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Drought Stress: A Major Constraint in Crop Production and Mitigation Strategies

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Agriculture is considered as the backbone of Indian economy it contributes around 17-18% in the country's wealth. The total area under agriculture and horticulture in India is around 140.1MHa and 27.59MHa respectively with employing around 50% of total work force of the country. With the increase in the population of the country, it is important to increase the production of food grain to feed the large population. It is also reported that the agriculture land is shrinking day by day with the rapid industrial development and urbanization. Large number of industries is dependent on agricultural produce. Hence, consequences in extra load on the available agricultural land. Elevating temperature and reduced water availability due to natural and anthropogenic activities, it is one of the major limiting factors for yield reduction as it affects almost every plant function. It was estimated that there might be a further rise in temperatures by 1.4°C-5.8°C to the year 2100. Climate change has already forcing biodiversity and ecosystem to adopt shifting habitat and changes in life cycle. It is not only a major worldwide environmental problem, but it is also an issue of great concern to a developing country like India. As stated by the International Panel on Climate Change (IPCC), climate change is "Unequivocal". In recent time, it has been reported that there are various abiotic and biotic constraints which restrict the crop yield and productivity. Among these, hydrological deficit due to the natural and anthropogenic activities is one of the major concern areas. Erratic changes in the rainfall patterns, reduction of ground water table, increased rate of transpiration as well as drying of the small and medium rivers leads to the desertification of agricultural land which diagnosed as major limiting factor and ultimately affects the production of crop yield. There are reports indicating that there is rapid increase in the land desertification. It is about

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30% of the total land area which is facing drought stress. Among the 29 states, 26 states had reports a rapid increase in area undergoing desertification out of which Rajasthan, Delhi, Goa, Maharashtra, Jharkhand, Nagaland, Tripura and Himachal Pradesh have around 40-70% of land has undergone desertification in the past 10 years. Water deficit conditions generally produce oxidative stress in plants. Stress imbalances reactive oxygen species metabolism, which characteristically alters the antioxidant enzyme activity and affects plants metabolic processes at various levels such as gene expression, signal transduction and enzyme synthesis and functioning.

Effect of drought stress on plant growth

Plants growth and development is directly or indirectly affects by water deficit condition. Reduction in morphological growth and alteration in physio-biochemical characteristics of plants were observed under moderate to severe stress. The negative impacts of drought on the yield mainly depend upon the severity of the stress and the plant growth stage. The effects are more pronounced in case of early season drought and causes weakening or destruction of established crop. Water relations are influenced by certain factors including leaf water potential, leaf and canopy temperature, transpiration rate and stomatal conductance. Exposure to drought stress disturbs all these factors in plants however, stomatal conductance is affected the most **(Farooq *et al.*, 2009)**. A significant reduction in the leaf water potential and transpiration rate was observed under the drought conditions which ultimately increased the leaf and canopy temperature. Another important feature for plant physiological regulation is water use efficiency which is the ratio of the dry matter accumulated to the water consumed. Efficient cultivars of wheat have higher water use efficiency under drought stress. This improvement in the water use efficiency is mainly due to the accumulation of the dry matter by consuming less amount of water due to the closing of stomata and less rate of transpiration. Reduced water use efficiency was observed in potato (*Solanum tuberosum* L.) when exposed to an early season water shortage and it ultimately resulted in poor biomass accumulation and yield. Significant yield losses have been reported in major field crops due to drought stress. Drought induced reduction in the yield might be due to various factors such as decreased rate of photosynthesis **(Bota *et al.*, 2004)**, disturbed assimilate partitioning or poor flag leaf development. The drought induced at the pre-anthesis stage shortened the time to anthesis

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while that applied after anthesis reduced the period of grain filling in cereals. The process of the grain filling in cereals is controlled by four major enzymes *i.e.*, Sucrose Synthase, Starch Synthase, Starch Branching Enzyme and Adenosine Diphosphate Glucose Pyrophosphorylase **(Taiz and Zeiger, 2006)**. A decreased activity of these enzymes has been reported under the drought conditions which have a negative impact on the yield of major cereal. Alteration in quality of grain, forage, fiber and oil etc is responsible for reduction in grain and fodder yield of field crops. The exposure of maize to drought conditions at the tasseling stage resulted in a significant yield loss **(Anjum *et al.*, 2011)**. Similarly, a significant reduction in the boll production and the abortion of the produced bolls was recorded in cotton under drought conditions which ultimately affected the lint yield. A significant reduction in the grain yield of barley (*Hordeum vulgare* L.) was also observed under drought conditions mainly because of less number of fertile tillers and grains along with less 1000 grain weight. The exposure of pigeon pea (*Cajanus cajan* L.) to drought stress at the flowering stage caused over 50% reduction in the seed yield **(Nam *et al.*, 2001)**.

The exposure of plants to drought stress at the flowering may result in complete sterility in pearl millet (*Pennisetum glaucum* L.) which is usually due to the disturbed assimilate movement to the developing ear **(Yadav *et al.*, 2005)**. Drought stress greatly impacts the nutrient relations of the plants. Many important nutrients including nitrogen, silicon, magnesium and calcium are uptake by roots along with water, the drought conditions limit the movement of these nutrients via diffusion and mass which leads to retarded plant growth. Plants increase the length and surface area of roots and change their architecture in order to capture the less mobile nutrients. The soil moisture deficit at times reduce the growth of the roots and hence, reduce the uptake of the less mobile nutrients such as phosphorus. Root–microbe interactions also play an important role in nutrient relations of a plant. The impaired carbon and oxygen flux to the nodules coupled with N accumulation under drought stress inhibited N fixing ability of certain legumes. Composition and activity of the soil microbial colonies are negatively affected by the soil water deficit which eventually disturbs the plant nutrient relations **(Schimel *et al.*, 2007)**. The response to the mineral uptake under moisture stress varies across the crop species. In general, N uptake is increased, P uptake is declined and K remains unaffected under drought conditions. However, nutrient relations become more complicated due to interactive effects of different nutrients on each other and overall plant physiology.

Mitigation strategies by plants under water deficit condition

Drought is a climatic event that cannot be prevented, but interventions and preparedness to drought can help to: (i) be better prepared to cope with drought (ii) develop more resilient ecosystems (iii) improve resilience to recover from drought and (iv) mitigate the impacts of drought. Preparedness strategies to drought include: (a) geographical shifts of agricultural systems (b) climate-proofing rainfall-based systems (c) making irrigated systems more efficient and (d) expanding the intermediate rainfed–irrigated systems.

Implementation of various crop management practices, modern advance crop improvement tools and hormonal treatment potentially can alleviate the detrimental impact of drought on crop growth and productivity. Moreover, plant also shows various morpho-physiological and biochemical defence mechanism to with stand drought stress. Under stressful condition of drought the major morphological mechanisms in plants include escape and avoidance, through promoting earliness by allowing plants to reproduce as soon as the environment becomes dry. It is achieved by synchronizing the period of plant growth with the period of water availability. Flower initiation and development is an important trait associated to drought adaptation, where a shortened life cycle might lead to drought escape. Drought avoidance consist series of mechanisms that reduce water loss from plants by controlled stomatal transpiration and also regulating water absorption through an extensive and prolific root structure, it is helpful in extracting water from considerable depths**.** Drought stress tolerance is also allied with the co-ordination of physiological and biochemical changes at molecular and cellular levels including accumulation of osmoregulants and proteins *viz.* late embryogenesis abundant (LEA) proteins coupled with a proficient antioxidant mechanism. Plants show diverse physiochemical responses at cellular and organism levels towards existing drought stress, thus making it a multifarious phenomenon. CO_2 assimilation in leaves is reduced mainly by stomatal closure, membrane damage and disturbing activity of various enzymes, especially those of CO_2 fixation and ATP synthesis. Drought stress decreases the leaf dimensions and area, stems extension and root proliferation that disturbs plant water relations and reduces water-use efficiency. In order to deal with the osmotic stress, plant synthesize and accumulate large number of small, neutral and non-toxic compounds identified as osmolytes (proline, glutamate, glycine-betaine, carnitine, sucrose and oligosaccharides) along with certain mineral ions like K^+, Na^+ and Cl^-. Osmolytes upholds the structural integrity of cellular membrane by stabilizing the tertiary structure of protein**.** The most important enzymes such as superoxide dismutase (SOD), peroxidase (POX) and catalase (CAT), mainly function to remove superoxide anion radicals in the antioxidant system of plants through readily neutralized by enzymatic or non-enzymatic means. Higher enzymatic activity elicits during mild drought in order to avert membrane peroxidation whereas severe drought stress can substantially inhibit enzymatic functions. If free radicals cannot be removed rapidly either by osmoregulatory substances or protective enzymatic systems, the huge amounts of membrane lipid peroxidation products like malondialdehyde (MDA) are accumulated and is often used to estimate the extent of membrane degradation by lipid peroxidation in plants. Apart from plants internal defence mechanism various crop management practices can also be helpful in alleviating the effect of water deficit condition. The effect of drought can be avoided by shifting cultivation of particular crop to the drought tolerant crop or by using drought resistant varieties. It can also be reduces by using appropriate irrigation mechanism to reduce water loss such as drip and sprinkler irrigation. Mulching crop with organic or synthetic mulches also helps in maintaining moisture in soil and reduces water loss in the form of vapour. Growth regulators also play an important role in mitigation of drought stress in plant and improve plant survival and productivity. It has been reported that application of growth regulators also helps in reducing impact of drought by regulation of osmolytes, accumulation of biomolecules and mineral ions in plants.

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