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Effect of Waterlogging and Drought Stress in Plants

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Abstracts: Drought and waterlogging are the most severe global problems for agriculture.When water is present in excess amount than its optimum requirement it refers to water logging. Drought stress occurs when the accessible water in the soil is concentrated and atmospheric circumstances cause permanent loss of water by evaporation or transpiration.In the water logged soils, water gets filled in the pores of the soil, so the oxygen concentration decreases in soil.O_2 deficiency decrease growth and survival of plants growing in it.The flooding frequently induces stomatal closing mostly in C3 plants. Drought results in leaf dehydration; therefore, wilting of leaves occurs due to the limited water flow from the roots to the shoots. Waterlogging and drought affects a number of biological andchemical processes, which can impact crop growth in both the short and long term, in plants and soils. Germinating seeds are very sensitive to water logging and drought as their level of metabolism is high. Plants growing under stress conditions also demonstrate the formation of adventitious roots and formation of aerenchyma. Aim of this review paper is exhibit the plant responses to the water Logging and drought stresses.

Key words: Water logging · Drought · Growth · Nutrients · UOG · Punjab · Pakistan

INTRODUCTION

Waterlogging is a severe problem, which affects crop growth and yield in those areas where the concentration of rain is low. The main cause of damage under water logging is oxygen deficiency, so the plants show wilting even when enclosed by excess of water, which affect nutrient and water uptake [1]. Water logging causes a condition of hypoxia (low oxygen concentrations) in soils, because of the low solubility of oxygen in water. Water logging can also cause the accumulation of ethylene and products of root and bacterial anaerobic metabolism [2]. Plants tolerant to water logging stress exhibit certain adaptation, such as, formation of aerenchyma and adventitious roots. Furthermore, due to the interaction of plant hormones, auxin and ethylene the formation of adventitious roots take place [3]. Rice is one of the important flooding tolerant crops. The rice has ability to germinate in the complete absence of oxygen and grow in standing water. Rice and some associated weed species, such as, barnyard grass (Echinochloa spp.), will germinate quickly under anoxia once the seeds are imbibed [4]. But in the case of drought some species grow deep root systems to tap deep water tables while some have large surface root systems to quickly absorb rainfall. Some plants avoid drought by quickly regrowing new leaves when environmental conditions and by improve dropping their leaves during droughts [5]. Some species are very sensitive to water logging at the germination stage. A decrease in germination ability is due to oxygen deficiency in water logging soil. Respiration, electron transport and ATP formation are inhibited during germination when oxygen is short [6]. Plants under drought and water logging stresses exhibit growth reduction, low SLA(Specific Leaf Area), photosynthesis declination, stomatal closure, decrease in respiration and biomass production and protein degradation [7]. Plants could get only two ATP per glucose molecule, in fermentation, whereas, 36 ATP molecules are produced per glucose molecule in aerobic respiration. Flood-tolerant plants are able to retain their energy status by using fermentation. In waterlogged plants, initial decline in cytosolic pH attributed to the production of lactic acid during fermentation. This initial decrease in pH helps the plant to change from lactate to ethanol fermentation by establishment of alcohol dehydrogenase and inhibition of lactate dehydrogenase [3].

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Drought is the absence of rainfall for a period of time sufficient to reduce soil moisture and injure plants. Drought stress results when the plant's water content is reduced enough to interfere with normal plant processes and when water loss from the plant exceeds the ability of the plant's roots to absorb water [5]. There are many physiological effects of drought on plant. The main drought effect is the decrease of photosynthesis. Drought symptoms include leaves drooping and loss of turgor in needles, yellowing, wilting and premature leaf are frequentlyconnected with moisture stress [8]. Drought stress leads to stomatal closure and limitation of gasexchange. Desiccation is much more wide-ranging loss of water, which can potentially lead to disgusting disturbance ofmetabolism and cell structure and eventually to thetermination of enzyme catalyzed reactions. Drought stress resulted reduction of water content, closure of stomata and decrease in cell enlargement, growth diminished leaf water potential and turgor loss. Severe water stress mayresult in the hold of photosynthesis, stoppage ofmetabolism and finally the death of plant[9].In drought tolerance the capability to maintain the functionality of thephotosynthetic mechanism under water stressis of major importance. The plant reacts to water shortage with aquickclosing of stomata to avoid more loss ofwater through transpiration [10].The time required to arise drought injury depends on the water-holding capability of the soil, stage of plant growth, plant species and environmental conditions. Plants growing in sandy soils are more vulnerable todrought stress than plants growing in clay soils [11].

Hypoxia and Anoxia: Low oxygen concentration in soil (hypoxia) or complete absence of oxygen (anoxia) affect the nutrient uptake, synthesis and translocation of growth regulators, respiration and carbohydrate partitioning, as well as photosynthesis decreasing the yield of crops grown in soil with insufficient drainage [12].

According toJackson [13], diffusion of oxygen through water is 104-fold slower than in air. Excess water also leads to other changes in the soil that influence plants, due to the threat of oxygen deficiency. Oxygen deficiency in roots causes a change from aerobic to anaerobic respiration, which is much less efficient in consumption of organic compounds as energy sources and effect in accumulation of toxic products e.g. ethanol [14]. The accumulation of starch in leaves of flooded plants is a reflection of reduced phloem transport. Furthermore, flooding reduces phloem transport and causes reduction of carbohydrates in roots [15]. The deleterious effects linked with hypoxia and anoxia, which are responsible for the slowed growth and reduced yield of many agriculturally important crops, include drop in cytoplasmic pH and decrease in cellular energy charge and the accumulation of toxic metabolites and reactive oxygen species (ROS) [16].

Water Logging and Drought Effect on Plants Roots: Through roots plants take minerals and water through roots tomaintain life and struggle for nutrition. When plants aregrown under water or salt stress, thecompetition is more distinct and roots describethe tolerance of plants against stress [17]. Roots in waterlogged soils frequently die of anoxia (oxygen deficiency). Most trees and shrubs cannot grow for long in waterlogged soil [14]. So plant roots, suffer hypoxia or anoxia. The formation of aerenchyma and adventitious roots is an indicator of the presence of adaptive mechanisms in many flood-tolerant plants. The interaction of auxin and ethylene is important for the stimulation of adventitious root formation [15]. Moreover, aerenchyma, which thought to contribute to water logging tolerance, is develops in cortex of new and existing root of some plant species. In the rice crop the aerenchyma well developed and adopt flooded condition [18]. Many plants such as *Paspalum dilatatum* responded to flooding by increasing root and leaf sheath aerenchyma and to drought by decreasing the thickness of metaxylem vessels. In contract, the number of root hairs increased under drought than flooding [19]. Water logging, under saline conditions, inhibits the ability of roots to screen out salt at the root surface; therefore, there are large increases in salt uptake and in salt concentrations in the shoots [16]. Reduction of root respiration is one of the earliest responses of plants under the absence of oxygen, in spite of whether the plants are flooding-tolerant or intolerant [12]. Oxygen deficiency inhibits the root respiration of plants, which results in considerable reduction in energy kind of root cells. Since in the absence of oxygen terminate electron acceptor in aerobic respiration, also Kreb's cycle and electron-transport system are blocked [3]. In flooded sunflowers starch accretion may show reduced phloem transport as a consequence of a discard in root metabolism caused by low oxygen levels [20].

Drought stress severely inhibits plant growth. However, development ofshoot is usually more affected than that of root under drought. In maize, it is reported that shoot growth is completely inhibited while root growthis maintained at lower water potentials. It is also showed that elongation activity in root tip regions underwater stress is highly retained. On the other hand, in the case of *Brassicaceae*, inhibition of primary root elongation under drought is accompanied with morphogeneticdifferentiation process in the lateral roots. In this process, lateral roots remain short, hairless andoften take a tuberized shape with concomitant accumulation of starch and proline [21]. In soybean plants some anatomical features related to parenchymatous cells, stomata index, size and average number of stomata and epidermal cells varying under stress [22]. Abscisicacid, pH, a precursor of ethylene, cytokinins and malate are some chemical signals that are significant for plant adaptation under drought [23]. Plants that escape water tissue deficits develop large roots to reach deep water tables, accrue water in tender tissues during complete their life cycle rapidly during little water availability [24].

Plant Responses to Water Stress: Plants under water stress show a number of physiological responses at the cellular, molecular and whole-plant levels [25]. Water logging in soil known, not only in natural ecosystem but also in agricultural and horticultural system, as a major abiotic factor affecting the growth, development and survival of plant species [26].

As an early response to flooding, stomata close to decreasetranspiration waterloss resulting in reduced net photosynthesis andstomatal conductance [27]. In contrast, earlyresponses of plants to drought stress helpthe plant to indicate by the accretion of certain newmetabolites related with the structural capabilitiesto enhance plant implementation under droughtstress [28]. Flooding adversely affects all developmental stages of flood-intolerant plants during the growing season, whereas flooding generally has little effect in the short term during the dormant season. Plant responses to flooding include injury, inhibition of seed germination, reproductive growth, vegetative growth, changes in plant anatomy and promotion of early senescence during the growing season [29]. Whereas, on yield of cropsthe effects of drought depend ontheir severity, plants growth and also on the species or genotype. First stage of growth is the seed germination thatis susceptible to water stress [30].

It suggested that water stress and osmotic stress cause a reduction in growth. Therefore, cytokinin decreases that transport from roots to shoots and an increase in leaf ABA; so due to changes in hormone balance cause changes in cell wall extensibility and therefore growth reduce [12]. Plantturgor and water potential are reduced, in water deficit situations, to interfere with usual functions and droughtstress because that changes in morphological and physiologicalcharacters in plants [31]. Due to the low turgor pressure cell expansion and cell growth suppresses under water stress. In pearl millet osmotic regulation can enable the maintenance of cell turgor for survival plant growth [32]. Occurrence of drought stress reduces the yield of corn, especially at grain filling or flowering period [33].

Tolerance to stress involves osmotic regulation and changes in the elastic properties of tissues [34].

Drought stress inhibits photosynthesis in plants by closing stomata and damaging the chlorophyll contents andphotosynthetic apparatus. It disturbs the balance between the production of reactive oxygen species (ROS) and the antioxidantdefence, causing accumulation of ROS which induces oxidative stress to proteins, membrane lipids and other cellular component.Mineral elements have numerous functions in plants including maintaining charge balance, electron carriers, structural components, enzyme activation and providing osmoticum for turgor and growth [35]. Under drought stress the decrease in chlorophyll content has been considered a distinctive symptom of oxidative stress and may be the effect of chlorophyll degradation and pigment photo-oxidation [36].

The plants resistance against drought can be divided into three categories:

- Escape
- Avoidance
- Tolerance.

Escape water-stress pants have ability to complete their life cycles before the water shortage that haveasevere effect on performance of pant. By *avoiding* tissue dehydration plants may be able to maintain moisture-stress. *Tolerance* of water deficitis associated with plants that have more rigid cell walls and have the ability tomake osmotic adjustments at the cellular level.

It seems that drought stress usually reduced NO emission and ethylene production while waterlogging improved ethylene and reduces NO emission [37].High salt stress disrupts homeostasis in ion distributionand waterpotential. Disruption of homeostasis occurs at both the cellular and the whole plant levels that has sever effect the plant development [38].

Effect of Water Stress in Nutrient Uptake: The major types of stresses, which potentially affect plant growth and nutrient uptake, are flooding, salinity and drought. Other stresses, which also at the same time affect the normal growth of plants and the nutrient uptake circumstances include, seedbed preparation, plant population, planting time, types of soil,soil N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, B, Mo, Co, Si, Cd, Cr, Se and Al, soil organisms, diseases, weeds, toxic metals, air pollution, growth regulators, wind, hailstorms, water-table and allelopathy [39]. Salinity and drought can differentially affectthe mineral nutrition of plants. Due to the competition of Na^+ and Cl^- with nutrients such as $Ca^{2+,}$ K^+ and NO^-_3 salinity may cause nutrientdeficiencies. On the other hand droughtcan affect nutrient uptake and translocation of some nutrients [40]. Potassium is a most important nutrients element that has an important role for endurance of plants in stress condition [41]. The availability of K+ to the plant,due to the decreasing mobility of K+ under stress environment, decreases with decreasing soil watercontent [42]. Macro-nutrients like K;N and Ca and micro- nutrients like Zn, Si and Mg reduce the toxicity of ROS by increasing theconcentration of antioxidants like superoxide dismutase (SOD) and improve drought tolerance in plants.The micronutrients like B and Cu lighten theadverse effects of drought in biochemical, physiological and metabolic processes in theplants [43]. In the case of water logging, even in tolerant plants the growth rate, nutrient uptake and root-shoot ratio reduced [12].

Under anaerobic conditions, the concentration of soluble carbohydrates such as glucose, fructose, sucrose increased in shoots indicating that photosynthesis did not limit nutrient uptake. Generally, when the growth is inhibited due to various stress conditions or nutrient deficiency carbohydrate accumulation occurs. Both and N deficiency and Mn toxicity may be induced by the low redox potential in waterlogged soils that promotes denitrification of NO^{-3} and produces plant-available Mn^{2+} [44]. Tolerant species, under flooding conditions, show a marked increase in nitrate reductase activity in roots and leaves [45]. Under drought stress nutrientshortage condition in plants takes place due to reduced low nutrient availability in soil, root growth and reduced mineral uptake [46]. Due to Water stress P concentrations in apricot (*Prunusarmeniaca)* leaves high, while K concentration reducing in roots.K concentrationin soyabean (*Glycine max) leaves*increased whereas in roots K concentrationdecreased [47].

Responses of ABA: Abiotic andpathogens stress such as salt stress and drought rigorously effect plant performance and yield. In biotic and abiotic stress the phytohormone ABA serves as an endogenous messenger. Drought and high salinity, accompanied by a main change in adaptive physiological responses and in gene expression, strong increases of plant ABA levels [48]. ABA is synthesized in plant tissue and transfer to the guard cell as a stress indicator under drought condition. Here ABA causes stomatal closure to develop the water associations of plant. In response of water deficit, ABA begins to increase in leaf tissues and to lesser in roots tissues of plant. This response decreased transpiration and leads to stomatal closure. It also inhibits to appears the shoot and root growth to be promoted whichprovide the water [49]. ABA synthesis induced by waterstress has been associated with decrease of root: shoot ratio [50]. ABA has central role in roots show that ABA concentrations of xylem sap from drought stressedplants is greatly lesser than the concentrationsof exogenous ABA necessary to closing stomata in separateleaves [23]. ABA did not have an effect on germination in distilled water,whereas ABA reserved germination in salty conditions [51]. Plant wilting can be caused by ABA when combination of enhanced water loss and insufficient watering occur [52]. Drought tolerancevarieties have been found to make higher levels of ABA than drought resistance varieties in *Sorghum bicolor* (sorghum) and *Zea mays* (maize) [53]. Water logging leads to increase in abscisic acid (ABA) that could be responsible for effecting the growth. After decrease in the growth, tissue water potential, rate the potential to absorb nutrients, concentrations of photosynthetic enzymes, rate of photosynthesis and turgor also decreases [44].

CONCLUSION

Through this study it is concluded the water logging and drought are the major threats to the agricultural crops. The oxygen deficient conditions affect plant growth, developmentand survival.Waterlogging causes deficiency of several essentialnutrients such as N, P, K, Ca, Mg, S, Fe etc. Drought and water logging affects a number of biological and chemical processes, which can impact crop growth and soils. Concentration of hormones also decreases as the result of water stress which reduces the plant growth.Plants growing under water stress conditions also demonstrate certain morphological and anatomical changes.

REFERENCES

1. Sairam, R.K., D. Kumutha, K. Ezhilmathi, P.S. Deshmukh and G.C. Srivastava, 2008. Physiology and biochemistry of waterlogging tolerance in plants.Biologia Plantarum, 52(3): 401-412.
2. Barrett-Lennard, E.G., 2003. The interaction between waterlogging and salinity in higher plantscauses, consequences and implications. Plant and Soil, 253: 35-54.
3. Ashraf, M.A.m 2012. Waterlogging stress in plants. A. J. A. R.7(13): 1976-1981.
4. Crawford, R.M.M., 2003. Seasonal differences in plant responses toflooding and anoxia. Can. J. Bot., 81: 1224-1246.
5. Knox, G., 2005. Drought-Tolerant Plants for North and Central Florida. University of Florida Cooperative Extension Service.
6. Hsu, F.S., J.B. Lin and S.R. Chang, 2000. Effects of waterlogging on seed germination, electric conductivity of seed leakage and developments of hypocotyl and radicle in sudangras. Bot. Bull. Acad. Sin., 41: 267-273.
7. Juan, A., González, M. Gallardo, A. Hilal, M. Rosa and F.E. Prado, 2009. Physiological responses of quinoa (*Chenopodium quinoa* Willd.) to drought and waterlogging stresses: drymatter partitioning. Botanical Studies, 50: 35-42.
8. Dougles, S.M., 2011. Drought, It after Effects and Management Strategies for Woody Ornamentals. The Connection Agricultural Experiment Station, pp: 123.
9. Jaleel, C.A., P. Manivannan, A. Wahid, M. Farooq, H. J. Al-Juburi, R. Somasundaram and R. Panneerselvam, 2009. Drought Stress in Plants: A Review on Morphological Characteristics and Pigments Composition. Int. J. Agric. Biol., 11: 100-105
10. Zlatev, Z. and F.C. Lidon, 2012. An overview on drought induced changes in plant growth, water relations and photosynthesis. Emir. J. Food Agric., 2. 24(1): 57-72.
11. Knox, G.W., 2005. Drought Tolerant Plants for North and Central Florida. CIR807.
12. Ferreira, J.L., C.H.M. Coelho, P.C. Magalhães, G.C. Sant'ana and A. Borém, 2008. Evaluation of mineral content in maize under floodi ng. Crop Breed. and Applied Biotech. 8: 134-140.
13. Jackson, M.B. and T.D. Colmer, 2005. Response and Adaptation by Plants to Flooding Stress. Annals of Bot., 96: 501-505.
14. Halcomb, M., 2003. Too much Water Kills More Plants than too little Water. The University of Tennessee Extension.
15. Liao, C.T. and C.H. Lin, 2000. Physiological Adaptation of Crop Plants to Flooding Stress. Proc. Natl. Sci. Counc. ROC(B), 25(3): 148-157.
16. Alam, I., D.G. Lee, K.H. Kim, C.H. Park, S. Akhtar, H. Lee, K. Oh, B.W. Yunand B.H. Lee, 2010. Proteome analysis of soybean roots under waterlogging stress at an early vegetative stage. J. Biosci., 35(1): 49-62.
17. Riaz, A., A. Younis, A. Riaz Taj, A. karim, U. Tariq, S. Munir and S. Riaz, 2013. Effect of Drought Stress on Growth and Flowering of Marigold (*Tagetes erecta L*.). Pak. J. Bot., 45(1): 123-131.
18. Tepwadee, C., M. Shigenori, J. Abe, I. Kaori, T. Ryosuke and P. Anan, 2008. Root at seedling stage of Three Cordage Fiber Crops. Plant Prod. Sci., 1(2): 232-237.
19. Vasellati, V., M. Oesterheld, D. Medan and J. Loreti, 2001. Effects of Flooding and Drought on the Anatomy of *Paspalum dilatatum*. Annals of Bot., 88: 000-000.
20. Wample, R.L. and R.W. Davis, 1983. Effect of Flooding on Starch Accumulation in Chloroplasts of Sunflower (*Helianthus annuus* L.). Plant Physiol., 73: 195-198.
21. Kato, A., S. Hoshiyasu, A. Yokota and K. Akashi, 2011. Response of Plant Roots to Drought Stress. Proceedings of the 7th ACSA Conference.
22. Makbul, S., N.S. Guler, N. Durmuş and S. Guven, 2011. Changes in anatomical and physiological parameters of soybean under drought stress. Turk J. Bot., 35: 369-377.
23. Schachtman, D.P. and J.Q.D. Goodger, 2008. Chemical root to shoot signaling under drought. Trends in Plant Sci., 13: 6.
24. González, R.G.G. and I.T. Pacheco, 2006. Genetic manipulation of plants for increased drought tolerance. Adv. in Agri. and Food Biotech., 71(97): 81-7736-269-0.
25. Raghavendra, A.S., V.K. Gonugunta, A. Christmann and E. Grill, 2010. ABA Perception and Signaling. Trends in Plant Sci., 15: 95-401.

26. Barman, T.S., U. Baruah, D.K. Deka, D. Borah, T. Lahon and J.K. Saikia, 2011. Selection and evaluation of waterlogging tolerant tea genotypes for plantation in marginal land. Two and a Bud, 58: 33-38.
27. Gil, P., B. Schaffer, S.M. Gutiérrez and C. Li, 2007. Effect of Waterlogging on Plant Water Status, Leaf Gas Exchange and Biomass of Avocado (*Persea americana Mill*). Viña Del Mar, Chile., 12(16): 978-956-17-0413-8.
28. Reddya, A.R., K. . Chaitanyaa and M. Vivekanandan, 2004. Drought-induced responses of photosynthesis and antioxidant metabolism in higher plants. J. Plant Physiol., 161: 1189-1202.
29. Kozlowski, T.T., 1997. Responses of woody plants to flooding and salinity. Tree Physiol. Mono: 1.Victoria, Canada.
30. Khakwani, A.A., M. D. Dennett and M. Munir, 2011. Drought tolerance screening of wheat varieties by inducing water stress conditions. J. Sci. Technol. 33(2): 135-142.
31. Rahdari, P. and S.M. Hoseini, 2012. Drought Stress. Int. J. Agro. and Plant Prod., 3(10): 443-446.
32. Jaleel, C.A., P. Manivannan, A. Wahid, M. Farooq, H.J. Al-Juburi, R. Somasundaram and R. Panneerselvam, 2009. Drought Stress in Plants: A Review on Morphological Characteristics and Pigments Composition. Int. J. Agric. Biol., 11: 100-105.
33. Soroushi, H., T.S. Nejad, A. Shoukofar and M. Soltani, 2011.The Interaction of Drought Stress and Gibberellic Acid on Corn(*Zea Mays* L.). World Acad. of Sci. Eng. and Tech., pp: 60.
34. Zlatev, Z. and F.C. Lidon, 2012. An overview on drought induced changes in plant growth, water relations and photosynthesis. Emir. J. Food Agric., 24(1): 57-72.
35. Ahmad, E., A. Rashid, M. Saifullah, Y. Ashraf, Ehsanullah, 2011. Role of mineral nutrition in alleviation of drought stress in plants. A.J.C.S., 5(6): 764-777.
36. Anjum, S.A., X. Xiao-Yu, W.L. Chang, M.F. Saleem, C. Man and W. Lei, 2011. Morphological, physiological and biochemical responses of plants to drought stress. Afri. J. Agric. Res,. 6(92): 026-2032.
37. Magalhaes, J.R., D.C. Monte and D. Durzan, 2000. Nitric oxide and ethylene emission in *Arabidopris thalana*. Physiol. Mol. Biol. Plants, 6: 117-127.
38. Zhu, J.K., 2001. Plant salt tolerance. Trends in Plant Sci., 6: 2.
39. Alam, S.M., 1999. Nutrient Uptake by Plants Under Stress Conditions. Marcel Dekker, Inc.
40. Hu, Y. and U. Schmidhalter, 2003. Drought and salinity: A comparison of their effects on mineral nutrition of Plants. J. Plant Nutr. Soil Sci., 168: 541-549.
41. Baque, M.A., M.A. Karim, A. Hamid and H. Tetsushi, 2006. Effects of fertilizer potassium on Growth, Yeild and Nutrient uptake of Wheat (*Tritcum aestivum*) under water stress condition. South pacific Studies, 27: 1.
42. Arjenaki, F.G., R. Jabbari, A. Morshedi, 2012. Evaluation of Drought Stress on Relative Water Content, Chlorophyll Content and Mineral Elements of Wheat (*Triticum aestivum L.)* Varieties. I. J. A. C.S., 4(11): 726-729.
43. Ahmad, E.. A. Rashid, Saifullah, M.Y. Ashraf, Ehsanullah, 2011. Role of mineral nutrition in alleviation of drought stress in plants. A.J.C.S., 5(6): 764-777.
44. Steffens, D., B.W. Hütsch, T. Eschholz, T. Lošák, S. Schuber, 2005. Water logging may inhibit plant growth primarilyby nutrient deficiency rather than nutrient toxicity. Plant Soil Environ. 51(12): 545-552.
45. Boonlertniruna, S., S. Meechouib and E. Sarobol, 2010. Physiological and morphological responses of field corn seedlings to chitosan under hypoxic conditions. Sci. Asia, 36: 89-93.
46. Ashraf, M., M. Shahbaz and Q. Ali, 2013. Drought-Induced Modulation in Growth and Mineral Nutrients in Canola (*Brassica napus* L.). Pak. J. Bot., 45(1): 93-98.
47. Huang, B., 2001. Nutrient Accumulation and Associated Root Characteristics in Response to Drought Stress in Tall Fescue Cultivars. Hortsci., 36(1): 148-152.
48. Raghavendra, A.S., V.K. Gonugunta, A. Christmann and E. Grill, 2010. ABA Perception and Signaling. Trends in Plant Sci., 15: 395-401.
49. Hussain, S., A. Ali, M. Ibrahim, M.F. Saleem and M.A.A. Bukhsh, 2012. Exogenous Application of Abscisic Acid for Drought Tolerance in Sunflower (*Helianthus annuus* L). The J. Ani. and Plant Sci., 22(3): 806-826.
50. Leskovar, D.I. and D.J. Cantliffe, 1992. Pepper Seedling Growth Response to Drought Stress and Exogenous Abscisic Acid. J. Amer. Soc. Hort. Sci., 117(3): 389-393.

51. Li, W., X. Liu, A. Hanada and M.A. Khan, 2011. Effect of cold Stratification, Scarification and Hormones on Germination of Dimorphic Seeds of (*Atriplex centralasiatica)*under saline conditions. Seed Sci. & Technol., 39: 82-92.
52. Nicole, L., C.A. Waterland, J. Campbell, J. Finer and M.L. Jones, 2010. Abscisic Acid Application Enhances Drought Stress Tolerance in Bedding Plants. Hort. Sci., 45(3): 409-413.
53. Wang, Z. and B. Huang, 2003. Genotypic Varation in Abscisic acid Accumulation, Water relation and Gas Exchange for Kentucky Bluegrss Exposed to Drought Stress. J. Amer. Soc. Hort. Sci., 128(3): 349-355.