Effects of Some Exogenous Applications on Some Agricultural Crops under Salt Stress

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***Abstract*—**All biotic and abiotic factors, that prevent the plant growth are called stress. As a result of global climate change, the importance of abiotic stress factors have been increasing year by year. Salinity, which is one of the most significant abiotic stress factors, causes some molecular, cellular, physiological and morphological alterations on plants. It reduces yield and the quality of plant production, especially in several semi arid and arid regions of the earth. Therefore, agricultural sustainability and constant food production will be able to overcome the salt stress.

In nature, plants develop some adaptation methods against salinity and based on the subject matter, some tolerance strategies have been developed to overcome salt stress. Exogenous proline, glycinebetaine, paclobutrazol, triacontanol selenium, silicone, salicylic acid, plant activators and nitrogen applications were investigated through studies conducted on some agricultural crops such as various tomato, cucurbita, mung bean, rice, wheat, tobacco and sorghum genotypes. These applications enhance the tolerance of plants against salt stress and promote the plant growth and yield.

***Keywords*—** Agricultural crops, exogenous applications, salinity.

I. Introduction

PLANTS encounter numerous types of biotic and abiotic stresses through their life cycles [1]. Various types of abiotic stress factors such as salinity, drought, extreme temperatures, flooding, metal toxicity, ultraviolet radiation, elevated ozone [1] and chilling, which are harmful for plant growth, might cause a reduction on agricultural productivity [2]. Salinity, which could be increased by over fertilizer application [3], low rainfall grade, saline irrigation water, native rock, strong evaporation and poor water management, is one of the most serious abiotic stress factors [4], [5]. Salinity stress, which usually occurs in arid and semi arid regions affects plant growth and agricultural productivity severely, throughout the world [3], [4], [5], [6]. It is estimated that, approximately 20% of the agricultural land is affected by salt [1], [7] and in every minute, almost 3 hectares of arable land is lost due to salinity, all over the world [5]. .

II. Effects of Salt Stress

The growth and the yields of various plants are reduced by water deficiency due to low water potential of soil, ion toxicity associated with the excessive ion uptake, ion and also nutritional imbalance [3], [7] due to the accumulation of the sodium ions [8] and the reduced nutrient uptake and transferred to the shoots, respectively [4], [5]. Plants hardly absorb needed water for growth when the water content of soil is decreased by excessive salt concentration [6], [7]. Various morphological, cellular, physiological and molecular changes take place depending on not only the genotypes and the development stage of the plant, but also the intensity and duration of the salt stress [9], [10]. As a result of salinity, hyperionic and hyperosmotic stresses, which may cause decreased germination rate [11], membrane damage, nutrient imbalance, altered levels of growth regulators, enzymatic inhibition [1] and some metabolic disorders involved lipid metabolisms, photosynthesis, protein synthesis and senescence occur on plants [12].

III. Some Exogenous Practices Against Salt Stress

Plants develop some defense strategies such as osmotic adjustment using potassium, soluble sugar, proline and glycinebetaine [3], [11], [13], inducing some plant growth regulators, increasing antioxidant enzyme activities, changing way of the photosynthesis [12], activating stress related genes and production of stress proteins to overcome salinity [9].

However, soil salinity intensely influences the global food production, improved irrigation techniques and reclamation of the salt affected soils are not only prohibitively expensive, but also provide short term solutions [4], [5]. Moreover, conventional breeding methods, used, to improve salt tolerant plants, are also laborious and time consuming [14].

Due to these facts, researchers are trying to develop some effective treatments such as exogenous proline [15], [16,] [17], glycine betaine [14], paclobutrazol [7], triacontanol [18], selenium, silicone [19], salicylic acid [1], plant activator [20] and nitrogen [21] applications to reduce the detrimental effects of salinity.

Proline, which accumulates under salt stress conditions, is an important organic compound [15], [17]. It is a key component which may act as a osmoprotectant to maintain membrane stability and detoxification enzymes in plants, exposed to salt stress [11], [13], [17]. Exogenous proline application has been reported to be protective against salt induced oxidative stress [15], [17]. Reactive oxygen species (ROS), such as superoxid radicals, singlet oxygen, hydroxyl radicals and hydrogen peroxide, which induce lipid peroxydation responsible to membrane deterioration, are enhanced in plants under high salt concentration [3].

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Antioxidant enzymes protect plant cells against reactive oxygen species [3]. It was reported that, the antioxidant enzyme's activities were induced severely in exogenous proline treated pumpkin plants [17]. The effects of exogenous proline application have been investigated through different species of agricultural crops, such as tomato [14], rice [16] , mung bean [22], olive[23] and canola [24] under salinity. The results of these investigations reported that the exogenous proline application efficiently regulated the osmotic potential and decreased the toxic effect of salinity by activating the antioxidant enzyme system.

Accumulation of compatible organic solutes is one of the cellular adaptive responses, which might be induced by environmental stress, including water deficit, salinity and low temperatures [25]. Glycinebetaine is an important organic metabolite that accumulates in various plants in response to salinity [25]. This compound plays an important role in membrane stabilization and reducing oxidative stress as an oxygen radical scavenger under salinity stress [14], [26]. Besides, it may also act as an enzyme protectant and stabilizing factor of the structure of macromolecules and organelles [27]. Exogenous glycinebetaine application on *Vicia faba* under salt stress reduced membrane injury, improved K^+ uptake and growth and also increased the chlorophyll contents [27]. Similar results have been obtained in *Prosopis ruscifolia* [25] under salt stress. Positive effects of exogenous application of glycinebetaine were also observed in wheat [28] and maize plants [29]. Glycinebetaine enhanced salt tolerance of perennial ryegrass via induced antioxidant enzyme activity has improved ion homeostasis and reduced oxidation of membrane lipid [30]. Although Na^+ and Cl^- accumulations were decreased by exogenous application of glycinebetaine on tomato plants, it was not possible to prevent the effects of salt stress in salt sensitive tomato genotypes [14]. On the contrary, it was reported that the development of the embryos of tomato plants were positively affected by glycinebetaine application [31].

Paclobutrozol is a triozole compound, which is used as a plant growth regulator in both agriculture and horticulture. Triozoles which have been referred to a plant multiprotectant, protects plants againts various stress [7]. Paclobutrozol, that increased the antioxidant enzyme content of plants, protects them against environmental stress [32]. It was reported that the paclobutrozol is a potential compound to increase salt tolerance in a wheat cultivar due to moderating the negative effect of salt stress on some growth parameters [7]. It was reported that the negative effects of salt stress were prevented by paclobutrozol application in barley seedlings [32].

Triacontanol, which is a natural component of epicuticular waxes, is a plant growth regulator [33]. Vegetative growth, chlorophyll content, dry weight [34], yield, photosynthesis, protein synthesis, uptake of nutrient and water, nitrogen fixation, enzyme activities and the content of free amino acids of various plants were enhanced by tricontanol application [33]. It was reported that total chlorophyll content, total soluble sugars and proteins and also ascorbate peroxidase, which is an antioxidant enzyme, were increased in *Arachis hypogaea* depending on the concentration of triacontanol [35]. Triacontanol pretreatment positively affected to germination rates, radicle elongation and the fresh weight of barley under saline conditions [18].

The role of silicon, the second most abundant element on the earth, has been poorly understood in plant biology [36] ,[37].However, it is one of the most important elements, plays a critical role in tolerance against some environmental stress including drought [37] and salt stress [36], [38] on plants. Similar to proline, silicone promotes the antioxidative defense mechanisms and reduces the lipid peroxydation under drought [37], salinity [36] and chilling [39] stresses. Antioxidant enzyme activities are enhanced by exogenous silicon application in barley [38] and cucumber [36] under salt stress.

Selenium, which is also an essential microelement for animals, positively affects growth and development of some plants by enhancing the activities of antioxidant enzyme [40]. The growth rate, photosynthetic pigment and proline content of cucumber were increased by exogenous selenium treatment under salt stress. This application have protected the cell membrane and enhanced the salt tolerance of the cucumber [41]. Similar results were obtained in salt stressed tomato plants. The growth and the photosynthesis of tomato seedlings were induced by selenium application under salt stress condition [40]. Although both silicon and selenium applications reduced the toxic effects of salinity on various tomato genoytpes, silicone is more effective for improving salt tolerance [19].

Salicylic acid, which is a chemical messenger, plays an important role in salt tolerance [42]. Various processes such as seed germination, ion uptake and transport, membrane permeability, photosynthesis ant plant growth are effected by exogenous application of salicylic acid [42] Exogenous application of salicylic acid is an effective protectant in salt stress tolerance of various *Brassica* genotypes. It enhances the endogenous antioxidant levels in *Brassica juncea* [43] and *Brassica napus* [1]. Salicylic acid also induced salt tolerance of *Artemisia annua* L. and promoted the growth and the activity of antioxidant enzymes of the plant under different levels of NaCl [42].

Plant activators are the chemical compounds that have some protective effects against the plant pathogens and they induce disease resistance [20]. Salt stress induce the severity of disease caused by some pathogens in tomato plant. Some commercial plant activators such as actigard and tiadinil induced the bacterial resistance of tomato under salt stress [20]. It was reported that a plant activator called as Stubble-Aid could enhance the tolerance of tomato plant against salinity. Exogenous application of this plant activator prevented the reduction of leaf relative water concent, chlorophyll fluorescence, stomatal conductance and total soluble protein under salt stress [44].

Nitrogen fertilizers, that enhance number of leaves, plant length, dry and fresh weight of seedling, could increase crop yield [45] such as wheat, corn [46], cotton and rice [47]. The application of nitrogen fertilizers, which plays a critical role in cell division, decrease the adverse effects caused by high salt stress [45]. Negative effects of salinity were reduced by exogenous nitrogen application as a foliar spray on the wheat plant. Nitrogen, which is one of the best nutrient to control salinity, increased the plant growth of wheat [45]. It was reported that the nitrogen application (1%) played a crucial role in protection against salt stress and enhanced the salinity tolerance of tomato plants via antioxidant enzyme activities [21].

Consequently, these exogenous applications play an important role to develop salt tolerance in various plants.

REFERENCES

[1] M. Hasanuzzaman, M. M.Alam, K. Nahar, J. Al-Mahmud, K. U. Ahamed and M. Fujita, "Exogenous salicylic acid alleviates salt stress-induced oxidative damage in *Brassica napus* by enhancing the antioxidant defense and glyoxalase systems", Australian Journal of Crop Science, vol 8(4), pp. 631-639, 2014a

[2] M. Hasanuzzaman , K. Nahar , M.M. Alam and M. Fujita , "Modulation of antioxidant machinery and the methylglyoxal detoxification system in selenium-supplemented *Brassica napus* seedlings confers tolerance to high temperature stress", Biol Trace Elem Res,vol 161, pp. 297–307, 2014b http://dx.doi.org/10.1007/s12011-014-0120-7

[3] Y. Huang, Z. Bie, S. He, B. Hua ,A. Zhen and Z. Liu, "Improving cucumber tolerance to major nutrients induced salinity by grafting onto *Cucurbita ficifolia*", Environmental and Experimental Botany, vol 69, pp. 32–38, 2010
http://dx.doi.org/10.1016/j.envexpbot.2010.02.002

[4] H. Yetişir and V. Uygur, "Plant growth and mineral element content of different gourd species and watermelon under salinity stres", Turk J Agric For, vol 33, pp. 65-77, 2009

[5] A. Arzani, "Improving salinity tolerance in crop plants: a biotechnological view", In Vitro Cell.Dev.Biol.-Plant, vol 44, pp.373–383, 2008 http://dx.doi.org/10.1007/s11627-008-9157-7

[6] R. Kurum , K. Ulukapı ,K. Aydınşakir and A.N. Onus, "The influence of salinity on seedling growth of some pumpkin varieties used as rootstock", Not Bot Horti Agrobo,vol 41(1), pp. 219-225, 2013

[7] S. Hajihashemi , K. Kiarostami, S Enteshari and A Saboora "Effect of paclobutrazol on wheat salt tolerance at pollination stage", Russian Journal of Plant Physiology, vol 56 (2), pp. 251–257, 2009
http://dx.doi.org/10.1134/S1021443709020149

[8] Ö. Çelik and S. G. Ünsal, "Expression analysis of proline metabolism-related genes in salt-tolerant soybean mutant plants", Plants Omic Journal, vol 6 (5), pp. 364-370, 2013

[9] E. Yılmaz, A.L. Tuna and B. Bürün "Tolerance strategies developed by plants to the effects of salt stres" C.B.U Journal of Science, vol 7.1, pp. 47-66, 2011

[10] Ş. Çulha and H. Çakırlar ,"The effect of salinity on plants and salt tolerance mechanisms", A.K.U. J. Sci, vol 11, pp.11-34 , 2011

[11] M. A. Turan, A. H. A. Elkarim, N. Taban, S. Taban, "Effect of salt stress on growth, stomatal resistance, proline and chlorophyll concentrations on maize plant", African Journal of Agricultural Research, vol 4 (9), pp. 893-897, 2009

[12] Ö. Çelik and Ç. Atak "The effect of salt stress on antioxidative enzymes and proline content of two Turkish tobacco varieties", Turk J Biol, vol 36,pp. 339-356, 2012.

[13] H. Benhassaini, A. Fetati, A. K. Hocine, and M. Belkhodja "Effect of salt stress on growth and accumulation of proline and soluble sugars on plantlets of *Pistacia atlantica* Desf. subsp. atlantica used as rootstocks", Biotechnol. Agron. Soc. Environ, vol 16(2),pp. 159-165, 2102

[14] B. Heuer, "Influence of exogenous application of proline and glycinebetain on growth of salt- stressed tomato plants", Plant Science. vol 165,pp. 693-699, 2003
http://dx.doi.org/10.1016/S0168-9452(03)00222-X

[15] A. H. A. Khedr, M. A. Abbas, A. A. A. Wahid, W. P. Quick, and G. M. Abogadallah, "Proline induces the expression of salt-stress-responsive proteins and may improve the adaptation of *Pancratium maritimum* L. to salt-stress" Journal of Experimental Botany, vol 54 (392),pp.2553-2562, 2003
http://dx.doi.org/10.1093/jxb/erg277

[16] S. Deivanai, R. Xavier, V. Vinod, K. Timalata, O. F. Lim "Role of exogenous proline in ameliorating salt stress at early stage in two rice cultivars", Journal of Stress Physiology and Biochemistry, vol 7 (4), pp. 157-174, 2011

[17] R. Bayat, Ş. Kuşvuran, Ş. Ellialtıoğlu and A. S. Üstün, "Effects of proline application on antioxidative enzymes activities in the young pumpkin plants (*Cucurbita pepo* L. and *C. moschata* Poir.) under Salt Stress" Turkish Journal of Agricultural and Natural Sciences, vol 1(1), pp.25-33, 2014

[18] K. Çavuşoğlu, S. Kılıç and K. Kabar, "Effects of triacontanol pretreatment on seed germination, seedling growth and leaf anatomy under saline (NaCl) conditions", S.D.Ü Fen Edebiyat Fakültesi Fen Dergisi, vol 2(2), pp.136.145, 2007

[19] S. Avcu, Y. Akhoundnejad and H. Y. Daşgan, "Effects on selenium and silicon applications on salt-stressed tomato" Tarım Bilimleri Araştırma Dergisi, vol 6(1), pp. 183-188, 2013

[20] M. F. Pye, F. Hakuna, J. D. MacDonald and R. M. Bostock, "Induced resistance in tomato by SAR activators during predisposing salinity stress." , Front Plant Sci, vol 4: 116, 2013
http://dx.doi.org/10.3389/fpls.2013.00116

[21] M Doğan, "The affect of nitrogen application on salt stress and antioxidant enzyme activities" Süleyman Demirel Üniversitesi Fen Bilimleri Enstitüsü Dergisi, vol 16 (3), pp. 297-306, 2012

[22] M. A. Hossain and M. Fujita, "Evidence for a role of exogenous glycinebetaine and proline in antioxidant defense and methylglyoxal detoxification systems in mung bean seedlings under salt stress", Physiology and Molecular Biology of Plants, vol 16 (1), pp. 19-29, 2010
http://dx.doi.org/10.1007/s12298-010-0003-0

[23] C. B. Ahmed, B. B. Rouina, S. Sensoy, M. Boukhriss and F. B. Abdullah, "Exogenous proline effects on photosynthetic performance and antioxidant defense system of young olive tree" Journal of Agricultural and Food Chemistry,vol 58 (7),pp. 4216–4222, 2010
http://dx.doi.org/10.1021/jf9041479

[24] H. Athar, M. Ashraf, A. Wahid and A Jamil, "Inducing salt tolerance in canola (*Brassica napus* L.) by exogenous application of glycinebetaine and proline: response at the initial growth stages", Pak. J. Bot , vol 41(3), pp. 1311-1319, 2009

[25] D.A. Meloni and C.A. Martinez, "Glycinebetaine improves salt tolerance in vinal (*Prosopis ruscifolia* Grieshbach) seedlings", Brazilian Society of Plant Physiology, vol 21(3), pp.233-241, 2009

[26] T. Demiral and I. Turkan, "Exogenous glycinebetaine affects growth and prolin accumulation and retards senescence in two rice cultivars under NaCl stress", Environ. Exp. Bot, vol 36, pp. 29-38, 2006

[27] M. A. A. Gadallah, "Effects of proline and glycinebetaine on *Vicia faba* responses to salt stress", Biologia Plantarum, vol 42 (2), pp.249-257, 1999
http://dx.doi.org/10.1023/A:1002164719609

[28] S. H. Raza, H. R. Athar, M. Ashraf and A. Hameed, "Glycinebetaine induced modulation of antioxidant enzymes activities and ion accumulation in two wheat cultivars differing in salt tolerance", Environ.Exp. Bot, vol 60, pp. 368–376, 2007
http://dx.doi.org/10.1016/j.envexpbot.2006.12.009

[29] X. Yang and C. Lu, "Photosynthesis is improved by exogenous glycinebetaine in salt-stressed maize plants", Physiol. Plant, vol 124, pp. 343–352, 2005
http://dx.doi.org/10.1111/j.1399-3054.2005.00518.x

[30] L. Hu, T. Hu, X. Zhang, H. Pang and J. Fu, "Exogenous glycinebetaine ameliorates the adverse effect of salt stress on perennial ryegrass", J. Amer. Soc. Hort. Sci, vol 137(1), pp.38–46, 2012

[31] R. Tıpırdamaz and Ş. Karakullukçu, "Prolin ve glisinbetain'in, tuzlu koşullarda kültüre alınmış domates embriyolarının gelişmesi ve bazı içsel madde değimleri üzerine etkileri", Doğa-Tr.J of Botany,vol 17, pp. 57-64, 1993

[32] A. D. Özmen, F. Özdemir and I. Türkan, "Effects of paclobutrozol on response of two barley cultivars to salt stress", Biologia Plantarum, vol 46 (2),pp.263-268, 2003
http://dx.doi.org/10.1023/A:1022862929881

[33] M. Naeem, M. A. A. Khan and Moinuddin, "Triacontanol: a potent plant growth regulator in agriculture", Journal of Plant Interactions, 7(2). 129-142, 2012
http://dx.doi.org/10.1080/17429145.2011.619281

[34] S. K. Ries, "Regulation of plant growth with triacontanol" Critical Rev Plant Sci, vol 2, pp. 239-285, 1985
http://dx.doi.org/10.1080/07352688509382197

[35] A. Verma, C. P. Malik, V. K. Gupta and B. K. Bajaj, "Effects of in vitro triacontanol on growth, antioxidant enzymes, and photosynthetic

characteristics in *Arachis hypogaea* L." Braz. J. Plant Physiol., vol 23(4), pp.271-277, 2011
http://dx.doi.org/10.1590/s1677-04202011000400004

[36] Z. Zhu, G. Wei, J. Li, Q. Qian and J. Yu, "Silicon alleviates salt stress and increases antioxidant enzymes activity in leaves of salt-stressed cucumber (*Cucumis sativus* L.)", Plant Science, vol 167, pp. 527-533, 2004
http://dx.doi.org/10.1016/j.plantsci.2004.04.020

[37] H. Gong, X. Zhu, K. Chen, S. Wang and C. Zhang, "Silicon alleviates oxidative damage of wheat plants in pots under drought", Plant Science, vol 169, pp.313-321, 2005
http://dx.doi.org/10.1016/j.plantsci.2005.02.023

[38] Y. Liang, Q. Chen, Q. Liu, W. Zhang and R. Ding, "Exogenous silicon (Si) increases antioxidant enzyme activity and reduces lipid peroxidationin roots of salt-stressed barley (*Hordeum vulgare* L.)", J. Plant Physiol, vol 160, pp. 1157–1164, 2003
http://dx.doi.org/10.1078/0176-1617-01065

[39] Y. Liang, J. Zhu, Z. Li, G. Chu, Y. Ding, J. Zhang and W. Sun, "Role of silicon in enhancing resistance to freezing stress in two contrasting winter wheat cultivars", Experimental and Environmerntal Botany, vol 64 (3), pp. 286-294, 2008
http://dx.doi.org/10.1016/j.envexpbot.2008.06.005

[40] M. Diao, L. Ma, J. Wang, J. Cui, A. Fu and H. Liu, "Selenium promotes the growth and photosynthesis of tomato seedlings under salt stress by enhancing chloroplast antioxidant defense system", J Plant Growth Regul,vol 33, pp. 671–682, 2014
http://dx.doi.org/10.1007/s00344-014-9416-2

[41] B. H. Nowak, "Beneficial effects of exogenous selenium in cucumber seedlings subjected to salt stress", Biol-Trace Elem Res. , vol 132 (1-3), pp. 259-269, 2009
http://dx.doi.org/10.1007/s12011-009-8402-1

[42] T. Aftab, M. Masroor, A. Khan, A. Jaime, T. Silva, M Idrees, M. Naeem and Moinuddin, "Role of salicylic acid in promoting salt stress tolerance and enhanced artemisinin production in *Artemisia annua* L.", J Plant Growth Regul,vol 30, pp. 425–435, 2011
http://dx.doi.org/10.1007/s00344-011-9205-0

[43] S. Syeed, N.A. Anjum, R. Nazar, N. Iqbal, A. Masood and N.A. Khan, "Salicylic acid-mediated changes in photosynthesis, nutrients content and antioxidant metabolism in two mustard (*Brassica juncea* L.) cultivars differing in salt tolerance", Acta Physiol Plant, vol 33, pp. 877–886, 2011
http://dx.doi.org/10.1007/s11738-010-0614-7

[44] A. H. Sekmen, T. Demiral, N. Tosun, H. Türküsay and İ. Türkan, "Effect of the plant activator on some physiological characteristics and total protein content of tomato plants under salt stress", Ege Üniv. Ziraat Fak. Derg, vol 42(1), pp.85-95, 2005

[45] A. Khan, Z. Shaheen and M. Nawaz, "Amelioration of salt stress in wheat (*Triticum aestivum* L.) by foliar applivcation of nitrogen and potassium", Sci. Tech and Dev, vol 32(2), pp. 85-98, 2013

[46] M. S. Soliman, H.G. Shalabi and W.F. Campbell, "Interaction of salinity, nitrogen and phosphorous fertilization on wheat"., J Plant Nutr, vol 17, pp. 1163–1173 , 1994
http://dx.doi.org/10.1080/01904169409364796

[47] S.R. Grattan and C.M. Grieve, "Mineral nutrient acquisition and response by plants grown in saline environments", In: Pessarakli M. (ed.): Handbook of Plant and Crop Stress. Marcel Dekker, New York, pp. 203–229. 1999.