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Drought's Impact on Crop Plants and Genetic Drought Resistance

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Abstract **– Drought is one of the biggest problems in the current climatic environment and is one of the most severe abiotic stresses in many parts of the globe. The most significant environmental stressor that adversely affects crop yield and quality globally is drought. In the coming decades, climate change raises the likelihood that droughts will become worse in many regions of the world, affecting crops already damaged by aberrant metabolism and possibly reducing their growth and development. Water stress also affects the physiological activity of the crop by inhibiting photosynthesis and the uptake of nutrients by the growing leaves. There is always a possibility that crops could fail or their yields might drop because of moisture stress, particularly in regions where crop production is entirely dependent on rainfall. When moisture stress is extreme, the crop may completely fail. At various growth stages, drought stress negatively impacts yield and qualities that are connected to yield, which results in a decrease in yield. The impact of drought stress is primarily influenced by the plant's stage of development, the intensity and length of the stress, the genetic potential of the species, and environmental interactions. Crop plants have developed numerous morphological, physiological, and biochemical systems as adaptation methods to survive under drought stress. A plant, however, may use multiple coping mechanisms when faced with drought stress. The mechanism (s) responsible for the least amount of crop loss during a drought are known as drought resistance. Some drought resistance methods include ways to avoid dehydration, reduce transpiration, or physiological variables. Climate change will eventually endanger global food security, making it more difficult than ever in the twenty-first century to feed the increasing world population. To maximize yield potential while reducing the risk of climate change, it is crucial to utilize well-adapted, high-yielding varieties that are resistant to drought stress. The only option to mitigate the negative effects of climate changes on crop adaptability is through climate-smart agriculture, which can be done before they have a significant impact on world crop production.**

Keywords **– Drought Resilience, Yield Loss, Resistance, Genetic Bases, Climate Smart, Food Security.**

I. INTRODUCTION

Global food security is seriously threatened by factors such as the expanding world population, the escalating effects of climate change, the scarcity of arable land, and stressors from the environment. Innovative methods are needed to increase crop yield and meet the world's growing need for food while the impact of climate change become severe across the world (Lesk *et al.*, 2016). Rapid population growth and significant climatic change threaten global food security (Lesk et al., 2016). Drought and heat stress have emerged as the most significant issues restricting crop production and eventually, food security. Around the world, droughts are beginning more frequently due to decreased precipitation and altered rainfall patterns (Lobell *et al.*, 2011). Due to their detrimental effects on plant development, physiology, and reproduction, severe droughts significantly reduce crop yields (Barnabas *et al.*, 2008).

According to Anjum *et al.* (2011), plants are prone to severe droughts when either the water supply to the roots is insufficient or the rate of water loss through transpiration is very high. The intensity of the drought's effects is typically unpredictable since it depends on a number of variables, such as rainfall patterns, the soil's ability to retain moisture, and water losses through evapotranspiration. According to Farooq *et al*. (2009), drought affects photosynthesis; assimilate partitioning, nutrient and water relations, growth, and other processes that affect crop yields. According to plant growth stage and other environmental conditions, plant responses to drought stress typically vary from species to species (Demirevska *et al*., 2009).

According to Chen *et al*. (2020), one of the main environmental factors that restricts agricultural production globally is drought, which prevents plants from growing and developing normally and from completing their life cycles. By significantly reducing crop growth and biomass accumulation, drought stress has a negative impact on plants. Decreased rates of cell division and expansion, root development, elongation of stems, and leaf growth are the primary effects of dry stress on plants. Additionally, stomatal oscillations, plant water and nutrient relationships, which lower the production of agriculture, and water usage efficiency are all affected by drought (Anjum *et al*., 2011). *The main cause of decreased crop yields and a significant constraint for agriculture. Developing plants that are drought-resistant will be made possible by the identification of genetic components involved in plant responses to drought stress.*

Due to the negative effects of numerous biotic and abiotic stresses, food productivity is declining; consequently, reducing these losses is an important issue of concern to assure food security in a changing climate. Abiotic environmental factors that affect plant development and productivity include drought, excessive salt, extreme heat, cold, and heavy metals. More than any other environmental element, drought seriously hinders plant growth and development, limits plant production, and negatively affects crop plant performance (Shao *et al*., 2009). When the water supply to the roots becomes difficult or when the transpiration rate increases significantly, a plant experiences drought stress. According to Praba *et al*. (2009), the effects of drought include changes in growth, yield, membrane integrity, pigment content, osmotic adjustment to water relations, and photosynthetic activity. Environmental, agronomic, and meteorological factors all have an impact on drought stress. The degree of stress, accompanied stress elements, plant species, and plant developmental phases all affect how susceptible plants are to drought stress (Demirevska *et al*., 2009).

Many production limits today, but two major difficulties demand immediate action in order to achieve sustainable development goals are the world's population expansion and climate change. A rise in food demand brought on by the growing population is driving up agricultural productivity. In order to satisfy the needs of the growing population, yields from agriculture must thus be increased; yet, yield reduction is seen in places where crop production has been severely damaged by drought. While extended drought stress results in plant death, short-term drought stress mostly affects grain yield. The development of superior varieties of crops to address the difficulties caused by climate change and the related abiotic and biotic stress is mainly dependent on improving crop characteristics. Global warming caused by climate change may intensify insect pest pressures and plant diseases, severely reducing crop productivity. In crop plants, traits that regulate the genes for stress or disease tolerance are essential commercially.

In general, drought is recurrent phenomena that imperils the yield of crops and poses a risk to the livelihoods of people everywhere (Liedtke *et al*., 2020). A significant problem for agriculture is the development of crop varieties that are resistant to drought through breeding or biotechnology. Designing improved cultivars with reliable high yields requires an understanding of how drought impacts plants. On the other hand, plant responses to drought stress are complex and vary depending on environmental factors, the frequency and length of the stress, the species and variety of the plant, and the physiological stage at the time of the stress. Because drought prevents crop plants from realizing their full genetic potential, it reduces agricultural production. Crop productivity is impacted by biotic and abiotic stresses that have been brought due to global climate change (Raza *et al*., 2023). Drought stress is one of them, posing a damaging risk to food security that affects a sizeable portion of the population, mostly those who reside in arid and semi-arid regions (Rai *et al*., 2021).

Since drought stress primarily results from a severe lack of humidity supply as precipitation, it is typically defined as a lengthy period of irregular, lower-than-average natural water accessibility. According to Cheng *et al*. (2002), plants are typically exposed to drought stress when either (a) the water transfer to the roots is insufficient or (b) the water loss through transpiration is too high. The degree of the damage brought by drought stress is typically unstable since it depends on a number of factors, including the types of rainfall, the amount of moisture in the soil, and water shortages from transpiration. As a result, drought stress impairs photosynthesis, water-nutrient relationships, and crop growth, leading to a significant drop in crop yields (Mubarik *et al*., 2021). According to growth stage and additional environmental factors, plant responses to drought stress typically vary from species to species (Ansari *et al*., 2019).

A serious agronomic problem that results in substantial crop losses worldwide is drought stress. Crops that are well adapted to climates that are prone to drought could be developed to help with this agricultural problem. These crops's ability to survive under such harsh conditions depends on complex and poorly understood mechanisms. Water scarcity, specifically drought, has an adverse effect on agricultural and plant productivity by reducing leaf size, stem extension, and root multiplication, altering the balance between water and nutrients, and decreasing water use efficiency. These losses can become much bigger and crop fall is a real possibility during periods of extreme drought. Plants modify a variety of physiological, biochemical, and molecular responses to deal with drought stress (Thatcher *et al*., 2016). These changes can occur quickly and with great precision, depending on the tissue type, developmental stage, and level of stress. According to Takahashi *et al*. (2018), the molecular effects of drought stress include transcriptional and post-transcriptional modulation of gene expression. Transcriptional modulations lead to variations in metabolite flow and physiological changes related to cellular damage protection by causing differential expression of genes implicated in different metabolic pathways (Knight H and Knight M.R. 2001).

With the help of advanced regulatory networks that include drought avoidance, tolerance, and recovery after stress, plants have evolved to be able to survive drought. Drought resistance involves three mechanisms: drought escape, drought avoidance, and drought tolerance. Drought resistance is conferred by a variety of morphological, physiological, and biochemical characteristics. While the genes responsible for the biosynthesis of various compatible solutes have been found and cloned from plants, yeasts, mice, and humans, morphological and physiological characteristics exhibit various types of inheritance patterns (monogenic or polygenic) and gene action (additive and non-additive). There are several breeding strategies for drought resistance, each having advantages and disadvantages. Effective screening methods are necessary for every breeding program's success in the selection of desired genotypes. The objective of the paper was to understand the effects of drought stress and genetic drought resistance mechanisms in water-limited regions.

II. CROP PLANT MECHANISMS FOR DROUGHT RESISTANCE

Both biotic and abiotic factors have an impact on plants, and as a result many internal changes take place in p-

-lants. These biotic and abiotic elements have an impact on the production and growth of plants. Biotic factors are interactions between organisms and plants that can be beneficial or harmful. Plant growth may be positively impacted by positive influences. Allelopathy, herbivores influence, or pathogen infection in plants are examples of negative effects (Ciura and Kruk, 2018). These harmful effects are resisted by plant defense mechanisms that use a variety of chemical substances (Li *et al*., 2019).

Drought resistance refers to systems that reduce yield loss in a drought circumstance. There are various ways that a crop might use to reduce the yield loss caused by drought stress. Plants activate their drought response mechanisms in response to drought stress, including morphological and structural changes, expression of drought-resistant genes, synthesis of hormones, and production of osmotic regulating chemicals. A more general word used to describe plant species with adaptive characteristics that allow them to escape, avoid, or withstand drought stress is drought resistance or tolerance (Levitt, 1980).

According to a critical assessment of plant breeding advancement over several decades, production has improved genetically under both favorable and stressful situations (Castleberry, Crum, & Krull, 1984). Before many of the physiological problems of drought resistance were fully understood, yields improved under drought stress, which was partly due to genetic improvements in yield potential and partly due to improvements in stress resistance. For instance, Bidinger *et al*. (1987) discovered that the production potential and growth duration of millet types under drought stress were primarily responsible for the yield. Early cultivars with a high potential yield were most likely to produce well under stress. Fischer and Maurer (1978) proposed a "susceptibility index" (S) that measured the relative susceptibility of a variety to drought stress and acknowledged the impact of prospective yield on wheat yield performance under drought stress. When they examined their wheat data, they discovered that the susceptibility index was not entirely independent of the variety's potential yield.

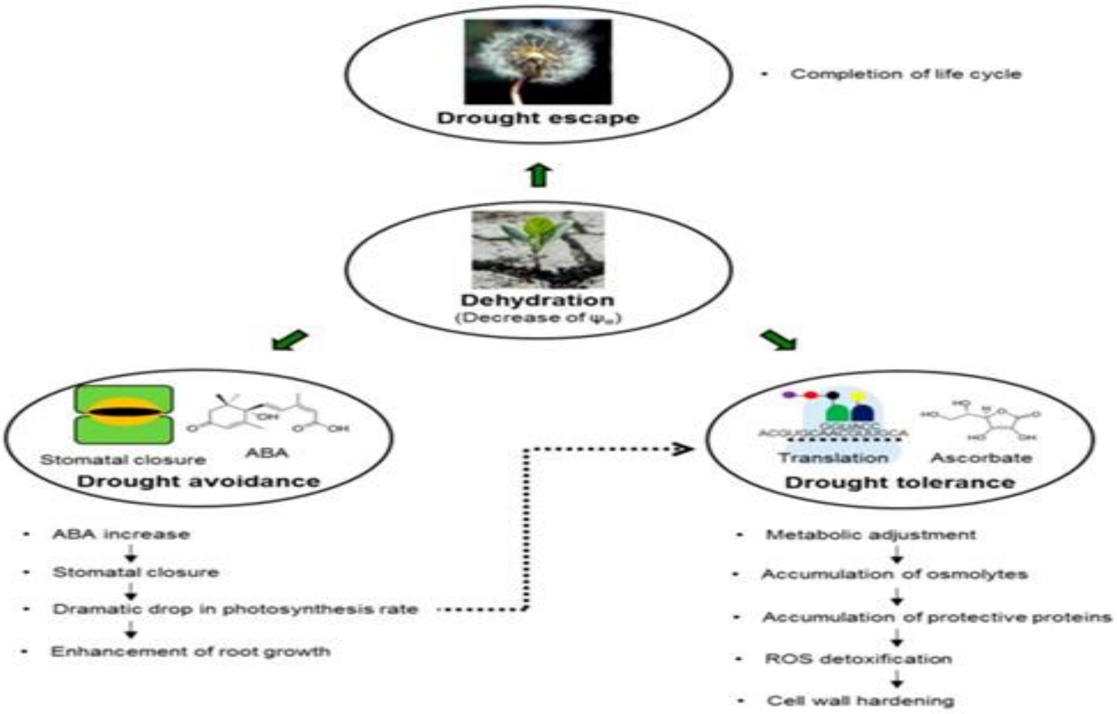

Fig. 1. The primary processes of the plant reaction to dehydration as well as the key drought resistance tactics used by plants to overcome water shortage times (drought escape, drought avoidance, and drought tolerance). Four distinct systems help with plant survival when there is a moisture deficiency. There are four ways to deal with droughts: recovery, avoidance, tolerance, and escape.

Therefore, a relatively high yield potential must be combined with particular plant characteristics that would protect yield from a severe reduction under stress (Blum et al., 1983) in order to improve yield under stress. On the other hand, it has occasionally been discovered that genotypes that could produce less effectively under drought stress conditions, particularly under severe drought stress (Blum, 1982). Reitz (1974) got at the persistently useful conclusion that “Varieties fall into three categories: (a) those with uniform superiority over all environments; (b) those relatively better in poor environments; and (c) those relatively better in favored environment.”

2.1. *Drought Escape*

The simplest approach for surviving a drought is escape it. Drought typically happens either in the middle or late of the crop season. Plants growing in arid climates are more prone to drought escape. In 4 to 6 weeks, they complete their life cycles. For some crop plants, drought escape is also crucial. For instance, severe drought has less of an impact on early-maturing types of wheat, sorghum, maize, and rice than it does on late-maturing ones. These crops all have a predictable growth pattern. In spring wheat, late maturing varieties yield more than early types, particularly when the season's first drought ends before anthesis.

2.2. *Drought Tolerance*

Drought tolerance is the capacity of crop plants to withstand low water content in their tissues. Because the crop may yield more while using less water, drought resistance is preferable. Drought tolerance in cereals often operates during the reproductive phase. Better photosynthesis, seedling development, and germination are displayed by tolerant cultivars. In Sorghum, a line that was more drought resistant than another line showed higher photosynthetic rates at the leaf water potential. In numerous ways, drought tolerance and drought avoidance are different.

Table 1. Characteristics of Drought Tolerance.

No	Category	Characteristics
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.

2.3. *Drought Avoidance*

The ability of the plant to maintain a favorable internal water balance under moisture stress is referred to as drought avoidance. Therefore, plants that do not experience drought retain a high level of water in their tissues. Through decreased water use or greater water uptake, drought avoidance can extend the crop's growth period. However, avoiding drought slows down photosynthesis, which in turn slows down the growth of aerial components. It increases the formation of roots and is therefore more significant than tolerance to drought. In cereals, tolerance to drought occurs during the reproductive phase, while avoidance occurs during the vegetative phase. There are two kinds of drought prevention strategies. Those that limit water loss through transpiration should come first. These traits include leaf form, size, and orientation, as well as stomatal characteristics.

2.4. *Drought Resistance*

Together, drought avoidance and tolerance contribute to drought resistance. In other words, the ability of crop plants to produce a satisfactory yield when there is a moisture deficiency is referred to as drought resistance. The many mechanisms linked to drought tolerance and yield under low soil moisture are used to measure drought resistance. Both avoidance and tolerance traits are crucial for drought resistance in wheat grown in winter.

III. KEY FEATURES CONTRIBUTING TO DROUGHT RESISTANCE

Several morphological and physiological characteristics, such as root morphology and rooting depth, plant architecture, leaf area, cuticular resistance and thickness, stomatal conductance, osmotic adjustment, antioxidant defense, hormonal regulation, and desiccation, have been linked to plant drought tolerance. The most significant ones are those related to plant reproductive biology, root architecture, leaf morphology, physiological traits like osmotic adjustment or proline accumulation, partitioning of total biomass (determined by dry matter or harvest index), timing of plant development (such as earliness), and others. While some of these traits are unique to certain species, others are shared by numerous species. According to several findings, there is a strong correlation between crop heat tolerance and corresponding adaptation to drought-prone conditions in the warm tropics.

3.1. *Leaf Traits: Senescence, Stay-Green and Leaf Area*

For investigating how plants adapt to the environment and researching climatic change, plant functional characteristics are helpful instruments (Fyllas *et al*., 2020). Due to their susceptibility to climate change and potential to represent the acquisition and use of plant resources, leaf traits have drawn particular attention among these characteristics (Ye *et al*., 2022). In order to prevent water loss and improve their capacity to adapt to drought conditions plants often exhibit thicker leaf thickness (LT), greater leaf dry mass per area (LMA), and larger leaf dry matter content (LDMC) in dry conditions (Akram *et al*., 2022). Photosynthesis and leaf nitrogen concentration are tightly connected (Zhan *et al*., 2018).

Nitrogen content per unit area (Narea), nitrogen content per unit mass (Nmass), and carbon: nitrogen ratio (C/N) can all be used to demonstrate the leaf carbon capture method (Zhan *et al*., 2018). Under hot and dry environmental conditions, plants typically had higher nitrogen content per unit area and higher leaf dry mass per area because this increased investment of nitrogen in structure improved their survival in challenging conditions (Blumenthal *et al*., 2020). Leaf characteristics, which are crucial components of a plant's functional characteristics, can shed light on how plants interact with their environment at both the local and global levels (Toledo-Aceves *et al*., 2022).

Senescence is a stage of plant development that causes the photosynthesis of the plant's leaves to stop, the decomposition of proteins and chloroplasts, and the mobilization of nitrogen, carbon, and other nutrient supplies 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. Environmental factors such as high temperatures, food deficiency, and drought may hasten the onset of senescence, influencing the nutritional makeup of seeds and the yield of crops (Distelfeld *et al.*, 2014). 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 production losses. Plant breeders frequently refer to a trait that extends photosynthetic activity as stay-green or green leaf area at maturity (GLAM). Sorghum, a crop adapted to a dry climate, has been extensively investigated for this characteristic and several stay-green quantitative trait loci (QTLs) have been found in it (Vadez *et al.*, 2011). However, according to Harris-Shultz et al. (2019), the genes driving these QTLs are still unknown.

The complicated characteristic of "stay-greenness" in sorghum is linked to some varieties' tendency for perennial growth (Thomas and Howarth, 2000). Other plant species obtain stay-green traits by significantly different mechanisms, such as inhibiting chlorophyll degradation (as in the case of Gregor Mendel's green peas) and changing how plants react to hormones (Armstead *et al.*, 2007). According to Hortensteiner (2009), some stay-green genes have also been found in Arabidopsis and rice, most notably the stay-green rice (SGR) genes and their Arabidopsis homologs SGR1, SGR2, and SGR-like (SGRL). The corresponding molecular pathways have been clarified, with the phytohormones strigolactone (SL), cytokinin (CK), ethylene, and ABA all playing significant roles in stress-induced leaf senescence. In cereal plants (Young *et al.*, 2004) and dicots (John *et al.*, 1995), several attempts to enhance photosynthetic activity and drought performance by altering ethylene production have been recorded. The relationship between ethylene and leaf senescence is well-established (Bleecker *et al.*, 1988).

3.2. *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 oldest methods used by scientists in their effort to create drought-resistant plants, as well as recent developments in Arabidopsis and commodities, was manipulating stomatal quantity, size, and control. According to Sussmilch and McAdam (2017), ABA is the primary hormone signal that causes stomatal closure in water-limited circumstances. Plant survival may be aided by adjusting ABA sensitivity to boost stomatal responses in response to drought. However, reduced photosynthetic activity brought on by insufficient CO_2 uptake is typically harmful to carbon intake and deleterious to crop yield. Additionally, stomatal holes allow water to evaporate, keeping plants from overheating.

Considering that, warm temperatures are likely to accompany dryness in natural environments, lowering stomata capacity could not be a long-term solution for improving drought resistance while maintaining yield and biomass production. In contrast to the improved drought resistance but decreased yield of the transgenic plants that overexpress PYL5, for example, a series of rice mutants of the ABA receptors pyrabactin resistance 1-like-1 (pyl1), pyl4, and pyl6 have improved yield but are more sensitive to drought (Miao *et al.*, 2018). Stomatal kinetics, or more specifically, increasing the pace of stomatal responses, could be controlled in order to prevent the trade-off between stomatal conductance and drought tolerance (McAusland *et al.*, 2016). With the help of the strong guard cell-specific promoter pMYB60, a synthetic blue light-induced K+ channel 1 (BLINK1) was recently expressed to improve plant stomatal kinetics (Cominelli *et al*., 2011). This significantly sped up stomatal reactions, resulting in plants that responded to changes in light conditions with greater speed.

3.3. *Cuticular Wax Production*

Wax is a significant component of the exterior cuticle layer found on aerial plant organs. This hydrophobic barrier controls permeability and water loss while protecting the epidermis from a variety of environmental stimuli like UV light, cold temperatures, fungi, and insects. Many of the important genes involved in wax metabolism, regulation, and transport still need to be characterized, despite the fact that numerous studies in Arabidopsis and crops have demonstrated a link between drought stress and changes in cuticular wax content, composition, and morphology (Patwari *et al*., 2019). Wax composition differs not only between different plant species but also across certain tissues or organs within the same plant. Both Arabidopsis and crop species have had their cutaneous wax content examined. All wax components must first be transferred to the plasma membrane from the endoplasmic reticulum before being released from the cell wall of the epidermal cells, where they form the cuticle (Fernandez *et al*., 2016).

3.4. *Root Traits*

In order to ensure plant survival during droughts, a variety of genes and a complex genetic network control the polygenic characteristic of drought resistance. Understanding the genetic factors behind drought resistance has been the focus of numerous investigations. In response to drought, roots modify their structural makeup to encourage soil penetration, dispersion, and interaction for better water and nutrient uptake. During a drought, these structural modifications guarantee that plants get the nutrition and water they need to stay healthy and productive. With root growth, each root acquires new characteristics related to development, resource acquisition, and transport. Through the distribution of roots in the soil, the integration of specific root features in the root system may show crop performance in a variety of situations.

When topsoil water is not available due to drought conditions, deep roots have long been thought to be one of the most efficient strategies to promote complete utilization of subsurface water. A deeper root system, however, is not always linked to greater drought resilience. Taproot-equipped plants typically adapt well to drought conditions. Even in dry temperatures or situations, many desert plants can spread roots down more than 75 feet, enabling them to find water. Taproots can be used to store food reserves, which increases their capacity for independence and resilience. Drought causes roots to change their characteristics, which enhances plant survival, yield, and adaptation. Root system architecture (RSA) is one of these characteristics that is crucial for boosting water uptake (Maurel C. and Nacry P, 2020).

Small fine root diameters, long specific root lengths, and significant root length density, especially at depths in soil with adequate water, are root features linked to preserving plant productivity under drought. Small xylem diameters in targeted seminal roots conserve soil water deep in the soil profile for use during crop maturation and lead to higher yields in situations with late-season water deficits. When there is plenty of water available at depth, the capacity for deep root growth, high xylem diameters in deep roots may help boost root water uptake.

Together with other morpho-physiological, and biochemical systems, roots are one of a plant's initial lines of defense against drought. Crop productivity and environmental adaptation are largely determined by the water and nutrient uptake capacity of the root system (Hulugalle *et al*., 2015). The study of a plant's root system lies far behind that of the plant's aboveground portion due to the difficulty of doing research beneath. Regulating root growth and root structure is the primary method used by plants to combat drought. According to several studies, field management and breeding both have the potential to increase yields of crops (Li *et al*., 2017).

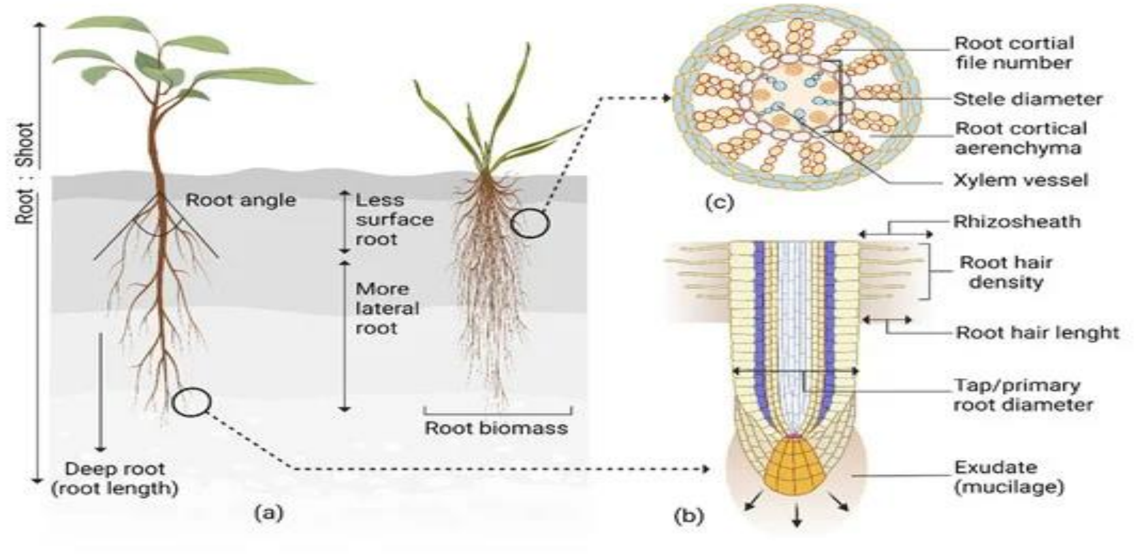

Fig. 2. Characteristics associated with drought-adaptive roots. Plants can respond to drought in two ways: (a) changes in root angle, length, and biomass; the ratio with the shoot; and enhanced lateral branching; and (b) key drought-responsive features such as root hair length and density, rhizosheath size, taproot diameter, and exudates. (c) In response to drought, plants modify their morphological characteristics, such as root cortical file number, cortical aerenchyma, stele diameter, and xylem vessel.

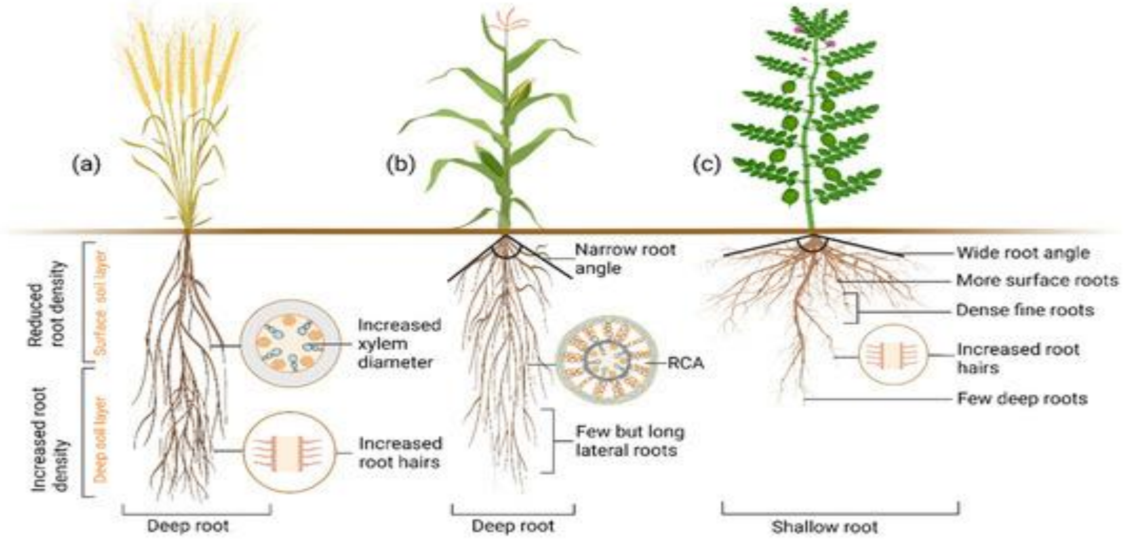

Fig. 3. Multiple root ideotypes that are drought-tolerant. (a) Important drought adaptation response features include deep root, reduced root on soil surface layer, more root in the deep layer, and increased root hair and xylem diameter. (b) To adapt to dryness, plants need have deep roots, a narrow root angle, few but long lateral roots, and more root cortical aerenchyma (RCA). (c) For low rainfall areas, shallow, wide-angle roots, more surface roots but few deep roots, and enlarged root hairs are essential root drought adaptation characteristics.

IV. CONCLUSION

One of the main challenges to agricultural production and global food security is abiotic stress. Drought is one of the main problems in the current climatic environment and is one of the most severe abiotic stresses in many parts of the planet. Plants experience moisture stress when their evapotranspiration requirements are not met. Drought is brought on by a lack of water because 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 spectrum of plant responses to this stress.

Among the most significant environmental factors, that negatively affects plant growth and production is drought. Due to the effects of global climate change, water shortage is one of the major problems that agriculture is currently experiencing. Given that agriculture depends so heavily on water, the global water shortage poses a challenge to food and agricultural security. To fulfill the demands of projected population expansion, crop yields must be increased; however, abiotic stresses globally significantly lower crop yields. The many biotic and abiotic environmental elements affect plant development and production. The influence of drought stress on plant characteristics as photosynthesis, respiration, water relations, and biomass production has a considerable detrimental effect on agricultural yield. It has a significant impact on plant yield components such as germination, growth, phenology, water and nutrient relations, photosynthesis, assimilate partitioning, and respiration. Plant growth is impacted at all phenological stages, which makes it clear that the effects of drought stress extend from morphological to molecular levels.

The mechanism (s) responsible for the least amount of crop loss during a drought are known as drought resistance. Some drought resistance methods include ways to avoid dehydration, reduce transpiration, or physiological variables. By limiting transpiration water loss, genotypes resistant to drought sustain high photosynthetic under moisture stress conditions. Finally yet importantly, climate change poses a threat to global food security, making it the most difficult challenge of the twenty-first century to feed a growing global population. To maximize yield potential while reducing the danger of climate change, it is crucial to utilize well adapted, high-yielding varieties that are resistant to drought stress. The only option to lessen the negative effects of climate changes on crop adaptability is through climate-smart agriculture, which can be done before they have a significant impact on world crop production.

Plants adapt some effective techniques to deal with the problem of drought stress. These morphological, anatomical, biochemical and molecular adaptation techniques are employed by organisms to adapt to and protect themselves from the stress of drought. The complex consequences of drought stress on plants affect them at every step of development, from seed germination through reproduction. In regions where rain is unpredictable, 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.

Declaration

The authors declare no competing interests.

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