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Effects of drought and salinity Stress on *Zea mays*: A review

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Abstract

Plants are anchored to a fixed spot by the roots; hence they are subjected to many environmental stresses which affect the growth and development of the plants. These adverse climatic conditions (stresses) can be of two types biotic and abiotic. Biotic stress may include pathogen infection and herbivore attack however, abiotic stresses include drought, heat, cold, nutrient deficiency, and excess of salt or toxic metals like aluminium, arsenate, and cadmium in the soil. Drought, salt, and temperature stresses are major environmental constraints that affect the geographical distribution of plants in nature, plant productivity, and create a menace on food security. Maize is considered as one of the most widely grown crop in the world. A complex and dynamic response is shown under stressful conditions. The changes occurring may be reversible or irreversible in nature. As the climate change drastically, it is having a direct impact on the intensity and frequency of both abiotic and biotic stresses. This review highlights current knowledge on the abiotic stress and maize plants. Drought stress mediated effects on maize plants is also displayed. Additionally, the impacts of salinity stress in maize have also been highlighted.

Key words : Drought stress, Growth and development, Herbivore, Maize.

About 80% of human food is constituted by crops, governed mostly by cereals which comprise 50% of the worldwide food production[14]. *Zea mays* (maize) has become the key crop with a global food supply of 1×109 tonnes (1012 kg) since 2013 [10]. Maize commonly called as corn is an important annual cereal crop of the world belonging to the family Poaceae. It acts as a renewable fossil fuel substitute due to its bio-ethanol production[26]. The edible part of maize plant is kernel which is nutritive in nature. It contains vitamin E, vitamin C, vitamin K, vitamin B1, vitamin B2, vitamin B3, vitamin B5, vitamin B6, folic acid, selenium, N-p-coumaryl tryptamine, and N-ferrulyl tryptamine. Potassium is a major nutrient present[13]. It supports the ever-increasing human population by fulfilling dietary demands directly as a consumptive foodstuff or indirectly as feed for the livestock[23] It is reported described that the presence of essential fatty acids, especially linoleic acid in maize oil plays an important role in the diet by maintaining blood pressure, regulating blood cholesterol level, and preventing cardiovascular maladies[21]. However, it is stated in report that even a table spoon of maize oil satisfies the requirements for essential fatty acids for a healthy child or adult[9].

Maize and abiotic stress :

The natural environment for plants is composed of a complex set of abiotic stresses and biotic stresses. Plant responses to these stresses are equally complex[8]. Among different abiotic stresses, temperature extremes, drought, nutrient deficiency and salinity are regarded as the cardinal environmental elements diminishing the overall production of maize[23]. A report on maize yield loss in China and India depicts that 20–30% and 25–30% of the crop is lost every year due to drought and waterlogging, respectively[30]. Maize is said to be the most negatively affected crop when the impacts of climate change on crops was assessed[25]. According to some studies conducted it was determined that due to rise in temperature in certain maize producing regions of the world the maturity time period shortens[16]. Due to which metabolism is altered resulting in reduced carbon assimilation and hence grain set and pollination is down set[17]. Particularly the prime stresses affecting the global maize production are drought, extreme temperature and salinity[23].

Effects of drought stress on maize plant :

Drought can be defined as a condition where water supply to soil from various sources like rainfall and precipitation is significantly less than the moisture loss from soil surface. Drought is a grave hazard for crop production and food security. Abiotic stress in general and drought in particular, have been proved to be very pernicious to the overall yield of maize[28]. Among various abiotic stresses drought is a very serious factor which results in reduced crop yields as maize is one of the most universally distributed crops, it often gets affected by drought stress causing a significant loss to the final kernel yield[28]. Drought affects the plant in many developmental stages of its lifecycle inhibiting its overall growth. Moreover, many physiological processes are also affected. Some of the affected plant parts or processes and their elicited responses are shown below:

The Early stage of seedling growth and establishment is very sensitive to drought because cell division in the meristematic tissues of primary root of maize plant seedling reduces Thus termination of elongation and expansion of cell retards the growth of seedling[(4)]. Water deficit conditions are very threatening for cell growth. According to an experiment carried out by Anjum *et al.*,[3] it was demonstrated that under induced water deficit conditions the germination % is affected significantly and shows remarkable reductions along with the increase in drought stress[3]. The germination % is affected if the drought stress occur at the time of germination but if the exposure of water deficit stress occurs at flowering and grain filling stage it brings severe negative effects on phenological and yield traits attributes

Table-1. Effects of drought stress on morpho-physiological attributes of plants

Plant process/part	Response	Reference
1. Seedling establishment	Very sensitive, growth stops	(4)
2. Germination %	Decreased considerably with increase in stress	(7)
3. Vegetative growth	Severely sensitive	(3)
a) Root	Comparatively less susceptible to water deficit condition than shoots	(4)
b) Shoot	Reduced length and fresh weight	(4)
4. Reproductive growth	slow growth	(4)
a) Pre anthesis stage	Final leaf area and internodal lengths of plant becomes smaller	(28)
b) Anthesis silking interval	Increase the interval resulting in reduced grain filling	(4)
5. Grain yield	Decreased	(7)
Kernel yield	Small kernels	(28)
6. RWC	significantly reduced	(7)
Proline content	Increased	(9)
7. photosynthesis	Rate diminishes. Photo-system-II affected more severely than PS1	(4)
8. Pigment analysis		
a) Chl a content	Decreased	(9)
b) Chl b content	Decreased	(9)
c) Chl a/b ratio	Increased	(9)
d) Carotenoids	Decreased	(9)
e) Anthocyanin	Increased	(9)
9. ROS production	Exaggerated	(3)

of the maize lines as observed in the experiment carried out by Sah *et al.,*[22]. Approximately 40 to 58 % of the fresh and dry shoot and root weight was reduced due to drought stress, the shoot length was also retarded[(27)] abortion of ovules, kernels and ear may occur if drought occurs in the period from one week before silking to two weeks after silking. If the drought occurs at the reproductive stage, by reducing the sink size the demand of carbon by the plant is decreased and the consequences occurring could be degeneration of tillers, flower dropping, and death of pollen and abortion of ovules[12]. When the drought occurs at the reproductive stage the gap between the anthesis and silking period is increased which may be the reason for the crop failure. Nearly 15-25% yield is lost under long term drought conditions, reduction in leaves and internodal length and delaying in tasselling and emergence of silk is noted[28]. The production and accumulation of osmolytes is triggered with the onset of drought stress and increases with increase in severity of stress. Under drought stress conditions proline content increases significantly. Concentrations of proline, carbohydrates, proteins, phenolics, and total free amino acids were considerably higher under Severe drought conditions as compared to well-watered control[3]. The first and foremost response of drought stress is the stomatal closure declining the rate of photosynthesis[16]. By controlling stomatal closure, the turgor pressure in guard cell is changed and the activity of PS-II is affected[27]. PS-II is more severely affected than the PS-I[4]. According to the experiment conducted by Efeoglu *et al.,* (2009) on pigment analysis under drought stress conditions, it was observed that both Chl a and Chl b content was decreased significantly and at the same time the Chl a/b ratio increased. It was also demonstrated that the anthocyanin content in all the cultivar tested under drought stress increased[9]. Due to drought stress the relative water content of leaves dips lower. Under water deficit conditions large reductions in relative water content are suggested by many investigators and water potential is also seen to drop under water deficit conditions[19]. An experiment was conducted on three varieties of maize, Dong Dan 80, Wan Dan 13, and Run Nong 3 by Anjum *et al.*,[3] they imposed drought stress to the three varieties at 45 days after plantation with three different levels of drought stress with respect to field capacity, *i.e.*, low drought stress at 80% Field capacity, moderate drought stress at 60% field capacity and severe drought stress at 40% field capacity and a well-watered control with 100% field capacity was maintained for comparison. They reported that under drought stress the levels of ROS accumulation and membrane damage in all maize hybrids were increased. When compared with well-watered control, drought stress treatments increased the values of O_2^-, H_2O_2, thiobarbituric acid relative substances, electrolyte leakage, and lipoxygenase activity. Overall, oxidative stress in terms of ROS production was increased with increase in drought levels with more severe oxidative stress at maximum level of drought stress that is at 40% field capacity and the variety Run Nong 3 was found to be very sensitive to drought stress[3].

Effects of salinity stress on maize plant :

Maize has the capability of growing in saline and non-saline conditions like many other C4 plants because it have some adaptive potential and is relatively tolerant towards salinity. Even though salinity negatively affects growth and yield throughout the complete life cycle but the stage or phase at which the stress is affecting the plant also crucial for the final impact on plant productivity[6]. Maize is moderately sensitive to salt stress; therefore, soil salinity is a threat to its production worldwide. Every soil which contains amount of exchangeable sodium and soluble salts in quantities more than required is considered as salt-affected soils. due to salinity stress the osmotic potential in the soil solution surpasses the level of the osmotic pressure in plant cells due to the presence of more salt, and thus, limits the ability of plants to take up water and minerals like K^+ and Ca^{2+}(5). The increase in phytotoxic ions creates the osmotic effect, oxidative stress is caused by ROS production and ionic effect is caused in the cytosol[24] Crops grown in arid and semi-arid regions where the rainfall is limited, evapo-transpiration is very high and soil management is poor are severely affected by the salinity stress[17]. Even though there is a generalised perception that salinization occur only in arid and semi-arid regions, every climatic zone is affected by it[20]. Severe wilting and stunted growth occur if the salinity level of the soil is above 0.25 M NaCl[9].

The most critical stage in seedling establishment which governs the outcome of the crop production under the salt stress condition is the seed germination, any stress occurring at this stage first of all delays the start of process, if started reduces the rate and all the germination events are disturbed[1]. Later developmental stages are less sensitive than the germination and seedling growth stage[24]. Leaf initiation and expansion is suppressed, internodal length is reduced and leaf abscission is accelerated which inhibits the growth of shoots[6]. Even though roots are first to get stress but shoot is more sensitive to salt stress than roots[24]. In maize the process of carbon fixation is extremely sensitive to salinity stress. The crucial elements restricting the carbon fixation capacity are reduction in stomatal conductance, impairment in enzymatic activities related to carbon fixation, decreased photosynthetic pigments and dismantling of

Table-2. Salt stress mediated changes in plants growth and development

Plant part/process	Response	Reference
Seed germination	Delayed, more sensitive than later development stages	(24)
Vegetative growth	suppressed	(6)
Reproductive growth	Decreases grain weight	(24)
Biomass	Reduced. Reduction increases as the severity increases	(1)
Grain yield	Reduced	(6)
RWC	Decreased gradually with the increase of NaCl level	(2)
Mineral uptake and assimilation	Disturbed	(11)
Relative chlorophyll content	Slow down	(29)
Light harvesting and carbon fixation	Decreased and limited	(11)
Enzymatic Antioxidant defence system	Increased activity	(1)
Non enzymatic defence system	Increased activity	(1)
Electrolyte leakage	Increased	(2)
Gas exchange rate	Reduced significantly under long term stress	(19)

photosynthetic apparatus and if the stress occurs during the reproductive stage it results in decline in grain number and reduction in grain weight. The main reason behind the dwindling of grain yield is the reduction in photosynthesis and the subsidised source sink relationship[24]. Whenever the sodium is accumulated in soil in excessive amounts, calcium nutrition is inhibited and nitrogen uptake and translocation is severely restricted[11]. Overall Nutritional imbalances occur due to the exaggerated build-up of sodium and chloride ions in the soil which interferes with the absorption of other essential mineral ions like manganese, iron, calcium, nitrogen, potassium, zinc and copper[11].

In conclusion, it is clear that abiotic stresses are destructive to the crops around the world. Of the various abiotic stresses, the available literature suggests that the drought and salinity may cause severe damage. Furthermore, this review emphasizes the impacts of drought and salinity stress in growth parameters, photosynthetic efficiency, mineral uptake, chlorophyll content and yield attributes. Further research is needed to explore the precise molecular mechanisms, which elicit the intra-cellular plant signaling responses with abiotic stress conditions.

Conflict of interest :

The author declares no conflict of interest.

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