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Thermopriming: A Key Strategy for Enhancing Crop Resilience in Response Heat Stress

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An increase in temperature exceeding a critical threshold level, leading to irreversible damage in plants, is termed as heat stress, while heat stress occurring during the reproductive or grain-filling stage is known as terminal heat stress. Heat stress profoundly affects plant growth and metabolic functions, posing challenges to their survival. Terminal heat stress disrupts the growth and development of crops by interfering with their physiological and biochemical processes during reproductive stages, such as grain or pod filling, development, maturation, and ripening, ultimately resulting in yield reduction. During the reproductive growth stages of plants, particularly in cereals, exposure to temperatures higher than the optimal level can lead to a shortened grain filling period, resulting in significant losses in grain yield (Khanzada et al., 2022). Heat stress can occur at various stages of plant growth and development, affecting critical physiological processes such as photosynthesis, cell membrane stability, RNA splicing and protein synthesis (Hossain et al., 2018). Several strategies are being employed to alleviate harmful effects of high temperature stress in plants. One such mechanism is priming, where prior exposure to stress alters responses to subsequent stress events (Taherifar & Taheri, 2024). Priming includes a time delay or memory phase between the initial exposure to stress and the subsequent stress event. There is growing interest in studying various priming effects and their molecular mechanisms. When plants experience a mild or moderate stress and subsequently recover, they establish a "memory" that shields them from future stressors, mitigating their harmful effects, even in susceptible plants. This process, known as stress priming, relies on this "memory" response to protect plants when they encounter subsequent severe stress (Bäurle, 2016). Stress priming is also referred to as stress hardening, stress training, or stress conditioning. In recent years, there has been a significant increase in research interest in priming because plants subjected to priming exhibit greater adaptability and improved tolerance to stress.

Priming of seeds, commonly referred to as pre-treatment, is a technique used by seed technologists to enhance the vigor of commercial seed lots, thereby improving germination potential and increasing tolerance to various stresses. Specifically, heat priming involves exposing plants to a pre-treatment at moderate temperatures, which enhances their tolerance when they are subsequently exposed to higher temperatures (Fig. 1). Some studies have suggested potential benefits of applying heat priming during the early vegetative stage, showing positive effects on plant performance when faced with subsequent high-temperature events. This approach appears to improve the plant's ability to withstand and endure elevated temperatures later in its development, as observed in wheat (Fan et al., 2018) and Arabidopsis (Serrano et al., 2019). Studies have confirmed that heat priming can effectively enhance thermotolerance to subsequent heat stress in several plant species. For example, in wheat, heat priming applied at the seven- and nine-leaf stages, with elevated temperatures of 32/28°C (compared to control), for two days, improved tolerance to heat stress occurring after flowering. Primed plants exhibited higher photosynthetic capacity and improved scavenging of reactive oxygen species (ROS) under post-flowering high temperature stress compared to non-primed plants (Wang et al., 2014). This was evident from the increased photosynthetic rate and activities of antioxidant enzymes such as superoxide dismutase (SOD) and glutathione reductase (GR) in chloroplasts and mitochondria, resulting in reduced damage to cell membranes indicated by lower malondialdehyde (MDA) content. Furthermore, primed plants showed enhanced grain starch accumulation by promoting the mobilization of reserves from vegetative organs to grains under post-flowering high temperature stress. This suggests that priming helps maintain grain quality by ensuring adequate starch accumulation despite heat stress. These improvements in photosynthetic rate, antioxidant capacity, and grain starch accumulation in primed plants are attributed to the up-regulation of certain genes involved in stress response (Wang et al., 2012).

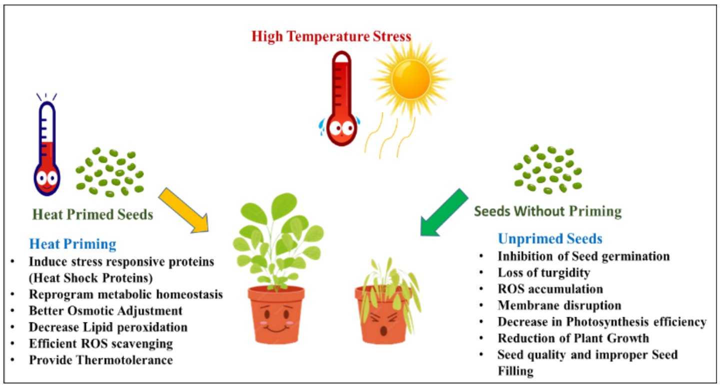

Figure: 1. Effect of high temperature stress on plants and its mitigation through heat priming of seeds

Conclusion

Thermopriming offers a promising avenue for enhancing crop resilience in the face of future climate challenges. By inducing a protective "memory" response in plants, thermopriming improves their ability to withstand subsequent stresses, thereby potentially mitigates crop losses due to environmental extremes. Continued research into thermopriming mechanisms holds significant potential for developing sustainable agricultural practices that ensure food security in a changing climate.

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