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Drought Effect and Tolerance Potential of Wheat: A Mini-Review

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Abstract
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. Drought affect is noticeable at all level of organization from cellular to whole plant level. Manifestation of combination of morpho-physiological changes decides the ability of plant to overcome limited water supply and sustain its growth. Plant drought tolerance does not remain same at all stages of wheat development due to the variable responses. Therefore, it is important to develop relationship between drought and yield traits at different stages of wheat development. Drought at booting or flowering stage of wheat development shows strong relationship with grain yield. While seedling growth shows higher correlation with drought tolerance in wheat under drought field condition. Relative yield for comparison of different genotypes made good indicator of tolerance potential.
Keywords: Drought tolerance, genotypes, grain, tolerance.

INTRODUCTION

If sufficient water is not available to the plants, the high yielding varieties, fertilizers and other resources become useless resulted in lower farmer's earning and poor standard of living (Arshad *et al.,* 2016). Drought is a worldwide problem, 43% of the world area is affected by this syndrome. Pakistan's total geographical area is 79.61 million hectares, of which only 25% (19.82 million hectares) is under cultivation by various crops. 15 million hectares of cultivated land of Pakistan is under various degrees of drought. The productivity is due to soil and climate factors. In 2001, it was predicted by IPCC (International panel for climate change) that the drought condition along with extreme temperature will prevail in many parts of the world that almost 1/3 of the world population will not receive enough water to drink (Chaves and Davies, 2010). Drought is a complex scenario with three factors, first duration; second timing of occurrence and third one is intensity. These factors vary widely in nature.

Drought-induced yield reduction has been reported in many crop species, which depends upon the severity and duration of the stress period (Arshad, 2017; Yousaf *et al.,* 2018). Wheat is an important cereal crop of Asia, with great yield potential under optimal conditions. Abiotic stress, especially drought reduces its potential from 10 to 90% depending upon the drought factors (Reynolds *et al.,* 2005). The aim of the breeders is to optimize the plant productivity in these marginal regions by understanding the responses of plants (Jones, 1993). Many physiological, morphological and biochemical factors are responsible for developing drought tolerance in plants. Abscisic acid (ABA), the factor in stomatal regulation under harsh environment (Maldonado *et al.,* 1997) also associated with osmolytes accumulation e.g glycine betaine, manitol, proline, soluble sugars etc that help in osmoregulation and avoid the movement of water outside the cell (Storey and Jones, 1977). Apart from these, reduced plant height, small leaf area, short vegetative growth period, early maturity, and great harvest index are some of the desirable factors for wheat breeding in marginal area (Khan *et al.,* 2013). According to estimates about 32- 99 m hectares of the Triticum area is under water stress (Peymaninia *et al.,* 2012), the great loss in yield happens, when stress occurs at the critical stages of growth. In wheat, booting and grain falling stages are the most sensitive that decide the total yield of plant. Stress at these stages result in less number of grains, low grain weight, reduced number of spikes, ultimately low grain yield/plant (Osborne *et al.,* 2002). Five Iranian wheat varieties (Cross-Flat, Atrak, Red-Seed, Darab, Hirmand) were given drought stress at flowering stage resulted in low number of seeds per spike, ultimately poorer yield. Red seed proved the low yielder while Darab was the high yielder among all but both showed the significant decrease in seed size. The experiment showed that stress at anthesis or flowering is not affordable and resulted in drastically reduced yield (Sangtarash, 2010). The aim of this review is to discuss the drought effect on wheat and how different strategies like screening, hybridization, marker-assisted selection, transgenic approaches are the breeding tools for developing stress tolerant varieties.

Effect of drought on plants

Drought affect is noticeable at all level of organization from cellular to whole plant level. Impede germination and poor stand establishment is the first one to affect. Meristematic division resulted in growth, new cell generation and expansion of the younger cells. Drought target the mitosis, resulted in poor cell division and impaired expansion and elongation of younger cells due to hinderance of H_2O via xylem (Nonami, 1998). Photosynthesis is one of the major physiological processes that are affected by drought. Leaf is a site for assimilates synthesis. Water deficiency reduces the leaf size, number and longevity (Shah *et al.,* 2018). The reduction in leaf size is due to the impede elongation and expansion of cells, improper leaf temperature and interrupted assimilates supply for growth (Rucker *et al.,* 1995). Apart from this, drought stress also disrupts the major components of photosynthetic machinery e.g. stomatal regulation for CO_2 intake, thylakoid membrane, electron transport chain, with peroxidative damage to the lipids and great accumulation of carbohydrates (Allen and Ort, 2001). Chlorophyll is also the major component of chloroplast, having close relation with photosynthetic rate. The reduction in chlorophyll contents is the result of oxidative damage, due to pigment photo oxidation and degradation and has direct effect on photosynthetic rate. Yield is a complex trait that integrates the physiological processes of plants. These processes respond to the drought stress depending upon its severity, duration and timing. For a plant breeder it is extremely important to understand the plant responses under stress, after removal of stress and the interaction between plant, other factors and stress. Triticale species reduce the time of anthesis, drought occurs on pre-anthesis. Drought stress affects yield in maize by reducing the number of ear and kernel/ plant by increasing the interval of anthesis to silking. At pollination stage, the stress results in kernel abortion. In wheat, stress after heading results in reduced grain weight by shortening the time between fertilization and maturity, while severe stress at flowering stage resulting in complete bareness that is due to interrupted flux of assimilates to the developing fluorescence for optimal growth (Yadav *et al.,* 2004). During reproductive stage, the onset of severe stress results in reduced lint yield due to low production and great abortion of bolls. At flowering stage, stress results in 40- 55 % seed yield reduction in pigeon pea (Nam *et al.,* 1998). In cereals, the grain filling is the process of starch synthesis from simple carbohydrates that is accomplished by the activity of 4 major enzymes: starch synthase, sucrose synthase, and adenosine diphosphate-glucose-pyrophosphorylase. Termination of seed enlargement is due to the inactivity of adenosine diphosphate-glucose-pyrophosphorylase while reduced growth is due to interrupted activity of sucrose synthase in triticum under drought. So, it is concluded that drought first affect the growth and development of the plant to the production of fewer and smaller grains resulted in low yield. The improper grain filling is due to the interrupted partitioning of the syntheses and the impede activity of starch and sucrose synthesis enzymes.

Mechanism of Drought Tolerance

Tolerance to the stress is not a heritable attribute. It involves changes at molecular, cellular, tissue to whole-plant level. Three mechanisms are: 1-Escape; 2-Avoidance; 3- Tolerance. Manifestation of combination of morpho-physiological changes decides the ability of plant to overcome limited water supply and sustain its growth. Escape short life cycle or growing season is the most important factor for the plants to escape from dry spell before its onset. Synchronization of moisture in soil with the growth duration of plant is important to obtain the high yield (Siddique *et al.,* 2001). Although, yield is directly related with the length of growth season of plant, so for the early maturing plants it is important to have high growth and gaseous exchange rate (Turner *et al.,* 2001). The breeders are focusing on developing early maturing varieties that complete their life cycle before stress occurs. Avoidance in this mechanism, plant maintains the tissue water level by avoiding the stress. Breeders concentrate on the morpho-physiological changes that enable the plant to survive under harsh conditions. Changes occur at molecular and cellular level that ultimately bring the change at whole plant level. In this type, plant is not directly exposed to the stress, but plant makes changes in the structure by avoiding the H_2O loss or by increasing the H_2O uptake. It includes the changes that help the plant to use rational available water, or efficient use of rainfall. Root system with characteristic of density, length, depth, and biomass contributes to the overall yield under stress. Deep root system is a characteristic of plants to avoid stress, as they can extract water from the deep horizon of soil. ABA is an important stress hormone, synthesized by the plant under water stress. First, stress is sensed by roots and ABA is produced, it then moves to the leaves through xylem. The half-life of this stress hormone is about 30 min in leaves. Hormone brings changes in the stomata structure and keeps stomata close to avoid water loss. Accumulation of ABA is positively related to the intensity of stress (Innes *et al.,* 1984). Transpiration happens via cuticle, waxy bloom over or within cuticle in leaves is suitable factor for tolerance that help to maintain tissue turgor pressure by avoiding excessive water loss (Ludlow and Muchow, 1990). Different degree of wax deposition on wheat reduces net temperature and amount of radiations absorbed. In wheat, leaves with waxy blooms have cooler leaves than non-waxy leaves (Richards *et al.,* 1986). It is suggested that 0.5°C lowering of leaf temperature per day for 6 hours can extend the seed filing duration for 3 days. But these profits are low because of fewer varieties with glaucousness. Leaf pubescence is one of the other characteristics, plant with hairs on leaves absorb low radiations and keep the temperature low under heat. This character shows positive relation with plant production under water stress. Leaf angle is another one to affect leaf temperature, erect leaves having good surface area with maximum absorbed radiations. Wheat varieties with leaf angle at 45 perform better than the varieties with pubescence. Tolerance is the ability of one plant to survive by inducing low level of changes in comparison to other, when both are subjected to same level of stress. Osmoregulation, an important approach that have positive relation with plant yield under stress by maintaining the turgor pressure due to some unknown mechanism (Hall, 2001). Osmolytes or cell compatible solutes are accumulated in the plant to avoid damage due to low water potential and help the plant to maintain its potential to threshold level. Stress responsive genes are expressed in response to ABA under stress. Several heat shock proteins, chaperon, Aquaporins, ATPase, proteinase, Lea proteins, dehydrin, osmotin and several other regulatory factors like DREB, WRKY, bZIP, NAC play their role in making the plant tolerant to stress. In this mechanism, when the plant undergo stress it dehydrates and regrow after dewatering. Following changes occur in plants; macro-molecules and solutes concentration, dehydration of macromolecules, and reduced water chemical activity. Drought avoidance and tolerance are two major mechanisms that decide the plant growth and can be determined by accessing the different characters of seedlings under stress. Tolerance can be accessed by measuring the solutes leakage from plant membrane.

Wheat Breeding for Drought Tolerance in Wheat

Significant area of the world especially Pakistan, Egypt, India, Bangladesh etc. is under water stress and requires breeding for stress tolerance in plants especially cereals. No significant improvement has been made for abiotic stresses tolerance in plants using conventional tools, as plant in a complicated manner respond to the stress environment, these system intricate different stress-responsive genes, enzymes, several proteins and most importantly cellular signal transduction pathways. Developing abiotic stress tolerant variety in plants by conventional methods has been a challenge due to polygenic nature of stress responses (Munns *et al.,* 2006). It is reliable and economical to develop drought tolerant wheat variety using genetic tools to cope with water deficit conditions. Many genes are involved in providing the water stress tolerance, these genes may be present on different chromosomes, and each gene contributes little in providing stress tolerance. The continuous variations in traits at different locations due to genes and environment interactions make the breeding a difficult task (Flowers and Flowers, 2005). Different strategies like screening, hybridization, marker-assisted selection, transgenic approaches are the breeding tools for developing stress tolerant varieties. The main objective of the wheat breeders throughout the world is to produce the high yielding varieties under stress environment. The pre-requisite of the breeding program is to find the adequate variations in wheat accessions to develop the new varieties that can further be utilized for improvement. Most of Pakistani wheat varieties have CIMMYT based origin, that have narrow genetic base with low genetic diversity (Oyiga *et al.,* 2016).Therefore, efforts are needed to develop the new wheat material for breeding drought tolerant cultivars. Plant drought tolerance does not remain same at all stages of wheat development due to the variable responses. Therefore, it is important to develop relationship between drought and yield traits at different stages of wheat development. Drought at booting or flowering stage of wheat development shows strong relationship with grain yield. While seedling growth shows higher correlation with drought tolerance in wheat under drought field condition. Concluded that relative yield for comparison of different genotypes made good indicator of tolerance potential. Evaluation of Triticum species for drought tolerance at seedling (Khakwani *et al.,* 2012) studied the effect of different moisture levels on morphological aspects of various wheat genotypes. Seeds of local and five approved varieties including irrigated and rain fed varieties were given stress with PEG 6000 i.e 0,15 and 25 % as treatments. Mean data of all seedling parameters was recorded showing that germination % age has positive but non-significant correlation with all the seedling traits while coleoptile is significantly and positively correlated with length of root, shoot, FRW and FSW. While positive correlation of length of root and shoot with RFW and SFW was observed. Bilal et al. (2015) conducted an experiment on 40 different wheat genotypes comprising old and new approved varieties and local land races. To induce water stress, PEG 6000 solution treatments i.e. 0, 7.5, 15 and 22.5% were used. Seeds of each genotype were placed on moist paper to check germination percentage, after this these seeds were given stress in petri plates and placed in growth chamber at 25°C. Mean data for root, shoot length, coleoptile and seedling vigor was computed. The results showed that the germination percentage is positively correlated with all the above-mentioned traits while root length has positive association with shoot and coleoptile length and shoot length with coleoptile length and seedling vigor. Hameed et al. (2014) studied physiological and biochemical aspects of *triticum*. Twenty-two genotypes comprising 7 accessions of *Triticum aestivum* and 15 *Triticum durum* accessions. Seeds of these genotypes were germinated on filter paper under stress condition that was induced by PEG 6000. i.e 0, 5 and 10% solutions. Germination %age data, shoot, root length and seedling vigor index was collected on the 10th day of germination. These seedlings were also subjected to biochemical analysis and the proline contents were found to be accumulated in rainfed varieties under the stress conditions as compared to irrigated varieties. Several isoenzyme analyses (catalase, paroxidase) showed that they were found in increased amount under stress condition. Water stress was imposed as 100% (control), 75%, and 50% field capacity. Genotypes were evaluated up to harvesting. Data was collected at vegetative as well as reproductive stages. Analysis revealed that reproductive stage was more sensitive than vegetative stage. It was also concluded that alarming reduction in yield happen when stress occurs at flowering stage (Arjenaki *et al.,* 2012).

CONCLUSION

Plant breeders showed interest in the Genomic selection (GS) and high-throughput phenotyping (HTP) techniques. These approaches revolutionize complex traits prediction, including yield, growth and stress adaptation. Developed techniques (i.e. GS and HTP) integrated with approaches such as genetics, breeding, agronomic and genomics, for drought improving strategies in wheat.

CONFLICT OF INTEREST

The authors declare that no competing interests exist.

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