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Abiotic stress on physiological and biochemical traits in rice-An overview

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Abstract
Rice staple food for a large part of the world's human population. An abiotic stress including drought, salinity, high temperature, and UV-irritation unfavorably influence the plant growth, development and ultimately prompts misfortunes in crop yield. Abiotic stress inspires different physiological and biochemical responses in rice plants incorporate reduction of relative water content (RWC), lower photosynthetic pigments, accumulation of osmolytes like proline, malondialdehyde (MDA) content, and ion leakage so as to acclimatize them for survival under such environmental stress condition. Consequently, understanding the physiological, biochemical, and molecular mechanisms associated with rice against ecological factors is of most extreme vital for rice breeders to improve abiotic stress tolerance in rice. This review illustrates physiological and biochemical trait responses to abiotic stress in rice plants.

Keywords: abiotic stress, proline, antioxidant activity, malondialdehyde, electrolyte leakage

Introduction

Rice (*Oryza sativa* L.) is the main cereal crop on the planet and it provides stable nourishment to the greater part of the world's human population. It is a primary nutritional energy source in various continents in Asia, Africa, North and South America. In Asia, half of the daily intake of calories is given by rice (Muthayya *et al*., 2014) [26]. Ecological factors, such as salinity, drought, cold, extreme temperature, submergence, and UV-irritation adversely affect crop productivity and quality by arresting plant growth and development (Venuprasad *et al*., 2008) [35]. Among the different abiotic stresses, drought, heat, and salinity are major stresses causes of yield loss in rice. The problem of water shortage, deprivation of soil nutrients, and global climate changes are becoming serious issues to agriculture threatening the food security of the rapidly growing population worldwide. Therefore, it is necessary to develop the abiotic stress tolerance crop varieties.

Abiotic stress influences plant development related physiological and biochemical trait, such as RWC, osmolytes like proline, photosynthetic pigments, and lipid peroxidation level i.e. MDA content, electrolyte leakage, and anti-oxidant enzyme activity are considered efficient indicators to decide an abiotic stress tolerance in crop plants. Many investigations demonstrated that plants have changes in molecular, physiological, and metabolic mechanisms, such as growth and development regulation, detoxification of reactive oxygen species (ROS), ion homeostasis, and osmotic adjustment to adapt to such harsh environmental stress conditions (Wang *et al*., 2003) [37]. RWC expresses the result of the osmotic adjustment of the plant, which provides an estimate of the level to which plants can be tolerated under stress conditions. Osmotic adjustment can be a powerful mechanism of defensive cellular hydration under abiotic stress. The investigation of Al-Khatib and Paulsen (1999) [2] revealed photosynthesis pigments are positively associated with photosynthesis rate and their activity of plants. Wang *et al* (2008) [36] revealed increased chlorophyll content, which effectively enhanced biomass production and grain yield in crops under stress conditions.

Cell membrane stability has often been used to evaluate capability abiotic stress tolerance in different crops (Hameed *et al*., 2012; Zafar *et al*., 2015) [12]. Singh *et al* (2018) [33] used the biochemical indicator of electrolyte leakage and MDA content to differentiate two rice cultivars under salinity stress. Cao *et al* (2008) [6] suggested that low MDA content and less electrolyte leakage in rice cultivar can be considered as relatively heat tolerant. Likewise, the study of Zafar *et al* (2017) [40] exhibited all rice cultivars had higher lipid peroxidation levels and more membrane damages under heat stress than the control conditions. Osmolytes like proline help plants to tolerate abiotic stress by maintaining osmotic balance within the cell (Ashraf and Foolad, 2007) [4]. The accumulation of proline in response to high salinity and drought is well documented (Kishor *et al*., 1995; Liu and Zhu, 1997) [17, 20] and proline concentration has been shown higher in stress tolerance as compared to stress susceptible plants (Anjum *et al*., 2011) [3]. This review provides a summary of physiological and biochemical trait responses to abiotic stress in rice plants.

Relative water content

RWC is a suitable physiological index to assess the water status and osmotic adjustments of plants in response to different abiotic stress. RWC is associated with water uptake by roots and water loss through transpiration (Nayyar and Gupta, 2006) [27]. During transpiration, transgenic plants revealed closure of its stomata was associated with its reducing water loss under drought stress as compared to wild-type plants. This result established that transgenic lines had retained more water content in their tissues than WT under drought stress. It can be used as a characteristic feature of improved water deficit tolerance (Pardo *et al*., 2010; Datta *et al*. 2012) [28, 9]. The wild variety plants RWC were decreased due to response to drought stress when leaves are exposed to water deficit stress, leaves showed huge reductions in RWC and water potential (Kranz *et al*., 1998; Nayyar and Gupta, 2006) [18, 27]. The study of Calcagno *et al* (2011) [5] found that closeness with osmotic potential and RWC in *Solanum lycopersicum* under drought stress.

Photosynthetic pigments

The change of chlorophyll content under abiotic stress has been considered as a characteristic index of oxidative or osmotic stress, which leads to ROS resulting in pigment photo-oxidation and chlorophyll degradation (Farooq *et al*., 2009) [11]. Mohan *et al* (2000) [21] stated that photosynthetic pigment content is a significant indication of the stress tolerance capability of plants and its higher values were confirmed that stress-tolerant plants have less affects on chlorophyll content during stress conditions. The study of Anjum *et al* (2011) [3] illustrated that the changes in chlorophyll content dependent on the duration and severity of the stress condition. Moradi and Isamil *et al* (2007) [25] observed that salt-sensitive rice cultivars had a significantly higher reduction of photosynthetic pigments as compared to the tolerant rice cultivars under salinity stress. Many researchers have reported that heat stress causes degradation of chlorophylls and carotenoids in various crops such as wheat (Efeoglu and Terzioglu, 2009) [10] and rice (Shanmugavedivel *et al*., 2017) [32]. The study of Zafar *et al* (2017) [40] found that genotypes with high photosynthetic pigments including chlorophyll a, b, and carotenoids under heat stress have improved heat tolerance in rice. Cold stress can inhibit chlorophyll synthesis and chloroplast formation in rice leaves. Over expression of the AtDREB1A gene helps to retention more photosynthetic pigments in transgenic rice plants compared to WT under water deficit and cold stresses (Latha *et al*., 2019) [19].

Osmolytes

Osmolytes, such as free proline and soluble carbohydrates are well known to be an occurrence in higher plants and accumulates in high concentration in response to diverse environmental stresses and provides an effective indicator to determine osmotic stress tolerance in crop plants. Proline acts osmoprotectant in the stress tolerance of the plants, which contributes too many biological functions like, enhances water retention capacity and reduces oxidative damage and improved adaptability of plants to abiotic stress. The study of Latha *et al* (2019) [19] reported that significantly increases of proline content in over expressing AtDREB1A transgenic lines than WT plants might be the reason to maintenance higher chlorophyll content in transgenic lines under drought stress, as a result proline helps in protecting the photosynthetic pigments. Proline, which acts as an antioxidant by scavenging free radical in plant metabolism and protecting cellular membranes and proteins under different abiotic stress (Yoshiba *et al*., 1997; Sengupta *et al*., 2016) [39, 31]. Several studies have been reported that proline content was negative correlated with electrolyte leakage under different abiotic stress in many plants such as rice (James *et al*., 2018; Tang *et al*., 2019) [15, 34]. Many plants species have shown higher level proline accumulation in stress-tolerant genotype than stress-sensitive ones under salt stress, such as rice (Singh *et al*., 2018) [33], sorghum (Jogeswar *et al*., 2006) [16], and wheat (Sairam *et al*., 2002) [30]. Overexpression of OsMYB and AmDUF1517 transgenic plants accumulated better amounts of soluble sugars and proline than wild-type plants under drought and salt stress (Hao *et al*., 2018; Tang *et al*., 2019) [13, 34].

Cell membrane stability

In plants, the cell membrane is one of the essential goals of all environmental stress. Electrolyte leakage and MDA content reflects the degree of cell membrane damage under different abiotic stress, such as drought, salinity, and heat stress (Mellacheruvu *et al*., 2016; James *et al*., 2018) [23, 15]. At the point when a plant is subjected to abiotic stress, induce the accumulation of ROS and enhanced membrane lipid peroxidation viz., oxidation of polyunsaturated fatty acids present in membranes as results in electrolyte leakage and cell membrane damage leading to cell death (Madhava Rao and Sresty, 2000) [22]. The quantification of MDA content confers an estimate the level of lipid peroxidation and membrane injury in response to different abiotic stress. The study of Singh *et al* (2018) [33] found that a salt-tolerant rice cultivar had less electrolyte leakage and MDA content than the salt sensitive rice cultivar. The results also in agreement with the study of Sairam *et al* (2002) [30] which differentiate two wheat genotypes growing at different salinity levels. Hameed *et al* (2012) [12] observed that when exposed to high temperature, oxidative stress was frequently produced in rice seedlings, which increases the lipid peroxidation level which led to membrane corrosion. The study of Tang *et al* (2019) [34] stated that over expressing transgenic rice plants had significantly less electrolyte leakage and lower MDA contents than WT plants under salt and drought stresses. The less membrane damages in transgenic plants than WT plants was supported by the expression levels of antioxidant related genes superoxide dismutase (SOD), catalase (CAT) and peroxidase (POD) was higher in transgenic plants and an improves antioxidant activities in transgenic plants would reduce MDA content and ion leakage by scavenging ROS results in enhanced stress tolerance in transgenic plants. Likewise, reduced electrolyte leakage and MDA contents were observed in various transgenic plants, which indicating the re-establishment of membrane integrity (James *et al*., 2018) [15].

Antioxidant enzyme activity

The accumulation of ROS is a common phenomenon in plants during cellular metabolism. When plants are subjected to environmental stress, such as drought, salinity, and extreme temperature stimulates the production of ROS, which cause corrosion of membrane biomolecules like proteins, lipids, carbohydrates, and nucleic acids and eventually to severe oxidative damage to the plants, which inhibiting plant growth and crop productivity (Xie *et al*., 2019) [38]. The production of ROS is mainly presented in the chloroplast, mitochondria, and peroxisomes in the plants. ROS acts as important signaling molecules in plants, controlling processes like plant growth, development, and responses to biotic and abiotic environmental stress (Huang *et al*., 2019) [14]. Plants have a complex ROS scavenging system against oxidative damage which is developed during environmental stress to stabilize the toxic level of ROS. This antioxidant defense system contains both enzymatic and non-enzymatic antioxidants. CAT, SOD, and POD are an essential component of the antioxidant defense system that play roles in eliminating superoxide (O_2^-) and hydrogen peroxide (H_2O_2) and non-enzymatic antioxidants enzymes like ascorbic acid (AA), reduced glutathione (GSH), α-tocopherol, carotenoids, flavonoids, and the osmolytes proline are cooperatively reduce oxidative state (Das *et al*., 2014; Huang *et al*.,2019) [8, 14]. Under stress conditions, plants have increased at least one antioxidant enzyme activity to protect the structure and function of cellular components against ROS. This increase in antioxidant enzyme activity had a positive correlation with enhancing stress tolerance. Several studies reported that SOD, POD, and CAT activities increased in response to abiotic stress in rice potato (Aghaei *et al*., 2009) [1] and mustard (Mittal *et al*., 2012) [24]. Induction of SOD and CAT activities under abiotic stress has been reported in rice and cotton over expression transgenic lines (Hao *et al*., 2018; Tang *et al*., 2019) [13, 34].

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