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Abstract

Environment fluctuations have become the greatest threat to global food security. Of various abiotic stress factors, aridity hampers the most yield contributing attributes. In the context of agriculture, term “aridity” refers to a protracted period of insufficient precipitation, having detrimental influence on crop development and overall biological output. A sustained drought has considerable negative effects on crops and livestock, including the reduced production, destruction of property, and livestock sell-offs. Consequently, plants themself exert various kinds of defensive mechanisms to combat the ill effects of climate change. For example, plants with small leaves, benefit from aridity as part of their strategy for modifying the soil to water shortages and nutrient restrictions. Furthermore, low genetic diversity among significant crop species, together with ecological productivity limits, must be addressed in order to adapt crops to episodic drought spells in the coming days. A deeper understanding of the molecular and genetic underpinnings of the most important intrinsic adaptation responses to drought stress seems to be beneficial for gene engineering as well as gene-based expression investigations in plant systems under hostile environment. Recently, molecular markers and “omics” have opened a huge opportunity to identify and develop specific gene constructs governing plant adaptation to environmental stress.

Keywords: environment, aridity, drought, molecular markers, omics

1. Introduction

The ability to produce enough food for an endlessly expanding population is a key issue for mankind in the twenty-first century [1]. Currently, the scenario has been more difficult by the loss of arable farmland brought on by human habitation, the deterioration of the soil, and a range of environmental conditions, such as flooding, drought, salinity, temperature, and heavy metal pollution [2]. Eventually, accumulation of osmolytes at cellular level, modification of water flow, and scavenging of reactive oxygen species are some of the most frequent and well-documented adaptations that plants, which are sessile, have developed to recognize and respond to stress situations [3].
Environmental stress known as abiotic stress restricts plant growth and metabolism. Abiotic stressors are thought to diminish major food and cash crop yields and output by more than 50% [4]. Abiotic pressures may be divided into two categories: above- and below-ground abiotic stresses. Abiotic strains that are atmospherically produced come from the atmosphere, whereas abiotic stresses that are edaphic come from the soil [5]. In regions where climatic variability and precipitation patterns alter with extended periods of drought interspersed with spells of copious rainfall, abiotic stressors of atmospheric origin are prevalent [6]. On the other hand, anthropogenic activities such as the use of brackish water and sewage water for irrigation, sewage sludge for fertilisation, and inorganic chemicals for fumigation may result in abiotic pressures of edaphic origin. This issue is frequently made worse by inadequate waste management procedures, the weathering of local rocks, and subpar cultural practices that have rendered vast tracts of land unsuitable for agricultural development [7].

Aridity has a significant impact on community structure as well as ecological exploits, including primary productivity and nutrient cycling, by acting as a powerful environmental filter for plant survival, growth, and development [8]. For instance, plants with tiny leaves benefit from aridity as part of their strategy for adjusting the soil to water shortfalls and nutrient constraints. Plants adapt to their environment and develop an ideal phenotype, producing a set of adaptation tactics at both the collective and individual levels.

2. Relevance of plant-water kinship in agriculture

Water is the most abundant material in any living entities across the globe. The weight of water contained in a plant is usually four to five times the total weight of dry matter [9]. Inside a plant body, about 80–90% of cell mass is comprised of water. Plants absorb water from soil through their roots and other parts in the way of vascular system. Xylem tissues of plant vascular system play a crucial role in the movement of water containing essential elements from roots to the shoot. Water supply through cells by diffusion alone is not enough to maintain the hydration of a perspiring canopy plant. The necessity for a vascular system becomes more apparent while studying the hydraulic dynamic of a tree on a hot day, which requires a massive flow of water. Water transport through xylem is over a million times more efficient than water transport through plasmodesmata of parenchyma. Several theories have been proposed to explain the mechanism of movement of water into xylem against the concentration gradient. The cohesion-tension theory, proposed by Boehm, Dixon and Joly (1894) in the late 19th century is thought to be the most appropriate tenet to explain the mechanism of upward movement of water. According to this theory, the water evaporated from leaf surface establishes a tensile strength in the xylem, where the hydrogen bonds provide a continuous intermolecular attraction (cohesion) between the water molecules from the leaf to the root. Thus, the water column in the xylem lumen is driven out of a region with a higher water potential, i.e., from the root and the stem, to a region with a lower water potential, as the leaves, and finally toward the air that can reach very low water potential. Once water reaches the xylem, it enters conducting elements of either conifer tracheid or angiosperm vessels, and flows upwards through the stem to the leaves. The conduit diameter of xylem gets smaller and tapered with plant height, indicating the widening aspect of xylem anatomy from apex to the base of plant. Plants that have an increased number of xylem conduits per cross-sectional area can maintain hydraulic conductance by reducing effects of path length [10].
Droughts can be classified as meteorological, agricultural, hydrological, or socio-economic, according to the American Meteorological Society (1997). Precipitation deficits can be used to categories meteorological droughts, and these crises can develop in other categories of droughts. Agricultural drought focusing on precipitation shortages, discrepancies between actual and potential evapotranspiration, inadequate soil water, and lower reservoir levels. A lack of water in the hydrological system is referred to as a “hydrological drought,” which is characterised by reduced river flow as well as declining dam, lake, and subsurface water levels on a basin-scale. Economic, social, and environmental harm brought on by many sorts of droughts refers to what is meant by socioeconomic droughts [11]. There is limited clarity over the metrics that better reflect the effects of drought on the environment and society.

Agriculture is a key activity of human being since it provides basic needs and water is a critical input for agriculture production. Several factors pose significant risk to farms leading to yield reduction like limited water condition. A limited water availability leading to drought, increased diseases and pest incidence and extreme weather events at local to regional scale. Limited water availability accounts for about 30–70% loss of productivity. It also results in abnormal metabolism that may reduce plant growth or cause the death of plant. Water stress is one of the most detrimental factors seriously affecting the growth and production of many plants mostly during the flowering phases. Under the exposure of severe water crisis, significant diminution in the major growth attributing characters including number of leaves, leaf area, stem length is very often in various plants. Furthermore, the crop yield and productivity are also found to be affected severely under water stress. The damaging effects on plants are associated with oxidative damage in the plant cells are commonly realised by elevated lipid peroxidation, reactive oxygen species (ROS) accumulation, and electrolyte leakage. Under usual conditions, ROS exist in plant organelles, mainly mitochondria, chloroplasts, and peroxisomes, while under stressful conditions such as drought, ROS levels increase resulting in lipid peroxidation and proteins degradation [12]. Also, biological yield and physiological characters such as stem length, number of leaves, leaf area, relative water content, and chlorophyll concentration as well as overall biological yield are decreased under stress condition in many plants [13]. Drought during blossoming is frequently associated with infertility [14], owing to a reduction in assimilating flow to the developing ear. Drought stress can significantly reduce production in important field crops by prolonging the anthesis period and delaying grain filling [15]. Numerous factors could explain the decline in yield, including decreased photosynthesis, inefficient flag leaf formation, uneven assimilate portioning, and a depleted pool of critical biosynthesis enzymes such as starch synthase, sucrose synthase, starch enzymes, and α-amylase.

3. Impact of water stress: physiological and biochemical alterations in plants

Agriculture output is gradually been threatened every year due to drought stress. Drought proves an obtrusive climatic factor for agriculture, livestock and climate. Climate change led to increased temperature and varied environmental conditions globally. So, we need plant varieties that are adapted to these environmental conditions specially drought stress. Water is crucial for plant survival and responsible for various biological, physical and biochemical activities of plant system. Influence of drought desperately hampers plant functioning and limits plant growth at various development stages. Water deficit conditions alter many metabolic activities in plants.
like reduced photosynthetic rate, increased reactive oxygen species (ROS) accumulation, and production of plant secondary metabolites etc.

### 3.1 Influence of water tension on plant adaptation at physiological level

The ever-changing nature of mercurial environment has forced the higher group of plants to develop a variety of intrinsic tactics at morphological, physiological ([Figure 1](#)), biochemical, and molecular levels for survival especially at limited water conditions. On the other hand, some plant species avoid water shortage circumstances by finishing their life cycle, for instance, before or after a drought period, while others showed adaptations to increase water absorption and minimise water loss to prevent its negative effects [15]. For example, *Phedimus aizoon* L., which was observed to respond the severity of drought stress by accelerated root system, thickened the waxy layer of leaf surface and closure of stomata for making sure of maximum water retention [16]. Under extreme arid conditions, the xerophyte *Zygophyllum xanthoxylum* is surprisingly found to accumulate ample amounts of Na\(^+\) ions, coming from the soils they thrive on. The primary role of accumulated Na\(^+\) in *Z. xanthoxylum* has been attributed to their ability to drastically reduce the osmotic potential of leaves, which enhances their ability to absorb water during drought spells [17]. *Reaumuria soongorica* shows specific characteristics during the process of adapting to desertification, such as an incredibly thick cuticle, hollow stomata, specialised leaf shape, deep root system, and efficient physiological mechanisms like a decreased transpiration rate, increased water use efficiency, and maintaining stem vigour to survive desiccation by leaf abscission [18].

![Figure 1. Plausible alterations in plant physiognomy under drought stress.](#)
3.1.1 Root modification

The soil provides nutrients and water to roots. As a result, the morphological and physiological traits of roots greatly influence the growth of shoots and overall production [19]. Plants attempt to extract water from deeper soil layers when there is a water shortage by strengthening their root architecture. In addition, roots are the primary organ that detects the presence of water, and control key aspects of plant growth and development [20]. In comparison with plants with shallow roots, those with deep root systems and perennial growth patterns demonstrated greater drought tolerance [21]. In addition to increasing the amount of soil that may be investigated for water and the surface area of roots in contact with moisture, roots with small diameters and long specific root lengths also boost hydraulic conductivity by lowering the apoplastic barrier to water entering the xylem. Additionally, decrease in root diameter also attribute the enhancement of water access and increases the productivity of plants under water stress. An examination of the root system of marigolds revealed a sharp decrease in the meta-xylem area (Tagetes erecta L.). Reducing the diameter of the meta-xylem vessels reduced embolism risk and improved water flow. Increased meta-xylem area is related to the flow of minerals and water and necessary for the growth of cortical parenchyma [22]. According to reports, the mechanism for drought tolerance in winter wheat, is supported by development of a deep root system, whereas a well-branched (albeit shallow) root system is found in spring wheat [23].

There are three alternative strategies to confer drought resistivity, viz., drought escape, drought avoidance, and drought tolerance. Each of these tactics could develop into a constitutive reaction that happens independently of environmental cues such as water deficit. Drought tolerance and drought avoidance are the major strategies of plants against water deficit stress. The ability of a plant to withstand a dry environment through a variety of physiological processes, such as osmotic adjustment using osmoprotectants, is known as drought tolerance [24]. The continuation of physiological functions including stomata regulation, and root system development even at the period of prolonged dry spell is known as drought avoidance. The ability to adjust short life cycle to avoid drought stress is known as drought resistance [25]. The root system plays a crucial part in the plant’s response to drought stress and may be the first organ to detect it. Shorter roots are less suited to drought tolerance than longer roots. Drought stress results in a significant reduction in the number of roots, as shown by Helichrysum petiolare [26]. Drought tolerant adaptive characters of plant roots including long roots, high density, and intense root system. Long roots with a high density are necessary for plants to retain performance when water is scarce, especially when the water is deeper. Factually, more roots may come into contact with more water vapours in the soil, and a denser root system absorbs comparatively more water than thinner ones [27].

3.1.2 Leaf modification

The majority of photosynthetic products are produced primarily in the leaf, which is the main portion of the plant. When Andrographis paniculate was subjected to water stress, precocious leaf fall was found [28]. Reduced leaf area due to water stress results in less photosynthesis, which lowers crop output. In order to achieve stability between the water received by roots and the water status in different plant parts, leaf area was found to be decreased in Petroselinum crispum and Stevia rabaudiana at limited water conditions [29]. Reducing leaf area is a method for avoiding drought
because it reduces the amount of water lost by transpiration. This reduction in leaf area is due to the suppression of leaf growth caused by a decline in cell division, which causes a loss in cell turgidity [30]. Reduced leaf area is probably a fundamental element of the drought resistance strategy used by eucalypts, and it might be more beneficial to survival than any physiological changes that have been observed [31].

The decline in leaf water potential is typically followed by the rolling of the leaves. Reduced leaf rolling, which occurs in plants with high osmotic adjustment, is thought to indicate that the plant is avoiding desiccation to a larger extent through a deep root system [32].

In addition, thick epidermis with large epidermal cells in plants also comes under the potential strategy of plant drought tolerance. Epidermal tissue thickness offers higher resistance of plants to water loss from root surface under arid climate [33].

With the application of the drought hardening treatment, the stomatal density of potato seedling leaves dramatically increased while the leaf area, stomatal size, and stomatal aperture decreased. These changes led to reduced leaf transpiration rate and improved water utilisation efficiency (WUE). The drought resistance of the potato seedlings that had undergone drought hardening was also enhanced by the alterations in leaf microstructure [34].

An intensive study on leaf trichomes in *Caragana korshinskii* has revealed that leaf trichomes are important structures on epidermis which uptake the dew from outer environment that assist in sustaining the leaf hydraulic assimilation system and mitigate the adverse effects of drought stress [35]. The outermost layer of defence against abiotic stress on plants is called cuticular wax. It was found that compared to healthy plants, sunflower genotypes exposed to drought stress had increased wax loads [36].

### 3.2 Influence of water tension on plant adaptation at biochemical level

#### 3.2.1 Photosynthesis

A severe drought results in decrease or suppression of photosynthesis. Increased stomatal closure, reduced leaf area, and consequent reduced leaf cooling by evapotranspiration leading to damages to the photosynthetic apparatus contribute as the major obstacles for photosynthesis [37]. Decline in CO$_2$ conductance via reduced stomatal activity enhances diffusive resistance and other vital metabolic processes [38]. Loss of CO$_2$ uptake, affect Rubisco activity and decrease the function of nitrate reductase and sucrose phosphate synthase and the ability for ribulose bisphosphate (RuBP) production [39]. The closing of stomata, restriction of gas exchange, degraded photosynthetic apparatus, primarily PSI and PSII, and increased metabolite fluxes are all factors that also contribute to reduced photosynthesis [40]. Drought induced water loss affects the activity of photosynthesis-related enzymes, causing the photosynthetic device to malfunction and resulting in the poor execution of metabolic processes [14]. Reduction in photosynthesis attributed to increased metabolite fluxes result in the production reactive oxygen species, which impede cell growth by causing oxidative stress [41]. Extreme water limitations substantially hinder the rate of CO$_2$ uptake and the photosynthetic system in cedar seedlings (*Cedrus atlantica* and *Cedrus libani*). The chlorophyll content, net photosynthesis, potential yield of the photochemical reaction of PSII and stomatal conductance of *Atractylodes lancea* shown persistent negative trends as the length of drought stress treatment increased [42].
3.2.2 Mineral nutrition

Water deficit situations usually lessen the ion content in various plant tissues by reducing the overall soil nutrient accessibility and root nutrient translocation [43]. Water stress conditions decreased plant potassium (K) uptake [44]. Reduced K mobility, declined transpiration rate and weakened action of root membrane transporters [44, 45]. Decrease in K level in leaves due to disrupted stomatal dynamism as well as irregular guard cell turgidity, also restricts the rate of photosynthesis and, backpedal the plant biomass production [46]. K transporters were inhibited by water stress conditions [47] and inner K channels were stimulated by a protein kinase, CIPK23, which in turn cooperates with calcium sensors (calcineurin B). This K channel was inhibited in roots but activated in leaves of grapevine [48]. K level decreased in Ocimum basilicum and Ocimum americanum plants subjected to limited water availability [49].

Leaf nitrogen (N) content did not change under drought-stress in Mentha piperita, Salvia lavandulifolia, Salvia sclarea and Thymus capitatus, whereas, in Lavandula latifolia and Thymus mastichina plants, reduced N level were observed. While leaf phosphorus (P) level reduced in all species except S. sclarea whose concentration remained the same [50]. Reduced N level and decline in K level in Thymus daenensis was considered as the main responsible factor for photosynthesis decline and leaf senescence under water deficit conditions [51]. Water deficit conditions increased the accumulation of manganese (Mn), molybdenum (Mo), P, K, copper (Cu), calcium (Ca) and zinc (Zn) in soybean [52].

3.2.3 Antioxidant defence system

Plants defensive system prevents the unwanted exposure of extraneous physical and biological agents which harm the plant body. In this context, a prompt, powerful and efficient antioxidant system is of pivotal importance to provide drought tolerance [53]. This system involves enzymatic and non-enzymatic detoxification moieties, which lessen and repair injury triggered by ROS. Antioxidant defence system helps in ROS scavenging that decreases electrolyte leakage and lipid peroxidation, therefore maintaining the vitality and integrity of organelles and cell membrane [54].

It is well established that drought induces oxidative stress by generating ROS, for instance O$_2^\cdot$-, hydroxyl radicals (OH$^\cdot$), singlet oxygen (O$_2$) and H$_2$O$_2$ [55]. Numerous studies conducted under water stress conditions found enhanced activities of pivotal antioxidant enzymes, namely CAT, SOD, POD and APX [56]. Usually, an enhanced antioxidant enzymes activity is observed in stress tolerant genotypes as compared to non-tolerant plants.

Antioxidant enzymes like superoxide dismutase (SOD), peroxidase (POD) and catalase (CAT) significantly involve in the production of antioxidants such as O$_2^\cdot$- and H$_2$O$_2$ [57]. Ascorbate peroxidase (APX) also participates as ROS scavenger. APX mainly occurs in the chloroplast and cytoplasm and is a crucial enzyme for scavenging H$_2$O$_2$ in chloroplasts which convert H$_2$O$_2$ to H$_2$O), and its activity is usually elevated under stress conditions. APX mainly occurs in the chloroplast and cytoplasm and is a crucial enzyme for scavenging H$_2$O$_2$ in chloroplasts [58].

Enzymatic activities of SOD, CAT and POD were stimulated by limited water availability in Vicia faba [59]. The amount of enzymatic and non-enzymatic antioxidants was improved in drought tolerant plants under mild and moderate water deficit conditions. CAT, SOD, POD and APX activities indicating that improved functioning
of these enzymes helps to lower the level of ROS and mitigate the drought generated oxidative stress [60]. Water deficit boosted the levels of SOD and POD levels of these enzymes which stimulate tolerance against drought stress and are vital to reduce its adverse effects [61].

3.2.4 Secondary metabolites

Plants produce some chemical compounds in response to various environmental stresses, called secondary metabolites [62]. Biosynthesis of secondary metabolites (SMs) is regulated by environmental factors, such as temperature, light regime and nutrient availability. In this context, the drought stress signals induce systemic SM biosynthesis such as terpenes, alkaloids, and phenolic complexes to protect the plant system from oxidative stress [63]. On the other hand, high temperatures can also induce changes in SM biosynthesis. For example, heat stress has shown that isoprene levels increase; this biosynthesis is energetically costly for the plant, but these SM protect the cell membrane against oxidative stress, showing physiological benefits that far outweigh their energetic cost. Improved production of secondary metabolites is usually observed under water deficit conditions, which is caused by reduction in biomass formation and destination of assimilated CO$_2$ to C-based secondary metabolites to avoid sugar-promoted feedback of photosynthesis.

4. Molecular symphony of plant adaptation: innate shield to aridity

The intrinsic ability of plant system to respond against drought stress involves a complex cascade of highly regulated genes and signal transduction pathways. Under drought prone conditions, competent stimuli are perceived and captured by uncharacterized membrane sensors, and the signals are then passed down through multiple signal transduction pathways, resulting in the expression of drought-responsive genes and drought adaptation. Secondary messengers (such as Ca$^{2+}$, ROS, phosphoglycerol, ABA, and diacylglycerol) and transcriptional regulators all play important roles in signalling pathways.

Drought stress increase ABA accumulation in plants, and exogenous ABA application, such as gene induction, can have similar effects to osmotic stress. According to Mittler and Blumwald (2015), drought causes the production of ABA in roots, which is then transferred to the shoots and causes stomatal closure, ultimately limiting development [64]. Additionally, ABA is produced in leaf cells and distributed throughout the plant. According to recent data, xylem/apoplastic pH affects ABA compartmentation, which in turn affects the quantity of ABA that reaches stomata. As a result of less ABA being removed from the xylem and leaf apoplast to the symplast in drought-stressed plants (a process known as alkaline trapping of ABA), more ABA reaches the guard cells, allowing for the modulation of stomatal aperture in response to various environmental factors.

Transcription factors are early genes that are activated within minutes of being stressed. Some of the gene families including RD29A contains both ABRE and DRE/CRT elements [65]. The RD29A gene has served as a model for both ABA-dependent and ABA-independent gene regulation. Although ABA does not activate the DRE element, it is required for the DRE to be fully activated by osmotic stress.

Both cis-acting and trans-acting regulatory elements involved in drought-induced ABA-independent/ABA-responsive gene expression have been thoroughly
investigated at the molecular level [66]. Several drought-inducible genes, on the other hand, do not respond to ABA treatment, implying the existence of an ABA-independent pathway during the dehydration stress response. Exogenous ABA treatment increases the expression of many osmotic stress inducible genes. ABRE is a key cis-acting element in ABA responsive gene expression. Two ABRE motifs are critical cis-acting elements that regulate RD29B-mediated ABA responsive expression [67]. ABA up-regulates three members of the AREB/ABF subfamily, AREB1, AREB2, and ABF3, and their full activation requires ABA. The triple mutant areb1 areb2 abf3 exhibits increased ABA resistance and decreased drought tolerance, indicating that the three factors co-ordinately govern ABRE-dependent gene expression under water stress conditions. Involvement of ABA in drought responsive system has been well depicted in the Figure 2.

Some ROS genes have been used to create drought-tolerant plants. The formation of ROS, also referred to as the “oxidative burst,” is a primary defence response of plants to water stress and serves as a secondary messenger to start additional defence responses in plants [68]. Overexpression of a pea manganese superoxide dismutase (MnSOD) gene in rice chloroplasts under the control of an oxidative stress-inducible promoter SWPA2 improved transgenic rice drought tolerance. Cytosolic APX1 has been shown to play an important role in the response to a combination of drought and heat stress.

Multiple mechanisms increase ROS generation when there is a drought stress. The Mehler process leaks more electrons to O₂ when photosynthesis is occurring. One of the main risks to the chloroplast during a drought is the Fenton reaction’s creation of the hydroxyl radical in the thylakoids. Since it has the strongest oxidising potential...
and the shortest half-life, the hydroxyl radical is the ROS that reacts with the majority of biological molecules.

LEA proteins are expressed at specific stages of late embryonic development and play critical roles in desiccation tolerance by capturing water, stabilising and protecting protein and membrane structure and function, and acting as molecular chaperons and hydrophilic solutes to protect cells from water stress damage [69].

Many transcription factor families, including APETALA2/Ethylene-responsive element binding protein (AP2/EREBP), basic leucine zipper (bZIP), MYB, NAM-ATAF1/2-CUC2 (NAC), and zinc finger, have been implicated in drought responses (as shown in Figure 3). Zinc finger proteins (bZIPs), a big family with 75 members identified in the Arabidopsis genome, are among the transcription factors dependent on ABA. Two basic leucine zipper (bZIP) transcription factors that are ABA-responsive element-binding proteins/factors (AREBs/ABFs) best known for their roles in ABRE-dependent ABA signalling during drought stress. The ABA-responsive

Figure 3. Schematic diagram showing genetic cross-talk as an important part of drought responsive system in plants.
elements-binding (AREB) proteins react to drought at the transcriptional and post-transcriptional level, enhancing tolerance to drought stress. AREB/ABF, bind to ABRE and activate ABA-dependent gene expression [67]. The AREB/ABF proteins require an ABA-mediated signal to be activated, as evidenced by their decreased activity in *Arabidopsis* ABA deficient aba2 and ABA insensitive cab1 mutants and increased activity in *Arabidopsis* ABA hypersensitive era1 mutant [66]. Several rice bZIP proteins, including OsbZIP23 and the constitutive active form of OsbZIP46, have also been identified as having a high potential for improving rice drought resistance [70, 71].

In transgenic petunia, constitutive over-expression of a Cys2/His2 (C2H2)-type zinc finger protein encoding the ZPT2-3 gene improved tolerance to dehydration stress. DST, another zinc finer protein, has been shown to act as a negative regulator of drought and salt tolerance in rice by controlling the genes involved in H\textsubscript{2}O\textsubscript{2}-mediated stomatal movement. *ATGPX3*, a gene encoding an *Arabidopsis thaliana* glutathione peroxidase, was discovered to function as a scavenger and an oxidative signal transducer in ABA and drought stress signalling, as well as a key player in H\textsubscript{2}O\textsubscript{2} homeostasis [72]. Several other genes, including *OsSKIPa* and *OsSRO1c*, have been shown to modulate drought resistance in plants by controlling ROS metabolism and regulating ROS homeostasis.

Numerous factors including heat-shock proteins, and other key enzymes involved in protein folding make up the most prevalent functional group of proteins responding to drought. Additionally, in order to generate drought-tolerant crop plants, aquaporin proteins could be used as possible targets. In *Arabidopsis*, constitutive over-expression of the aquaporin gene *GpPIP1* enhanced the rosette/root ratio while lowering drought resistance due to stunted development. It was discovered that the expression of stress-responsive genes, particularly genes of a large set of antioxidant enzymes that directly affect water stress-related traits in rice, was regulated by the plant-specific protein OsGRAS23.

Numerous candidate genes identified through mutant screening or expression profiling studies have been studied further for their roles in drought response. Regulatory proteins have been shown to play critical roles in plant responses to drought stress. Protein phosphorylation and dephosphorylation are common events in plants caused by drought stress. Several kinases have been implicated in drought response, including calcium dependent protein kinases (CDPKs), CBL (calcineurin B-like) interacting protein kinase (CIPK), mitogen-activated protein kinases (MAPKs), and sucrose nonfermenting protein (SNF1)-related kinase 2 (SnRK2). In response to drought stress, the *Arabidopsis* CDPK gene CPK10 was found to mediate stomatal movement via the ABA and Ca\textsuperscript{2+} signalling pathways [73].

5. Conclusion

The frequency and severity of agricultural aridity are predicted to increase in the near future due to a warming environment. Under intermittent drought situations, it will be crucial to provide sustainable agricultural production so that plants can retain physiological activities at low plant water status and swiftly recover once the stress is eliminated. In this scenario, selection of individuals with better water use efficiency, stronger antioxidant defences, and ability to produce important osmolytes as well as secondary metabolites seems potential approach to minimise yield loss under limited water conditions. Currently, the use of genetically modified agricultural plants to
introduce and/or overexpress candidate genes appears to be a promising alternative for accelerating the breeding of improved adaptable and high-yielding crop genotypes. The introduction of genomic technology and gene mapping methods like as genome-wide association studies (GWAS) and precision genome editing with the CRISPR/Cas9 system has aided in the development of alleles that can increase plant yield and performance under a variety of conditions. The sincere research of drought response networks that may be targeted by diverse strategies has currently been possible by molecular studies that combine tissue- or cell-specific promoters with live imaging methods for real-time monitoring of cellular processes. In addition, trans- and multidisciplinary research is urgently required to develop pertinent answers for all the environmental issues affecting agricultural yields and guaranteeing food security. Together, research projects targeted at revealing the physiology of plant responses to water scarcity in model systems and employing innovative discoveries to agriculture are believed to find out some effective avenue to deal with aridity.
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References


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[31] Pritzkow C, Szota C, Williamson V, Arndt SK. Previous drought exposure leads to greater drought resistance in eucalypts through changes in morphology rather than physiology. Tree Physiology. 2020;41:1186-1198


[43] Kheradmand MA, Fahraji SS, Fatahi E, Raoofi MM. Effect of


[71] Tang N, Zhang H, Li X, Xiao J, Xiong L. Constitutive activation of
transcription factor OsbZIP46 improves drought tolerance in rice. Plant Physiology. 2012;158:1755-1768
