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Exploring the Impact of Heavy Metals on the Germination Process of Raphanus sativus cv Pusa Rashmi Seeds

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ABSTRACT:

This study intricately explores the repercussions of heavy metals on the germination process of Raphanus sativus cv Pusa Rashmi seeds, a critical aspect in Indian agricultural practices. Radishes, known for their diverse varieties across different seasons, exemplify their agricultural significance. The chosen variety, Pusa Rashmi, categorised within the Tropical classification, serves as the focal point due to concerns about the deleterious effects of industrial water on crop health. Specifically, the study delves into the influence of nickel sulphate, zinc chloride, cadmium chloride, copper sulphate, and lead nitrate on seed germination.

Under meticulously controlled conditions, these seeds underwent treatments and were subjected to a germination process, unveiling a gradual decline in germination rates with the escalation of metal concentrations. Heightened concentrations of lead and cadmium significantly impeded the germination process. Rigorous statistical analyses performed on the results underscored substantial disparities between the control group and the treated seeds, emphasising the adverse impact of heavy metals on the germination potential of Pusa Rashmi seeds.

Discussion surrounding these findings posits potential disruptions in metabolic processes, enzyme activity, and the incitement of oxidative damage by these metals, aligning with previous research observations. The study's implications are profound, highlighting the sensitivity of plants to varying concentrations of heavy metals, thus emphasising the potential risks associated with the utilisation of metal-contaminated irrigation water on crop germination. These findings also underscore the paramount importance of adopting measures for environmental safety and sustainable agricultural management in handling metal-contaminated irrigation water to safeguard crop health and yield.

Keywords: Laboratory experiments, Petri dishes, seed germination, Pusa rashmi, Raphanus sativus.

Objectives:

- Determine the impact of varying concentrations of the chemicals (nickel sulphate, zinc chloride, cadmium chloride, copper sulphate, and lead nitrate) on the germination rates of Raphanus sativus cv Pusa Rashmi seeds.
- Quantify and compare the percentage of seed germination under different concentrations of heavy metals to establish a relationship between metal concentration and its inhibitory effect on germination.
- Investigate the specific effects of individual heavy metals on seed germination, aiming to identify variations in toxicity levels towards Pusa Rashmi seeds.
- Employ statistical analyses to validate and assess significant differences between control (untreated) seeds and those treated with toxic metals, confirming the influence of toxic metals on seed growth.
- Explore potential physiological mechanisms influenced by heavy metals, such as metabolic processes, enzyme activity, and oxidative damage, contributing to the inhibition of seed germination.
- Examine dose-related patterns in seed germination concerning various concentrations of heavy metals, identifying critical thresholds where germination is notably affected.
- Discuss practical implications of the findings for agricultural practices, emphasizing the potential risks associated with metal-contaminated irrigation water and proposing strategies for mitigating adverse effects on crop germination and growth.

Introduction:

Radishes, versatile in their adaptability to diverse climates, are cultivated in various seasonal cycles across the globe. These hardy vegetables manifest as winter crops in some regions, while in others, they thrive during spring, late summer, or autumn. The plains of India, known for their mild climate, witness a continuous cultivation of radishes throughout the year. However, the flavor profile alters notably when grown during hotter seasons, rendering them notably pungent. The cultivation scale peaks during autumn and winter, spanning from September to January in the plains and extending from March to August in the hilly terrains.

Characteristic of radishes are their relatively sizable seeds, which weigh approximately 70-100 seeds per gram, distinguishing them from other vegetable crops. Yet, it's not just the seeds that vary; radish roots boast a wide array of sizes, shapes, colors, and varying edible durations, adding diversity to culinary experiences.

Categorically, radish varieties can be classified into three main groups—Indian, European (Temperate), and Asiatic (Tropical/Subtropical). The focus of the ongoing study, the Pusa Rashmi plant, aligns with the Asiatic or Tropical category, indicative of its regional adaptability.

In close proximity to industrial areas, local cultivators face challenges due to their reliance on factory-polluted water for irrigating their fields. This unfortunate practice has led to extensive crop damage and prompted numerous research endeavors delving into the detrimental effects of industrial effluents on crop health, productivity, and chemical composition.

Of growing concern is the accumulation of toxic metals in cultivated crops. The very presence of trace metal ions in water sources raises alarms for potential high toxicity risks. This concern extends to the soil as well, with studies reporting the accumulation of heavy metals as a consequence of sewage irrigation, further highlighting the multifaceted challenges within agricultural ecosystems.

Material and methods:

In this investigation, the foundation was laid using seeds of the Pusa Rashmi variety, meticulously sourced from the National Seed Corporation in New Delhi and certified for their quality. These seeds underwent rigorous measures to maintain their integrity, securely housed in glass stoppered bottles after a detailed sorting process based on their size and color. This sorting was followed by a comprehensive surface sterilization using 0.1% $HgCl_2$ for a duration of two minutes, subsequently rinsed extensively with distilled water.

Post-preparation, these treated seeds were submerged for two hours in distinct solutions encompassing various concentrations (10, 50, 100, 200, and 500 ppm) of copper sulphate, cadmium chloride, lead nitrate, nickel sulphate, and zinc chloride. Simultaneously, an additional set of seeds soaked solely in distilled water was maintained to serve as the control group for comparative analysis.

Each treatment comprised soaking 60 seeds, ensuring triple replication for heightened reliability. Following these treatments, the seeds were placed onto petri dishes containing wet filter paper, providing an optimal setting for fostering germination and the subsequent growth of seedlings. Under meticulously controlled laboratory conditions maintaining a stable temperature (25±2°C) and adequate diffuse light, the experiments unfolded over ten days.

During this period, the seeds received consistent irrigation using distilled water to monitor their daily progress. The experiment culminated on the 11th day, wherein the total number of germinated seeds was recorded, collating the average values derived from triplicate experiments. Conforming to I.S.T.A. guidelines from 1976, meticulous daily recordings tracked the progress of seed germination, relying on the emergence of a distinct stub through the seed coat as the criterion for successful germination.

Result and Discussion:

It was observed that in control conditions the seeds of Raphanus sativus cv Pusa rashmi showed maximum germination (95 - 100%) which decreased gradually with increasing amounts of metallic elements. In the processed seeds at highest concentration of heavy metals (500 ppm) it was 65% (Cu), 45% (Cd), 53% (Pb), 70% (Ni) and 63% (Zn). At 500 ppm concentration of Cd and Pb, respectively, only 9 and 10 seats out of 20 germinated. The differences between control and treatments and also among various concentrations were found to be statistically very highly significant. The differences among chemicals were statistically not significant.

An intricate analysis of the gathered data revealed an unfavourable impact on seed germination within the Pusa Rashmi cultivar due to the exposure to heavy metals. The count of germinated seeds, thereby affecting the overall germination percentage, notably diminished as the concentrations of heavy metals increased. This decline was most pronounced, especially in instances of higher concentrations, specifically at 200 and 500 ppm of lead and cadmium, resulting in notably poor germination rates. The germination decreased highly at 500 ppm of Ni, 200 and 500 ppm of Cu, 100, 200 and 500 ppm of Zn and from 50 to 500 ppm of lead and even from 10 ppm to 500 ppm of cadmium, in the variety Pusa Rashmi.

At 10 ppm concentration of Ni, the number of germinated seeds was the same as in the control in this variety. Further among the five heavy metals taken, cadmium and lead were found to be more toxic than copper, nickel and zinc in respect of seed germination of Raphanus sativus. At 500 ppm concentration of cadmium many seeds failed to germinate in the cultivar Pusa Rashmi.

Table - Showing the impact of trace elements on the process of seed germination. (%) in Raphanus sativus cv Pusa rashmi

Sr. No.	Name of the chemicals	Concentration (ppm)					
		Control	10	50	100	200	500
1	Copper sulphate	95	95	93.3	86.6	75	65
2	Cadmium chloride	100	85	76.6	70	60	45

3	Lead nitrate	100	93.3	80	75	66.6	53.3
4	Nickel sulphate	95	95	93.3	90	81.6	70
5	Zinc chloride	100	96.6	86.6	83.3	75	63.3

Values represent the mean of three replicates.

Analysis of variance :

F-ratios:

(i) Control vs Treatment = 44.9160***
(ii)Among Treatments = 18.8725***
(iii)Among Chemicals = -5.3185 (Ins)

The suppression of seed germination in Raphanus sativus due to exposure to heavy metals can be attributed to the decline in metabolic activities, such as cell division, inhibition of crucial enzymes required for germination, and interference with the mobilization of stored nutrients. Additionally, heavy metal toxicity might cause damage to the seed tissues, further impeding the germination process.

Several workers have revealed the importance of some enzymes at the time of seed germination. The activity of these enzymes can be influenced greatly by the pollutants present in the waste waters.

Gupta and Agrawal (1992) also reported that the mechanism involved in reduced seed germination and delayed germination of Cicer arietinum and Brassica campestris with the application of higher concentrations of industrial effluent might be associated with the activity of several enzymes.

The harmful nature of various heavy metals stems from their capacity to induce oxidative harm to tissues (Stohs and Bagchi, 1995). This harm leads to increased lipid peroxidation, DNA impairment, and the oxidation of protein sulfhydryl groups.

In this current study, observations on seed germination in the Pusa Rashmi cultivar showed evident differences linked to varying doses of heavy metals. Singh (1986) similarly noted dose-dependent variations among three cultivars (cv. Arkel, cv. Bonnewille, and cv. T-163) of Pisum sativum in response to Nickel's impact on seed germination.

Prasad (1995) highlighted that plants generally combat heavy metal toxicity through resistance mechanisms like avoidance (shielding the plant from stress) or tolerance (adapting to toxic metal concentrations). These mechanisms allow plants to either protect themselves from the stress's influence or survive internal stress by adjusting to high metal concentrations through diverse strategies.

Conclusion:

The study systematically evaluated how various heavy metals affect Raphanus sativus cv Pusa Rashmi seed germination. Increasing concentrations of nickel sulphate, zinc chloride, cadmium chloride, copper sulphate, and lead nitrate displayed a clear trend: a dose-dependent reduction in germination rates. This highlighted the susceptibility of Pusa Rashmi seeds to heavy metal toxicity.

Statistical analyses confirmed significant differences between untreated and treated seeds, solidifying the adverse impact of heavy metals on germination. Insights into potential mechanisms—disrupted metabolic processes, altered enzyme activities, and potential oxidative damage—provided crucial context for understanding the inhibition of seed germination.

Critical concentration thresholds, particularly evident with lead and cadmium, underscored the sensitivity of these seeds to specific metals. These findings stress the agricultural risks linked to metal-contaminated irrigation, urging proactive measures to minimize metal exposure for sustained crop germination and environmental preservation.

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