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Low Temperature Stress Tolerance in Rice: Morpho-Physiological and Molecular Responses

(*Sushma M Awaji[1], Prashantkumar S Hanjagi[1], Repudi Shalem Raju[2] and Laxmipriya Behera[2])
[1]ICAR-National Rice Research Institute, Cuttack, Odisha-753006
[2]Odisha University of Agriculture and Technology, Bhubaneswar, Odisha-751003
*Corresponding Author's email: sma1624@gmail.com

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Rice is a staple food for more than half of the world's population, and ensuring its productivity and quality is a critical global concern. However, rice production is restricted by its sensitivity to abiotic stresses such as low temperatures at all stages of development, due to structural features such as a small root system and lower wax deposition (MoonHee et al.,2001). Low temperatures can cause reduced yields, poor grain quality, and even complete crop failure. In general, the mean critical temperature for rice is +4.7°C, and once the ambient temperature (AT) is below 5–10°C, irreversible low temperature-induced damage to seedling growth and development can occur (Sanchez et al., 2014). During different developmental stages, rice shows growth responses to low temperatures. Low temperature stress can have a range of negative effects on rice plants, including reduced photosynthesis, altered nutrient uptake, and changes in hormone levels. These effects can lead to reduced growth and yield, and can also make plants more susceptible to pests and diseases (De Freitas *et al*., 2018).

Several studies have been conducted to show the efficacy of the Low temperature stress imposed during early vegetative stage to improve the reproductive stage high temperature stress tolerance in rice. Study of Suriyasak *et al*., 2017 found that exposing rice plants to Low temperature stress during the vegetative stage improved their tolerance to high-temperature stress during the reproductive stage, resulting in higher yields and better grain quality. Another study of Jagadish *et al*., 2010 showed that Low temperature stress improved the expression of heat shock proteins in rice, which are essential for protecting the plant from heat-induced damage.

Low temperature stress in rice has been shown to induce several morphological, molecular (Zeng et al., 2017), biochemical and physiological changes (Xu et al., 2021) in rice plants that help them to cope with high-temperature stress later at the reproductive stage. And these changes induced by Low temperature stress in rice plants can help improve their ability to cope with high-temperature stress during the reproductive stage, resulting in higher yields and better grain quality. Low temperature induced several morphological, physiological, biochemical and molecular changes are summarized in the below figure.

Developing Low temperature stress-tolerant rice varieties is crucial for ensuring food security in the face of climate change. With the growing threat of global warming and increasing frequency of heat stress events, it is essential to explore innovative approaches to develop Low temperature stress tolerant rice cultivars which can provide crop resilience and productivity under adverse climatic situations.

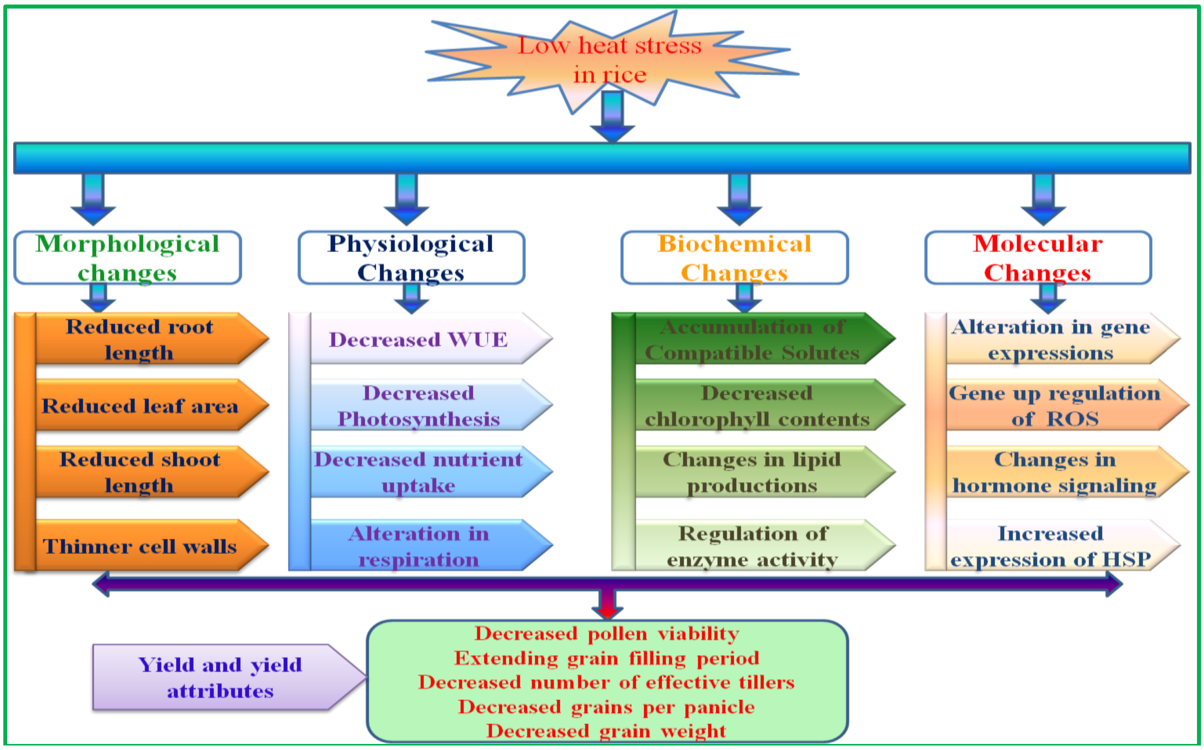

Figure 1: Low temperature induced various responses in rice leading to yield loss

Low temperature stress in rice can be mitigated by employing various physiological approaches viz.,

1. Seed Priming: Seed priming is the process of pre-soaking the seeds in water or a nutrient solution to initiate germination before planting. This technique can increase the cold tolerance of rice plants by stimulating the synthesis of antioxidants and other protective compounds.
2. Hormonal Regulation: Hormonal regulation can help mitigate cold tolerance in rice by controlling the expression of genes involved in cold tolerance. For example, the application of exogenous abscisic acid (ABA) can induce the expression of genes that encode for cold-responsive proteins, thereby enhancing the plant's cold tolerance (Liu et al., 2022**)**.
3. Foliar Application of Nutrients: Foliar application of nutrients such as potassium, calcium, and magnesium can enhance the cold tolerance of rice plants by improving their physiological processes. These nutrients help in maintaining cell membrane stability and regulating the balance between reactive oxygen species and antioxidants.
4. Genetic Improvement: Genetic improvement of rice varieties can also enhance their cold tolerance. For example, the overexpression of certain genes such as OsDREB1A can increase the cold tolerance of rice plants by regulating the expression of cold-responsive genes.
5. Use of Biostimulants: Biostimulants such as humic acid and seaweed extracts can enhance the cold tolerance of rice plants by improving their root development, nutrient uptake, and stress tolerance. These biostimulants can also stimulate the synthesis of protective compounds such as osmolytes and antioxidants.

Conclusion

It is clear that much progress has been achieved in the understanding of cold tolerance in rice plants. However, decreased productivity caused by low temperatures remains as a problem. New cold-tolerant cultivars needs to be designed according to the growth stage when plants will be exposed to cold in a particular region, and a combined strategy that considers breeding and genetic engineering as tools to be used hand-in-hand could lead to successful projects.

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