DROUGHT AND ITS EFFECT ON BARLEY

Abstract

Most of the world's areas use more than 70 percent of its freshwater for agriculture. Worldwide, abiotic stress conditions are an issue. In many dry and semi-arid regions, where climate change has a considerable influence, water scarcity and drought stress are thought to be the most crucial environmental parameters, lowering crop output. Drought stress seems to have a straightforward impact on plant productivity and output. The intentions of this article are to assess relevant information on general drought tolerance processes in important agricultural production and to present the most notable, trimming insight on drought-coping mechanisms in crops, with such a greater emphasis on barley. The term "drought" describes a lack of soil moisture or a water shortage. The dry and semi-arid tropics, as well as regions having steep slopes, are more likely to suffer from soil drought. Drought resistance is a broader term for plant species that have adaptive traits that permit them to endure, avert, or tolerate drought stress. Plants respond to drought stress with a range of different of morphological, biochemical, and physiological reactions, as well as a molecular system that starts in when there is a water scarcity. The world's temperate and tropical climates both cultivate the major rabi cereal crop known as barley. In the last century, barley was primarily planted and utilised to supply human food, but it is currently widely grown for animal feed, malt products, and human food, in that order. Historically, distinct varieties of barley have been divided into two rowed and six rowed varieties based on physical characteristics.

Keywords: Drought, Barley, escape, avoidance, tolerance

Authors

K. B. Joshi
Ph.D. Scholar
Department of Genetics and
Plant Breeding Chimanbhai
Patel College of Agriculture
Sardarkrushinagar Dantiwada
Agricultural University S.K. Nagar
Banaskantha, Gujarat, India

Gauravrajsinh K. Vaghela
Ph.D. Scholar
Department of Genetics and
Plant Breeding Chimanbhai
Patel College of Agriculture
Sardarkrushinagar Dantiwada
Agricultural University S.K. Nagar
Banaskantha, Gujarat, India

I. INTRODUCTION

Most of the world's areas use more than 70 percent of its freshwater for agriculture (FAO, AQUASTAT data). Agriculture can use more water than 90% over all water usage in regions with a water shortage, which covers many developing countries (Boyer, 2017). In many nations around the world, food production is constrained by a water shortage. In plants, it manifests as a wide range of morphological, physiological, biochemical, genetic, and even drought-induced alteration in gene expression levels. (Gerszberg and Hnatuszko-Konka, 2017).

Worldwide, abiotic stress conditions are an issue. In many dry and semi-arid regions, where climate change has a considerable influence, water scarcity and drought stress are thought to be the most crucial environmental parameters, lowering crop output (Wassmann *et al*., 2009). When we take into account the fact that more than one-fourth of the earth's land is comprised of dry and semi-arid regions, this problem becomes more apparent (Komeili *et al*., 2008). Cultivars that are tolerant of drought are necessary for high and sustainable yield production in arid environments. The ability to tolerate drought is a complex feature that requires intricate interactions with genes related to metabolism and stress tolerance. This makes it challenging to select cultivars that are resistant to drought using a common evaluation technique (Hao *et al*., 2011).

Drought stress seems to have a straightforward impact on plant productivity and output, with the germination and seedling development phases being the times when barley and the majority of other crops are most vulnerable to such conditions. Early on in seed development, drought stress slows and decreases the rate of germination. From the 1970s to the 2000s, the percentage of territory impacted by drought increased, and regrettably, the trend for the future appears to be similar (Mostajeran and Rahimi-Eichim, 2009).

Drought can occur at any phase of growth, subject to the local eco system. Since some genotypes could indeed withstand drought during germination or seedling stage but seem to be extremely sensitive to drought during the flowering stage, genotypes could be assessed for drought tolerance at appropriate and oftenly diverse stages of growth. Drought tolerance is determined by recognizing a characteristic that can be used to assess the effects of drought stress on plants. This characteristic ought to separate susceptible and tolerant genotypes. Selecting the right drought-tolerant attribute(s) is thus extremely crucial in any drought investigation. Furthermore, as farmers must produce their crops profitably while facing drought stress, drought tolerance and yield should be improved concurrently.

Climate change is anticipated to negatively impact crop output by increasing the frequency of dry spells and hot weather (Caine *et al*., 2019). Severe temperatures and drought stress incidences become increasingly common as climate variability intensifies (Wu et al., 2018). Climate change is anticipated to mitigate crop productivity by increasing the number of dry seasons and hot weather. (Caine *et al*., 2019). Extreme heat and drought stress episodes are occurring more frequently as a result of increased climate variability (Wu *et al*., 2018).

The intentions of this article are to assess relevant information on general drought tolerance processes in important agricultural production and to present the most notable, trimming insight on drought-coping mechanisms in crops, with such a greater emphasis on barley.

Every year, there is a drought somewhere in the world, which frequently has disastrous repercussions on food production (Ludlow and Muchow, 1990). Drought, often considered as a water deficit, which characterised by a lack of sufficient moisture that generally required by plant for their normal growth and for the completion of the life cycle (Zhu, 2002). In rainfed areas, inadequate irrigation and infrequent showers are the main contributors to the lack of appropriate moisture that results in water stress (Wang *et al*., 2005).

II. WHAT IS DROUGHT? AN EXPLANATION OF WHAT CAUSES DROUGHT

Lack of adequate water supply, including insufficient precipitation and soil moisture storage, during a crop's life cycle restricts the expression of its full genetic capability. The term **"drought"** describes a lack of soil moisture or a water shortage. The dry and semi-arid tropics, as well as regions having steep slopes, are more likely to suffer from soil drought.

As per the Folger (2017), drought is regarded as a naturally occurring hazard that could have serious effects on the economy, society, and environment. He defined it as a shortage of precipitation over a long period of time, typically a season or more. It could be simpler conceptually to comprehend drought through its effects. In order to categorise drought, Wilhite and Glantz (1985) used two criteria: Drought quantification and the consequences of drought A meteorological drought was the one based on quantifying the drought (it relates to degree of dryness and duration of dry period; rainfall and probabilities). According to the effects of drought, the other three types are agricultural drought, hydrological drought, and socioeconomic drought.

Being a complicated phenomenon, drought is challenging to observe and characterise. A dry spell occurs when there is no water. As drought is slowly progressing and which affects the majority of the economic sectors as well as occur at variety of time. The agricultural drought is caused by lack of adequate precipitation or rainfall over a longer period of time, which influence on agriculture. The crop water demands cannot be met by the available water supply. A time of insufficient surface and subterranean water for usage without a direct impact from a lack of precipitation is referred to as a hydrological drought. It has the possibility of influencing groundwater resources, soil moisture, reservoir and lake levels, and streamflow. After several months of meteorological droughts, hydrological droughts develop. The socio-economic drought is defined as the condition that occurring when the amount of water required for plant growth and development is much higher than the amount of water that plants can actually use due to a weather-related lack of water. This situation greatly affecting the human activity. Ground-water drought has been included as a new category, and is described as an imbalance that occurs between ground-water recharge and discharge amount of water (Mishra and Singh, 2010). Crop failure due to agricultural drought has the greatest relevance because it affects both people and animals. In terms of agricultural effects, a drought could be defined as a prolonged period of inadequate rainfall that causes serious crop loss, particularly yield decline. (Folger, 2017).

Finally, meteorological drought occurs whenever a region experiences a long spell of dry weather. That after a few months of meteorological drought, a hydrological drought begins to develop when there is a decrease in the water supply, most particularly in rivers, ponds, and underground water. Drought occurs in agriculture when crops are negatively affected. Moreover, socioeconomic drought attaches the availability and demand for various goods to the drought. Hydrological drought takes considerably more time to develop and recover than meteorological drought, which can start and stop quickly.

The variables mentioned below, which include the consequences of global climate change, the depletion of the subsurface water table, and irregular rainfall patterns, can all contribute to drought.

1. Lack of or insufficient precipitation
2. Change in climate
3. Anthropogenic activities
4. Overexploitation of surface water resources
5. Deforestation
6. Overgrazing
7. Greenhouse gas emissions

III. DROUGHT ESCAPE, AVOIDANCE, TOLERANCE AND RESISTANCE IN PLANTS

Drought resistance is a broader term for plant species that have adaptive traits that permit them to endure, avert, or tolerate drought stress.

Drought escape is the potential of a plant species to complete its life cycle before the commencement of drought. Plants do not experience drought stress due to its capacity to adjust their vegetative and reproductive growth in response to water availability. This is primarily due to two separate mechanisms: fast phenological development and developmental adaptability. The capacity of the plants to maintain relatively higher amount of tissue water content despite lower soil water content is described as drought avoidance. Avoidance can be achieved in a number of methods, including reducing water loss and improving water absorption. Under dry conditions, water spenders are plants that acquire higher tissue water by maintaining hydraulic conductivity and enhanced roots, whereas water savers are those that can utilise water more efficiently by declining in transpiration rate, transpiration area, radiation absorption, etc. Through adaptive features, plants can tolerate low tissue water content during droughts. These adaptive characteristics include enhancing protoplasmic resistance and maintaining cell turgor through osmotic adjustment and cellular flexibility (Basu *et al*. 2016). Therefore, stability of yield components should be emphasised rather than only plant survival in order to increase crop plant drought resistance.

1. **Mechanism of drought resistance:** Plants respond to drought stress with a range of different of morphological, biochemical, and physiological reactions, as well as a molecular system that starts in when there is a water scarcity.

   Water preservation in cell and tissues, stability of cell membrane, and naturally occurring growth regulators are a few examples of physiological systems. However, dry soil conditions that are thought to be molecular pathways cause a lack of cellular water in plants. Plants that are under water stress use some modifications in gene expression to counteract its potentially harmful effects. At the cellular, tissue, and organ levels, drought stress changes how plants relate to water, leading to both specialised and generalised reactions, damage, and adaptability processes.

2. **Morphological mechanisms:** Drought triggers a wide range of changes in plants, notably those that impact the entire plant, specific tissues, as well as the plant's physiological and molecular levels. The plant's capacity to endure dry conditions depends on whether one or more of its intrinsic modification’s manifests. Under dry conditions, plants use a variety of morphological strategies, including:

3. **Escape:** A shortened or quick life cycle or growth season gives plant chance to reproduce before environment gets adverse or dry, providing a means of escaping drought. A brief life cycle can enable drought escape, and flowering time is a crucial characteristic connected to drought adaptation. When phenological development and available soil moisture are well matched, drought escape occurs even though the growth period is shorter and terminal drought stress is more in occurrence (Araus *et al*., 2002). Flower initiation time is a critical aspect of crop adaptability, particularly when the growing season is strictly limited by end drought and high temperature levels. Short-duration cultivars had already proven to be an effective strategy for reducing reduction in yield due to terminal drought, as early maturity allows the crop to avoid the stress timespan (Kumar and Abbo, 2001). However, yield is predominantly associated with crop period under advantageous growing conditions, and any reduction in crop duration underneath the optimum would lower the yield (Turner et al., 2001).

4. **Drought avoidance:** Drought avoidance techniques entail mechanisms that minimise water loss from plants due to stomatal control of transpiration, and also mechanisms that maintain water uptake via a large and impactful root system (Turner et al., 2001; Kavar et al., 2008). Root attributes such as biomass, length, density, and depth are the main drought avoidance traits that make a contribution to yield attributes in terminal drought situations (Subbarao et al., 1995; Turner et al., 2001). A thick and deep root system is beneficial for extracting water from deep levels (Kavar et al., 2008). Waxy bloom on leaves tends to help to maintain high tissue water potential, creating it a desirable trait for drought tolerance (Richards et al., 1986; Ludlow and Muchow, 1990).

5. **Phenotypic flexibility:** Plants with small leaves had also come to be associated with xeric environments. Regardless of their actual growth rate and biomass, such plants tolerate drought very well (Ball et al., 1994). Leaf pubescence is a xeromorphic characteristic that provides protection the leaves from excessive heat. Hairy leaves hamper transpiration and elevate leaf temperatures (Sandquist and Ehleringer, 2003). By increasing the boundary layer resistance to water vapour movement away from the leaf surface, hairiness enhances light reflectance and diminishes water loss under elevated temp and radiation stress. The most essential plant tissue for drought adaptation is the roots. If tolerance is understood as the propensity to sustain leaf area and growth during long - lasting vegetative stage stress, the fundamental root system architecture appears to be the main differential, allowing the plant to uphold a more advantageous water balance. (Nguyen *et al*., 1997).

To sum up, plants could avoid drought stress by narrowing their growth life span and retaining tissue water potential, either by decreasing water loss or increasing water uptake, or both. Some plants can reduce the surface area of their leaves by shedding them or producing relatively small leaves.

6. **Physiological mechanisms:** Drought tolerance is typically focused on osmotic adjustment, osmo-protection, antioxidation, and a scavenging defence system.

7. **Cell and tissue water conservation:** Osmotic adjustment allows the cell to decrease its osmotic potential, which elevates the gradient for water ingress and, as a result, turgor maintenance. To improve tissue water status, adjustments in cell wall flexibility and/or osmotic adjustment could be used. This is required to maintain physiological function during prolonged drought. (1995, Kramer and Boyer). Osmotic adjustment, abscisic acid, and dehydrin activation have all been found to provide drought tolerance by ensuring consistent tissue water potential (Turner *et al*., 2001). As solutes build up, the cell osmotic potential decreases, thus water enters inside of the cell and aiding in maintenance of cell turgor. As there is active accumulation of different solutes in the cytoplasm and through osmotic adjustment water balance and cell turgor maintained in cell, which actively supress the negative effects that caused due to the dryness. (Morgan, 1990). To maintain cell turgor and various physiological functions, osmotic adjustment is a key characteristic in preventing dehydration-related harm in environments with limited water resources. (Taiz and Zeiger, 2006). The pre-anthesis carbohydrate partitioning is more effectively transferred during grain filling thanks to the osmotic adjustment. (Subbarao *et al*., 2000), maintenance of high turgor pressure ultimately leads to higher photosynthetic rate and plant growth (Ludlow and Muchow, 1990; Subbarao *et al*., 2000).

8. **Antioxidant defence:** Plant cell's antioxidant defence mechanism is made up of the enzymatic as well as the non-enzymatic components. Peroxidase, superoxide dismutase, ascorbate peroxidase, catalase, and glutathione reductase are examples of enzymes. Reduced glutathione, cysteine, and ascorbic acid are non-enzymatic components. (Gong *et al*., 2005). Different types of lipid- and water-soluble antioxidant enzymes and/or scavenging substances remove reactive oxygen molecules from plants. (Hasegawa *et al*., 2000); Antioxidant enzymes represent the most beneficial oxidative stress defences. (Farooq *et al*., 2009). Some antioxidant genes transcript which includes glutathione reductase and ascorbate peroxidase seems to be greater in fraction, thus believed to be involve in the defence mechanism of cells which acts against the ROS damage during the water deficit or scarcity period (Ratnayaka *et al*., 2003). Oxidative damage to the plant cell is reduced by the action of the enzymatic as well as non-enzymatic mechanisms of antioxidants (Hasegawa *et al*., 2000; Prochazkova *et al*., 2001).

9. **Cell membrane stability:** Stability of cell membrane, which is inversely correlated to cell unit membrane damage, is a physiological indicator that is frequently used to assess drought resistance. (Premachandra *et al*., 1991). Additionally, rice under drought stress has quantitative trait loci for this at various growth stages, indicating that the occurrence is genetically connected. (Tripathy *et al*., 2000). Dhanda *et al*. (2004) illustrated that membrane stability of the leaf segment was the most important attribute to evaluate for drought resistance in germplasm. Drought tolerance had also been assessed as a rise in

the cell membrane stability under water shortage conditions, which also was closely related to a decline in relative growth under stress (Premachandra *et al*., 1991). Arabidopsis leaf membranes' capacity to maintain polar lipid levels and the stability of their constituents in the context of severe drought appeared to suggest that they were especially resistant to water deficiency (Gigon *et al*., 2004).

10. **Plant growth regulators:** Plant physiological processes are influenced by substances that are created internally and applied externally as phytohormones and plant growth regulators, respectively. (Morgan, 1990) *i.e*., auxins, gibberellins, cytokinin, ethylene and abscisic acid. When there is occurrence of drought *i.e.* water shortage, levels of auxins, gibberellins, and cytokinin often declines while abscisic acid and ethylene levels typically increases (Nilsen and Orcutte, 1996). Abscisic acid inhibits development and is produced in response to many different environmental conditions, including drought. As response to water shortage all plants generally produce more abscisic acid. All flowering plants produce abscisic acid, which is generally regarded as a stress hormone that controls gene expression and serves as a signal to start processes that help plants adapt to environmental challenges like drought. Closing of the stomata is due to the increase in the abscisic acid and decline in the level of cytokinin (Morgan, 1990). Cereals generally respond to drought by losing leaf functionality and by hastening the senescence in older leaves. Ethylene may control a performance of leaf over the course of its life, as well as decide when natural senescence begins and mediate senescence brought on by drought. (Young *et al*., 2004).

11. **Compatible solutes and osmotic adjustment:** One of the most widely common strategies used by plants to deal with stress is the overproduction of different kinds of appropriate organic solutes (Serraj and Sinclair, 2002). Low-molecular-weight, completely soluble compounds known as compatibility solutes are frequently safe also at high cytosolic amounts. They protect plants from stress in a variety of ways, such as by assisting with osmotic adjustment, eliminating reactive oxygen species, maintaining membranes, and maintaining native enzyme and protein structure. When under abiotic stresses, osmotic adjustment is a procedure to maintain water relations. It involves the accumulation of a wide range of osmotically active compounds, including soluble sugars, sugar alcohols, organic acids, calcium, potassium, chloride, proline, glycine betaine, and sugar alcohols. Water is drawn into the cell and helps maintain turgor when the osmotic potential of the cell is decreased due to water deprivation and solute buildup. Osmotic adjustment, which enables the organelles and cytoplasmic functions to operate at a pace that is generally normal, allows plants achieve higher levels of growth, photosynthesis, and assimilation partitioning to grain filling (Ludlow and Muchow, 1990; Subbarao *et al*., 2000).

12. **Molecular mechanisms:** In the event of drought, a number of genes are transcriptionally stimulated, and the gene products from these genes are hypothesised to contribute to drought tolerance (Kavar et al., 2008). It is possible for secondary stresses, damage reactions, or direct stress conditions to activate gene expression. Nevertheless, it is widely known that tolerance to drought is a complicated phenomenon requiring the coordinated activity of numerous genes (Agarwal *et al*., 2006; Cattivelli *et al*., 2002).

13. **Aquaporins:** Aquaporins help in regulating the passive exchange of water across cell membranes. They are highly conserved intrinsic membrane proteins (Tyerman *et al*., 2002). The plasma membrane and vacuole membrane of plants are both rich in aquaporins. The fundamental process of protein-mediated membrane water transport was identified by an investigation of the structure of aquaporin. The link between aquaporins and plant drought resistance is still unclear, despite the fact that the identification of aquaporins in plants has caused a paradigm shift in our knowledge of plant water interactions (Maurel and Chrispeels, 2001).

14. **Stress proteins:** Stress protein synthesis is a resultant due to the common response to stressful conditions. The majority of stress proteins are water soluble and thus contribute to tolerance to stress by cellular structures hydration (Wahid *et al*., 2007). Tolerance is individually associated with the production of a variety of transcription factors and stress proteins (Taiz and Zeiger, 2006).

15. **Signalling and drought stress tolerance:** Cell cycle checkpoints, deoxyribonucleic acid repair activities induced in reaction to deoxyribonucleic acid damage, and stress recognition via the redox system are examples of typical stress responses. Reactive oxygen species, calcium, calcium-regulated proteins, mitogen-activated protein kinase cascades, and cross-talk between various transcription factors are believed to play a role in the complexity of stress detecting, defensive performance, and acclimation signalling events. (Kovtun *et al*., 2000; Chen *et al*., 2000).

IV. BREEDING FOR DROUGHT TOLERANCE IN BARLEY

The world's temperate and tropical climates both cultivate the major rabi cereal crop known as barley (*Hordeum vulgare* L.). The most significant cereal crop, it was the first cultivated grain utilised by humans for food and for raising cattle (Potla *et al*., 2013). In terms of global cereal production, barley comes in fourth place, after wheat, rice, and maize, each of which accounts for around 30% of the total. (FAOSTAT, 2004). Poaceae is the family that includes barley (formerly called Gramineae or grass family). This crop has chromosomal number 14 (2n=2x=14) and is self-pollinated. Since the Stone Age, barley has been grown as a crop, making it one of the oldest domesticated plants ever. (Salamini *et al*., 2002).

In the last century, barley was primarily planted and utilised to supply human food, but it is currently widely grown for animal feed, malt products, and human food, in that order. The model crop status of barley in genetics, cytogenetics, pathology, virology, and biotechnology research is also well known (Hockett and Nilan 1985; Hagberg, 1987). Barley is grown in a wide diverse variety of temperatures around the world, from 4200 metres on Atipano and the Andes in Bolivia to 330 metres below sea level near the Dead Sea in the Middle East. According to sources, the Fertile Crescent of the Middle East, which includes Turkey, Iran, Iraq, and Lebanon, is where barley, the earliest grain crop, was first cultivated (Harlan, 1979). According to findings, domestication of barley began at least 17,000 years ago in the Nile River Valley of Egypt (Wendorf *et al*., 1979).

Taxonomic status of barley

Kingdom	Plantae
Subkingdom	Tracheobionta -Vascular plants
Superdivision	Spermatophyta - Seed plants
Division	Magnoliophyta - Flowering plants
Class	Liliopsida - Monocotyledons
Order	Cyperales
Family	Poaceae - Grass family
Genus	*Hordeum*
Chromosome No.(2n)	14

Historically, distinct varieties of barley have been divided into two rowed and six rowed varieties based on physical characteristics. *Hordeum spontaneum* is the name given to two-rowed barley with shattering spikes, whereas *H. distichum* is the name given to two-rowed barley with non-shattering spikes. *H. vulgare* L. (or *H. hexastichum* L.) is the scientific name for six-rowed barley with non-shattering spikes, while *H. agriocrithon* berg is the name for six-rowed barley with shattering spikes. Because of the modifications brought about by single genetic mutations and confirmed by cytological and molecular data, the most recent classifications have classified these forms as belonging to a single species, *H. vulgare* (Sarkar *et al*.).

Barley spikelets are typically arranged along the rachis in triplicate. Two row and six row variations are available. In wild barley and other Old-World species of Hordeum, only the central spikelet of a triplet bears fruit; the other two are reduced. Certain cultivars are known as two row barleys maintaining this characteristic. Fertile lateral spikelets have been produced in barley by one dominant and one recessive mutation. Six row barleys were the result. Recent genetic research has shown that the switch from two to six rows of barley is caused by a mutation in the gene vrs1. naked and hulled barley: Barley groats is the common name for hulled barley. It is barley in its full grain form, with only the outermost hull removed. A variety of cultivated barley with an easily detachable hull is known as "naked" or "hull less" barley. *Hordeum vulgare* var. nudum is its scientific name. (Sarkar *et al*.)
Screening Criteria for selecting drought tolerance genotypes

The selection criteria primarily based on morphological characters. Correlations between the yield and high heritable traits under stress are generally selected. Grain or economic yield under stress prevailing environment is usually the main trait for carrying selection.

Secondary characters should have

1. Genetically association with economic yield under stress,
2. High heritability,
3. Stable and feasible to measure,
4. Lack of association with yield loss in normal growth environments.

V. EFFECT OF DROUGHT ON QUANTITATIVE AND QUALITATIVE TRAITS OF BARLEY

Drought stress during early period of growth *i.e.*, germination stage lower down the germination ratio of seed. Seedling failure can be caused due to the lack of moisture in the soil surface after emergence of seedling (Abdel-Ghani *et al*., 2015; Al-Karaki *et al*., 2007). Drought stress can limit shoot elongation, leaf area, and tillering during the early vegetative phase (Barnabás *et al*., 2008). When it happens during gametogenesis and early grain commencement, or at the beginning of meiosis, drought has the highest influence on plant yield (Saini *et al*., 1999). The spike emergence and early stage of grain development are crucial stages for barley stress due to drought (Saini *et al*., 1999, Sehgal *et al*., 2018). During gametogenesis, drought stress results in pollen sterility, and it delays or completely prevents blooming during the growth of inflorescences and flowers. Conversely, a lack of endosperm cells during a drought limits the potential growth of the grain, hence diminishing grain weight and size. Finally, further in development, starch deposition in the endosperm is influenced by dryness in terms of its rate and duration (Saini *et al*., 1999; Alqudah *et al*., 2011).

The final stage of cereal grain development is seed filling. Several biochemical processes are involved in seed carbohydrate, protein, and lipid synthesis, as well as constituent import (Li *et al*., 2006). The moisture condition of the cells during the storage phase has a significant impact on the division of endosperm cells and the buildup of seed reserves. Low grain yield is caused by ovary abortion, decreased starch deposition, increased internal ABA level, and water shortages. (Andersen *et al*., 2002). Drought stress increases assimilate remobilization during the grain-filling stage, but it also accelerates senescence, reducing grain-filling duration (Plaut *et al*., 2004).

As per the Ceccarelli (1987), water shortage in early plant growth stages found to have negative effect on spikelet primordia, whereas water scarcity in later growth stages of plant generally flower and spikelet death or shattering. Economic as well as biomass yield was found greater under irrigated situation. While making selection for barley genotypes under stress two traits are primarily concerned are grain yield and thousand grain weight. Yield is significant and crucial trait for selection but is greatly influenced by environmental conditions (Vaezi B. *et al*., 2010). A genotype's performance under stress shows its yield capabilities and its response to stress condition (Sadiq *et al*.,1994). Plant performance can be improved by increasing the farm's share of total dry matter production or by improving economic performance (Koochaki and Srmdnya, 1993). Other character such as number of grain per spike is also believed to be important to cope with drought stress. Drought stress causes photosynthetic sources to decrease and enzyme activity to decrease, influencing this process (Koochaki, 2003).

Drought has caused a decrease in plant height in barley plants (Ahmed I M *et al*., 2013). Plant height decreased with increasing drought stress can be impaired to deficit photosynthesis due to low soil moisture and reduction in photosynthetic potential in plant, among other things. Irrigation has a positive effect on increasing plant growth and phenological stages in accordance with environmental conditions, and it also makes optimal use of resources in this process. (Sefatgol and Ganjali 2017).

Another significant trait that can be used to assess the barley genotypes performance under stress is relative water content. Increase in the performance of plant yield as well as stability under drought are due to the maintaining relative water content and high osmotic adjustment. Increased osmotic adjustment capacity is advantageous because it would help in maintenance of cells turgidity when there is rise in the stress condition at grain-filling stage. Drought significantly reduced the osmotic potential of barley (Ahmed I M *et al*., 2013).

A post-flowering dehydration tolerance mechanism is called "stay green." Delaying leaf senescence increases overall photosynthesis over the course of the crop life cycle and maintains consistent transpiration. Programs aimed towards improving barley may find the knowledge on the interrelationships between the qualities described above valuable. Breeders choose features to increase drought tolerance by considering phenotypic correlations in addition to genetic factors like heritability.

REFRENCES

[1] Abdel-Ghani, A. H., Neumann, K., Wabila, C., Sharma, R., Dhanagond, S., Owais, S. J. & Kilian, B. (2015). Diversity of germination and seedling traits in a spring barley (Hordeum vulgare L.) collection under drought simulated conditions. Genetic Resources and Crop Evolution, 62(2), 275-292.
[2] Agarwal, P. K., Agarwal, P., Reddy, M. K., & Sopory, S. K. (2006). Role of DREB transcription factors in abiotic and biotic stress tolerance in plants. Plant cell reports, 25(12), 1263-1274.
[3] Aharon, R., Shahak, Y., Wininger, S., Bendov, R., Kapulnik, Y., & Galili, G. (2003). Overexpression of a plasma membrane aquaporin in transgenic tobacco improves plant vigor under favorable growth conditions but not under drought or salt stress. The Plant Cell, 15(2), 439-447.
[4] Ahmed, I. M., Dai, H., Zheng, W., Cao, F., Zhang, G., Sun, D., & Wu, F. (2013). Genotypic differences in physiological characteristics in the tolerance to drought and salinity combined stress between Tibetan wild and cultivated barley. Plant Physiology and Biochemistry, 63, 49-60.
[5] Al-Karaki, G. N., Al-Ajmi, A., & Othman, Y. (2007). Seed germination and early root growth of three barley cultivars as affected by temperature and water stress. American-Eurasian Journal Agriculture and Environment Science, 2(2), 112-117.
[6] Alqudah, A. M., Samarah, N. H., & Mullen, R. E. (2011). Drought stress effect on crop pollination, seed set, yield and quality. In Alternative farming systems, biotechnology, drought stress and ecological fertilisation (pp. 193-213). Springer, Dordrecht.
[7] Andersen, M. N., Asch, F., Wu, Y., Jensen, C. R., Næsted, H., Mogensen, V. O., & Koch, K. E. (2002). Soluble invertase expression is an early target of drought stress during the critical, abortion-sensitive phase of young ovary development in maize. Plant physiology, 130(2), 591-604.
[8] Araus, J. L., Slafer, G. A., Reynolds, M. P., & Royo, C. (2002). Plant breeding and drought in C3 cereals: what should we breed for?. Annals of botany, 89(7), 925-940.
[9] Ball, R. A., Oosterhuis, D. M., & Mauromoustakos, A. (1994). Growth dynamics of the cotton plant during water- deficit stress. Agronomy journal, 86(5), 788-795.
[10] Barnabás, B., Jäger, K., & Fehér, A. (2008). The effect of drought and heat stress on reproductive processes in cereals. Plant, cell & environment, 31(1), 11-38.
[11] Basu, S., Ramegowda, V., Kumar, A., & Pereira, A. (2016). Plant adaptation to water deficit. F1000Research, 5, 1554.
[12] Boyer, J. S. (1982). Plant productivity and environment. Science, 218(4571), 443-448.

[13] Caine, R.S., Yin, X., Sloan, J., Harrison, E.L., Mohammad, U., Fulton, T., Biswal, A.K., Dionora, J., Chater, C.C., Coe, R.A., Bandyopadhyay, A., Murchie, E.H., Swarup, R., Quick, W.P., Gray, J.E. (2019). Rice with reduced stomatal density conserves water and has improved drought tolerance under future climate conditions. New Phytologist, 221(1), 371-384.

[14] Cattivelli, L., Baldi, P., Crosatti, C., Di Fonzo, N., Faccioli, P., Grossi, M., ... & Stanca, A. M. (2002). Chromosome regions and stress-related sequences involved in resistance to abiotic stress in Triticeae. Plant molecular biology, 48(5), 649-665.

[15] Ceccarelli S (1987). Yield potential and drought tolerance of segregating population of barley in contrasting environments. Euphetica 36: 265-273.

[16] Chen, W. P., Li, P. H., & Chen, T. H. H. (2000). Glycinebetaine increases chilling tolerance and reduces chilling- induced lipid peroxidation in Zea mays L. Plant, Cell & Environment, 23(6), 609-618.

[17] Dhanda, S. S., Sethi, G. S., & Behl, R. K. (2004). Indices of drought tolerance in wheat genotypes at early stages of plant growth. Journal of agronomy and crop science, 190(1), 6-12.

[18] Dhanda, S. S., Sethi, G. S., & Behl, R. K. (2004). Indices of drought tolerance in wheat genotypes at early stages of plant growth. Journal of agronomy and crop science, 190(1), 6-12.

[19] Farooq, M., Wahid, A., Kobayashi, N. S. M. A., Fujita, D. B. S. M. A., & Basra, S. M. A. (2009). Plant drought stress: effects, mechanisms and management. In Sustainable agriculture (pp. 153-188). Springer, Dordrecht.

[20] Folger, P., 2017. Drought in the United States: Causes and Current understanding. In: https://fas.org/sgp/crs/misc/R43407.pdf, Accessed 26 July 2018.

[21] Gerszberg, A., & Hnatuszko-Konka, K. (2017). Tomato tolerance to abiotic stress: a review of most often engineered target sequences. Plant growth regulation, 83(2), 175-198.

[22] Gigon, A., Matos, A. R., Laffray, D., Zuily-Fodil, Y., & Pham-Thi, A. T. (2004). Effect of drought stress on lipid metabolism in the leaves of Arabidopsis thaliana (ecotype Columbia). Annals of botany, 94(3), 345-351.

[23] Gong, H., Zhu, X., Chen, K., Wang, S., & Zhang, C. (2005). Silicon alleviates oxidative damage of wheat plants in pots under drought. Plant science, 169(2), 313-321.

[24] Hagberg, A. (1987). Barley as a model crop on plant genetic research. In proceedings of the 5th Int. Barley Genet. Symp. S.Yasuda and T.Konishi, eds., Sanyo Press, Okoyama, Japan, pp.3-6.

[25] Hao, Z. F., Li, X. H., Su, Z. J., Xie, C. X., Li, M. S., Liang, X. L., Weng, J. F., Zhang, D. G., Li, L., & Zhang, S. H. (2011). A proposed selection criterion for drought resistance across multiple environments in maize. Breeding science, 61(2), 101-108.

[26] Harlan, J.R. (1979). On the origin of barley. In Origin, Botany, culture, winter hardness, Genetics, Utilization, Pests. Agric. Handb. 338.US. Dept.Agr.Washington, D.C., pp. 10-36.

[27] Hasegawa, P. M., Bressan, R. A., Zhu, J. K., & Bohnert, H. J. (2000). Plant cellular and molecular responses to high salinity. Annual review of plant biology, 51(1), 463-499.

[28] Hockett, E.A., and Nilan R.A.(1985). Genetics. In Barley. D.C. Rasmusson, ed. American Society of Agronomy, Madison, WI, pp 187-230.

[29] Kavar, T., Maras, M., Kidrič, M., Šuštar-Vozlič, J., & Meglič, V. (2008). Identification of genes involved in the response of leaves of Phaseolus vulgaris to drought stress. Molecular Breeding, 21(2), 159-172.

[30] Komeili, H. R., Rashed-Mohassel, M. H., Ghodsi, M., & Zare-FeizAbadi, A. (2008). Evaluation of modern wheat genotypes in drought resistance condition. Agricultural researches, 4, 301-312.

[31] Koochaki, A. (2003). Organic farming of Esfarzeh and Pytaniom in response to water stress. Iran arable Journal, No 2 (1), pp.111-103.

[32] Koochaki A., & Sarmadnia, G. (1993). Crop Physiology (Translation). Mashhad University, Jahad Daneshgahi Press.

[33] Kovtun, Y., Chiu, W. L., Tena, G., & Sheen, J. (2000). Functional analysis of oxidative stress-activated mitogen-activated protein kinase cascade in plants. Proceedings of the National Academy of Sciences, 97(6), 2940-2945.

[34] Kramer, P. J., & Boyer, J. S. (1995). Water relations of plants and soils. Academic press.

[35] Kumar, J., & Abbo, S. (2001). Genetics of flowering time in chickpea and its bearing on productivity in semiarid environments.
[36] Li, M., Lopato, S., Kovalchuk, N., & Langridge, P. (2013). Functional genomics of seed development in cereals. In Cereal genomics II (pp. 215-245). Springer, Dordrecht.
[37] Li, X., Waddington, S. R., Dixon, J., Joshi, A. K., & De Vicente, M. C. (2011). The relative importance of drought and other water-related constraints for major food crops in South Asian farming systems. Food Security, 3(1), 19-33.
[38] Ludlow, M. M., & Muchow, R. C. (1990). A critical evaluation of traits for improving crop yields in water-limited environments. Advances in agronomy, 43, 107-153.
[39] Maurel, C., & Chrispeels, M. J. (2001). Aquaporins. A molecular entry into plant water relations. Plant physiology, 125(1), 135-138.
[40] Mishra, A. K., & Singh, V. P. (2010). A review of drought concepts. Journal of hydrology, 391(1-2), 202-216.
[41] Morgan, P. W. (1990). Effects of abiotic stresses on plant hormone systems. Plant biology (USA).
[42] Mostajeran, A., & Rahimi-Eichi, V. (2009). Effects of drought stress on growth and yield of rice (Oryza sativa L.) cultivars and accumulation of proline and soluble sugars in sheath and blades of their different ages leaves. Agric. & Environ. Sci, 5(2), 264-272.
[43] Nguyen, H. T., Babu, R. C., & Blum, A. (1997). Breeding for drought resistance in rice: physiology and molecular genetics considerations. Crop Science, 37(5), 1426-1434.
[44] Nilsen, E. T., & Orcutt, D. M. (1996). Physiology of plants under stress. Abiotic factors. John Wiley and Sons.
[45] Plaut, Z., Butow, B. J., Blumenthal, C. S., & Wrigley, C. W. (2004). Transport of dry matter into developing wheat kernels and its contribution to grain yield under post-anthesis water deficit and elevated temperature. Field Crops Research. 86(2-3), 185-198.
[46] Potla K. R., Bornare S. S., Prasad L. C., Prasad R. and Madakemohekar A. H. (2013) Study of Heterosis and Combining Ability For Yield And Yield Contributing Traits In Barley (Hordeum vulgare L.) The Bioscan. 8 (4): 1231-1235,
[47] Premachandra, G. S., Saneoka, H., Kanaya, M., & Ogata, S. (1991). Cell membrane stability and leaf surface wax content as affected by increasing water deficits in maize. Journal of experimental botany, 42(2), 167-171.
[48] Prochazkova, D., Sairam, R. K., Srivastava, G. C., & Singh, D. V. (2001). Oxidative stress and antioxidant activity as the basis of senescence in maize leaves. Plant Science, 161(4), 765-771.
[49] Ratnayaka, H. H., Molin, W. T., & Sterling, T. M. (2003). Physiological and antioxidant responses of cotton and spurred anoda under interference and mild drought. Journal of Experimental Botany, 54(391), 2293-2305.
[50] Richards, R. A., Rawson, H. M., & Johnson, D. A. (1986). Glaucousness in wheat: its development and effect on water-use efficiency, gas exchange and photosynthetic tissue temperatures. Functional Plant Biology, 13(4), 465-473.
[51] Sadiq, I. I. S., Siddiqui, K. A., Arain, C. R., & Azmi, A. R. (1994). Wheat breeding in a water- stressed environment. I. Delineation of drought tolerance and susceptibility. Plant Breeding, 113(1), 36-46.
[52] Saeidi, M.; Abdoli, M.; Azhand, M. And Khas, A. M. (2013). Evaluation of drought resistance of barley (Hordeum vulgare L.) cultivars using agronomic characteristics and drought tolerance indices. Albanian journal of agriculture science. **12**(4): 545-554.
[53] Saini H. S. and Westgate M.E. (1999). Reproductive Development in Grain Crops during Drought. Advances in Agronomy. 68:59-96.
[54] Salamini, F.; Ozkan, H.; Brandolini, A.; Schafer-Pregl; R. and Martin, W. (2002). Genetics and geography of wild cereal domestication in the near east. Nature Reviews Genetics. 3: 429-441.
[55] Sandquist, D. R., & Ehleringer, J. R. (2003). Population- and family- level variation of brittlebush (Encelia farinosa, Asteraceae) pubescence: its relation to drought and implications for selection in variable environments. American Journal of Botany, 90(10), 1481-1486.
[56] Sarkar, S. K. C. M. B., & Singh, S. S. Barley (Hordeum vulgare L).

[57] Sefatgol, F., & Ganjali, H. (2017). Evaluation of drought stress tolerance in advanced barley cultivars in Sistan region. Bioscience biotechnology research communications, 10(2), 276-286.
[58] Sehgal, A., Sita, K., Siddique, K. H., Kumar, R., Bhogireddy, S., Varshney, R. K., ... & Nayyar, H. (2018). Drought or/and heat-stress effects on seed filling in food crops: impacts on functional biochemistry, seed yields, and nutritional quality. Frontiers in plant science, 9, 1705.
[59] Serraj, R. A. C. H. I. D., & Sinclair, T. R. (2002). Osmolyte accumulation: can it really help increase crop yield under drought conditions. Plant, cell & environment, 25(2), 333-341.
[60] Serraj, R., Shelp, B. J., & Sinclair, T. R. (1998). Accumulation of γ- aminobutyric acid in nodulated soybean in response to drought stress. Physiologia Plantarum, 102(1), 79-86.
[61] Subbarao, G. V., Johansen, C., Slinkard, A. E., Nageswara Rao, R. C., Saxena, N. P., Chauhan, Y. S., & Lawn, R. J. (1995). Strategies for improving drought resistance in grain legumes. Critical reviews in plant sciences, 14(6), 469-523.
[62] Subbarao, G. V., Nam, N. H., Chauhan, Y. S., & Johansen, C. (2000). Osmotic adjustment, water relations and carbohydrate remobilization in pigeonpea under water deficits. Journal of plant physiology, 157(6), 651-659.
[63] Taiz, L., & Zeiger, E. (2006). Plant Physiology Sinauer Associates. Inc., Sunderland, MA.
[64] Tripathy, J. N., Zhang, J., Robin, S., Nguyen, T. T., & Nguyen, H. T. (2000). QTLs for cell-membrane stability mapped in rice (Oryza sativa L.) under drought stress. Theoretical and Applied Genetics, 100(8), 1197-1202.
[65] Turner, N. C., Wright, G. C., & Siddique, K. H. M. (2001). Adaptation of grain legumes (pulses) to water-limited environments.
[66] Tyerman, S. D., Niemietz, C. M., & Bramley, H. (2002). Plant aquaporins: multifunctional water and solute channels with expanding roles. Plant, cell & environment, 25(2), 173-194.
[67] Vaezi, B., Bavei, V., & Shiran, B. (2010). Screening of barley genotypes for drought tolerance by agro-physiological traits in field condition. African Journal of Agricultural Research, 5(9), 881-892.
[68] Wahid, A., Gelani, S., Ashraf, M., & Foolad, M. R. (2007). Heat tolerance in plants: an overview. Environmental and experimental botany, 61(3), 199-223.
[69] Wan, B., Lin, Y., & Mou, T. (2007). Expression of rice Ca2+-dependent protein kinases (CDPKs) genes under different environmental stresses. FEBS letters, 581(6), 1179-1189.
[70] Wang, Y., Ying, J., Kuzma, M., Chalifoux, M., Sample, A., McArthur, C., Uchacz, T., Sarvas, C., Wan, J., Dennis, D.T., McCourt, P. and Huang, Y., (2005). Molecular tailoring of farnesylation for plant drought tolerance and yield protection. The Plant Journal, 43(3), 413-424.
[71] Wassmann, R., Jagadish, S. V. K., Heuer, S., Ismail, A., Redona, E., Serraj, R., Singh, R. K., Howell, G., & Sumfleth, K. (2009). Climate change affecting rice production: the physiological and agronomic basis for possible adaptation strategies. Advances in agronomy, 101, 59-122.
[72] Wendorf, F., Schild, R., Hadidi, N.E., Close, A.E., Kabusıewicz, M., Wieckowska, H., Issawı, B. and Haas, H., (1979). Use of barley in the Egyptian late paleolithic. Science. 205: 1341-1347.
[73] Wilhite, D. A., & Glantz, M. H. (1985). Understanding: the drought phenomenon: the role of definitions. Water international, 10(3), 111-120.
[74] Wu, W., Ma, B. L., & Whalen, J. K. (2018). Enhancing rapeseed tolerance to heat and drought stresses in a changing climate: perspectives for stress adaptation from root system architecture. Advances in agronomy, 151, 87-157.
[75] Young, T. E., Meeley, R. B., & Gallie, D. R. (2004). ACC synthase expression regulates leaf performance and drought tolerance in maize. The Plant Journal, 40(5), 813-825.
[76] Zhu, J. K. (2002). Salt and drought stress signal transduction in plants. Annual review of plant biology, 53, 247.

