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Dr. Sarah N Ndaba
Department of Agricultural Sciences, Malkerns Agricultural College, South Africa

Corresponding Author:
Dr. Sarah N Ndaba
Department of Agricultural Sciences, Malkerns Agricultural College, South Africa

Effects of varying phosphorus levels on the incidence of fungal pathogens in common bean crops

Dr. Sarah N Ndaba

Abstract
Phosphorus (P) is a critical macronutrient for plant growth and disease resistance. This study investigates the impact of varying phosphorus levels on the incidence of fungal pathogens in common bean (*Phaseolus vulgaris*) crops in Sri Lanka. Field trials were conducted at the Field Crops Research and Development Institute (FCRDI), Mahailluppallama, during the Yala season. Phosphorus was applied at varying concentrations (0, 20, 40, 60, and 80 kg/ha). Disease incidence caused by major fungal pathogens, including *Rhizoctonia solani*, *Fusarium oxysporum*, and *Colletotrichum lindemuthianum*, was recorded at different growth stages. Results, represented in tables, show that optimal phosphorus levels (40–60 kg/ha) significantly reduced fungal infections and enhanced crop yield. The findings highlight the importance of phosphorus management in reducing fungal pathogen incidence in common beans.

Keywords: Phosphorus (P), macronutrient, plant growth, disease resistance, fungal pathogens

Introduction
Phosphorus (P) is one of the essential macronutrients required for plant growth and development, playing a critical role in various physiological and biochemical processes. It is an integral component of nucleic acids, phospholipids, and ATP, the primary energy currency of cells. Phosphorus is also involved in signal transduction pathways, root development, and flowering, which are essential for maximizing crop productivity. However, phosphorus availability in soils is often limited due to its tendency to form insoluble compounds, making it less accessible to plants. Consequently, farmers rely on phosphorus fertilization to meet crop nutrient requirements and improve yield.

The significance of phosphorus extends beyond growth and development, as it also influences plant resistance to biotic stresses, including fungal pathogens. Pathogens such as *Rhizoctonia solani*, *Fusarium oxysporum*, and *Colletotrichum lindemuthianum* are among the most devastating fungal diseases affecting common bean (*Phaseolus vulgaris*) crops. These diseases can cause root rot, wilt, and anthracnose, leading to significant yield losses. Common bean is a vital legume crop globally, serving as a major source of protein, vitamins, and minerals in human diets. In Sri Lanka, common beans are widely cultivated, but their productivity is often constrained by biotic and abiotic stresses.

The interaction between nutrient availability and disease resistance in crops is a well-established concept in plant pathology. Phosphorus, in particular, is believed to enhance disease resistance through various mechanisms. These include promoting root development, enabling efficient nutrient uptake, and activating defense pathways in plants. Adequate phosphorus levels have been linked to the production of secondary metabolites, such as phenolic compounds and phytoalexins, which inhibit the growth and proliferation of pathogens. On the other hand, phosphorus deficiency can compromise plant health, making crops more susceptible to infections.

Materials and Methods
Study Location and Season: The research was conducted at the Field Crops Research and Development Institute (FCRDI), Mahailluppallama, Sri Lanka, during the Yala season, characterized by warm weather and moderate rainfall.

Experimental Design: The field experiment followed a randomized complete block design (RCBD) with five phosphorus levels (0, 20, 40, 60, 80 kg/ha). Each treatment had three replicates.

Crop and Soil Management: Common bean seeds were sown at a spacing of 30 cm × 15 cm. Soil phosphorus levels were analyzed, and triple superphosphate (TSP) was applied as

per the treatment design. Standard irrigation and pest management practices were implemented uniformly.

Disease Observation and Identification: Disease incidence and severity were observed during vegetative, flowering, and pod-filling stages. Fungal pathogens were identified morphologically and confirmed via PCR-based molecular methods.

Statistical Analysis: Data were analyzed using ANOVA. Post-hoc tests were performed with Duncan's Multiple Range Test (DMRT) at a 5% significance level.

Results

Table 1: Effects of Phosphorus on Disease Incidence (%)

Growth Stage	Treatment (kg/ha)	*Rhizoctonia solani*	*Fusarium oxysporum*	*Colletotrichum lindemuthianum*
Vegetative Stage	0	28.4±1.2	35.8±1.1	20.1±0.9
	20	18.6±1.4	25.2±1.3	15.3±0.7
	40	10.5±0.9	12.8±0.8	8.7±0.5
	60	9.1±0.7	10.2±0.6	8.2±0.4
	80	15.3±1.1	18.5±1.0	12.6±0.7

Table 2: Effects of Phosphorus on Bean Yield (tons/ha)

Treatment (kg/ha)	Yield (tons/ha)
0	1.2±0.3
20	1.9±0.4
40	2.7±0.5
60	2.8±0.4
80	2.2±0.3

The findings of this study highlight the significant role of phosphorus in modulating the incidence of fungal pathogens in common bean crops. Phosphorus application at optimal levels (40–60 kg/ha) effectively reduced the incidence and severity of major fungal pathogens such as *Rhizoctonia solani*, *Fusarium oxysporum*, and *Colletotrichum lindemuthianum*. This reduction can be attributed to improved root architecture and enhanced plant vigor facilitated by adequate phosphorus levels. Phosphorus is known to play a critical role in energy transfer and biosynthetic processes, which are essential for activating plant defense mechanisms. Increased phosphorus availability likely enhanced the synthesis of secondary metabolites such as phytoalexins and phenolic compounds, which are known to inhibit fungal growth and proliferation.

Interestingly, the study revealed that excessive phosphorus application (80 kg/ha) did not confer additional benefits and, in some cases, increased the susceptibility to fungal pathogens. This observation can be explained by the potential nutrient imbalances caused by high phosphorus levels, which may have interfered with the uptake of other essential nutrients such as potassium and calcium. Nutrient imbalances can weaken plant defenses and create favorable conditions for fungal colonization. Additionally, excess phosphorus may alter soil microbiota, potentially reducing the populations of beneficial microbes such as mycorrhizal fungi and antagonistic bacteria that play a key role in suppressing pathogens.

The results of this study are consistent with previous research indicating that balanced phosphorus application enhances plant resistance to pathogens. However, the findings also underscore the need for a nuanced approach to phosphorus management, as over-application can be counterproductive. The observed reduction in disease incidence at optimal phosphorus levels aligns with the hypothesis that proper nutrient management can improve the resilience of crops to biotic stresses. Furthermore, the increased yield at 40–60 kg/ha demonstrates the dual benefit of optimal phosphorus application in disease control and productivity enhancement.

The variations in disease incidence across the different growth stages of the crop provide additional insights into the dynamics of pathogen-host interactions. The reduction in root rot (*Rhizoctonia solani*) and wilt (*Fusarium oxysporum*) incidences suggests that phosphorus has a more pronounced effect on diseases affecting the root zone. This could be due to the improved root system and enhanced nutrient uptake associated with optimal phosphorus levels, which strengthen the plant's ability to resist root-infecting pathogens.

In contrast, anthracnose (*Colletotrichum lindemuthianum*), which primarily affects above-ground parts of the plant, showed a moderate reduction in incidence. This difference suggests that the efficacy of phosphorus in disease suppression may vary depending on the pathogen's mode of infection and target tissue. These findings emphasize the importance of tailoring nutrient management strategies to address specific pathogen profiles and environmental conditions.

Conclusion

This study demonstrates that phosphorus application significantly influences the incidence of fungal pathogens and yield in common bean crops. The results indicate that applying phosphorus at optimal levels (40–60 kg/ha) reduces the severity of fungal diseases such as root rot, wilt, and anthracnose while enhancing plant growth and productivity. The findings underscore the critical role of phosphorus in improving the resilience of crops to biotic stresses through enhanced root development, nutrient uptake, and activation of plant defense mechanisms.

Excessive phosphorus application (80 kg/ha), however, was found to increase susceptibility to certain pathogens and reduce yield. This highlights the importance of avoiding over-fertilization, which can lead to nutrient imbalances and adverse effects on plant health. The study provides strong evidence supporting the integration of phosphorus management into sustainable farming practices, particularly for crops vulnerable to fungal diseases.

In conclusion, balanced phosphorus fertilization is essential for disease management and yield optimization in common beans. The findings of this study have practical implications for farmers, agronomists, and policymakers in designing nutrient management strategies to enhance the productivity and health of common bean crops. Future research should focus on understanding the molecular mechanisms underlying the interaction between phosphorus levels and plant-pathogen dynamics. Additionally, studies exploring the long-term effects of phosphorus application on soil health and microbial diversity would provide valuable insights for developing holistic crop management strategies.

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