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Preventing Pre-Harvest Sprouting in Rice: Unveiling the Role of Phytohormones and Genetic Strategies

(*Repudi Shalem Raju, Shraddha Bhaskar Sawant, Laxmipriya Behera and GBN Jyothi)
Odisha University of Agriculture and Technology, Bhubaneswar, Odisha-751003
*Corresponding Author's email: repudishalemraj@gmail.com

Rice, one of the world's most important staple crops, faces numerous challenges during its growth cycle. One such challenge is pre-harvest sprouting (PHS), a phenomenon where rice grains germinate prematurely while still on the plant, leading to reduced quality and significant yield losses (Hung *et al.* 2016). PHS poses a major threat to rice production worldwide, impacting food security and economic sustainability. In this article, we will explore the causes and consequences of PHS in rice, shedding light on the efforts made to mitigate this issue. PHS in rice is primarily triggered by unfavorable environmental conditions, particularly periods of high humidity and rainfall near harvest time. When mature rice grains are exposed to extended periods of moisture, the husk surrounding the grain becomes permeable, allowing water absorption. As a result, the dormant embryo within the grain is stimulated, leading to premature germination. Other factors such as fluctuations in temperature, inadequate seed dormancy, and genetic predisposition can also contribute to pre-harvest sprouting (Deng *et al.* 2017).

Keywords: ABA, dormancy, GA, germination, mitigation, pre-harvest sprouting

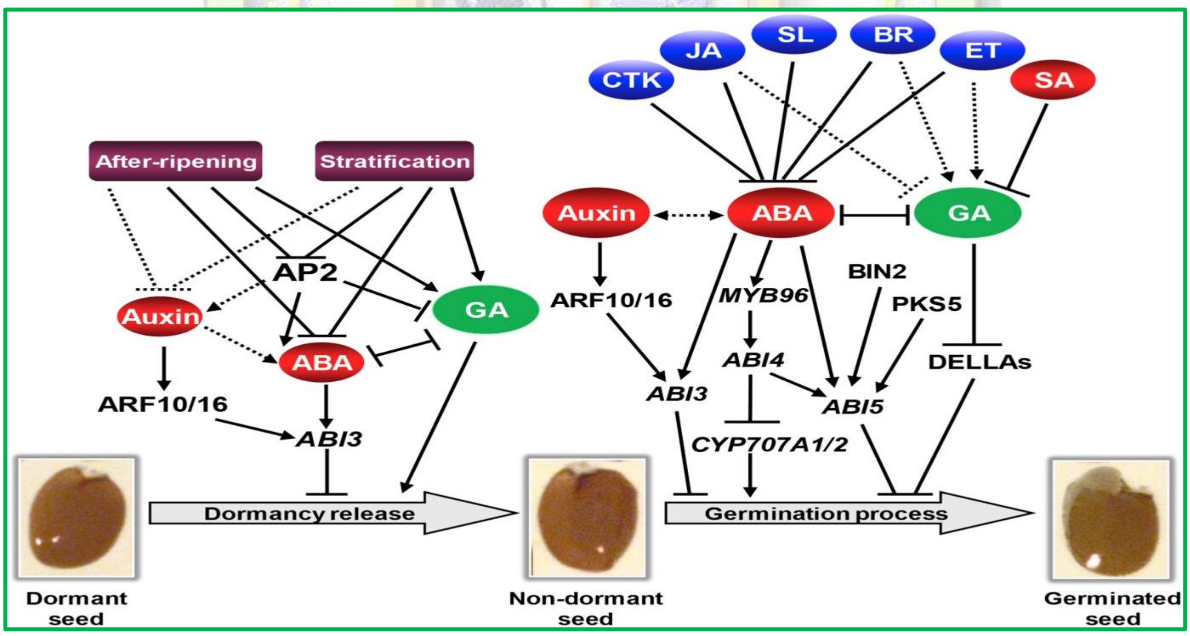

Figure 1. Network of phytohormones function in seed dormancy and seed germination (Shu *et al.* 2016)

Consequences of PHS: The consequences of PHS in rice are multifaceted and detrimental to both farmers and consumers. Firstly, sprouted grains have reduced market value due to diminished quality attributes, such as altered taste, texture, and cooking properties. Additionally, the germination process consumes valuable stored nutrients, resulting in reduced grain weight and yield losses. Sprouted grains are also more susceptible to post-harvest diseases and insect damage, further compromising the overall quality and safety of the crop (Zhang et al. 2018).

Mitigating PHS: To combat PHS and its associated losses, extensive research and breeding efforts have been undertaken. The focus has been on developing rice varieties with improved seed dormancy and resistance to premature germination. Scientists have identified genes associated with seed dormancy and developed molecular markers to facilitate breeding for desirable traits. Through traditional breeding methods and genetic engineering techniques, breeders aim to enhance the expression of dormancy-related genes and improve the resilience of rice varieties against pre-harvest sprouting. Furthermore, agronomic practices play a crucial role in managing PHS. Timely and proper harvesting, avoiding excessive moisture during grain drying, and utilizing post-harvest storage techniques to maintain low humidity levels are essential to prevent sprouting. Farmers are encouraged to monitor weather conditions closely, as well as adopt improved storage and drying methods, such as mechanical dryers or hermetic storage systems, to minimize the risk of PHS.

Role of phytohormones in PHS regulation: Seed dormancy is controlled by a delicate balance of phytohormones, which act as regulators of various stages of seed development and germination. In pre-harvest sprouting, the delicate balance between ABA and GAs is disrupted, leading to unwanted germination while the seeds are still attached to the plant. Factors such as prolonged exposure to rain or high humidity can trigger the production of GAs or reduce ABA levels, overriding the dormant state and initiating germination prematurely. Once germination begins, the seeds lose their market value and become susceptible to diseases and other environmental stressors.

The Role of Abscisic Acid (ABA): Among the key phytohormones involved in seed dormancy is abscisic acid (ABA). ABA plays a pivotal role in maintaining seed dormancy by inhibiting germination processes. It does so by repressing the production of enzymes responsible for breaking down stored nutrients within the seed, thereby preventing premature growth. ABA levels are high during seed maturation, keeping seeds dormant until favorable conditions for germination are met.

Several ABA-regulating genes have been identified that control the levels and sensitivity of ABA in seeds, directly influencing seed dormancy and germination. These genes modulate ABA biosynthesis, catabolism, and signal transduction pathways. Key ABA-regulating genes include those involved in ABA biosynthesis, such as 9-cis-epoxycarotenoid dioxygenase (NCED), which catalyzes the rate-limiting step in ABA synthesis. Other genes, such as ABA-insensitive 3 (ABI3) and ABA-insensitive 5 (ABI5), are involved in ABA signal transduction and regulate downstream targets. ABA signaling pathways regulate seed dormancy and germination in response to environmental cues. In the absence of ABA, ABA receptors, such as pyrabactin resistance-like (PYL)/regulatory component of ABA receptor (RCAR), are active, leading to the activation of protein phosphatase 2C (PP2C). PP2C negatively regulates ABA responses by inhibiting the activity of ABA-responsive kinases (SnRK2s). When ABA levels are high, ABA binds to receptors, leading to the inhibition of PP2C, thereby activating SnRK2s. Activated SnRK2s phosphorylate and regulate downstream transcription factors, such as ABI3 and ABI5, which control the expression of genes involved in seed dormancy and germination (Finkelstein, 2013).

Gibberellins and Seed Germination: Gibberellins (GAs) are another class of phytohormones that play a vital role in seed germination. Unlike ABA, GAs promote the synthesis of enzymes necessary for seed germination. These enzymes break down complex storage compounds, such as starch, into simpler forms that fuel seedling growth. As seeds mature, the balance between ABA and GAs shifts, with GA levels increasing while ABA levels decrease, triggering the germination process.

The regulation of GA levels and responsiveness is orchestrated by a set of genes involved in GA biosynthesis, catabolism, and signaling pathways. Key GA-regulating genes include those encoding enzymes such as gibberellin 20-oxidase (GA20ox) and gibberellin 3-oxidase (GA3ox), which are involved in GA biosynthesis. Other genes, such as GA2 oxidase (GA2ox), are responsible for GA catabolism. These genes collectively modulate the levels and activity of GAs, influencing seed germination and dormancy. GA signaling pathways regulate seed germination and growth by activating downstream transcription factors and genes associated with cell elongation and hydrolytic enzyme production. GAs bind to GIBBERELLIN INSENSITIVE DWARF1 (GID1) receptors, forming a complex that interacts with DELLA proteins, which are negative regulators of GA signaling. In the absence of GAs, DELLA proteins inhibit the expression of GA-responsive genes involved in germination. When GAs are present, they promote the degradation of DELLA proteins, relieving their inhibitory effect and allowing the activation of GA-responsive genes (Hedden and Sponsel, 2015).

Phytohormones, particularly ABA and GAs, play a critical role in seed dormancy and germination. The delicate balance between these hormones ensures seeds remain dormant until the appropriate environmental cues are received. However, disturbances in this balance, as seen in pre-harvest sprouting, can result in economic losses for farmers. By unraveling the secrets of phytohormones and their interactions, scientists are making significant strides towards developing strategies to prevent pre-harvest sprouting and ensure healthier crop yields.

Conclusion

In conclusion, pre-harvest sprouting (PHS) in rice poses a significant challenge to global food security and agricultural sustainability. PHS is triggered by unfavorable environmental conditions and disruptions in the delicate balance between phytohormones, particularly abscisic acid (ABA) and gibberellins (GAs). Efforts to mitigate PHS involve the development of rice varieties with enhanced seed dormancy, as well as agronomic practices to minimize moisture exposure. Understanding the role of ABA and GA-regulating genes provides valuable insights for breeding strategies and the management of PHS, ultimately aiming to ensure improved grain quality and yield stability in rice production.

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