Plant Drought Stress: Fromimpact Of Drought Stress On Plant Morphological, Biochemical And Physiological Features To Role Of Nutrients In Drought Stress Alleviation

Yasaman Shahriari

Master of Natural Resources Engineering - Environment - Land Management and Planning Islamic Azad University, Science and Research Branch, Faculty of Natural Resources,Tehran, IranEmail:shahriari93yasi93@gmail.com

Abstract

Water, the basic element for humanity and agriculture, is becoming an increasingly limited resource. Water shortage is a major abiotic problem that affects productivity in agriculture worldwide. The effects of drought stress on the normal physiology and growth of plants are diverse. It leads to increased solutes outside the root concentration relative to the inner roots, which leads to reverse osmosis. This removes the cell membrane from the cellular wall, which can lead to cell death. The interaction with water-absorbing roots creates water stress, resulting in a gap in the soil-plant-air continuum. Water is drawn from root cells, resulting to cell membrane shrinking and decreased membrane integrity as the plant continues to lose water through transpiration, which may eventually result in cell death. Drought stress affects photosynthesis in plants by stomach removal, chlorophyll destruction and photosynthesis. They disturb the balance of the production and antioxidant defense of reactive oxygen species (ROS) resulting in the increase of ROS that causes oxidative stress on proteins, membrane lipids and other cell components. Mineral elements serve for a range of plant functions, including preservation of the charged balance, transporting electron, building blocks, activation of enzymes and supplying osmotic turgor and development. The aim of the study is to offer a comprehensive review of numerous macronutrients and micronutrients, such as nitrogen, phosphorus, potassium, calcium and magnesium, zinc and examine ways in which those nutrients help to reduce the adverse effect of drought on farmers.

Keywords: Macronutrients; micronutrients, drought stress; photosynthesis; antioxidant

Introduction

Plants are constantly exposed to various environmental conditions, some of which may be abiotic stressors such as lack of accessible water, salt, excessive light, extreme heat or cold, and an imbalanced nutritional profile. These conditions, which may act simultaneously or separately, can have a major impact on plant health(1). Plasticity, along with plant adaptation, relates to the potential of plants to react to abiotic stress(2). Drought (or water shortage) stress is a fundamental constraint on agricultural output in many arid and semi-arid countries, and has been intensively studied(3). Inadequate precipitation, lowered ground water levels, or water retention by soil particles can lead to a water deficit in the plants(4,5). When plants experience water stress, they adapt by changing their morphological, physiological, and biochemical traits(2).

In natural habitats, plants are sessile, which means they are fixed to the ground. They are thus exposed to a variety of unfavorable influences, such as things like climate change, drought, etc. as well as a variety of defense mechanisms and resistance mechanisms developed in response to these types of stressors(6). The duration, speed, and efficacy of stress recovery also govern plant performance when it is necessary to maintain severe water shortage periods, which are based on the genetic features of each plant species(7,8). Because plants must immediately adapt to a water shortage, nearly all biological processes are effected across the entire plant. To absorb water through their roots, plants need to use a number of different mechanisms, which benefit them. One such mechanism is maintaining cell turgor, which means not losing water(11). There have been several negative impacts of drought on plants, including decreased cell division and growth rate, increased root differentiation, larger leaves, increased length of shoots, and altered stomatal movements, water and mineral nutrition, and decreased yield and water usage efficacy(12). Caused by stomatal closure, membrane damage, and reduced activity of several enzymes, especially those that are involved in ATP generation, reduced photosynthesis occurs [12,13]. Reactive oxygen and nitrogen species (ROS and RNS) are both produced during conditions of drought stress, and therefore this results in a reduction in redox regulating capability of the cell(8,14).

One of the most active fields of agricultural research is studying plants that can endure lengthy periods of drought stress and preserve their vitality and productivity(15). Tolerant plants may be aided by having more than one quality that enables them to better tolerate water shortages. Also, an advanced root system gives the plant the ability to dig deeper into the soil, which improves the ability to absorb water(16).

Drought Stress on Plant responses.

An further possibility is that particular plant individuals' reactions to drought might be physiological (e.g., fast stomata closure and enhanced water usage efficiency) or biochemical (e.g., production of osmolytes, aquaporins, and a strong antioxidant apparatus)(17). Many innovative techniques have been employed to fight the impact of drought on agricultural species, aside from the usual breeding techniques utilized for drought-tolerant genotypes. An example of regulated deficit irrigation might be helpful to plants, including the fact that it provides a large quantity of useful factors like sugars, organic acids, and antioxidants(18,19). Not only may some compounds applied to plants through their leaves help plants in coping with low water availability, but this may be done because some drought-tolerant genotypes supposedly contribute to their drought tolerance(20,21). Salicylic acid [22], amino acids [22,23], polyamines [24], and micronutrients (such as potassium and phosphorus) [25] have an incredibly uniform impact across species, whereas brassinosteroids [20,21], salicylic acid [22], and amino acids [22,23] are far more likely to be effective. While the understanding the mechanisms that support drought tolerance is beneficial, particularly for crops with water scarcity, it is particularly important in marginal zones (e.g., semi-arid settings) when the water supply is the principal restriction on plant development.the negative impact of Drought Stress on plant performance is seen in morpho-anatomy to biochemical alterations. A number of reactions in plants, such as morphology, physiology, biochemistry, and molecular alterations, follow periods of water shortage(26). Figure 1 shows how drought events impair plant performance at various phases of growth. Because of a lack of water, plants that are just starting out may not germinate or grow well(27).

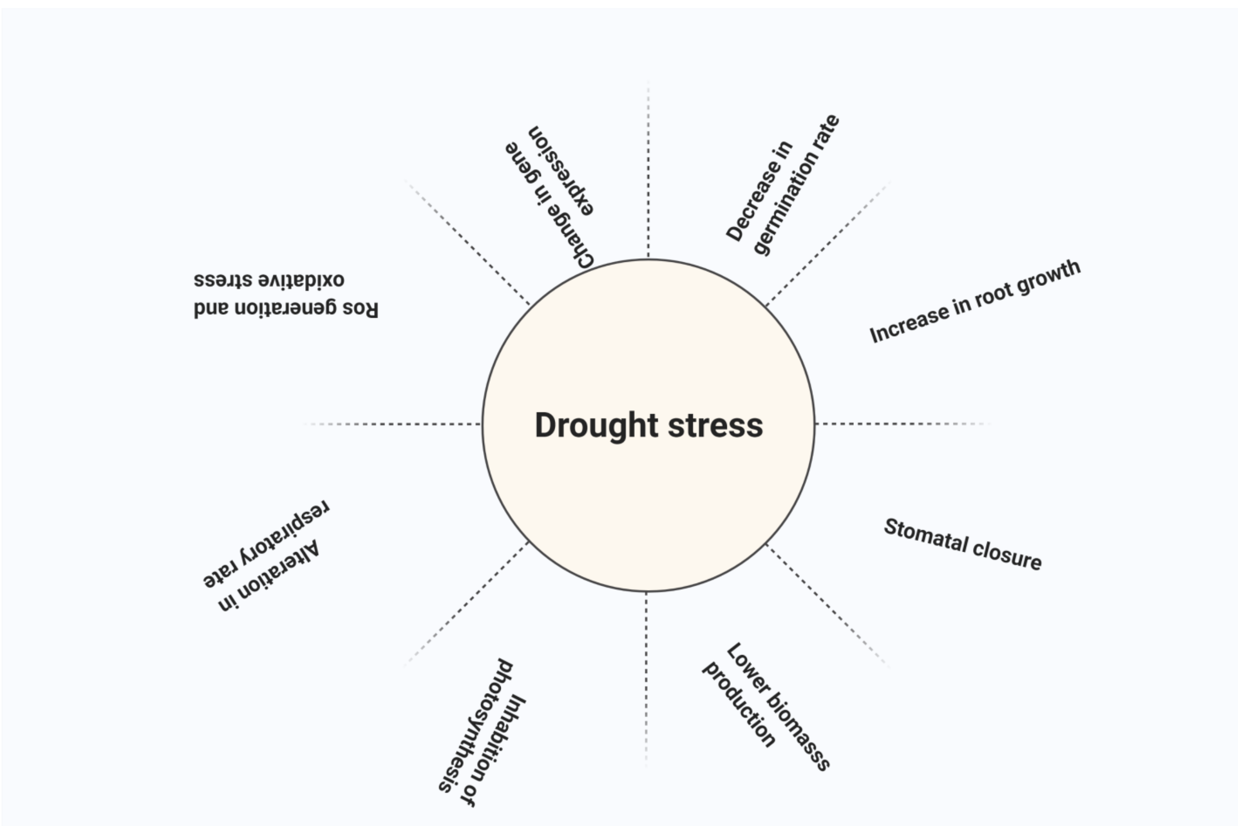

Figure1: Drought stress effect on plant growth and development

Due to drought, plants' water relations throughout their whole growth cycle are disrupted, resulting in a major disturbance of all three of their metabolic pathways (physiological, biochemical, and molecular)(14,28). Decreases in photosynthetic activity lead to decreases in overall plant output(29,30). Plant responses to drought stress are driven in part by oxidative stress. Causes acute metabolic issues, reduces plant output, and affects membrane integrity(33,34,35).

Plant growth due to drought stress.

Plant growth and development is frequently inhibited by drought stress, which negatively affects several facets of plant growth and development. In order for plants to progress, germination, overall health, and the number of secondary leaves are all essential(36). Seeding is the primary factor involved in growth that is affected by drought. It has been observed that the germination of many plant species has undergone dramatic alterations, including some of the most frequently farmed crops, such as maize, sorghum, and wheat(37,38,39). Watching plants wither, fall, and cease development in their vegetative stage due to water constraint is a good indicator that they're experiencing water shortage throughout the early stages of growth [40]. For the same reason, drought reduces the amount of nutritional absorption in plants, resulting in a shorter stem [41]. as well, the shoot length of Lathyrussativus L. was reduced in times of water deficit.(42).

Plants expand their root architecture in times of water shortage in order to access deeper layers of soil (43). While they are essential sensors of water availability, roots are not just sensors of that but are also involved in determining many of the characteristics of root growth, such as root length, spread, and the quantity and length of lateral roots(44). Furthermore, roots perform several biological functions, including the accumulation of nutrients and the absorption of water, and they interact with other microorganisms in the rhizosphere to form a symbiotic connection. Root length of the common crocus (Crocus sativus L.) rose in response to drought stress(45). As a result, a healthy root system contributes to plant growth by providing it with stability, particularly during the active phase of plant growth (46). A good root system helps provide stability and increases nutrient accumulation, resulting in increased plant biomass output (47). In periods of water shortage, plants have a greater proportion of roots to shoots, which results in reduced plant biomass(48). Most of the photosynthetic chemicals are produced in the leaf, which is the plant's principal photosynthetic organ. A stress treatment of Andrographispaniculate caused the number of leaves to drop by (49). Plant growth relies on photosynthesis, the fundamental process for creating leaves. Increased water stress decreases leaf area, lowering photosynthesis and agricultural yield. To maintain a balance between water absorbed by roots and water status of various plant components, a reduction in leaf area occurred in Petroselinum crispum L. and Stevia rabaudiana plants under water stress (50,51). Because it results in lesser water loss by transpiration, a reduced leaf area is a drought avoidance technique. Cell turgidity loss results from a reduced rate of cell division, which decreases leaf area(52). Concurrent reduction in leaf water content and stomata closing leads in the guard cell turgor pressure decreasing, causing stomata to close. There is a noticeable increase in the rate of premature leaf senescence under drier circumstances (17).

Photosynthesis under stress of drought

When there is a water shortage, plants will slow or cease photosynthesis(54). Figure 2 Increased osmotic stress impacts the photosynthetic machinery because of lower leaf area, increased stomata closure, and because of this, reduced leaf cooling through evapotranspiration(55,56). To a great extent, this loss in photosynthetic activity is related to the decreased CO2 transport across stomatal and mesophyll limitations in drought-stressed plants(57). Lowered photosynthetic activity is an indicator of possible reduced stomatal mobility, as a result of dryness(58,59) .Rubisco activity, the functioning of nitrate reductase and sucrose phosphate synthase, as well as the capacity to generate ribulose bisphosphate, have all been proven to be impacted by the reduction in photosynthetic activity (60). (RuBP). It was discovered that with CO2 enrichment, early reactions of maize metabolites and transcripts to drought stress were completely inhibited(61).As a result of water scarcity, leaf area per shoot reduced, impacting gas exchange, water relations, vegetative growth, and fruit/grain development, for example, in grape and maize (i.e., kernel number and 100-kernel dry weight decreased as kernel number increased)(62,63). Another important photosynthesis-related parameter that is greatly influenced by water constraint is chlorophyll concentration, which is crucial for photosynthesis (65). Research has found that when chlorophyll photooxidation and degradation go unaddressed, photosynthesis would be hampered (66). For example, during periods of drought stress, which decrease the supply of water, leaf chlorophyll synthesis is reduced and the chlorophyll a/b ratio in soybean is altered(67). Photosynthetic activity, chlorophyll content, photosystem II photochemical efficiency, stomatal movement, and the state of the plant water cycle all dropped when crop output was reduced(68).Peroxidative lipid peroxidation, followed by chlorophyll degradation, results from drought-induced O2 and H2O2 generation. Problems with photosynthesis, in particular chlorophyll content, have often been associated with reduced plant growth and output(70). Severe water restriction decreases the photosynthetic activities of photosynthetic components and chlorophyll pigments in Vigna mungo (71).Due to a long period of drought, a plant's photosynthesis will be diminished, along with its ability to allocate and utilize carbon, resulting in decreased production(72). This reduction in photosynthetic product production was the primary way in which drought stress decreased metabolic aberrations in soybean(16). Since water stress led to a decrease in the amount of several Calvin cycle proteins, including a drop in the expression of Rubisco in olives, drought stress led to a decline in Rubisco expression in olives(73). To further the drought stress, even other photosynthesis-related enzymes, such the Rubisco enzyme, are disrupted. This results in a drop in the concentration of photosynthetic pigment molecules (74).

Drought stress reduction with nutrient inputs

Aiding plant development even in poor weather conditions is only one of the many ways optimum nutrient delivery aids crop development. Plant growth requires seventeen nutrients(75). There are macronutrients (requiring higher intake levels) and micronutrients (with lower needs). This review stresses the essential nutrients' role in countering drought-related stress.

Macronutrients

Nitric oxide

In dry climatic conditions, water consumption efficiency and agricultural development are lowered because of limited water accessibility. With inefficient nitrogen treatment, effective nitrogen treatment may be helpful in drought circumstances (75, 76). Plants that are suffering from the effects of drought may also be more sensitive to heat shock. At the time of drought stress, lack of nitrogen causes crop biomass loss(77, 78). The prior research shown that root biomass is not considerably impacted by drought and low nitrogen levels, but shoot biomass is(79). In contrast, when enough nitrogen is present in the soil, plants become drought resistant (75, 80, 81). Adding nitrogen to the soil boosted crop output greatly during a drought. Plasma membrane damage is prevented and the osmotic equilibrium is maintained thanks to the important role of nitrogen. In arid conditions, applying nitrogen has the additional benefit of improving the uptake of important nutrients like potassium and calcium (82).When available, nitrogen helps lower malondialdehyde concentrations in the air, thus mitigating drought stress (83). It helps photosynthesis, which means it improves photosynthetic content and cell proliferation, leading in an increase in leaf area. In dry conditions, photosystem II efficiency suffers because of reduced nitrogen accessibility (84, 85, 86).

Phosphorus Sulfate

Applying phosphorus to various crops during periods of water shortage has previously been proven to increase their water usage ability and help with drought tolerance (87, 88). Studies have shown that a good supply of phosphorus in crops leads to the growth of root and stomatal activity(89). Additionally, phosphorus is found in higher quantities, which boosts leaf area, membrane integrity, and water consumption efficiency(90). During periods of excellent water availability, phosphorus concentrations in leaves were significantly larger, implying that it has a function in drought resistance.(91). Phosphorus is also capable of increasing nitrogen mobility in a water-deficient environment(92). During a prolonged drought, phosphorus supplementation increased the height, leaf area, weight, and water use efficiency of plants (93). Phosphorus placement, DPP, also has an influence on crop development under drought, eventually boosting root growth (94)

Potassium

The well-known agricultural use of potassium is for osmoregulation. The optimum dose of potassium regulates stomatal conductance and water absorption, resulting in an improved WUE(95). The biological properties of potassium include: regulating water absorption, stomatal regulation, carbon intake, cell elongation, and oxidative stress detoxification through aquaporins and osmotic pressure(96). During drought, applications of K treatments boost photosynthesis in grasses like sorghum, which in turn helps produce a greater amount of biomass and yields (97). Knots are needed for photosynthate assimilation in maize, which is a good reference for biologists(98). The activity of aquaporins and stem cell development (growth) is inversely related to the level of potassium (availability). (99).A large role is played by the root hydraulic conductivity and morphological features when it comes to agricultural productivity. A direct relationship exists between drought tolerance and increased hydraulic conductivity (100). Elevated levels of K reduce yield and affect several properties in higher plants, as seen by the findings above. When a drought occurs, ethylene levels rise, inhibiting the activity of abscisic acid. Further delays of stomatal conductance occur due to lack of K. In addition to playing a role in the detoxification of reactive oxygen species (ROS), potassium is important for supporting photosynthesis and chlorophyll synthesis(101).

Magnesium

Magnesium plays a major function in the chlorophyll molecule since it is included within the chlorophyll molecule. This is important because it separates dry materials from the sink to the source. To avoid flower sterility, Mg must be acceptable throughout the reproductive stage. This use of vegetation also increases nutrient mobility and contributes to development preservation in stressful settings (102).

Magnesium is a mobile nutrient. Nitrogen and potassium are positively correlated with each other. Magnesium sufficiently increases their mobility; in addition, it enhances stress tolerance. (103).Magnesium uptake from the soil in field crops is influenced by drought stress. One approach of eliminating this deficiency is by applying foliar magnesium (104). Mg causes drought stress through contributing to root growth, absorption of NPK, and water usage efficiency (WUE)(105).

Calcium

Because of drought stress, ROS is produced in excess, which damages cells (106). Calcium serves a key role in the detoxification of ROS (107). The importance of pH and calcium in the function of aquaporins has been shown in several studies(108). Calcium supplementation given to wheat cultivars during periods of stress promotes drought resistance. The process that controls cell signaling in mammals, including humans, is analogous to the accumulation of proline in cells.Calcium boosts chlorophyll and catalase activity, and minimizes plasma membrane damage when administered during drought. Additionally, it maintains water-soluble antioxidants such as proline and other antioxidants, such as cysteine and glutathione.(109). Ca supplied to foliage under drought stress assists in the decrease of drought stress by refining catalase, peroxidase, and superoxide dismutase activities [Ca and its byproducts aid in the refinement of catalase, peroxidase, and superoxide dismutase activities when given to foliage under drought stress] (110).

sulfur

Sulfur treatment was unknown until recently as to its role in alleviating drought stress. Significant stress signaling system involvement. It supports crop development, anatomical features, and the nutritional value of the food(111). A critical function in stress resistance is played by increased glutathione levels. Treatment of reactive oxygen species aids in the detoxification of the individual. Crops must be able to tolerate drought conditions with adequate sulfur absorption. The two responses to drought stress include transport and absorption (112).

Minerals and vitamins

zinc

Zinc plays an important role in a number of physiological processes, including catalysis, carboxypeptidase activity, superoxide dismutase activity, RNA polymerase activity, and the production of alkaline phosphates(113). Zinc has been shown to help crops withstand drought in regions where water is scarce by improving water use efficiency (WUE) and water activity(114).The fact that water shortage reduces zinc absorption means that plants are under stress. In dry soils, zinc is immobile (115).Grain filling and anthesis (when cereals such as wheat are subjected to drought) both hinder nutrient absorption, which means that seed development is decreased(116). When zinc is present in an appropriate level, it helps the crop survive drought by supporting photosynthesis. Inactivation of ROS occurs due to its involvement in reducing reactive oxygen species (ROS) [4, 140]. Plants are particularly susceptible to Zn deficiency when they are at their most vulnerable in the breeding period (117)In prolonged periods of dryness, several cell metabolic components, such as NADPH, decline in function. Reduced oxidative stress, decreased ROS levels, and an increase in osmolytes (e.g., SOD) are some of the many effects of zinc therapy on the skin. (118).

Manganese

micronutrient required by plants for several purposes. It helps the metabolic enzymes in the tricarboxylic acid (TCA) cycle get started. Photosystem II employs it as a component and produces ATP and RuBP carboxylase activity, too. In areas of water shortage, there is a relationship between superoxide dismutase activity and chlorophyll content. (119). It is widely recognized that manganese has a well-established role in the removal of superoxide and hydrogen peroxide in the detoxification of ROS such as superoxide and hydrogen peroxide. A shortage of manganese is quite different from an excess. In the case of a deficit, oxidative stress is induced in plants, causing the breakdown of chlorophyll and the reduction of photosynthetic activity. A lack of water might lead to a manganese deficit as well. When the soil is dry, manganese is difficult for plants to acquire because of its limited availability (120). WUE decreases as a result of a deficit in manganese. In cereals such as barley, decreased WUE is linked to abrupt stomatal control during the day and insufficient stomatal closure at night. ROS activity causes the plasma membrane's waxy covering to be shed, leading to cell death (121).

Ferrous

Chlorophyll pigments are synthesized in association with it. This refers to the part of enzymes that is responsible for transferring energy, reducing nitrogen, and synthesizing lignin. It serves as a catalyst for other biochemical processes in plants, and has sulfur in common with this group of compounds. The decreased chlorophyll concentration causes chlorosis because to an iron deficiency. Iron deficiency makes the leaves turn yellow, a sign of imminent death. In soils with a high pH, iron uptake is significantly decreased. it has the ability to stimulate phosphorus and manganese, which means it is antagonistic.Iron absorption is limited by the moisture content of the soil (122). Iron is absolutely critical in helping leaves maintain their vitality and avoid oxidative damage(123). It has a considerable detrimental influence on plant development if it is missing. Antioxidant activity in plants is possible only with the presence of iron(124).

Conclusion

Drought stress is a major limitation on worldwide agricultural production. For the development of drought tolerance in plants the management of plant nutrients is vital. A number of strategies can successfully alleviate the effects of drought by improving plant nutrition. Drought stimulates the synthesis in stressed plants of reactive oxygen (ROS) as a result of energy growth, which improves the photo-oxidation effect and destroys the membrane of chloroplastic. The use of macronutrients such as N, K, and Ca lowers the reactive oxygen (ROS) toxicity by increasing plant cell antioxidant contents such as superoxide dismutase (SOD); catalase (CAT) and peroxidase (POD). These antioxidants scavenge the photooxidation block, maintain the integrity of the membrane and enhance the rates of photocyanisation of agricultural plants. The antioxidants are a reactive oxygen (ROS). The use of a few micronutrients, such as Zn, Si and Mg, also improves antioxidant levels and promotes plant drought resistance. Nutrients like P, K, Mg and Zn are otherwise supportive to root developments, improving water absorption, supporting stomach management and promoting drought resistance. The addition of potassium and calcium helps maintain high tissue water potential under dry weather and increases drought tolerance via osmotic adjustments. Micronutrients like as copper and bore reduce indirectly, through physiological, biochemical, and metabolic processes the negative effects of drought in plants,alsoDrought is a generally adverse limitor which impacts a range of plant growth, physiology and metabolism. All key aspects to take into account while choosing drought-tolerant plants for different ecosystems include timing, length, intensity and growth rate. The effect of drought stress on a number of biological processes, from the embryonic stage to the breeding and maturity stage, is negative. Drought stress has an unfavorable influence on plant morphology, physiology, biochemistry, and metabolic processes and reduces productivity. When plants are driven by different stages of their development, the cells, organs and complete plants utilise a range of biological processes. By optimizing the stomach function, enhancing water transport, developing larder, deeper rooted structures and creating appropriate solutes, the loss of water was decreased. The creation and development of drought tolerance among plants contributes with the creation of a scavenging of ROS by an antioxidant defense system, the maintenance of membrane integrity, the use of specific plant genotypes, the use and implementation of regulators for plant growth, production of compatible solutes and the production of stress-related proteins. Individuals that have higher efficiency in water use, increased antioxidant power or the creation of osmolites and secondary metabolites may be possible for boosting drought resistance in plants. These are possible strategies. In addition, an exogenous supply of compounds that can promote drought tolerance can be used in plants in water-scarce conditions. For the development of transgenic plants that are resilient to water shortages, biotechnological methods should also be investigated but cannot be validated before field tests are performed.

References

1. Verslues, P.E.; Agarwal, M.; Katiyar-Agarwal, S.; Zhu, J.; Zhu, J.K. Methods and concepts in quantifying resistance to drought, salt and freezing, abiotic stresses that affect plant water status. Plant J. **2006**, 45, 523–539. [CrossRef] [PubMed]

2. Chaves, M.M.; Costa, J.M.; Saibo, N.J.M. Recent advances in photosynthesis under drought and salinity. Adv. Bot. Res. **2011**, 57, 49–104.

3. Kabiri, R.; Nasibi, F.; Farahbakhsh, H. Effect of exogenous salicylic acid on some physiological parameters and alleviation of drought stress in Nigella sativa plant under hydroponic culture. Plant Protect. Sci. **2014**, 50, 43–51. [CrossRef]

4. Lambers, H.; Chapin, F.S., III; Pons, T.L. Plant Physiological Ecology; Springer: New York, NY, USA, 2008.

5. Salehi-Lisar, S.Y.; Bakhshayeshan-Agdam, H. Drought stress in plants: Causes, consequences, and tolerance. In Drought Stress Tolerance in Plants; Springer: Cham, Switzerland, 2016.

6. Ballhorn, D.J.; Kautz, S.; Heil, M.; Hegeman, A.D. Cyanogenesis of wild lima bean (PhaseoluslunatusL.) is an efficient direct defence in nature. PLoS ONE **2009**, 4, e5450. [CrossRef]

7. Hazrati, S.; Tahmasebi-Sarvestani, Z.; Mokhtassi-Bidgoli, A.; Modarres-Sanavy, S.A.M.; Mohammadi, H.; Nicola, S. Effects of zeolite and water stress on growth, yield and chemical compositions of Aloe veraL. Agric. Water Manag. **2017**, 181, 66–72. [CrossRef]

8. Laxa, M.; Liebthal, M.; Telman, W.; Chibani, K.; Dietz, K.-J. The role of the plant antioxidant system

in
drought tolerance. Antioxidants **2019**, 8, 94. [CrossRef]
9. Kögler, F.; Söffker, D. Water (stress) models and deficit irrigation: System-theoretical description and causality
mapping. Ecol. Model. **2017**, 361, 135–156. [CrossRef]
10. Wang, J.; Chen, J.; Sharma, A.; Tao, S.; Zheng, B.; Landi, M.; Yuan, H.; Yan, D. Melatonin Stimulates Activities
and Expression Level of Antioxidant Enzymes and Preserves Functionality of Photosynthetic Apparatus in
Hickory Plants (CaryacathayensisSarg.) under PEG-Promoted Drought. Agronomy **2019**, 9, 702. [CrossRef]
11. Geilfus, C.M. Drought Stress. In Controlled Environment Horticulture; Springer: Cham, Switzerland, 2019;
pp. 81–97.
12. Kumawat, K.R.; Sharma, N.K. Effect of Drought Stress on Plants Growth. Popular Kheti**2018**, 6, 239–241.
13. Sharma, A.; Kumar, V.; Shahzad, B.; Ramakrishnan, M.; Sidhu, G.P.S.; Bali, A.S.; Handa, N.; Kapoor, D.;
Yadav, P.; Khanna, K. Photosynthetic response of plants under different abiotic stresses: A review. J. Plant
Growth Regul. **2020**, 39, 509–531. [CrossRef]
14. Sharma, A.; Wang, J.; Xu, D.; Tao, S.; Chong, S.; Yan, D.; Li, Z.; Yuan, H.; Zheng, B. Melatonin regulates the
functional components of photosynthesis, antioxidant system, gene expression, and metabolic pathways to
induce drought resistance in grafted Caryacathayensisplants. Sci. Total Environ. **2020**, 713, 136675. [CrossRef]
[PubMed]
15. Khalid, M.F.; Hussain, S.; Ahmad, S.; Ejaz, S.; Zakir, I.; Ali, M.A.; Ahmed, N.; Anjum, M.A. Impacts of
Abiotic Stresses on Growth and Development of Plants. In Plant Tolerance to Environmental Stress; CRC Press:

Boca Raton, FL, USA, 2019; pp. 1–8.
16. Du, Y.; Zhao, Q.; Chen, L.; Yao, X.; Zhang, W.; Zhang, B.; Xie, F. Effect of drought stress on sugar metabolism
in leaves and roots of soybean seedlings. Plant PhysiolyBiochem. PPB **2020**, 146, 1–12. [CrossRef] [PubMed]
17. Farooq, M.; Wahid, A.; Kobayashi, N.; Fujita, D.; Basra, S. Plant drought stress: Effects, mechanisms and
management. In Sustainable Agriculture; Springer: Dordrecht, TheNetherlands, 2009; pp. 153–188.
18. Bogale, A.; Nagle, M.; Latif, S.; Aguila, M.; Müller, J. Regulated deficit irrigation and partial root-zone drying
irrigation impact bioactive compounds and antioxidant activity in two select tomato cultivars. Sci. Hortic.
2016, 213, 115–124. [CrossRef]
19. Coyago-Cruz, E.; Corell, M.; Moriana, A.; Hernanz, D.; Stinco, C.M.; Mel éndez-Mart ínez, A.J. Effect of the
fruit position on the cluster on fruit quality, carotenoids, phenolics and sugars in cherry tomatoes (Solanum
lycopersicumL.). Food Res. Int. **2017**, 100, 804–813. [CrossRef] [PubMed]
20. Anjum, S.A.; Wang, L.C.; Farooq, M.; Hussain, M.; Xue, L.L.; Zou, C.M. Brassinolide application improves the
drought tolerance in maize through modulation of enzymatic antioxidants and leaf gas exchange. J. Agron.
Crop Sci. **2011**, 197, 177–185. [CrossRef]
21. Tanveer, M.; Shahzad, B.; Sharma, A.; Khan, E.A. 24-Epibrassinolide application in plants: An implication
for improving drought stress tolerance in plants. Plant Physiol. Biochem. **2019**, 135, 295–303. [CrossRef]
22. Rao, S.; Qayyum, A.; Razzaq, A.; Ahmad, M.; Mahmood, I.; Sher, A. Role of foliar application of salicylic acid
and l-tryptophan in drought tolerance of maize. J. Anim. Plant Sci. **2012**, 22, 768–772.
23. Hammad, S.A.R.; Ali, O.A.M. Physiological and biochemical studies on drought tolerance of wheat plants by

application of amino acids and yeast extract. Ann. Agric. Sci. **2014**, 59, 133–145. [CrossRef]
24. Farooq, M.; Wahid, A.; Lee, D.-J. Exogenously applied polyamines increase drought tolerance of rice by
improving leaf water status, photosynthesis and membrane properties. Acta Physiol. Plant. **2009**, 31, 937–945.
[CrossRef]
25. Santos, M.G.D.; Ribeiro, R.V.; Oliveira, R.F.D.; Pimentel, C. Gas exchange and yield response to foliar
phosphorus application in Phaseolus vulgaris L. under drought. Braz. J. Plant Physiol. **2004**, 16, 171–179.
[CrossRef]
26. Zlatev, Z.; Lidon, F.C. An overview on drought induced changes in plant growth, water relationsand
photosynthesis. Emir J. Food Agr. **2012**, 24, 57–72.
27. Yigit, N.; Sevik, H.; Cetin, M.; Kaya, N. Determination of the effect of drought stress on the seed germination
in some plant species. In Water Stress in Plants; Intech Open: London, UK, 2016; pp. 43–62.
28. Osakabe, Y.; Osakabe, K.; Shinozaki, K.; Tran, L.-S.P. Response of plants to water stress. Front. Plant Sci. **2014**,
5, 86. [CrossRef] [PubMed]
29. Bota, J.; Medrano, H.; Flexas, J. Is photosynthesis limited by decreased Rubisco activity and RuBP content
under progressive water stress? New Phytol. **2004**, 162, 671–681. [CrossRef]
30. Flexas, J.; Bota, J.; Galmes, J.; Medrano, H.; Ribas-Carb ó, M. Keeping a positive carbon balance under adverse
conditions: Responses of photosynthesis and respiration to water stress. Physiol. Planta **2006**, 127, 343–352.
[CrossRef]
31. Vurayai, R.; Emongor, V.; Moseki, B. Effect of water stress imposed at different growth and development
stages on morphological traits and yield of bambara groundnuts (VignasubterraneaL. Verdc). Am. J. Plant Physiol. **2011**, 6, 17–27. [CrossRef]

32. Mafakheri, A.; Siosemardeh, A.; Bahramnejad, B.; Struik, P.; Sohrabi, Y. Effect of drought stress on yield,
proline and chlorophyll contents in three chickpea cultivars. Aus. J. Crop Sci. **2010**, 4, 580.
33. Wang, X.; Liu, H.; Yu, F.; Hu, B.; Jia, Y.; Sha, H.; Zhao, H. Differential activity of the antioxidant defence
system and alterations in the accumulation of osmolyte and reactive oxygen species under drought stress
and recovery in rice (Oryza sativa L.) tillering. Sci. Rep. **2019**, 9, 8543. [CrossRef]
34. Sharma, A.; Zheng, B. Melatonin mediated regulation of drought stress: Physiological and molecular aspects.
Plants **2019**, 8, 190. [CrossRef]
35. Ghatak, A.; Chaturvedi, P.; Weckwerth, W. Cereal Crop Proteomics: Systemic Analysis of Crop Drought
Stress Responses Towards Marker-Assisted Selection Breeding. Front Plant Sci**2017**, 8, 757. [CrossRef]
36. Sourour, A.; Afef, O.; Mounir, R.; Mongi, B.Y. A review: Morphological, physiological, biochemical and
molecular plant responses to water deficit stress. Int. J. Eng. Sci. **2017**, 6, 1–4. [CrossRef]
37. Queiroz, M.S.; Oliveira, C.E.S.; Steiner, F.; Zuffo, A.M.; Zoz, T.; Vendruscolo, E.P.; Menis, V.S.; Mello, B.F.F.R.;
Cabral, R.C.; Menis, T.F. Drought stresses on seed germination and early growth of maize and sorghum.
J. Agric. Sci. **2019**, 11, 310–318. [CrossRef]
38. Patanè, C.; Saita, A.; Sortino, O. Comparative effects of salt and water stress on seed germination and early
embryo growth in two cultivars of sweet sorghum. J. Agron. Crop Sci. **2013**, 199, 30–37. [CrossRef]
39. Qayyum, A.; Razzaq, A.; Ahmad, M.; Jenks, M.A. Water stress causes differential effects on germination
indices, total soluble sugar and proline content in wheat (TriticumaestivumL.) genotypes. Afr. J. Biotechnol.
2011, 10, 14038–14045.
40. Bhatt, R.M.; Rao, N.K.S. Influence of pod load on response of okra to water stress. Indian J. Plant

Physiol. **2005**, 10, 54–59.

41. Razmjoo, K.; Heydarizadeh, P.; Sabzalian, M.R. Effect of salinity and drought stresses on growth parameters and essential oil content of Matricaria chamomile. Int. J. Agric. Biol. **2008**, 10, 451–454.

42. Gheidary, S.; Akhzari, D.; Pessarakli, M. Effects of salinity, drought, and priming treatments on seed germination and growth parameters of LathyrussativusL. J. Plant Nutr. **2017**, 40, 1507–1514. [CrossRef]

43. Asadi, S.; Lebaschy, M.H.; Khourgami, A.; Rad, A.H.S. Effect of drought stress on the morphology of three Salvia sclarea populations. Ann. Biol. Res. **2012**, 3, 4503–4507.

44. Salazar, C.; Hernández, C.; Pino, M.T. Plant water stress: Associations between ethylene and abscisic acid response. Chil. J. Agric. Res. **2015**, 75, 71–79. [CrossRef]

45. Maleki, M.; Ebrahimzade, H.; Gholami, M.; Niknam, V. The effect of drought stress and exogenous abscisic acid on growth, protein content and antioxidative enzyme activity in saffron (Crocus sativusL.). Afr. J. Biotechnol. **2011**, 10, 9068–9075.

46. Smith, S.; De Smet, I. Root system architecture: Insights from Arabidopsis and cereal crops. Philos. Trans. R. Soc. B **2012**, 367, 1441–1452. [CrossRef]

47. Zulfiqar, F.; Younis, A.; Riaz, A.; Mansoor, F.; Hameed, M.; Akram, N.A.; Abideen, Z. Morpho-anatomical adaptations of two TagetesErectaL. cultivars with contrasting response to drought stress. Pak. J. Bot. **2020**, 52, 801–810. [CrossRef]

48. Akhtar, I.; Nazir, N. Effect of waterlogging and drought stress in plants. Int. J. Water Res. Environ. Eng. **2013**, 2, 34–40.

49. Bhargavi, B.; Kalpana, K.; Reddy, J.K. Influence of Water Stress on Morphological and Physiological Changes

in Andrographispaniculata. Int. J. Pure Appl. Biosci. **2017**, 5, 1550–1556.
50. Najla, S.; Sanoubar, R.; Murshed, R. Morphological and biochemical changes in two parsley varieties upon
water stress. Physiol. Mol. Biol. Plants **2012**, 18, 133–139. [CrossRef] [PubMed]
51. Srivastava, S.; Srivastava, M. Morphological changes and antioxidant activity of Stevia rebaudianaunder
water stress. Am. J. Plant Sci. **2014**, 5, 3417. [CrossRef]
52. Bangar, P.; Chaudhury, A.; Tiwari, B.; Kumar, S.; Kumari, R.; Bhat, K.V. Morphophysiological and biochemical
response of mungbean [Vignaradiata(L.) Wilczek] varieties at different developmental stages under drought
stress. Turk. J. Biol. **2019**, 43, 58–69. [CrossRef]
53. Deka, D.; Singh, A.K.; Singh, A.K. Effect of Drought Stress on Crop Plants with Special Reference to Drought
Avoidance and Tolerance Mechanisms: A Review. Int. J. Curr. Microbiol. App. Sci. **2018**, 7, 2703–2721.
[CrossRef]
54. Nezhadahmadi, A.; Prodhan, Z.H.; Faruq, G. Drought tolerance in wheat. Sci. World J. **2013**, 610721.
[CrossRef]
55. Zare, M.; Azizi, M.H.; Bazrafshan, F. Effect of drought stress on some agronomic traits in ten barley (Hordeum
vulgareL.) cultivars. Tech. J. Eng. Appl. Sci. **2011**, 1, 57–62.
56. Bhargava, S.; Sawant, K. Drought stress adaptation: Metabolic adjustment and regulation of gene expression.
Plant Breed. **2013**, 132, 21–32. [CrossRef]
57. Singh, J.; Thakur, J.K. Photosynthesis and abiotic stress in plants. In Biotic and Abiotic Stress Tolerance in Plants;
Springer: Singapore, 2018; pp. 27–46.
58. Marci´nska, I.; Czyczyło-Mysza, I.; Skrzypek, E.; Filek, M.; Grzesiak, S.; Grzesiak, M.T.; Janowiak, F.; Hura, T.; Dziurka, M.; Dziurka, K. Impact of osmotic stress on physiological and biochemical characteristics

in drought-susceptible and drought-resistant wheat genotypes. Acta Physiol. Plant. **2013**, 35, 451–461.
[CrossRef]
59. Chaves, M.M.; Flexas, J.; Pinheiro, C. Photosynthesis under drought and salt stress: Regulation mechanisms
from whole plant to cell. Ann. Bot. **2009**, 103, 551–560. [CrossRef] [PubMed]
60. Deepak, S.B.; Thakur, A.; Singh, S.; Bakshi, M.; Bansal, S. Changes in crop physiology under drought stress:
A review. J. Pharmacogn. Phytochem. **2019**, 8, 1251–1253.
61. Sicher, R.C.; Barnaby, J.Y. Impact of carbon dioxide enrichment on the responses of maize leaf transcripts and
metabolites to water stress. Physiol. Planta **2012**, 144, 238–253. [CrossRef]
62. Rahmati, M.; Mir ás-Avalos, J.M.; Valsesia, P.; Lescourret, F.; G énard, M.; Davarynejad, G.H.; Bannayan, M.;
Azizi, M.; Vercambre, G. Disentangling the effects of water stress on carbon acquisition, vegetative growth,
and fruit quality of peach trees by means of the QualiTree model. Front. Plant Sci. **2018**, 9, 3. [CrossRef]
63. Zsófi, Z.; T óth, E.; Rusjan, D.; B álo, B. Terroir aspects of grape quality in a cool climate wine region:
Relationship between water deficit, vegetative growth and berry sugar concentration. Sci. Hortic. **2011**, 127,
494–499. [CrossRef]
64. Ge, T.; Sui, F.; Bai, L.; Tong, C.; Sun, N. Effects of water stress on growth, biomass partitioning, and water-use
efficiency in summer maize (Zea mays L.) throughout the growth cycle. Acta Physiol. Planta **2012**, 34, 1043–1053. [CrossRef]
65. Rahdari, P.; Hosseini, S.M.; Tavakoli, S. The studying effect of drought stress on germination, proline, sugar,
lipid, protein and chlorophyll content in purslane (PortulacaoleraceaL.) leaves. J. Med. Plants Res. **2012**, 6,
1539–1547.

66. Anjum, S.A.; Xie, X.-y.; Wang, L.-c.; Saleem, M.F.; Man, C.; Lei, W. Morphological, physiological and
biochemical responses of plants to drought stress. Afr. J. Agric. Res. **2011**, 6, 2026–2032.
67. Chowdhury, J.; Karim, M.; Khaliq, Q.; Ahmed, A. Effect of drought stress on bio-chemical change and cell
membrane stability of soybean genotypes. Bangladesh J. Agric. Res. **2017**, 42, 475–485. [CrossRef]
68. Xiang, D.-B.; Peng, L.-X.; Zhao, J.-L.; Zou, L.; Zhao, G.; Song, C. Effect of drought stress on yield, chlorophyll
contents and photosynthesis in tartary buckwheat (Fagopyrumtataricum). J. Food Agric. Environ. **2013**, 11,
1358–1363.
69. Karimpour, M. Effect of Drought Stress on RWC and Chlorophyll Content on Wheat (Triticum durum L.)
Genotypes. World. Ess. J. **2019**, 7, 52–56.
70. Abid, G.; M'hamdi, M.; Mingeot, D.; Aouida, M.; Aroua, I.; Muhovski, Y.; Sassi, K.; Souissi, F.; Mannai, K.;
Jebara, M. Effect of drought stress on chlorophyll fluorescence, antioxidant enzyme activities and gene
expression patterns in faba bean (ViciafabaL.). Arch. Agron. Soil Sci. **2017**, 63, 536–552. [CrossRef]
71. Gurumurthy, S.; Sarkar, B.; Vanaja, M.; Lakshmi, J.; Yadav, S.; Maheswari, M. Morpho-physiological and
biochemical changes in black gram (Vigna mungo L. Hepper) genotypes under drought stress at flowering
stage. Acta Physiol. Plant. **2019**, 41, 42. [CrossRef]
72. Cuellar-Ortiz, S.M.; De La Paz Arrieta-Montiel, M.; Acosta-Gallegos, J.; Covarrubias, A.A. Relationship
between carbohydrate partitioning and drought resistance in common bean. Plant Cell Environ. **2008**, 31,
1399–1409. [CrossRef]
73. Abdallah, M.B.; Trupiano, D.; Polzella, A.; De Zio, E.; Sassi, M.; Scaloni, A.; Zarrouk, M.; Youssef, N.B.;
Scippa, G.S. Unraveling physiological, biochemical and molecular mechanisms involved in olive (Olea

europaeaL. cv. Chétoui) tolerance to drought and salt stresses. J. Plant Physiol. **2018**, 220, 83–95. [CrossRef]

74. Brito, C.; Dinis, L.-T.; Moutinho-Pereira, J.; Correia, C.M. Drought stress effects and olive tree acclimation
under a changing climate. Plants **2019**, 8, 232. [CrossRef]

75. Hussain, S.; Rao, M.J.; Anjum, M.A.; Ejaz, S.; Zakir, I.; Ali, M.A.; Ahmad, N.; Ahmad, S. Oxidative Stress
and Antioxidant Defense in Plants Under Drought Conditions. In Plant Abiotic Stress Tolerance: Agronomic,
Molecular and Biotechnological Approaches; Hasanuzzaman, M., Hakeem, K.R., Nahar, K., Alharby, H.F., Eds.;
Springer International Publishing: Cham, Switzerland, 2019; pp. 207–219. [CrossRef]

76. Gharibi, S.; Tabatabaei, B.E.S.; Saeidi, G.; Goli, S.A.H. Effect of drought stress on total phenolic, lipid
peroxidation, and antioxidant activity of Achillea species. Appl. Biochem. Biotechnol. **2016**, 178, 796–809.
[CrossRef]

77. Impa, S.M.; Nadaradjan, S.; Jagadish, S.V.K. Drought stress induced reactive oxygen species and anti-oxidants
in plants. In Abiotic Stress Responses in Plants; Springer: New York, NY, USA, 2012; pp. 131–147.

78. Møller, I.M.; Jensen, P.E.; Hansson, A. Oxidative modifications to cellular components in plants. Ann. Rev.
Plant Biol. **2007**, 58, 459–481. [CrossRef]

79. Cao, Y.; Luo, Q.; Tian, Y.; Meng, F. Physiological and proteomic analyses of the drought stress response in
Amygdalus Mira (Koehne) Yü et Lu roots. BMC Plant Biol. **2017**, 17, 53. [CrossRef]

80. Moussa, H.R.; Abdel-Aziz, S.M. Comparative response of drought tolerant and drought sensitive maize
genotypes to water stress. Aust. J. Crop Sci. **2008**, 1, 31–36.

81. Shi, S.; Fan, M.; Iwama, K.; Li, F.; Zhang, Z.; Jia, L. Physiological basis of drought tolerance in potato grown
under long-term water deficiency. Int. J. Plant Prod. **2015**, 9, 305–320.

82. Hossain, Z.; Nouri, M.Z.; Komatsu, S. Plant cell organelle proteomics in response to abiotic stress. J. Proteome Res. **2012**, 11, 37–48. [CrossRef] [PubMed]

83. Caverzan, A.; Casassola, A.; Brammer, S.P. Reactive oxygen species and antioxidant enzymes involved in plant tolerance to stress. In Abiotic and Biotic Stress in Plants-Recent Advances and Future Perspectives; Shanker, A., Shanker, C., Eds.; Publisher InTech Open: London, UK, 2016; pp. 463–480.

84. Wang, Q.; Zhao, R.; Chen, Q.; da Silva, J.A.T.; Chen, L.; Yu, X. Physiological and Biochemical Responses of Two Herbaceous Peony Cultivars to Drought Stress. HortSci. **2019**, 54, 492–498. [CrossRef]

85. Prathyusha, I.V.S.N.; Chaitanya, K.V. Effect of water stress on the physiological and biochemical responses of two different Coleus (Plectranthus) species. Biol. Fut. **2019**, 70, 312–322. [CrossRef]

86. Siddiqui, M.H.; Al-Khaishany, M.Y.; Al-Qutami, M.A.; Al-Whaibi, M.H.; Grover, A.; Ali, H.M.; Al-Wahibi, M.S.; Bukhari, N.A. Response of different genotypes of faba bean plant to drought stress. Int. J. Mol. Sci. **2015**, 16, 10214–10227. [CrossRef]

87. Flexas, J.; Gall é, A.; Galmés, J.; Ribas-Carbo, M.; Medrano, H. The response of photosynthesis to soil water stress. In Plant Responses to Drought Stress; Springer: Berlin/Heidelberg, Germany, 2012; pp. 129–144.

88. Gao, S.; Wang, Y.; Yu, S.; Huang, Y.; Liu, H.; Chen, W.; He, X. Effects of drought stress on growth, physiology and secondary metabolites of Two Adonis species in Northeast China. Sci. Hortic. **2020**, 259, 108795. [CrossRef]

89. Hosseini, M.S.; Samsampour, D.; Ebrahimi, M.; Abad ía, J.; Khanahmadi, M. Effect of drought stress on growth parameters, osmolyte contents, antioxidant enzymes and glycyrrhizin synthesis in licorice (Glycyrrhizaglabra L.) grown in the field. Phytochemistry**2018**, 156, 124–134. [CrossRef]

90. Kleinwächter, M.; Selmar, D. New insights explain that drought stress enhances the quality of spice and medicinal plants: Potential applications. Agron. Sustain. Dev. **2015**, 35, 121–131. [CrossRef]

91. Sharma, A.; Shahzad, B.; Rehman, A.; Bhardwaj, R.; Landi, M.; Zheng, B. Response of phenylpropanoid pathway and the role of polyphenols in plants under abiotic stress. Molecules **2019**, 24, 2452. [CrossRef]

92. Ballhorn, D.J.; Kautz, S.; Jensen, M.; Schmitt, I.; Heil, M.; Hegeman, A.D. Genetic and environmental interactions determine plant defences against herbivores. J. Ecol. **2011**, 99, 313–326. [CrossRef]

93. Selmar, D.; Kleinwächter, M. Stress enhances the synthesis of secondary plant products: The impact of stress-related over-reduction on the accumulation of natural products. Plant Cell Physiol. **2013**, 54, 817–826. [CrossRef] [PubMed]

94. Nacif de Abreu, I.; Mazzafera, P. Effect of water and temperature stress on the content of active constituents of HypericumbrasilienseChoisy. Plant Physiol. Biochem. **2005**, 43, 241–248. [CrossRef] [PubMed]

95. Morshedloo, M.R.; Craker, L.E.; Salami, A.; Nazeri, V.; Sang, H.; Maggi, F. Effect of prolonged water stress on essential oil content, compositions and gene expression patterns of mono- and sesquiterpene synthesis in two oregano (OriganumvulgareL.) subspecies. Plant Physiol. Biochem. **2017**, 111, 119–128. [CrossRef]

96. Yin, J.; Liang, T.; Wang, S.; Zhang, M.; Xiao, J.; Zhan, Y.; Li, C. Effect of Drought and Nitrogen on Betulin and Oleanolic Acid Accumulation and OSC Gene Expression in White Birch Saplings. Plant Mol. Biol Rep. **2015**, 33, 705–715. [CrossRef]

97. Nasrollahi, V.; Mirzaie-Asl, A.; Piri, K.; Nazeri, S.; Mehrabi, R. The effect of drought stress on the expression of key genes involved in the biosynthesis of triterpenoid saponins in liquorice (Glycyrrhizaglabra). Phytochemistry

2014, 103, 32–37. [CrossRef]
98. Saha, U.; Hancock, D.; Stewart, L.; Kissel, D.; Sonon, L. The Effect of Drought on Lignin Content and
Digestibility of Tifton-85 and Coastal Bermudagrass (CynodondactylonL.) Hays Produced in Georgia. Int. J.
Appl. Agric. Sci. **2016**, 2, 69. [CrossRef]
99. Jaafar, H.Z.; Ibrahim, M.H.; Fakri, M.; Farhana, N. Impact of soil field water capacity on secondary metabolites,
phenylalanine ammonia-lyase (PAL), maliondialdehyde (MDA) and photosynthetic responses of Malaysian
Kacip Fatimah (LabisiapumilaBenth). Molecules **2012**, 17, 7305–7322. [CrossRef]
100. García-Caparrós, P.; Romero, M.J.; Llanderal, A.; Cermeño, P.; Lao, M.T.; Segura, M.L. Effects of drought
stress on biomass, essential oil content, nutritional parameters, and costs of production in six Lamiaceae
species. Water **2019**, 11, 573. [CrossRef]
101. Gharibi, S.; Sayed Tabatabaei, B.E.; Saeidi, G.; Talebi, M.; Matkowski, A. The effect of drought stress on
polyphenolic compounds and expression of flavonoid biosynthesis related genes in Achilleapachycephala
Rech.f. Phytochemistry**2019**, 162, 90–98. [CrossRef]
102. Kheradmand, M.A.; Fahraji, S.S.; Fatahi, E.; Raoofi, M.M. Effect of water stress on oil yield and some
characteristics of Brassica napus. Int. Res. J. Basic Appl. Sci. **2014**, 8, 1447–1453.
103. Hu, Y.; Schmidhalter, U. Drought and salinity: A comparison of their effects on mineral nutrition of plants.
J. Plant Nutr. Soil. Sc. **2005**, 168, 541–549. [CrossRef]
104. Hu, L.; Wang, Z.; Huang, B. Effects of cytokinin and potassium on stomatal and photosynthetic recovery of
Kentucky bluegrass from drought stress. Crop Sci. **2013**, 53, 221–231. [CrossRef]
105. Qi, J.; Sun, S.; Yang, L.; Li, M.; Ma, F.; Zou, Y. Potassium uptake and transport in apple roots under drought

stress. Hortic. Plant J. **2019**, 5, 10–16. [CrossRef]
106. Li, Y.; Sun, C.; Huang, Z.; Pan, J.; Wang, L.; Fan, X. Mechanisms of progressive water deficit tolerance and
growth recovery of Chinese maize foundation genotypes Huangzao 4 and Chang 7-2, which are proposed on
the basis of comparison of physiological and transcriptomic responses. Plant Cell Physiol. **2009**, 50, 2092–2111.
[CrossRef]
107. Cu éllar, T.; Pascaud, F.; Verdeil, J.L.; Torregrosa, L.; Adam-Blondon, A.F.; Thibaud, J.B.; Sentenac, H.;
Gaillard, I. A grapevine Shaker inward K(+) channel activated by the calcineurin B-like calcium sensor 1-protein kinase CIPK23 network is expressed in grape berries under drought stress conditions. Plant J. **2010**,
61, 58–69. [CrossRef]
108. Da Silva, E.C.; Nogueira, R.J.M.C.; da Silva, M.A.; de Albuquerque, M.B. Drought stress and plant nutrition.
Plant Stress **2011**, 5, 32–41.
109. Osuagwu, G.G.E.; Edeoga, H.O.; Osuagwu, A.N. The influence of water stress (drought) on the mineral and
vitamin potential of the leaves of Ocimumgratissimum(L). Recent Res. Sci. Technol. **2010**, 2, 27–33.
110. Bahreininejad, B.; Razmjou, J.; Mirza, M. Influence of water stress on morpho-physiological and phytochemical
traits in Thymus daenensis. Int. J. Plant Prod. **2013**, 7, 151–166.
111. Khalid, K.A. Influence of water stress on growth, essential oil, and chemical composition of herbs (Ocimum
sp.). Int. Agrophys. **2006**, 20, 289–296.
112. Sarani, M.; Namrudi, M.; Hashemi, S.M.; Raoofi, M.M. The effect of drought stress on chlorophyll content,
root growth, glucosinolate and proline in crop plants. Intl. J. Farm. Alli. Sci. **2014**, 3, 994–997.
113. Samarah, N.; Mullen, R.; Cianzio, S. Size distribution and mineral nutrients of soybean seeds in response to
drought stress. J. Plant Nutr. **2004**, 27, 815–835. [CrossRef]

114. Zhang, Z. Fundamentals of Physiology and Genetics and Breeding in Crop Drought Resistance and Water Saving; Science Press: Beijing, China, 2003. (In Chinese)
115. Luo, L.J. Breeding for water-saving and drought-resistance rice (WDR) in China. J. Exp. Bot. **2010**, 61, 3509–3517. [CrossRef] [PubMed]
116. Luo, L.; Zhang, Q. The status and strategies on studying drought resistance of rice. Chin. J. Rice. Sci. **2001**, 15, 209–214.
117. Zhang, M.; Chen, R. Molecular Physiology and Genetic Improvement on Drought Resistance in Crop; Science Press: Beijing, China, 2005.
118. Zargar, S.M.; Gupta, N.; Nazir, M.; Mahajan, R.; Malik, F.A.; Sofi, N.R.; Shikari, A.B.; Salgotra, R.K. Impact of drought on photosynthesis: Molecular perspective. Plant Gene **2017**, 11, 154–159. [CrossRef]
119. Chowdhury, J.A.; Karim, M.A.; Khaliq, Q.A.; Ahmed, A.U.; Khan, M.S.A. Effect of drought stress on gas exchange characteristics of four soybean genotypes. Bangladesh J. Agric. Res. **2016**, 41, 195–205. [CrossRef]
120. Steele, K.A.; Price, A.H.; Shashidhar, H.E.; Witcombe, J.R. Marker-assisted selection to introgress rice QTLs controlling root traits into an Indian upland rice variety. Theor. App. Genet. **2006**, 112, 208–221. [CrossRef]
121. Karim, S.; Aronsson, H.; Ericson, H.; Pirhonen, M.; Leyman, B.; Welin, B.; Mäntylä, E.; Palva, E.T.; Van Dijck, P.; Holmström, K.O. Improved drought tolerance without undesired side effects in transgenic plants producing trehalose. Plant Mol. Biol. **2007**, 64, 371–386. [CrossRef]
122. Waraich, E.A.; Ahmad, R.; Ashraf, M.Y. Role of mineral nutrition in alleviation of drought stress in plants. Aust. J. Crop Sci. **2011**, 5, 764.
123. Satisha, J.; Prakash, G.; Venugopalan, R. Statistical modeling of the effect of physio-biochemical

parameters
on water use efficiency of grape varieties, rootstocks and their stionic combinations under moisture stress
conditions. Turk. J. Agric. For. **2006**, 30, 261–271.
124. Fathi, A.; Tari, D.B. Effect of drought stress and its mechanism in plants. Int. J. Life Sci. **2016**, 10, 1–6.
[CrossRef]