REVIEW

Wheat Production under Drought Stress Conditions: Physiological and Biochemical Responses and Mitigation Options

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Drought is a global problem, limiting crop production and quality, and it is more detrimental under climate change conditions. It decreases crop yield by affecting the key plant metabolic pathways. Drought triggers a wide variety of plant responses, ranging from cellular metabolism to changes in growth rates and crop yields. Wheat is one of the most important cereal crops and extensively cultivated in wide ranges of altitudes in Afghanistan. With an alarming population growth in the era of climatic change, there is a need for further crop improvement for sustainable production. Understanding the physiological and biochemical responses wheat to drought is essential for a holistic perception of resistance mechanisms to drought conditions. This review article has been divided into two parts, i.e., Physiological and biochemical responses of wheat to drought stress, and drought stress mitigation approaches. In the first part, physiological and biochemical responses of wheat to stress were discussed. Drought stress reduces relative water content of leaves, chlorophyll content, and membrane stability. It adversely affects photosynthesis by changing the inner structure of chloroplasts, mitochondria, and chlorophyll content and minerals. Drought stress induces generation of active oxygen species, and the production of antioxidant enzymes in response to water stress as an adaptive mechanism against oxidative damage. This review article elucidates the physiological and biochemical responses of wheat to drought stress conditions and provides drought mitigation options that could contribute in food security under changing climate.

Key words: wheat, drought stress, antioxidant enzymes, photosynthesis, osmolytes
Drought stress is considered the most detrimental factor for crop growth and productivity and a serious threat to sustainable crop production in the face of climate change. Drought triggers a variety of plant responses, ranging from changes in cellular metabolism to changes in growth rates and yields. Drought stress gradually reduces CO\textsubscript{2} assimilation rates due to reduced stomatal conductivity. It reduces leaf size, stem elongation, and root proliferation, disturbs plant water quality, and reduces water utilization efficiency. Drought interferes with photosynthetic pigments and reduces gas exchange, resulting in reduced plant growth and productivity (Anjum et al., 2011a). Drought stress occurs when water supply to the roots is restricted or transpiration rates are too high. Low water availability impairs photosynthetic activity and causes oxidative stress due to the imbalance between light uptake and utilization (Celik and Cimen, 2012). Global food security is plagued by rapid population growth and dramatic climate change (Lesk et al., 2016). With climate change, drought and heat stress are major limiting factors for crop yields and, ultimately, food security. Droughts are becoming more frequent around the world due to decreased precipitation and changes in precipitation patterns (Lobell et al., 2011). Water shortages caused by irregular and inadequate rainfall are causing enormous losses to agriculture around the world. In Russia, drought and other natural disasters are estimated to have cost over 800 million US$ in 2000 alone. Drought affects all stages of plant development, from germination to vegetative and reproductive growth, grain filling and crop maturity (Hossain et al., 2012).

Among plants, wheat (Triticum aestivum L.) is an excellent health food and an excellent source of minerals, fiber, protein and B vitamins. Wheat is cultivated for its starch and protein. It is the world’s most important cereal crop and, along with rice and corn, is an integral part of the diet of over 4.5 billion people. Wheat’s success in temperate regions of the world offers distinct advantages over other temperate crops due to its adaptability and high yields, as well as its unique flour properties (Shewry 2007). Demand for wheat is estimated to increase by 60% by 2050, but environmental pressures from climate change could reduce production by 29% (Manickavelu et al., 2012). Understanding physiological and biochemical responses of wheat crop to drought stress is essential for a holistic understanding of plant tolerance mechanisms to water-limited conditions. It provides a framework for work on the development of wheat plants with increased drought stress. This article, aims to provide an overview of the physiological and biochemical responses of plants, especially wheat, to drought stress, and to provide management options to minimize the detrimental effects of drought stress on wheat productivity.

**Drought stress**

Drought is a polygenic stress that reduces crop productivity (Kilic and Tacettin, 2010) and quality (Waraich et al., 2010, 2011) and limits effective use of land potential worldwide (Liu et al., 2016). Drought reduces the uptake and utilization of nitrogen (N) by plants. Decreased nutrient uptake is due to impaired membrane permeability and active transport, and reduced transpiration rates, resulting in reduced root absorptive capacity. In semi-arid and arid regions of the world, drought is one of the main causes of limiting agricultural production. Many plant growth parameters and functions are affected by drought stress (Nezhadahmadi et al., 2013). Drought is one of the major abiotic pressures, affecting at least 60% of wheat production in high-income countries and around 32% of 99 million hectares in low-income least developed countries (Chen et al., 2012). Water scarcity can reduce wheat yields from 17% to 70% (Nouri-Ganbalani et al., 2009).

Drought is severely limits the production and quality of the crops, and recent global climate change has exacerbated this situation. Drought stress affects plant growth, dry matter and yield. The timing, duration, severity, and rate of development undoubtedly play an important role in determining how plants respond to drought. After drought, stomata gradually close, resulting in a simultaneous decrease in net photosynthesis and water use efficiency (Anjum et al., 2011a). Cell proliferation is considered one of the most drought-sensitive physiological processes due to reduced turgor pressure. Growth is the result of mitotic
cell division and subsequent massive expansion of young cells to produce daughter cells. Grain yield is the result of the expression and association of multiple plant growth components. Water deficit leads to severe deterioration of crop yield-related traits, possibly by perturbing leaf gas exchange properties. This not only limits the size of source and sink tissues, but also affects phloem loading, anabolic translocation, and dry matter partitioning (Farooq et al., 2009a). Drought stress suppresses dry matter production, primarily through an inhibitory effect on leaf elongation and leaf development, resulting in reduced shading (Nam et al., 1998). Drought during flowering often leads to infertility. The main, if not the only, cause was that assimilate flux to the developing ear fell below the threshold required to maintain optimal grain growth (Yadav et al., 2004).

Decreases in grain yield and could be attributed to stomatal closure and reduced CO₂ uptake in response to lower soil water content, resulting in reduced photosynthesis (Flexas et al., 2004). Drought reduces plant growth and development, resulting in impaired flower production and grain filling, resulting in smaller and less grains. It occurs due to decreased partitioning and activity of sucrose and starch synthases (Anjum et al., 2011a).

RESPONSES OF WHEAT TO DROUGHT STRESS

Water relation

Relative water content (RWC) is considered a measure of the water status of plants, reflecting tissue metabolic activity and used as the most important indicator of dehydration tolerance. Leaf RWC is high during the early stages of leaf development and decreases as dry matter accumulates and leaves mature. RWC is associated with water uptake by roots and water loss through transpiration (Anjum et al., 2011a). When plants are exposed to drought stress, leaf water potential, relative water content, and transpiration rate decrease significantly, while leaf temperature increases (Siddique et al., 2001). Although the water-related component of plants is affected by the reduction in available water, in fact stomatal opening and closing is more affected. In addition, changes in leaf temperature could be a key factor in controlling leaf water status under drought stress. Drought-tolerant species maintain water-use efficiency by reducing water loss. However, water use efficiency was also significantly reduced when plant growth was more constrained (Anjum et al., 2011a).

Drought at a later stage of plant growth (6 weeks after germination) had a greater effect on water status, nutrient uptake, growth and yield than drought imposed at earlier stage (3 weeks after seedling germination) in wheat (Nawaz et al., 2014). Drought significantly reduces chlorophyll content, membrane stability and RWC of wheat cultivars at flowering stage (Moayedi et al., 2010). As the RWC decreases, the stomata close and the photosynthetic rate slows down. Although water deficit hampered osmotic regulation, alternating drying and rewatering induced osmotic regulation and improved plant water use efficiency under drought conditions due to the large regulation of osmotic pressure (Keyvan, 2010). Drought-tolerant genotypes retained high turgor potential and relative water content, suggesting that limited water had little effect on plasma structure compared to sensitive genotypes, indicating a highly positive correlation between RWC and photosynthetic rate (Moayedi et al., 2010). Maintaining leaf turgor is an important adaptive mechanism that plays a key role in regulating stomatal and photosynthetic activity under drought conditions (Lipiec et al., 2013).

Antioxidant enzyme

The production of antioxidant enzymes such as catalase (CAT), superoxide dismutase (SOD), peroxidase (POD), ascorbate peroxidase (APX), and glutathione peroxidase (GPx) in response to water stress is a well-known adaptive mechanism in plants. Plants increase peroxidase and glutathione activity against oxidative damage caused by water stress. APX is a major antioxidant enzyme that scavenges chloroplast superoxide radicals and H₂O₂ under conditions of drought (Gill and Tuteja, 2010). Similarly, in wheat cultivars, APX activity varied by leaf development stage and drought duration. Wheat exposed to mild drought increases APX activity in leaves, whereas prolonged water deficit reduced that...
activity due to increased malondialdehyde (MDA) production (Nikolaeva et al., 2010). Peroxidase plays an important role in removing $\mathrm{H}_2\mathrm{O}_2$ produced by SOD-catalyzed disproportionation of $\mathrm{O}_2^-$. CAT is a key enzyme for $\mathrm{H}_2\mathrm{O}_2$ removal in mitochondria and microbodies (Shigeoka et al., 2002) and helps mitigate the detrimental effects of oxidative stress. Although it occurs in peroxisomes, it is thought to be essential for the breakdown of $\mathrm{H}_2\mathrm{O}_2$ during stress. Maintaining higher levels of antioxidant enzyme activity may help in reducing oxidative damage (Sharma and Dubey, 2005). The ability of antioxidant enzymes to mitigate the effects of drought may be correlated with plant drought tolerance. SOD, glutathione reductase, and APX contribute significantly to the reduction of reactive oxygen species (ROS) generated by drought stress (Hernández et al. 2012). As hydrogen peroxide scavengers, CAT and POD convert toxic levels of endogenous $\mathrm{H}_2\mathrm{O}_2$ to water and oxygen. Similarly, CAT activity in wheat leaves exposed to severe drought was examined and an increase in the CAT activity of wheat plants was found in particularly susceptible cultivars (Simova-Stoilova et al., 2010). Ascorbic acid applied to leaves mitigates drought by affecting stomatal closure, nutrient uptake, total chlorophyll content, protein synthesis, transpiration, flowering and photosynthesis (Xu et al., 2015). Leaf-applied ascorbic acid increased wheat yield and chlorophyll content in combination with leaf water potential regulation by transporting minerals from leaves to flowers and enhancing CAT and APX activity (Hafez and Gharib. 2016).

**Chlorophyll content and photosynthesis**

Chlorophyll is one of the most important chloroplast components for photosynthesis, and relative chlorophyll content is positively correlated with photosynthetic rate. Decrease in chlorophyll content under drought stress is considered a typical symptom of oxidative stress and may be the result of pigment photo-oxidation and chlorophyll degradation. Photosynthetic pigments are important to plants primarily for capturing light and photosynthesis. Both chlorophyll a and b are susceptible to soil water-deficit conditions (Faroq et al., 2009b). Depending on cultivar, plant growth, and various environmental factors, the ratio of chlorophyll a to b is 3:1. However, the highest chlorophyll content is found in early flowering plants (Simova-Stoilova et al., 2009). Severe drought stress in wheat is associated with changes in leaf chlorophyll content (Fotovat et al., 2007) and leaf photosynthesis (Prasad et al., 2011). A decrease in wheat chlorophyll content is associated with leaf age. Chlorophyll content increased in young leaves due to activation of enzymes in the photoreaction of chlorophyll synthesis, but decreased by 13-15% in older leaves due to activation of chlorophyllase and deactivation of enzymes under drought (Nikolaeva et al., 2010). Differences in chlorophyll content were not only caused by drought stress, but also existed between genotypes. Higher chlorophyll content resulted in better seed yields under water stress conditions (Alaei 2011). Kilic and Tacettin (2010) evaluated the yield and physiological characteristics of 14 durum wheat cultivars under drought stress and found differences between grain yield and chlorophyll content, grain filling time, and number of grains per ear (Mir et al., 2012). Dehydration adversely affects photosynthesis by altering the internal structure of chloroplasts, mitochondria, chlorophyll content, and minerals (Huseynova et al., 2016). However, stomatal responses under drought conditions vary greatly among plant species (Lawlor and Crow, 2002). Photosynthesis is limited by reduced stomatal conductivity during mild droughts, but dysfunction of Rubisco becomes a major factor affecting photosynthesis (Bota et al., 2004). Low concentrations of photosynthetic pigments may directly limit photosynthetic potential and thus primary production. From a physiological point of view, leaf chlorophyll content is an independent parameter of considerable interest. Most studies of plant chlorophyll loss in response to drought stress occur in mesophyll cells, with lesser loss from bundle sheath cells (Anjum et al., 2011a). Drought-stressed plants have been reported to have higher concentrations of chlorophyll a compared to chlorophyll b (Jain et al., 2010).

**Accumulation of osmolytes**

Osmotic adaptation as a plant defense mechanism improves plant drought tolerance and allows cell growth and plant growth in severe water deficits (Shao et al.,
Plants accumulate a wide variety of organic and inorganic solutes in the cytosol to reduce osmotic pressure and thereby maintain cellular turgor (Rhodes and Samaras, 1994). The stomata remain partially open to continue CO$_2$ fixation during periods of water deficit. Accumulation of osmolytes allows cells to cope with desiccation and membrane structural integrity and achieve resistance to desiccation and cellular desiccation (Loutfy et al., 2012). Osmotic adaptation of drought-exposed plants may follow storage of low-molecular-weight organic solutes. Wheat plants accumulate several inorganic and organic solutes in their cytosol to reduce osmotic pressure to maintain cellular turgor (Zahoor et al., 2018).

Leaf turgor can also be maintained during drought by osmotic adjustment in response to accumulation of proline, sucrose, soluble carbohydrates, glycine betaine, and other solutes in the cytoplasm. The process of such solute accumulation under drought stress is known as osmotic adaptation, which is highly dependent on the rate of plant water stress. Wheat is characterized by low levels of these compatible solutes, and proline accumulation and mobilization have been observed to increase resistance to water stress (Nayyar and Walia, 2003). Compatible osmolytes present in higher plants act as osmoprotectants and protect cells from dehydration by maintaining an osmotic balance between the extracellular and intracellular environment and protein quaternary structure. It also regulates intracellular osmotic pressure, regulates cytosolic pH, and stabilizes cell membrane structure in wheat under drought stress (Huseynova et al., 2016). Among these solutes, proline has been the most extensively studied as it is of great importance in stress tolerance. Accumulation of proline is the first response by water-stressed plants to reduce cellular damage. Progressive drought stress led to significant accumulation of proline in water-stressed maize plants. Proline levels increased as drought stress progressed, peaked as recorded after 10 days of stress, and decreased under severe water stress, as observed after 15 days of stress (Anjum et al., 2011b). Accumulation of proline under stress in many plant species is correlated with stress tolerance, and its concentrations have been shown to be generally higher in stress-tolerant than stress-sensitive plants. It affects protein solvation, maintains complex protein quaternary structure, maintains membrane integrity under drought stress, and reduces oxidation or photo-inhibition of lipid membranes (Demiral and Turkan, 2004).

Wheat plants accumulate more proline than other osmolytes, especially in leaves (Farshadfar et al., 2008). This is due to increased protein degradation and an immediate decrease in its synthesis during the grain filling stage under water deficit (Nazarli and Faraji, 2011). Wheat genotypes accumulate more soluble sugars during the grain-filling stage than during the anthesis stage under drought stress. The optimal stages for screening drought-tolerant cultivars are the ripening and post-flowering stages (Farshadfar et al., 2008). Qayyum et al. (2011) reported that hyperosmotic stress increased the endogenous content of soluble sugars in wheat from 1.49 mg in controls to 2.65 mg per gram leaf under -8 bar osmotic stress. Proline levels increased under imposed stress, with the greatest increase (69.8%) occurring under combined (drought and heat) stress compared to controls. Individual drought and heat stress increased proline levels by 53% and 58.9%, respectively, compared to controls. Soluble protein was also affected by the imposed stress, with minimal values observed in control treatments. Increases in soluble protein of 3.6 mg g$^{-1}$, 4.3 mg g$^{-1}$ and 4.5 mg g$^{-1}$ were recorded under drought, heat and combined stress, respectively, compared to control treatments. A minimal level of soluble sugars (1.46 mg g$^{-1}$) was observed in the control treatment. Drought stress increased soluble protein by 61% compared to controls (Abdul-Sattar et al., 2020). Evaluation of wheat genotypes under drought stress showed that drought-tolerant genotypes accumulated higher concentrations of physiological indices such as free proline, glycine betaine, total sugars and potassium content. These organic and inorganic substances help maintaining osmoregulation under water stress. In addition, high concentrations of these solutes provide wheat with the advantage of withstanding drought stress (Muhammad et al., 2016).
Reactive oxygen species

Generation of reactive oxygen species (ROS) is one of the earliest biochemical responses of eukaryotic cells to biotic and abiotic stress. Generation of ROS in plants, known as oxidative burst, is an early event in plant defense responses to water stress and acts as a secondary massager that triggers subsequent defense responses in plants. ROS, including oxygen ions, free radicals, and peroxides, are natural byproducts of normal oxygen metabolism and play important roles in cell signaling. However, environmental stresses such as drought dramatically increase ROS levels, causing oxidative damage to proteins, DNA, and lipids (Apel and Hirt, 2004). Drought stress increases production of ROS. However, the main source of ROS generation is the electron transport chain that occurs in the chloroplast. Disruption of the photosystem II (PSII) oxygen-releasing complex and reaction center impedes electron production and utilization, generating ROS that expose cell membranes to lipid peroxidation (Wang et al., 2014).

High concentrations of singlet oxygen (1O_2), superoxide radicals (O_2^-), hydrogen peroxide (H_2O_2), and hydroxyl radicals (OH) caused oxidative damage in plants, depending on endogenous levels. ROS are deoxyribonucleic acids, lipids, and proteins cause photosynthetic-related oxidative damage, enzyme inactivation, and disruption of cellular structure by affecting normal functioning of cells (Huseynova et al., 2016). ROS production is linear with the severity of water stress that induces membrane lipid peroxidation and nucleic acid degradation. Organelles such as Chloroplasts, mitochondria and peroxisomes are cytological sites and primary targets for reactive oxygen species. An alternative nitric oxide-mediated pathway enhances photosynthesis under water deficit by avoiding severe reduction of the photosynthetic electron transport chain and ultimately inhibiting the ROS production and oxidative damage in wheat leaves (Wang et al., 2016). ROS are highly reactive and can seriously damage plants by increasing lipid peroxidation, protein degradation, DNA fragmentation, and ultimately cell death. Drought induces oxidative stress in plants through the formation of ROS (Faroq et al., 2009a).

Drought stress and nutrients

Many essential nutrients such as nitrogen, silicon, magnesium and calcium are taken up by the roots along with the water. Drought conditions limit the diffusion and mass transfer of these nutrients, retarding plant growth (Barber, 1995). A lack of soil moisture temporarily reduces root growth and reduces the uptake of less mobile nutrients such as phosphorus (Garg, 2003). Soil microbial colony composition and activity are adversely affected by soil moisture deficit, ultimately disrupting plant nutrient balance (Schimel et al., 2007). Responses to mineral uptake under water stress vary among plant species. In general, under drought conditions, N uptake increases, P uptake decreases, and potassium remains unaffected. However, nutrient relationships are more complex as different nutrients interact with each other, complicating overall plant physiology. This aspect requires detailed studies at a sophisticated molecular level (Fahad et al., 2017).

Drought can lead to nutrient deficiencies in the agricultural sector, as individual nutrient intakes depend on soil physicochemical properties (Nawaz et al., 2020).
Water deficit conditions have a significant impact on nutrient uptake by roots and transport to shoots. It has been found that drought stress causes an increase in plant N content, a decrease in P content, and generally does not affect K content (Farooq et al., 2009b). Under drought stress conditions, roots are ineffective at uptake of nutrients from the soil due to poor root function and slow water diffusion rates (Dubey and Pessarakli, 2001). Water deficit conditions also lead to stomatal closure, reduced transpiration, and restricted movement of nutrients from the roots to the upper part of the plant. Thus, drought conditions reduce soil nutrient availability and reduce the consistency of plant nutrient migration (Bashir et al., 2022).

**DROUGHT STRESS MITIGATION**

**Plant natural defense**

Some plants have different morphological, physiological and biochemical adaptation strategies that enable them to cope with water stress conditions. Plant responses to water stress are influenced by several factors, including developmental stage, stress intensity and duration, and cultivar genetics (Tefera et al., 2021). To cope with oxidative stress, plants usually rely on enzymatic or non-enzymatic antioxidant defenses. Enzymatic defenses are generally considered to be the most effective (Farooq et al., 2008). The main enzymes involved in this system are SOD, GR, POD and CAT (Farooq et al., 2009b). In addition to these enzymes, certain carotenoids and glutathione may also be involved as non-enzymatic components of the antioxidant system which indirectly protects plants (Anjum et al., 2011c). Therefore, maintaining higher levels of antioxidants may be a good strategy for plants to counteract the negative effects of ROS (Sharma and Dubey, 2005). Phytohormones are also natural defense molecules in plants that maintain high levels of antioxidants even under stress. They help plants adapt to different environments by mediating growth, development, source/sink transitions, and nutrient allocation (Fahad et al., 2015).

**Application of growth regulators**

Exogenous application of growth regulators and osmoprotectants at different growth stages may play an important role in inducing drought tolerance. Hydration of seeds before sowing initiated germination metabolism but prevented the emergence of radicles (Farooq et al., 2006). It has been reported that several wheat cultivars performed better under drought conditions after priming with potassium chloride (Eivazi, 2012). Priming wheat seeds with ascorbic acid improved proline accumulation, increased drought tolerance, and maintained tissue water content and membrane stability (Farooq et al., 2013). External application of Salicylic acid (SA) also improves drought tolerance (Azooz and Youssef, 2010). Studies conducted primarily at the physiological level, suggest that drought tolerance by SA is associated with enhanced antioxidant defense mechanisms (Horváth et al., 2007). It has been reported that applying SA at the seedling stage to mitigate drought may result in real economic yields from wheat genotypes grown under water stress. Safar-Noori et al. (2018) reported that combined application of SA and appropriate levels of potassium (K) fertilizer can ameliorate the adverse effects of post-anthesis drought stress, improves wheat productivity, and partially enhances grain minerals content, and nutritional quality of wheat. Anjum et al. (2011c) reported that exogenous application of brassinolide improved maize performance under drought conditions by improving water balance and antioxidant defenses. Application of glycine betaine helps improve plant performance under drought conditions (Hussain et al., 2008). It improves stomatal conductivity, photosynthetic rate and proline accumulation in plants (Ma et al., 2007). Other studies also highlighted the potential application of silicon to improve drought tolerance of wheat mainly through root growth, stomatal conductance, photosynthetic rate, and antioxidant defense (Gong et al., 2005).

**Selection and genetic improvement**

Screening and selection of drought tolerant genotypes of wheat can be considered as a good approach to minimize the deleterious effect of drought stress. In drought conditions, cell membrane stability (CMS) is another important selection criterion for drought-tolerant genotypes. Genotypes with values below 50% and with 71–80% are considered sensitive or tolerant to drought, respectively (Bilal et al., 2015).
drought-tolerant wheat, higher CMS protects the plant from ROS, which cause decreased membrane stability through the generation of lipid peroxidation. Physiological responses such as chlorophyll levels, stomatal closure and decreased photosynthetic activity, generation of oxidative stress, changes in cell wall integrity, and metabolite production play important roles in water-limited wheat. Therefore, these physiological traits can be considered as potential indicators for indirect selection of resistant wheat genotypes under drought conditions (Negi et al., 2018). Transgenic wheat plants rapidly close stomata under drought stress conditions, reducing transpiration and water loss, thereby improving drought tolerance of wheat (Yu et al., 2017). Some studies have shown that photosynthesis under drought stress is directly related to wheat grain production due to reduced stomatal openings, resulting in reduced CO$_2$ fixation levels and reduced photosynthesis (Mafakheri et al., 2010). Genetic modification of root shoot structure can improve water and mineral uptake in water-stressed wheat. The wheat tiller inhibitor gene (Zinn) strongly affects root shoot structure. This gene improves root-to-shoot ratio and root biomass during early stem elongation and also increases root depth at maturity in a wheat near-isogenic line (NIL). It also slows soil moisture utilization by lowering canopy temperature, increasing stomatal conductivity, and keeping the grain green during filling of these NILs. These changes can increase harvest index and ultimately yield (Hendriks et al., 2016).

**Opportunities in Drought Tolerance Development**

The following factors are known to pose challenges in developing drought-tolerant wheat cultivars. These include timing (growth stage), genetic diversity, drought intensity, complex and large genome, low heritability and quantitative/polygenicity of drought responsive traits, epistatic qualitative trait loci (QTL) interactions, interaction between genotype and environment, and co-occurrence of abiotic and biotic factors. The genetics of drought tolerance/susceptibility are complex, and the traits involved are complex and polygenic, complicating the task of developing drought-tolerant cultivars. However, current high-throughput techniques (transcriptomics, proteomics, metabolomics, genotyping, SNP chip assays) for accurate phenotyping and analysis of the wheat genome and the bioinformatics software employed to identify drought-tolerant wheat. Therefore, recent technologies such as high-throughput phenotyping, next-generation sequencing (NGS), and genetic engineering can be utilized for drought tolerance improvement in wheat (Mwadzingeni et al., 2015). Climate change conditions that make plants more susceptible to abiotic stresses, emphasis should also be placed on breeding for stress tolerance. Recently, studies have been initiated to improve plant stress tolerance using conventional and molecular breeding approaches (Farooq et al., 2009b). Higher plants have evolved distinct but interrelated strategies to survive and overcome stress. On the contrary, these strategies are not equally present in most crops. In addition, for crops, traditional breeding programs involving the transfer of desirable genetic traits from wild relatives are often used to manipulate resistance traits. However, it is not effective because breeding is objectively difficult. Especially in cereals, most traits of abiotic stress tolerance are localized in landraces and related wild species, whereas most of these traits are yet to be identified in grasses. Wheat, rye, and barley have good levels of abiotic stress tolerance compared to maize and rice, but information on the genes and mechanisms involved is very sparse or sometimes absent, so it is difficult or impossible to improve commercial varieties for stress-tolerant traits. A future challenge for abiotic stress research is therefore needed to bridge the gap between knowledge and translation of relevant traits into promising materials (Lichtfouse and Goyal, 2015).

**CONCLUSION**

Drought stress is a key constraint that limits wheat growth and productivity. Wheat exhibits a wide range of responses to drought stress, which are mainly expressed by various changes in plant growth, morphology and physiology. The effects of drought stresses including damaged photosynthetic machinery, oxidative damage, and membrane instability. As a natural defense mechanism, wheat plants produces many organic and inorganic solutes to reduce osmotic pressure and maintain cellular turgor under drought
stress conditions. Scavenging of reactive oxygen species by enzymatic and non-enzymatic systems, cell membrane stability, and expression of stress proteins are vital mechanisms of drought tolerance. Application of some phytohormones and osmoprotectants can play an important role in mitigation of drought stress. The ability of plants to withstand damaging effects of drought stress varies greatly between wheat genotypes. Genotypes with higher yields under drought stress can be considered as tolerant one. Therefore, screening of wheat varieties for their yield under drought stress condition and identification drought tolerant genotypes is a powerful tool to minimize the loss of yield due to drought stress. Employing genetic approaches and plant breeding techniques may help in avoiding the yield losses by inducing stress tolerance. Cultivation of transgenic wheat varieties which close their stomata under drought stress conditions, and therefore improves drought tolerance through reducing transpiration and water loss could be another approach to successful wheat production under drought stress condition. However, there is great advances in genetic approaches such as conventional breeding and transgenic approaches, there is still much opportunities for improvement of drought tolerant wheat varieties.

CONFLICTS OF INTEREST

The author declare that has no potential conflicts of interest.

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