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Differential Growth Responses of *Vicia faba* L. to Water Samples from Kali Nadi and Hindon River

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Abstract: ***This study aimed to quantify the differential growth patterns of an economically important dicotyledonous crop Vicia faba also known as broad bean or faba bean against the water samples collected from the "Kali Nadi" (river) of Muzaffarnagar and "Hindon River" of Ghaziabad district of Uttar Pradesh. Faba bean is a member of the pea family Fabaceae which is widely grown for its nutritional values and also as a cover crop to prevent erosion. During the present study several growth parameters of seven days old seedlings were observed. However, different parameters gave differential results related to the quantification of growth pattern. About 80% of seeds were tolerant to S-G but only 20% of seeds were tolerant to S-M.***

Keywords: *Vicia faba*, growth pattern, Kali Nadi, Hindon River, water pollutants

1. Introduction

Industrialization is widely recognized as a hallmark of economic development, yet it poses substantial environmental challenges, particularly through the release of industrial emissions and waste. Numerous studies have documented the detrimental effects of industrial pollutants on water quality, highlighting the frequent discharge of untreated industrial waste containing hazardous heavy metals into aquatic ecosystems [4]. These heavy metals, including Arsenic (As), Copper (Cu), Cadmium (Cd), Lead (Pb), Mercury (Hg), Nickel (Ni), and Zinc (Zn), have been consistently detected in river waters impacted by industrial activities [3,6]. The volume and concentration of such pollutants are closely linked to human industrial activities, which have intensified over recent decades, thereby exacerbating environmental contamination [1].

The accumulation of heavy metals in the environment raises significant concerns due to their persistence and bioaccumulative nature. Contaminated water used for irrigation leads to the uptake of toxic metals by crops, resulting in their accumulation in grains and vegetables [15]. This bioaccumulation poses direct risks to human health, as these metals are known to cause neurological disorders, liver damage, bone deterioration, and disruption of vital enzymatic functions. Beyond human health, the ecological consequences are profound, with documented adverse effects on both plant and animal species inhabiting polluted environments.

The study focuses on two emerging industrial cities, Muzaffarnagar and Ghaziabad, where industrialization has rapidly expanded. These locations serve as critical case studies for assessing the extent of heavy metal contamination attributable to industrial waste discharge. Understanding the spatial distribution and concentration of these pollutants in such urban-industrial contexts is essential for developing targeted mitigation strategies and informing policy decisions aimed at environmental protection and public health safety.

Samples were named as S-M for the water sample collected from Muzaffarnagar, S-G for the water sample collected from Ghaziabad.

2. Materials & Method

Seeds used in this work were collected from local farmers' own seed stock. In these experiments, seven days old seedlings of *Vicia faba* were used as a parameter for quantifying the differential growth patterns. The control and experimental groups were cultivated separately in a Seed Germinator at a temperature range of 25–27°C, in complete darkness. Seeds were grown in sterilized Petri plates for seven days. Control sets were raised in normal solution while treated sets in the samples collected.

Radicle length, cotyledon length, hypocotyl length, and the fresh and dry weights of roots and cotyledons in seven-day-old seedlings were measured to assess their relative responses.

A formula Response Coefficient (RC) was applied to calculate the response against the water samples collected.

$$\mathbf{RC} = \frac{VT\text{-}VC}{VC}$$

(VT = value of the treated set; VC = value of the control set).

On the basis of above-mentioned formula seeds were categorized into tolerant (A), non-tolerant (E) and partially tolerant categories (B-D).

3. Results & Discussion

Access to clean water is essential for the successful germination of seeds, and water pollution can greatly impede this critical process [5,7]. Polluted water contains contaminants that can alter the permeability of seed coats, resulting in decreased water absorption. Additionally, pollutants can stress seeds, causing them to become dormant rather than germinate. Furthermore, harmful microorganisms present in polluted water can cause diseases that compromise seed health. Consequently, fewer seeds will germinate, and the survival rate of seedlings will significantly drop, leading to a reduced number of mature plants in the ecosystem, which negatively impacts biodiversity and overall plant populations.

During the present study several growth parameters of seven-day-old seedlings were tested. However, different parameters gave differential results related to the quantification of growth pattern.

Based on the values of RCs for different growth parameters revealed certain information worth mentioning:

1) About 80% seeds of *Vicia faba* were tolerant to S-G but only 20% seeds were tolerant to S-M. The classification based on the RC values for radicle lengths did not agree with the classifications based on the RC values for other parameters. RC values for radicle fresh and dry weights in response to S-G showed that most seeds were tolerant (Fig. 1). For S-M, most seeds were partially or non-tolerant, as shown by the RCs for these parameters (Fig. 4).
2) Based on the RC values for cotyledon length, fresh weight, and dry weight in both samples (see Fig. 2 & 5), most seeds were classified as tolerant.
3) In response to S-G, based on the RC values for hypocotyl lengths, hypocotyl fresh weights and hypocotyl dry weights, majority of the seeds exhibited tolerance (Fig. 3) while against the (S-M) most of the seeds were either partially tolerant or non-tolerant (Fig. 6).
4) The classification based on the response coefficients (RCs) for total seedling length indicated that most seeds exhibited tolerance to S-G, whereas a smaller proportion demonstrated tolerance to S-M. Similar behavior for the RC values for the fresh weights of the total seedlings was observed in response to S-G and S-M, respectively. However, more than 80% seeds could be put under category tolerant, based on RCs for dry weights of the total seedlings against both the samples.

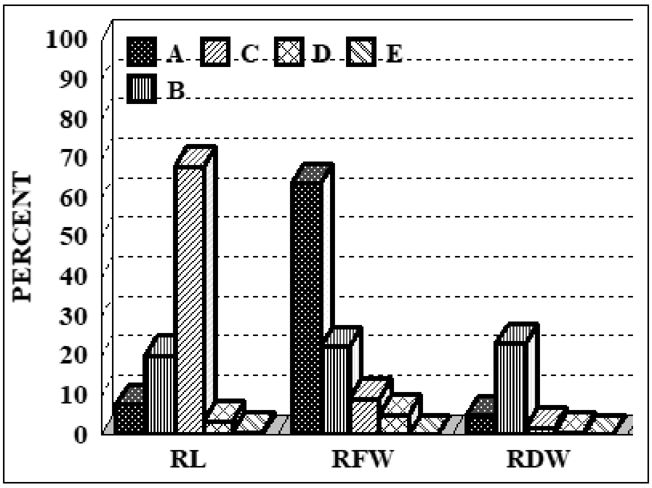

Figure 1: Graphical representation of the effect of sample S-G on root.

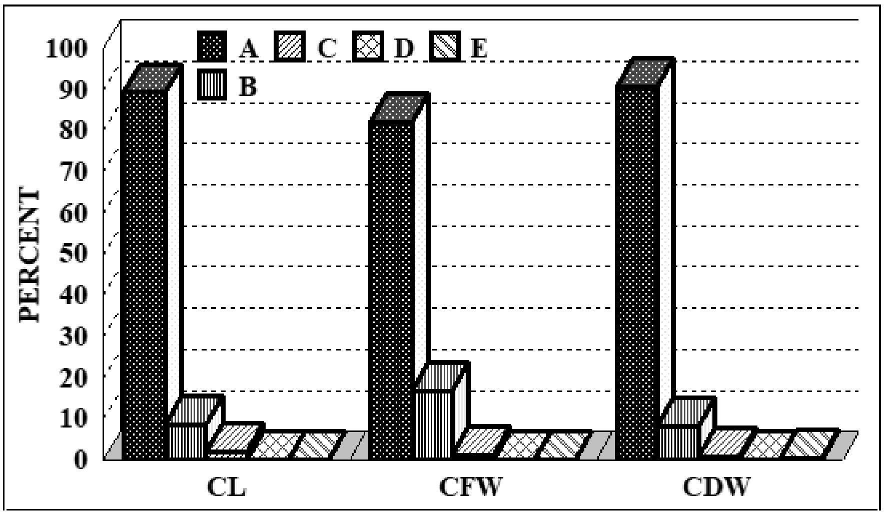

Figure 2: Graphical representation of the effect of sample S-G on cotyledon.

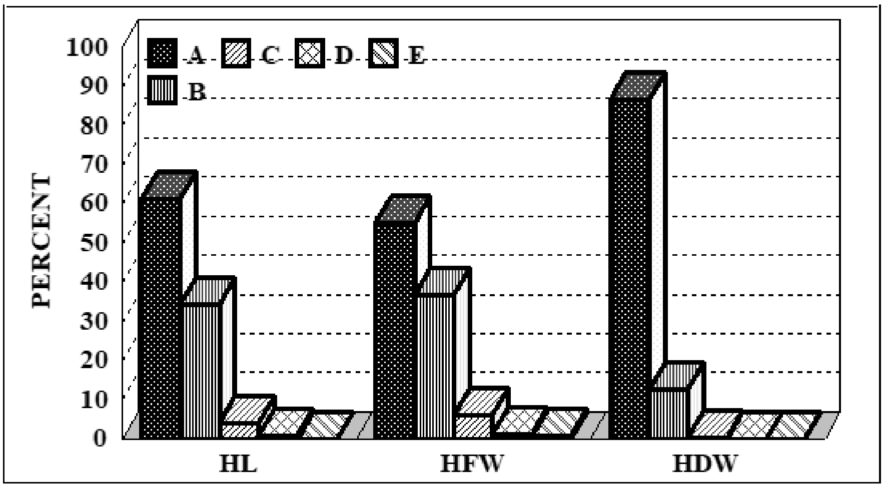

Figure 3: Graphical representation of the effect of sample S-G on hypocotyl.

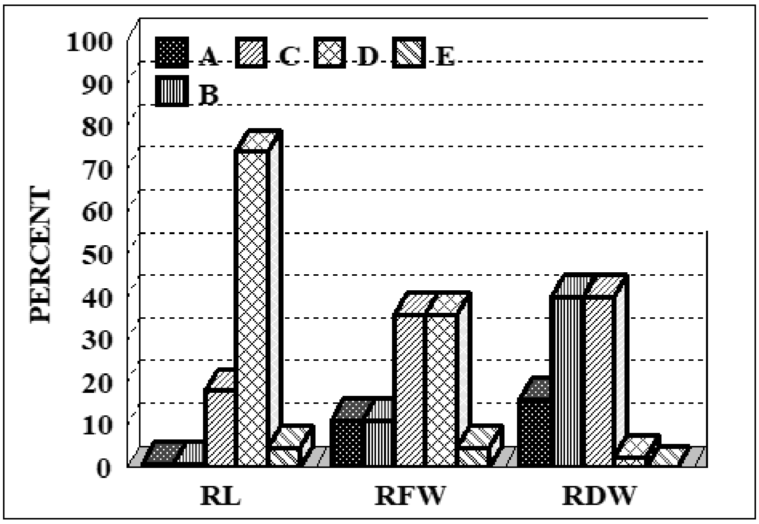

Figure 4: Graph showing sample S-M's impact on root

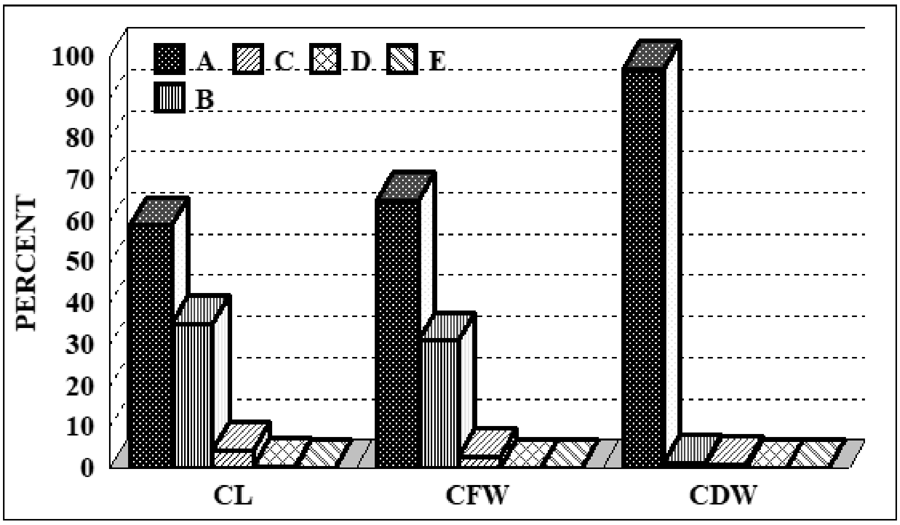

Figure 5: Graph showing sample S-M's impact on the cotyledon.

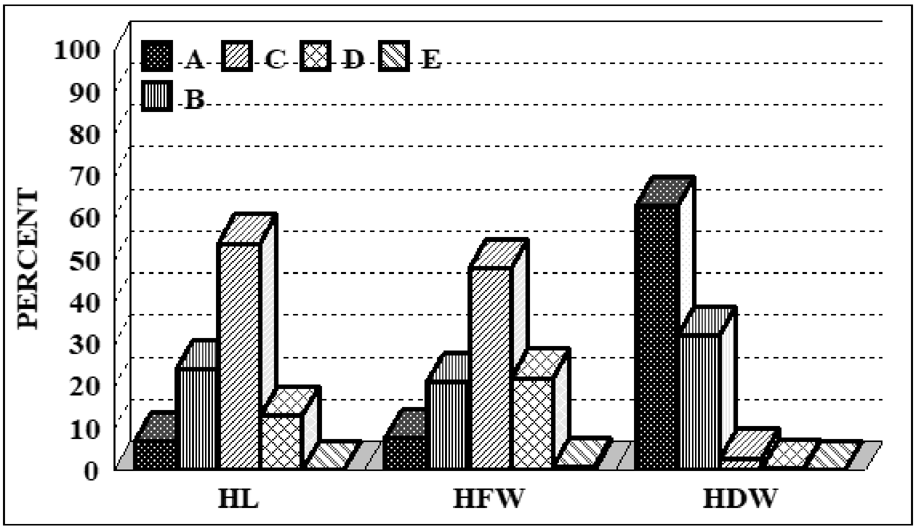

Figure 6: Graph showing sample S-M's impact on the hypocotyl. [RL- root length, RFW- fresh weight of root, RDW- dry weight of root, CL- cotyledon length, CFW-cotyledon fresh weight, CDW- cotyledon dry weight, HL- hypocotyl length, HFW- hypocotyl fresh weight, HDW- hypocotyl dry weight]

At the stage of seed germination, the difference in toxicity between the two samples was not noticeable. The impact of heavy metals or pollutants on germination is minimal, suggesting that seeds depend on internal resources that remain unaffected by these substances during this phase. Consequently, the presence of low levels of heavy metals or pollutants does not hinder seed germination. During present investigation the seedlings were grown in total darkness. Therefore, the required energy for the growth of the seedlings was obtained by utilizing the stored food material.

Different pollutants/heavy metals have been reported to inhibit seed germination to varying degrees [8,14]. Germination of seeds is drastically affected by higher concentrations of pollutants [12,13]. Several workers have also highlighted the detrimental effects that pollutants and heavy metals have on both seed germination and the development of seedlings. [9,10,2,11]. Growth in dormant embryo starts with the absorption of water, if physiological and biochemical set up of the seeds did not inhibit germination. In other words, water plays a prime role in inducing morphogenetic provocation for activating otherwise dormant embryo. The initial growth of the seedlings completely depends upon the stored food material in the seeds for energy and carbon requirements unless the seedlings achieve the capability of photosynthesis. In such seedlings both dry weight as well as fresh weight will show an increasing trend with time. Since, during present investigation these were grown in darkness therefore, fresh weight increased and dry weight decreased regularly. Analysis of fresh weight per seedling after 7 days provided information concerning the effect of pollutants on water absorption and increase of fresh weight. Perusal of the data obtained for the effects of pollutants on fresh weight and dry weight clearly pointed out that the net gain in water content was retarded significantly. Decline in fresh weights of the treated seedlings was the sum total effect of the decrease in water content and decrease/increase of the consumption of stored dry matter. However, reduction of the net gain of water content appeared relatively more accountable for lowering fresh weight of treated seedlings. Higher and lower dry weights of residual seed suggested decrease/increase in mobilization of stored food.

4. Conclusion

The observations demonstrate that industrial wastewater from Muzaffarnagar (S-M) and Ghaziabad (S-G) differentially affects the growth parameters of *Vicia faba* seedlings, reflecting varying degrees of heavy metal contamination and toxicity. While seed germination was largely unaffected due to reliance on internal seed reserves, subsequent seedling growth showed significant sensitivity to pollutants, particularly in samples from Muzaffarnagar, where a higher proportion of seeds exhibited partial or non-tolerance. The reduction in fresh weight primarily resulted from impaired water absorption, underscoring the detrimental impact of industrial pollutants on seedling vigour and development. These findings highlight the critical need for monitoring and mitigating industrial effluents to protect agricultural productivity and ecosystem health in rapidly industrializing urban centres. The differential tolerance observed among growth parameters suggests that comprehensive assessment using multiple metrics is essential for accurately evaluating environmental toxicity. Ultimately, this study provides valuable insights into the ecological risks posed by industrial contamination and underscores the importance of implementing effective environmental regulations to safeguard both plant health and public safety.

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