DROUGHT AND ITS EFFECT ON BARLEY

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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. It manifests in plants as a range of morphological, physiological, biochemical, genetic, and even drought-induced changes 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 significant impact, water scarcity and drought stress are considered to be the most important environmental factors, 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).

The effects of drought stress on plant performance and output are evident, 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).

Depending on the local environment, drought stress can happen at any stage of growth. Because some genotypes may withstand dryness at the germination or seedling stage but may be extremely sensitive to drought at the flowering stage, or vice versa, genotypes may be examined for their drought tolerance at relevant and frequently diverse growth phases. Finding a trait that can be used to gauge the impact of drought stress on plants is how drought tolerance is determined. This characteristic ought to separate susceptible and tolerant genotypes. Determining the proper trait(s) that are drought-tolerant characteristics is therefore crucial in any drought experiment. 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). Extreme heat and drought stress episodes are occurring more frequently as a result of increased climate variability (Wu *et al*., 2018). Climate change is anticipated to negatively impact crop output by increasing the frequency of dry spells 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).

This chapter's objectives are to review relevant material on general processes of drought tolerance in significant field crops and to present the most recent, cutting-edge knowledge on drought-coping mechanisms in crops, with a focused-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 known as a water deficit, is characterised by a lack of sufficient moisture for normal plant growth and 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).

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.

According to Folger (2017), drought is a natural hazard that could have serious effects on the economy, society, and environment. It was described by him as a lack of precipitation over a protracted period of time, typically a season or longer. It could be simpler conceptually to comprehend drought through its effects. In order to categorise drought, Wilhite and Glantz (1985) used two criteria: the quantification of drought and the impact of drought. The one based on quantifying the drought was referred to as a meteorological drought (it relates to degree of dryness and duration of dry period; rainfall and probabilities). Agricultural drought, hydrological drought, and socio-economic drought are the other three types, according to the effects of drought.

Being a complicated phenomenon, drought is challenging to observe and characterise. A dry spell occurs when there is no water. It is a slow-moving phenomenon that affects numerous economic sectors and occurs on a variety of time scales. The agricultural drought is caused by insufficient precipitation over a prolonged period of time, which has an influence on agriculture. The crop water demands cannot be met by the available water supply. Low precipitation, the timing of water availability, or restricted access to water supplies are only a few causes that it could happen for. 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 may have an impact on groundwater recharge, 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 situation when the amount of water needed for plant growth and development is greater than the amount of water that plants can actually use due to a weather-related shortage. This has an effect on human activity. Ground-water drought has been included as a new category, and is described as an imbalance between ground-water recharge and discharge (Mishra and Singh, 2010). According to us, crop failure due to agricultural drought has the greatest relevance because it affects both people and animals. When assessing the effects on agriculture, a drought could be characterised as a protracted period of insufficient precipitation that causes significant crop damage, particularly yield loss (Folger, 2017).

Finally, meteorological drought occurs when dry weather patterns are prevalent in a region. After several months of meteorological drought, a hydrological drought develops when reduced water supply becomes apparent, particularly in streams, reservoirs, and groundwater levels. Drought in agriculture occurs when crops are harmed. Additionally, socioeconomic drought links the availability and demand of different goods to the drought. Hydrological drought takes significantly longer to develop and subsequently recover than meteorological drought, which can start and stop quickly.

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

a) Lack of or insufficient precipitation
b) Change in climate
c) Anthropogenic activities
d) Overexploitation of surface water resources
e) Deforestation
f) Overgrazing
g) Greenhouse gas emissions

Drought escape, avoidance, tolerance and resistance in plants

A more general word used to describe plant species with adaptive traits that allow them to withstand, avoid, or tolerate drought stress is drought resistance.

The capability of a plant species to finish its life cycle before the onset of drought is known as drought escape. Because of their ability to adjust their vegetative and reproductive growth in response to water availability, plants do not experience drought stress. This is primarily due to two separate mechanisms: fast phenological development and developmental adaptability. The ability of plants to maintain relatively higher tissue water content despite lower soil water content is described as drought avoidance. Avoidance can be accomplished 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 reducing transpiration, 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.

Mechanism of drought resistance

Plants undergo a variety of morphological, biochemical, and physiological reactions in response to drought stress, and they also have a molecular system that kicks in when there is a water shortage.

Cell and tissue water preservation, cell membrane stability, 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.

Morphological mechanisms

When exposed to drought, plants undergo a variety of changes, including those that affect the entire plant, individual tissues, and the physiological and molecular levels of the plant. 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:

Escape

A shortened life cycle or growth season enables plants to reproduce before the environment gets 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 season is shorter and terminal drought stress is more prevalent (Araus *et al*., 2002). The timing of flowering is an important aspect of crop adaptation to the environment, especially when the growing season is limited by terminal drought and high temperatures. Developing short-duration varieties has proven to be an effective strategy for reducing yield loss from terminal drought, as early maturity allows the crop to avoid the stress period (Kumar and Abbo, 2001). However, under favourable growing conditions, yield is generally correlated with crop duration, and any decrease in crop duration below the optimum would tax yield (Turner *et al*., 2001).

Drought avoidance

Drought avoidance mechanisms encompass mechanisms that reduce water loss from plants due to stomatal control of transpiration, in addition to mechanisms that maintain water uptake through an extensive and prolific root system (Turner *et al*., 2001; Kavar *et al*., 2008). The main drought avoidance traits that contribute to final yield in terminal drought environments are root characters such as biomass, length, density, and depth (Subbarao *et al*., 1995; Turner *et al*., 2001). A deep and thick root system is beneficial for extracting water from great depths (Kavar *et al*., 2008). Waxy bloom on leaves aids in the preservation of high tissue water potential and is thus regarded as a desirable trait for drought tolerance (Richards *et al*., 1986; Ludlow and Muchow, 1990).

Phenotypic flexibility

Plants with small leaves have long been recognised as being typical of xeric environments. Although their growth rate and biomass are relatively low, such plants withstand drought very well (Ball *et al*., 1994). Leaf pubescence is a xeromorphic trait that provides protection the leaves from overheating. Hairy leaves reduce transpiration and leaf temperatures (Sandquist and Ehleringer, 2003). Hairiness increases light reflectance and reduces water loss under high temperature and radiation stress by increasing the boundary layer resistance to water vapour movement away from the leaf surface. The roots are the most important plant organ for drought adaptation. If tolerance is defined as the ability to maintain leaf area and growth during prolonged vegetative stage stress, the main source of variation appears to be constitutive root system architecture, which allows the plant to maintain a more favourable water status (Nguyen *et al*., 1997).

To summarise, plants could avoid drought stress by narrowing their growth duration and sustaining tissue water potential, either by reducing water loss from plants or enhancing water uptake, or both. Some plants can reduce their surface area by shedding leaves or producing smaller leaves.

Physiological mechanisms

The most significant grounds for drought tolerance have been osmotic adjustment, osmo-protection, antioxidation, and a scavenging defence system.

Cell and tissue water conservation

Osmotic adjustment enables the cell to lower its osmotic potential, which raises the gradient for water ingress and turgor maintenance as a result. Changes in cell wall flexibility and/or osmotic adjustment may be used to improve tissue water status. This is necessary to preserve physiological function during prolonged drought. (Kramer and Boyer, 1995). Osmotic adjustment, abscisic acid, and the activation of dehydrins have all been found to offer tolerance against drought damage by maintaining high tissue water potential. (Turner *et al*., 2001). As solutes build up, the osmotic potential of the cell decreases, luring water into the cell and aiding in turgor maintenance. According to prior research of species with elastic cell walls, turgor was maintained despite a drop in leaf water volume. With the active accumulation of solutes in the cytoplasm, osmotic adjustment helps to maintain the cell's water balance, limiting the negative effects of dryness. (Morgan, 1990). By continuing to maintain cell turgor and 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), while high turgor maintenance leads to higher photosynthetic rate and growth (Ludlow and Muchow, 1990; Subbarao *et al*., 2000).

Antioxidant defence

Enzymatic and non-enzymatic parts make up the plant cell's antioxidant defence mechanism. Superoxide dismutase, catalase, peroxidase, ascorbate peroxidase, and glutathione reductase are examples of enzymes. Cysteine, reduced glutathione, and ascorbic acid are non-enzymatic components. (Gong *et al*., 2005). A range of antioxidant enzymes and/or scavenging compounds that are lipid- and water-soluble remove the reactive oxygen species from plants. (Hasegawa *et al*., 2000); The most effective defences against oxidative stress are antioxidant enzymes. (Farooq *et al*., 2009). Superoxide dismutase is a key player in enzymatic mechanisms that catalyses the initial step in reactive oxygen species scavenging systems, the dismutation of two superoxide molecules into O_2 and H_2O_2. In spite of their ability to scavenge singlet oxygen and lipid peroxy-radicals as well as to suppress lipid peroxidation and superoxide formation when dehydrative forces are present, carotenoids and other substances, such as abietane diterpenes, have received little attention. (Deltoro *et al*., 1998). During the recovery from a water deficit period, the transcript of some antioxidant genes, including glutathione reductase and ascorbate peroxidase, was higher and appeared to be involved in the defence of cellular machinery against ROS damage. (Ratnayaka *et al*., 2003). Enzymatic and non-enzymatic antioxidant mechanisms work together to reduce oxidative damage in plant tissue. These contain antioxidants such -carotenes, ascorbic acid, -tocopherol, reduced glutathione, and enzymes including catalase, polyphenol oxidase, glutathione reductase, and superoxide dismutase. (Hasegawa *et al*., 2000; Prochazkova *et al*., 2001).

Cell membrane stability

Cell membrane stability, which is inversely correlated to cell 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) demonstrated that the most crucial characteristic to screen the germplasm for drought resistance was membrane stability of the leaf segment. Differentiating across cultivars revealed drought tolerance measured as an increase in cell membrane stability under water deficit conditions, which was closely connected with a decrease in relative growth rate under stress. (Premachandra *et al*., 1991). The ability of Arabidopsis leaf membranes to sustain polar lipid concentrations and the stability of their composition despite extreme drought seemed to indicate that they were particularly robust to water deficiency. (Gigon *et al*., 2004).

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 a drought, endogenous levels of auxins, gibberellins, and cytokinin often drop while abscisic acid and ethylene levels typically rise. (Nilsen and Orcutte, 1996). Nevertheless, phytohormones are crucial to plants' ability to withstand drought. By preventing the root apical dominance brought on by cytokinins, auxins promote the development of new roots. Endogenous auxin production is restricted by drought stress, typically when abscisic acid and ethylene levels rise. (Nilsen and Orcutte, 1996). Abscisic acid inhibits development and is produced in response to many different environmental conditions, including drought. All plants produce more abscisic acid as a response to drought and other stressors. All flowering plants produce abscisic acid, which is widely recognised 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. According to certain theories, cytokinin and abscisic acid play opposing functions in drought stress. Under conditions of water stress, an increase in abscisic acid and a decrease in cytokinin levels encourage stomatal closure and reduce water loss by transpiration. (Morgan, 1990). Although it is involved in both environmental-driven growth inhibition and stimulation, ethylene has long been thought of as a growth-inhibitory hormone. (Taiz and Zeiger, 2006). Cereals respond to drought by losing leaf functionality and by hastening the onset of senescence in older leaves. Ethylene may control a leaf's performance 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).

Compatible solutes and osmotic adjustment

The overproduction of various kinds of suitable organic solutes is one of plants' most popular methods of stress tolerance. (Serraj and Sinclair, 2002). Compatibility solutes are low-molecular-weight, highly soluble substances that are often harmless even at high cytosolic concentrations. In general, they defend plants from stress in a variety of ways, including by aiding in osmotic adjustment, detoxifying reactive oxygen species, stabilising membranes, and preserving enzyme and protein native structures. Osmotic adjustment is a process to preserve water relations when under osmotic stress. It involves the build-up of a variety of osmotically active molecules/ions, such as soluble sugars, sugar alcohols, proline, glycine betaine, organic acids, calcium, potassium, chloride ions, etc. The osmotic potential of the cell is lowered in conditions of water deficiency and as a result of solute accumulation, which draws water into the cell and aids in turgor maintenance. Plants perform better in terms of growth, photosynthesis, and assimilation partitioning to grain filling thanks to osmotic adjustment, which allows the organelles and cytoplasmic activities to proceed at a pace that is roughly normal. (Ludlow and Muchow, 1990; Subbarao *et al*., 2000).

Molecular mechanisms

Several genes are induced at the transcriptional level in response to drought, and these gene products are thought to function in drought tolerance (Kavar *et al*., 2008). Gene expression may be directly triggered by stress conditions or as a result of secondary stresses and/or injury responses. Despite this, it is well understood that drought tolerance is a complex phenomenon involving the coordinated action of many genes (Agarwal *et al*., 2006; Cattivelli *et al*., 2002).

Aquaporins

Aquaporins also can facilitate and regulate the passive exchange of water across membranes. They are members of a large family of highly conserved intrinsic membrane proteins (Tyerman *et al*., 2002). Aquaporins are abundant in the plasma membrane and the vacuole membrane of plants. Aquaporin structural analysis revealed the general mechanism of protein-mediated membrane water transport. Although the discovery of aquaporins in plants has resulted in a prototype shift in the understanding of plant water relations (Maurel and Chrispeels, 2001), the relationship between aquaporins and plant drought resistance remains elusive (Aharon *et al*., 2003).

Stress proteins

Stress protein synthesis is a common response to prevailing stressful conditions such as water deficit. The majority of stress proteins are water soluble and thus contribute to stress tolerance by hydrating cellular structures (Wahid *et al*., 2007). Drought tolerance is solely associated with the synthesis of a variety of transcription factors and stress proteins (Taiz and Zeiger, 2006). Heat shock proteins are part of a larger class of molecules known as chaperones. They help to keep the structure of other proteins stable. Low-molecular-weight heat shock proteins are typically only produced in response to environmental stress, specifically high temperatures (Wahid *et al*., 2007). Many heat shock proteins, however, have been discovered to be induced by various stresses such as drought, anaerobic conditions, and low temperatures (Coca *et al*., 1994).

Signalling and drought stress tolerance

General stress responses include stress detection via the redox system, cell cycle checkpoints, and deoxyribonucleic acid repair processes stimulated in response to deoxyribonucleic acid damage. The complexity of stress sensing and defence and acclimation signalling events is thought to involve reactive oxygen species, calcium, calcium regulated proteins, mitogen-activated protein kinase cascades, and cross-talk between different transcription factors (Kovtun *et al*., 2000; Chen *et al*., 2000). Chemical signals, such as reactive oxygen species, calcium, and plant hormones, play a role in stress tolerance by stimulating genomic re-programming via transduction cascades (Joyce *et al*., 2003).

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.). It is the most important cereal crop and is regarded as the first domesticated cereal used by humans for nourishment and for raising livestock. (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. Barley is also well known for being a model crop for research in genetics, cytogenetics, pathology, virology, and biotechnology. (Hockett and Nilan 1985; Hagberg, 1987). From 330 metres below sea level near the Dead Sea in the Middle East to 4200 metres on Atipano and the Andes in Bolivia, barley is grown in a very broad range of climates around the globe. According to reports, barley, the oldest grain crop, originated in the Fertile Crescent of the Middle East, which is made up of Turkey, Iran, Iraq, and Lebanon. (Harlan, 1979). Barley was domesticated in Egypt's Nile River Valley at least 17,000 years ago, according to excavations. (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. The most recent classifications have treated these forms as belonging to a single species, H. vulgare, because of the changes that were caused by single gene mutations and supported by cytological and molecular data. (Sarkar *et al*.)

In general, barley spikelets are placed in triplets and alternate along the rachis. There are two row and six row varieties. Only the central spikelet of a triplet is productive in wild barley and other Hordeum species from the Old World; the other two are diminished. Certain varieties known as two row barleys maintain 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
During selection, characters have high heritability's and high correlation with yield under stress across the environments are selected.
Grain yield under stress conditions is usually the primary traits for selection.
The suitable secondary traits should have

a) Genetically association with grain yield under drought,
b) High heritability,
c) Stable and feasible to measure,
d) Lack of association with yield loss under ideal growing conditions

Effect of drought on quantitative and qualitative traits of barley.

Early drought stress during the seed germination stage decreases the seed germination ratio. Seedling failure can be caused by drying of the soil surface after seedling emergence (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). Drought has the greatest impact on yield when it occurs at the start of meiosis, *i.e*., during gametogenesis and early grain initiation (Saini *et al*., 1999). The spike emergence and early stage of grain development are the most sensitive stages of barley growth to drought stress (Saini *et al*., 1999, Sehgal *et al*., 2018). Drought stress causes pollen sterility during gametogenesis and a delay or complete inhibition of flowering during flower induction and inflorescence development. Drought, on the other hand, reduces grain size and weight by limiting the number of endosperm cells, thereby reducing the potential size of the grain. Finally, drought affects the rate and duration of starch accumulation in the endosperm later in development (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). Endosperm cell division and seed reserve accumulation are heavily influenced by the moisture status of the cells during the storage phase. Water scarcity increases endogenous ABA concentration, decreases starch accumulation, and causes ovary abortion, resulting in low grain yield (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).

According to Ceccarelli (1987), water deficit early in plant development causes a reduction in spikelet primordia, whereas water deficit late in plant development causes flower and spikelet death. The number of grains per spike (fertility) is determined by the availability of water during the early vegetative phase and the shooting stage. If there is a water deficit after the flowering stage, grain weight and thus yield are reduced.

Yield was higher under irrigated conditions than under water stress conditions. Grain yield, as a component that was stressed, showed a reduction in drought stress when compared to the irrigated condition. When selecting barley plants to improve yield under water stress conditions, it may be concluded that a high potential yield and a high thousand grain weight are the most important traits. Yield is an important trait, but it is highly affected by environmental conditions (Vaezi B. *et al*., 2010). A genotype's yield performance under stress reflects both its yield potential and its response to stress (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). One of the most important factors in improving the performance of the barely is the number of grains per panicle. 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) Jafarzadeh reported on the effect of drought stress on plant height reduction in another experiment (2004)

The relative water content was shown to be a useful screening tool for drought tolerance. Increased yield and yield stability under drought are aided by maintaining relative water content and high osmotic adjustment. A high osmotic adjustment capacity would also be advantageous because it would help keep cells turgid when water stress increased during the grain-filling period. Drought significantly reduced the osmotic potential of barley (Ahmed I M *et al*., 2013).

A post-flowering dehydration tolerance mechanism is called "stay green." In particular under source-limiting conditions that frequently define crops under drought stress, a well-sustained source capacity is a vital aspect to maximising yield potential during both vegetative and reproductive phases. Delaying leaf senescence keeps transpiration constant and boosts total photosynthesis throughout the crop life cycle. 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.

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