https://doi.org/10.53964/jmab.2022009

https://www.innovationforever.com

Journal of
Modern Agriculture and Biotechnology

ISSN 2788-810X (Online)

Open Access

Review

Roles of Some Abiotic Stresses on Plant Growth Characters

Soha E Khalil[1*]

[1]Department of Water Relations and Field Irrigation, National Research Center, Dokki, Cairo, Egypt

[*]**Correspondence to: Soha E Khalil, PhD, Head,** Department of Water Relation and Field Irrigation, National Research Center, 33 El Buhouth St., Dokki, Cairo 12622, Egypt; Email: soha_khalil2012@yahoo.com

Received: January 12, 2022 **Revised:** March 17, 2022 **Accepted:** March 22, 2022 **Published:** April 28, 2022

Abstract

Abiotic stress such as salinity, drought, high temperature, and weighty metals is associated with crop efficiency and improvement. Abiotic stress is a primary danger for sanitation because of the disruption of climate caused by human activities and consistent changes in the environment. A deep understanding of the yield response to stress will contribute substantially to current and customary reproducing procedures for the further development of stress resilience.

Keywords: abiotic stress, salinity, drought, high temperature, weighty metals

Citation: Khalil SE. Roles of Some Abiotic Stresses on Plant Growth Characters. *J Mod Agric Biotechnol*, 2022; 1(2): 9. DOI: 10.53964/jmab.2022009.

1 INTRODUCTION

Abiotic stress such as salinity, drought, cold, high temperature, and weighty metals severely compromises crop efficiency and advancement. Abiotic stress is a primary danger for sanitation because of the breakdown of climate caused by human activities and consistent changes of environment. Physiological, atomic, and cell alterations are found in various yields to cope with stresses. Thus, a deep understanding of the yield response to stress will contribute substantially to current and customary reproducing methods for the further development of stress resistance. Salinity and drought are two primary risky abiotic stresses that jeopardize the yield and development of various harvests on a global scale[1]. 33% of the total population lives in water-scarce areas[2]. Abiotic stress originates from the improvement of the monetary area, populace development of the population, and the opposition to water assets[3], and global environmental changes result in an increased water stress[4].

Water stress impacts over 10% of arable land, which prompts desertification and facilitates the rapid expansion of salinization, substantially compromising the normal yields of various harvests. Besides, the expanding salt fixation in the dirt layers diminishes the water capability of the soil, which seriously reduces water content and plant water conductance in plant tissues[5]. Salts gathering in soils leads to a decrease of water in the soil and then the presence of "osmotic pressure." High salinity activates the use of energy that plants normally should use to obtain water from the soil and carry out physiological changes, thereby reducing plant growth. Salt stress declines the overall leaf water content, water potential, leaf water connection boundaries, osmotic potential, turgor potential, and eventually restrained plant development and diminished the yields[6]. Water stress occurs because of water shortfall elicited by high soil salinity or drought. In the event of high salinity, water exists in the soil but cannot be absorbed by plants, which is known as physiological drought[7]. After the excess water is drained away and the velocity of downward movement is reduced by gravity and other factors, the amount of soil water or water content maintained in the soil at this time is called the field capacity. Through uptake or dissipation by the plant roots, water is further reduced until the point of minimum soil moisture required for the plant not to wilt, called the wilting point. At this stage, the inability of the root system to take up the water necessary to solve its problem leads to the beginning of plant wilting and death[8,9].

The understanding of resistance systems to salinity and drought is important to provide experiences at the subatomic, physiological and biochemical levels for the resilience tools against these abiotic stresses.

2 SALINITY

Salinity is the most abiotic stress in bone-dry and semi-parched locales, where over 6% of the world surfaces are salt impacted. NaCl is the most inescapable, bountiful and dissolvable salt on the planet[10]. In arid and semi-arid areas, the scarcity of natural and inorganic supplements and the high rate of evapotranspiration results in an increase in soil salinity and sodium[11]. An important cause of pungent soil could be the utilization of inferior quality water. The top-notch water is used for homegrown purposes or in industry and contaminated or pungent water is utilized for land development[12].

Pungent soils can be identified by the electrical conductivity (EC) of soil immersion. By definition, soils with EC of 4dS/m or more are considered saline and those with EC values of over 15dS/m are considered emphatically or strongly saline[13].

Contributing factors to soil salinization include human activities, ground geology, environment, and salt composition[14]. The Cl ions in salts cause high toxicity and complementary irregular properties in plants, while Na ions in particular cause soil scattering[15]. Salt grouping in soil layers alters the plant's normal interactions, such as the atomic, biochemical, and physiological cycles as well as harvest yield , in terms of quantity and quality, which are reduced by soil or water salinization[16,17].

Force of salinity relies upon material science, science of soils, the convergence of salt in water, plants type, water system timetables, and plant development stages[18]. Thus, research on salt-tolerant genotypes is vital to address this issue. At low salinity levels, plant damage is attributed to healthful awkward nature, osmotic pressure, and particle poisonousness[19]. At moderate to high salinity levels, the healthful awkward nature is attributable to the hindrance of salt particles and their deleteriousness due to the aggregation particles especially Na^+ and Cl^- which are important for the biochemical and physiological synthesis of salinity on various yielding plants[20]. Attempts to deliver salt lenient genotypes need a decent comprehension of the impacts of salinity on plants of various harvests, the biochemical, sub-atomic, and physiological responses of plants to salinity, and recognition of the complex system of salt resilience in plants[21].

2.1 Morphological Effects of Salt Stress on Crop Plants

A decrease in plant development under salt stress has been documented by many scientists and the degree of reduction depends on ecological conditions, salinity levels, developmental stages, and plant species. High salinity results in decreased germination, seedling length, root/shoot length ratio, and seed power[22]. It limits the rapid development of stems and leaves but may increase root extension. The toxicity of particle matter is the main reason for development decrease under saline conditions[23]. The main impact of high salinity on plants is the decrease in in the uptake of supplements and water by roots due to the decrease in osmotic potential, leading to a reduction in their developmental range[24] and a more pronounced decrease in root and shoot development, contributing to leaf senescence, decay, and shrinkage[25]. In addition, high salinity alters the morphology of root framework and reduces the absolute root length of the plant[26]. An overall decrease in new and dry tips has been recorded in most plant tissues under the effect of high salinity, which has been previously reported to be associated with the decline in the quantity of leaves or in leaf abscissions. Also, the reduction in leaf number because of salinity could be attributable to its immediate impact on cell division. The reduction in leaf number may also be elicited by the expansion in leaf abscission associated with hormonal irregularities from the increment in ABA and abatement in IAA levels in the focal plant when compared with control leaves[27].The decline in the leaf zone may be considered an opposing means of water deficit through the occurrence of water limitation[28]. The expansion of salt fixation in the water system limits the leaf zone, leading to a decrease in plant development and changing the connection between the roots and the aerial parts. Salinity causes plants with different yields to exhibit root mass drier than shoot, which expands the proportion of root shoot[29]. The progressions shaped in leaf life systems are additionally a significant technique to concentrate on the impact of abiotic stress and the salt pressure for various harvests[30]. Longstreth et al.[31] completed a field exploration focusing on the impact of various salinity levels on three plants with various responses to salinity (Atriplexpatula, salt-open minded plant; *Gossypium hirsutum*, decently salt-lenient plant; and *Phaseolus vulgaris*, salt-delicate plant). To establish the responses occurring in plant leaf life systems, these researchers recorded different leaf characteristics such as leaf epidermis, leaf thickness, the surface area of mesophylls per unit leaf surface area, the distance of across of light cells, the length and breadth of palisade cells and the ratio of mesophyll cell surface region to leaf surface region. The salt-lenient species treated with various saline concentrations (0.05, 0.1, 0.2, 0.3 and 0.4M) showed a greater leaf thickness, due to the increment in mesophyll and epidermal thickness. The other two species, which are less tolerant to salt stress, produced the opposite effect. Similarly, Romero-Aranda et al.[32] recorded the different effects of physical instability originating from chloride salts, such as the different effects of NaCl, KCl, and $ClCa_2$ in the citrus varieties of tolerant (*Cleopatra mandarin*) and delicate (*Carrizo citrange*). They saw changes in the physical characters of the leaves of both varieties, such as the increment in the lower area/volume of the mesophyll cells and leaf thickness. Salt stress also decreased the intercellular air spaces and expanded the surface/volume proportion of tissue and cells thickness. These outcomes demonstrated that inundation of citrus crops with saline water causes an increase in leaf thickness accompanied by several metabolic changes, such as low Mg^{2+} content, low chloride excess, chlorophyll harm, and stomatal conclusion, which might contribute to a decrease in photosynthesis. Navarro et al.[33] found physical changes in the cross-section of Arbutus undo leaves under saline conditions by optical microscopy. Compared to control plants, saline-treated plants had similar cell sizes in the upper palisade and significant cell enlargement in the lower palisade, with more marked enlargement with higher salinity of NaCl (0mM, 52mM and 105mM NaCl). In addition, the intercellular air spaces were abnormally reduced in the light mesophyll tissue of saline-treated leaves contrasted with untreated leaves, which reduced the conductance of CO_2. Fernández-García et al.[29] studied the leaf volume/leaf area ratio of henna plants treated with high salinity and the response of henna plants to high and low salinity and found that high salinity led to an increase in the leaf thickness in salt-treated henna plants, which might augment the photosynthesis potential. Kelij[34] revealed a decline in the quantities of vascular clusters in the stem of *Aeluropus littoralis* under salt stress conditions. Naz et al.[35] showed a decrease in the metaxylem area of five ecotypes of *Aeluropus lagopoides* as a consequence of increasing salt concentration in various ecotypes. Behrouz et al.[36] similar documented in certain halophytes that the distance of xylem vessels decreased sharply to 800mM after saline treatment, and that phloem measurement decreased under NaCl stress. A study by Akinci et al.[37] showed that under salt stress conditions, the most physical and morphological characteristics such as stem transverse spacing, stem length, metaxylem breadth, vascular clusters, and phloem width were decreased, and salt stress conditions resulted in abnormal decreases in stem height, leaf zone records, leaf number, new growth, and dry weight in cotton (*Gossypium hirsutum*) plants and some Cucurbitaceae species They stated the pressure conditions effect on morphological characters as well as changes bio-mass proportion and that similar outcomes could be observed on *Salvia officinalis*[38]; *Thymus capitatus*[9,39]; *Nigella sativa*[40]; and basil[41].

3 DROUGHT

The effects of the dry season include yield, development, shade content, osmotic changes, and photosynthetic action[42]. Plant vulnerability to drought varies with plant species, stress degree, different stress factors, and their formative stages[43]. Adaptation of plants to water deficit leads to multiple changes in physio-biochemical cycles and plant development, such as changes in plant development, tissue osmotic potential, plant structure rate, and protection against cancer agents[44]. It is critical to understand the transformation and reactions of harvests to water stress with actions to further develop the dry season blocking capacity of various harvests and to guarantee higher harvest development and yields.

3.1 Morphological Effects of Drought Stress on Crop Plants

Water stress is a significant ecological limiting factor for plant foundation and development. Germination is the main stage of plant development and is extremely sensitive to water deficiency; therefore, the resources for growth during the germination period are crucial for yield. The apparent side effects of water stress on plants during the asexual reproduction stage include dwarfed plants, a decline in area and number of leaves, wilting of leaves, and delayed buds and blossoms[45,46], among which The underdevelopment of the leaves is the earliest apparent side effect since leaves are photosynthetic organs[47]. Reduction in leaf area and leaf senescence occurs in plants under severe drought conditions[48]. As per Lonbani et al.[49], Khalil et al.[50], during the dry season, leaf expansion is reduced to obtain coordination between the water consumed by plant roots and the water status of plant tissues[51]. Furthermore, Blum[52] indicated that a decrease in leaf region is advantageous under drought. Additionally, drought also influences root framework design (root length, length of horizontal roots, its number, and spread) and roots development[53]. Water and nutrient uptake are important functions of the root system, and therefore, the root framework is essential for activating and sustaining plant development during the early asexual reproductive stages of plants[54]. Water stress diminished plants' new and dry biomass creation[55]. Yield is little impacted when water stress happens during the blossoming stages or the heading stages. Water stress can reduce harvested grain yield by 17% to 70%[56]. During development, drought reduces crop yield by around 10% yet moderate stress at the early vegetative development stage has little impact on yield[57].

3.2 Biotechnology and Water Stress

Significant endeavors of plant reproducers and physiologists over the last 30 years have focused on further developing the drought tolerance of various plants and rural harvests. Obviously, the growing demand for food urgently requires further development of stress toleran ce and better management strategies for various yield plants to maintain food production to meet demand, regardless of water and land accessibility. Borlaug et al.[58] indicated that yield creation should be accomplished through the development of planting areas or expansion of crop utility per hectare. To date, different approaches have been employed, including the use of ole-fashioned genetic methods and further developed plant rearing strategies for further development of stress-relief plants. One of the approaches to cope with plant resistance and harvest resilience increments in water-restricted conditions is to screen out genotypes that increase plant yield in water pressure conditions, which has been proved effective but infeasible due to the polygenic nature of dry season stress tolerance and the variability of precipitation. Attributes of importance to plant reproduction include water-use productivity, water-extraction proficiency, osmotic and versatile changes, pressure driven conductance, and adjustment of leaf region. Changes in plants change for upgraded resilience is founded on the control of qualities that maintain and secure the constitution and capacity of various cell parts. Present designing systems depend on the exchange of one or a few qualities related with pressure responsive pathways, albeit the current endeavors to further develop plant stress resistance by quality change have brought about significant accomplishments[59].

4 CONCLUSION

Abiotic stress is the main danger for sanitation because of the disruption of the climate caused by human activities and consistent changes in the environment. To deal with various abiotic stresses physiological, sub-atomic, and cell alterations are found in various harvests. A deep understanding of the yield response to stresses will contribute substantially to current and customary reproducing procedures for the further development of stress resilience.

Acknowledgements

Not applicable.

Conflicts of Interest

The author declared no conflict of interest.

Author Contribution

Khalil SE studied, wrote, reviewed and corrected this article.

Abbreviation List

EC, Electrical conductivity

References

[1] Guo J, Ling H, Wu Q et al. The choice of reference genes for assessing gene expression in sugarcane under salinity and drought stresses. *Sci Rep-UK*, 2014: 4; 1-10. DOI: 10.1038/srep07042

[2] Kijne JW. Unlocking the water potential of agriculture. Food and Agriculture Organization. FAO: United Nation, 2003.

[3] Laraus J.The problems of sustainable water use in the mediterranean and research requirements for agriculture. *Ann Appl Biol*, 2004; 144: 259-272. DOI: 10.1111/j.1744-7348.2004.tb00342.x

[4] Sheffield J, Wood EF, Roderick ML. Little change in global drought over the past 60 years. *Nature*, 2012; 491: 435-438. DOI: 10.1038/nature11575

[5] Munns R. Comparative physiology of salt and water stress. *Plant Cell Environ*, 2002; 25: 239-250. DOI: 10.1046/j.0016-8025.2001.00808.x

[6] Jabeen N, Ahmad R. Improvement in growth and leaf water relation parameters of sunflower and safflower plants with foliar application of nutrient solutions under salt stress. *Pak J Bot*, 2012; 44: 1341-1345.

[7] Chaves MM, Maroco JP, Pereira JS. Understanding plant response to drought-from genes to the whole plant. *Funct Plant Biol*, 2003; 30: 239-264. DOI: 10.1071/FP02076

[8] Nagarajan S, Nagarajan S. Abiotic Tolerance and Crop Improvement. In: Abiotic stress adaptation in plants. Physiological, molecular and genomic foundation. Pareek A, Sopory SK, Bohnert HI et al. ed. Springer: Dordrecht, The Netherlands, 2010; 1-11.

[9] Khalil SE. Alleviating salt stress in Thymus capitatus plant using plant growth-promoting bacteria (PGPR). *Int J ChemTech Res*, 2016; 9: 140-155.

[10] FAO. Global network on integrated soil management for sustainable use of salt-affected soils. 2008. Soils, 2008. Accessed 2022. Available at https://www.fao.org/ag/agl/agll/spush

[11] Shannon MC, Grieve CM, Francois LE. Whole-plant response to salinity. In: Plant Environ Interact. Wilkinson RE ed. Marcel Dekker: New York, USA, 1994; 199-244.

[12] Bouwer H. Integrated water management for the 21st century: problems and solutions. *J Irrig Drain Eng*, 2002; 28: 193-202. DOI: 10.1061/(ASCE)0733-9437(2002)128:4(193)

[13] Omami NE. Response of amaranth to salinity stress [PhD's thesis]. Pretoria, South Africa: University of Pretoria; 2005.

[14] Blumwald E, Grover A, Good AG. Breeding for abiotic stress resistance: challenges and opportunities. Proceedings of the 4th International Crop Science Congress, Brisbane, Australia, September 26-October 1 2004. CDROM; 2004.

[15] Hasegawa PM, Bressan RA, Zhu JK et al. Plant cellular and molecular responses to high salinity. *Annu Rev Plant Biol*, 2000; 51: 463-499. DOI: 10.1146/annurev.arplant.51.1.463.

[16] Silveira JAG, Melo ARB, Viégas RA et al. Salinity-induced effects on nitrogen assimilation related to growth in cowpea plants. *Environ Exp Bot*, 2001; 46: 171-179. DOI: 10.1016/S0098-8472(01)00095-8

[17] Ali TB, Khalil SE, Khalil AM. Magnetic Treatments of Capsicum AnnuumL. Grown Under Saline Irrigation Conditions. *J Appl Sci Res*, 2011; 7: 1558-1568.

[18] Vicente O, Boscaiu M, Naranjo MA et al. Responses to salt stress in the halophyte Plantagocrassifolia (Plantaginaceae). *J Arid Environ*, 2004; 58: 463-481. DOI: 10.1016/j.jaridenv.2003.12.003

[19] Wahome PK, Jesch HH, Grittner I. Mechanisms of salt stress tolerance in two rose rootstocks: Rosa chinensis "Major" and R. rubiginosa. *Sci Hortic-Amsterdam*, 2001; 87: 207-216. DOI: 10.1016/S0304-4238(00)00168-0

[20] De-Pascale S, Ruggiero C, Barbieri G et al. Physiological responses of pepper to salinity and drought. *J Am Soc Hortic*

Sci, 2003; 128: 48-54. DOI: 10.21273/JASHS.128.1.0048

[21] Khalil SE, Abou Leila BH. Effect of Magnetic treatment in improving Growth, Yield and fruit quality of Physali spubescens plant grown under saline irrigation conditions. *Int J ChemTech Res*, 2016; 9: 246-258.

[22] Khodadad M. An evaluation of safflower genotypes (Carthamustinctorius L.), seed germination and seedling characters in salt stressconditions. *Afr J Agric Res*, 2011; 6: 1667-1672. DOI: 10.5897/AJAR10.915

[23] Chinnusamy V, Xiong L, Zhu J. Use of genetic engineering andmolecular biology approaches for crop improvement for stress environments. In: Abiotic stresses: plant resistance through breeding andmolecular approaches. Ashraf M, Harris P ed. Food Product Press: New York, USA, 2005; 47-107.

[24] Acosta-Motos JR, Ortuño MF, Bernal-Vicente A et al. Plant Responses to Salt Stress: Adaptive Mechanisms. *Agronomy*, 2017; 7: 18. DOI: 10.3390/agronomy7010018

[25] Álvarez S, Sánchez-Blanco MJ. Long-term effect of salinity on plant quality, water relations, photosynthetic parameters and ion distribution in Callistemon citrinus. *Plant Biol*, 2014; 16: 757-764. DOI: 10.1111/plb.12106

[26] Farooq M, Hussain M, Wakeel A et al. Salt stress in maize: effects, resistance mechanisms and management. A review. *Agron Sustain Dev*, 2015; 35: 461-481. DOI: 10.1007/s13593-015-0287-0

[27] Wu QS, Xia RX, Zou YN. Reactive oxygen metabolism in mycorrhizal and nonmycorrhizal citrus (Poncirus trifoliate) seedlings subjected to water stress. *J Plant Physiol*, 2006; 163: 1101-1110. DOI: 10.1016/j.jplph.2005.09.001

[28] Ruiz-Sánchez MC, Domingo R, Torrecillas A et al. Water stress preconditioning to improve drought resistance in young apricot plants. *Plant Sci*, 2000; 156: 245-251. DOI: 10.1016/S0168-9452(00)00262-4

[29] Fernández-García N, Olmos E, Bardisi E et al. Intrinsic water use efficiency controls the adaptation to high salinity in a semi-arid adapted plant, henna (Lawsoniainermis L.). *J Plant Physiol*, 2014; 171: 64-75. DOI: 10.1016/j.jplph.2013.11.004

[30] Acosta-Motos JR, Diaz-Vivancos P, Alvarez S et al. Physiological and biochemical mechanisms of the ornamental Eugenia myrtifolia L. plantsfor coping with NaCl stress and recovery. *Planta*, 2015; 242: 829-846. DOI: 10.1007/s00425-015-2315-3

[31] Longstreth DJ, Nobel PS. Salinity effects on leaf anatomy: consequences for photosynthesis. *Plant Physiol*, 1979; 63: 700-703. DOI: 10.1104/pp.63.4.700

[32] Romero-Aranda R, Moya JL, Tadeo FR et al. Physiological and anatomicaldisturbances induced by chloride salts in sensitive and tolerant citrus: Beneficial and detrimental effects of cations. *Plant Cell Environ*, 1998; 21: 1243-1253. DOI: 10.1046/j.1365-3040.1998.00349.x

[33] Navarro A, Bañon S, Olmos E et al. Effects of sodium chloride on water potential components, hydraulic conductivity, gas exchange and leaf ultrastructure of Arbutus unedo plants. *Plant Sci*, 2007; 172: 473-480. DOI: 10.1016/j.plantsci.2006.10.006

[34] Kelij S. Anatomic and metabolic changes of lignindeposition during various developmental stages inhalophyte (Aeluropuslittoralis Parl.) [PhD Thesis]. Tehran, Iran: Kharazmi University; 2013.

[35] Naz N, Hameed M, Nawaz T et al. Structural adaptations in thedesert halophyte Aeluropuslagopoides (L.) Trin. exThw. under high salinity. *J Biol Res*, 2013; 19: 150-164.

[36] Barzegargolchini B, Movafeghi A, Dehestani A et al. Morphological and anatomical changes in stems of Aeluropuslittoralis under salt stress. *J Plant Mol Breed*, 2017; 5: 40-48.

[37] Akinci S, Lösel DM. The effects of water stress and recovery periods on soluble sugars and starch content in cucumber cultivars. *Fresen Environ Bull*, 2010; 19: 164-171.

[38] Taarit MB, Msaada K, Hosni K et al. Plant growth, essential oil yield and composition of sage (Salvia officinalis L.) fruits cultivated under salt stress conditions. *Ind Crop Prod*, 2009; 30: 333-337. DOI: 10.1016/j.indcrop.2009.06.001

[39] El-Din AE, Aziz EE, Hendawy SF et al. Response of Thymus vulgaris L. to salt stress and alar (B9) in newly reclaimed soil. *J Appl Sci Res*, 2009; 5: 2165-2170

[40] Farahani HA, Valadabadi SA, Daneshian J et al. Medicinal and aromatic plants farming under drought conditions. *J Hortic Forestry*, 2009; 1: 086-092. DOI: 10.5897/JHF.9000075

[41] Said-Al Ahl HAH, Mahmoud AA. Effect of zinc and/or iron foliar application on growth and essential oil of sweet basil (Ocimumbasilicum L.) under salt stress. *Ozean J Appl Sci*, 2010; 3: 97-111.

[42] Benjamin JG, Nielsen DC. Water deficit effects on root distribution of soybean, field pea and chickpea. *Field Crops Res*, 2006; 97: 248-253. DOI: 10.1016/j.fcr.2005.10.005

[43] Demirevska K, Zasheva D, Dimitrov R et al. Drought stress effects on Rubisco in wheat: changes in the Rubisco large subunit. *Acta Physiol Plant*, 2009; 31: 1129-1138. DOI: 10.1007/s11738-009-0331-2

[44] Duan B, Yang Y, Lu Y et al. Interactions between drought stress, ABA and genotypes in Piceaasperata. *J Exp Bot*, 2007; 58: 3025-3036.

[45] Bhatt RM, Rao NKS. Influence of pod load response of okra to water stress. *Indian J Plant Physiol*, 2005; 10: 54-59.

[46] Khalil SE, Seleem FM. Role of biochar soil amendment for alleviation of adverse effects of water stress on Dimorphotheca ecklonisplants. *Biosci Res*, 2019; 16: 1337-1353.

[47] Seleem FM, Khalil SE. Response of marigold (Calendula officinalisL.) Plant to irrigation water regime and exogenous application of silicon. *Biosci Res*, 2018; 15: 4322-4334.

[48] Luo HH, Zhang YL, Zhang WF. Effect of water stress and rewateringon photosynthesis, root activity, and yield of cotton with drip irrigation under mulch. *Photosynthetica*, 2016; 54: 65-73. DOI: 10.1007/s11099-015-0165-7

[49] Lonbani M, Arzani A. Morpho-physiological traits associated with terminal drought stress tolerance in triticale and Wheat. *Agric Res*, 2011; 9: 315-329.

[50] Khalil SE, Khalil AM. Effect of water irrigation intervals, Compost and Dry Yeast on Growth, Yield and Oil Content of Rosmarinus officinalis L. plant. *American-Eurasian J Sustain Agr*, 2015; 9: 36-51.

[51] Passioura JB. Drought and drought tolerance. *Plant Growth*

Regul, 1996; 20: 79-83. DOI: 10.1007/BF00024003

[52] Blum A. Plant Stress. Mitigation Of Drought Stress By Crop Management. Accessed 2022. Available at https://plantstress.com/drought-mitigation

[53] Salazar C, Hernández C, Pino MT. Plant water stress: Associations between ethylene and abscisic acid response. *Chil J Agr Res*, 2015; 75: 71-79. DOI: 10.4067/S0718-58392015000300008

[54] Smith S, De Smet I. Root system architecture: insights from Arabidopsis and cereal crops. *Philos T R Soc B*, 2012; 367: 1441-52. DOI: 10.1098/rstb.2011.0234

[55] Kiliç H, Yağbasanlar T. The effect of drought stress on grain yield, yield components and some quality traits of durum wheat (Triticumturgidum ssp. durum) cultivars. *Not Bot Horti Agrobo*, 2010; 38: 164-170. DOI: 10.15835/nbha3814274

[56] Sourour A, Afef O, Mounir R et al. A review: Morphological, physiological, biochemical and molecular plant responses to water deficit stress. *Int J Eng Sci*, 2017; 6: 1-4. DOI: 10.9790/1813-0601010104

[57] Bauder J. Montana State University. Irrigation with limited water supplies. Accessed 2022. Available at http://region8water.colostate.edu/PDFs/Irrigating%20with%20Limited%20Water%20Supplies.pdf

[58] Borlaug NE, Dowswell CR. Feeding a world of ten billion people: a 21st century challenge. Proceedings of the International Congress "In the Wake of the Double Helix: From the Green Revolution to the Gene Revolution", Bologna, Italy, 27-31 May 2003. Bologna, Italy: Avenue media; 2005.

[59] Cherian S, Reddy MP, Ferreira RB. Transgenic plants with improved dehydration stress tolerance: Progress and future prospects. *Biol Plantarum*, 2006; 50: 481- 495. DOI: 10.1007/s10535-006-0141-y