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Original Article

To Study The Effect Of Temprature And Salinity On Germination Of *Moringa Oleifera* From Ahmednagar District With Special Reference To Seeds As A Natural Absorbant Agent For River Water Treatment

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Abstract

*This study explores the dual potential of Moringa oleifera seeds from the Ahmednagar district of India. The first part of the research investigates how different temperatures (**20°C, 25 °C, 30°C, 35°C**) and salinity levels (**0.1%, 0.3%, 0.5%, 0.8%, 1%**) affect seed germination and seedling growth. The second part, which is a novel aspect of this research, examines the efficacy of crushed Moringa seeds as a natural flocculant to purify polluted river water. The seeds' proteins can bind to various pollutants, and experiments will assess their effectiveness in reducing turbidity, chemical oxygen demand (COD), and microbial load. Ultimately, this integrated approach highlights the potential of Moringa seeds for both sustainable agriculture and as a low-cost, eco-friendly solution for water purification.*

Keywords: *Absorbent; Germination; Moringa; River; Seeds.*

Introduction

The genus *Moringa Oleifera* belongs to the family Moringaceae and is characterized as a tree that typically attains heights ranging from 5 to 10 meters. Its leaves are composed of leaflets measuring 0.5 to 1 centimeter, with lateral leaflets exhibiting an elliptic shape and terminal leaflets being obovate. The plant produces tuberculous panicles as its inflorescence, with flowers approximately 1 centimeter in diameter. These flowers are white, and the plant bears capsules that are 25 to 50 centimeters long with nine ribs. The seeds are triangular with winged angles, facilitating dispersal. The flowering and fruiting period extends from January to April, as documented by Singh et al. (2000). Native to India, *Moringa Oleifera* has been cultivated globally and has become naturalized in numerous regions. It is known by various local names; in the Philippines, the leaves are cooked and fed to infants, earning the name "Malunggay." Other regional names include the benzolive tree in Haiti, horseradish tree in Florida, nebeday in Senegal, and drumstick tree in India. These diverse names reflect its widespread cultural significance and utilization across different countries.

The family Moringaceae comprises approximately 13 species, primarily native to India, the Red Sea region, and parts of Africa, including Madagascar. Among these, *Moringa Oleifera* is the most extensively recognized and cultivated species. In this context, the term Moringa generally refers to *M. Oleifera*, as noted by Martin (1985).Moringa is regarded as a highly versatile and valuable tree species, well-adapted to various soil types and environmental conditions. It demonstrates particular resilience in arid and semi-arid regions, showing tolerance to poor soil quality, which makes it suitable for cultivation in challenging environments (Mridha and Arabia, 2015). Soil salinity presents a significant environmental challenge, severely impacting crop productivity. The ongoing accumulation of salts in the soil renders large areas of land unsuitable for cultivation, thereby reducing available arable land.

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The detrimental effects of salinity on plant growth are primarily due to disruptions in metabolic processes, impairing physiological functions essential for development. Taneja (1988) emphasizes that managing soil salinity is crucial for maintaining agricultural productivity and ensuring sustainable crop production in affected regions.

Antimicrobial

Seeds and leaves, along with extracts, demonstrate activity against various fungal species, including *Rhizopus stolonifer*, *Fusarium solani*, *Rhizopus solani*, and *Mucor* spp. (Ferreira et al., 2014). Moringa oleifera is cultivated with relative ease; however, limited scientific research has been conducted to expand knowledge and improve cultivation techniques. Outside certain regions of India where large-scale cultivation is prevalent, the tree receives minimal professional horticultural attention and has not undergone formal comparative trials (National Research Council, 2006). Access to safe and adequate water remains one of the most significant challenges in recent times. Water scarcity, in terms of both quantity and quality, has severe implications for overall development and public health (Jodi et al., 2012). The high costs associated with water treatment often hinder the supply of potable water in many communities.

Research has examined the effects of temperature and salinity on the germination of *Artemisia fragrantissima* and *Moringa peregrina*. The study aimed to provide insights into germination requirements under various conditions, including constant temperatures (5°C, 15°C, 25°C, and 35°C) and alternating temperatures (5/15°C, 10/20°C, 15/25°C, and 25/35°C). Seeds were germinated under different NaCl concentrations (0, 1000, 2000, 3000, 4000, and 5000 ppm). Results indicated that, at both constant and alternating temperatures, germination rates for *A. fragrantissima* and *M. peregrina* were maximized at 25°C, with germination percentages of 67.7% and 83.0%, respectively. Notably, under alternating temperature conditions, the optimal germination for *A. fragrantissima* was observed at 15/25°C (81.0%), while for *M. peregrina*, it was at 25/35°C (95.3%). Germination under alternating temperatures was higher than under constant temperatures. Additionally, *M. peregrina* exhibited higher germination rates at elevated temperatures compared to *A. fragrantissima*. Salinity significantly inhibited seed germination in both species.

Ahmed et al. (2014) investigated the influence of shade, as a proxy for light intensity and temperature, on seed germination, biomass accumulation, and partitioning in *Moringa oleifera* seedlings. Three shading levels were tested: high shade, medium shade, and no shade. Germination was monitored over two weeks post-sowing, with germination rates and final percentages recorded. Four sequential harvests were conducted starting four weeks after sowing, assessing seedling growth variables at each stage. The primary objectives of this research include: to determine the effect of different temperatures on seed germination percentage, uniformity, and rate; to evaluate the growth rate and development of *M. oleifera* trees under varying temperature conditions; to assess the species' tolerance to sodium chloride during germination and emergence; and to evaluate the efficacy of Moringa seed powder as a low-cost coagulant for water treatment in semi-urban and rural areas of Ahmednagar district, Maharashtra.

Plate No. 1. *Moringa oleifera* plant in natural habitat

Plate No. 2. Flower of *Moring oleifera*

Materials and Methods: Moringa oleifera Studies

Seed Germination and Tree Growth Responses to Temperature

Seed Collection and Preparation

Healthy pods were collected from both wild and cultivated Moringa oleifera plants. Seeds were carefully extracted, and only healthy samples were selected for further analysis. The kernels were removed from the seeds prior to sowing.

Germination and Seedling Growth

Seedlings were cultivated in 50-cavity trays filled with moistened coconut peat. Each cavity received a single seed, and the trays were covered with black plastic to maintain optimal moisture levels and darkness. The trays were subjected to three different temperature regimes: 20–25°C, 25–30°C, and 30–35°C. After germination, the plastic covers were removed. Seedlings were monitored daily over a period of 40 days to record germination percentage, germination rate, and uniformity. Additionally, seedling height, stem diameter, and the number of leaves were measured regularly. Daily watering was maintained throughout the experiment, with no fertilizers applied during this stage.

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Tree Growth

Eight-five seedlings were transplanted into black plastic bags filled with fertilized soil. These containers were also maintained under the same three temperature conditions. Manual irrigation was performed three times weekly. Tree height and stem diameter were measured weekly over a 16-week period to assess growth parameters.

Response to Saline Conditions

Seed Preparation

Moringa seeds of the PKM-1 variety were surface-sterilized using 0.1% mercuric chloride and 70% ethanol, followed by rinsing with sterile distilled water to eliminate surface contaminants.

Experimental Setup

Sterilized Petri dishes lined with blotting paper were prepared for the experiment. Five concentrations of sodium chloride (NaCl) were tested: 0.1%, 0.3%, 0.5%, 0.8%, and 1.0%. A control group with distilled water was also included. Ten seeds were placed in each Petri dish and kept in darkness to facilitate germination.

Data Collection

Germination percentage was recorded after one week. Measurements of shoot length, root length, and germination percentage were taken at regular intervals over a one-month period. Additionally, fresh and dry biomass weights were measured after 30 days to evaluate the effects of saline stress on seedling development.

Seed as a Coagulant for Water Purification

Preparation of Coagulant

Dried Moringa oleifera seeds were selected, with wings and seed coats removed. The seeds were dried in an oven to ensure complete dehydration. A fine powder was then prepared using a mortar and pestle. The powder was sieved through muslin cloth and used directly as a natural coagulant for water treatment applications.

Plate No. 3. *Moringa oleifera* seeds without seed coats

Result and Discussion

Effect of Temperature on Seed Germination:

The research indicates that elevated temperatures accelerate seed germination rates. Although the final germination percentage was consistent across different temperature conditions—reaching approximately 84% at the highest temperature—the temperature range of 30-35°C proved to be the most effective for commercial seedling production. This range facilitated the fastest and most uniform germination, making it the optimal choice for practical applications. Consequently, it is recommended that seed germination processes be maintained within this temperature range to maximize efficiency and uniformity in seedling development.

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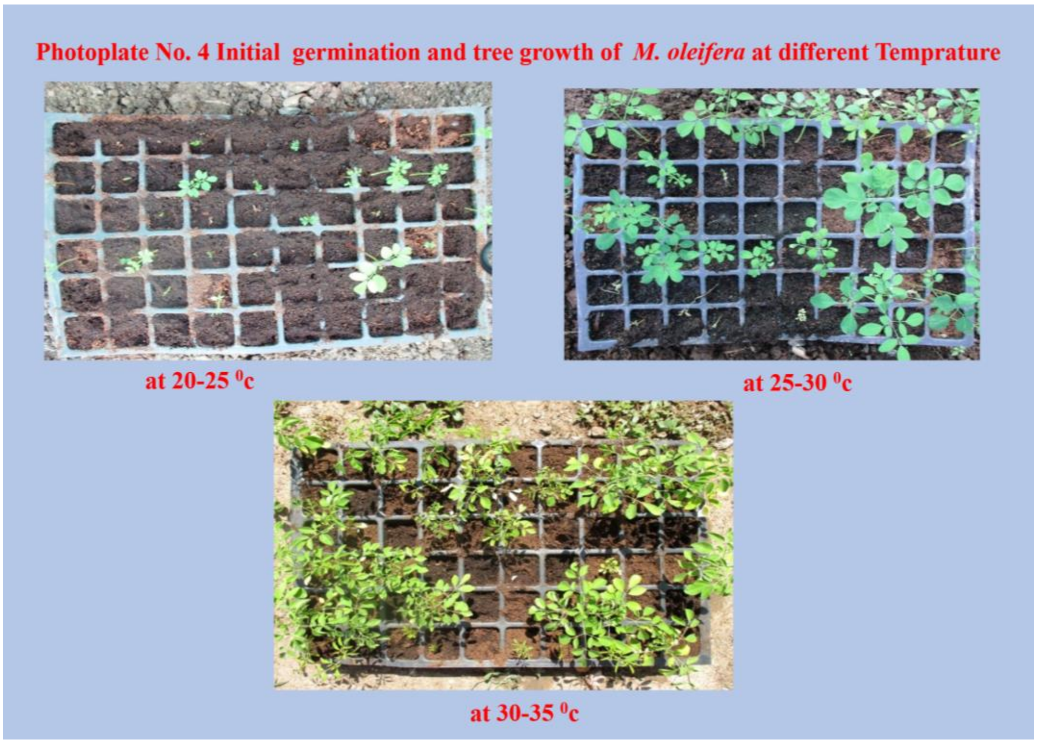

Table No. 1. Mean effect of temperatures at 20-25 ^{0}c on seed germination and growth of *Moringa oleifera*

Sr. No.	Days	Germination %	Height (CM)	No. of leaves
1	12th	2 %	2	0
2	16th	32%	4.47	0
3	20th	42%	7.47	2
4	24th	42%	13.78	3
5	28th	62%	14.8	6

Table No. 2. Mean effect of temperatures at 25-30 ^{0}c on seed germination and growth of *Moringa oleifera*

Sr. No	Days	Germination %	Height (CM)	Number of leaves
1	12th	No germination	No germination	No germination
2	16th	4%	1.72	0
3	20th	46%	3.05	0
4	24th	58%	5.9	2
5	28th	58%	7.4	5

Table No. 3. Mean effect of temperatures at 30-35 ^{0}c on seed germination and growth of *Moringa oleifera*

Sr. No.	Days	Germination %	Height (CM	No. of leaves
1	12th	28%	1.2	0
2	16th	64%	3.95	2
3	20th	64%	5.45	4
4	24th	64%	8.13	6
5	28th	64%	9.7	9

Temperature effect on growth and development:

Among the temperatures tested, **30-35°C** was the most favourable for growth, resulting in an average tree height of 35.3 cm and a stem diameter of 1.68 cm. Growth was significantly lower at **25-30°C**, while the **20-25°C** temperature severely limited growth. The application of fertilizer at week 8 caused a sudden increase in the growth rate.

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Photoplate No. 5. Tree growth of *M. oleifera* at 30-35 ⁰c, 25-30 ⁰c and 20-25 ⁰c after 16 weeks

Table No. 4. Effect of temperatures on seed growth of *Moringa oleifera* after 16th weeks

Sr. No.	Temperatures	Height (CM)	Diameter (CM)	No. of leaves
1	20 - 25 ^{0}c	13.3	1.2	15
2	25 - 30 ^{0}c	27	1.54	26
3	30 - 35 ^{0}c	35.1	1.68	17

Response of Moringa oleifera to saline conditions:

The seed germination was observed to be rapid in controlled conditions on the 5th day, and it was 100% in the control treatment and 40% in 0.1% NaCl concentration, while other concentrations showed no significant germination was observed on the 5th day. It was noted on the 30th day that the germination is 100% in control, 0.1%, 0.3%, and 0.5% concentrations of sodium chloride, while 0.8 and 1.0 % concentrations showed 80% and 70% germination of seeds, indicating that with an increase in concentrations of sodium chloride, the rate of germination.

Plate No. 6. Initial germination of *M. oleifera* seeds at following concentration of NaCl

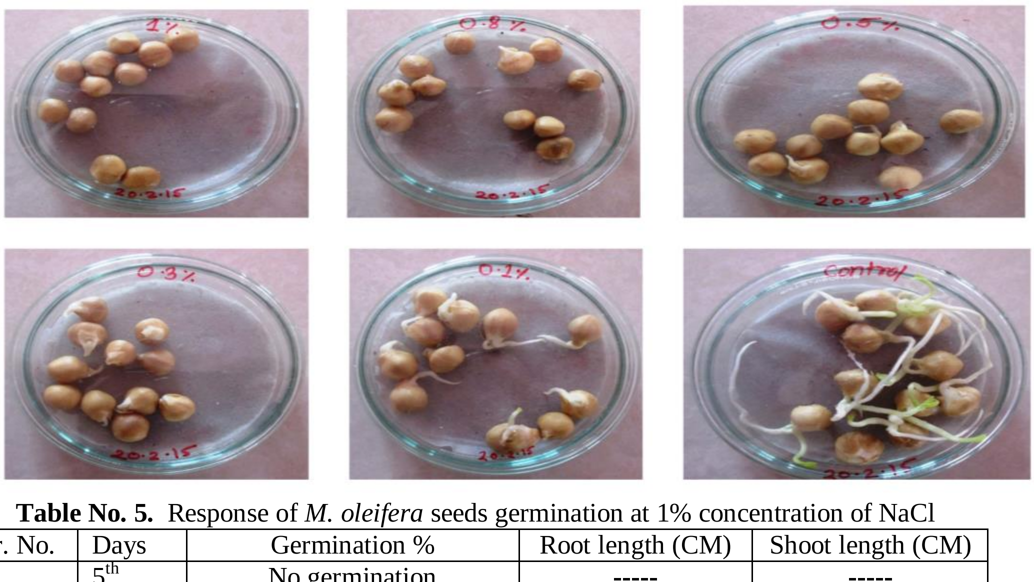

Table No. 5. Response of *M. oleifera* seeds germination at 1% concentration of NaCl

Sr. No.	Days	Germination %	Root length (CM)	Shoot length (CM)
1	5th	No germination	-----	-----
2	9th	No germination	-----	-----
3	13th	20%	0.45	0
4	23rd	70%	1.3	1
5	30th	70%	1.6	1.3

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Table No. 6. Response of *M. oleifera* seeds germination at 0.8% concentration of NaCl

Sr. No.	Days	Germination %	Root length (CM)	Shoot length (CM)
1	5th	No germination	-----	-----
2	9th	30%	0.0	0.0
3	13th	30%	0.0	1.77
4	23rd	80%	2.0	5.1
5	30th	80%	2.5	5.4

Table No. 7. Response of *M. oleifera* seeds germination at 0.5% concentration of NaCl

Sr. No.	Days	Germination %	Root length (CM)	Shoot length (CM)
1	5th	No germination	No	No
2	9th	50%	1.16	0.0
3	13th	90%	2.07	1.77
4	23rd	100%	2.41	5.1
5	30th	100%	2.62	5.56

.**Table No. 8.** Response of *M. oleifera* seeds germination at 0.3% concentration of NaCl

Sr. No.	Days	Germination %	Root length (CM)	Shoot length (CM)
1	5th	0%	0.0	0.0
2	9th	100%	1.55	1.3
3	13th	100%	2.41	2.69
4	23rd	100%	2.9	4.62
5	30th	100%	3.2	5.53

Table No. 9. Response of *M. oleifera* seeds germination at 0.1% concentration of NaCl

Sr. No.	Days	Germination %	Root length (CM)	Shoot length (CM)
1	5th	40%	0.0	0.0
2	9th	100%	2.68	3
3	13th	100%	3.2	5.9
4	23rd	100%	4.3	9.06
5	30th	100%.	4.7	9.5

Table No. 10. Response of *M. oleifera* seeds germination at control treatment (Water)

Sr. No.	Days	Germination %	Root length (CM)	Shoot length (CM)
1	5th	100%	0.0	0.0
2	9th	100%	4.62	4.96
3	13th	100%	5.5	6.15
4	23rd	100%	6.7	9.6
5	30th	100%	6.9	10.0

Response of *Moringa oleifera* to NaCl concentration 0.1, 0.3, 0.5, 0.8, 1% and Control after 30days.

Table No. 11. Fresh and dry weight biomass *M. oleifera* seeds after different treatments

Sr. No.	Concentrations of NaCl	Fresh Weight	Dry Weight
Sr. No.	1.0	0.66	0.22
1	0.8	0.93	0.21
2	0.5	1.42	0.27
3	0.3	1.48	0.28
4	0.1	1.57	0.26
5	Control	1.67	0.23

On the 30th day, the shoot length was observed. The control showed 10.00 cm, 0.1% showed 9.5 cm, and further higher concentrations produced a decrease in soot length. Similar observations are coming as per as root length is concerned. (1cm)

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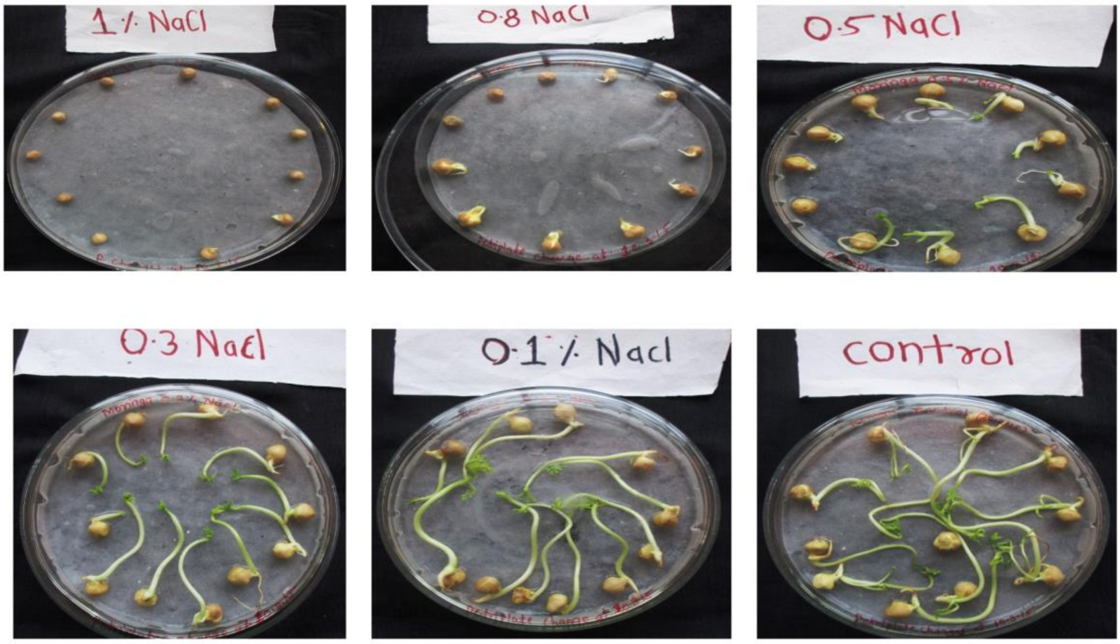
The total length was observed after 30th days, higher in the control condition, 16.9 cm and lower in 1% conc. of NaCl is 2.9 cm, and in other concentrations of NaCl, 0.1, 0.3, 0.5, 0.8% there was a decrease in the height with an increase in concentration of NaCl.

Fresh weight: During the present study, all NaCl concentrations had significant negative effects on seedling growth, and also affected the weight of the seedling of *Moringa*. The highest weight of the seedling was in the control condition, which is 1.67 gm, and the lowest weight was in 1% is 0.66gm at the 30th day.

Plate No. 7. Response of *M. oleifera* seeds at following concentration of NaCl after 30th day



Physico-chemical characteristics of water samples:

For the water samples were collected from Godavari, Pravara and Mula River showed in table no. 1,2 and 3 respectively, following drinking water quality parameters were analyzed before and after the treatment of various doses of *Moringa oleifera* seed powder.

Table No. 12. Physico-chemical characters of Godavari River water before and after treatment with various doses of Moringa oleifera seed powder

Sr. No.	Parameters	Before Treatment	After Treatment			WHO/ USTH Standards
			50mg/lit	100mg/lit	150mg/lit	
1	Colour	Faint yellow	Colourless	Colourless	Colourless	Colourless
2	pH	6.1 ± 0.05	6.5 ± 0.05	6.6 ± 0.05	6.9 ± 0.05	6.5 – 8.5
3	Acidity (mg/l)	40 ± 0.05	14 ± 0.76	13 ± 0.76	13 ±0.56	_
4	Alkalinity(mg/l)	132 ± 0.06	87 ± 0.09	72 ± 0.03	76 ± 0.04	200
5	Turbidity (NTU)	17.8 ± 0.05	5.0 ± 0.05	3.9 ± 0.28	2.2 ± 0.05	5
6	TS (mg/lit)	602 ± 0.05	505 ± 0.06	470 ± 0.05	468 ± 0.07	_
7	TDS (mg/lit)	587 ± 0.06	450 ± 0.7	420 ±0.05	380 ± 0.06	500
8	Chloride(mg/l)	28 ±0.02	17 ± 0.09	14.2 ± 0.2	13.5±0.06	250
9	Hardness (mg/l)	260 ±0.01	140 ± 0.57	140 ± 0.04	117 ± 0.05	500

Table No. 13. Physico-chemical characters of **Pravara** River water before and after treatment with various doses of Moringa oleifera seed powder

Sr. No.	Parameters	Before Treatment	After Treatment			WHO/ USTH Standards
			50mg/lit	100mg/lit	150mg/lit	
1	Colour	Faint brown	Colourless	Colourless	Colourless	Colourless
2	pH	6.4 ± 0.05	6.6 ± 0.02	6.6 ± 0.03	6.7 ± 0.08	6.5 – 8.5
3	Acidity (mg/l)	37 ± 0.05	12 ± 0.05	12 ± 0.03	11 ± 0.09	_
4	Alkalinity(mg/l)	122 ± 0.01	87 ± 0.42	86 ± 0.42	86 ± 0.02	200

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5	Turbidity (NTU)	12 ± 0.01	4.8 ± 0.01	2.6 ± 0.56	1.7 ± 0.01	5
6	TS (mg/lit)	614 ± 0.05	509 ± 0.05	465 ± 0.04	454 ± 0.05	_
7	TDS (mg/lit)	567 ± 0.06	450 ± 0.7	430 ±0.05	375 ± 0.05	500
8	Chloride(mg/l)	16 ±0.07	9 ± 0.03	6.5 ± 0.4	6 ± 0.03	250
9	Hardness (mg/l)	192 ±0.05	174 ± 0.05	168 ± 0.01	161 ± 0.04	500

Table No. 14. Physico-chemical characters of **Mula** River water before and after treatment with various doses of Moringa oleifera seed powder

Sr. No.	Parameters	Before Treatment	After Treatment			WHO/ USTH Standards
			50mg/lit	100mg/lit	150mg/lit	
1	Colour	Colourless	Colourless	Colourless	Colourless	Colourless
2	pH	5.3 ± 0.02	6.6 ± 0.04	6.9 ± 0.02	7.2 ± 0.05	6.5 – 8.5
3	Acidity (mg/l)	24 ± 0.03	6 ± 0.56	5 ± 0.28	5 ± 0.10	_
4	Alkalinity(mg/l)	70 ± 0.05	36 ± 0.05	36 ± 0.08	37 ± 0.03	200
5	Turbidity (NTU)	10.9 ± 0.05	4.0 ± 0.01	3.2 ± 0.05	2.7 ± 0.05	5
6	TS (mg/lit)	609 ± 0.05	428 ± 0.01	416 ± 0.05	375 ± 0.05	_
7	TDS (mg/lit)	535 ± 0.05	465 ± 0.06	334 ±0.05	334 ± 0.05	500
8	Chloride(mg/l)	18 ± 0.06	7 ± 0.02	5.5 ± 0.6	5.3 ± 0.03	250
9	Hardness (mg/l)	172 ± 0.04	130 ± 0.03	119 ± 0.04	109 ± 0.08	500

Analysis of Water Treatment Using Moringa oleifera Seed Powder

The study investigates the efficacy of *Moringa oleifera* seed powder in water purification across three different river water samples: Godavari, Pravara, and Mula. The primary parameters assessed include color, pH, acidity, alkalinity, turbidity, total solids, dissolved solids, chloride levels, hardness, and overall water quality compliance with WHO standards.

Color Removal Efficiency

Initial observations indicated that water from the Godavari River exhibited a faint yellow coloration, which was completely eliminated after treatment with seed powder concentrations of 50, 100, and 150 mg/L, resulting in colorless water. Similarly, Pravara River water showed a transition from faint brown to colorless, whereas Mula River water did not demonstrate significant color change. All treated samples conformed to WHO acceptability limits, highlighting the effectiveness of *Moringa oleifera* in color removal.

pH Adjustment

Post-treatment pH values for all samples remained within the WHO recommended range. The Mula River water showed a slight increase in pH at 50 and 100 mg/L seed powder doses, whereas Godavari and Pravara samples exhibited a consistent pH increase across all doses. This indicates that seed powder treatment can effectively modulate pH levels without exceeding acceptable limits.

Acidity Reduction

Pre-treatment acidity levels varied among the rivers, with Godavari at 40 ± 0.05 mg/L, Pravara at 37 ± 0.05 mg/L, and Mula at 24 ± 0.03 mg/L. Post-treatment, acidity significantly decreased in all samples, with reductions correlating with increased seed powder doses. Notably, Mula River water showed a consistent decrease in acidity, falling within WHO permissible limits, demonstrating the potential of *Moringa oleifera* in reducing water acidity effectively.

Alkalinity Changes

Initial alkalinity levels were highest in Godavari River water (132 ± 0.06 mg/L), with Pravara and Mula showing 122 ± 0.01 mg/L and 70 ± 0.05 mg/L, respectively. Treatment resulted in decreased alkalinity in Godavari and Pravara samples, especially at lower doses, while Mula water exhibited slight fluctuations. All treated samples maintained alkalinity within WHO standards, indicating the suitability of seed powder treatment for alkalinity management.

Turbidity Reduction

Turbidity measurements post-treatment revealed significant reductions across all samples. Godavari River water's turbidity decreased from initial levels to below 5 NTU at higher seed powder doses, aligning with WHO standards. Pravara River water, initially exceeding permissible limits, was effectively treated to acceptable turbidity levels. Mula River water also showed substantial turbidity reduction, confirming the efficacy of *Moringa oleifera* in clarifying water.

Total Solids and Dissolved Solids

Initial total solids ranged from 600 to 650 mg/L, with dissolved solids between 500 and 600 mg/L. Treatment with seed powder reduced these parameters across all samples, bringing them within WHO permissible limits. The reductions ranged from approximately 375 to 510 mg/L, demonstrating the capacity of *Moringa oleifera* to effectively decrease total and dissolved solids in contaminated water sources.

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Chloride Content

Chloride levels in untreated water were 28 ± 0.02 mg/L (Godavari), 16 ± 0.07 mg/L (Pravara), and 18 ± 0.06 mg/L (Mula). Post-treatment, chloride concentrations significantly decreased, with Mula River water exhibiting the lowest levels (4-6 mg/L). These reductions suggest that seed powder treatment can effectively lower chloride content, improving overall water quality.

Hardness Reduction

Pre-treatment hardness levels were 260 ± 0.01 mg/L (Godavari), 192 ± 0.05 mg/L (Pravara), and 172 ± 0.04 mg/L (Mula). Treatment resulted in decreased hardness across all samples, with Mula River water showing the lowest post-treatment hardness (108-130 mg/L). All treated waters remained within WHO standards, indicating the potential of *Moringa oleifera* in softening hard water sources.

Discussion

Impact of Temperature on Moringa oleifera Growth

Temperature plays a crucial role in influencing the growth and development of *Moringa oleifera*. Optimal growth conditions are typically observed within the temperature range of 30-35°C, where seedling development and leaf production are most vigorous. Elevated temperatures tend to accelerate germination processes and promote linear growth patterns, which aligns with findings observed in other tropical plant species. Conversely, lower temperatures result in slower growth rates characterized by sigmoidal growth curves, underscoring the importance of maintaining appropriate thermal conditions for optimal cultivation and productivity.

Response to Salinity Stress

The study further investigated the response of *Moringa oleifera* to saline conditions. Increasing concentrations of NaCl negatively affected germination rates, shoot elongation, and overall seedling vigor. Higher salinity levels delayed germination and reduced shoot length, consistent with previous research indicating that salt stress inhibits plant growth. Interestingly, root elongation was observed to increase under saline stress, suggesting an adaptive mechanism where roots expand to seek water and nutrients in challenging environments. These findings emphasize the importance of managing salinity levels in cultivation practices and water treatment applications involving *Moringa oleifera*, to ensure healthy growth and optimal yield.

Physico-chemical characteristic of water samples:

Moringa oleifera seeds serve as a natural coagulant, flocculant, and absorbent in water treatment processes (Mangale et al., 2012). The coagulation mechanism primarily involves the adsorption and neutralization of negatively charged impurities by positively charged, water-soluble proteins present in the seeds (Vikashni et al., 2012; Omm-e et al., 2013).

The addition of seed powder increases the pH of water, rendering it more basic. This occurs because the basic amino acids in the proteins release hydroxyl groups, which effectively reduce the acidity of raw water. Results have shown that acidity levels can decrease to between 5-15 mg/liter, aligning with findings from previous studies (Amagloh and Benang, 2009; Mangale et al., 2012).

During the current study, it was observed that the alkalinity of all three river water samples significantly decreased at a dose of 50 mg/liter of *Moringa* seed powder. At a higher dose of 100 mg/liter, the alkalinity of the Godavari and Pravara river water samples continued to decrease, whereas the alkalinity of the Mula river water sample increased. At an even higher dose of 150 mg/liter, alkalinity slightly increased across all three samples. Similar findings have been reported by Balakrishnan et al. (2014), who observed a gradual increase in alkalinity at doses of 100 and 150 mg/liter of *Moringa* seed powder.

The slight decrease in alkalinity and pH across all water samples may be attributed to the precipitation of insoluble reaction products between *M. oleifera* and hardness-causing ions, akin to the process of lime or soda ash softening. The *M. oleifera* seed extract appears to possess natural buffering capacity. The precipitates formed are light and do not settle easily, and their chemical composition remains unidentified. Nonetheless, the reduction in alkalinity during coagulation with *M. oleifera* seeds has been documented (Amagloh and Benang, 2009).

Amagloh and Benang (2009) also reported that turbidity may result from light scattering caused by suspended particles such as silt, microorganisms, plant fibers, sawdust, wood ashes, chemicals, and coal dust.

In the present study, increasing doses of *M. oleifera* significantly decreased water turbidity, indicating the potential of *Moringa* as an effective water purifier. Similar findings were reported by Amagloh and Benang (2009), who observed that a loading dose of 12.0 g/liter of *Moringa* seed powder effectively reduced turbidity. The formation of flocs and subsequent decrease in turbidity demonstrate the coagulation activity of *Moringa* seed extract, as supported by Mohammed et al. (2013). Conversely, Futi et al. (2011) reported that higher concentrations (1 g/liter) of *Moringa* could increase water turbidity. Based on these observations, it is recommended to use lower doses of *Moringa oleifera* for water treatment to ensure optimal purification of drinking water.

Total dissolved solids (TDS) in water vary considerably across different geographical regions due to differences in mineral solubility. Although there is no universal standard value for TDS, high levels in drinking water may be objectionable to consumers (WHO, 2006).

In this study, increasing concentrations of *Moringa* treatment resulted in decreased conductivity values, consistent with observations by Amagloh and Benang (2009). All three water samples treated with 50, 100, and 150 mg/liter of seed powder showed reductions in total solids and TDS. Specifically, TDS was reduced by more than 40% when water was treated with *M. oleifera* seed powder (Aho and Lagasi, 2012).

The chloride levels in the three water samples—Godavari, Pravara, and Mula—decreased at doses of 50, 100, and 150 mg/liter, remaining within the standard permissible range of 4-17 mg/liter. Similar findings were reported by Udayasri et al. (2014), who noted that *Moringa* seed treatment reduces chloride ions by neutralizing negatively charged chloride ions through cationic interactions with seed constituents.

Regarding water hardness, the study observed a decrease in hardness with increasing doses of *M. oleifera* seeds. This aligns with the findings of Mangale et al. (2012), who reported that higher doses of *Moringa* seed powder effectively reduce water hardness. As a polyelectrolyte, *M. oleifera* likely removes hardness through adsorption and inter-particle bridging mechanisms. The higher hardness levels in surface water samples are attributable to calcium, magnesium, and other hardness-causing substances. These results suggest that increased hardness necessitates higher doses of *Moringa* seed powder for effective treatment.

Conclusions

Optimal Growing Conditions: The ideal temperature for Moringa (Moringa oleifera) ranges between **30-35°C**, which promotes optimal germination, seedling development, and leaf growth. This temperature range aligns with the plant's preference for tropical climates, ensuring vigorous growth and productivity.

Salinity Sensitivity: Moringa exhibits sensitivity to salinity, particularly to sodium chloride. Elevated salt concentrations adversely affect seed germination, emergence, and overall seedling development, highlighting the importance of maintaining low salinity levels in cultivation areas.

Water Purification: Moringa seeds possess natural coagulant properties, making them an effective, low-cost solution for water purification. They can significantly reduce water hardness, turbidity, and various impurities, rendering them suitable for rural communities with limited access to clean drinking water.

Cultivation Recommendations: To ensure a consistent supply of Moringa seeds for water purification purposes, it is advisable to promote intensive cultivation in tropical regions. This approach is similar to the cultivation practices used for cash crops, emphasizing high yield and sustainable production.

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