Summary of Doctoral Thesis

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Title	Impact of deep-placed fertilization on root system architecture and productivity in rice

With rice being a staple for over half the global population, the need for sustainable practices is imperative. The excessive use of fertilizers has raised environmental concerns, necessitating innovative approaches to enhance nutrient use efficiency. The research explores deep-placed fertilization (DPF) as an innovative approach to enhance nutrient use efficiency and mitigate environmental impacts. DPF has proven to be a promising technology, providing higher yield at lower fertilizer consumption. The research, conducted in relatively cool regions, sheds light on the adaptability and potential benefits of DPF technology across diverse climatic environments. This investigation evaluates the impact of DPF on rice root system architecture (RSA) and its consequential effects on growth, nutrient uptake, and overall productivity.

In Chapter 2, A comprehensive three-year field trial utilizing the Akitakomachi rice cultivar to assess the effects of DPF on rice root system development in a cool climate is presented. The experiment included three treatments: Mix Plot, where NPK fertilizer was uniformly mixed at a 15 cm depth before transplantation; DP1, where fertilizer was locally placed at 7 cm/ 10 cm depth; and DP2, with dual-depth placement at 7 and 15 cm after transplantation with a ratio of N:P:K of 8:6.5:7.5 (g/m^2). Here, DP1 and DP2 served as representatives of DPF treatments. A root box experiment utilizing identical planting materials and treatment conditions was also conducted to visualize the development of the root system. DPF plots showed a notable delay in initial growth but eventually outgrew Mix plots. The study demonstrates positive outcomes for DPF of combined N, P, and K fertilizers through changes in RSA. Spatial-temporal changes in RSA, characterized by increased root surface area and thicker roots at the fertilization site, led to improved acquisition of fertilizer components and essential elements such as Ca and Mg from the lower soil layers during the ripening period. DPF contributed to higher yields compared to conventional broadcasting fertilization. Overall, the study from this chapter provides valuable insights into the complex interactions between the DPF method, root dynamics, and nutrient management, offering a comprehensive understanding essential for sustainable and efficient rice production practices.

Chapter 3 builds upon these findings, demonstrating the positive impact of the DPF method on nutrient absorption and rice productivity across diverse RSA. The *DRO1* and *qSOR1* genes are associated with root gravitropism and are crucial in determining RSA. In this study, the parent variety IR64 and its three NILs were designated as the DEEP, INTERMEDIATE, and SHALLOW lines. Two treatments were implemented: the Mix

plot, where NPK fertilizer was uniformly mixed at a 15 cm depth, and DP1 as the DPF treatment, where NPK fertilizer was locally placed at 10 cm. A root box experiment with the same plant materials and treatment conditions was also implemented to visualize the root system development. The study demonstrates that DPF positively influences nutrient uptake, sink capacity rice, and productivity, contributing to higher yields across different RSA lines. While confirming the overall benefits of DPF, the study unveils differences in the responses of IR64 and its NILs to localized fertilization, influencing final yield production. In the root box experiment, IR64 and its NILs, excluding the DEEP line, exhibited higher root accumulation at the fertilizer position under DPF, whereas, in the field condition, even the DEEP line displayed root acquisition at the fertilizer position under DP1 treatment, along with IR64 and the INTERMEDIATE line, while the SHALLOW line showed diminished root surface area and limited responsiveness to fertilizer. Furthermore, the chapter investigates the impact of DPF at different experimental sites with distinct soil properties such as high phosphate absorption coefficient and low P and K availability, and highlights the adaptability and transferability of DPF's effects across diverse soil conditions because ANOVA showed no significant effect of different location on yield production for any of the plant material. A preliminary examination under extreme soil conditions reveals differential responses among RSA lines, offering insights into their adaptability to nutrient deficiencies. IR64 exhibits better growth under P-deficient conditions, while IR64 and its DEEP and INTERMEDIATE lines performed comparably when P is present. This intriguing finding suggests that genetically different root system distributions respond differently to nutrient deficiencies, warranting further investigation. The overall results suggest that along with deep rooting line DEEP, a combination of deep and shallow RSA, represented by the INTERMEDIATE line, prove beneficial for efficient rice production under DPF condition. This chapter provides valuable insights into the interplay between RSA, DPF method, and rice productivity under varied soil properties, contributing to a comprehensive understanding of sustainable rice cultivation practices.

In conclusion, this study underscores the complexity of RSA responses to DPF and the importance of considering genetic diversity for targeted and efficient nutrient management in rice cultivation. The results confirm that the DP of combined NPK fertilizers initiates root spatial-temporal changes with greater root accumulation around the localized nutrient source. The study further confirms that a blend of both deep and shallow RSA proves advantageous for effective rice production along with DEEP line having deep RSA, as evidenced by the higher yield production among the tested plant materials. This suggests that the combination of accumulation ability of roots to fertilizer and the extensive distribution of roots, both horizontally and vertically in the soil, may contribute to optimal yield potential under DPF conditions. The study not only contributes practical knowledge for optimizing DPF technology but also emphasizes the need for tailored approaches based on specific genetic traits and environmental conditions. The potential of DPF technology to adapt to varying climates and its capacity to reduce fertilizer dosage make it a compelling option for both developing and fertilizer-dependent countries. This study collectively provides a foundation for future research, suggesting that understanding the intricate interplay between RSA and nutrient responses is crucial for advancing sustainable and high-yield rice production practices.

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