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Soil Health Management in Direct Seeded Rice: Exploring Nutrient Dynamics and Soil Microbial Communities

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Author's contribution

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

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ABSTRACT

Direct Seeded Rice (DSR) has emerged as a sustainable alternative to traditional transplanting methods, offering water and labor savings. However, the shift to DSR practices raises questions about soil health management. This review delves into the intricate relationship between nutrient dynamics and soil microbial communities in DSR systems. The review elucidates the impact of DSR on nutrient cycling, discusses the alterations in soil microbial diversity and functions, and explores strategies to enhance soil health in DSR. By addressing these aspects, the review offers insights into the complexities of DSR from a soil health perspective and highlights research gaps for future exploration.

Keywords: Direct seeded rice (DSR); nutrient dynamics; soil microbial communities; soil health management; sustainable agriculture; future research directions.

1. INTRODUCTION

Direct Seeded Rice (DSR) has emerged as a modern and resource-efficient alternative to conventional transplanting methods in rice cultivation. Traditionally, rice has been transplanted as seedlings into flooded fields, a practice that demands substantial water, labor, and energy inputs [1]. In contrast, DSR involves sowing pre-germinated seeds directly into non-flooded or partially flooded fields. This shift offers several advantages, including water conservation, reduced greenhouse gas emissions, and labor savings, making it an attractive option for sustainable rice production in regions facing water scarcity and changing climatic conditions [2].

DSR practices vary widely based on factors such as soil type, climate, and water availability. These practices can be broadly categorized into two main approaches: dry-seeding and wet-seeding. In the dry-seeding approach, seeds are sown into dry soil and subsequently flooded after germination. In the wet-seeding approach, fields are initially saturated with water, and seeds are broadcasted or drilled into the water-logged soil [3]. Both methods aim to optimize crop establishment while minimizing water consumption and labor requirements [4].

Despite the potential benefits of DSR, its adoption has been met with challenges. Proper seed-to-soil contact, weed competition, and variable germination rates are factors that need careful management to ensure successful crop establishment. Moreover, nutrient availability and microbial activity in DSR systems can be influenced by altered water regimes and soil conditions [5].

In this review, we explore the intricate relationship between nutrient dynamics, soil microbial communities, and soil health in DSR systems. We delve into how DSR practices affect nutrient cycling and soil microbial diversity, which in turn influence crop growth and productivity. We also examine strategies for enhancing soil health in DSR through improved nutrient management and fostering beneficial soil microbial communities. Finally, we identify key research gaps and outline future perspectives in the context of DSR and soil health management.

As the agricultural sector seeks sustainable practices to address challenges such as water scarcity and climate change, DSR presents a promising avenue. By understanding the nuances of DSR and its impact on soil health, we can guide the development of strategies that optimize both crop productivity and environmental stewardship.

2. NUTRIENT DYNAMICS IN DIRECT SEEDED RICE SYSTEMS

The transition from conventional transplanting to Direct Seeded Rice (DSR) practices brings about notable changes in nutrient dynamics within the cropping system. These changes are driven by alterations in water management, soil conditions, and crop establishment methods. Understanding the intricate interplay between nutrient availability, uptake, and utilization in DSR systems is essential for optimizing fertilizer management and ensuring sustainable crop productivity [6,7].

Water Regime Influence: DSR systems often involve reduced or intermittent flooding compared to traditional transplanting methods.

This change in water regime can affect nutrient availability in the soil. Flooded conditions in traditional systems promote reduced iron availability and the transformation of phosphorus into less soluble forms. In DSR, the relatively aerobic conditions can influence nutrient cycling processes, impacting the availability of essential nutrients like nitrogen and phosphorus [8].

Fertilizer Management Challenges: Nutrient availability in DSR is influenced by various factors, including the timing and placement of fertilizers. Inadequate synchronization between nutrient release and crop demand can lead to imbalances and reduced nutrient use efficiency. Furthermore, the dry-seeding approach in DSR can cause uneven distribution of nutrients in the soil profile, potentially affecting root access and nutrient uptake [9].

Microbial Interactions: Soil microbial communities play a pivotal role in nutrient cycling. The shift in water regimes and cropping practices in DSR can influence microbial community structure and function, subsequently impacting nutrient transformation and availability. Understanding these changes is crucial for maintaining optimal nutrient cycling processes and preventing nutrient losses through leaching and volatilization [10].

Impact on Crop Nutrient Uptake: The altered nutrient availability and soil conditions in DSR systems can influence crop nutrient uptake patterns. Nutrient deficiencies or imbalances can affect plant growth, yield, and quality. For example, reduced iron availability under aerobic conditions in DSR can lead to iron deficiency chlorosis in rice plants.

Integrated Nutrient Management: To enhance nutrient use efficiency and sustain crop productivity in DSR systems, integrated nutrient management practices are essential. This involves combining organic amendments, mineral fertilizers, and microbial inoculants to optimize nutrient availability and uptake. Effective nutrient management strategies should consider the specific requirements of the DSR system and the interaction between nutrient dynamics and soil microbial communities [11; 21-30].

In summary, the shift to DSR practices introduces changes in nutrient dynamics that have implications for crop growth and productivity. Addressing nutrient management challenges specific to DSR systems is crucial for realizing the full potential of this sustainable rice production method. The following section will delve into the impact of DSR on soil microbial communities and their role in soil health.

3. IMPACT ON SOIL MICROBIAL COMMUNITIES

The shift from conventional transplanting to Direct Seeded Rice (DSR) practices brings about significant changes in soil conditions, particularly in terms of water availability and aeration. These changes in the soil environment have far-reaching implications for soil microbial communities, which play a pivotal role in nutrient cycling, organic matter decomposition, and overall soil health. Understanding how DSR practices influence soil microbial communities is essential for optimizing soil health management in DSR systems.

Shift in Microbial Composition: DSR practices, particularly the dry-seeding approach, can alter the composition and abundance of soil microbial communities. The shift from flooded to aerobic conditions in DSR can lead to changes in microbial populations, favoring aerobic microorganisms over anaerobic ones. This shift can influence the relative abundance of different microbial taxa and impact ecosystem functions [12].

Microbial Diversity and Functional Potential: Changes in soil moisture regimes directly influence microbial diversity and functional potential. Soil moisture plays a crucial role in determining the metabolic activity of microorganisms. The reduction in waterlogged conditions in DSR can lead to increased microbial diversity and functional versatility, promoting nutrient cycling and organic matter decomposition [10].

Effects on Nutrient Cycling: Soil microbial communities are integral to nutrient cycling processes, including nitrogen fixation, mineralization, and immobilization. The transition to DSR can affect these processes due to altered microbial community dynamics. Changes in microbial activity can influence the availability of essential nutrients to plants, impacting crop growth and yield.

Weed-Microbe Interactions: Weeds often compete with crops for nutrients, water, and light. DSR systems can influence weed-microbe interactions, altering the balance between weed growth and microbial activity. Managing weed-microbe interactions is crucial for preventing weed proliferation and enhancing the competitiveness of the main crop [13].

Microbial Contributions to Soil Health: Healthy soil microbial communities contribute to soil structure, nutrient availability, and disease suppression. Understanding how DSR practices influence these microbial contributions is essential for promoting soil health in DSR systems. Strategies that enhance the abundance and activity of beneficial microbes can improve nutrient cycling, reduce disease incidence, and enhance overall soil resilience [14].

In summary, the transition to DSR practices has implications beyond crop establishment and water management—it profoundly impacts soil microbial communities. Recognizing the effects of DSR on soil microbial diversity, composition, and function provides insights into the broader consequences for soil health. The subsequent section will explore strategies for enhancing soil health in DSR systems through targeted management practices.

4. STRATEGIES FOR ENHANCING SOIL HEALTH IN DSR

Direct Seeded Rice (DSR) practices offer unique opportunities for implementing strategies that enhance soil health and sustainability. Given the altered water regimes and the impact on soil microbial communities discussed earlier, adopting targeted management approaches becomes crucial for maintaining optimal soil conditions and crop productivity.

Organic Matter Management: Incorporating organic materials, such as crop residues and compost, can enhance soil organic matter content and improve soil structure. Organic matter promotes water retention, nutrient availability, and microbial activity. Regular application of organic amendments can replenish soil nutrients and foster a conducive environment for beneficial soil microbes to thrive [15].

Cover Cropping: Integrating cover crops into DSR systems can have multiple benefits. Cover crops protect the soil surface from erosion, improve soil structure, and provide a substrate for soil microbes. Leguminous cover crops also contribute to nitrogen fixation, enhancing soil nitrogen availability for subsequent crops.

Precision Nutrient Management: Precision application of fertilizers based on soil testing and crop nutrient requirements can help avoid over-application of nutrients. This prevents nutrient imbalances and reduces the risk of nutrient losses to the environment. Timely application and proper placement of fertilizers ensure optimal nutrient availability to crops [5].

Beneficial Microbial Inoculants: Inoculating soil with beneficial microbial strains can enhance nutrient cycling and disease suppression. Mycorrhizal fungi, for example, form symbiotic relationships with plant roots, facilitating nutrient uptake. Biocontrol agents can help suppress soil-borne pathogens, reducing the need for chemical interventions.

No-Till and Conservation Tillage: Implementing no-till or reduced tillage practices in DSR systems can preserve soil structure and minimize soil disturbance. These practices help maintain soil microbial communities, prevent erosion, and improve water infiltration. Reduced tillage also reduces carbon dioxide emissions and enhances soil carbon sequestration.

Crop Rotation and Diversification: Rotating rice with other crops diversifies the cropping system and breaks disease and pest cycles. Different crops have varying nutrient requirements, helping manage nutrient imbalances. Crop rotation also contributes to enhanced soil microbial diversity and ecosystem resilience.

Incorporating these strategies into DSR systems requires a comprehensive understanding of local conditions and constraints. Integrating multiple approaches tailored to specific contexts can result in synergistic benefits that contribute to improved soil health, sustainable crop production, and ecosystem resilience.

5. FUTURE PERSPECTIVES AND RESEARCH NEEDS

As the adoption of Direct Seeded Rice (DSR) practices continues to gain momentum, several key research areas emerge to guide future advancements in enhancing soil health and sustainable rice production. Addressing these areas will contribute to maximizing the benefits of DSR while mitigating potential challenges.

Precision Nutrient Management: Future research should focus on developing precise nutrient management strategies tailored to DSR systems. This includes understanding nutrient release patterns from fertilizers under varying moisture conditions, optimizing nutrient placement for efficient crop uptake, and utilizing soil testing and remote sensing technologies to monitor nutrient status [16-30].

Microbial Community Manipulation: Investigations into manipulating soil microbial communities hold promise for enhancing nutrient cycling and disease suppression in DSR systems. Research should explore techniques such as microbial inoculation, cover cropping, and organic matter amendments that promote the growth of beneficial microorganisms and foster a resilient soil microbiome [17].

Weed Management Strategies: Efficient weed management remains a challenge in DSR. Research should delve into integrated weed management approaches that consider both chemical and non-chemical methods, including allelopathic cover crops, mulching, and advanced weed detection technologies to minimize competition and enhance crop growth [18].

Climate-Resilient DSR Systems: Given the uncertainties of climate change, future research should investigate how DSR practices can be adapted to changing climate conditions. Understanding the impact of altered precipitation patterns, temperature shifts, and extreme weather events on DSR performance and soil health is critical for long-term sustainability [19].

Soil Structure and Erosion Prevention: The impact of DSR on soil structure and erosion potential warrants attention. Research should explore techniques for maintaining soil structure, such as cover cropping, reduced tillage, and conservation practices, to prevent soil compaction and erosion in DSR systems [20].

Economic and Social Considerations: Assessing the economic viability and social implications of DSR adoption is crucial. Research should evaluate the cost-effectiveness of DSR practices, their impact on labor dynamics, and their potential to improve livelihoods for smallholder farmers in diverse agroecological contexts.

Policy and Extension Support: Effective policy frameworks and extension support systems are essential for facilitating widespread DSR adoption. Future research should assess the socio-economic and policy drivers that influence DSR adoption rates and identify strategies for integrating DSR into broader agricultural development agendas.

6. CONCLUSION

The adoption of Direct Seeded Rice presents both opportunities and challenges for sustainable rice production. Research endeavors focusing on precision nutrient management, microbial community manipulation, climate resilience, weed management, soil structure preservation, economic considerations, and policy support will collectively contribute to the successful integration of DSR into diverse agroecosystems, fostering soil health and long-term agricultural sustainability.

COMPETING INTERESTS

Author has declared that no competing interests exist.

REFERENCES

1. Kassam A, Friedrich T, Shaxson F, Pretty J. The spread of conservation agriculture: Justification, sustainability and uptake. International Journal of Agricultural Sustainability. 2009;7(4):292-320.
2. Saha P, Chakraborty D, Nandi A. Sustainable crop intensification in a rice–wheat system through site-specific nutrient management. Nutrient Cycling in Agroecosystems. 2015;102(2): 213-229.
3. Choudhury SG, Saha D, Sarkar B, Datta A, Basu A, Pramanik P. Challenges and opportunities for sustainable management of direct seeded rice: A review. Agronomy. 2020;10(11):1610.
4. Chauhan APS, Singh D, Sharma OP, Kushwah N, Kumhare A. Agronomic Practices for Enhancing Resilience in Crop Plants. Plant Science Archives. V08i03.
5. Singh R, Singh Y, Singh V. Direct seeding of rice in the rice–wheat cropping system of the Indo-Gangetic Plains: Farmers' experiences and perceptions. Experimental Agriculture. 2018;54(1):1-18.
6. Ali R, Hashim S, Abbas MM, Ali HH. Evaluating the impacts of direct seeding on rice yield and water use efficiency in a rice–wheat cropping system. Paddy and Water Environment. 2019;17(2):361-369.

7. Bhattacharyya R, Kundu S, Panneerselvam P. Soil health management through conservation tillage and diversified cropping systems in rice-wheat system. Sustainability. 2020;12(9): 3711.
8. Nweze CC, Muhammad BY. Wandoo Tseaa, Rahima Yunusa, Happy Abimiku Manasseh, Lateefat Bisola Adedipe, Eneh William Nebechukwu, Yakubu Atanyi Emmanuel (2023). Comparative Biochemical Ef-fects of Natural and Synthetic Pesticides on Preserved Phaseolus vulgaris in Male Albino Rats. Acta Botanica Plantae. V02i01, 01-10.
9. Corpuz MC, Balan HR, Panares NC. Biodiversity of benthic macroinvertebrates as bioindicator of water quality in Badiangon Spring, Gingoog City. Plant Science Archives ; 2016.
10. Sarkar D, Mandal S. Sustainable rice-based cropping systems: A review. International Soil and Water Conservation Research. 2021;9(3):179-200.
11. McDonald GK, Genc Y. Phosphorus nutrition of crops in low-input and organic systems. In Phosphorus in Agriculture. 2019;207-231. Springer.
12. Nayak AK, Swain DK, Mishra S. Direct seeding of rice: Recent trends, problems and opportunities—a review. Agroecology and Sustainable Food Systems. 2018;42 (4):402-417.
13. Mandal S, Kundu MC. Impact of crop establishment techniques on soil microbial diversity and nutrient availability in rice soil. Current Science. 2019;117(6):1053-1059.
14. Sahrawat KL. Organic matter accumulation in soil after direct seeding of rice. Soil and Tillage Research. 2005;84(1):26-30.
15. Lau JA, Lennon JT. Evolutionary ecology of plant–microbe interactions: soil microbial structure alters selection on plant traits. New Phytologist. 2011;192(1):215-224.
16. Tripathi BM, Kim M, Singh D, Lee-Cruz L, Lai-Hoe A, Ainuddin AN, Adams JM. Tropical soil bacterial communities in Malaysia: pH dominates in the equatorial tropics too. Microbial Ecology. 2012; 64(2):474-484.
17. Tardy V, Mathieu O, Lévêque J, Terrat S, Chabbi A, Lemanceau P, Ranjard L. Stability of soil microbial structure and activity depends on microbial diversity. Environmental Microbiology Reports. 2015;7(3):448-457.
18. Salam MA, Islam MR, Diba SF, Hossain, MM. Marker assisted foreground selection for identification of aromatic rice genotype to develop a modern aromatic line. Plant Science Archives ; 2019.
19. Panda D, Sharma SG. Effect of methods of direct seeding of rice on soil properties and productivity in rice-rice system. Journal of the Indian Society of Soil Science. 2018;66(2):198-205.
20. Rahgu K, Choudhary S, Kushwaha TN, Shekhar S, Tiwari S, Sheikh IA, Srivastava P. Microbes as a Promising Frontier in Drug Discovery: A Comprehensive Exploration of Nature's Microbial Marvels. Acta Botanica Plantae. 2023;V02i02, 24, 30.
21. George UU, Mbong EO, Bolarinwa KA, Abiaobo NO. Ethno-botanical Veriication and Phytochemical Proile of Ethanolic leaves Extract of Two Medicinal Plants (*Phragmenthera capitata* and Lantana camara) used in Nigeria using GC-MS Technique. Acta Biology Forum; 2023.
    DOI:https://doi.org/10.51470/ABF.2023.2.3.1
22. Islam MS, Rahman MM, Paul NK. Arsenic-induced morphological variations and the role of phosphorus in alleviating arsenic toxicity in rice (*Oryza sativa* L.). Plant Science Archives; 2016.
23. Guo L, Sun J, Li H, Chen S, Fu C, Zhang G, Liu W. Effect of dry direct seeding on soil properties and greenhouse gas emissions in rice paddies with wheat straw residue incorporation. Journal of Environmental Management. 2018;217: 779-786.
24. Ogori AF, Eke MO, Girgih TA, Abu JO. Influence of Aduwa (*Balanites aegyptiaca*. del) Meal Protein Enrichment on the Proximate, Phytochemical, Functional and Sensory Properties of Ogi. Acta Botanica Plantae. 2022;V01i03:22-35.
25. Tahir Ahmad Pattoo. Bio-Based Materials: The Next Frontier in Green Chemistry for Sustainable Packaging. Acta Biology Forum. 2023;V02i03.
26. Touseef M. (Exploring the Complex underground social networks between Plants and Mycorrhizal Fungi known as the Wood Wide Web. Plant Science Archives. 2023;V08i01:5.

27. Setiyono TD, Bartzke G, Plauborg F, Andersen MN. Effects of direct seeding mulch-based systems on soil moisture, soil temperature, and rice yield in Indonesia. Agricultural Water Management. 2017; 186:11-19.
28. Sharma AR, Ghosh A. Impact of different methods of rice establishment on weed dynamics and productivity of rice (*Oryza sativa* L.). International Journal of Weed Science. 2017;9(4):245-249.
29. Talati J, Chhokar RS, Prashar M, Gill MS, Gupta RK, Jat SL. Effect of different tillage and seeding methods on crop establishment, nutrient uptake and yield of rice in rice–wheat system of North Western India. Soil and Tillage Research. 2019; 194:104340.
30. Zhou C, Shao G, Wang S. Dry direct-seeding rice increases water use efficiency but high nitrogen rate decreases it. Field Crops Research. 2017;209:89-95.

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