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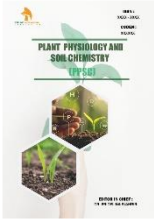

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RESEARCH ARTICLE

INTRODUCTION TO ABIOTIC STRESS AND ITS EFFECT IN WHEAT: A REVIEW

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ABSTRACT

Wheat is considered as a major staple food crop in the world that fulfil the nutritional requirement of people globally. Since ages, wheat production has been providing nutritional security to people all around the world. But there are several factors that hinders the production of wheat and abiotic stress is one of them. This article is a review of abiotic stress that leads into several physiological, morphological and biochemical alterations in wheat. Abiotic stress is environmental condition that reduces growth and yield of plant below optimum level. Drought, salt, heat, wind is the major abiotic stress that adversely affect plant growth and productivity. These stress alone or in combined form can pose a serious intimidation on the wheat production. Delayed germination, decreased net photosynthetic rate, plant stunting, water and nutrient stress, reduced tillering and number of spikelets, lower grain test weight and low grain yield are the consequences of abiotic stress in wheat. Some of the wheat varieties are found to be highly tolerant to this abiotic stress while some are sensitive to these stresses. Stress resistance superior wheat genotypes with suitable agronomic management and scheduling is found to be the ultimate solution to this abiotic stress.

KEYWORDS

Physiological, photosynthesis, yield.

1. Introduction

Wheat (Triticum aestivum L.), the world's third-largest crop after maize and rice, covers around 218.5 million hectares, or about 4% of the total area suitable for crop production, with an average yield of 3.26 t ha-1 (Kajla et al., 2015). During the last 50 years, increased global population and varied consumption predilection have led to the elevated demand for wheat worldwide. Crop production is hampered by highly abnormal, fast mutating climatic conditions, which pose a severe risk that must be addressed in order to maintain fruitful output. These changing environmental conditions have led to different abiotic stresses in plants such as drought, salinity, heavy metal, waterlogging, and temperature that abet substantial losses in growth and yield of wheat worldwide (Barlow et al., 2015). Stress is any external factor that affects the normal growth and development of plants.

Every plant is subjected to stress of some sort during its lifetime. Stress changes the normal physiology of plants and is responsible for reduction of productivity of plant. Stress can be categorized into: - A) Biotic stress - Plant pathogens like fungi, bacteria, virus, nematodes etc. B) Abiotic stress - Temperature related stress (heat stress and cold stress), Moisture related stress (drought and flooding), Salinity, Wind etc. The detrimental impact of non-living forces on living organisms in a certain habitat is known as abiotic stress (Onaga and Wydra 2016). Between 2006 and 2017, Nepal planted wheat on 0.7 million hectares of land on a yearly basis. The average output is 2.29 tons per hectare, which is much lower than the global average of 3.16 tons per hectare. Wheat yields in the rainfed area were 1.74 MT/ha, whereas they were 2.71 MT/ha in the irrigated area. Similarly, the yield from indigenous seeds was 1.12 MT/ha, compared to 2.34 MT/ha from modified seeds (MoALMC 2018).

The fact that abiotic forces collectively pose the greatest constraint to crop output around the world underscores the undeniable significance of abiotic stress in global agriculture. Abiotic stress causes 51–82 percent of the potential yield of annual crops to be lost (Bray et al., 2000). The problem of non-optimal temperatures, which are either too cold for efficient crop production in the extreme northern and southern portions of the world, or too warm in the more equatorial regions, is one of the major roadblocks to increasing traditional field crop production. Drought, salinity, sub- and supra-optimal temperatures, poor soil nutrient status, and anthropogenic factors are all limiting crop yield, so using new crops with improved above factors resistance would benefit agriculture globally by reducing the use of groundwater resources and expanding crop productivity on existing and new lands. Drought is a leading environmental stress declining the global cereals productivity, with up to half of the agricultural land prone to frequent drought.

2. Methodology

The source used to prepare this article is solely secondary source. Various research, articles, journals, online sites and relevant reports were taken as reference for the summarization.

2.1 Effects of abiotic stress

Any deviation the external conditions, that is, an excess or deficit in the chemical or physical environment, is regarded as abiotic stress and adversely affects plant growth, development, and/or productivity (Bray et al., 2000). Abiotic stresses such as drought, salt and low temperature, which adversely affect plant growth and productivity, lead to a series of morphological, physiological, biochemical and molecular changes in plants in order to adapt and as such survive under stress conditions (Wang et al., 2003). Plant productivity is severely affected by abiotic stresses. Abiotic stresses negatively influence survival, biomass production,

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accumulation and grain yield of most crops (Grover et al., 2001).

2.2 Temperature Stress

Temperature is an important environmental component that influences crop development and growth (Slafer and Rawson 1994). Heat stress is commonly defined as a temperature rise that exceeds a threshold level for a long enough period of time to cause irreparable damage to plant growth and development. Plants undergo a variety of adaptations in response to heat stress. Heat stress impacts wheat at many phases of growth and development, resulting in significant yield loss. The effect of HS on plants, on the other hand, is dependent on the length of heat exposure and the stage of growth during the high temperature period (Balla et al. 2012). Wheat photosynthesis is reduced due to poor germination, lower leaf area, early leaf senescence, and impaired photosynthetic machinery caused by heat stress.

Wheat morphology, physiology, and biochemistry are all affected by heat stress. Wheat undergoes physiological, biological, and biochemical changes as a result of high temperatures (Asseng 2015). Heat stress (HS) in wheat results in poor seed germination, shorter grain filling times, fewer grains, inactivation of the Rubisco enzyme, reduced photosynthetic capability, slower nutrient transport, premature leaf senescence, lower chlorophyll content, and lower yield. Grain starch and protein composition are also affected by HS. HS causes the generation of reactive oxygen species (ROS), which leads to membrane instability, lipid peroxidation, protein oxidation, and nucleic acid damage.

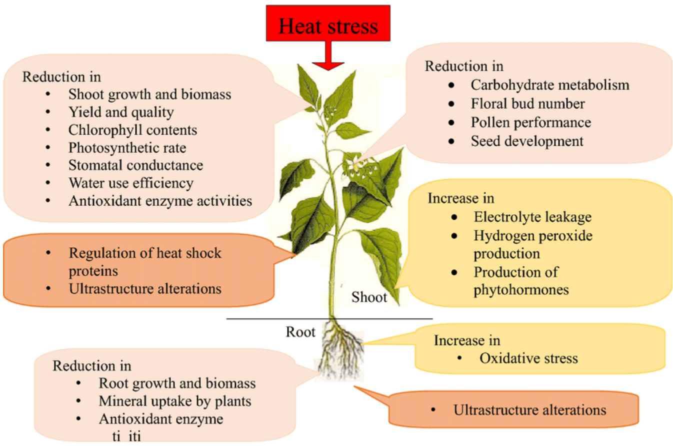

Figure 1: Possible effects of heat stress on different parts of plants (Ali et al., 2020)

Nepal is growing wheat in 0.7 million hectares of land on average annually between 2006-2017. The average

2.3 Moisture Stress

2.3.1 Drought

Drought is one of the most prevalent environmental challenges that plants face as they grow and develop. Drought is a significant concern for agricultural scientists and plant breeders. Around 1.8 billion people are expected to experience complete water scarcity by 2025, with 65 percent of the world's population living in underwater-stressed settings. Water stress tolerance is a complex measure that can be altered by a variety of factors (Nezhadahmadi et al., 2013). Drought stress causes morphological, physiological, and biological changes in plants. Drought causes distinct morphological changes in wheat crops, which can be noticed at various phases of plant growth.

The morphological response of wheat can be divided into two parts: the shoot part and the root part. Changes in leaf form, leaf expansion, leaf area, leaf size, leaf senescence, leaf pubescence, leaf waxiness, cuticle tolerance, and shoot length are all components of the shoot. Changes in root dry weight, root density, and root length are all included in the lower root section (Denčić, et al., 2000). Drought stress has been linked to a wide range of physiological responses. Drought stress on wheat crops is mitigated by a variety of physiological characteristics. There is a direct link between the availability of water and the effectiveness of several plant physiological systems. These physiological processes are disrupted when water availability is reduced, and plants are unable to create appropriate amounts of dry matter. Plant nutrient intake, growth rate, and height, as well as photosynthetic activities and dry matter production, are all reduced during drought conditions, according to studies. Water deficiency also causes a decrease in chlorophyll concentration, a decrease in water content, and a decrease in membrane stability (Rijal et al., 2021).

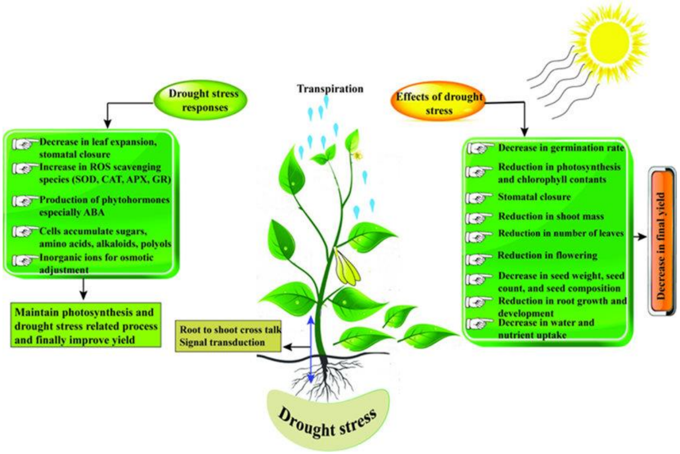

Figure 2: Effect of drought stress (DS) on plants and possible responses (Nadeem et al., 2019)

Wheat plants collect proline content to a greater extent than any other osmoregulators due to a lack of water. It has been found that when wheat plants are subjected to drought stress, their proline content increases (GruszkaVendruscolo et al., 2007). When wheat is subjected to water stress, the greatest amount of proline is seen to increase in the heading stage (Maralian et al., 2010). Several studies in wheat have found that the antioxidant defence system in the plant changes its activity in response to oxidative stress caused by a variety of environmental conditions such as drought.

2.3.1 Water Logging

When there is too much water in a plant's root zone, it causes waterlogging, which reduces the amount of oxygen available to the roots. Waterlogging can be a serious stumbling block to plant growth and output, and in some cases, it can even kill plants. This constraint may not be visible until the entire soil profile has been saturated and water has surfaced. Waterlogging and yield loss in wheat are caused by heavy rainfall, floods, poorly drained soil, or incorrect irrigation management. Waterlogging stress reduced yield, spike number per m2, seed weight and number per spike, protein content, and chlorophyll a and b levels, as well as increasing proline levels. Climate change is the main reason for waterlogging which includes higher risk of flood and increase in precipitation. Increase in population and demand for wheat varieties which is better adapted to temporary water logging and oxygen deficiency.

When soil is introduced to water logging, water displaces air from the pore space in soil and soil microorganisms and plant roots respire the remaining oxygen and reservoir is rapidly emptied. As we know, waterlogging cause oxygen deficiency which has immediate impact on plant cell respiration and inhibit adenosine triphosphate (ATP) synthesis through oxidative phosphorylation pathway. Setter et al. found grain yield loss in wheat varied from 16 to 49% in wheat varieties. Number of tillers, spikelet per spike and floret formations per spikelet as well as grain weight decreases due to water logging. A group researcher registered a wheat yield loss equivalent to 175 kg per hectare per one day when water logging occurred in stem elongation period (Marti et al., 2015). Water logging has a great impact on both root and shoot traits. Leaf extension and/or reduced biomass accumulation, foliar chlorosis or reduced chlorophyll content as well as leaf senescence is seen due to water logging.

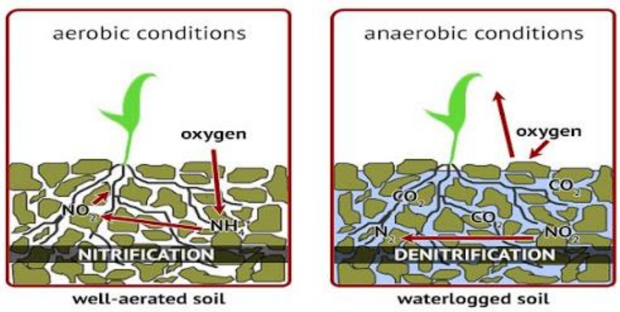

Figure 3: Aerobic Condition and Anaerobic Condition in plant (Bureau 2018)

Wheat is a versatile crop that thrives in a variety of temperatures and environments. Waterlogging causes oxygen deficiency, prevent to root and shoot growth, reduce the accumulation of dry matter and as a result of these yield is reduced. Wheat (Triticum aestivum L.) is one of the most sensitive crops to waterlogging in the soil (Thomson et al., 1992). Long durations of rain combined with inadequate soil drainage can result in low oxygen levels in the soil. Under flooded conditions, a decrease in soil O2 is frequently accompanied by a rise in soil CO2 and ethylene content.

Wheat root and shoot growth are harmed as a result of these changes (Manske and Vlek 2002). Productivity from soils susceptible to waterlogging may be increased by drainage and the introduction of waterlogging-tolerant genotypes (Thomson et al., 1992). The harmful impacts of waterlogging are exacerbated by high temperatures. Depending on the crop's stage of growth at the moment stress is administered, yield is altered differently (Brisson et al., 2002). Plants with older leaves show chlorosis and necrotic patches on wet sites. Low redox potential in wet soils, which creates plant-available Mn2+ and promotes denitrification of N O3, can cause both Mn toxicity and N shortage. Root metabolism and root growth are impeded in these anaerobic conditions because the plant's energy status is affected by the lack of oxygen (Steffens et al., 2005).

2.3.2 Salinity

Salinity is defined as a high salt content in soil with high concentrations of ions such as Na, Cl, Mg, SO4, and HCO3. Approximately 20% of the total cultivated land and 33% of irrigated agricultural land around the world are affected by salinity (Shrivastava and Kumar 2014). In Nepal, there is tremendous problem of Salinity in arid and semi-arid regions. Irrigation, evapotranspiration, naturally salty soil, low rainfall, poor drainage and high number of fertilizers are the major sources of soil salinity. Reduced germination, interrupted photosynthesis, altered enzymatic activity, altered reproductive behaviour, hormonal instability, and reduced growth are all symptoms of salinity, one of the most damaging abiotic stresses (Hasanuzzaman et al., 2017). Salinity lowers the germination and growth rate of wheat. Excess salt concentration reduces the water uptake by roots resulting in water stress and nutrient stress. Long term exposure to salinity leads to premature senescence of adult leaves lowering the net photosynthetic rate. Salinity reduces the cell division and cell expansion causing overall plant stunting. Thus, Salinity ultimately results in reduction of yield of wheat.

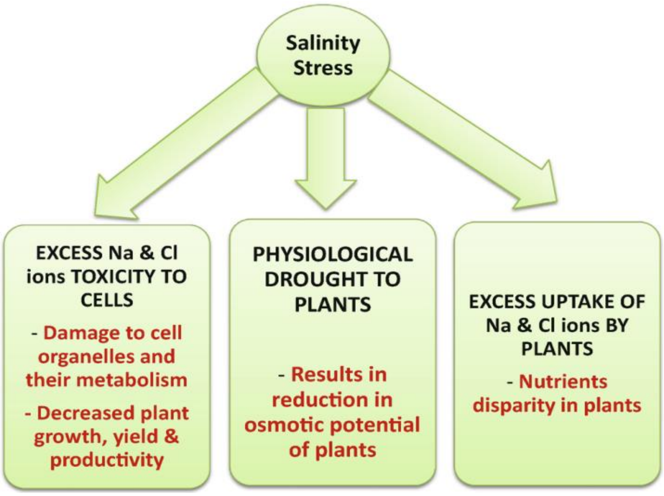

Figure 4: Effect of salinity stress on plants. Salinity stress results in physiological drought to plants as a result of water deficit, disparity in macro- and micronutrient uptake and composition as a result of excessive toxicity due to Na and Cl ion accumulation thereby leading to damage of cell organelles and disruption of essential metabolic activities, ultimately resulting in poor plant growth and reduces plant productivity (Okon 2019).

Wheat is considered most sensitive to salinity during germination and during tiller appearance (Ayers et al., 1952). With increasing salinity tillering capacity is reduced (Ehtaiwesh 2016). Under saline condition, the number of effective ears per plant is the most seriously affected yield component (Mass and Hoffman 1977). Salinity also reduces the number of leaves in the main shoot as well as the number of spikelets in the main spike, lowering seed set and grain production (Mass and Grieve 1986). The physiological responses of cereals to overcome salinity stress differ according to different growth stages and also with the severity of the stress. The response of plants to salinity stress is affected by the nature of the salts present in the soil (Ehtaiwesh 2016). The ability of cereal plants to manage the entry of salts into their shoots through the transpiration stream is critical for their continued growth in salinity (Greenway and Munns 1980).

3. Conclusion

Abiotic stress is found to be a major concern of agriculture production. The physiological, morphological and biochemical alterations in the cells induced by abiotic stress reduces the growth and development of plant that ultimately decrease the yield of wheat. Rapid change in earth climate have been accelerating abiotic stresses like temperature stress, moisture stress, salinity leading into yield losses that may bring problem in food security in future. From the study of several research papers, it is concluded that in order to cope with these abiotic stresses, the development of stress tolerant wheat genotypes to be used in agriculture production is highly needed. Besides, appropriate agronomic management practices like adjusting the sowing time according to the climatic and edaphic condition of the respective area, selection of appropriate planting method, adopting conservation agriculture practices like minimum tillage, irrigation scheduling, soil amendments, integrated nutrient management can play an important role to manage the abiotic stress.

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