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PHYSIOLOGICAL CHANGES IN RICE DURING DROUGHT SITUATION

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Introduction

Rice is the staple food for its large population, and this crop is cultivated in almost all the Indian states under a remarkably wide range of agro-climatic conditions and ecological situations. Rice is feeding more than three billion people and providing 50-80 % of their daily calories intake.India has the world's largest area and is the second highest producer of rice. The crop is grown under varying climatic and soil conditions under diverse ecologies spread over about 43 million hectares. The crop is cultivated round the year in one or the other parts of the country. It is the staple food for more than two thirds of Indian population contributing more than 40% to the total food grain production, thereby, occupies a pivotal role in the food and livelihood security of people. The country has made significant progress in rice production. For last few years, the production of ricehas been around 110 million tons (Mt). Almost all the states are now self-sufficient in rice and India is also exporting about 10 Mt rice annually. Despite these achievements, rice farmers face serious challenges of low income, degradation of soil and water resources, emergence of new pest and diseases and unforeseen climatic extremes.Rice is a drought susceptible crop exhibiting serious deleterious effects when exposed to water stress at critical growth stagesespecially at reproductive stage.

An extended period of rainfall compared to normal rainfall of the region is called drought.A definition of drought generally accepted by plant breeders is: “a shortfall of water availability sufficient to cause a loss in yield" (Price *et al.,* 2002) or “a period of no rainfall or irrigation that affects crop growth". Drought stress is multidimensional stress that affects plants at different growth stages. The impact of drought stress on the total green plant surface and plant response to drought stress are very intricate because it reflects a combination of stress impacts and plant response in all essential levels of the plant over time and place (Blum, 1996). Scarcity of water is a severe environmental constraint to plant productivity. Drought-induced loss in crop yield probably exceeds losses from all other causes, since both the severity and duration of the stress are critical.

The major mechanisms include curtailed water loss by increased diffusive resistance, enhanced water uptake with prolific and deep root systems and its efficient use, and smaller and succulent leaves. Injury caused by reactive oxygen species to biological macromolecules under drought stress is among the major deterrents to growth. Plants display a range of mechanisms to withstand drought stress. The major mechanisms include curtailed water loss by increased diffusive resistance, enhanced water uptake with prolific and deep root systems and its efficient use, and smaller and succulent leaves to reduce the transpirational loss. Among the nutrients, potassium ions help in osmotic adjustment; silicon increases root endodermal silicification and improves the cell water balance. Low-molecular-weight osmolytes, including glycinebetaine, proline and other amino acids, organic acids, and polyols, are crucial to sustain cellular functions under drought. Plant growth substances such as salicylic acid, auxins, gibberrellins, cytokinin and abscisic acid modulate the plant responses towards drought (Farooq *et al.,* 2009).

Rice responses to drought stress

Rice responds and adapts to drought stress by induction of various morphological, physiological and molecular modifications, with these modifications being made according to the developmental stage.

A. Marphological responses

Reduction in germination, leaf size, leaf number, biomass, cell growth and elongation. Increase in stomata closure, leaf tip drying,leaf rolling and root length.

B. Physiological and biochemical responses

Reduction in transpiration, photosynthesis, chlorophyll content, membrane stability, stomatal conductance and photostem II activity. Increase in osmoprotectant.

C. Molecular responses

Changes in gene expression (Up or down regulation).Activation of relevant transcription factors and signalling pathways.All three (Marphological, Physiological and Molecular) plant responses to affects on yield attibutes are given below:

1. Reduced Tillering	2. Reduced grain yield
3. Reduced grain filling rate	4. Reduction in number and size of panicles
5. Delayed flowering	6. Reduction in grain size and weight
7. Reduced spikelet fertility	

Physiological responses

In response to water deficit, plants are able to establish a series of physiological responses that allow them to act on their own water state in order to adapt to environmental conditions. Some of the physiological responses to drought include:

Decrease in leaf size: Generally, growth decrease is one of the first drought manifestations in rice plant. Drought is manifested in the plant by a slowing down of the initiation of the new aerial organs (leaves and stems) and a reduction in the pre-existing organs (Davies and Zhang 1991; Boyer and Kramer, 1995; and Chaves *et al.,* 2002).

Root elongation: Contrary to aerial organs which are reduced under the effect of water stress, these conditions promote the development of the root system. Enhancing the development of the root system traits such as root length allows the plants to access deep ground water resources. Plant production is the function of water use (WU), water use efficiency (WUE) and harvest index (HI). Leaf water potential (LWP) is a measure of whole plant water status and has long been recognized as an indicator of dehydration avoidance (Pantuwan *et al.,* 2002). When water deficit in leaf goes beyond a certain threshold level, the stomata closes as a mechanism of lowering the rate of transpiration. Stomatas help to regulate water loss when the tissue water status becomes too low, thereby minimizing the severity of water deficiency in plants. Thus, higher LWP is maintained by stomatal closure and varietal differences in stomatal response to water status have been reported (Jongdee *et al.,* 1998).

Molecular responses to drought stress

As soon as the stress is detected by plant receptors, a coordinated series of cellular responses is established. In fact, the physiological and morphological reactions are based on these coordinated cellular responses which induce the expression of a large number of genes. In rice, more than 5,000 genes are up-regulated and more than 6,000 are down-regulated by drought stress (Maruyama *et al.,* 2014).

Mitigation against Drought

Mitigating drought and climate change requires robust, well-planned and informed strategies in order to enhance agricultural sustainability and ensure that human livelihood is not negatively affected. Improved rice technologies that help reduce losses from drought can play an important role in long-term drought mitigation. Improving the resilience of rice production systems to climate change requires the development and dissemination of appropriate combinations of improved stress-tolerant rice germplasm, natural resource management strategies and creation of appropriate policy environments to help increase and stabilize yields in variable cultivation conditions (Noelle *et al.,* 2018).

Conclusion

Drought is one of the major climatic hazards even in the sub humid rice-growing areas of Asia. It is an event that reoccurs, affecting agriculture and the livelihoods of millions of farmers and agriculture laborers. The socio-economic impact of drought is enormous. It has huge economic costs, in terms of both actual economic losses during drought years and losses arising from foregone opportunities for economic gains. Drought contributes directly to an increase in the incidence and severity of poverty. It is therefore critical that we establish effective strategies to mitigate the effects of drought in order to ensure agricultural productivity and environmental sustainability. Use of adapted genotypes and improvement in rice production technology are some of the components of an overall strategy for effective drought mitigation. Increased moisture availability to crops through water conservation and harvesting, and watershed development is an important component.

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