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Impact of drought stress on crop production and its management options

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Abstract

In the development of agricultural crops, biotic and abiotic stresses result in considerable yield losses. One of the main obstacles to agricultural production and global food security is abiotic stress. Stress is a word that refers to several biotic and abiotic environmental factors that prevent crop plants from reaching their full genetic potential. Drought is one of the fundamental issues in the current climatic environment and is one of the most severe abiotic stresses in many areas of the world. Plants experience moisture stress when their evapotranspiration requirements are not met. Drought has a negative impact on plant development and other metabolic processes, making it one of the most significant abiotic stresses and factors restricting the successful production of plant products globally. Drought is caused by a lack of water as a result of erratic rainfall or inadequate irrigation, but it can also be hampered by other elements such as soil salinity, physical characteristics, and excessive air or soil temperatures. Insufficient water supply throughout a crop's life cycle, including precipitation and the capability of the soil to store moisture, limits the crop's potential to produce the highest possible genetic grain yield. The most significant stressor that has a significant impact on crop development and productivity is without a doubt drought. For better management, it is crucial to comprehend the physiological, biochemical, and ecological actions connected to these stresses. It is possible to generalize morphological, physiological, and biochemical responses to a broad range of plant responses to this stress. Due to physical damage, physiological disruptions, and biochemical alterations, inadequate water supplies and abnormal temperatures have a severe impact on crop growth and yields. Drought stress reduces the size of the leaves, stem extension, and root proliferation within the soil; it also disturbs plant water relations and reduces water-use efficiency, which in turn reduces the plant's ability to yield; as a result, breeding for drought resistance is a good approach. This approach combines conventional and molecular methods to develop a drought-tolerant variety. Breeding more drought-tolerant cultivars may be more successful when selection is based on a thorough testing strategy. Practical implications for treatments and management result from a greater understanding of how plants react to this stress. High demand for drought-tolerant types would seem to be a difficult issue for plant breeders, but difficulties are aggravated by the difficulty of crop yield on a genetic and physiological basis. Food security is seriously threatened by drought, which is the main reason for agricultural loss worldwide. Plant biotechnology is currently one of the most promising areas for creating crops that can generate large amounts of food in moisture environments.

Keywords: Drought avoidance, drought escape, drought tolerance, early flowering, yield potential

1. Introduction

The challenges facing agriculture today are unprecedented. Arable land is being lost due to harmful processes such salinization, desertification, and soil erosion and degradation, all of which are being accelerated by climate change. This might place the world's food supply at risk, which must be increased to meet both the United Nations' goals for food security and the world's expanding population. Drought poses a serious challenge to agriculture around the world now more than ever. According to statistics from the Food and Agriculture Organization (FAO) of the United Nations, between 2005 and 2015, drought in the developing world directly cost agriculture USD 29 billion, with the 2008-2011 droughts in Kenya alone costing USD 1.5 billion (FAO, 2018) `. Additionally, irrigation uses up more than 70% of the world's freshwater supply. Plant breeders will need to start creating innovative crop varieties with enhanced yield, tolerance to abiotic stresses, and improved water and nutrient uptake efficiency in order to meet these difficulties (Fita *et al*., 2015) [21].

In general, agronomists define a drought as a prolonged absence of water that impairs plant development and survival and, as a result, lowers agricultural productivity. When the rate of transpiration exceeds the rate of water intake, which occurs in plants, the definition of water deficit and the largest definition of drought stress are congruent (Bray, 1997) [11]. This could be the result of a lack of water, but also of increased salinity or osmotic pressure. The first occurrence of drought stress, from the standpoint of molecular biology, is the loss of water from the cell, or dehydration. Dehydration typically results in osmotic and hormonal signals, with abscisic acid (ABA) playing a major role in the latter (Blum, 2015) [10]. Following these signals, a response occurs that can be generally divided into three basic tactics: Drought avoidance, dehydration avoidance and tolerance for dehydration or desiccation (Blum and Tuberosa, 2018) [9].

Rapid population growth and significant climate change are challenging global food security (Lesk *et al*., 2016) [37]. Drought and heat stress have emerged as the most significant issues restricting crop productivity and, eventually, food security, as a result of climate change. Droughts are beginning more frequently all across the world due to less precipitation and altered rainfall patterns (Lobell *et al*., 2011) [38]. Strong droughts have an adverse effect on plant growth, physiology, and reproduction, which results in a significant drop in crop yields (Barnabas *et al*., 2008) [6]. One of the main contributors to global warming is the concentration of greenhouse gases, which is increasing. There has been a 30 to 150 percent increase in CO_2 and methane levels during the past 250 years (Friedlingstein P and Prentice I.C., 2010) [22]. More than any other environmental element, these stresses restrict plant growth and productivity.

When either the water supply to the roots is insufficient or there is a significant loss of water through transpiration, plants are vulnerable to drought conditions (Anjum *et al*., 2011) [2]. The severity of the drought's effects is typically unpredictable since it depends on a number of factors, such as rainfall patterns, the soil's capacity to retain moisture, and water losses through evapotranspiration. Droughts affects photosynthesis, assimilate partitioning, nutrient and water relations, growth, and finally results in a major decrease in agricultural production (Praba *et al*., 2009) [46]. According to the stage of the plant's growth and other environmental conditions, the reaction of the plant to drought stress generally differs from species to species (Demirevska *et al*., 2009) [14]. Under conditions of low soil moisture supply, the main factors reducing production are decreased absorption of photosynthetically active radiations, reduced radiation use efficiency, and decreased harvest index (Earl and Davis, 2003) [17]. To adapt to the severe consequences of drought stress, plants alter their physiological processes and growth patterns (Duan *et al*., 2009) [16].

The numerous morphological, biochemical, and physiological changes brought on by high-temperature stress have a significant impact on the growth and development of plants as well (Wahid *et al*., 2007) [59]. Drought's initial effects on plants include poor seed germination and hampered seedling establishment. Numerous studies have demonstrated the detrimental effects of drought stress on seedling germination and growth (Farooq *et al*., 2009b) [20]. Important field crops under drought stress have reported reduced germination potential, early seedling growth, root and shoot dry weight, hypocotyl length, and vegetative growth (Zeid and Shedeed, 2006) [64]. The primary mechanisms for plant growth are cell division, expansion, and differentiation. Poor growth is the outcome of impaired cell elongation and mitosis caused by drought (Hussain *et al*., 2008) [29]. Due to the absence of turgor, drought primarily inhibits the process of cell development. In water-limited conditions, cell elongation is impeded, mostly due to the insufficient water flow from the xylem to the surrounding cells. Under drought conditions, both the number of leaves and the size of each individual leaf are decreased. The supply of assimilates and the turgor pressure often determine how much the leaf expands. Under dry conditions, reduced turgor pressure and a slow rate of photosynthesis are what primarily prevent leaves from expanding (Rucker *et al*., 1995) [52].

Under the water limiting conditions, fresh and dry weights are also significantly decreased (Zhao *et al*., 2007) [66]. Under the water-limiting conditions, plant height, leaf size, and stem girth were all significantly decreased in maize (Khan *et al*., 2015) [33]. According to a different study by Kamara *et al*. (2003) [31], maize biomass accumulation was dramatically decreased under drought conditions induced at different growth stages. A huge number of minor genes and loci on chromosomes that contain those genes are known as QTLs, and they play a significant role in the complicated phenomena of drought tolerance in plants (Mohammadi *et al*., 2008) [41]. It is possible to use QTLs mapping followed by a marker-assisted selection technique or natural selection in demanding environments to take use of the genetic heterogeneity among existing cultivars for stress resistance (Ashraf *et al*., 2013) [5]. Assessment of the total number of genes, their location, and action pattern are mostly aided by QTL mapping. A significant issue in choosing the right QTL for drought tolerance is the degree to which QTL and the environment interact (Tuberosa and Salvi, 2006) [57]. As a result, isogenization is essential for a QTL's proper characterization after it has been found to confer drought tolerance (Salvi and Tuberosa, 2005) [53]. The modification of the appropriate QTLs to develop drought-tolerant cultivars comes next in significance after the identification of the correct QTLs.

The surroundings that plants survive in are constantly changing and frequently unfavorable or stressful for their growth and development. These unfavorable circumstances include biotic challenges like pathogen infections and herbivore attacks as well as abiotic factors including drought, heat, nutrient inadequacy, cold, and salinity. Drought, which impacts 40% of the world's land area, is one of the most significant abiotic factors hindering seed germination and productivity in global agriculture (Zhang Z and Xiao B, 2018) [65]. Seed germination is substantially impacted by drought, which lowers plant density and production. Drought is anticipated to become more prevalent in some parts of the world in the future. Unfortunately, global climate change may cause more droughts in many regions of the world, which might have a significant impact on crops. Producing crop varieties that can adapt to these conditions and sustain high levels of yield is therefore urgently needed. Due to these difficulties, scientists are working harder to increase the capacity of crops to withstand such extreme weather (Zhang Z and Xiao B, 2018) [65]. A necessary step in the development of many efficient strategies to increase the potential of adapting to adversity and increase yield production under abiotic stress is the genetic dissection of the quantitative traits that influence the adaptation of crops to adverse conditions. The objective of this paper was to understand the effect of drought on crop production and its breeding strategies.

2. Effects of drought on plant growth and development

Abiotic stress significantly affects plant development and growth, causing significant losses in worldwide agriculture (Zinta, 2016) [67]. Abiotic stress is one of the most important elements limiting crop production. Crop growth and productivity are both hampered by drought. People now live on a globe that is hotter and more arid due to human-caused global warming. In the following 30 years, it is anticipated that this scenario will worsen, and by 2050, it is anticipated that over 50% of the world's regions will experience water scarcity (Gupta *et al*., 2020a) [25]. So it is crucial to cultivate drought-tolerant crops now to secure food security. Drought is complicated abiotic stress that can influence plant growth at any stage and to varying degrees of severity. Drought can have an impact on three critical stages of cereal plant development: Pre-anthesis (from tillering and booting through full blooming), Vegetative (before transition to the reproductive stage), Post-anthesis or Terminal (after flowering and until maturity).

Among abiotic factors, drought is the main global cause of crop yield loss. It is a significant issue that contributes to global food shortages and makes it difficult for small-holder farmers to produce enough crop grain. The key factor causing biotic and abiotic stresses, which have a negative impact on crop productivity worldwide, is climate change. There is always a chance that crops could fail or their yields will decrease owing to moisture stress, particularly in areas where crop production is entirely dependent on rainfall. In severe cases, the stress could lead to total crop loss. Water stress has a significant impact on the cell activities, growth, and economic yield of plants. It has an impact on the hydration and structure of proteins and nucleic acids, as well as the pressure differential across the membrane cell wall complex at the cellular level. Since leaves are directly involved in the synthesis of assimilation for growth and yield, water stress is often quantified as the water potential of the leaf.

2.1 Major Traits Contributing to Drought Resistance

2.1.1 Early Flowering and Drought Escape: A common adaptive strategy, drought escape involves rapid plant growth to permit the completion of the entire life cycle before an impending drought event. The majority of natural plant populations employ this strategy, which also applies to cereal crops. In times of terminal drought, early flowering time and a shorter vegetative phase might be crucial for crop production because they can reduce exposure to dehydration during the critical flowering and post-anthesis grain filling stages. Over the past century of crop breeding, early flowering has gradually become more prevalent in nations with Mediterranean-style climates and periodic terminal droughts. In reaction to global climate change, agricultural production is expected to follow this trend in the coming future. In conditions of looming terminal drought, early flowering crops are advantageous, and modern varieties are much more productive because the risk of drought stress is reduced.

A short vegetative phase might lower plant biomass under favorable circumstances since there is less time for photosynthetic production and seed nutrient accumulation. However, it has been noted that both shallow and deep root formation has a high yield potential, demonstrating adaptability in response to drought when combined with the early flowering characteristic. Both in well-watered and drought-affected field trials, where an effective drought escape strategy was related to rapid growth, yield potential, and water usage efficiency, crop productivity can be high. Therefore, early flowering offers a potentially effective method for the development of advanced drought-tolerant crop cultivars. Plants use a variety of strategies, including drought escape, to ensure that they can complete their life cycle as quickly as possible during the small timeframe of favorable conditions when water shortages later in the growing season are likely (Kooyers, 2015) [34].

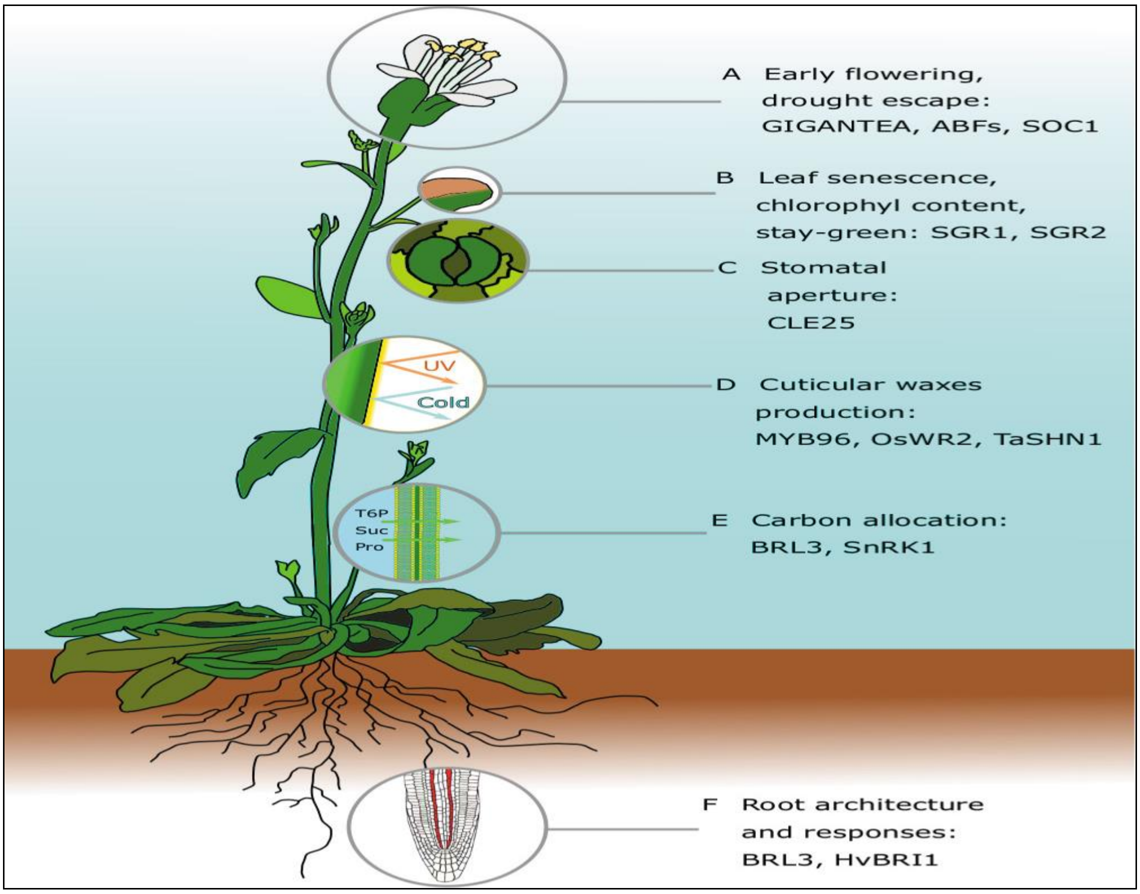

Fig 1: Major traits contributing to drought resistance in Arabidopsis thaliana

2.1.2 Leaf Traits: Senescence, Stay-Green, and Leaf Area

Plant development and nutrient cycles are significantly influenced by leaf characteristics such as photosynthetic capacity, nitrogen content, and leaf mass per area. Therefore, one of the fundamental problems in plant biology, crop science, and ecology understands the links among leaf traits. Different leaf groups display distinctive correlations between trait pairs. In terms of a plant's ability to function and long-term environmental adaption, leaves are essential. Phylogenetic relationships and adaptation to particular environments result in apparent differences in area, thickness, and form across different species of leaves, despite their basic composition of epidermis, stomata, and mesophyll (Royer *et al*., 2010) [51].

Senescence is a stage of plant development that causes the photosynthesis of plant leaves to stop, the breakdown of proteins and chloroplasts, and the mobilization of nitrogen, carbon, and other nutrient resources from the leaves to other organs. Senescence thus plays a significant effect in crop yield since most cereals are monocarpic annual species and focus their energies toward growing seeds. Senescence may be accelerated by environmental challenges like temperature, nutrient deficiency, and drought, which could influence the nutritional makeup of seeds and crop productivity (Distelfeld *et al*., 2014) [15]. Senescence can be delayed or slowed down, which can help crops that are in danger of terminal drought maintain photosynthetic activity for longer and possibly prevent yield losses. As a result, crop leaf senescence has been thoroughly investigated. Plant breeders frequently refer to the characteristic that promotes prolonged photosynthetic activity as stay-green, which is also referred to as mature green leaf area. Sorghum, a dry climate-adapted crop in which several stay-green quantitative trait loci have been found, has been extensively studied for this attribute (Vadez *et al*., 2011) [58]. But these quantitative trait loci's underlying genes are still unknown (Harris-Shultz *et al*., 2019) [27].

Sorghum's complicated trait of "stay-greenness" is also linked to some varieties' perennial tendencies (Thomas and Howarth, 2000) [56]. Other plant species obtain stay-green traits through significantly different means, such as inhibiting chlorophyll degradation and changing how they react to plant hormones (Armstead *et al*., 2007) [4]. In fact, some stay-green genes have been found in both rice and Arabidopsis (Hortensteiner, 2009) [28], particularly the stay-green rice genes and their Arabidopsis homologs SGR1, SGR2, and SGR-like (SGRL). The corresponding molecular pathways have been revealed, and stress-induced leaf senescence is largely mediated by the phytohormones ethylene, ABA, cytokinin (CK), and strigolactone (SL) (Abdelrahman *et al*., 2017) [1]. The relationship between ethylene and leaf senescence has traditionally been known and several attempts have been made to manipulate ethylene biosynthesis in dicots (John *et al*., 1995) [30] and cereal plants to enhance photosynthetic activity and drought performance (Young *et al*., 2004) [63].

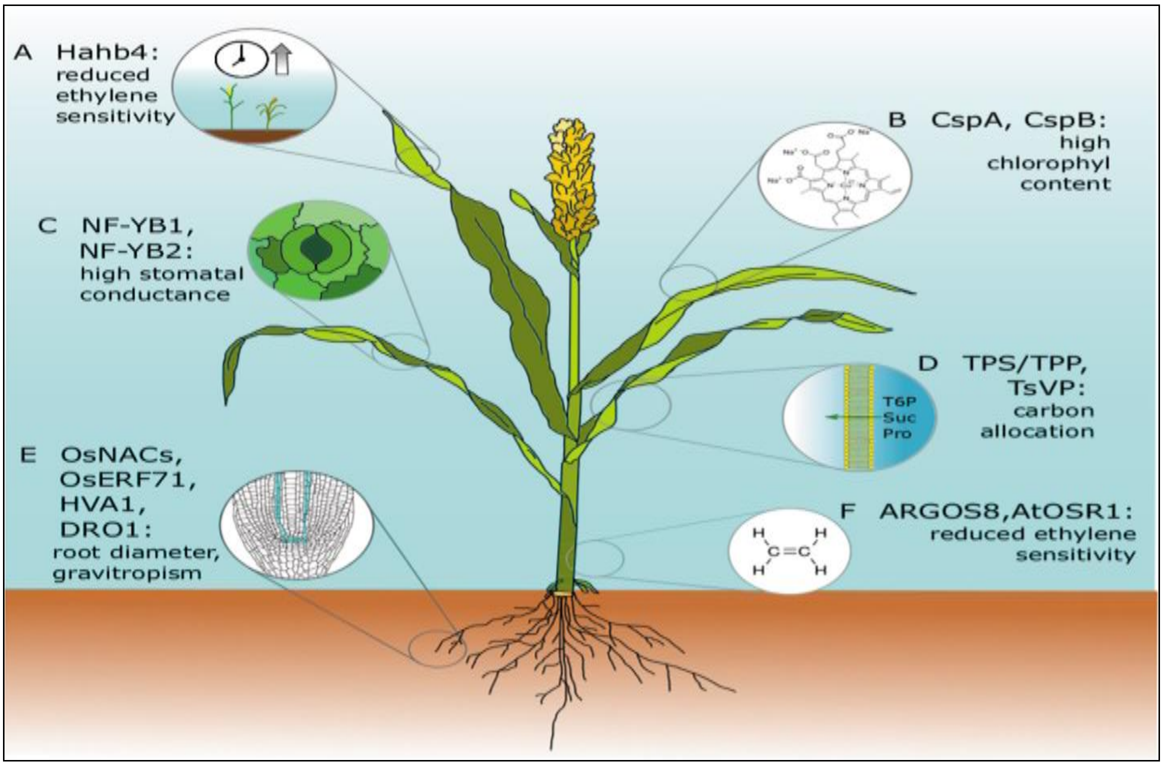

Fig 2: Drought tolerance genes model species and translated successfully into crop species

2.1.3 Stomatal-Mediated Drought Responses

Two specialized guard cells surround stomata, which are holes on the surface of a plant's aerial section. These guard cells can change their turgor pressure to open and close the pore. Stomata play a key role in CO_2 uptake in photosynthetic organs and are tightly controlled by a biochemical route that enables plants to absorb CO_2 while minimizing water loss. One of the early methods used by scientists to try to create drought-resistant plants was manipulating stomatal quantity, size, and control. Recent developments in Arabidopsis and commodities have furthered this goal (Bertolino *et al*., 2019) [7]. ABA is the primary hormone signal in water-limited conditions that causes stomatal closure (Sussmilch and McAdam, 2017) [5]. Plant survival may be improved by adjusting ABA sensitivity to boost stomatal responses in response to drought. However, reduced photosynthetic activity brought on by insufficient CO_2 uptake is often harmful to carbon intake and has a severe effect on crop yield. Additionally, stomatal openings allow water to evaporate, keeping plants from overheating. Considering that warm temperatures are likely to accompany dryness in a naturalistic way, lowering stomata capacity could not be a long-term solution for improving drought resistance while maintaining yield and biomass production.

2.1.4 Cuticular Wax Production

Wax is a significant component of the exterior cuticle layer found on aerial plant organs. The epidermis is physically protected by this hydrophobic barrier, which also controls permeability and water loss, from a variety of external influences such as UV light, cold temperatures, fungal infections, and insects. However, many of the important genes involved in wax metabolism, regulation, and transport still need to be characterized despite the fact that a number of studies in Arabidopsis and crops have shown a connection between drought stress and changes in cuticular wax content, composition, and morphology (Patwari *et al*., 2019) [43]. Wax composition differs not just between plant species but also between certain tissues or organs within the same plant, according to research on both Arabidopsis and crop species. The biosynthesis of cuticular waxes occurs in epidermal cells in the most extensively researched model, where newly generated C16-C18 fatty acids created in plastids are exported by acyl-acyl carrier proteins (acyl-ACP). As a result, rather than overexpressing different components of the biosynthetic pathways, the majority of biotechnological approaches that have attempted to improve drought performance by altering cuticular wax levels concentrate on TFs that control the whole process.

2.1.5 Carbon Allocation

Photosynthetic organisms like plants can convert atmospheric carbon into macromolecules needed for cellular growth and survival. Therefore, it is clear that carbon metabolism and allocation are tightly controlled, and that this regulation is crucial for plant stress resistance and crop yield. Carbon is the fundamental factor in cereals that determines crop productivity, and cereals' carbs are the main source of calories in the human diet (Lafiandra *et al*., 2014) [36]. Trehalose 6-phosphate (T6P) /SNF1-related/AMPK protein kinase (SnRK1) is one of the key pathways that control carbon allocation in plants. T6P is a nonproducing disaccharide that is found in very small amounts in plants and serves as a signal for the presence of sucrose. Auxin and ABA signals have also been connected to this circuit (Paul *et al*., 2018) [44]. During flowering, T6P is known to function as a signaling molecule (Wahl *et al*., 2013) [60]. A well-known method for increasing plants' resistance to drought is to increase the amount of the disaccharide T6P present inside their cells. Most temperate plants contain trace levels of T6P, whereas resurrection plants accumulate it (Wingler, 2002) [62].

The expression of T6P regulatory or biosynthetic genes under strong constitutive promoters, however, drastically changes plant growth and development and may have a negative impact on crop production (Guan and Koch, 2015) [24]. A promising biotechnology strategy for creating drought-tolerant plants involves changing sugar distribution via the T6P pathway, with the better result coming from manipulations targeted at certain tissues like seeds and developing reproductive structures (Oszvald *et al*., 2018) [42]. Notably, seed-specific T6P modification may improve tolerance to drought as well as flooding (Kretzschmar *et al*., 2015) [35]. As most of the plant sugar trafficking happens through the phloem, shoot and root vascular tissues are also candidate targets for T6P manipulation (Fabregas *et al*., 2018) [18].

2.1.6 Root Traits

The primary plant organ responsible for providing crops with water to support their physiological functions is the root, which is susceptible to drought and environmental stresses on the soil (Prince *et al*., 2015) [47]. Breeding plants with root characteristics that increase productivity in drought conditions is a task for geneticists and plant breeders. To boost crop yield under various drought conditions, a deeper comprehension of root functional features and how traits connect to whole plant strategies is required. Small fine root diameters, long specific root lengths, and significant root length density, especially at depths in soil with adequate water, are root traits linked to maintaining plant productivity under drought. Small xylem diameters in targeted seminal roots save soil water deep in the soil profile for use during crop maturation and lead to higher yields in environments with late-season water deficits. In sorghum, a positive association between drought tolerance and root length suggests that root depth and root length density are qualities that contribute to drought tolerance. The degree of drought stress tolerance is strongly correlated with root characteristics, particularly root length.

A center for the biosynthesis and transport of plant hormones like abscisic acid, plant roots are vital organs that help plants absorb water and nutrients from the soil (ABA). The growth of a plant's aerial parts is influenced by the morphological and physiological traits of roots (Arai-Sanoh *et al*., 2014) [3]. Crop roots and aerial portions interact and depend on one another (Kashiwagi *et al*., 2006) [32]. Maintaining high root vitality is therefore crucial, and altering root shape is more likely to encourage crop growth than altering stem and leaf structure (Craine *et al*., 2003) [13]. The adaptability of wheat to various conditions mostly depends on the modification of root characteristics to adapt to the surrounding environment and maximize resource use.

According to Sebastian *et al*. (2016) [54] study, crop productivity may actually increase when crown roots are suppressed more severely. According to Hammer *et al*. (2009) [26], historical advancements in yield breeding in the U.S. maize belt may have been made possible by optimizing root structure and water use. Therefore, it is important to investigate the impact of the root system on crop development and yield production, specifically the role of deep roots under challenging circumstances like drought stress. This will help you determine what kind of root system is advantageous to crop growth. Deep roots are also essential for a crop's ability to adapt to its environment.

According to Manschadi *et al*. (2006) [39], drought-tolerant wheat has tighter, more uniform, and longer roots than drought-sensitive wheat, and the plants utilize water more effectively overall. Crops' deep roots can decrease environmental nitrogen leaching while simultaneously enhancing water and nitrogen uptake, which in turn can increase production. Therefore, when creating new varieties, breeders strongly emphasize the significance of deep roots in absorbing water and nutrients (Wasson *et al*., 2014) [61]. According to Chaves *et al*. (2004) [12], deep-rooted plants have a higher chance of surviving in arid environments since these soil layers have larger moisture levels. In arid environments, deep roots can absorb more nutrients and water while maintaining the function of shallow roots through material transport (Bleby *et al*., 2010) [8]. While certain of the physiological functions of deep roots and their influence on the production of above-ground crops are well recognized, some of the physiological functions of the root system are less well demonstrated.

Table 1: Traits associated with drought tolerance

S.N	Category	Traits
1	Morphological & Anatomical	Yield; More Root length, Root Volume, Root Dry Weight, Root Thickness; Root surface area, More Plant Biomass; Harvest index; Leaf drying; Leaf tip firing; Delay in flowering.
2	Phenological	Early to maturity, Late Flowering; Anthesis, Silking Interval; Seedling vigor; Weed competitiveness; Photosensitivity; perennially.
3	Physiological & Biochemical	Osmotic Adjustment; Carbon Isotope Discrimination; Stomatal conductance; Remobilization of stem reserves; Specific leaf weight; ABA; Electrolyte leakage; leaf rolling, tip firing, Stay-green; Epicuticular wax; Feed forward response to stress; Heat shock proteins; Cell wall proteins; Leaf water potential; Water use efficiency; Aquaporins; Nitrogen use efficiency; Dehydrins.

3. Breeding Approaches for Drought Resistance

One of the most prevalent abiotic stresses that directly threatens the proper growth and development of plants is drought stress. The productivity and quality of crops and ornamental plants are predicted to be significantly reduced by drought stress as a result of population increase, fresh-water shortages, and more exacerbated global warming (Prudhomme *et al*., 2014) [48]. Therefore, more research into the physiological and molecular pathways is required to create plants that can withstand drought. Plants have developed physiological, biochemical, and molecular defenses against water shortage and adaptation to arid situations. For plants to endure drought stress, physiological flexibility, including variations in abscisic acid (ABA) concentration, proline accumulation, and superoxide dismutase (SOD) and peroxidase (POD) enzyme activity, is essential.

Conventional breeding for enhancing drought resistance has mostly focused on selecting the genotypes that produce more grain under drought stress (Rosales *et al*., 2012) [50], with little attention paid to understanding the physiological basis of drought resistance. The development of physiological selection methods to support plant breeding programs will be assisted by the integration and comprehension of the physiological foundations of yield restrictions brought on by drought stress (Mir *et al*., 2012) [40]. The ability to combine parents with complementary qualities, resulting in additive gene activity for boosting drought tolerance, would be one benefit from a better understanding and use of physiological traits and mechanisms (Mir *et al*., 2012) [40]. Some morpho-physiological traits and processes connected to enhanced drought resistance have been identified as a result of phenotypic characterization for drought resistance. More root system water uptake from the soil profile to allow transpiration, enhanced canopy biomass production, and effective and increased mobilization of stored carbon to the harvestable product are all known processes that affect drought resistance (Rao *et al*., 2017) [49].

There are a number of traits that have been shown to increase drought resistance, and depending on the kind of drought (early, intermittent, or terminal) and the agro-ecological conditions where the crop is grown, they may contribute to a superior grain production. Ideotypes and plant models, such as the anisohydric ("water spending") plant model and the isohydric ("water saving") plant model, have been developed for targeting in plant breeding according to agro-ecological zones and types of drought. The water spending ideotype will function substantially better in more tolerable drought situations, whilst the water-conserving ideotype may have an advantage in hard environments (Polania *et al*., 2016a) [45]. Plant breeders typically focus more on using intra-specific variation, which is readily exploitable without any genetic barriers, to improve crops at the genetic level. To find the best potential descendants, including pure lines, intra-specific crossings follow standard Mendelian segregation and selection at subsequent generations. In addition to certain other techniques like in-vitro selection and the use of somaclonal variants, many breeding procedures can be used, including mass selection, pure line recurrent selection, and approaches.

3.1 Mass selection

By combining positive and negative mass selection methods, mass selection is a simple form of selection that is used to produce vast populations. Populations are subjected to mass selection in search of traits with high narrow sense heritability. Environment plays a significant role in mass selection, which is detrimental to the development and phenotypic expression of individual plants. Additionally, it helps in choosing the kinds best suited for local performance.

3.2 Pure Line Selection

Using this method, segregating individuals are created by crossing a parent with drought tolerance with a high-yielding parent. Recombination and the segregation of characteristics produce new allele combinations. The best-performing plants in both irrigated and drought-stressed conditions are chosen for the F_2 generation. To create new plant generations, seeds from the selected plants are gathered. In order to create pure lines, new plant kinds are developed to select the best offspring and population-level superior plants. Very few recombinants are produced using these techniques, which is a drawback. Because homozygosity is attained to about 87.5 percent in the F_4 generation, there is extremely little chance that genotypes will alter in the following generations.

3.3 Recurrent Selection

According to this method, the individual plants are chosen from the original population and subjected to Progeny testing. After that, they are crossed with one another in all possible ways to produce seeds that will be used to create a new base population. Selfing produces heterozygosity in F_2 plants, which results in novel genetic variation in each population, produces new recombinants, and aids in combining promising alleles into a single genotype. Gene linkage gradually diminishes and new recombinations are introduced among these individuals. In each cycle of selection, the process is repeated numerous times, resulting in the formation of new genetic recombination. Recurrent selection is frequently employed to improve yield potential and drought resilience. Exact selection is conducted to increase genetic variety after each cycle. Recurrent selection in drought has been shown in numerous studies to boost gain yield (Gimenez *et al*., 2001) [23].

3.4 Manipulation of Somaclonal Variation

Variations in cells derived from somatic or gametic explants are phenotypic variations caused by epigenetic alterations. Most of the time, these variances are undesirable since they reduce the uniformity of the recovered plants. The fact that these differences are spontaneous, however, allows plant breeders to spot novel variations among the plants' newly emerged individuals. Both permanent and transient alterations are possible. Temporary in nature are the differences brought on by physiological effects in plants that are not inherited. Mutations, polyploidy, endopolyploidy, and chromosomal abnormalities can all lead to the development of permanent variants. The inclusion of drought resistance in materials with higher yield potential is significant. Improved cultivated, landraces, related wild species, or varieties created using molecular breeding techniques can all have the ability to withstand drought. Selection of individuals is a challenging operation that must be carried out in rainout shelter conditions when breeding for drought-resistant cultivars in drought stress situations (Gimenez *et al*., 2001) [23].

Both yield and yield-related characteristics are assessed in both watered and water-stress environments in order to find cultivars that are drought resistant and have high producing capacity. Select individuals' yield stability is assessed in irrigated and stressful environments across various environments. High yields and broad adaptability should be possible to combine through breeding. Individual offspring are chosen by taking into account their average performance under stressful conditions under a variety of environmental conditions. The chosen individuals are raised in the best conditions, and progeny choices are supported based on yield and yield characteristics. After being evaluated in a variety of conditions, the breeding material developed from breeding environments is finally released for cultivation if it exhibits high mean performance and high stability.

4. Conclusion

One of the most significant abiotic stresses, drought stress has a detrimental impact on crop growth and lowers agricultural productivity globally. By limiting the amount of water available, drought stress produces stomatal closure, which limits gas exchange and completely alters crop metabolism and cellular structure. In hot and dry areas, drought is the most important abiotic factor influencing growth and agricultural productivity. In agriculture, drought has a detrimental effect on crop production by reducing leaf size, stem extension, and root multiplication, causing an imbalance between water and nutrients, and decreasing the effectiveness of water usage. There are considerable yield losses that might cause crops to fail during periods of extreme drought. In regions with irregular and uneven rainfall and insufficient water supplies for crop plants to survive and generate the necessary yields, drought is the biggest yield-reducing factor. In order to balance global population growth and food demand, drought resistant or tolerant varieties must be developed in addition to plants' natural drought resistance capabilities. Around the world, crop production is severely constrained by drought.

The main cause of decreased crop yields and a significant limiting factor for agriculture. Breeding drought-resistant plants will be made possible by the identification of genetic elements involved in plant responses to drought stress. Due to its exceptional drought tolerance, sorghum is one of the most important food and feed crops in the world's arid and semi-arid regions. Sorghum is an important resource for the nation's economic development, so figuring out the genetic diversity of the current germplasm is essential for better agricultural improvement, conservation, and use. Through evolution, many adaptation mechanisms have been created that help plants be more resilient to the negative consequences of drought stress. When under stress from drought, plants' three main coping mechanisms are stress avoidance, escape, and tolerance. As a result, from the molecular up to the plant level, plants respond differently to drought stress.

Three fundamental general tactics are recommended for plant survival in drought-prone areas. These tactics include avoiding the drought, escaping drought, and tolerating that too. Crop plants, however, employ multiple mechanisms simultaneously to fight against drought. Plants adapt some effective techniques to deal with the problem of drought stress. Morphological, anatomical, biochemical, and molecular techniques are a few examples of adaptation mechanisms that organisms adapt to protect themselves against the stress of drought. The intricate nature of drought stress's impacts on plants, affecting them at every step of development from seed germination to reproduction. In areas where rain is erratic, unevenly distributed, and water availability is constrained for crop plants to survive and produce the predicted potential yields, drought ultimately becomes the most yield-reducing factor. The development of drought-resistant or tolerant cultivars, in addition to plants' natural capabilities for drought tolerance, is essential for achieving global food security by balancing population expansion and food demand.

5. References

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