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REVIEW ARTICLE

EFFECT OF DROUGHT STRESS AND MANAGEMENT IN WHEAT - A REVIEW

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ABSTRACT

Wheat is a major cereal crop in the world. However, drought stress causes a severe loss in the productivity of wheat in different growing regions worldwide. Water deficit at the critical stage of the wheat growth causes a significant loss in yield of wheat. Drought stress affects every aspect of wheat growth from germination to maturity. Drought stress hampers different metabolic processes in the plant. It reduces chlorophyll content and photosynthesis in the leaf. It increases the production and accumulation of reactive oxygen species (ROS) which affects the various cellular mechanisms and also causes oxidative damage to RNA and DNA. Production of appropriate wheat genotype along with the adjustment of agronomic practices like efficient use of irrigation water, changing the sowing time and seed priming helps to minimize the effect of drought. Here in this review various effects of drought stress in wheat and its management options are discussed in brief.

KEYWORDS

water, affect, reduce, increase, decrease.

1. Introduction

Wheat is one of the major cereal crops in the world. It is used as a staple food in many countries supplying more than half of the calories and half of the protein diet for more than one-third population of the world (Dhanda et al., 2004). The constantly increasing population of the world has increased the demand for wheat in the world. It has been estimated that the production of wheat in the world should increase by 60% by 2050 to feed 9 billion population of the world (Langridge, 2013; Borisjuk et al., 2019). The maximum yield of the wheat can be obtained in a stress-free environment. However, there are several abiotic stress which affect the production of wheat like drought, water excess, heat, salinity, cold, and chemical. Abiotic factors cause a reduction in the yield of wheat up to 71% (Rana et al., 2013). Among these abiotic stresses, drought stress is a major constraint that plays a significant role in the reduction of wheat production and also affects its performance to a great extent (Naeem et al., 2015). 50% of the wheat in the developing countries is grown under the rainfed condition (Reynolds et al., 2001). 32% of 99 million hectares of the wheat cultivated area in developing countries and at least 60 million hectares of the wheat cultivated area in the developed countries is affected due to drought (Shamsi et al., 2011). Wheat suffers from the drought stress in many parts of the world leading to the decreased production of wheat.

In the scenario of climate change, drought can be considered as major stress affecting the productivity of crops (Ali et al., 2017). The plant suffers from the drought stress when the loss of water from the plant by transpiration through the leaves surface exceeds the water uptake by the plant through roots (Jamali et al., 2020). Drought stress in plants is mainly characterized by the decrease in water content, reduce leaf water potential, and loss of turgidity, stomatal closure, and decreased growth of cells (Jaleel et al., 2009). Drought causes significant alterations in the physiology and biochemistry of plants (Almeselmani et al., 2011). The plant shows different morphological changes in response to water stress but at the severe stress condition, plants suffer from functional damage and loss of the plant parts (Sangtarash, 2010). Jointing, tillering, and anthesis are the critical stages of water requirement in wheat (Thapa et al., 2020). Wheat needs water at all its growth stages but critical stages of wheat are more vulnerable to the shortage of water and any decrease in the supply of water at these stages leads to significant loss of yield (Mahpara et al., 2015). Drought stress affects the growth, nutrient and water relation, phenology, respiration, photosynthesis and partitioning of assimilates in plants (Farroq et al., 2009). Here in this review, the different morphological, physiological, and biochemical effects of drought stress on the wheat crop are discussed. Similarly, different management options to minimize the effect of drought stress in wheat are also studied in detail.

1.1 Objective of the study

The objective of this study is to provide information about the different effects of drought stress on wheat, including various suggestions regarding the management of drought stress in wheat.

2. Methodology

This review is prepared by using secondary sources of information. The relevant reports related to the effect of drought stress and management in wheat were collected from the thorough study of journal articles, research papers, books, review articles, etc. and major findings were summarized.

3. Discussion

3.1 Effect of drought stress on wheat

The effect of drought stress ranges from morphological to molecular levels and it is seen at all phonological stages whenever the shortage of water takes place. An account of the various effect of drought stress on wheat is explained below.

3.1.1 Effect on wheat morphology

Water deficit brings the alternation in the morphology of plants. Drought

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stress affects every aspect of wheat growth from germination to maturity. Drought stress has a significant influence on the germination of the seed, growth of the seedling, partitioning of dry matter, and growth of root, root depth, and extension (Lonbani & Arzani, 2011). It is an important limiting factor for plant growth and development at the initial stage. Seed germination is the first stage that is very sensitive to water stress. The seed needs a sufficient amount of water for germination. However, under water deficit condition, seed cannot imbibe water and germination do not occur. The main effect of the drought is that it affects germination and causes the poor establishment of the plants (Harris et al., 2002) including wheat. Water stress generally lowers the turgor pressure and hence, suppresses the expansion and growth of cells (Jaleel et al., 2009). It is reported that drought stress has a negative effect on the grain components yield, such as the kernel weight, biological yield, and the number of ears per meter square (Farnia & Tork, 2015). Drought stress before the anthesis stage leads to a decreased number of ear heads and kernels per ear (Denčić et al., 2000; Guttieri et al., 2001). Drought stress during the reproductive and grain filling stage is very sensitive and it leads to the significant reduction of the yield of wheat. During the period of grain development in wheat, flag leaf works as a major source of assimilates as it contributes 30 to 50% of the total assimilates to the wheat plant (Sylvester-Bradley et al., 1990). However, drought stress increases the rate of leaf senescence (Evans, 1996). And this is greatly responsible for the reduction of the grain yield in wheat. Drought stress during the grain filling stage cause the early senescence and grain filling duration may decrease (Plaut et al., 2004). Water scarcity during the early grain development stage decreases the potential grain size by reducing the rate and the duration of grain filling (Saini &Westgate, 1999). Terminal drought is mainly responsible for the reduction in the grain number, rather than the grain size, which causes a significant reduction of wheat yield (Dolferus et al., 2011). Under water stress conditions, the growth of the root occurs to search for water, but the growth of the shooting part is reduced (Ahmad et al., 2018). However, under moderate and high drought conditions, the growth of the wheat root was found to be diminished (Noctor & Foyer, 1998). So, drought stress results in the reduction of plant height. Biomass of the plant was found to be decreased in the spring wheat due to drought (Wang et al., 2005) which ultimately reduce the yield.

3.1.2 Effect on wheat physiology

Photosynthesis is an important physiological process and chlorophyll is a major chloroplast component for photosynthesis that occurs in wheat. Drought stress in wheat reduces the chlorophyll content of the leaf (Fotovat et al., 2007) and photosynthesis in the leaf (Prasad et al., 2011). Different metabolic processes are affected by drought stress which leads to the reduction of chlorophyll content. It is found that combined heat and drought stress reduced chlorophyll content in the leaf by 49% while the drought stress alone reduced by 9% (Pradhan et al., 2012; Awasthi et al., 2014). The loss of chlorophyll content can be considered as a major factor responsible for the inactivation of photosynthesis. Photosynthetic response in the wheat is determined by the intensity, duration, and rate of the stress. The main physiological effect of the drought is that it limits the photosynthesis through the closing of stomata which decreases the uptake of carbon dioxide by leaves and also prevent the transpirational loss of water because of decrease in leaf turgor and water potential (Yokota et al., 2002; Anjum et al., 2003). When the uptake of carbon dioxide decreases, photodamage occurs (Cornic & Massacci, 1996). Photochemical efficiency of photosystem PS II is suppressed by drought stress through the reduction in transport of electron, external proteins removal, and release of magnesium and calcium ions from their bindings (Barta et al., 2010; Zlatev & Lidon, 2012). Carbon fixation in the plant is affected by drought which causes a reduction in the influx of carbon dioxide into the mesophyll cells (Chaves et al., 2003; Flexas et al., 2004). This directly affects the metabolic activities by reducing the content and availability of ribulose 1,5-bisphosphate carboxylase/oxygenase (Rubisco) (Parry et al., 2002; Bota et al., 2004) and ribulose bisphosphate (RuBP) regeneration. It also decreases the synthesis of ATP (Farooq et al., 2009). Reproductive organs are most sensitive to water stress (Saini & Lalonde, 1997). Pollen sterility occurs in the wheat if the scarcity of water occurs during meiosis at the young microspore stage of pollen development which results in the reduction of the grain number (Saini &Westgate, 1999; Ji et al., 2010). Drought stress at the early stage that is during the stage of grain filling period reduces the number of endosperm cells and the number of starch granules per cell, which may be the reason for the decrease in the size of grain (Nicolas et al., 1985). Relative water content and water potential of the leaf decrease when the leaf is exposed to drought (Nayyar & Gupta, 2006).

3.1.3 Effect on wheat biochemistry

Drought stress brings a significant alteration to the biochemistry of the wheat. Total Soluble Sugar (TSS), Total Carbohydrate (TC), enzyme activities are negatively affected due to drought stress in wheat (Hammad &Ali, 2014). Under optimal condition, there is a balance between the formation of reactive oxygen species (ROS) and consumption that is maintained by antioxidant enzymes and redox metabolites (Foyer & Noctor, 2005) which includes catalase (CAT), superoxide dismutase (SOD), glutathione reductase (GR), peroxidase (POD), ascorbate peroxidase (APX) and redox metabolites like glutathione and ascorbic acid (Amirjani & Mahdiyeh, 2013). Antioxidant enzymes help to avoid oxidative stress and maintain normal cellular function (Horváth et al., 2007). But drought stress causes the increased production of ROS (Ashraf, 2009) which leads to the increased accumulation of reactive oxygen species (ROS) in plants. Chloroplast, mitochondrion, and peroxisomes are the subcellular organelles involved in ROS production. When the production and accumulation of ROS are increased, it causes an effect to the various cellular mechanisms like degradation of proteins, inhibition of enzymes, oxidative damage to DNA and RNA, and membrane lipid peroxidation which cause the death of the cell (Ishikawa et al., 2010; Huseynova, 2012). Under water scarcity conditions in the soil, the amount of ABA (a form of abscisic acid) increases significantly in the xylem saps which causes an increase in the concentration of ABA in different leaf compartments. The activity of PM-ATPase decreases with an increase in drought in plants including wheat which results in the increase in the pH of the cell wall and the formation of ABA. The penetration of ABA through the plasma membrane and translocation towards the guard cell by the stream of water in the apoplasm of the leaf cannot take place. This causes an increase in the concentration of ABA around the guard cell which results in the closure of stomata (Sourour et al., 2017).

3.2 Management of drought stress on wheat

Drought stress in wheat can be managed by the production of the appropriate wheat genotypes along with the adjustment of agronomic practices (plant density, sowing time, and management of soil). These practices must ensure that the crop sensitive stages of the wheat development occur at the time when the probability of drought is minimum.

3.2.1 Drought-tolerant varieties

Several efforts have been made since the past decade to develop the drought-tolerant wheat varieties by breeding methods. Different international institutes of the world have made significant progress to develop the drought-tolerant cultivars of the wheat. Germplasm that gives the higher yield under drought condition was developed by cross-breeding among the wild species of wheat at the International Centre for Agricultural Research in Dry Areas (ICARDA) (Nezhadahmadi et al., 2013). Genetic engineering helps to develop drought-tolerant varieties in wheat. There are two ways of improving water use efficiency by the means of genetic engineering. Inserting genes for compatible osmolytes like amino acids and sugar is one way (Abebe et al., 2003) while constitutive over-expression of the late embryogenic proteins which provide tolerance to dehydration is another way of genetic engineering (Khan et al., 2019). Seeking for the increased yield of the wheat has been the major priority to improve drought tolerance in breeding programs of wheat. But the characterization of the physiological parameters of drought-sensitive or tolerant cultivars is necessary before the successful manipulation can be made (Veesar et al., 2007). Analysis of physiological parameters of yield that responds to water stress can be useful in breeding for higher yields and genotype stability under drought conditions. For identifying the water stress-tolerant genotypes, water stresses can be applied at different stages of crop growth and development like tillering, booting, and grain formation stage. Roots of the crop expand deep into the soil during the drought and alter their morphology. So, one of the selection targets for drought tolerance can be root system size (RSS) (Nezhadahmadi et al., 2013). Under drought stress conditions, wheat genotypes with good management of water can give higher yields. Therefore, new breeding lines and cultivars with developed drought resistance can be made by the use of wheat genotypes with better management of water (Nezhadahmadi et al., 2013).

3.2.2 Agronomic practices

Efficient use of irrigation water, changing the sowing times and seed priming are important agronomic practices that can be helpful to reduce the effect of drought (Hussain et al., 2019). The drought management strategies must focus on the extraction of moisture available in the soil, crop establishment, biomass, growth, and grain yield. The major goal should be to maintain yield stability under water deficit conditions. Seed priming helps in improving germination, emergence, and seedling vigor. Seed priming along with osmoprotectant helps in repairing and protecting the nucleic acids, enhancing the protein synthesis, and also repairing cellular membrane (Ahmad et al., 2018). Similarly, bacterial priming is also considered as an effective approach to minimize the effect of drought in wheat. It was found that the inoculation of wheat with endophytic actinobacteria enhanced the yield of wheat by the hormone production in the plant, increasing mineralization of soil and availability of nitrogen under drought (Yandigeri et al., 2012). The goal of drought management strategies is to preserve water sources like rain, irrigation water, and snow. Surface residue helps to reduce the rate of evaporation during the growing season. Crop rotation also helps to preserve the water. It is considered that crop rotation helps to improve the water relation in soils and yield as well as biomass of the crop also increases with crop rotation (Pierce & Rice, 1988). Similarly, the external application of macro and micronutrient help to improve drought tolerance in wheat. These nutrients help in drought stress tolerance by enhancing the synthesis of protein, stomatal conductance, homeostasis, and osmoregulation through the ROS quenching (Cakmak, 2005). Application of nitrogen fertilizer in adequate amount helps to improve remobilization and increase grain filling which helps to compensate for the loss due to decreased photosynthesis and reduced grain filling under drought stress conditions (Yang & Zhang, 2006). The Application of organic manure is also found to increase the water retention capacity of the soil (Carter, 2002). Thus, the application of organic manure in the wheat field also helps to improve the drought tolerance in wheat.

4. Conclusion

Drought stress results in a significant loss in the growth and yield of the wheat crop. Drought stress causes various morphological, physiological, and biochemical effects in wheat. It generally affects seed germination and impairs the stand establishment. It causes the reduction in leaf area, the overall growth of the plant, and the accumulation of total dry mass in wheat. It causes a negative effect on the photosynthesis process and biosynthesis of gas exchange attributes chlorophyll. Drought stress increases the production of ROS which affects the various cellular mechanisms and causes oxidative damage to DNA and RNA. To deal with this situation, wheat plants adopt various mechanisms such as drought tolerance, drought avoidance, and drought escape. The use of resistant varieties and the adoption of various agronomic practices can be helpful to overcome the harmful effects of drought stress.

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