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Research Article

Effect of salicylic acid and drought stress on crop yield

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Abstract Crop plants are exposed to several environmental stresses, all affecting plant growth and development, which consequently hampers the productivity of crop plants. Drought is considered the single most devastating environmental stress, which decreases crop productivity more than any other environmental stress. Drought severely affects plant growth and development with substantial reductions in crop growth rate and biomass accumulation. The main consequences of drought in crop plants are reduced rate of cell division and expansion, leaf size, stem elongation and root proliferation, and disturbed stomatal oscillations, plant water and nutrient relations with diminished crop productivity, and water use efficiency. Relative water content (RWC), leaf water potential, stomatal resistance, the rate of transpiration, leaf temperature and canopy temperature are important characteristics that influence plant water relations. Salicylic acid is considered to be an endogenous growth regulator of phenolic nature that enhanced the leaf area and dry mass production in corn and soybean. Salicylic acid (SA) as a potent signaling molecule in plants is involved in eliciting specific responses to biotic and abiotic stresses.

Keywords antioxidant enzymes, drought stress, yield, respiration

Introduction

Drought stress

The plant response to drought consists of numerous processes that must function in coordination to alleviate both cellular hyperosmolarity and ion disequilibrium. To cope with drought stress, plants respond with physiological and biochemical changes. These changes aim at the retention of water in spite of the high external osmoticum and the maintenance of photosynthetic activity, while stomatal opening is reduced to counter water loss. Accumulation of low molecular compounds, such as glycine betaine, sugars, sugar alcohols and proline, is a mechanism aimed at balancing water potential following drought [1]. This article is review and the aims and scope is effect of salicylic acid and drought stress on crop yield.

Drought or water deficit stress elicits many different physiological responses in plants. It causes reduction in leaf water potential, stomatal conductance, nitrate reduction and inhibits leaf enlargement while osmolytes such as total soluble sugars and proline are increased [2-3]. In addition to synthesis of these osmolytic compounds, specific proteins and translatable mRNA are induced and increased by drought chlorophyll which is one of the major chloroplast components for photosynthesis, and relative chlorophyll content has a positive relationship with photosynthetic rate. The decrease in chlorophyll content under drought stress has been considered a typical symptom of oxidative stress and may be the result of pigment photo-oxidation and chlorophyll degradation [4]. Photosynthesis is one of the most sensitive processes to drought stress [5]. The inhibitory effects of drought on photosynthesis may be associated with low CO_2 availability due to low stomatal and mesophyll conductance [6] and/or impairments in carbon assimilation metabolism [7]. Stomatal closure is an early response to drought and an efficient way to reduce water loss in water-limiting environments. Biochemical limitation of photosynthesis also plays an important role under prolonged periods of drought stress [6].

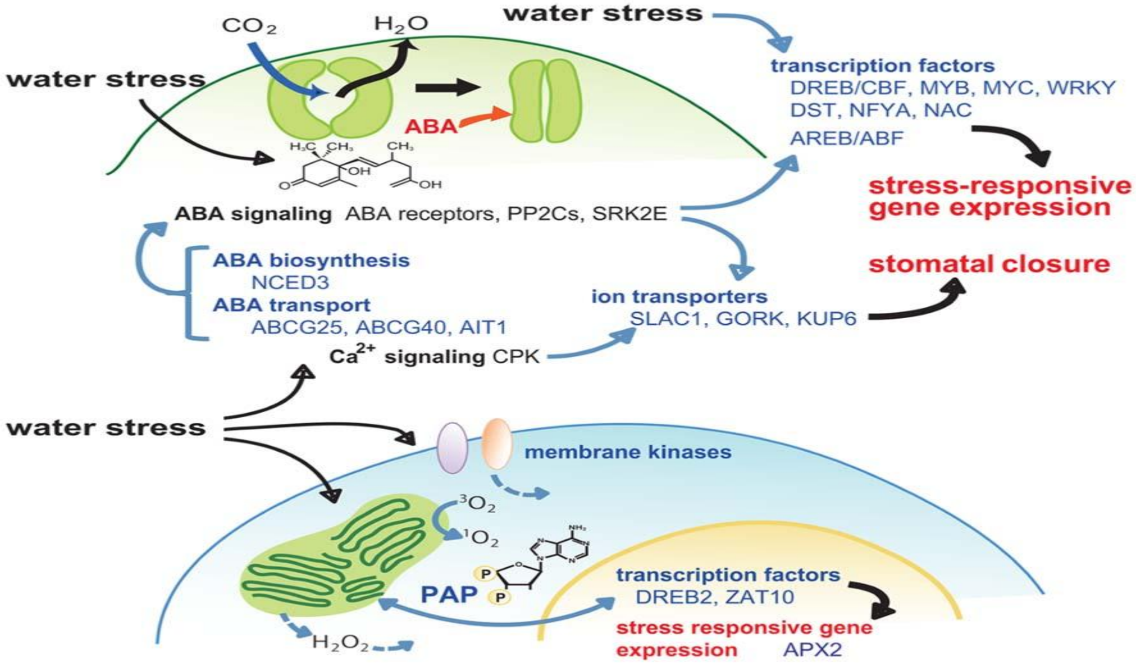

Figure 1: Model for the role of signaling factors in stomatal closure and retrograde signaling during water stress

Physiological Attributes

Different types of plant physiological responses have been reported by various Plant physiologists in their findings under drought stress situation. Zaharieva et al. (2001) [8] reported that in globally drought affected areas physiological mechanism is very handy approach in evaluating and screening the extraordinary genotypes having drought resistant mechanism. Comprehensive information of physiological mechanisms permits plant researcher to develop promising genotypes that would be utilized efficiently, continue his growth and production under water deficit stage [10].

Cell-membrane stability (CMS)

Cell-membrane stability (CMS) is of vital important selection criteria of drought tolerant genotypes [10]. It has been reported that under water stress cell membrane integrity and stability confers drought resistance [11]. The water stress activates the reactive oxygen species which ultimately decreases membrane stability caused by lipid peroxidation [12]. Although many reports depicted lower lipid peroxidation and higher cell membrane stability (CMS) in drought tolerant wheat and maize genotypes [13].

Plant Growth and Productivity

Establishment of an early and optimum crop stand is important for harvesting maximum productivity. However, if the crop experiences an early drought, thereby affecting germination, then the suboptimal plant population is the major cause of low grain yield. Early season drought severely reduces germination and stand establishment principally due to reduced water uptake during the inhibition phase of germination, reduced energy supply, and impaired enzyme activities [14-15]. Growth is an irreversible increase in volume, size, or weight, which includes the phases of cell division, cell elongation, and differentiation. Both cell division and cell enlargement are affected under drought owing to impaired enzyme activities, loss of turgor, and decreased energy supply [15-17]. For example, drought decreases growth and productivity of sunflower (*Heliantus annuus* L.) owing to reductions in leaf water potential, rate of cell division, and enlargement primarily due to loss of turgor [16, 18]. Under drought, reduced dry matter accumulation occurs in all plant organs, although different organs manifest varying degrees of reduction. For instance, drought decreased shoot and flower fresh and dry weights of marigold (*Tagetes erecta* L.) plants [19].

Adapt to water stress

Plants tend to adapt to drought by accumulation of cyto-compatible organic osmolytes [20] such as polyols, proline and betaines. Seed treatment or foliar application of chemicals like glycinebetaine, kinetin, salicylic acid [21-22] may increase yield of different crops due to reduction in stress induced inhibition of plant growth [23], enhanced photosynthetic rates, leaf area and plant dry matter production [24].

Respiration

Drought tolerance is a cost-intensive phenomenon, as a considerable quantity of energy is spent to cope with it. The fraction of carbohydrate that is lost through respiration determines the overall metabolic efficiency of the plant [25]. The root is a major consumer of carbon fixed in photosynthesis and uses it for growth and maintenance, as well as dry matter production [26]. Plant growth and developmental processes as well as environmental conditions affect the size of this fraction (i.e. utilized in respiration). However, the rate of photosynthesis often limits plant growth when soil water availability is reduced [27]. A negative carbon balance can occur as a result of diminished photosynthetic capacity during drought, unless simultaneous and proportionate reductions in growth and carbon consumption take place. In wheat, depending on the growth stage, cultivar and nutritional status, more than 50% of the daily accumulated photosynthates were transported to the root, and around 60% of this fraction was respired [26]. Droughtsensitive spring wheat (Longchun, 8139–2) used a relatively greater amount of glucose to absorb water, especially in severe drought stress [28].

Chlorophyll content

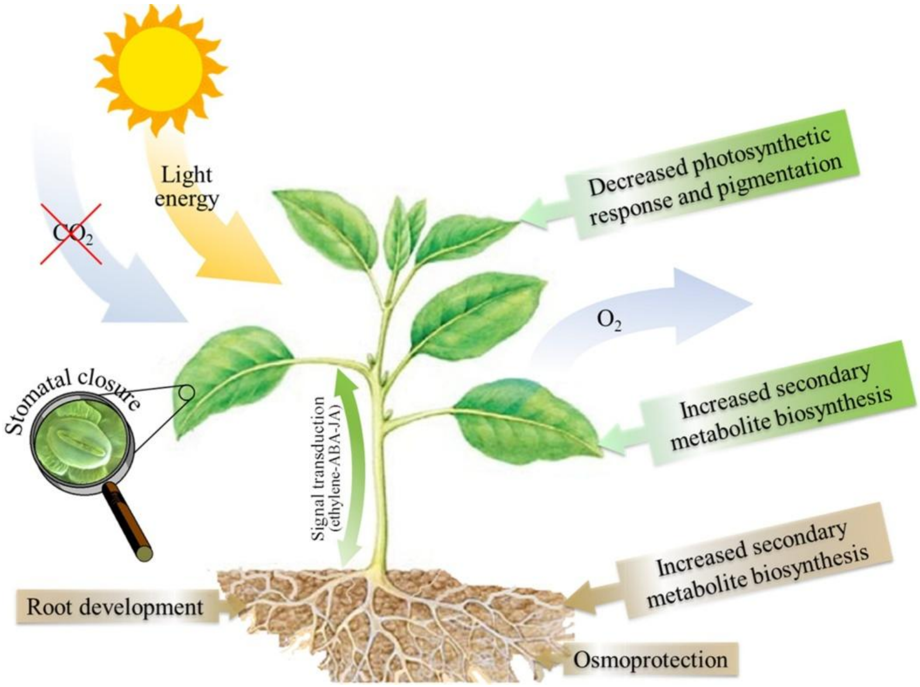

Figure 2: Plant global response to water stress, high temperature and salinity

Chlorophyll which is one of the major chloroplast components for photosynthesis, and relative chlorophyll content has a positive relationship with photosynthetic rate. The decrease in chlorophyll content under drought stress has been considered a typical symptom of oxidative stress and may be the result of pigment photo-oxidation and chlorophyll degradation [4]. Limited water supply usually causes a reduction in chlorophyll content [29]. Being positively correlated with yield [30] relatively high chlorophyll content may contribute to the plant productivity under stress conditions. Photosynthesis is one of the most sensitive processes to drought stress [5]. The inhibitory effects of drought on photosynthesis may be associated with low CO_2 availability due to low stomatal and mesophyll conductance [6] and/or impairments in carbon assimilation metabolism [7]. Stomatal closure is an early response to drought and an efficient way to reduce water loss in water-limiting environments. Biochemical limitation of photosynthesis also plays an important role under prolonged periods of drought stress [6].

Relative water content

Relative water content (RWC), leaf water potential, stomatal resistance, the rate of transpiration, leaf temperature and canopy temperature are important characteristics that influence plant water relations. Relative water content is considered a measure of plant water status, reflecting the metabolic activity in tissues and used as a most meaningful index for dehydration tolerance. RWC of leaves is higher in the initial stages of leaf development and declines as the dry matter accumulates and leaf matures. RWC related to water uptake by the roots as well as water loss by transpiration [4]. RWC tend to decline when transpiration exceeds water absorption under drought condition [31] leading to decrease in cell turgor. Maintenance of high RWC under drought due to relatively more growth of the roots than shoots and/or abscisic acid induced reduction in stomatal opening [32] tends to maintain cell turgidity, chlorophyll content [33].

Effect of drought stress on glycine betaine content

Drought stressed shallot plants showed an increase in glycine betaine content when compared to control. The glycine betaine content increased under drought stress in Radix astragali [34], in barley [35] and in higher plants [36].

Glycine betaine is considered to be one of the most abundant quaternary ammonium compounds produced in higher plants under stressful environment [37]. Glycine betaine has been shown to protect the enzymes and membranes and also to stabilize PSII protein pigment complexes under stressful conditions [38].

Salicylic acid

Salicylic acid (SA) (o-hydroxybenzoic acid), which belongs to a group of plant phenolics, is widely distributed in plants and is now considered as a hormone-like substance, which plays an important role in the regulation of plant growth and development [39]. During the last 20 years this substance has drawn the attention of researchers because of its ability to induce systemic acquired resistance (SAR) in plants. At the present, considerable interest has been aroused by the ability of SA to produce a protective effect on plants under the action of stress factors of different abiotic nature. Salicylic acid (SA) is a signaling or messenger molecule in plants and induces plant tolerance against various biotic and abiotic stresses [40]. SA also plays an important role in the regulation of some physiological processes in plants such as effects on growth and development, ion uptake and transport and membrane permeability [41]. Salicylic acid (SA) or ortho-hydroxy benzoic acid and other salicylates are known to affect various physiological and biochemical activities of plants and may play a key role in regulating their growth and productivity [42]. Salicylic acid is considered to be an endogenous growth regulator of phenolic nature that enhanced the leaf area and dry mass production in corn and soybean [24]. Salicylic acid (SA) as a potent signaling molecule in plants is involved in eliciting specific responses to biotic and abiotic stresses. It has been shown that SA provides protection in maize [43] and winter wheat plants [44] against low-temperature stress, induces termotolerence in mustard seedlings [45-46] or modulates plant responses to salt and osmotic stresses [47] ozone or UV light [48] drought [49] and herbicides [50]. It has been found that SA has different effects on stress adaptation and damage development of plants that depend on plant species, concentration, method and time of SA application [51]. Furthermore, SA is a potential non-enzymatic antioxidant and an important signal molecule for modifying plant responses to environmental stressors. Some earlier reports display that exogenous SA can ameliorate the impairing effects of drought stress in different species [52]. SA has obtained particular attention because of inducing protective effects on plants under NaCl salinity [53]. Several studies have shown that the effects of cytotoxicity induced by salt stress can be ameliorated by the exogenous application of SA [41]. Thus considerable data have been obtained concerning the SA induced increase in the resistance of wheat seedlings to salinity [54], and water deficit

[55], of tomato and bean plants to low and high temperature [56], as well as the injurious action of heavy metals on rice plants [57].

Enhance the activities of antioxidant enzymes

Other studies have shown that exogenous SA can regulate the activities of antioxidant enzymes and increase plant tolerance to abiotic stress [58]. Salicylic acid was found to enhance the activities of antioxidant enzymes such as peroxidase (POD), SOD and CAT, when sprayed exogenously to the drought stressed plants of tomato [59] or to the salinity stressed plants [60-61].

Plant growth

Several studies have demonstrated that exogenous SA application enhances plant growth and development. Fariduddin *et al*. (2003) [62] showed that mustard plants sprayed with low concentrations of SA produced larger amounts of dry matter and had higher photosynthetic rate in comparison with control plants. SA application to corn and soybean promoted leaf area and dry weight of plants [24]. In another study Hussein et al. (2007) [18] revealed that growth traits of wheat plants were improved as a result of SA spraying on the plants. In addition, Hayat et al. (2005) [63] reported that soaking of wheat grains in low concentrations of SA significantly promoted growth of wheat seedlings.

Fruit yield

Another important parameter that is directly related to yield and productivity of plants. Salicylic acid has been reported to induce flowering in a number of plants. In cucumber and tomato, the fruit yield enhanced significantly when the plants were sprayed with lower concentrations of salicylic acid [64]. It was reported that the foliar application of salicylic acid to soybean also enhanced the flowering and pod formation [42]. Flowering is another important parameter that is directly related to yield and productivity of plants. Salicylic acid has been reported to induce flowering in a number of plants. In cucumber and tomato, the fruit yield enhanced significantly when the plants were sprayed with lower concentrations of salicylic acid [64]. It was reported that the foliar application of salicylic acid to soybean also enhanced the flowering and pod formation [42]. Exogenous SA application to the drought stressed plants increased glycine betaine content as compared to drought stressed plants as well as control plants. The accumulation of glycine betaine might serve as an intercellular osmoticum and it can be closely correlated with the elevation of osmotic pressure [65].

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