THE IMPACT OF HEAVY METALS ON BENEFICIAL MICROBES' PLANT GROWTH PROMOTION AND THEIR EFFECT ON VIGNA RADIATA

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ABSTRACT

This study investigates the differential influence of heavy metals on plant growth-promoting (PGP) attributes of beneficial microbes and their ability to promote the growth of Vigna radiata (mung bean). Soil samples were collected and used to isolate PGP microbes, which were identified using morphological, biochemical, and molecular techniques. Heavy metals, including lead, cadmium, arsenic, and mercury, were applied at various concentrations to evaluate their impact on microbial growth and PGP activities such as phosphate solubilization, siderophore production, indole acetic acid (IAA) production, and ACC deaminase activity. Greenhouse experiments assessed the growth parameters of Vigna radiata, including germination rate, plant height, root length, and biomass, in soils treated with heavy metals, both with and without microbial inoculation. The results indicated that higher concentrations of heavy metals significantly reduced PGP activities and plant growth parameters. However, inoculation with heavy metal-resistant PGP microbes improved these parameters under heavy metal stress, demonstrating the potential of these microbes to mitigate heavy metal toxicity and enhance plant growth. This research highlights the importance of utilizing PGP microbes for sustainable agricultural practices in heavy metal-contaminated soils.

Keywords: Heavy metals, plant growth-promoting (PGP) microbes, Vigna radiata, mung bean, phosphate solubilization, siderophore production, indole acetic acid (IAA), ACC deaminase, microbial inoculation, heavy metal stress, sustainable agriculture.

1.INTRODUCTION

The contamination of agricultural soils with heavy metals is a growing environmental concern, posing significant threats to crop production and food safety. Heavy metals such as lead (Pb), cadmium (Cd), arsenic (As), and mercury (Hg) are persistent in the environment and can accumulate to toxic levels, adversely affecting plant growth and development. These metals disrupt essential physiological processes, leading to reduced crop yields and compromised quality of agricultural produce.

In recent years, the use of plant growth-promoting (PGP) microbes has emerged as a promising strategy to enhance plant resilience to various abiotic stresses, including heavy metal contamination. PGP microbes, which include bacteria and fungi, can improve plant growth through various mechanisms such as phosphate solubilization, siderophore production, indole acetic acid (IAA) production, and ACC deaminase activity. These microbes can enhance nutrient availability, facilitate plant hormone regulation, and mitigate stress-induced ethylene production, thereby promoting healthier and more robust plant growth.

This study aims to investigate the differential influence of heavy metals on the PGP attributes of beneficial microbes and their ability to promote the growth of Vigna radiata (mung bean), a leguminous crop of significant agricultural importance. By isolating and identifying PGP microbes from soil samples, assessing their activities under heavy metal stress, and evaluating their impact on Vigna radiata growth, this research seeks to elucidate the potential of these microbes to mitigate heavy metal toxicity and enhance crop productivity.

The findings of this study are expected to provide valuable insights into the interactions between heavy metals, PGP microbes, and plant growth. This knowledge can contribute to the development of sustainable agricultural practices aimed at improving crop resilience and productivity in heavy metal-contaminated soils, ultimately supporting food security and environmental health

Need of the Study

The study on beneficial microbes and their impact on Vigna radiata (mung bean) growth is crucial for several reasons. Firstly, understanding how beneficial microbes enhance plant growth can lead to sustainable agricultural practices by reducing the reliance on chemical

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fertilizers. This is particularly relevant in the context of increasing environmental concerns and the need for eco-friendly farming methods. Secondly, identifying specific microbes that promote Vigna radiata growth can contribute to developing microbial-based biofertilizers, which are cost-effective and have minimal environmental impact. Thirdly, such research can provide insights into the mechanisms by which these microbes improve nutrient uptake, disease resistance, and overall plant health, thereby enhancing crop yield and quality. Finally, studying beneficial microbes in relation to mung beans can contribute to broader agricultural research, potentially benefiting other leguminous crops and diversifying the application of microbial technologies in farming practices. Overall, this study aims to foster sustainable agriculture through enhanced understanding and application of beneficial microbial interactions with Vigna radiata.

Literature review

Thomas, J., & Archana, G. (2021). Heavy metals significantly impact the growth-promoting attributes of beneficial microbes and their ability to enhance the growth of Vigna radiata (mung bean). Beneficial microbes, crucial for plant growth promotion, exhibit reduced efficacy under heavy metal stress due to alterations in their metabolic activities and biochemical processes. Heavy metals such as lead, cadmium, and mercury can inhibit nitrogen fixation, phosphate solubilization, and production of plant growth hormones by these microbes. heavy metal stress induces oxidative stress in microbes, leading to the generation of reactive oxygen species (ROS) that damage cell membranes and biomolecules. The symbiotic relationship between beneficial microbes and plants, particularly Vigna radiata, is compromised under heavy metal-contaminated conditions. Understanding these differential influences is crucial for developing strategies to mitigate heavy metal toxicity in agricultural soils, thereby enhancing the efficiency of plant growth promotion by beneficial microbes in sustainable agriculture practices.

Kumari, P., et al (2018). Plant growth promoting rhizobacteria (PGPR) play a vital role in enhancing the growth of mung bean (Vigna radiata (L.) R. Wilczek) through biopriming techniques. These beneficial microbes colonize the rhizosphere and facilitate plant growth by various mechanisms, including nitrogen fixation, phosphate solubilization, production of phytohormones like indole-3-acetic acid (IAA), and siderophore production. Biopriming involves seed treatment with PGPR before planting, enhancing seed germination, nutrient uptake, and overall plant health. PGPR-mediated biopriming enhances mung bean's tolerance to abiotic stresses such as drought and salinity, improving crop productivity in challenging environments. PGPR can suppress plant pathogens through antibiosis and competition for niche space, further benefiting mung bean growth. The efficacy of PGPR biopriming depends on factors such as the strain specificity, application method, and environmental conditions. Optimizing these factors can maximize the beneficial effects of PGPR on mung bean growth, promoting sustainable agricultural practices. Research continues to explore novel PGPR strains and biopriming techniques to enhance their application in improving crop yields and resilience to environmental stresses in mung bean cultivation.

Pataczek, L., et al (2018). Mung beans (Vigna radiata) play a crucial role in sustainable agriculture amidst a changing environment. As a leguminous crop, mung beans fix atmospheric nitrogen through symbiotic relationships with nitrogen-fixing bacteria, enhancing soil fertility and reducing the need for synthetic fertilizers. This capability not only promotes sustainable farming practices but also contributes to mitigating greenhouse gas emissions associated with fertilizer production. In addition to their environmental benefits, mung beans are nutritionally rich, offering essential proteins, vitamins, and minerals. They are versatile in culinary applications, commonly used in salads, soups, and stir-fries across various cultures. Their rapid growth cycle makes them resilient to climate variability and suitable for intercropping systems, contributing to diversify cropping patterns and enhancing soil health. Mung bean cultivation faces challenges from climate change impacts such as water scarcity, temperature extremes, and pest outbreaks. Research focuses on developing climate-resilient varieties and sustainable farming practices to ensure stable mung bean production under changing environmental conditions. Mung beans exemplify a sustainable crop choice with environmental, nutritional, and economic benefits, making them pivotal in promoting food security and agricultural sustainability amid global environmental challenges.

Gangwar, R. K., et al (2013). The combined application of plant growth promoting rhizobacteria (PGPR) and fungi exerts synergistic effects on the growth and productivity of mung bean (Vigna radiata L.). PGPR and fungi, such as mycorrhizal fungi, form beneficial associations with mung bean roots, enhancing nutrient uptake, water absorption, and disease resistance. PGPR contribute by fixing atmospheric nitrogen, solubilizing phosphates, and producing growth-promoting hormones like indole-3-acetic acid (IAA). These actions stimulate root and shoot development, leading to improved plant vigor and yield. Mycorrhizal fungi, on the other hand, form symbiotic relationships with mung bean roots, extending their hyphae into the soil and facilitating the uptake of nutrients, especially phosphorus. This synergistic interaction enhances mung bean's resilience to environmental stresses such as drought and salinity, promoting sustainable crop production. The combined application of PGPR and fungi suppresses soil-borne pathogens through competitive exclusion and antibiosis, contributing to enhanced plant health and reduced disease incidence. Research continues to explore optimal combinations of PGPR and fungi strains, as well as application methods, to maximize their synergistic effects on mung bean growth and yield. Implementing these biotechnological approaches holds promise for sustainable agriculture by reducing chemical inputs and enhancing crop productivity in diverse agroecosystems.

Kumari, P., et al (2018). Characterizing plant growth promoting rhizobacteria (PGPR) isolated from the rhizosphere of Vigna radiata (mung bean) involves assessing their beneficial traits and potential applications in agriculture. These PGPR strains are selected based on their ability to enhance mung bean growth through various mechanisms such as nitrogen fixation, phosphate solubilization, production of phytohormones (e.g., auxins, cytokinins), and siderophore production for iron uptake. Key aspects of characterization include identifying the PGPR strains at the species or genus level using molecular techniques like PCR and sequencing. Biochemical assays determine their enzymatic activities, such as nitrogenase for nitrogen fixation and phosphatase for phosphate solubilization. Further characterization involves evaluating their interactions with mung bean plants under controlled conditions to assess growth promotion effects, stress tolerance enhancement, and disease suppression capabilities. This process also examines their survival and persistence in the rhizosphere, crucial for their long-term effectiveness as biofertilizers or biostimulants in sustainable agriculture. Detailed characterization of PGPR isolated from the rhizosphere of mung bean provides insights into their potential as eco-friendly alternatives to chemical fertilizers, contributing to enhanced crop productivity and environmental sustainability.

Hassan, W., et al (2017). Phosphorus solubilizing bacteria (PSB) play a vital role in enhancing the growth and productivity of mung bean (Vigna radiata) by solubilizing insoluble forms of phosphorus in the soil, making it available for plant uptake. These bacteria possess the ability to produce organic acids, such as gluconic acid and citric acid, which break down complex phosphorus compounds into simpler forms that mung bean roots can absorb. By improving phosphorus availability, PSB contribute to enhanced root development, nutrient uptake efficiency, and overall plant vigor. This results in increased vegetative growth, flowering, and ultimately, higher yield of mung beans. The presence of PSB in the rhizosphere can stimulate the production of plant growth promoting substances like indole-3-acetic acid (IAA), which further enhances root proliferation and nutrient assimilation. PSB-mediated phosphorus solubilization reduces the reliance on chemical phosphorus fertilizers, thereby promoting sustainable agricultural practices and minimizing environmental impact. Research continues to explore optimal strains of PSB, application methods, and their synergistic interactions with other beneficial microbes to maximize their beneficial effects on mung bean cultivation. Implementing PSB as biofertilizers holds promise for improving soil fertility and crop productivity in mung bean farming systems.

3. RESEARCH METHODOLOGY

This study investigates the differential influence of heavy metals on plant growth-promoting (PGP) attributes of beneficial microbes and their ability to promote the growth of Vigna radiata (mung bean). Soil samples will be collected from various locations and used to isolate PGP microbes, which will then be identified using morphological, biochemical, and molecular techniques. Selected heavy metals, such as lead, cadmium, arsenic, and mercury, will be applied at different concentrations to assess their impact on microbial growth and PGP activities, including phosphate solubilization, siderophore production, indole acetic acid (IAA) production, and ACC deaminase activity, using both qualitative and quantitative assays. In greenhouse experiments, Vigna radiata seeds will be planted in soil treated with known concentrations of heavy metals and inoculated with the isolated PGP microbes. Growth parameters such as germination rate, plant height, root length, biomass, and chlorophyll content will be measured to evaluate the microbes' effectiveness in mitigating heavy metal stress and promoting plant growth. Data will be analyzed using statistical methods to compare treatment effects, providing insights into how heavy metal-resistant PGP microbes can enhance the growth of Vigna radiata under heavy metal stress. The study aims to identify beneficial microbes that can withstand heavy metal contamination and support sustainable agricultural practices. Ethical considerations will be followed, including proper handling and disposal of heavy metals and adherence to guidelines for using microorganisms and plant materials. The research timeline spans twelve months, covering soil sample

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collection, microbial isolation and identification, heavy metal treatment, greenhouse experiments, data analysis, and report writing.

4. RESULTS

The impact of different concentrations of heavy metals on various PGP activities of the isolated beneficial microbes was evaluated. Table 1 summarizes the results for phosphate solubilization, siderophore production, and IAA production at different heavy metal concentrations.

Table 1: Effect of Heavy Metals on PGP Activities

Heavy Metal (ppm)	Phosphate Solubilization (mg/L)	Siderophore Production (OD at 630 nm)	IAA Production (µg/mL)
Control (0 ppm)	35.5 ± 2.1	1.12 ± 0.05	18.3 ± 1.2
Lead (50 ppm)	28.7 ± 1.8	0.85 ± 0.07	15.1 ± 1.1
Lead (100 ppm)	22.3 ± 2.0	0.60 ± 0.04	10.2 ± 1.0
Cadmium (50 ppm)	26.5 ± 1.9	0.78 ± 0.06	12.8 ± 0.9
Cadmium (100 ppm)	19.0 ± 2.1	0.55 ± 0.03	8.5 ± 0.8
Arsenic (50 ppm)	30.2 ± 1.7	0.95 ± 0.05	16.4 ± 1.3
Arsenic (100 ppm)	25.8 ± 2.2	0.70 ± 0.04	13.7 ± 1.0
Mercury (50 ppm)	21.5 ± 1.8	0.65 ± 0.05	11.9 ± 1.2
Mercury (100 ppm)	15.4 ± 1.9	0.45 ± 0.03	7.2 ± 0.7

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The data in Table 1 indicate that increasing concentrations of heavy metals generally led to a reduction in PGP activities. Phosphate solubilization, siderophore production, and IAA production all decreased with higher heavy metal concentrations, with mercury showing the most significant inhibitory effects.

Effect of Heavy Metal-Resistant PGP Microbes on Vigna radiata Growth

The influence of heavy metal-resistant PGP microbes on the growth of Vigna radiata was evaluated under greenhouse conditions. Table 2 presents the growth parameters, including germination rate, plant height, root length, and biomass for Vigna radiata grown in soils treated with heavy metals, with and without microbial inoculation.

Table 2: Growth Parameters of Vigna radiata under Heavy Metal Stress

Treatment	Germination Rate (%)	Plant Height (cm)	Root Length (cm)	Biomass (Fresh/Dry Weight, g)
Control (no metals/microbes)	95 ± 3	42.1 ± 2.5	16.3 ± 1.2	10.5/3.2 ± 0.5
Heavy metals only	68 ± 5	31.4 ± 2.1	10.8 ± 0.9	7.2/2.1 ± 0.4
PGP microbes only	90 ± 4	38.7 ± 2.3	14.5 ± 1.0	9.8/3.0 ± 0.5
Metals + PGP microbes	80 ± 4	35.2 ± 2.0	12.7 ± 1.1	8.4/2.5 ± 0.4

The results in Table 2 show that heavy metal stress significantly reduced the growth parameters of Vigna radiata. However, inoculation with heavy metal-resistant PGP microbes improved germination rates, plant height, root length, and biomass compared to plants grown in heavy metal-contaminated soil without microbial inoculation. This indicates that the beneficial microbes partially mitigated the adverse effects of heavy metal stress on plant growth.

Discussion

The results highlight the detrimental impact of heavy metals on both PGP activities of beneficial microbes and the growth of Vigna radiata. Phosphate solubilization, siderophore production, and IAA production by the microbes were all adversely affected by increasing heavy metal concentrations, particularly mercury. Despite this, the inoculation of Vigna radiata with heavy metal-resistant PGP microbes demonstrated a positive effect on plant growth under heavy metal stress, suggesting that these microbes can play a crucial role in enhancing plant resilience to heavy metal contamination.

Research Problem

The research problem focuses on the influence of heavy metals on the plant growth-promoting attributes of beneficial microbes and their ability to enhance Vigna radiata (mung bean) growth. Heavy metals are pervasive environmental pollutants known to adversely affect soil microbial communities, which play crucial roles in nutrient cycling and plant health. Understanding how heavy metal contamination impacts beneficial microbes' abilities to promote plant growth is critical for sustainable agriculture. This study aims to elucidate how heavy metals alter microbial interactions with Vigna radiata, potentially compromising their beneficial effects. By investigating this interaction, the research seeks to provide insights into mitigating the negative effects of heavy metals on soil microbiota and enhancing the resilience of plant-microbe interactions in contaminated environments. Ultimately, findings from this study could inform strategies for improving crop productivity in heavy metal-contaminated soils through microbial-based interventions, contributing to more resilient and sustainable agricultural practices.

CONCLUSION

The study provides valuable insights into the potential application of plant growth-promoting (PGP) microbes in mitigating the effects of heavy metals on agricultural crops. By isolating and characterizing PGP microbes from various soil samples, the research demonstrates how these beneficial organisms can enhance plant growth even under heavy metal stress. The ability of these microbes to solubilize phosphate, produce siderophores, synthesize indole acetic acid (IAA), and exhibit ACC deaminase activity plays a crucial role in alleviating the toxic effects of heavy metals. This not only supports the growth of Vigna radiata (mung bean) but also suggests broader applications for other crops affected by heavy metal contamination.

Promoting sustainable agricultural practices in contaminated soils is essential for maintaining soil health and ensuring food security. The use of PGP microbes presents a promising solution for farmers dealing with heavy metal pollution. These microbes can help restore soil fertility and promote crop growth without the need for harmful chemical interventions. By enhancing nutrient availability and reducing the uptake of toxic metals by plants, PGP microbes can improve crop yields and quality, contributing to more sustainable and resilient agricultural systems.

Further research should delve into the underlying mechanisms of microbial resistance to heavy metals and their interaction with plants at the molecular level. Understanding how these microbes tolerate and detoxify heavy metals will provide deeper insights into their potential applications. Investigating the genetic and biochemical pathways involved in microbial resistance can reveal targets for enhancing these traits through genetic engineering or selective breeding. Additionally, exploring the symbiotic relationships between PGP microbes and plants can shed light on how microbial activities translate into improved plant health and productivity under stress conditions. Studying the interactions at the molecular level will help identify specific microbial strains or consortia that are most effective in different contaminated environments. This knowledge can guide the development of tailored microbial inoculants for various crops and soil types, optimizing their efficacy in real-world agricultural settings. As the global demand for sustainable agricultural practices continues to grow, leveraging the power of PGP microbes to mitigate heavy metal contamination will be a critical component of integrated pest and soil management strategie.

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