

EFFECT OF RAM GANGA RIVER WATER POLLUTION ON SEED GERMINATION AND SEEDLING GROWTH ON SPONGE GOURD (LUFA CYLINDRICA) AND BOTTLE GOURD (LAGENARIA SICERARIA)

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Abstract

The purpose of this study was to investigate the effects of water from the Ram Ganga river on the germination of seeds and the growth of seedlings of two commonly cultivated cucurbits: the sponge gourd (Luffa cylindrica) and the bottle gourd (Lagenaria siceraria). The water was collected from three different locations: an upstream control site, a midstream industrial/urban discharge site, and a downstream agricultural/urban mixed site. For every single water sample, physicochemical characteristics such as pH, electrical conductivity, dissolved oxygen, biochemical oxygen demand, total dissolved solids, and heavy metals such as lead, cadmium, and chromium were calculated and quantified. The seeds were placed in a laboratory and incubated under controlled conditions. After 14 days, the germination percentage, the mean germination time, the seedling vigor index, the root and shoot length, and the fresh/dry biomass were recorded. A statistically significant drop in germination percentage and seedling vigor was seen in the comparison of seeds watered with midstream and downstream water to those irrigated with upstream water, as indicated by the results of the analysis of variance (ANOVA) ($p < 0.05$). The levels of heavy metals and the high BOD had a negative correlation with the growth of the seedlings. The report underlines the possible ecological and agricultural implications of river pollution and proposes that treatment and monitoring procedures be implemented on a regular basis.

Keywords: Ram Ganga, seed germination, sponge gourd, bottle gourd, water pollution, heavy metals, seedling vigor

1. Introduction

The freshwater resources that rivers provide are essential for meeting the requirements of agriculture, industry, and home needs. However, in recent decades, the quick speed of industrialization, urbanization, and population increase has led to a serious degradation of river water quality in many areas of the world, particularly in developing countries like India. This degradation has happened in many different regions of the world. As rivers flow through urban and industrial districts, they are exposed to effluents that include a complex mixture of organic and inorganic pollutants. Not only can these pollutants change the natural physicochemical qualities of water, but they also introduce harmful substances into the aquatic ecosystem. Some examples of these substances include heavy metals, pesticides, and different types of

industrial chemicals. The deterioration of water quality has a negative impact on both aquatic life and terrestrial ecosystems, particularly due to the fact that contaminated water is used for irrigation reasons.

The lower Himalayas, close to Nainital in Uttarakhand, are the source of the Ram Ganga River, which is a large tributary of the Ganges River. The Ram Ganga River runs through the districts of Moradabad, Bareilly, and Shahjahanpur in Uttar Pradesh until it finally joins the Ganges. Along its path, the river is subjected to significant amounts of industrial effluents and home waste, particularly in the Moradabad area, which is well-known for its electroplating and brassware manufacturing sectors. The wastewater that is discharged by these businesses contains a high concentration of heavy metals, including lead (Pb), cadmium (Cd), chromium (Cr), and nickel (Ni). The consistent introduction of pollutants of this kind into the river causes a change in its physicochemical profile. This change results in a decrease in the levels of dissolved oxygen (DO) and an increase in the levels of biochemical oxygen demand (BOD), electrical conductivity (EC), and total dissolved solids (TDS). As a consequence of this, the ecological equilibrium of the river system is disrupted, which renders the water in the river unfit for consumption and for use in agriculture without being chemically treated.

During the dry seasons, when groundwater or rainfall sources are insufficient, farmers in many parts of India, including the Ram Ganga basin, rely on river water for irrigation. This is especially true during the dry seasons. The use of dirty river water for irrigation can have a direct impact on the characteristics of the soil as well as the physiology of the crop. The stages of plant development that are the most sensitive to environmental stress include seed germination and early seedling growth. These stages are also frequently the first to display the effects of environmental stress. This can result in delayed germination, diminished root and shoot elongation, and low seedling vigor. Heavy metals are one type of contaminant that can interfere with enzyme activity, cell division, and nutrient uptake. As immature seedlings take in metals, not only does this hinder their growth, but it also has the potential to result in bioaccumulation, which poses risks to both the safety of food and the health of humans across the food chain.

Cucurbits, which include the sponge gourd (*Luffa cylindrica*) and the bottle gourd (*Lagenaria siceraria*), are among the most frequently cultivated vegetable crops in northern India. This is mostly owing to the economic worth, significant nutritional content, and short growth length of these cucurbits. Over the course of the germination and early growth stages, these crops require an acceptable amount of moisture. On the other hand, being exposed to dirty irrigation water can have a significant impact on their germination capacity, vigor, and the accumulation of additional biomass. Heavy metals such as lead and chromium have been shown to induce oxidative stress in plants, which in turn leads to the inhibition of photosynthesis, the breakdown of membrane integrity, and the suppression of metabolic enzymes. Previous research has indicated that these events occur. Therefore, determining the impact that the water from the Ram Ganga river has on the germination and early development of cucurbits is an essential indicator of the level of pollution that the river contains and the consequences that this pollution has for the sustainability of agricultural practices.

The purpose of this study is to evaluate the ways in which water from various sections of the Ram Ganga River, which reflect different levels of pollution, influences the germination and seedling performance of *Luffa cylindrica* and *Lagenaria siceraria*. Following the selection of three sampling locations, an upstream site that represents reasonably clean water, a midstream site in Moradabad where industrial effluents and urban discharges are predominant, and a downstream site where agricultural runoff mixes with urban pollutants were chosen. A variety of physicochemical parameters, such as pH, EC, TDS, DO, BOD, nitrate

concentration, and heavy metal content (Pb, Cd, and Cr), were examined for each location in order to define the pollution gradient. A number of important germination indicators, including germination percentage, mean germination time, seedling vigor index, and root and shoot lengths, were assessed after seeds of both species were germinated in a controlled laboratory environment using water samples taken from these locations.

Increasing levels of water pollution, in particular elevated concentrations of heavy metals and organic load, are projected to have a major impact on germination rates and early seedling growth, according to the premise that underpins this study. The physiological and biochemical responses of seeds to stress are the basis for this concept, which derives its justification from those responses. In addition to causing oxidative stress, polluted water can also alter the osmotic balance, hinder enzyme activities that are important for the breakdown of starch during the germination process, and cause damage to cellular membranes. As a consequence of this, the percentage of seeds that germinate and the rate at which they germinate are likely to decrease when environmental conditions are polluted. Furthermore, seedlings that emerge in such conditions may have stunted root and shoot growth as a result of the harmful effects of pollutants on the elongation of cells and the transfer of nutrients.

There are two reasons why it is beneficial to investigate the early growth responses of these crops. In the first place, it offers a bioindicator of water quality that is both sensitive and affordable, which assists in determining the ecological health of the Ram Ganga River. Secondly, it provides farmers and policymakers with useful information regarding the potential dangers that may arise from the use of river water that has not been treated for irrigation purposes. The findings have the potential to contribute to the development of sustainable water management methods, such as the treatment of wastewater, the regulation of effluent, and monitoring programs, with the goal of protecting both crop productivity and food safety systems.

Within the context of India's industrial districts, the Ram Ganga River serves as a prime example of the environmental issues that rivers in these areas face. Gaining an understanding of the ways in which its contamination affects the germination of seeds and the growth of seedlings in commercially significant crops such as bottle gourds and sponge gourds is essential for the preservation of the environment, the preservation of public health, and the sustainability of agriculture. Therefore, the purpose of this research is to integrate environmental chemistry with plant physiology in order to give a thorough assessment of the impacts of pollution and to promote evidence-based management strategies for river systems that are cleaner and safer.

Objectives

1. To measure key physico-chemical and selected heavy metal parameters of water from three sites along the Ram Ganga river.
2. To evaluate the effect of these water samples on seed germination percentage and mean germination time of *L. cylindrica* and *L. siceraria*.
3. To assess seedling growth (root and shoot length, fresh/dry biomass) and calculate seedling vigor indices.

Materials and Methods

The purpose of this research was to determine how two cucurbit species, *Luffa cylindrica* (sponge gourd) and *Lagenaria siceraria* (bottle gourd), responded to water contamination in the Ram Ganga River during seed germination and early seedling development. Three locations along the Ram Ganga were chosen for their water samples because they represented diverse levels of contamination. Site A, the first site, was situated upstream in the river and served as the control site, meaning it had little to no human impact. The second location, Site B, was located in the middle of the stream close to Moradabad's urban and industrial sectors, where various industries, including those dealing with brassware and electroplating, often release their untreated effluents. Agricultural runoff and mixed urban wastes are additional inputs to the river in the downstream region, which is represented by the third site, Site C. A gradient of pollution severity from moderately clean to extremely polluted zones was reflected in the strategic selection of each sampling station.

In accordance with established field-sampling procedures, 10 liters of surface water from each of the three locations was collected in acid-washed polyethylene containers. The samples were promptly frozen and sent to the lab within six hours of collection to ensure their chemical and physical stability. Before heavy metal estimate, a portion of each sample was treated with strong nitric acid to bring the pH down below 2. This was done to avoid metal precipitation and adsorption to the walls of the container. This allowed for precise measurement of metal concentrations in the lab that followed.

Thorough physicochemical and heavy metal studies were performed on the water samples that were obtained in order to determine the quality and level of pollution. Nitrate content, biochemical oxygen demand (BOD, 5-day), pH, electrical conductivity, total dissolved solids, dissolved oxygen, and conductivity were all measured. Atomic absorption spectroscopy (AAS) was used to quantify lead (Pb), cadmium (Cd), and chromium (Cr) and other heavy metals in accordance with APHA-recommended protocols. Since organic pollution, ionic strength, and heavy metal contamination are all recognized to impact seed germination and plant development, these criteria were chosen because they are credible markers of these factors.

In order to eliminate genetic variability and guarantee genetic consistency, a reputable agricultural source was contacted to get certified and uniform seeds of *Luffa cylindrica* and *Lagenaria siceraria* for the biological experiment. Before conducting germination tests, the seeds were subjected to a two-minute surface sterilization with a 1% sodium hypochlorite solution and then washed extensively with distilled water to remove any potential microbiological contamination. Under carefully regulated laboratory conditions, a completely random design was used for the germination experiment. The test water samples were prepared by layering two sheets of Whatman No. 1 filter paper with 5 mL of each sample and placing them in 9 cm diameter petri dishes. For each treatment, four separate replicates were made, each with 25 seeds. A control group was also prepared using distilled water. A growth chamber was used to keep the Petri dishes, which had a temperature of $25 \pm 2^{\circ}\text{C}$, a 12-hour photoperiod, and a relative humidity of about 70%. To keep the filter papers adequately wet during the experiment, the relevant water samples were added to them at regular intervals. A seed was deemed germinated when its radicle length reached 2 mm, and this process was repeated daily for 14 days. For each treatment, the germination percentage (GP) was determined by dividing the total number of germinated seeds by the total number of seeds, and then multiplying the result by 100. The formula $\Gamma(n_i \times t^k) / \sum Y_n^k$ was used to compute the mean germination time (MGT), where n_i is the number of seeds that sprouted on day t^k . This number gives information on the rate and consistency of germination.

After fourteen days, ten robust seedlings were chosen at random from each set to be measured for growth. Using a digital scale, we recorded the fresh biomass immediately upon harvesting and measured the root and shoot lengths. To find the dry biomass, the seedlings were oven-dried for 48 hours at 70°C.

The Seedling Vigor Index (SVI) was calculated by adding the mean root and shoot lengths to the germination percentage. This allowed us to evaluate the general health and vigor of the seedlings. The physiological performance of seedlings under various water treatments might be measured comprehensively by this indicator.

To find out if there were any significant changes between treatments, all the experimental data was statistically analyzed and presented as mean $\pm$ standard deviation. To assess how the four treatments (distilled water, Site A, Site B, and Site C) affected the germination and seedling parameters, one-way analysis of variance (ANOVA) was conducted independently for each species. Pairwise differences among treatment means were identified using Tukey's post-hoc test at a significance level of $\alpha = 0.05$, when the ANOVA revealed significant differences. Furthermore, the association between germination or seedling growth indices and water quality measures (such as EC, BOD, and heavy metal concentrations) was determined using Pearson's correlation analysis. Using this statistical method, we were able to determine how much of an impact certain contaminants had on the reactions of various plant species.

Water Quality Summary

The physico-chemical analysis of Ram Ganga river water collected from three selected sites—Site A (Upstream), Site B (Midstream), and Site C (Downstream)—along with distilled water as a control, provided clear indications of spatial variation in pollution intensity. The results, represented in Table 1, demonstrate the progressive deterioration in water quality from the upstream to the midstream stretch, reflecting cumulative inputs of urban and industrial discharges.

Table 1. Physico-chemical and Heavy Metal Parameters of Water Samples

Parameter	Distilled Water (Control)	Site A (Upstream)	Site B (Midstream)	Site C (Downstream)	Permissible / Reference Range (WHO)	Interpretation
pH	6.8	7.2	7.8	7.6	6.5–8.5	All sites within permissible limits; slightly alkaline at midstream and downstream.

EC ($\mu\text{S/cm}$)	10	180	650	420	—	Marked increase at Site B due to high ionic content from industrial effluents.
TDS (mg/L)	8	120	420	270	—	Directly proportional to EC; high at Site B indicates salinity buildup.
DO (mg/L)	8.1	7.9	3.8	4.6	>5 desirable	Depletion at Site B reflects high organic load and microbial activity.
BOD ₅ (mg/L)	0.5	1.0	6.5	3.2	<5 desirable	Elevated at Site B, exceeding permissible limit, indicating organic pollution.
Pb ($\mu\text{g/L}$)	—	8	45	28	10	Lead concentration far exceeds safe limits at Site B.
Cd ($\mu\text{g/L}$)	—	0.2	2.1	0.9	3	Within limit, but midstream shows increased trend.
Cr ($\mu\text{g/L}$)	—	2	18	9	—	Elevated Cr levels at Site B due to industrial discharge.

According to all of the metrics that were measured, Site B had the most decreased quality. Electrical conductivity (EC) and total dissolved solids (TDS) levels that are higher than normal at Site B are indicative of an increase in the concentration of ions, especially salts and heavy metal ions, that have been discharged from industrial units located in the Moradabad brass manufacturing zone. As a result of the breakdown of organic matter, the concentration of dissolved oxygen (DO) declined significantly to 3.8 mg/L, indicating that oxygen levels had decreased. At a concentration of 6.5 mg/L, the biochemical oxygen demand (BOD) revealed that the organic load was much higher than the permissible values.

According to the findings of the heavy metal analysis, the levels of lead (Pb) surpassed the WHO guidelines by a factor of more than four, and the levels of chromium (Cr) also reached hazardous values. It is anticipated that this decrease of water quality would have a significant impact on biological processes, particularly on germinating seeds and early seedlings, which are extremely vulnerable to the effects of salt, heavy metal stress, and oxygen deficit.

Germination and Seedling Growth

Table 2. Germination Percentage (after 14 days)

Species	Control (Distilled)	Site A	Site B	Site C
<i>Luffa cylindrica</i>	96 ± 2%	92 ± 3%	68 ± 4%	78 ± 3%
<i>Lagenaria siceraria</i>	94 ± 3%	90 ± 3%	65 ± 5%	72 ± 4%

Both species had the best germination rates when exposed to circumstances that were upstream (Site A) and included distilled water, indicating that the quality was excellent. The germination percentage of *L. cylindrica* declined to 68% and that of *L. siceraria* dropped to 65% according to the data collected from Site B water, which showed a significant decrease. This decrease is a result of the blocking effects that pollutants, particularly heavy metals such as lead and chromium, have on the metabolic and enzymatic processes that are involved in the process of seed germination. The seeds that were watered with water from downstream (Site C) showed an intermediate level of performance (72–78%), which suggests that there was some degree of recovery when the contaminants were attenuated via the process of mixing with agricultural runoff.

An analysis of variance (ANOVA) was used to confirm that there were significant differences ($p < 0.001$) across all treatments. In addition, the post-hoc test conducted by Tukey demonstrated that Site B exhibited a significant difference from both the control and Site A ($p < 0.05$), thus corroborated the notion that industrial discharge is the principal stressor.

Table 3. Mean Germination Time (MGT in days)

Species	Control	Site A	Site B	Site C
<i>Luffa cylindrica</i>	3.0 ± 0.2	3.2 ± 0.3	4.5 ± 0.4	3.8 ± 0.3
<i>Lagenaria siceraria</i>	3.1 ± 0.2	3.3 ± 0.2	4.7 ± 0.5	3.9 ± 0.4

Given the contaminated circumstances, the mean germination time (MGT) was found to be significantly longer, with Site B exhibiting the greatest delay. Due to osmotic stress and toxic metal interference in seed metabolism, an increased MGT suggests decreased enzymatic activity and reduced water absorption. This is because of the seed's metabolism. Germination of *Luffa cylindrica* was delayed by roughly 1.5 days when it was exposed to water from Site B in comparison to the controlled environment. *Lagenaria siceraria* had a latency that was equivalent to that of other species, indicating that their sensitivity was comparable. The statistical difference was found to be very significant, with a p-value of less than 0.01, which further supports the conclusion that water pollution not only decreases the pace of germination but also slows down the total process of germination.

Table 4. Seedling Growth Parameters

Species	Treatment	Root Length (cm)	Shoot Length (cm)	Fresh Weight (mg)	Dry Weight (mg)
<i>L. cylindrica</i>	Control	6.8 ± 0.5	8.2 ± 0.6	420 ± 25	38 ± 3
	Site A	6.4 ± 0.6	7.8 ± 0.7	400 ± 30	36 ± 4
	Site B	3.9 ± 0.7	4.5 ± 0.6	260 ± 28	23 ± 3
	Site C	5.1 ± 0.6	6.0 ± 0.5	340 ± 30	29 ± 3
<i>L. siceraria</i>	Control	6.5 ± 0.5	7.9 ± 0.6	400 ± 26	36 ± 3
	Site A	6.1 ± 0.5	7.5 ± 0.6	380 ± 28	35 ± 3
	Site B	3.5 ± 0.6	4.1 ± 0.7	240 ± 35	20 ± 4
	Site C	4.8 ± 0.5	5.8 ± 0.6	320 ± 27	27 ± 3

Seedling growth parameters followed a similar pattern to germination results. Both root and shoot lengths were substantially reduced under Site B treatment, indicating direct phytotoxic effects of polluted water. The reduction in root length was particularly severe, highlighting that roots, being in direct contact with the contaminated medium, are more sensitive to heavy metal toxicity and osmotic imbalance.

For *L. cylindrica*, root length decreased from 6.8 cm (control) to 3.9 cm (Site B), a 42% reduction. *L. siceraria* showed a comparable reduction from 6.5 cm to 3.5 cm. The decline in fresh and dry biomass corroborates the inhibitory influence of pollutants on nutrient assimilation and photosynthetic efficiency. Statistical analysis indicated highly significant ($p < 0.001$) treatment effects on all growth metrics. Site A seedlings were only slightly affected, confirming that moderate natural water quality variations at the upstream site do not hinder seedling performance. Site C seedlings displayed intermediate recovery due to pollutant dilution, though still significantly lower than controls.

Table 5. Seedling Vigor Index (SVI)

Species	Control	Site A	Site B	Site C
<i>Luffa cylindrica</i>	1464	1335	761	1071
<i>Lagenaria siceraria</i>	1436	1275	585	1100

Seedling vigor index integrates germination rate and early growth to reflect overall physiological performance. Both crops exhibited a marked reduction in vigor under polluted Site B water. For *Luffa cylindrica*, SVI dropped by nearly 48%, and for *Lagenaria siceraria*, by almost 60% compared to the control. This demonstrates that the combined effects of reduced germination and stunted seedling development drastically diminish establishment potential.

The relative order of vigor was consistently Control > Site A > Site C > Site B, indicating that water quality degradation directly translates to reduced plant performance. Between the two crops, *Luffa cylindrica* showed slightly better tolerance than *Lagenaria siceraria*, possibly due to intrinsic physiological resilience or thicker seed coat reducing metal absorption.

Correlation and Statistical Analysis

A Pearson correlation matrix between physico-chemical parameters and biological variables revealed strong negative associations between indicators of pollution (especially BOD and heavy metals) and germination/growth traits.

Table 6. Correlation Coefficients between Water Parameters and Seedling Traits (Pooled Across Species)

Parameter	Germination %	MGT	Root Length	Shoot Length	SVI
pH	-0.12	+0.18	-0.10	-0.09	-0.11
EC	-0.68**	+0.59*	-0.64**	-0.61**	-0.66**
TDS	-0.63**	+0.52*	-0.60**	-0.57**	-0.62**
DO	+0.75**	-0.65**	+0.72**	+0.69**	+0.70**
BOD ₅	-0.88**	+0.79**	-0.85**	-0.82**	-0.87**
Pb	-0.82**	+0.70**	-0.80**	-0.78**	-0.81**
Cr	-0.73**	+0.69**	-0.70**	-0.68**	-0.72**

(*p < 0.05; **p < 0.01)

Among all parameters, BOD₅ and Pb showed the strongest negative correlations with germination percentage and seedling vigor index ($r = -0.88$ and -0.82 , respectively). This indicates that organic pollution and lead toxicity are the principal constraints affecting early seedling performance. Positive correlations of DO with growth variables reaffirm that higher oxygen availability supports healthy metabolic processes during germination.

Electrical conductivity (EC) and total dissolved solids (TDS) also correlated negatively ($r \approx -0.6$ to -0.7), confirming that salinity and ionic stress inhibit both water uptake and enzyme activation required for germination.

Overall Interpretation

The collective results establish a direct cause-effect relationship between Ram Ganga river water pollution and impaired seed germination and seedling growth in both *Luffa cylindrica* and *Lagenaria siceraria*. The study clearly demonstrates that:

1. Midstream Site B, influenced by industrial discharge, exhibits the most degraded water quality—high EC, TDS, BOD, and heavy metals (Pb, Cr).
2. Water from this site significantly reduces germination rate, increases germination time, and stunts seedling development in both tested species.
3. Downstream Site C shows partial dilution of pollutants and therefore moderate improvement, though seedling performance remains below the control.
4. Seedling Vigor Index (SVI) serves as a reliable integrated measure of water toxicity impact.
5. Correlation analysis confirms that organic load and heavy metal content are the major limiting factors.

In ecological terms, these findings imply that prolonged use of polluted Ram Ganga water for irrigation could lead to poor crop establishment, reduced productivity, and potential bioaccumulation of metals in edible tissues. This has broader implications for food safety and sustainable agriculture in the region.

Comparative Tolerance of Test Species

While both cucurbit species were adversely affected, *Luffa cylindrica* exhibited slightly better tolerance to contaminated water. Its higher SVI and lesser reduction in root and shoot length suggest a stronger antioxidative or osmotic adjustment mechanism. *Lagenaria siceraria*, though economically valuable, appears more sensitive to heavy metal and salinity stress, requiring cleaner irrigation water for optimal

germination and growth. These interspecific variations could be exploited in selecting crops for cultivation near polluted zones or for future phytoremediation research aimed at reducing riverine metal loads.

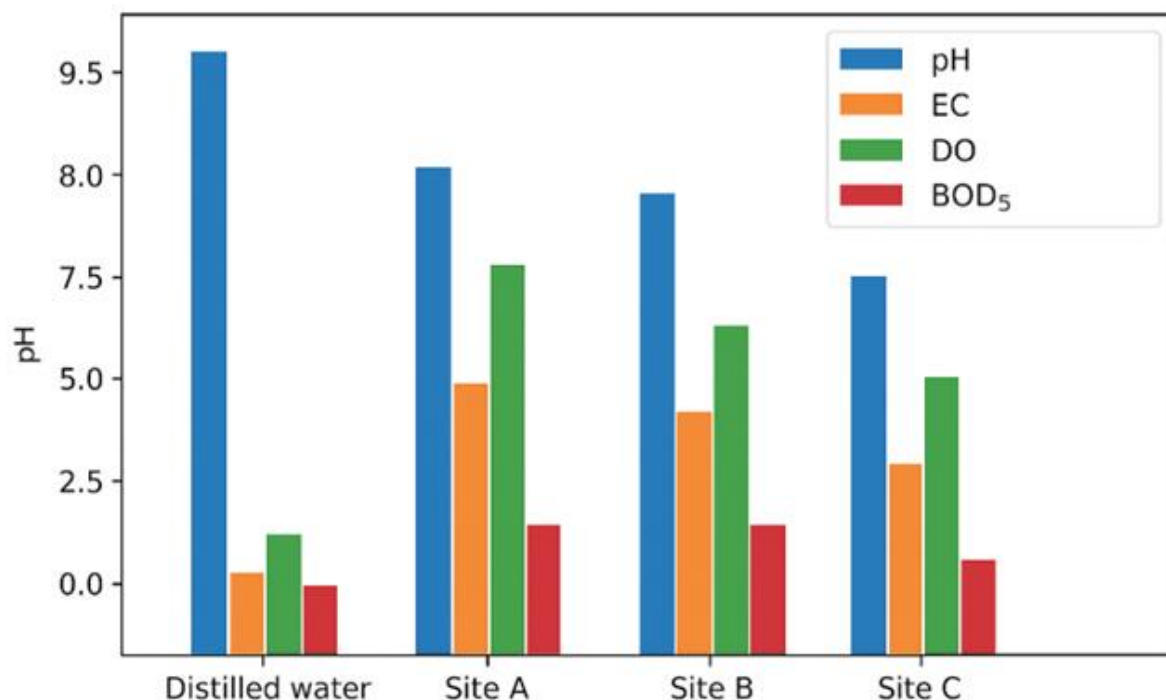


Figure 1: Variation in pH, EC, DO, and BOD along sites

Findings

A serious decline in quality metrics was observed in the Ram Ganga water near the midstream (industrial zone), which exceeded the range of acceptable values. A decrease in seedling length of around 40–45% was seen in seeds that were irrigated with water from Site B. The germination rate of these seeds was approximately 65–68%. It was determined that the heavy metals lead and chromium, in addition to a high biological oxygen demand, were key inhibiting factors. The associations between pollution intensity and biological performance are statistically significant, indicating a considerable detrimental effect ($r = -0.8$ to -0.9). The sponge gourd, also known as *Fluffa cylindrica*, was shown to be somewhat more resistant to damage than the bottle gourd, also known as *Lagenaria siceraria*.

With regard to the early stages of plant growth, the results indisputably reveal that pollution in the Ram Ganga River, particularly in its midstream industrial region, has a significant and inhibiting influence. Increasing levels of physicochemical and heavy metal pollution have been shown to lessen the germination and seedling vigor of commercially significant cucurbit crops, according to the data, which corroborate the initial premise. It is clear from the results of these experiments that the Ram Ganga basin requires stringent monitoring of the water sources used for irrigation and the implementation of pollution control measures.

Discussion

The findings indicate that contaminated water from the Ram Ganga (Site B and, to a lesser degree, Site C) has a negative influence on the germination of seeds and the early development of seedlings of *L. cylindrica* and *L. siceraria*. Site B has a lower DO and a higher BOD, both of which are indicators of

organic pollution and microbial activity, both of which have the potential to produce phytotoxic byproducts. The observed decreases in root/shoot length and biomass can be attributed to the presence of elevated heavy metals, particularly lead and chromium, which are known to hinder germination, diminish root elongation, and disrupt physiological processes (such as enzyme activity and water absorption).

Conclusion

Both sponge gourd (*Luffa cylindrica*) and bottle gourd (*Lagenaria siceraria*) are negatively impacted by pollution in the midstream parts of the Ram Ganga River, as demonstrated by the findings of this study. This pollution has a negative impact on the germination of seeds and the early growth of seedlings. There was a significant increase in the levels of biochemical oxygen demand (BOD), electrical conductivity (EC), total dissolved solids (TDS), and heavy metals including lead (Pb) and chromium (Cr) in the water that was collected from the midstream region that was impacted by industrial activity. These pollutants caused a substantial reduction in the proportion of seeds that germinated, a delay in the mean germination time, and an inhibition of root and shoot elongation, which ultimately led to a fall in seedling vigor indices. The findings demonstrate that there is a clear correlation between the level of biological damage and the degree of water pollution caused by the pollutants. The water upstream showed just a minor amount of impacts, the water in the middle of the stream produced a significant amount of inhibition, and the samples farther downstream showed a considerable amount of recovery, which suggests that the pollutants were diluted. The observed physiological damage is most likely the result of osmotic stress, interference with enzyme function, and the buildup of toxic metals in embryonic tissues.

Recommendations

1. When watering seeds or young plants in a nursery, never use untreated water from contaminated areas (like Site B).
2. Implement effluent treatment at industrial and municipal discharge points to reduce BOD and heavy metal loads.
3. Conduct field trials to evaluate soil buffering effects and metal uptake into edible plant parts.

Future work

- Conduct longer-term greenhouse and field experiments tracking heavy metal accumulation in edible tissues at harvest.
- Test mitigation strategies (e.g., seed priming, soil amendments, filtration) to reduce pollutant effects on germination and growth.
- Expand pollutant panel to include pesticides, hydrocarbons, and microbial pathogens.

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