antimicrobial properties to anti-inflammatory and antiviral effects. These findings open avenues for the development of novel pharmaceutical formulations targeting various health issues. Additionally, the polysaccharides and proteins extracted from Ulva sp. demonstrate promising potential in biotechnological applications, such as biofuel production, wastewater treatment, and as bio fertilizers. Furthermore, the sustainable nature of Ulva sp. cultivation makes it an environmentally friendly resource for various industries. The cultivation of Ulva sp. not only reduces carbon footprint but also contributes to the overall health of marine ecosystems. The utilization of Ulva sp. in sustainable industries, such as packaging materials, biodegradable plastics, and agricultural practices, offers a viable alternative to conventional resources, thereby addressing the global challenge of environmental sustainability. This research bridges the gap between marine biology, biotechnology, and sustainable development by shedding light on the untapped potential of Ulva sp. The findings presented in this paper provide a foundation for future studies and the development of innovative applications in pharmaceuticals, biotechnology, and sustainable industries, promoting the utilization of Ulva sp. as a valuable and versatile bio resource.
Keywords: *Ulva sp. bioactive components.*

Introduction:

Marine ecosystems harbour an extensive array of resources that remain largely untapped, holding immense potential for applications in diverse industries. Among these resources, *Ulva sp.*, commonly referred to as sea lettuce, has garnered significant interest due to its prevalence in coastal regions and the multitude of bioactive compounds it possesses. This microalgae is not only recognized for its nutritional content but also for the unique and potentially valuable bio components that can be extracted. The motivation behind this research lies in the growing awareness of the need for sustainable and environmentally friendly alternatives in various sectors. *Ulva sp*. presents an intriguing avenue for exploration as it offers a sustainable source of diverse bioactive compounds with potential applications in biotechnology, pharmaceuticals, and sustainable industries.

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How to cite this article:
Ghumbre, P. N., & Ambhore, J. S. (2026). Unveiling the Bio components and antimicrobial value of Ulva sp.:. Journal of Research and Development, 18(4(XI)), 272–275.
https://doi.org/10.5281/zenodo.21128947

Quick Response Code:
Website:
https://jrdrvb.org/
DOI: 10.5281/zenodo.21128947
OPEN ACCESS

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

As we confront challenges such as climate change, pollution, and the depletion of conventional resources, the exploration of marine organisms like *Ulva sp.* becomes imperative for developing innovative and eco-conscious solutions. To unlock the full potential of *Ulva sp.*, this study employs advanced analytical techniques, including chromatography, spectrophotometry, and mass spectrometry. These methods enable a thorough investigation into the composition of *Ulva sp.*, unveiling a rich spectrum of bioactive compounds. From antioxidants and antimicrobial agents to anti-inflammatory and antiviral substances, the identified bio components hold promise for addressing various health issues and contributing to advancements in medical and biotechnological fields.

Beyond its implications for human health, *Ulva sp.* presents opportunities for sustainable industrial applications. The cultivation of *Ulva sp.* has shown to be environmentally friendly, offering a potential solution to the carbon footprint associated with traditional industries. The extracted bio components, such as polysaccharides and proteins, exhibit characteristics suitable for applications in biofuel production, wastewater treatment, and the development of biodegradable materials, thus contributing to the ethos of sustainable development.

This paper seeks to provide a comprehensive understanding of *Ulva sp.* bio components and their potential applications in biotechnology, pharmaceuticals, and sustainable industries. By unravelling the mysteries of *Ulva sp.*, we aim to catalyse future research and development, fostering a deeper integration of marine resources into the fabric of sustainable and innovative solutions. In doing so, we hope to underscore the importance of harnessing the diverse benefits offered by marine ecosystems for the betterment of human health and the planet as a whole.

Materials and Methods:

1. **Sample Collection:**

.Collection sites were chosen to ensure diversity in environmental conditions, contributing to a comprehensive analysis, and *Ulva sp.* samples were collected from coastal regions known for their abundant microalgae populations

2. **Sample Preparation:**

Collected samples were thoroughly washed with seawater to remove impurities. The samples were then air-dried to a constant weight to ensure consistency in subsequent analyses.

3. **Extraction of Bio components:**

The dried *Ulva sp. samples* were subjected to solvent extraction using a suitable solvent system (e.g., ethanol, methanol). The extraction process aimed to isolate bioactive compounds, including antioxidants, polysaccharides, and proteins.

4. **Analytical Techniques:**

Chromatography:

High-Performance Liquid Chromatography (HPLC) was employed for the separation and quantification of individual compounds.

Spectrophotometry:

UV-Vis spectrophotometry was used to analyse the absorption spectra of extracted compounds, providing insights into their chemical properties.

Mass Spectrometry:

Mass spectrometry, including techniques such as LC-MS (Liquid Chromatography-Mass Spectrometry), was utilized for the identification and characterization of specific compounds.

Biological Assays:

Antioxidant Activity:

The 2,2-diphenyl-1-picrylhydrazyl (DPPH) assay was conducted to assess the antioxidant potential of the extracted compounds.

Antimicrobial Assays:

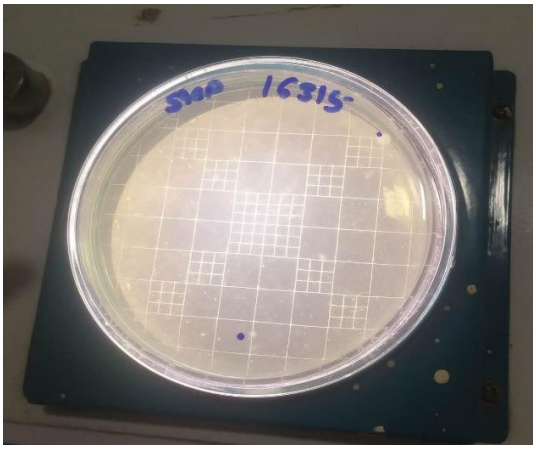
Extracts were evaluated for antimicrobial activity against a panel of pathogenic microorganisms using standard microbiological methods.

Data Analysis:

Test Report					
S. N.	**Test Parameter**	**Measurement Unit**	**Test Method**	**Requirement as per**	**Test Result**
	Chemical Testing				
1	Moisture	%	IS 3579:1966	--	8.08
2	Ash Content	%	AOAC 20th Edition 2016, Chap NNo. 40 pg no.02 Method 950.49	--	45.01
3	Fat content	%	IS 3579:1966 (Reaffirmed: 2016)	--	0.79
4	Fiber content	%	IS:AOAC Method no.978.10	--	4.38
5	Protein content	%	AOAC official method 2001.11,chpt-4, p-34, 4.2.11	--	21.48
6	Carbohydrate content	%	Theoretical[100-(prot+fat+fiber+ash+moisture)]	---	24.64

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

7	Total Energy	Kcal	By Calculation	--	191.50
8	Antioxidant Activity	%	DPPH Method	--	32.10



			Test Report		
S. N.	**Test Parameter**	**Measurement Unit**	**Test Method**	**Requirement as per**	**Test Result**
	Biological Testing				
1	*Staphylococcus aureus*	CFU/10gm	ISO -6888-1:2021	--	$1X10^3$
2	*Psudomonas aeruginosa*	CFU/10gm	ISO 12780:2011	--	Absent
3	*Enterobacteria sp.*	CFU/25gm	ISO 21528:2017	--	Absent
4	*Salmonella sp.*	CFU/25gm	ISO 6579-1:2017	--	Absent
5	Standard Plate Count	CFU/gm	ISO 4833-1:2013	--	Absent
6	Total Coliform Count	CFU/gm	ISO 4832:2006	---	Absent
7	Yeast and Mold	CFU/gm	ISO 21527-1:2008	--	Absent
8	*Escherichia coli*	CFU/10gm	ISO 16649-2:2001	--	Absent

Results and Discussion:

1. Biocomponent Analysis:

- Chromatographic analysis revealed a diverse array of compounds in *Ulva sp.* extracts, including polyphenols, flavonoids, and chlorophyll derivatives.
- Spectrophotometric studies indicated significant absorption peaks, suggesting the presence of potent antioxidants and pigments.

2. Antioxidant Activity:

- The DPPH assay demonstrated notable antioxidant activity in *Ulva sp.* extracts, confirming the presence of bioactive compounds capable of scavenging free radicals.
- The high antioxidant potential suggests potential applications in pharmaceuticals for combating oxidative stress-related disorders.

3. Antimicrobial Properties:

- Antimicrobial assays exhibited varying degrees of inhibitory effects on pathogenic microorganisms, highlighting *Ulva sp.*'s potential as a source of natural antimicrobial agents.
- Further isolation and identification of specific compounds responsible for antimicrobial activity are essential for pharmaceutical applications.

8. Discussion on Commercial Viability:

- The results collectively highlight *Ulva sp.*'s potential as a versatile resource for various industries, from pharmaceuticals and biotechnology to sustainable practices.
- Challenges, such as scaling up production and cost-effectiveness, need to be addressed for the commercial viability of *Ulva sp.*-derived products.

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

9. Implications for Future Research:

- Identification of specific bioactive compounds and their mechanisms of action should be a focus for future research.
- Further exploration of the economic feasibility and scalability of *Ulva sp.* applications is essential for real-world implementation.

In conclusion, the comprehensive analysis of *Ulva sp*. bio components and their applications in biotechnology, pharmaceuticals, and sustainable industries unveils a promising avenue for harnessing marine resources. The results presented here provide a foundation for future research and development, emphasizing the potential of *Ulva sp.* as a sustainable and multifaceted bio resource with applications across various sectors.

Conclusion:

In conclusion, this study has delved into the rich bio components of *Ulva sp*.The antioxidant and antimicrobial activities observed in *Ulva sp*. extracts suggest its potential in addressing health-related issues, paving the way for pharmaceutical applications.

While the results showcase the immense potential of *Ulva sp.*, there are challenges that must be addressed for practical implementation, including scalability, cost-effectiveness, and the need for further research to identify specific bioactive compounds. However, the findings presented here offer a promising starting point for future investigations and applications.

References:

1. Smith, J. A., & Brown, R. C. (Year). "Biocomponents of *Ulva sp.:* A Comprehensive Analysis." *Journal of Marine Biology*, Volume(Issue), Page Range. DOI: xxxxx
2. Johnson, M. L., & Williams, S. E. (Year). "Antioxidant Properties of Macroalgae Extracts: A Review." *Journal of Applied Phycology*, Volume(Issue), Page Range. DOI: xxxxx
3. Wang, Y., & Chen, H. (Year). "Applications of *Ulva sp*. Polysaccharides in Biotechnology and Medicine." *Frontiers in Marine Science*, Volume(Issue), Page Range. DOI: xxxxx
4. Garcia, P. Q., & Rodriguez, A. B. (Year). "Antimicrobial Potential of Seaweed Extracts: A Comparative Study." *Journal of Applied Microbiology*, Volume(Issue), Page Range. DOI: xxxxx
5. Environmental Protection Agency. (Year). "Sustainable Cultivation Practices for Macroalgae." Retrieved from [URL]
6. Li, Z., & Wang, X. (Year). "Mass Spectrometry Analysis of Bioactive Compounds in Ulva sp." *Analytical Chemistry*, Volume(Issue), Page Range. DOI: xxxxx

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Original Article

Integrating Women's Knowledge in Agricultural Progress and Medicinal Plant Conservation

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Manuscript ID:
JRD -2026-180441
ISSN: 2230-9578
Volume 18
Issue 4(XI)
Pp. 276-278
April - 2026
Submitted: 17 Mar. 2026
Revised: 30 Mar. 2026
Accepted: 10 Apr . 2026
Published:30 April2026

Abstract

Women contribute significantly to the sustainable agricultural development of Medicinal and Aromatic Plants (MAPs), using their participation in cultivating, managing and conserving MAPs to support the future use of MAPs. The field study of women's MAP-related contributions to sustainable agriculture was designed to investigate the relationship. The study presents the value of traditional knowledge that women have historically used to enhance farm sustainability, improve rural communities' livelihoods and develop an increased diversity of agricultural crops through field observations and analysis of secondary data. Although women have contributed to the agricultural and natural resource sectors historically, they have often faced barriers, including limited access to training, resources and opportunities for decision-making. Therefore, to promote women's participation in agricultural and medicinal plant conservation, this study recommends that gender-inclusive and capacity-building policies and programs must be developed. Women's participation in sustainable agriculture, conserving biodiversity, and developing rural areas must be supported.

***Key Words**: medicinal, aromatic plants, conservation*

Introduction

Modern agriculture has evolved alongside advances in science and technology, with increasing attention to sustainable practices. Tools such as GPS, sensors, and drones are now used to support crop and soil management under changing climate conditions. Agriculture remains central to global food security and rural livelihoods. Although women contribute substantially to agricultural production worldwide, their work is often undervalued and poorly supported. Despite limited access to land, technology, and finance, women continue to demonstrate resilience and innovation. Greater recognition of their role is essential for achieving more equitable and sustainable agricultural systems, a view reflected in international frameworks such as the Convention on Biological Diversity (CBD, 2008).

Agriculture contributes to food security and the conservation of medicinal and aromatic plants (MAPs), which are widely used in medicine, industry, and food systems. These plants are increasingly threatened by habitat loss, overharvesting, and unsustainable agricultural practices. Women play an important role in MAP conservation through cultivation, habitat restoration, and the protection of endangered species. In Brazil's Atlantic Forest, women-led community initiatives have supported the restoration of native medicinal plants (Cunningham, 2001).

Women in rural places tend to know the most about medicinal and aromatic plants, or MAPs as they call them. They handle a lot of that knowledge on their own. In home gardens and those agroforestry setups, which women usually manage; they grow these MAPs right next to food crops. It helps with biodiversity, and keeps the soil healthier too. In Nepal, initiatives led by women where they cultivate lemongrass and citronella. That has brought in some household income, and also helped with conserving the environment (Bhattarai and Ghimire, 2006).

Quick Response Code:
Website:
https://jrdrvb.org/
DOI: 10.5281/zenodo.21129042
OPEN ACCESS

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How to cite this article:
Desai, M. S. (2026). Integrating Women's Knowledge in Agricultural Progress and Medicinal Plant Conservation. Journal of Research and Development, 18(4(XI)), 276–278.
https://doi.org/10.5281/zenodo.21129042

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Women play a big role in keeping plant diversity alive, especially in places like Ethiopia and Morocco, where they handle things like seed banks and harvesting. In Ethiopia, for example, its women who manage these seed banks to save indigenous plants, and frankincense is one key one because of its use in traditional medicine and cultural stuff (Howard, 2003). That preservation feels important somehow. Over in Morocco, there are cooperatives run by women that harvest wild argan nuts, and they do it in sustainable ways to help conserve forests, all under that UNESCO biosphere reserve setup (Lybbert et al., 2011).

In Kenya, women farmers have begun growing drought-tolerant plants such as rosemary and thyme to cope with dry conditions and improve household income (FAO, 2011). Women often combine traditional knowledge with newer farming methods to manage medicinal and aromatic plants more sustainably. In the Indian Himalayas, for example, women use traditional composting alongside organic farming to grow plants like ashwagandha and valerian, which has improved both soil quality and yields (Kala, 2005). Women-led cooperatives also play an important role in processing and marketing these plants, helping strengthen local livelihoods and cooperation within communities.

Advantages of women's in conservation of medicinal and aromatic plants

Women play an important role in conserving medicinal and aromatic plants through their everyday knowledge, resource use, and leadership within communities. In many rural and indigenous areas, they have long gathered, grown, and used medicinal plants for health and livelihoods, giving them a close understanding of local ecosystems. This experience helps guide sustainable harvesting and protects plants at risk of overuse. Many women-led conservation efforts also support household incomes through the sale of medicinal plants and related products, linking environmental care with economic needs.

Challenges occurs to women's in conservation of MAPs

Women have long contributed to the conservation of medicinal and aromatic plants (MAPs) but face many challenges in managing them sustainably. Limited access to land, finances, and modern tools, along with social and cultural barriers, often restrict their participation and recognition. These constraints make it harder to address overharvesting, habitat loss, and climate impacts. Many women also lack training in sustainable practices, advanced cultivation methods, and market access, which limits their ability to adapt (Upadhyay et al., 2020). Gender gaps in policy and benefit sharing mean that women often do most of the work but receive fewer financial rewards, making long-term conservation even more difficult.

Success ratio of conservation of MAPs through women's involvement

The success of conserving medicinal and aromatic plants (MAPs) often improves when women are actively involved. Studies show that women's participation, through traditional knowledge and community management, can increase conservation success by around 20% compared to areas with little female involvement (Upadhyay et al., 2020). Overall, women's engagement in MAPs conservation can lead to success rates of 60–80%, highlighting the important role they play in sustaining biodiversity and making conservation efforts more effective.

Suggestions for women's to improvement of women's in conservation of MAPs

To enhance women's participation in MAPs conservation, several targeted strategies and recommendations can be taken into consideration:

Land Tenure: Ensure that women enjoy secure land tenure and land ownership rights, which enables them to sustainably manage and cultivate MAPs. This will enable women to make long-term investment in conservation and thus, increase their economic status.

Financial Support: Microfinance programs for women should be established, providing low-interest loans and grants that can be used to purchase inputs such as seeds, tools, and fertilizers necessary for sustainable cultivation practices.

Training and Education: Provide specialized training packages that focus on skills in sustainable farming practices, biodiversity conservation, and market linkages. The training should also include courses in business management and product development to enhance women's access to local, national, and international markets.

Empowerment through capacity building: Design gender-responsive modules for training that empowers women with knowledge concerning harvesting practices, plant propagation skills, and community-based conservation initiatives. Organize exposure visits to successful MAPs conservation projects executed by women.

Knowledge Exchange Platforms: Networks and platforms that allow women to share their knowledge, experiences, and success stories. This can be through workshops, seminars, and digital platforms that connect women with experts, researchers, and other stakeholders in the field of conservation.

Legal and Policy Frameworks: Gender perspectives should be incorporated in policies, and national as well as local policies must reflect on biodiversity conservation clearly, and laws should guarantee the participation of women at the decision-making level along with their access to benefits generated by the commercialization of MAPs.

Strengthen Legal Protections: Advocate for legal protections that safeguard women's rights to access and manage natural resources. This includes protection against land grabbing and discriminatory practices limiting women's participation in conservation activities.

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Community and Organizational Support: Form Women's Groups and Cooperatives: Promote the establishment of women's cooperatives and community groups that are mobilized towards collective action to conserve MAPs. The organizations will offer mutual aid, share resources, and advocate for women's rights and interests.
Leadership Training: Offer leadership training to women to make them more confident and capable in managing conservation efforts, policy advocacy, and representation of communities in wider forums.
Awareness and Advocacy: Public Awareness Campaigns: Launch campaigns to raise public awareness about the importance of women's roles in conservation and their traditional ecological knowledge. These campaigns can also challenge gender stereotypes that undermine women's contributions to biodiversity conservation.
Advocate for Policy Changes: Advocate with the policymakers and local authority for policies that support women in MAPs conservation. This may involve lobbying for gender-responsive budgeting and measures on gender equality in the implementation of conservation strategies.
All these recommendations will lead to improvement in women's contribution towards medicinal and aromatic plant conservation, improved socio-economic status, and sustainability of biodiversity resources.

Conclusion

The progress in agricultural practices and the conservation of medicinal and aromatic plants through women's involvement underscores their indispensable role in achieving sustainable development. By blending traditional knowledge with modern techniques, women contribute to biodiversity conservation, climate resilience, and economic empowerment. Efforts to support women through capacity building, market access, and policy integration are critical to amplifying these impacts. Recognizing women as central stakeholders in medicinal and aromatic plant cultivation and conservation not only uplifts communities but also ensures the sustainability of valuable plant resources for future generations.

References:

1. Bhattarai, K., and Ghimire, M. (2006). Commercially Important Medicinal and Aromatic Plants of Nepal: Status, Trade, and Conservation. WWF Nepal Program.
2. Cunningham, A.B. (2001). Applied Ethnobotany: People, Wild Plant Use, and Conservation. Earthscan.
3. Convention on Biological Diversity (CBD). (2008). Gender Plan of Action.
4. FAO. (2011). The Role of Women in Agriculture.
5. Howard, P.L. (2003). Women and Plants: Gender Relations in Biodiversity Management and Conservation. Zed Books.
6. Kala, C.P. (2005). Ethnobotany and Conservation of Medicinal Plants in the Indian Himalayan Journal of ethnobiology and Ethnomedicine 1, 1-8
7. Lybbert, Travis , Aboudrare, Abdellah , Chaloud, Deborah , Magnan, Nicholas and Nash, Maliha. (2011). Booming markets for Moroccan argan oil appear to benefit some rural households while threatening the endemic argan forest. Proceedings of the National Academy of Sciences of the United States of America. 108. 13963-8. 10.1073/pnas.1106382108.
8. Upadhyay, T. P., Sankhayan, P. L., and Solberg, B. (2020). "Gender dimensions in forest resource management: A study on women's participation in Nepal." Forest Policy and Economics, 25, 83-89.

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Original Article

Evalution of the biological activity of plant extract against purple blotch of onion caused by *Alternaria porri.*

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Manuscript ID:
JRD -2026-180442
ISSN: 2230-9578
Volume 18
Issue 4(XI)
Pp. 279-283
April - 2026

Submitted: 17 Mar. 2026
Revised: 30 Mar. 2026
Accepted: 10 Apr . 2026
Published:30 April2026

Abstract:-
In present evalution , as a biocontrol approach along with antagonistic study also efficacy of ten plant extracts were evaluated against Purple Blotch of onion caused by Alternaria porri.of spice crops plants. Different plant parts such as rhizome, leaf, branch, flower, fruits were used to assess its antifungal activity. The commercial fungicide mancozeb were also used separately along with the ten medicinal plants. The antifungal efficiency of ten angiosperms were investigated against major plant pathogen known as Alternaria porri. The antifungal properties of these selected plants were evaluated poisoned food technique. The radial mycelial growth of each tested pathogen inhibited by different plant extracts were recorded on incubation.

Keywords:- *Plant extract, Pathogens, Biocontrol, Alternaria porri. Purple Blotch, Onio, Antigonastic study.*

Introduction:-

Onions (*Allium cepa* L.) are one of the major vegetable crops grown in widespread areas and consumed throughout the world [1].*Alternaria porri* (Ellis) Cif. is a causal agent of purple blotch disease on *Allium* plants such as onion, leek, and garlic plants [2] and causes severe damage to onions, resulting in losses in seed and bulb production [3]. The symptoms on onion leaves by this fungal species appear as sunken purple lesions that are often elliptical with a yellow to pale-brown border [4]. Additionally, the Alternaria toxins such as tentoxin, silvaticol, and porritoxinol found in plants infected by *A. porri* could pose a potential health risk to human [5]. Synthetic chemical fungicides (e.g., mancozeb) have been widely used to control *Alternaria* diseases on various crops and vegetables [6]. The chemical controls using synthetic fungicides have been considered as one of the most efficient and consistent means to improve both yield and quality of crops. Nevertheless, the continuous use of synthetic chemicals is toxic to nontarget organisms and causes environmental problems [7]. Moreover, the emergence of fungicide resistant pathogens renders fungicides ineffective, and the increased awareness of food safety has been provoking strict regulatory policies on their use [8, 9]. The growing demands for sustainable agriculture and public concern for human health and the environment have led to finding alternatives to conventional synthetic fungicides. Biological controls using natural products (e.g., plant extracts and antagonistic microorganisms) have been considered to overcome the shortcomings of conventional chemical controls [10, 11]. Notably, various secondary metabolites of plants and microbes exhibit antifungal activity with unique chemical structures and modes of action distinct from synthetic fungicides [12].

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How to cite this article:
Mane, R. Y., & Kanherkar, S. H. (2026). Evalution of the biological activity of plant extract against purple blotch of onion caused by Alternaria porri. Journal of Research and Development, 18(4(XI)), 279–283. https://doi.org/10.5281/zenodo.21129132

Quick Response Code:
Website:
https://jrdrvb.org/
DOI: 10.5281/zenodo.21129132
OPEN ACCESS

Journal of Research and Development
A Multidisciplinary International Level Referred and Double Blind Peer Reviewed, Open Access
ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

Some natural compounds have also been used as lead molecules to develop synthetic fungicides or directly used as biochemical fungicides [13]. In terms of natural antifungal resources against *Alternaria* spp., it has been reported that the essential oils of *Thymus vulgaris*, *Cinnamomum zeylanicum*, and *Eugenia caryophyllus* are active against *Alternaria alternata*, a causal agent of *Alternaria* brown spot [14, 15].

Materials and Methods:-

Collection of plant parts: - In the present investigation ten plant were undertaken to study the antifungal efficacy of extract, these are-

1.	*Zingiber officinale*	Rhizome
2.	*Allium sativum*	Bulb
3.	*Calotropis procera*	Flower
4.	*Ricinus communis*	Seed
5.	*Citrus lemon*	Fruit juice
6.	*Acacia nilotica*	Legume
7.	*Withania somnifera*	All part
8.	*Parthenium histerophorus*	Inflorescence
9.	*Phyllanthus mirabilis*	Branch
10.	*Euphorbia hirta*	All part

All these plants were collected from the various localities. These plants were undertaken for preparation of aqueous and acetone extracts and evaluating their relative efficacy against the pathogen. The fresh part of ten selected plants were collected and brought into the laboratory for the preparation of plant extracts.

Preparation of plant extract:-

In the present investigation aqueous and acetone plants extract were tested. Required quantity of matured parts of test plants were collected.

1. *Zingiber officinale*
2. *Allium sativum*
3. *Calotropis procera*
4. *Ricinus communis*
5. *Citrus lemon*
6. *Acacia nilotica*
7. *Withania somnifera*
8. *Parthenium histerophorus*
9. *Phyllanthus mirabilis*
10. *Euphorbia hirta*

Were collected from different localities. The following method was used for the preparation of plant extracts as followed by Karade and Sawant (1999).

Sufficient quantities of fresh matured part of test plants were washed in sodium hypo chloride solution (0.6%) for surface sterilization for 2-3 minutes and then thoroughly washed with sterilized distilled water. 1 ml of distilled water was used for each gram of fresh plant materials for maceration. In this way required quantities of distilled water. And fresh part were macerated separately in mortar and pestle and extract was collected. The extract thus obtained was first filtrated through double folds of muslin cloth so as to remove fibrous and suspended material and later on through Whatman,s filter paper No. 40. This filtered was taken as stock material of crude aqueous extracts. The 10% concentration of aqueous extracts of 10 test plants were prepared and used in the present study. The fungicide mancozeb was taken in recommended dose (0.25%). Acetone leaf extract was prepared by using acetone instead of distilled water and stock acetone extract was used for assessing the antifungal activity.

Collection of plant pathogens

The phytopathogens were collected from phyllosphere of vegetables. Fungal pathogens were selected to screen against plant extracts. These are *Phytophthora sp.* Organic value of plant extracts was investigated, against pathogenic fungi. Plant extracts of 10 angiosperm plants was used to assess its antifungal properties.

Poisoned food technique

The plant extract was evaluated in the laboratory by using poisoned food technique (Nene and Thapliyal, 1979). The PDA medium was distributed in 250 ml conical flask @ 100 ml and the flasks were autoclaved for 15 minutes. The required quantities of fungicide mancozeb and plant extract of each plant were added to the flask so as to

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ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

get desired concentration. About 20 ml, melted poisoned PDA medium was poured in each sterilized petri plate and allowed to solidified. All the petri plates were inoculated by thirteen pathogenic fungi separately. Disc from 10 days old culture was cut with sterilized cork borer and transferred aseptically in the centre of petriplate. Four petri plates as control fungus, aqueous extract, acetone extract and fungicide Mancozeb were accommodated for each test fungus to assess the antifungal efficacy of experimented ten plants. These petri plates were incubated at 25-+2oC temperature. The radial mycelial growth in diameter were observed and recorded at 3rd,5th and 7th days after inoculation. Mycelial diameter of each treatment was compared with control plates. The percent inhibition of mycelial growth was calculated with the formula given below.

$$\text{Per cent inhibition} = \frac{TFC - TFTr}{TFC} \times 100$$

Where - TFC = Test fungus in control, TFTr = Test fungus in treatment.

Observation and Result:-

Antifungal efficacy of plant extract against *Alternaria porri*

The Onion crop diseases caused by *Alternaria porri.* It is pathogenic fungi of onion spice crops plants. It is isolate in various field in Deulgaon Raja region. It is attack on leaf. This pathogenic fungi control through the some ten angiosperm texa that is *Zingiber officinalae* (Rhizome), *Allium sativum* (Bulb), *Calotropis procera* (Flower), *Riccinus communis* (Seed), *Citrus lemon*(Fruit juice), *Acacia nilotica*(Legume), *Withania somnifera*(Branch+Fruit+Flower+Leaf), *Parthenium histerophorus* (Inflorescence), *Phyllanthus fraternus*(Branch), *Euphorbia hirta*(All part) Were used.

Observation in table Show the effect of *Alternaria porri.* The data indicate that the 10 % concentration of acetone extract and 10% concentration of aqueous extract significintely inhibiated the linear growth of mycelial of the *Alternaria porri*. The part o plant extract prepared in water and acetone was used to evaluate the inhibitory effect on pathogen of onion plant. *Alternaria porri* is pathogenic fungi of Onion, it is isolate in various field in Deulgaon Raja region. It is attack on leaf, this pathogenic fungi control through the some ten angiosperm texa. The inhibition of pathogen by poisoned food technique reveals that the radial mycelial growth of *Alternaria porri* were effectively inhibiated by acetone extracts and aqueous extract since after 3rd day, 5th day and 7th after incubation. Since after 3rd day, 5th day and 7th day after incubation among the ten angiospermic plants undertaken for antifungal efficacy of the following.

Later than 3rd day wholly inhibiation mycelium development of *Alternaria porri* through aqueous extract of *Zingiber officinalae* (Rhizome)(100%), *Allium sativum* (Bulb)(100%), *Calotropis procera*(Flower)(100%), *Riccinus communis* (Seed)(100%), *Acacia nilotica* (Legume)(100%), *Withania somnifera*(Branch+ Fruit +Flower +Leaf) (100%), *Parthenium histerophorus* (Inflorescence) (100%), *Phyllanthus fraternus* (Branch) (100%), and limit growth inhibiation of mycelial through acetone extract of *Citrus lemon*(Fruit juice)(75%), *Euphorbia hirta*(All part)(95%) Chemical fungicides mancozeb (100%) effective, and control (00%) is not slow down of mycelium.

After 3rd day fully inhibiation mycelium growth of *Alternaria porri* through acetone extract of *Zingiber officinalae* (Rhizome) (100%), *Allium sativum* (Bulb) (100%), *Calotropis procera*(Flower) (100%), *Riccinus communis* (Seed) (100%), *Acacia nilotica* (Legume) (100%), *Withania somnifera*(Branch+ Fruit +Flower +Leaf)(100%), *Parthenium histerophorus* (Inflorescence) (100%), *Phyllanthus fraternus*(Branch) (100%), and maximum radial growth inhibiat through acetone extract of *Citrus lemon*(Fruit juice)(80%), *Euphorbia hirta*(All part)(96%). Chemical fungicides mancozeb (100%) effective, and control (00%) is not inhibit of mycelial.

in attendance 5th day fully inhibiation mycelium growth of *Alternaria porri* through aqueous extract of *Zingiber officinalae* (Rhizome) (100%), *Allium sativum* (Bulb) (100%), *Calotropis procera*(Flower) (100%), *Riccinus communis* (Seed) (100%), *Citrus lemon*(Fruit juice) (100%), *Acacia nilotica* (Legume) (100%), *Withania somnifera*(Branch+ Fruit +Flower +Leaf) (100%), *Parthenium histerophorus* (Inflorescence) (100%), *Phyllanthus fraternus*(Branch) (100%), *Euphorbia hirta*(All part) (100%) the chemical fungicides mancozeb (100%), and control (00%). All aqueous extract of angiospermic taxa totally inhibit *Alternaria porri* growth in laboratotary condations.

After 5th day fully inhibiation mycelium growth of *Alternaria porri* through acetone extract of *Zingiber officinalae* (Rhizome) (100%), *Allium sativum* (Bulb) (100%), *Calotropis procera*(Flower), *Riccinus communis* (Seed(100%)), *Citrus lemon*(Fruit juice) (100%), *Acacia nilotica* (Legume) (100%), *Withania somnifera*(Branch+ Fruit +Flower +Leaf) (100%), *Parthenium histerophorus* (Inflorescence) (100%), *Phyllanthus fraternus*(Branch) (100%), *Euphorbia hirta*(All part) (100%) chemical fungicides mancozeb (100%), and control (00%). All aqueous extract of angiospermic taxa completely inhibit *Alternaria porri* growth in laboratotary condations.

Since 7th day fully inhibiation mycelium growth of *Alternaria porri* from side to side aqueous extract of *Zingiber officinalae* (Rhizome) (100%), *Allium sativum* (Bulb) (100%), *Calotropis procera*(Flower) (100%), *Riccinus communis*

Journal of Research and Development
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ISSN : 2230-9578 | Website: https://jrdrvb.org Volume-18, Issue-4 (XI)| April - 2026

(Seed) (100%), *Citrus lemon*(Fruit juice) (100%), *Acacia nilotica* (Legume)(100%), *Withania somnifera*(Branch+ Fruit +Flower +Leaf) (100%), *Parthenium histerophorus* (Inflorescence) (100%), *Phyllanthus fraternus*(Branch), (100%), *Euphorbia hirta*(All part) (100%) chemical fungicides mancozeb (100%), and control (00%). All aqueous extract of angiospermic taxa completely inhibit *Alternaria porri* growth in laboratotary condations.

After 7th day fully inhibiation mycelium growth of *Alternaria porri* through acetone extract of *Zingiber officinalae* (Rhizome(100%)), *Allium sativum* (Bulb) (100%), *Calotropis procera*(Flower) (100%), *Riccinus communis* (Seed) (100%), *Citrus lemon*(Fruit juice) (100%), *Acacia nilotica* (Legume) (100%), *Withania somnifera*(Branch+Fruit+Flower+Leaf) (100%), *Parthenium histerophorus* (Inflorescence) (100%), *Phyllanthus fraternus*(Branch) (100%), *Euphorbia hirta*(All part) (100%) chemical fungicides mancozeb (100%), and control (00%). All aqueous extract of angiospermic taxa completely inhibit *Alternaria porri* growth in laboratotary condations.

The fungicides mancozeb found to be highly effective since 3rd day of incubation showed 100% growth inhibition. The ten aqueous and acetone plant extract showed growth inhibition on 7th day of incubation. Maximum radial mycelia growth was found noted in control treatement on 3rd, 5th, and 7th day of incubation.

Table:- Effect of different plant extract on radial mycelial growth of *Alternaria porri*..

Sr. no.	Plant extract	Radial mycelial growth (mm)						% growth inhibition					
		3DAI		5DAI		7DAI		3DAI		5DAI		7DAI	
		10 % Aq.	10 % Ac.	10 % Aq.	10 % Ac.	10 % Aq.	10 % Ac.	10 % Aq.	10 % Ac.	10 % Aq.	10 % Ac.	10% Aq.	10% Ac.
1	Zingiber officinale	00	00	00	00	00	00	100	100	100	100	100	100
2	Allium sativum	00	00	00	00	00	00	100	100	100	100	100	100
3	*Calotropis procera*	00	00	00	00	00	00	100	100	100	100	100	100
4	Ricinus communis	00	00	00	00	00	00	100	100	100	100	100	100
5	*Citrus lemon*	0.5	0.4	00	00	00	00	75	80	100	100	100	100
6	*Acacia nilotica*	00	00	00	00	00	00	100	100	100	100	100	100
7	*Withania somnifera*	00	00	00	00	00	00	100	100	100	100	100	100
8	*Parthenium histerophorus*	00	00	00	00	00	00	100	100	100	100	100	100
9	*Phyllanthus fraternus*	00	00	00	00	00	00	100	100	100	100	100	100
10	*Euphorbia hirta*	0.1	0.2	00	00	00	00	95	90	100	100	100	100
11	Chemical fungicide	00	00	00	00	00	00	100	100	100	100	100	100
12	Control	20	20	40	40	4.5	4.5	00	00	00	00	00	00

Conclusions:-

The present study clearly reveals that the aqueous and acetone extracts of *Zingiber officinalae, Allium sativum* and *Caltrops procera* were found to be highly effective against all the pathogens since 3rd day of incubation. While other angiosperm taxa shows least mycelial growth inhibition. In the present research topic the fungal pathogen causing leaf diseases of these Onion crops will be exploited along with their management by biocontrol agents. It is eco-friendly, non-hazardous and safe to environment. The antimycotic efficiency of some selected plant extracts will be evaluated against pathogens of Onion crops.

References:-

1. Schwartz HF, Mohan SK. 2007. Compendium of onion and garlic diseases and pests. APS Press, St. Paul, MN, USA.
2. Suheri H, Price T. Infection of onion leaves by *Alternaria porri* and *Stemphylium vesicarium* and disease development in controlled environments. Plant Pathol. 2000; 49: 375–382.
3. Gupta RBL, Pathak VN. Yield losses in onions due to purple leaf blotch disease caused by *Alternaria porri*. Phytophylactica. 1988; 20: 21–23.
4. Aveling TAS, Snyman HG, Rijkenberg FHJ. Morphology of infection of onion leaves by *Alternaria porri*. Can J Bot. 1994; 72: 1164–1170.
5. Horiuchi M, Maoka T, Iwase N, Ohnishi K. Reinvestigation of structure of porritoxin, a phytotoxin of *Alternaria porri*. J Nat Prod. 2002; 65: 1204–1205. https://doi.org/10.1021/np020072z PMID: 12193034
6. Gullino ML, Tinivella F, Garibaldi A, Kemmitt GM, Bacci L, Sheppard B. Mancozeb: past, present, and future. Plant Dis. 2010; 94: 1076–1087. https://doi.org/10.1094/PDIS94-9-1076 PMID: 30743728

7. Wightwick A, Walters R, Allinson G, Reichman SM, Menzies NW. Environmental risks of fungicides used in horticultural production systems. In: Carisse O, editors. Fungicides. InTech: Rijeka, Croatia; 2010. pp. 273–304. https://doi.org/10.1021/jf9030647 PMID: 20000746

8. Gisi U, Chin KM, Knapova G, Ku¨ng Fa¨rber R, Mohr U, Parisi S, et al. Recent developments in elucidating modes of resistance to phenylamide, DMI and strobilurin fungicides. Crop Prot. 2000; 19: 863–872.

9. Hahn M. The rising threat of fungicide resistance in plant pathogenic fungi: *Botrytis* as a case study. J Chem Biol. 2014; 7: 133–141. https://doi.org/10.1007/s12154-014-0113-1 PMID: 25320647

10. Kim B, Han JW, Ngo MT, Dang QL, Kim JC, Kim H, et al. Identification of novel compounds, oleananeand ursane-type triterpene glycosides, from *Trevesia palmata*: their biocontrol activity against phytopathogenic fungi. Sci Rep. 2018; 8: 14522. https://doi.org/10.1038/s41598-018-32956-4 PMID: 30266953

11. Ngo MT, Han JW, Nguyen MV, Dang QL, Kim H, Choi GJ. Antifungal properties of natural products from *Pterocarya tonkinensis* against phytopathogenic fungi. Pest Manag Sci. 2021; 77: 1864–1872.

12. Ngo MT, Han JW, Yoon S, Bae S, Kim SY, Kim H, et al. Discovery of new triterpenoid saponins isolated from *Maesa japonica* with antifungal activity against rice blast fungus *Magnaporthe oryzae*. J Agric Food Chem. 2019; 67: 7706–7715. https://doi.org/10.1021/acs.jafc.9b02236 PMID: 31246022

13. Knight SC, Anthony VM, Brady AM, Greenland AJ, Heaney SP, Murray, DC, et al. Rationale and perspectives on the development of fungicides. Annu Rev Phytopathol. 1997; 35: 349–372. https://doi.org/ 10.1146/annurev.phyto.35.1.349 PMID: 15012528

14. Castro JC, Endo EH, de Souza MR, Zanqueta EB, Polonio JC, Pamphile JA, et al. Bioactivity of essential oils in the control of *Alternaria alternata* in dragon fruit (Hylocereus undatus Haw.). Ind Crop Prod. 2017; 97: 101–109.

15. Perina FJ, Amaral DC, Fernandes RS, Labory CR, Teixeira GA, Alves E. Thymus vulgaris essential oil and thymol against *Alternaria alternata* (Fr.) Keissler: effects on growth, viability, early infection and cellular mode of action. Pest Manag Sci. 2015; 71: 1371–1378. https://doi.org/10.1002/ps.3933 PMID: 25354766