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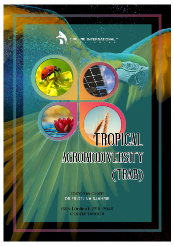

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RESEARCH ARTICLE

BIOCHEMICAL AND PHYSICAL CHANGES DUE TO DROUGHT STRESS IN WHEAT (*Triticum aestivum L.*)

Niruta Gautam, Mamta Sah, Laxmi Bhandari, Saraswati Aryal, Jyoti Kafle, Sudha Pokharel, Keshav Dhakal

Institute of Agriculture and Animal Science, Paklihawa Campus, Nepal
****Corresponding author mail address: nirutagautam2076@gmail.com***

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ABSTRACT

Wheat is the major staple cereal crop of the world population. In developing countries like Nepal, cultivation of wheat is dependent upon the monsoon and the irregular monsoon gives way to the drought condition. The studies and researches of recent years have found pronounced effect of drought on the wheat production. The drought stress in crop leads to several changes in the physiological, morphological and biochemical traits leading to the economic losses. The morphological changes can be viewed through two ways as change in shoot and root system such as effect on plant height, leaf senescence, flowering and so on. Similarly, physiological changes involve change in cell growth pattern, chlorophyll content, photosynthesis disturbance and biochemical changes occur in concentration of different chemicals and activity of different enzymes, hence resulting alteration in the natural processes in different phenological stages of wheat. To reduce the effect of drought stress, various approaches have been made but the more focus has been given in the identification of traits that yields high rather than introducing those traits which show better responses towards environmental irregularities. This review study is done to assess the various changes in characters of wheat due to drought and their effect on the crop yield and productivity.

KEYWORDS

Leaf senescence, Biochemical, Morphological, Physiological.

1. INTRODUCTION

Wheat (*Triticum aestivum*) is an important food grain cereal which contributes about 21% to world food supply (Al-Maskri et al., 2016). It is the number one crop in the world and ranks in third position in Nepal after rice and maize in terms of cultivated area and total production according to Wheat (MoAD, 2015). It contributes highest percentage of calorie and protein to the world's diet. Also provides substantial number of numbers of components which are beneficial for health, notably protein, vitamins (notably vitamin B), dietary fibers and phytochemicals (Shewry and Hey, 2015). In Nepal, wheat is generally cultivated under rainfed condition due to which it faces various environmental stresses, drought stress being one of the severe among them.

Drought usually occurs from march through June, which is onset of monsoon and winter precipitation has almost declined to zero, also ground water has hardly been replenished (Joshi, 2018). Drought stress results when water is lost from the plants in the amount that exceeds the ability of the plant roots to absorb the water (Al-Maskri et al., 2016). The predicted global warming and climate fluctuation increases the frequency of drought, therefore leads to the loss of the wheat yield (Rezaei et al., 2018). Judicious to enhance drought stress considerably disturbs several morphological, physiological and biochemical functions of the plant in various stages of its growth negatively affecting the plants growth and development (Al-Maskri et al., 2016).

Drought reduces wheat biomass and yield by 25% and 27.5% respectively (Zhang et al., 2018). The low winter precipitation in 2015/2016 reduced winter crop yield, affecting 87 per cent of the population across Western Nepal (Sharma and Pokharel, 2021). It is also assumed that by the year 2025, around 1.8 billion people will face absolute water shortage and 65% of the world population will live under water stress environments (Nezhadahmadi et al., 2013a). Drought stress influences plants in term of protein changes, antioxidant production, osmotic adjustment, hormone composition, root depth and extension, opening and closing of stomata, cuticle thickness, inhibition of photosynthesis, decrease in chlorophyll content, reduction in transpiration and growth inhibition to stand with some osmotic changes in their organs and also causes pollen sterility, grain loss, accumulation of abscisic acid in spikes of drought susceptible wheat genotype, and abscission acid synthesis genes in anthers (Nezhadahmadi et al., 2013a).

2. METHODOLOGY

The review is based on secondary source of information. The sources include published reports, articles, books etc. from ResearchGate, PubMed,

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Google Scholar etc. The sources of information were acknowledged in main text and reference in APA style using EndNote X7.

3. Discussion

Drought is one of the most crucial environmental stresses and occurs for various reasons, including erratic rainfall, salinity, fluctuating temperatures and high intensity of light. It is a multi-dimensional stress and brings alternation in the physiological, morphological, biochemical and molecular attributes in plants. Different development stages of plant from germination, vegetative and reproductive stages to grain filling and maturation of crops are disturbed when the plant suffers from drought stress (Ahmed et al., 2018). Such changes in wheat crops are explained as below:

3.1 Morphological Changes

As per a response of drought, there occur various morphological changes in wheat crops, which are directly observed throughout the different stages of plant growth. Generally, the morphological response of wheat towards drought is reflected on the shoot part and root part. The response in shoot part includes change in leaf shape, leaf expansion, leaf area, leaf size, senescence, pubescence, waxiness & cuticle tolerance and response in root part includes change in dry weight, density and length (Bartels and Sunkar, 2005). In overall view, the morphological change includes small plant size, early maturity, reduced leaf area, reduced yield, limited leaf extension, diminished leaf size, decrease the number of leaves, reduced leaf longevity, increased root-to-shoot ratio, reduced total shoot length and decreased plant height (Nezhadahmadi et al., 2013a).

3.1.1 Change in plant height

Under serious water shortage, cell elongation of wheat can be altered by interruption of water flow from the xylem to the surrounding elongating cells (Anjum et al., 2011). The reduced water availability leads to fall in turgor pressure and dehydration of protoplasm, impaired mitosis which can result in reduced expansion of cell and cell division and hence growth is diminished (Siddique et al., 2000).

3.1.2 Changes in leaf

During drought, leaf extension becomes limited in order to get balance between the water absorbed by root and water status of plant tissues (Lonbani and Arzani, 2011). Mesophyll cells of the Leaf start losing water and become dehydrated. This results in increment of the abscisic acid in guard cells of chloroplast and mesophyll cells. Change in acidity results in change in the osmotic pressure and results in minerals like potassium and calcium out of the guard cells. Loss of minerals, result in closure of the guard cell of the leaves (Fathi and Tari, 2016; Tezara et al.,1999). This causes in distortion of shape and size of the leaf. This also results in lowered photosynthetic activities as the leaves curl in response of dehydration.

Table 1: Reduction (%) in various wheat traits under drought and heat stress conditions

SN	Trait	Drought stress (%)
1	Plant height	11.6
2	Productive tillers	19.7
3	Days to heading	6.2
4	Days to anthesis	3.8
5	Days to maturity	4.5
6	Grain filling duration	6.7
7	Number of grains per spike	4.4
8	Grain weight per spike	3.7
9	Thousand grains weight	-1.1
10	Grain yield	29.1

Source (Sareen et al., 2014)

3.1.3 Change in root system

Plant root obtains minerals and water from the soil. When there is scarcity of water, root growth is favored over shoot growth i.e., the plant root goes deep into the soil and laterally in order to survive against drought condition. The adaptive mechanism shown by wheat in order to fight against drought stress are osmotic adjustment of root, increase root penetration to the soil, increased root density and increased root to shoot ratio (Ali et al., 2020). Similarly, there is increase in cross section diameter which helps in maintaining water retention in vascular bundles of wheat and also, there is increase in sclerenchyma cell diameter and decrease in aerenchyma cell formation during drought stress (Henry et al., 2012).

Figure 1: Root development on wheat plants making a difference in drought year (Kay, 2018).

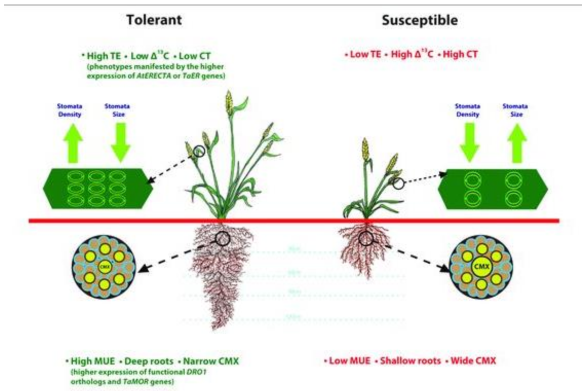


Figure 2: Root and stomatal traits that define drought tolerant and susceptible wheat plant ideotypes (Kulkarni et al., 2017).

3.2 Physiological Changes

In drought condition, various physiological changes occurs which causes about 30-50% reduction in plant growth and this changes includes closure of stomata, decrease in the activity of photosynthesis, development of oxidative stress, alteration in the integrity of cell wall, production of metabolism which are toxic and causes plant death (Alghabari and Ihsan, 2018; Blum, 1998; Nezhadahmadi et al., 2013a). It also causes turgor loss and adjustment of osmosis, reduction in water potential of leaf, decrease in stomata conductance to CO_2, reduction in internal CO_2 concentration, decline in transpiration, developed water use efficiency, reduced relative water content, enhanced of AOX (Alternative oxidase) path way etc (Nezhadahmadi et al., 2013a).

Drought stress during the initial stage of seed development reduces ability of kernel/seed sink strength by decreasing the number of endosperm cells and amyloplasts formed, thus reducing grain yield with a decline in endosperm competence to gather starch in terms of both rate and duration (Dupont, 2008). Drought reduces photosynthesis, a source strength, and also the turgor in phloem cells, thereby increasing the viscosity of sucrose to inhibit its flow through the conducting cells towards the sink seed (Sevanto, 2014). Evaluation of wheat genotype under drought stress illustrated that drought tolerance genotype accumulate higher concentration of physiological indices such as free proline, glycine, betaine, total sugars, and potassium content (Gupta et al., 2014).

Similarly leaf mesophyll cell become dehydrate due to drought. The amount of abscisic acid stored in the chloroplast of guard cell is used and the construction of ABA in the guard cell and mesophyll cells increase and with the increase of ABA, potassium and calcium comes out of the guard cell, resulting in the closure of stomata and decrease in rate of photosynthesis due to decrease of photosynthetic enzymes (Heidari and Moaveni, 2009). According to long duration drought stress leads to denature of stomata in guard and mesophyll cell, reducing the diffusion of CO_2 resulting in the fall of photosynthetic activities (Lawson et al., 2008).

3.3 Biochemical Changes

Water stress contributes to the drastic changes in the biochemical attributes of the wheat plant. These changes include reduction in rubisco efficiency, declined photochemical efficiency, produced reactive oxygen species (ROS), oxidative damage, antioxidant defense, ABA generation, diminished chlorophyll content, proline production, polyamine generation, increase in antioxidative enzymes, carbohydrate production & ABA accumulation (Nezhadahmadi et al., 2013a).

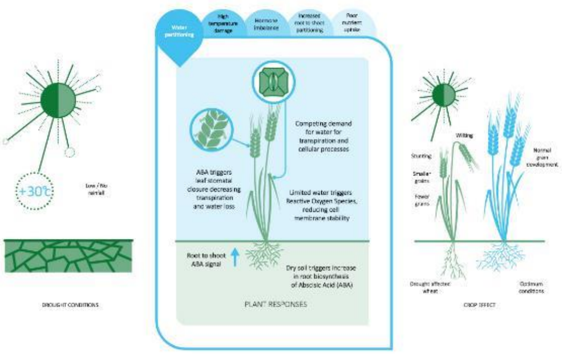


Figure 3: Stress response of plant to drought (Plantimpact, 2020)

Proline content is increased under drought stress conditions (Saleem et al., 2017). Proline is one of the major amino acids which is produced by wheat in response to water stress. Genotype having maximum proline content would be able to survive under drought stress condition as it protects them embraces from damage under stress and can be used for the development of drought tolerant varieties (Nowsherwan et al., 2018). It is found that the maximum amount of proline increase in heading stage of wheat is under water stress condition (Maralian et al., 2010). Similarly, drought stress leads to an imbalance between anti-oxidant defenses and the amount of reactive oxygen species(ROS) resulting in oxidative stress (Fathi and Tari, 2016).

3.4 Effect Of Drought Stress in Phenological Growth Stages of Wheat

3.4.1 Vegetative stage

The first and foremost effect of drought is impaired germination and poor seedling stand (Harris et al., 2000). The germination of wheat seeds is inhibited by drought stress as the germination energy significantly decreases with the increase of drought degree (Duan et al., 2017). Drought during vegetative stages affect wheat performance mainly by reducing total dry matter accumulation (Abid et al., 2018). The yield of wheat was found to decrease due to drought in tillering stage by 27.4 % and in jointing stage by 21.4% (Zhang et al., 2018). Severe water deficit during the vegetative stage results in reduced leaf area and this in turn affects tillering and spike size (Mayaki et al., 1976). Photosynthesis in the leaves, peduncle and spike is reduced resulting in decreased dry matter accumulation (Nagarajan et al., 1999).

Table 2: Showing reduction on growth stage due to drought stress

SN	Growth of stage	Reduction (%)
1	Vegetative	50-91
2	Flowering	13
3	Reproductive	45-70
4	Grain filling	60-80
5	Seed filling	49-57

Source: (Mohammadi, 2018)

3.4.2 Reproductive stage

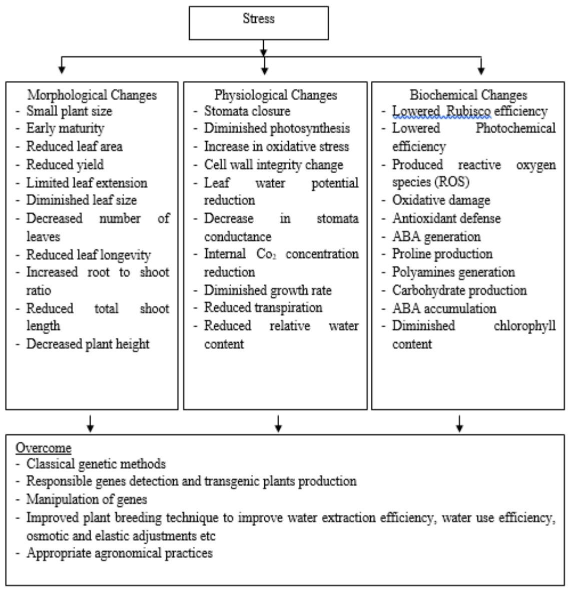
During meiosis, cells are extremely sensitive to moisture content and a drought at this stage will cause pollen sterility and spikelet death while at anthesis, drought can cause further reduction in seed set (Saini and Lalonde, 1997; Schmidt et al., 2020). Stress after anthesis result in smaller seed size both from direct effect on the grains and of accelerated flag leaf senescence (Jamieson et al., 1995; Schmidt et al., 2020; Hafsi et al., 2000). It is estimated that the drought during heading stage reduces yield by 17.7% and during grain filling stage by 16.3% (Zhang et al., 2018).

Figure 4: Spikes of (A, C) controlled and (B, D) HD-stressed (A, B), 7 days after anthesis (DAA). Sterile florets located in the upper half in D (Fábián et al., 2019)

3.4.3 Maturity stage

According to the decrease in the maturity days under drought stress is due to the lowering of nutrients in the plant i.e (Khan et al., 2017). Nitrogen needed for assimilation which cause decrease in chlorophyll content in the leaves. It results in early senescence ultimately leading plant to mature earlier (Kataki, 2001; Bhandari, 2012; Adhikari, 2018). Grain filling period is an important phenological traits that is associated with current photosynthesis and relocation of assimilates from reserve pool in vegetative tissues. Drought shortens the lifecycle and duration of grain filling due to the accelerated leaf senescence, reduced photosynthesis and sink limitation (Pour-Aboughadareh et al., 2020). The wheat yield loss is higher when drought is experienced in seed germination phase and reproductive phases reducing seed robustness by limiting soil moisture availability (Hussain et al., 2018). The wheat crops grown in the central and eastern region of Nepal were found more sensitive to drought but were less sensitive in western region of Nepal during the period of 1987-2017 (Hamal et al., 2020).

Table 3: Changes and overcoming strategy of drought stress in wheat



Source: (Nezhadahmadi et al., 2013b)

4. Conclusion

In the context of Nepal, drought has severely caused reduction in the yield of the wheat crop, the yield being highly deviated from actual yield potential. The average yield of wheat in Nepal during drought condition was found to be 1.6 ton/ha, which is far below the average yield of south Asian countries i.e. 2.5 ton /ha. Drought stress retards crop growth and development to a large extent by bringing changes in morphological, physiological and biochemical attributes of crops in different growth stage of wheat. The effect was comparatively more pronounced at tillering stage. As agriculture contributes about 27% of Nepal's total GDP, it is important to better understand the impact of drought on wheat crop yield to minimize drought stress effect. Various wheat breeding programs have been working to develop varieties suited to rainfed condition since its inception, but the progress in drought tolerance breeding is slow, mainly due to lack of appropriate technique as mass screening of large scale genotype to physiological drought resistance. Drought related risk can also be minimized by adopting small scale measures such as rain water harvesting, conservation ponds and irrigation channels, drip water irrigation and early warning system for drought events. In addition, various drought tolerant varieties need to be introduced through breeding programs. More approaches need to be forwarded towards the development of trait which shows better performance in environmental irregularities instead of introducing those which yields high.

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