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Effect of Phosphorus Levels on Early Seedlings of Rice (*Oryza sativa*) under Varying Moisture Stress Conditions

Jayesh Pathak [a*], Sneha Biswas [a] and J Himanshu Rao [a]

[a] College of Agriculture, RVSKVV, Indore, Madhya Pradesh, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This study investigated the impact of moisture levels and phosphorus applications on different rice varieties. It aimed to: 1. Identify optimal rice varieties for specific moisture and phosphorus combinations. 2. Understand how moisture stress affects seed germination speed and root and shoot development. 3. Analyze the influence of increased phosphorus on root growth, especially under moisture stress. 4. Evaluate if additional NPK application enhances the positive effects of phosphorus.

The meticulously controlled experiment, conducted within the International Rice Research Institute (IRRI)'s RGA facility from October to November 2023, utilized five rice varieties, three moisture levels (flooded, ideal, and Drought-like), and varying phosphorus levels.

The findings revealed a positive correlation between phosphorus levels and root length across all rice varieties. This emphasizes the crucial role of phosphorus in promoting root development under challenging conditions. Notably, while increased phosphorus significantly enhanced root adhesion under flooding and aided seedling recovery, drought remained a significant barrier to root growth, regardless of phosphorus application. Interestingly, despite general genetic uniformity in germination and root-shoot parameters among the varieties, a clear positive correlation between phosphorus levels and root length was still observed.

**Corresponding author: E-mail: jayeshgpathak@gmail.com;*

In conclusion, this study highlights the importance of phosphorus in strengthening root grip during floods, thereby aiding seedling recovery. However, it also emphasizes that drought remains a dominant factor hindering plant growth. The consistency observed across different rice varieties strengthens the findings, and the significant increase in root length with increased phosphorus application underscores its vital role in root development under challenging conditions. This study provides valuable insights for optimizing rice growth strategies by considering specific rice varieties, moisture levels, and phosphorus applications.

Keywords: Rice varieties; moisture stress; phosphorus application; root development; germination; flooded conditions; drought conditions.

1. INTRODUCTION

Rice (*Oryza sativa* L.) is a major and staple food crop in many parts of the world, feeding more than three billion people and providing 50-80 % of their daily calories' intake [1]. Given its prominence, it becomes imperative to understand the prominent factors affecting its growth and development. Among these, the role of phosphorus, a vital nutrient, in nurturing early rice seedlings under varying moisture stress conditions has emerged as a topic of paramount significance [2].

This study primary focuses on rice cultivation by exploring the effect of different levels of phosphorus on early rice seedlings. We focus on five distinct rice varieties, namely IR-192, IR-193, IR-206, IR-205, and IR-204 [3]. Each of these varieties exhibits its unique characteristics, including variations in germination percentages, root and shoot lengths, and germination speed.

Moisture stress is a challenge often faced by rice crops, particularly in regions with irregular rainfall patterns or water scarcity [2]. As moisture stress levels escalate, rice seedlings experience a decline in their germination speed, leading to concerns about crop viability. It is within this context that we investigate the potential of phosphorus to mitigate the impact of moisture stress on early rice growth.

The essential part of our research lies in understanding the extent to which phosphorus application influences the germination speed and root growth of these rice varieties when confronted with moisture stress [4]. In addition, we seek to unveil the synergistic effects of NPK (Nitrogen, Phosphorus, and Potassium) application on rice seedling development [5].

This research aids in contributing valuable insights into optimizing nutrient management practices for rice cultivation, ultimately working towards strengthening the resilience of this essential crop in varying environmental conditions. In the following sections, we shall further discuss the methodology employed, the outcomes observed, and the broader implications of our study in the context of rice cultivation and food security.

2. MATERIALS AND METHODS

2.1 Study Area

The experiment was conducted in the RGA (rapid generation advance) facility of The International Rice Research Institute, located in The Philippines.

2.2 Material

Tray Selection: For this study, a total of 15 trays were employed, each containing 5 × 7 cells. These cells were designed to accommodate 3 rice seeds per cell.

Variety Selection: Five different rice varieties, namely IR-192, IR-193, IR-206, IR-205, and IR-204, were selected for the experiment [2]. These varieties were planted in separate rows within the trays.

Moisture Stress Levels: Three distinct moisture stress levels were considered in the experiment:

a. **T1 (Drought-Like Condition):** It represented conditions of severe moisture stress, stimulating drought.
b. **T2 (Ideal Moisture Stress Level):** This level aimed to match the optimal moisture conditions for rice growth.
c. **T3 (Flood-Like Condition):** It represented conditions with excessive moisture, representing flooded or waterlogged conditions.

Phosphorus Levels: Five different phosphorus levels of 0.36g, 0.86g, 1.11g, 1.36g + 0.68g, and

1.61g+1.2g were applied to each tray depicting differences in moisture stress to investigate their impact on growth and development. These levels were systematically varied to create experimental conditions with different phosphorus concentrations.

Thus, three significant stages of an experimental setup were maintained- Randomization, Localization and Repetition.

2.3 Method

Tray Planting: The selected rice varieties were planted in each tray, with each row designated for a particular variety. The trays were organized to ensure a balanced distribution of varieties and treatments.

Seed Planting: Three rice seeds were planted in each cell within the trays. This provided an opportunity to assess germination rates and competition among seeds within the same cell.

Moisture Stress Application: The designated moisture stress levels (T1, T2, and T3) were simulated by adjusting the water supply to the trays. T1 received minimal water, matching drought-like conditions, while T2 maintained ideal moisture levels, and T3 involved waterlogging conditions.

Phosphorus Application: The five different phosphorus levels were systematically applied to the trays. This allowed for a comprehensive examination of the influence of varying phosphorus concentrations on the rice seedlings.

Data Collection: Throughout the experimental period, data on germination rates, root and shoot lengths, and germination speed were regularly collected and recorded for each tray, variety, moisture stress level, and phosphorus level combination.

3. RESULTS

The experiment demonstrated that increased phosphorus application significantly aided root adhesion to the soil in flooded conditions [6]. This enhanced root-soil interaction promoted better re-establishment of rice seedlings after periods of flooding. The roots of the treated seedlings exhibited improved anchorage and resistance to the effects of flooding [7].

Regardless of phosphorus application levels, the study found that the lowest root development was consistently observed under all drought conditions. This suggests that drought stress had a more substantial impact on root development than phosphorus application [8]. Drought conditions negatively affected root growth irrespective of the phosphorus levels applied.

The research showed that all tested rice varieties exhibited nearly identical germination percentages and root-shoot ratios and development. This indicates that the rice varieties tested had similar responses to the experimental conditions, suggesting that genetic factors had limited influence on these specific parameters [9].

A nota outcome of the experiment was the observation that with every 25% increase in phosphorus application, there was a substantial increase in root length and root hair growth [10,11]. This suggests a positive correlation between phosphorus levels and root length, with a significant boost in root growth as phosphorus application rates were increased by 25% increments. This highlights the role of phosphorus in stimulating root development in rice seedlings.

4. DISCUSSION

Flooded Fields and Phosphorus: Increased phosphorus application proved a boon in flooded conditions. By enhancing root adhesion to the soil, it boosted seedling re-establishment and anchorage after submergence. This suggests that optimizing phosphorus levels could significantly improve seedling resilience in flood-prone regions.

Drought: Drought, however, painted a starkly different picture. Regardless of phosphorus application, it consistently suppressed root growth. This emphasizes the need for additional strategies to combat drought stress, as phosphorus alone seems insufficient to mitigate its adverse effects on root development.

Varieties in Harmony: Intriguingly, all tested rice varieties exhibited near-identical germination and root-shoot development across all conditions. This suggests that genetic factors played a limited role in these specific parameters within the experiment's context.

Phosphorus: The clear positive correlation between phosphorus levels and root length was a resounding observation. Every 25% increase in phosphorus significantly spurred root growth, highlighting its crucial role in stimulating seedling development. This opens exciting avenues for optimizing phosphorus application to enhance root systems and potentially improve overall rice performance.

Among all five varieties, IRRI 193 exhibited the highest germination percentage (91%), while the lowest was observed in IRRI 206 (86%) Fig. 1. In terms of growth at the basal dosage of NPK and with ideal moisture levels, IRRI 192 demonstrated the highest mean root growth, whereas the lowest was recorded in IRRI 206. The lowest mean shoot growth was observed in IRRI 205 Fig. 2.

The mean root growth at a 50% increase in phosphorus levels with ideal moisture conditions was highest in IRRI 206 and lowest in IRRI 205, while the highest shoot growth was observed in both IRRI 206 and IRRI 205 at this level Fig. 3. At a 75% increase in phosphorus levels with ideal moisture conditions, the highest mean root growth was observed in IRRI 204 and the lowest in IRRI 192, while the highest shoot growth was observed in both IRRI 193 and IRRI 204 Fig. 4.

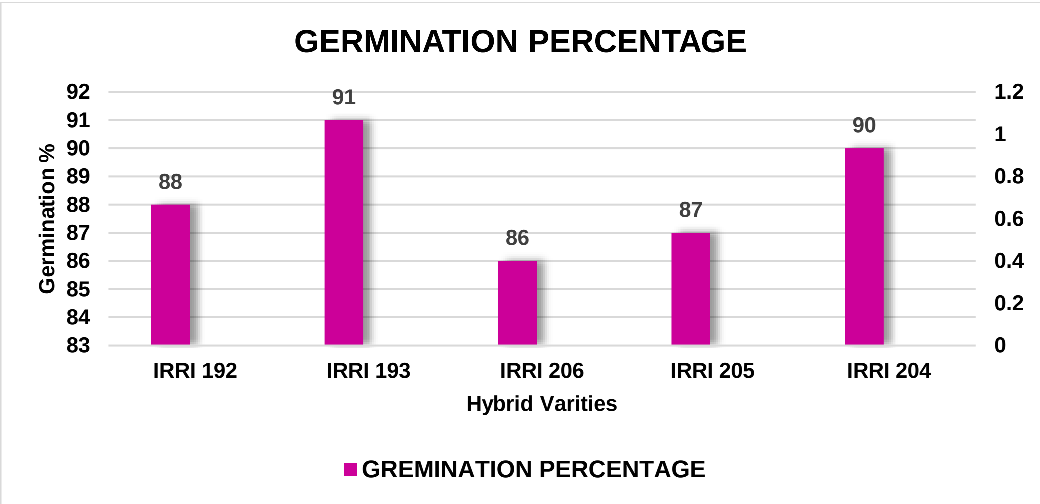

Fig. 1. Germination percentage of different rice verities

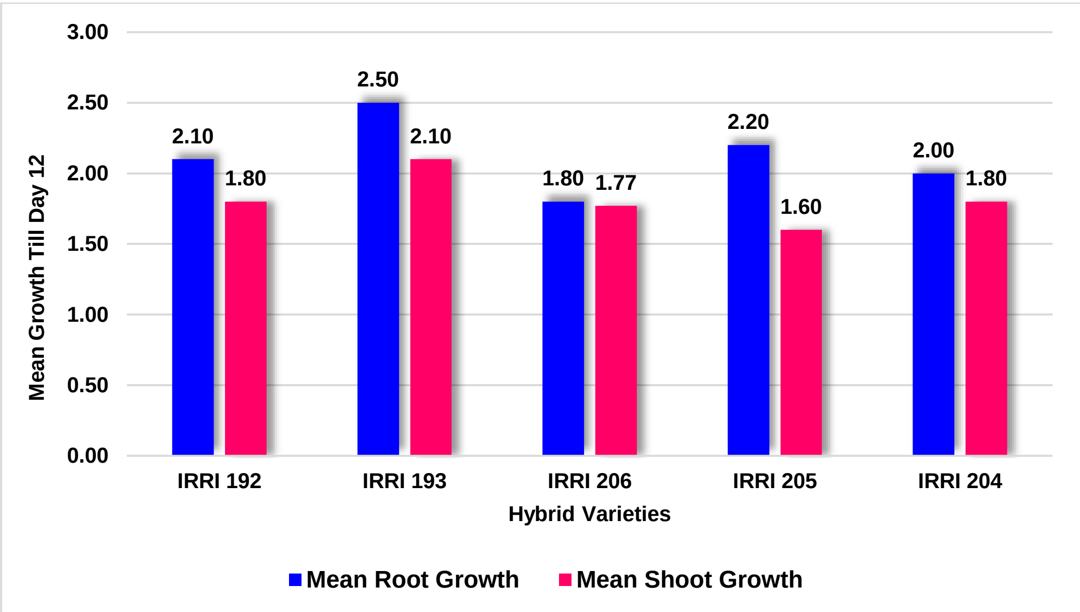

Fig. 2. Growth at basal dosage at ideal moisture level

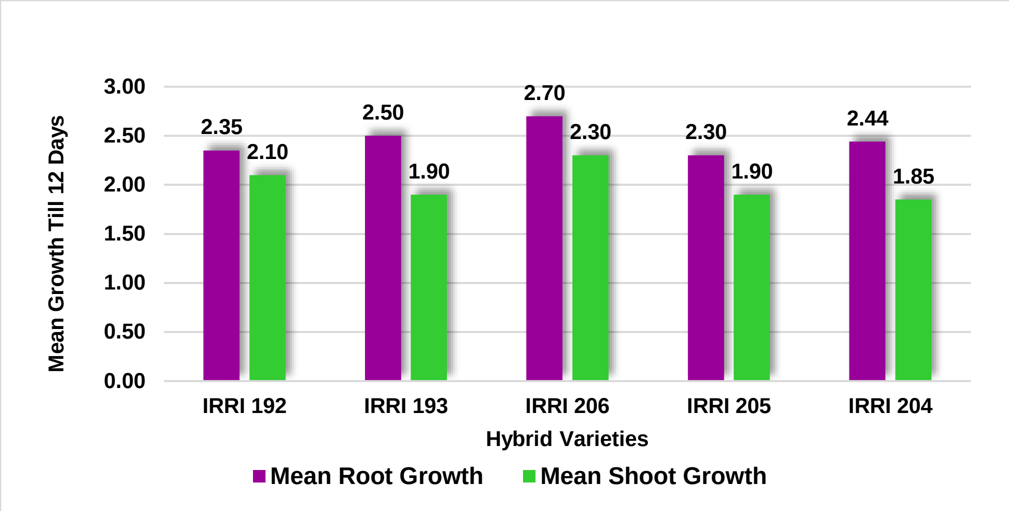

Fig. 3. Growth at 50 per cent increase in phosphorous at ideal moisture level

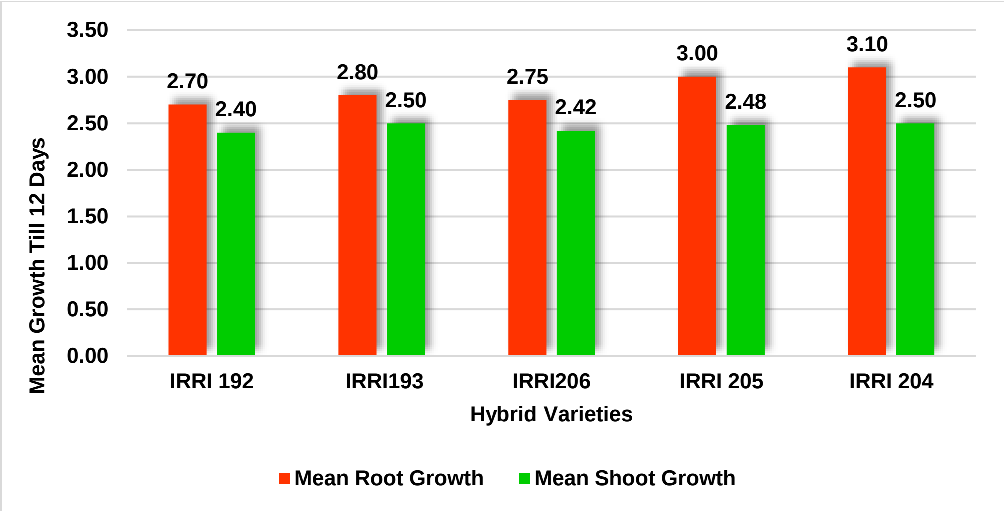

Fig. 4. Growth at 75 per cent increase in phosphorus at ideal moisture level

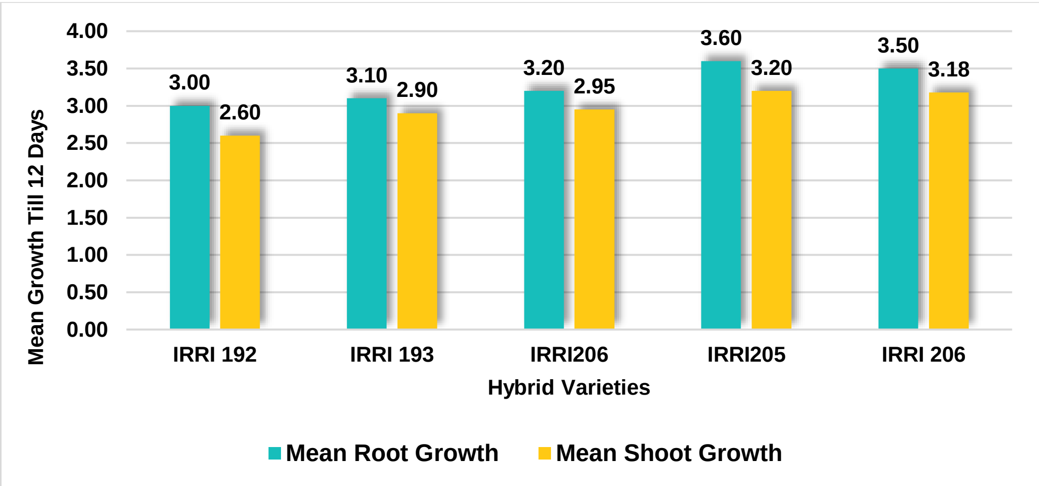

Fig. 5. Growth at 100 per cent increase in phosphorus at ideal moisture level

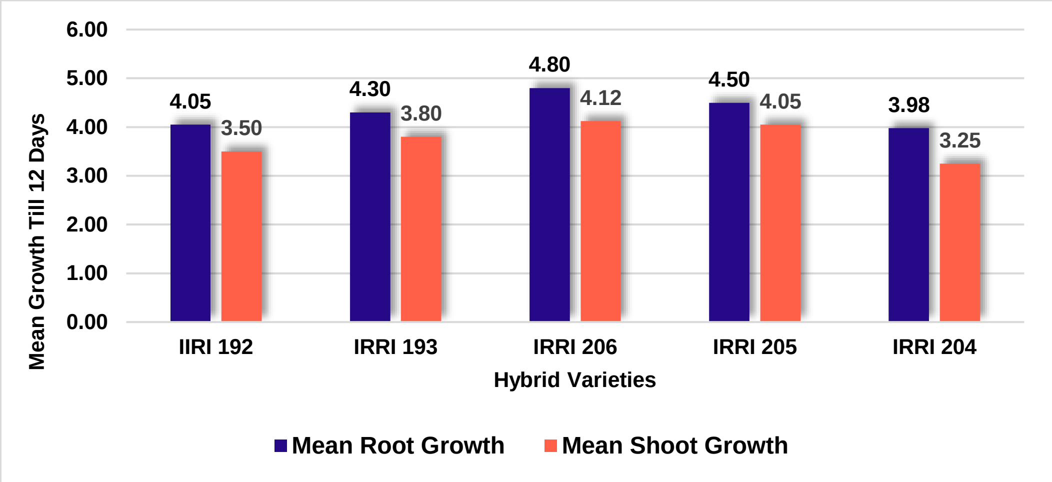

Fig. 6. Growth at 125 per cent increase in phosphorus at ideal moisture level

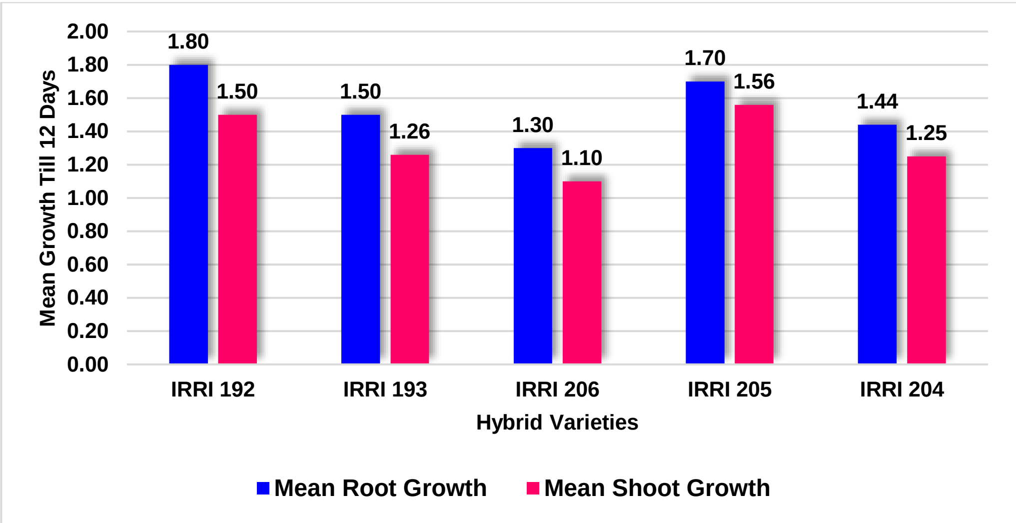

Fig. 7. Growth at basal dose (drought conditions)

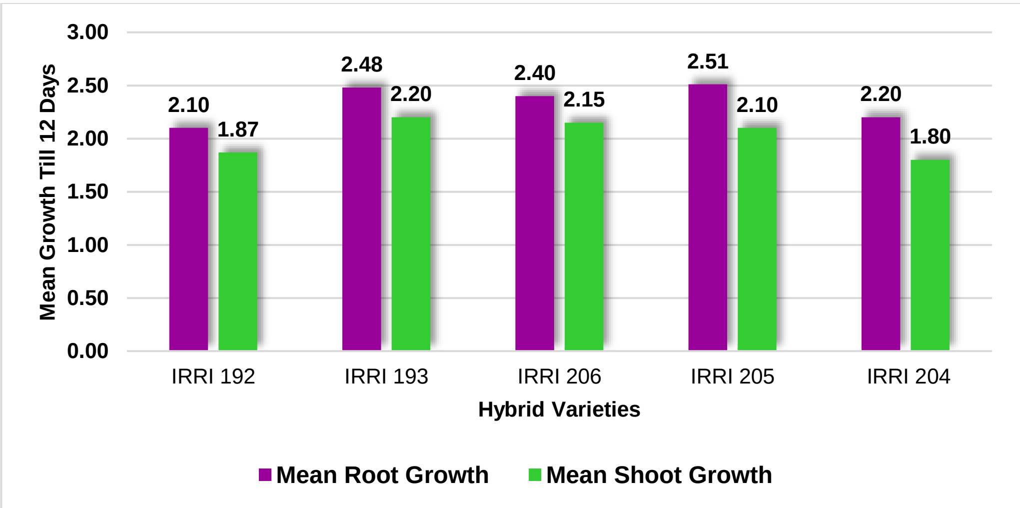

Fig. 8. Growth at 50% increase in phosphorous (drought conditions)

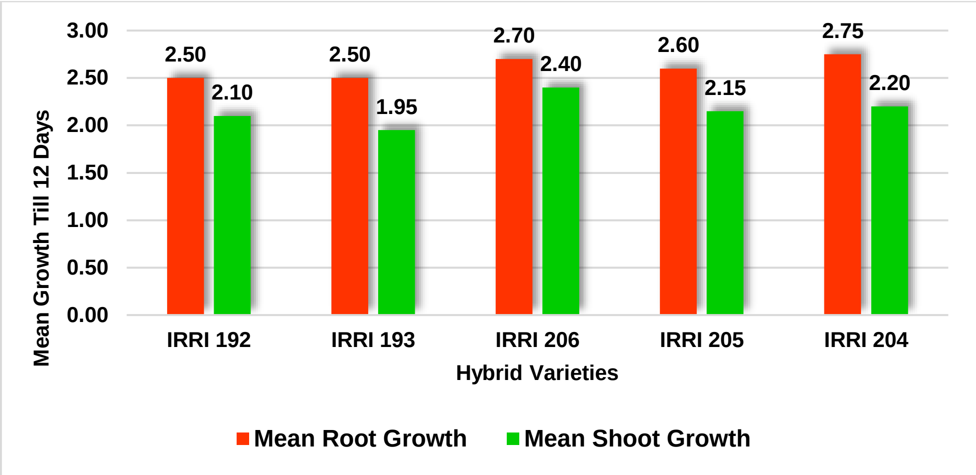

Fig. 9. Growth at 75% increase in phosphorous (drought conditions)

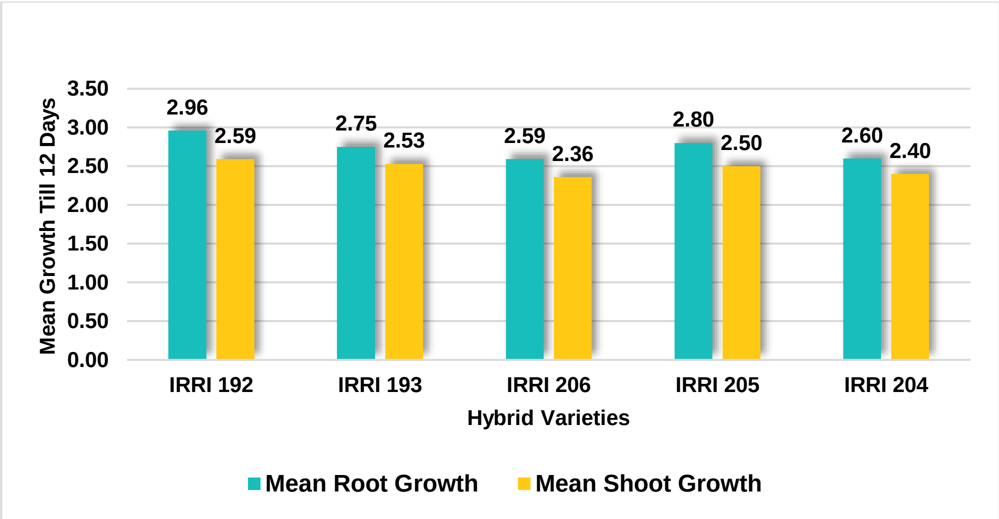

Fig. 10. Growth at 100% increase in phosphorous (drought conditions)

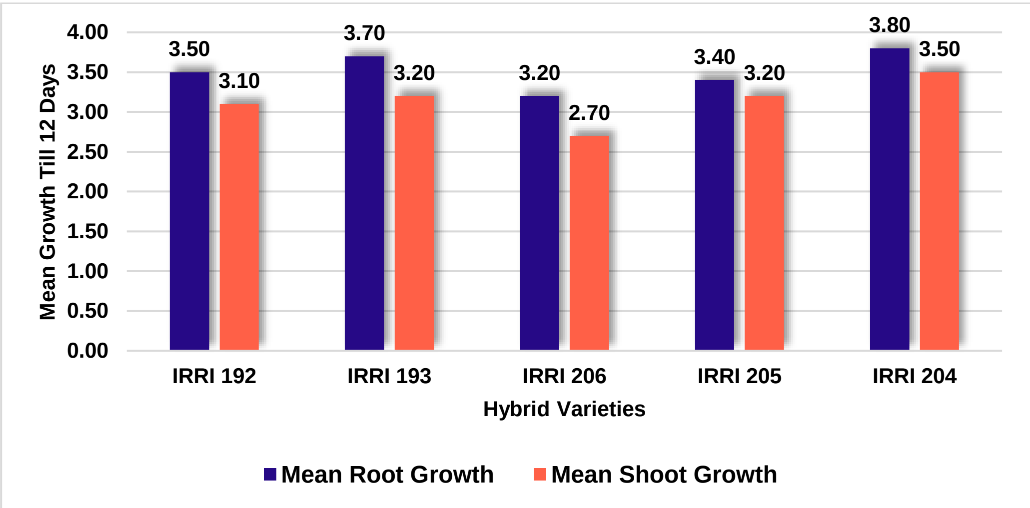

Fig. 11. Growth at 125% increase in phosphorous (drought conditions)

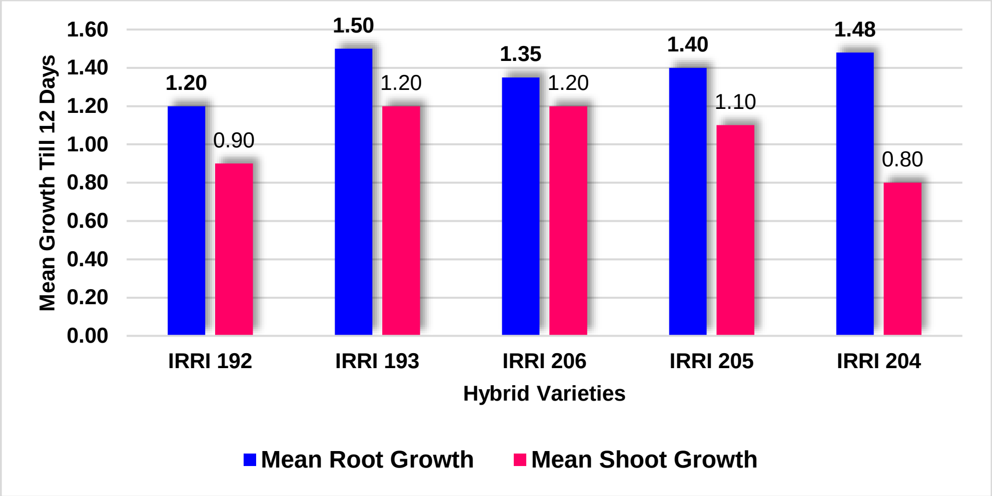

Fig. 12. Growth at basal dose (flooded conditions)

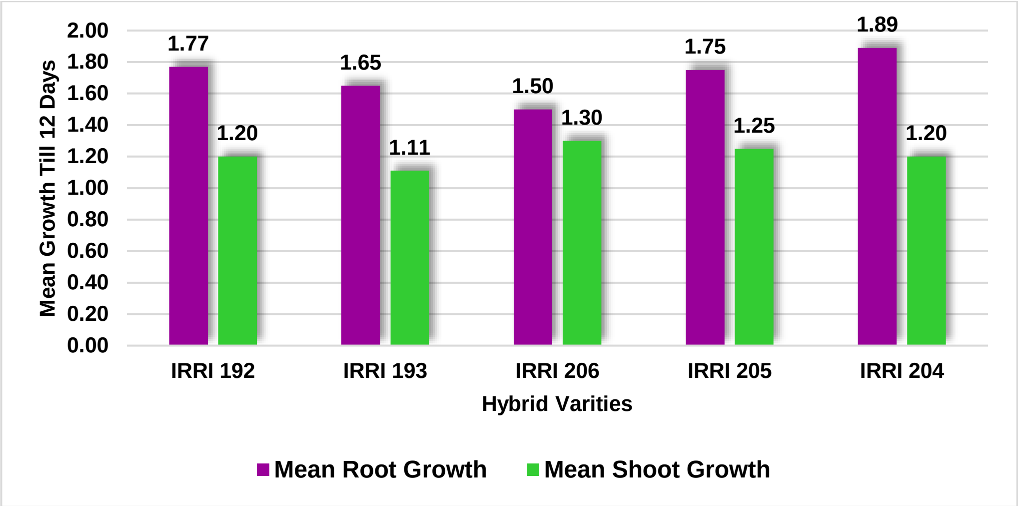

Fig. 13. Growth at 50% increase in phosphorous (flooded condition)

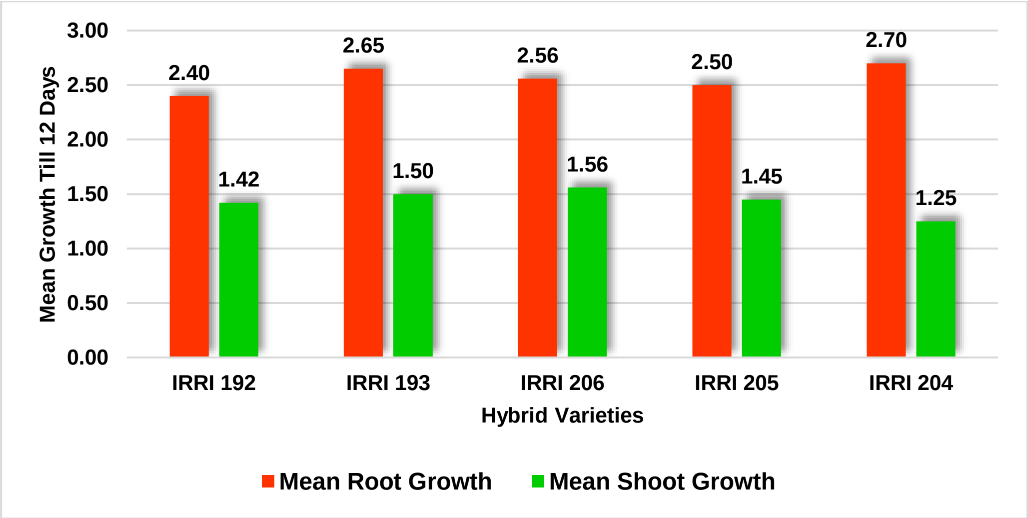

Fig. 14. Growth at 75% increase in phosphorous (flooded condition)

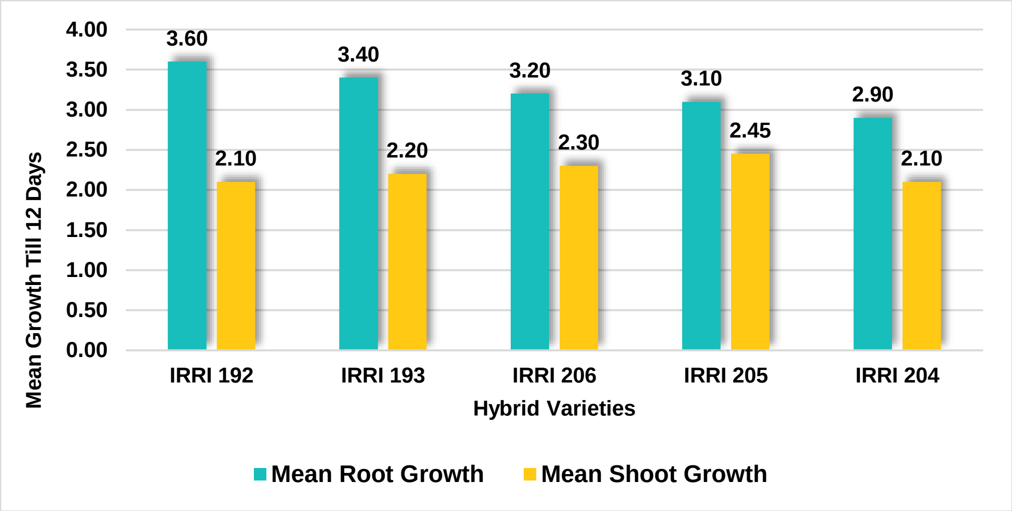

Fig. 15. Growth at 100% increase + increased by 50% on the 5th day in phosphorous (flooded condition)

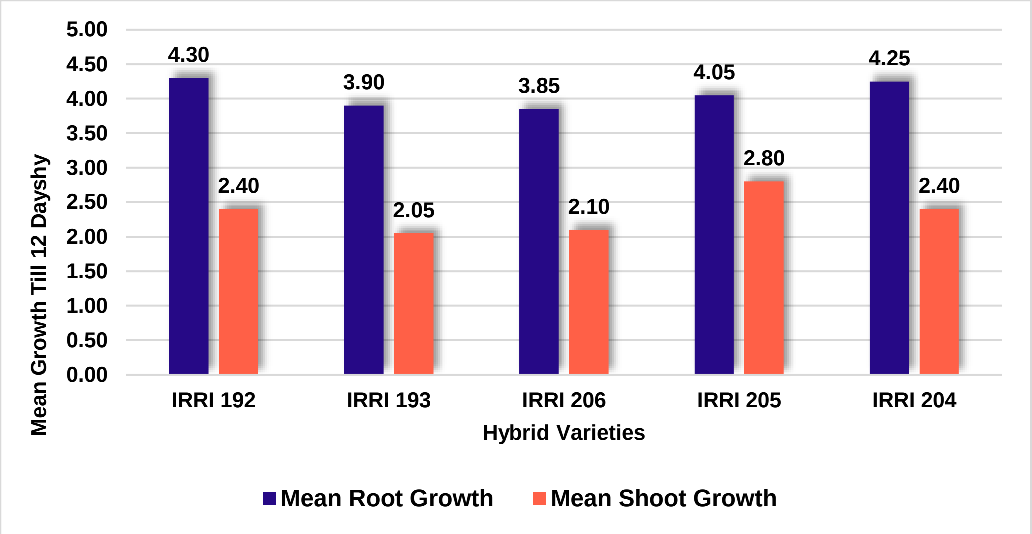

Fig. 16. Growth at 125% increase + increased by 75% on the 5th day in phosphorous (flooded condition)

At a 100% increase in phosphorus levels with ideal moisture conditions, both mean root and shoot growth were highest in IRRI 205 Fig. 5. Similarly, at a 125% increase in phosphorus levels with ideal moisture conditions, both mean root and shoot growth were highest in IRRI 206 Fig. 6.

Under drought-like conditions, mean root growth at the basal dosage was highest in IRRI 192, while mean shoot growth was highest in IRRI 205 Fig. 7. At a 50% increase in phosphorus levels under drought-like conditions, mean root growth was highest in IRRI 205, and mean shoot growth was highest in IRRI 193 Fig. 8.

In Fig. 9 at 75% increase in Phosphorus level under drought condition yielded a maximum root growth of 2.75cm in IRRI 204 and a maximum mean shoot growth of 2.40 cm in IRRI 206. In Fig. 10 at 100% increase in Phosphorus level under drought condition yielded a maximum mean root growth of 2.96cm in IRRI 192 and a maximum mean shoot growth of 2.59 cm in IRRI 192.

In Fig. 11 at 125% increase in Phosphorus level under drought condition yielded a maximum mean root growth of 3.80cm in IRRI 204 and a maximum mean shoot growth of 3.50cm in IRRI 204. In Fig. 12 at ideal Phosphorus level under flooded condition yielded a maximum mean root growth of 1.50cm in IRRI 193 and a maximum mean shoot growth of 1.20cm in IRRI 193 and IRRI 206.

In Fig. 13 at 50% increase in Phosphorus level under flooded condition recorded a maximum mean root growth of 1.89cm in IRRI 204 and a maximum mean shoot growth of 1.30cm in IRRI 206. In Fig. 14 at 75% increase in Phosphorus level under flooded condition recorded a maximum mean root growth of 2.60cm in IRRI 204 and a maximum mean shoot growth of 1.56cm in IRRI 206.

In Fig. 15 at 100% increase and an additional increase of 50% on the fifth day in Phosphorus level under flooded condition recorded a maximum mean root growth of 3.60cm in IRRI 192 and a maximum mean shoot growth of 2.45cm in IRRI 205. In Fig. 16 at 125% increase and an additional increase of 75% on the fifth day in Phosphorus level under flooded condition recorded a maximum mean root growth of 4.20cm in IRRI 192 and a maximum mean shoot growth of 2.80cm in IRRI 205.

4. CONCLUSION

In conclusion, the experiment yielded valuable insights into the impact of phosphorus application on rice seedlings across diverse environmental conditions. The findings underscore several key points. Firstly, phosphorus application proved instrumental in bolstering root adhesion to soil under flooded conditions, thereby enhancing the seedlings' resilience to flooding stress—a critical consideration for rice cultivation in flood-prone regions. Secondly, regardless of phosphorus levels, drought conditions adversely affected root development in rice seedlings, emphasizing the imperative of addressing drought stress through complementary strategies alongside phosphorus application. Thirdly, the consistent germination percentages, root-shoot ratios, and overall development across various rice varieties suggest that genetic factors exerted minimal influence on these specific parameters within the experimental framework. Lastly, a notable observation was the significant increase in root length corresponding to incremental phosphorus application, indicating a positive correlation between phosphorus levels and root growth—a finding that underscores the potential for optimizing root development by fine-tuning phosphorus application rates. These insights provide valuable guidance for refining agricultural practices aimed at enhancing rice yield and resilience in diverse environmental contexts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Khush GS. What it will take to feed 5.0 billion rice consumers in 2030. Plant molecular biology. 2005;59(1):1–6. Available:https://doi.org/10.1007/s11103-005-2159-5
2. Khan F, Siddique AB, Shabala S, Zhou M, Zhao C. Phosphorus plays key roles in regulating plants' physiological responses to abiotic stresses. Plants (Basel, Switzerland). 2023;12(15): 2861. Available:https://doi.org/10.3390/plants12152861
3. De Bauw P, Vandamme E, Lupembe A, Mwakasege L, Senthilkumar K, Dramé KN, Merckx R. Anatomical root responses of rice to combined phosphorus and water stress - relations to tolerance and breeding opportunities. Functional plant biology: FPB. 2019;46(11):1009–1022. Available:https://doi.org/10.1071/FP19002

4. Hou W, Yan J, Jákli B, Lu J, Ren T, Cong R, Li X. Synergistic effects of nitrogen and potassium on quantitative limitations to photosynthesis in rice (*Oryza sativa* L.). Journal of Agricultural and Food Chemistry. 2018;66(20):5125–5132. Available:https://doi.org/10.1021/acs.jafc.8b01135
5. Bu, Wensheng & Wang, Fangchao & Zhang, Can-Can & Bruelheide, Helge & Fang, Xiangmin & Wang, Hui-Min, Chen Fu-Sheng. The contrasting effects of nitrogen and phosphorus fertilizations on the growth of *Cunninghamia lanceolata* depend on the season in subtropical China. Forest Ecology and Management. 2021;482:118874. DOI: 10.1016/j.foreco.2020.118874
6. Abdolzadeh A, Wang X, Veneklaas E, Lambers H. Effects of phosphorus supply on growth, phosphate concentration and cluster-root formation in three *Lupinus species*. Annals of Botany. 2010;105(3): 365-374. Available:https://doi.org/10.1093/aob/mcp297
7. Bonser AM, Lynch J, Snapp S. Effect of phosphorus deficiency on growth angle of basal roots in *Phaseolus vulgaris*. The New phytologist. 1996;132(2):281–288. Available:https://doi.org/10.1111/j.1469-8137.1996.tb01847.x
8. Aeschbacher RA, Schiefelbein J, Benfey PN. The genetic and molecular basis of root development; 1994.
9. Anthony RG, Henriques R, Helfer A, Mészáros T, Rios G, Testerink C, Munnik T, Deák M, Koncz C, Bögre L. A protein kinase target of a PDK1 signalling pathway is involved in root hair growth in Arabidopsis. The EMBO Journal. 2004;23 (3):572–581. Available:https://doi.org/10.1038/sj.emboj.7600068
10. Bonser AM, Lynch J, Snapp S. Effect of phosphorus deficiency on growth angle of basal roots in *Phaseolus vulgaris*. The New phytologist. 1996;132(2):281–288.Available:https://doi.org/10.1111/j.1469-8137.1996.tb01847.x
11. Kayoumu M, Li X, Iqbal A, Wang X, Gui H, Qi Q, Ruan S, Guo R, Dong Q, Zhang X, Song M. Genetic variation in morphological traits in cotton and their roles in increasing phosphorus-use-efficiency in response to low phosphorus availability. Frontiers in Plant Science. 2022;13:1051080.

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