Effect of Drought Stress and Tolerance in Wheat

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Abstract

Wheat is the most important cereal crop and is the major source of protein and calories in the daily diet. Drought is the major abiotic stress that severely affect the production of wheat worldwide. Morphology, physiology and biochemistry of wheat is severely affected under drought stress condition. The severity depends upon the time, stage and severity of water stress. Drought stress produces reactive oxygen species that cause the oxidative damage to the crops. Drought stress causes reduction in germination percentage, reduce seed vigor, early leaf senescence, early maturity, decrease chlorophyll content, reduces photosynthesis, decrease starch accumulation and decrease number of grains. Morphological structures such as trichome and leaf waxiness, stay green, accumulation of metabolites such as proline, various enzymes *viz*; Superoxide Dismutase (SOD), Ascorbate (APX), Peroxidase (POD), Catalase (CAT) were produced by the plants to protect from drought stress. Development of drought stress tolerant varieties through studying the effect of drought stress in wheat morphology, physiology and biochemistry is most important to meet the future food demands of growing population in the world.

Keywords: Drought stress • Food security • Wheat • Tolerance

Introduction

Wheat (*Triticun aestivum* L.) is the most important, highly nutritious, widely grown and mostly consumed crop in the world. It provides 1.8% fiber, 9.4% protein, 69% carbohydrates and 2.5% fat. Increasing demand due to population growth increases the wheat crop importance even more. To acquire the future food demand imposed population growth globally, the average annual wheat production has increased by 2%. Abiotic stresses are the major yield limiting factor in the area of low water availability for the production in arid and semi-arid regions [1].

Drought stress is one of the most important abiotic stress that the farmers were facing all over the world as a result of global climate change. Only 40 % area of south Asia and 48% of the Nepalese crop-growing areas are under irrigation and the rest fully depends upon the weather. Annually, the temperature of the earth is rising at the rate of 0.06 degree centigrade with the decline in precipitation of 16.09 mm. In the developing countries like Nepal, the potential yield of wheat under drought stress is 12 t ha^{-1} which can reduce up to 800 kg ha^{-1}. The drought stress can reduces the production of wheat on an average of 50%-60%. Hence, the average productivity of wheat in the drought stress 1.5 tons/ha-2.5 tons/ha which is very low in compare to production 0f 3 tons/ha-4 tons/ha under irrigated condition. If the trends continue, it will further decline the production of wheat. It is estimated that, 1.8 billion people will suffer from food deficit by 2025. Therefore shortage of water and aggravation in yield is in parallel with the excessive increase in population. In 1961, 3.5 billion people around the world feed on 1.36 billion hectare of land [2].

After half century, population of the world becomes double but the area under cultivation was increased only by 12%-13%. Increasing production through increasing area is almost impossible. Therefore the sustainable increase in production is prerequisite to meet current and future food demands. Plant species with narrow genetic diversity suffers from the yield losses due to abiotic stresses. Therefore, drought stress tolerance breeding using novel genetic resources is the most important strategy for sustainable wheat production and to overcome the changing climatic conditions all over the world. The grain yield is the main criterion that can be used for drought tolerance. Worldwide, drought not only cause the decrease in the production but also leads to soil erosion and ecological damage.

Literature Review

Wheat response to drought stress

In plants, drought stress causes various morphological, physiological, biochemical as well as molecular abnormalities that leads to the reduction in growth and development of crops depending upon the time, stage and severity of water stress [3]. Tillering, jointing, booting, an-thesis and grain filling are the most critical stages in response to drought and drought stress at these stages can cause yield reduction of 46% whereas, under severe drought stress during an-thesis leads yield loss up to 69%.

Effect on wheat morphology

Water deficit reduces germination percentage, reduce seed vigor, reduce seedling vigor, decrease leaf area, early leaf senescence, early maturity, increase dry weight and increase root shoot ratio. Drought stress has a negative impact on morphological traits of wheat such as plant height, tillers per plant, number of spikes per plant, grains per spike, grains per spike, thousand kernel weight, grain weight and leaf area that have a direct effect on grain yield. The significant decrease in plant height may due to the dehydration of protoplasm that ultimately reduces the cell division, cell expansion and loss of cell turgidity [4].

Effect on wheat physiology

Drought stress reduces relative water content, chlorophyll content, osmotic potential and leaf water potential, leaf turgor potential as well as leaf diffusive resistance and affects the leaf transpiration rate. It affects the photosystem II through slowing the electron transport, increase the ability of non-photochemicals and ultimately lowers the relative moisture content in wheat. Reduction in leaf water potential has a direct effect on gaseous exchange through stomata leads to the decrease in stomatal conductance and transpiration. Relative water content under drought stress is decreases by 43% that closes stomata leads to lower supply of CO_2 for photosynthesis and decrease in photosynthetic rate. This would have the direct effect on the availability of Ribulose 1,5-bisphosphate carboxylase/ oxygenase (Rubisco) and also decrease in the production of ATP. decreases by 13%-15% under drought stress due to activation of chlorophyllase and enzyme inactivation.

In wheat, meiosis stage of pollen development is highly. In wheat, flowering stage is with highest chlorophyll content that significantly reduces under drought stress and leads to the decrease in leaf photosynthesis. Chlorophyll content sensitive to drought leads to the pollen sterility that results in the decrease in grain yield [5].

Effect on wheat biochemistry

Wheat grain composition including starch protein, gliadins, glutenin and fibres were significantly affected by drought stress. Starch is synthesized by the amyloplast of endosperm composed of glucose polymers namely, amylose and amylopectin. Drought can reduce the starch content up to 45% exposed to 10 days after anthesis to before harvesting. Soluble Starch Synthase (SSS) activity, Granule-Bound Starch Synthase (GBSS) activity, Starch Branching Enzyme (SBE) activity, Starch Debranching Enzyme (DBE) activity were the key enzymes for starch accumulation in wheat. Drought stress during flowering stage of wheat significantly decrease the activity of these SSS, GBSS, SBE and DBE enzymes that inhibits the starch synthesis activity at different levels. The baking quality of the wheat depends upon the protein content in the grains. Drought stress has a great influence in the grain protein concentration that would alter the baking quality [6]. Observed the significant effect of drought stress in starch accumulation.

Drought stress tolerance in wheat

Drought tolerance is the mechanism of wheat to adopt under water deficit condition. Tolerance can be further understood as drought avoidance, drought tolerance and drought escape.

Drought avoidance

Drought stress conditions creates the lower water content in the soil. Deep spread of the roots into the soil and decreasing transpiration through closing the stomata helps plants to maintain the higher water potential.

Drought tolerance

Plants improves the drought tolerance mechanism through osmotic adjustment that accumulates various organic and inorganic solutes and maintains the cell turgor that allows cell expansion, growth and development under drought stress condition. This permits the co_2 fixation through stomata opening even under water deficit condition results in accumulation of the osmolytes. Management of dehydration and cell membrane integrity due to osmolyte accumulation enhance tolerance of wheat against drought stress [7].

Drought escape

It is the mechanism of completion of the life cycle of plant when there is sufficient water before the drought stress.

Mechanisms of tolerance

The drought induced oxidative stress was detrimental to wheat that can be ameliorated through different enzymes in plants such as Superoxide Dismutase (SOD), Ascorbate (APX), Peroxidase (POD) and Catalase (CAT) and increases tolerance against drought induced detrimental effects. Leaf waxiness and trichome density are the major morphological characteristics of wheat that reduces the loss of water through transpiration and protect against the drought for longer period. The size and length of the roots increases in the continue search of water whereas the above ground parts shows a restricted growth under water stress condition.Drought stress causes the early senescence of leaves of wheat. The ability of the leaves to remain photo synthetically active due to late senescence of leaves is said to be the stay green defense mechanism in wheat [8]. SG property continue supplies sugar in the growing reproductive organs helps to retains the pollen and ovule viability. Therefore, the selection of drought tolerant genotypes can also be done through stay green trait of wheat under drought stress condition.

Discussion

Drought stress cause excessive production of Reactive Oxygen Species (ROS) during photosynthesis and respiration of the plants due to the release of surplus electrons to oxygen leads to the oxidative damage in plants cell organelles that is; chloroplast mitochondria, nucleic acids, membrane lipid and metabolic enzymes. ROS change in membrane potential, lipid peroxidation, protein oxidation, damage nucleic acids, decrease enzymes production and leads to programmed cell death [9]. Oxidative damage can be prevented through detoxification of ROS by ant oxidative defense system.

Under drought stress condition there was the accumulation of metabolites such as glycine, betaine, proline, mannitol and soluble sugars. Increase in the proline content under stress condition improve tolerance through control storage of useful nitrogen, increase in membrane stability, scavenging free radicals and buffering cellular redox potential. Increase in soluble sugars and proline under water stress condition were the potential contributors to osmotic adjustment. Proline accumulates in large amount than other amino acids [10].

Conclusion

Drought stress is one of the major abiotic stress faced by the farmers all over the world. Drought stress causes various morphological, physiological, biochemical as well as molecular abnormalities that leads to the reduction in growth and development of crops depending upon the time, stage and severity of water stress. Drought stress causes in the significantly decrease in wheat production depending upon the time, stage and severity of water stress. Hence, drought stress breeding is the major requisite to meet the future food demand of growing population in the world. Plants have evolved the various defense mechanism such as avoidance, tolerance and escape for defense against drought stress.

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