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Anaerobic Germination Tolerance: Paving the Way to Sustainable Direct Seeded Rice Cultivation

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Introduction

Rice (Oryza sativa) is a staple food crop that plays a vital role in global food security, particularly in Asia where it serves as a primary source of calories for a significant proportion of the population. It serves as a crucial source of sustenance, providing essential nutrients and energy for millions of people. Additionally, rice cultivation contributes to socio-economic development by supporting the livelihoods of numerous farmers worldwide, offering employment opportunities and fostering rural economies. Traditionally, rice has been cultivated using the labour-intensive method of transplanting seedlings, which allows for better control over weed competition and ensures optimal seedling establishment, leading to higher crop yields. However, this method is associated with high labour and production costs.

Key words: Direct seeded Rice and anaerobic germination

Direct Seeded rice (DSR)

In recent years, there has been a shift towards the adoption of Direct-seeded rice (DSR) in many Asian regions. DSR involves sowing rice seeds directly into the field without transplanting seedlings. This practice offers several advantages, including labour and cost savings, as it eliminates the need for labour-intensive transplanting operations. DSR also provides flexibility in planting timing, allowing farmers to adapt to varying climate and market conditions. The adoption of DSR is particularly beneficial in regions facing challenges such as water scarcity, limited labour availability, or a desire to enhance resource efficiency. This method of cultivation reduces water requirements compared to traditional transplanting, as it eliminates the need for standing water during the initial growth stage. It promotes efficient water use, minimizing water loss through evaporation and seepage, and conserving this valuable resource. Furthermore, DSR cultivation can contribute to sustainable agricultural practices by reducing greenhouse gas emissions associated with continuous flooding in traditional rice cultivation methods.

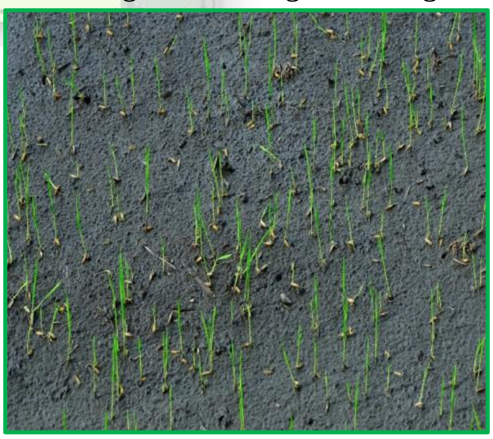
Figure 1. Wet dry direct seeded (WDSR)

Direct-seeded rice (DSR) cultivation presents unique challenges in terms of germination and weed management, necessitating effective strategies for successful crop establishment. Achieving uniform germination across the field is crucial, but factors such as inconsistent seed depth, inadequate seed-soil contact, and variations in soil moisture can lead to uneven germination and patchy seedling emergence. This non-uniform germination pattern impacts crop uniformity and productivity. In addition, the absence of a nursery phase in DSR allows weeds to quickly establish and compete with rice seedlings for essential resources, such as nutrients, light, and water. Weed competition can significantly reduce yields if not adequately managed. Moreover, DSR seedlings are particularly vulnerable to mortality due to unfavourable soil conditions like poor drainage, waterlogging conditions in rainfed low-lying areas leading to oxygen deficiency (anaerobic conditions). Inadequate oxygen availability impedes root respiration and nutrient uptake, jeopardizing seedling establishment and leading to reduced plant stand density and yield potential. To address these challenges, scientific approaches can be implemented, by incorporating the anaerobic germination tolerance traits in DSR cultivars to ensure proper germination and good seedling establishment.

Advantages of Anaerobic germination tolerance in DSR

Anaerobic germination holds immense importance in the context of direct-seeded rice (DSR) cultivation, providing several physiological and ecological advantages for the crop. In scientific terms, let's explore the elaborate significance of anaerobic germination in DSR:

1. Seedling Establishment: Anaerobic germination is a critical adaptive response in rice seeds to submerged conditions. Under anaerobic respiration, the seeds undergo a series of biochemical reactions, including the conversion of starch to fermentative end products like ethanol and organic acids. This metabolic adaptation allows for energy production and sustains the necessary physiological processes during germination, leading to successful seedling establishment in flooded or waterlogged environments.

2. Weed Suppression: The anaerobic conditions during germination in flooded or waterlogged fields create an unfavourable environment for weed growth. Rice seeds, germinating under anaerobic conditions, possess an advantage over weed species due to their inherent ability to tolerate oxygen-deprived conditions. This leads to differential germination and growth responses, where rice seedlings exhibit competitive dominance, inhibiting the establishment and growth of weeds in the early stages of crop development.

3. Nutrient Mobilization: Anaerobic germination triggers the enzymatic breakdown of stored reserves, such as starch, proteins, and lipids, to sustain seedling growth. Enzymes involved in starch hydrolysis, such as α-amylase and β-amylase, are activated in response to the anaerobic conditions, resulting in the release of glucose and other fermentative by-products that serve as energy sources for early seedling development. This efficient mobilization of stored nutrients facilitates rapid root and shoot growth, ensuring the establishment of a robust root system capable of nutrient uptake and assimilation.

4. Stress Tolerance: Anaerobic germination provides rice seeds with the ability to tolerate and adapt to various abiotic stresses, particularly water-related stressors. The anaerobic response in flooded environments allows rice seeds to maintain metabolic activities, sustain energy production, and avoid cell damage under conditions of limited oxygen availability. This stress tolerance mechanism enables rice seedlings to survive and continue growing even in the face of prolonged soil saturation, waterlogging, or flooding, enhancing the resilience and productivity of DSR systems.

5.Water Management: Anaerobic germination is intimately linked to water management strategies in DSR. By initiating germination under flooded or waterlogged conditions, DSR reduces the need for excessive irrigation during the critical early growth stage. This water-saving approach contributes to water conservation efforts, mitigates the environmental impact of rice cultivation, and promotes sustainable agricultural practices, particularly in regions where water scarcity is a concern.

Conclusion

In conclusion, direct-seeded rice (DSR) cultivation offers a promising approach to rice production with benefits such as labour and cost savings, flexibility, and resource efficiency. However, challenges related to germination and weed management must be addressed for successful DSR establishment. Scientific strategies, like incorporating anaerobic germination tolerance traits from various donors and seed priming, proper seedbed preparation, integrated weed management, optimized soil and water management, play a crucial role in achieving uniform germination, minimizing weed competition, and ensuring seedling survival. Continued research and innovation in seed improvement, and weed control, are key to further enhancing DSR practices. By addressing these challenges, DSR has the potential to contribute to sustainable and productive rice cultivation, meeting global food demands while minimizing environmental impacts.