MedCrave Step into the World of Research

Horticulture International Journal

Research Article

Open Access

In vitro saline sodic status of *Camelina sativa* cv. Blaine creek

Abstract

The capability of *Camelina sativa* to survive salinity and sodicity stress *invitro* by developing saline sodic soils (<4dSm^{-1}+12.9 (mmolL^{-1})$^{1/2}$, 4.5 dSm^{-1}+20 (mmolL^{-1})$^{1/2}$, 9.0 dSm^{-1}+20 (mmolL^{-1})$^{1/2}$, 13.5 dSm^{-1}+20 (mmolL^{-1})$^{1/2}$, 4.5 dSm^{-1}+30 (mmolL^{-1})$^{1/2}$, 9.0 dSm^{-1}+30 (mmolL^{-1})$^{1/2}$, 13.5 dSm^{-1}+30 (mmolL^{-1})$^{1/2}$, 4.5 dSm^{-1}+40 (mmolL^{-1})$^{1/2}$, 9.0 dSm^{-1}+40 (mmolL^{-1})$^{1/2}$ and 13.5 dSm^{-1}+40 (mmolL^{-1})$^{1/2}$ at green house of Land Resources Research Institute, National Agricultural Research Centre, Islamabad, Pakistan was conducted during, 2016. Saline sodic status of the plants was deliberated with various growth and yield parameters at maturity. Completely randomized deign was applied with three repeats. % decrease over control in plant height showed positive behaviour with increased saline sodic conditions. 57% decrease over control in plant height was gained by the highest saline sodic treatment. However, the highest% decrease over control in # of branches plant^{-1}(67) of this plant was found with the highest saline sodic treatment. Reduction in number of branches plant^{-1}was increased as well as saline sodic level increased. Further, % decrease over control in grain yield was increased by increasing the intensiveness of salinity and sodicity.

Keywords: *camelina* seedlings, electrical conductivity, sodium absorption ratio, salt tolerance

Volume 2 Issue 4 - 2018

Muhammad Arshad Ullah,[1] Imdad Ali Mahmood,[1] Badar uz Zaman,[1] Syed Ishtiaq Hyder,[1] Arshad Mahmood,[2] Raheel Baber[1]

[1]National Agricultural Research Centre, Pakistan

[2]Department of Economics, University of Arid Agriculture, Pakistan

Correspondence: Muhammad Arshad Ullah, National Agricultural Research centre, Islamabad, Pakistan, Email arshadullah1965@gmail.com

Received: July 13, 2018 | **Published:** July 31, 2018

Introduction

Salinity causes the disruption of the homeostatic balance of water potential and ion distribution in plants resulting in decreased availability of water to root cells and the plants tend to accumulate high concentrations of Na^+ and Cl^- in their vacuoles to protect their cytoplasmic water potential and metabolic imbalances. These metabolic imbalances cause oxidative stress[1] and increased production of reactive oxygen species (ROS) – hydrogen peroxide (H_2O_2), hydroxyl radical (OH), and superoxide ions.[2] Scavenging of ROS in plant cells occurs by an endogenous protective mechanism involving antioxidant molecules and enzymes.[3,4] On the other hand, it is well known that current world population of 7.6 billion is expected to reach 8.6 billion in 2030, 9.8 billion in 2050 and 11.2 billion in 2100, according to a new United Nations report being launched today.[5] The world economy grew by 2.6 percent a year to almost double in size between 1990 and 2014. During that period, global economic growth was driven mainly by low-income and middle-income countries, whose gross domestic product (GDP) grew by some 5.1 percent annually. China's GDP grew at double that rate, by more than 10 percent year, and in 2014 the country accounted for 9 percent of global GDP, compared to just 2 percent in 1990.[6] Salinity is one of the most severe environmental factors limiting the productivity of agricultural crops, because most crops are sensitive to salinity induced by high concentrations of salts in the soil.[7] This brief presentation of data suggests that salt tolerant plants should be taken into consideration, since they could play an important role in biosaline agriculture.[8] It also reduces photosynthetic activity by destruction of green pigments, lowering leaf area or by decreasing the activity of photosynthetic enzymes. Further, salinity affects the cell membranes and causes lipid peroxidation leading to higher accumulation of malondialdehyde (MDA).[9] Soil salinity presents a notable challenge to agriculture, which may be a consequence of human activities, such as irrigation, or alterations in rainfall patterns that reduce leaching of salts and minerals from soils. Lands that were once highly fertile have become less productive due to increased salt levels.[10] Furthermore, increasing pressure to use marginal lands for farming often means that growers struggle with naturally-occurring high levels of salt.[11] The effect of salt on plant growth and productivity is dependent on salt type, concentration, sensitivity of the crop, and the capacity of the plants to tolerate or mitigate the effects of salts alone or in combination.[12] For example, exposure to salt alters differentiation of the Casparian strip causing it to be unusually close to the root meristem[13] which changes root architecture[14] and the root gravitrophic response, halotropism.[15] In addition, cell cycle inhibition as a result of salt stress causes cells in the meristem to stop dividing; cells elongate at the root tip, but do not divide[16] and root size is reduced.[17] The interest in the study of halophytes is still argued by theoretical reasons, and especially by the current context of human condition, regarded as a well-defined part of surrounding environment. Salinity has affected agriculture from millennia, having a deeply negative impact in agriculture and most likely, being involved in the fall of some ancient flourishing civilizations.[8] Of the cultivated lands, about 340 million ha (23%) are saline (salt affected) and another 560 million ha (37%) are sodic (sodium-affected).[18] Here are many different projections, suggesting that human population will increase over 8 billion by the year 2020 that will worsen the current scenario about food insecurity.[19] There are often not sufficient reservoirs of freshwater available and most of the agronomical used irrigation systems are leading to a permanent increase in soil-salinity and slowly to growth conditions unacceptable for most of the common crops.[20] Moreover, salinity causes an increase in the concentration of some leaf osmolites such as proline, betaine and free and bound polyamines.[21] A previous study carried out by our group[22] on a high oleic sunflower hybrid showed the oleic acid content to increase and the linoleic acid content to decrease with salinity increase.

Camelina sativa (*camelina*, false flax or gold of pleasure) is a close relative of the model plant *Arabidopsis thaliana* (Arabidopsis) and the oilseed Brassica crops. *Camelina* was cultivated in Europe as an oilseed crop for food and fuel before being displaced by higher-yielding crops, such as oilseed rape/canola (*Brassica napus*) and wheat. The *C. sativa* genome was suggested to have arisen from a genome triplication event,[23] a supposition supported by genome sequencing.[24] However, the evolutionary origin of the ancestral genomes and the polyploidization and post-polyploidization events that led to diploidization are not fully understood.[24] There is little evidence of fractionation bias in the *C. sativa* genome and the highly undifferentiated polyploid genome presents significant challenges for breeding and genetic manipulation.[24–26] Efforts to diversify annual crop rotation portfolios renewed interest in this ancient crop as it can be grown on marginal lands that are not well-suited for food crops and has the potential to be a low cost, high value oil and meal bio-feedstock.[27–29] It has enhanced drought, some degree of salinity and cold tolerance, displays early maturation, and requires fewer inputs compared to other oilseeds.[30–32] It is also naturally resistant to diseases that afflict canola, such as blackspot,[33] blackleg,[34] and stem rot,[35] as well as insect pests, such as the flea beetle and diamondback moth.[36–38] Keeping in view the above facts an invitro experiment was planned to investigate the salt tolerance of *camelina sativa* plants under different concentrations of salinity and sodicity.

Materials and methods

A pot study was conducted to evaluate the growth and yield of *camelina sativa* under different artificial developed saline- sodic soils at green house of Land Resources Research Institute, National Agricultural Research Centre, Islamabad, Pakistan during, 2016. The soil used for the pot experiment was analysed and having 8.01pH_s, 2.02ECe (dSm^{-1}), 6.75SAR ($(mmolL^{-1})^{1/2}$), 27.98 Saturation Percentage (%), 0.46O.M. (%), 7.86 Available P($mgKg^{-1}$) and 99.98 Extractable K ($mgKg^{-1}$). Considering the pre- sowing soil analysis the ECe (Electrical conductivity) and SAR (Sodium Absorption Ratio) was artificially developed with salts of NaCl, Na_2 SO_4, $CaCl_2$ and $MgSO_4$ using Quadratic Equation.8 Kg soil was used to fill each pot. 8 seeds of *camelina sativa* were sown in each pot. Fertilizer was applied @75-60-50NPKKgha^{-1}. Treatments were as $T_{1=}$<4 dSm^{-1}+12.9 $(mmolL^{-1})^{1/2}$, $T_{2=}$ 4.5dSm^{-1}+20 $(mmolL^{-1})^{1/2}$, $T_{3=}$ 9.0 dSm^{-1}+20 $(mmolL^{-1})^{1/2}$, $T_{4=}$13.5dSm^{-1}+20 $(mmolL^{-1})^{1/2}$ $T_{5=}$ 4.5 dSm^{-1}+30 $(mmolL^{-1})^{1/2}$, $T_{6=}$ 9.0 dSm^{-1}+30 $(mmolL^{-1})^{1/2}$, $T_{7=}$ 13.5 dSm^{-1}+30 $(mmolL^{-1})^{1/2}$, $T_{8=}$ 4.5 dSm^{-1}+40 $(mmolL^{-1})^{1/2}$, $T_{9=}$ 9.0 dSm^{-1}+40 $(mmolL^{-1})^{1/2}$ and $T_{10=}$ 13.5 dSm^{-1}+40 $(mmolL^{-1})^{1/2}$. Completely randomized deign was applied with three repeats. Post- harvest soil analysis was done. The data obtained were subjected to statistical analysis using the STATISTIX statistical software (Version 8.1) and the mean values were compared using least significant difference (LSD).[39]

Results and discussion

Salinity and sodicity disturbs the growth as well as yield. The reduction in growth parameters of *Camelina sativa* was increased as well as the saline sodic level was increased. In other words reduction in growth of *camellia sativa* is directly proportional to the combine effect of salinity and sodicity. Significant differences were indicated among treatments regarding plant height (Table 1). The highest plant height (58.50cm) was attained by the T_1 having the lowest ECe and SAR. Lowest plant height (25.1cm) was produced in T_{10}. % decrease over control in plant height showed positive behaviour with increased saline sodic conditions. 57% decrease over control in plant height was gained by T_{10}. # of branches plant^{-1} is the important growth parameter under saline sodic environment. Statistically significant results were produced in # of branches plant^{-1} as mentioned in Table 1. T_1 produced the maximum number of branches plant^{-1}(10.8) while the lowest figure (3.6) was attained in the highest saline sodic severity as depicted by $T_{10.}$ % decrease over control in # of branches plant^{-1} varied from 17 to 67 in different treatments. However, the highest% decrease over control in # of branches plant^{-1}(67) of this plant was found with T_{10}. Reduction in number of branches plant^{-1}was increased as well as saline sodic level increased. Many physiological processes of plants like seed germination, seedling growth, flowering, and fruit set are adversely affected by high salt concentrations. In particular, salinity delays germination, reduces the shoot growth as expressed by reduced leaf area, and affects many physiological processes like electrical conductivity (EC) and relative water content (RWC).[40,41] Sunflower plants grown under saline stress show worsening leaf water status.[42] This means that salinity disturbs the plant growth affecting important physiological processes in plants. Yield is the final product of every plant or crop. The performance of better growth under saline sodic environment hopes for the survival of this plant to provide some yield to utilize such soils for the betterment of salt- affected communities. Data of grain yield presented in Table 1 showed significant differences among treatments. Decreasing trend in yield was observed as well as the salinity and sodicity increased. Further, % decrease over control in grain yield was increased by increasing the intensiveness of salinity and sodicity. However, the differences among treatments was huge i.e. 25 to76%. This variation in percentage decrease in yield was understood the worse influence of saline sodic environment. Similar behaviour was also depicted in straw yield as indicated in Table 1.

Each unit increase in ECe above 4.8dSm^{-1} was found to reduce yield by 5 by 4.5% according to Flagella et al.[22] Yield reduction was attributed mainly to a decrease in achene per head and in the 1000 achene weight,[22] Katerji et al.,[43] also classified sunflower as a tolerant crop based on the estimation of the crop water stress index. Salinity inhibits plant growth and development by reducing water availability, similar to drought, and via ion toxicity.[44] Salt stress affects many cellular processes, including gene expression, protein synthesis, carbohydrate and lipid metabolism, osmotic and pH homeostasis[45] and limits plant growth by impairing photosynthesis, metabolic processes and nutrient acquisition[46,47] While species and even genotypes may respond differently to stress, many stresses share the same set of general responses.[48] Since *camelina* is somewhat resistant to drought, some degree of salinity resistance is to be expected. Indeed, the ability to avoid drought by developing deep root systems or making metabolic adjustments[49] is a common feature of both drought and salt tolerance. Typically, salt affects root elongation Potters et al.,[50] Bernstein et al.,[51] and root architecture by reducing cell size and cell division and altering differentiation patterns. Pre and post harvest soil analysis i.e. pH, ECe and SAR presented in Table 2. Minute differences were found among treatments. Soil ECe reduction showed the salt tolerance of *camelina sativa* plant. Better salt tolerance in case of ECe was depicted in T_3 (4.5dSm^{-1}), T_5 (9.0dSm^{-1}) and T_7 (13.5dSm^{-1}) due to utilization of more salts than other treatments. Regarding SAR, treatments T_2 [20 $(mmolL^{-1})^{1/2}$], T_4 [30 $(mmolL^{-1})^{1/2}$] and T_9 [40 $(mmolL^{-1})^{1/2}$] showed better salt tolerance than other treatments.

Table1 Effect of different combinations of salinity/sodicity on growth and yield per pot of *Camelina sativa*

Treatment	Plant height(cm)	% decrease over control	# of branches plant^{-1}	% decrease over control	Grain yield (g)	% decrease over control	Straw yield (g)	% decrease over control
T_1	58.5a	---	10.8a	------	4.12a	-------	6.30a	--------
T_2	55.8 a	5	9.0b	17	3.08ab	25	5.45b	13
T_3	49.5ab	15	8.4bc	22	2.92c	29	4.44bc	30
T_4	45.0c	23	8.1 bc	25	2.30de	44	4.25cd	33
T_5	42.7cd	27	7.8bc	28	2.46d	48	3.80d	40
T_6	39.5d	32	7.2cd	33	2.06e	50	3.51de	44
T_7	37.8de	35	6.3de	40	1. 90e	53	2.60ef	59
T_8	31.6f	46	5.4ef	50	1. 30f	68	2.20fg	65
T_9	27.9fg	52	4.5fg	58	1.15g	72	1.93g	69
T_{10}	25.1g	57	3.6g	67	0.98g	76	1.61g	76
LSD	4.4	-----	1.2	-------	0.41	---------	0.53	-------

Table 2 Pre and post- harvest of soil analysis of pots of *Camelina sativa* plants

Treatments	pHs		Soil ECe (dSm^{-1})		Soil SAR(mmol L^{-1})$^{1/2}$	
	Pre-Harvest	Post- Harvest	Pre- Harvest	Post- Harvest	Pre- Harvest	Post- Harvest
T_1	8.01	8.03	<4 dSm^{-1}	2.29	12.9	7.18
T_2	8.01	8.13	4.5	3.9	20	18
T_3	8.01	8.22	9	7.79	20	18.52
T_4	8.01	8.35	13.5	11.52	20	18.64
T_5	8.01	8.37	4.5	3.79	30	27.77
T_6	8.01	8.49	9	7.85	30	28.55
T_7	8.01	8.4	13.5	11.28	30	28.92
T_8	8.01	8.41	4.5	3.8	40	38.25
T_9	8.01	8. 49	9	7.88	40	37.58
T_{10}	8.01	8.56	13.5	11.66	40	37.86

$T_{1=}$ <4 dSm^{-1}+12.9 (mmol L^{-1})$^{1/2}$,$T_{2=}$4.5 dSm^{-1}+20 (mmol L^{-1})$^{1/2}$,$T_{3=}$9.0 dSm^{-1}+20 (mmol L^{-1})$^{1/2}$,$T_{4=}$13.5 dSm^{-1}+20 (mmol L^{-1})$^{1/2}$ $T_{5=}$4.5 dSm^{-1}+30 (mmol L^{-1})$^{1/2}$,$T_{6=}$9.0 dSm^{-1}+30 (mmol L^{-1})$^{1/2}$,$T_{7=}$13.5 dSm^{-1}+30 (mmol L^{-1})$^{1/2}$,$T_{8=}$ 4.5 dSm^{-1}+40 (mmol L^{-1})$^{1/2}$,$T_{9=}$9.0 dSm^{-1}+40 (mmol L^{-1})$^{1/2}$ and $T_{10=}$13.5 dSm^{-1}+40 (mmol L^{-1})$^{1/2}$

Conclusion

Camelina sativa plant can withstand with saline sodic soil having13.5dSm^{-1}+40 (mmolL^{-1})$^{1/2}$ at 76 % decreases over control in grain yield. Survival of *camelina* plant is the gift for the psychoanalysis of salt- affected lands.

Acknowledgements

None.

Conflict of interest

Author declares that there is no conflict of interest.

References

1. Zhu JK. Salt and drought stress signal transduction in plants. *Annu Rev Plant Biol.* 2002;53:247–273.
2. Simaei M, Khavarinejad A, Saadatmand S, et al. Interactive effects of salycylic acid and nitric oxide on soybean plants under NaCl salinity. *Russian J Plant Physiol.* 2011;58:783–790.
3. Jaleel CA, Manivannan P, Murali PV, et al. Antioxidant potential and indole alkaloid profile variations with water deficits along different parts of two varieties of *Catharanthus roseus*. *Colloids Surf B Biointerfaces.* 2008;62(2):312–318.
4. Turkan I, Demiral T. Recent developments in understanding salinity tolerance. *Environ Experimental Botany.* 2009;67(1):2–9.
5. The World Population Prospects. The 2017 Revision: UN Department of Economic and Social Affairs; 2017.
6. United Nations. *The Millennium Development Goals Report.* New York: United Nations Department of Economic and Social Affairs (DESA); 2008.
7. Pitman MG, Läuchli A. Global impact of salinity and agricultural ecosystems. In: *Salinity: Environment-Plants- Molecules.* Läuchli A. and Lüttge U, editors. Moscow: Kluwer Academic Publishers; 2002;21–51.

8. Grigore MN, Toma C. Halophytes, between the fall of civilizations and bio saline agriculture. Ecological disturbances over time. *Muz Olteniei Craiova Stud Si Com Şt Nat.* 2010a;26(2):199–204.
9. Lokhande VH, Srivastava S, Patade VY, et al. Investigation of arsenic accumulation and tolerance potential of *Sesuvium portulacastrum* (L.) L. *Chemosphere.* 2011;82(4):529–534.
10. Cheng Z, Woody OZ, Mc Conkey BJ, et al. Combined effects of the plant growth-promoting bacterium *Pseudomonas putida* UW4 and salinity stress on the *Brassica napus* proteome. *Appl Soil Ecol.* 2012;61:255–263.
11. Kang S, Wilfred Post, Jeff Nichols, et al. Marginal Lands: Concept, assessment and management. *J Agricultural Sci*. 2013;5(5):5–29.
12. Munns R. Genes and salt tolerance: bringing them together. *New Phytol.* 2005;167(3):645–663.
13. Chen T, Cai X, Wu X, et al. Casparian strip development and its potential function in salt tolerance. *Plant Signal Behav.* 2011;6(10);1499–1502.
14. Julkowska MM, Hoefsloot HC, Mol S, et al. Capturing Arabidopsis root architecture dynamics with ROOT-FIT reveals diversity in responses to salinity. *Plant Physiol*. 2014;166(3):13887–1402.
15. Sun F, Zhang W, Hu H, et al. Salt modulates gravity signaling pathway to regulate growth direction of primary roots in Arabidopsis. *Plant Physiol*. 2008;146(1):178–188.
16. West G, Inzé D, Beemster GTS. Cell cycle modulation in the response of the primary root of Arabidopsis to salt stress. *Plant Physiol.* 2004;135(2):1050–1058.
17. Jiang K, Moe Lange J, Hennet L, et al. Salt stress affects the redox status of Arabidopsis root meristems. *Front Plant Sci.* 2016;7:81.
18. Tanji KK. Salinity in the soil environment. In: *Salinity: Environment-Plants-Molecules.* Läuchli A, Lüttge U, editors. Moscow: Kluwer Academic Publishers; 2002.
19. Athar HR, Ashraf M. Strategies for crop improvement against salinity and drought stress: an overview. In: *Salinity and water stress* Ashraf M, Ozturk M, Athar HR, editors. Improving crop efficiency. Springer Science + Business Media BV. 2009;1–18.
20. Koyro HW, Geissler N, Hussin S. Survival at extreme locations: life strategies of halophytes. In: *Salinity and water stress. Improving crop efficiency*. Ashraf M, Ozturk M, Athar HR, editors. Springer Science + Business Media B. V. 2009;167–177.
21. Mutlu F, Bozcuk S. Effects of salinity on the contents of polyamines and some other compounds in sunflower plants differing in salt tolerance. *Russian J Plant Physiol.* 2005;52(1):29–34.
22. Flagella Z, Giuliani MM, Rotunno T, et al. Effect of saline water on oil yield and quality of a high oleic sunflower (*Helianthus annuus* L.) hybrid. *European J Agronomy.* 2004;21(2):267–272.
23. Hutcheon C, Ditt RF, Beilstein M, et al. Polyploid genome of *Camelina sativa* revealed by isolation of fatty acid synthesis genes. *BMC Plant Biol.* 2010;10:233–247.
24. Kagale S, Koh C, Nixon J, et al. The emerging biofuel crop *Camelina sativa* retains a highly undifferentiated hexaploid genome structure. *Nat Commun.* 2014;5;3706.
25. Kanth BK, Kumari S, Choi SH, et al. Generation and analysis of expressed sequence tags (ESTs) of *Camelina sativa* to mine drought stress-responsive genes. *Biochem Biophys Res Commun.* 2015;467(1);83–93.
26. Poudel S, Aryal N, Lu C. Identification of microRNAs and transcript targets in *Camelina sativa* by deep sequencing and computational methods. *PLoS One.* 2015;10(3):e0121542.
27. Blackshaw R, Eric Johnson, Yantai Gan, et al. Alternative oilseed crops for biodiesel feedstock on the Canadian prairies. *Can J Plant Sci.* 2011;91(5);889–896.
28. Zubr J. Qualitative variation of *Camelina sativa* seed from different locations. *Ind Crops Prod.* 2003;17(3):161–169.
29. Heydarian Z, Yu M, Gruber M, et al. Inoculation of soil with plant growth promoting bacteria producing 1-aminocyclopropane-1-carboxylate deaminase or expression of the corresponding *acdS* gene in transgenic plants increases salinity tolerance in *Camelina sativa*. *Front Microbiol.* 2016;7:1966.
30. Li X, Mupondwa E. Life cycle assessment of camelina oil derived biodiesel and jet fuel in the Canadian prairies. *Sci Total Environ.* 2014;481:17–26.
31. Vollmann J, Damboeck A, Eckl A, et al. Improvement of *Camelina sativa*, an underexploited oilseed, in progress in new crops. Janick J, Alexandria, VA. Editors. ASHS Press; 1996:357-362.
32. Steppuhn H, Falk KC, Zhou R. Emergence, height, grain yield and oil content of camelina and canola grown in saline media. *Can J Soil Sci.* 2010;90(1):151–164.
33. Sharma G, Dinesh KV, Haque A, et al. Brassica coenospecies: a rich reservoir for genetic resistance to leaf spot caused by *Alternaria brassicae*. *Euphytica.* 2002;125(3):411–417.
34. Li H, Barbetti M J, Sivasithamparam K. Hazard from reliance on cruciferous hosts as sources of major gene-based resistance for managing blackleg (*Leptosphaeria maculans*) disease. *Field CropsRes.* 2005;91(2-3):185–198.
35. Eynck C, Seguin Swartz G, Clarke WE, et al. Monolignol biosynthesis is associated with resistance to *Sclerotinia sclerotiorum* in *Camelina sativa*. *Mol Plant Pathol*. 2012;13(8):887–899.
36. Yun GL, Zhang QW, Xu HL, et al. Effect of false flax (*Camelina sativa*) on larval feeding and adult behavioral response of the diamondback moth (*Plutella xylostella)*. *Acta Entomol Fenn.* 2002;47(4):474–478.
37. Henderson AE, Hallett RH, Soroka JJ. Pre-feeding behavior of the crucifer *flea beetle*, *Phyllotreta cruciferae*, on host and nonhost crucifers. *J Insect Behav.* 2004;17(1):17–39.
38. Soroka J, Olivier C, Grenkow L, et al.. Interactions between *Camelina sativa* (Brassicaceae) and insect pests of canola. *Can Entomol.* 2014;147(2):193–214.
39. Steel RGD, Torrie JH. Principles and Procedureof Statistics. Singapore: McGraw Hill Book; 1997;173–177.
40. Ahmad S, Khan NI, Iqbal MZ, et al. Salt tolerance of cotton (*Gossypium hirsutum* L.). *Asian J Plant Sci*. 2002;1:715–719.
41. Ali Y, Aslam Z, Ashraf MY, et al. Effect of salinity on chlorophyll concentration, leaf area, yield and yield components of rice genotypes grown under saline environment. *Int J Environ Sci Technol.* 2004;1(3):221–225.
42. Rivelli AR, Lovelli S, Perniola M. Effects of salinity on gas exchange, water relations and growth of sunflower (*Helianthus annuus*). *Functional Plant Biol.* 2002;29:1405–1415.
43. Katerji N, Van Hoorn JW, Hamdy A, et al. Salt tolerance classification of crops according to soil salinity and to water stress day index. *Agricultural Water Management.* 2000;43(1):99–109.
44. Tester M, Davenport R. Na+ tolerance and Na+ transport in higher plants. *Ann Bot.* 2003;91(5): 503–527.
45. Hasegawa PM, Bressan RA, Zhu JK, et al. Plant cellular and molecular responses to high salinity. *Annu Rev Plant Physiol Mol Biol.* 2000;51:463–499.

46. Hu YC, Schmidhalter U. Drought and salinity: a comparison of their effects on mineral nutrition of plants. *J Plant Nutr Soil Sci.* 2005;168(4):541–549.
47. Bohnert HJ, Gong Q, Li P, et al. Unraveling abiotic stress tolerance mechanisms-getting genomics going. *Curr Opin Plant Biol.* 2006;9(2):180–188.
48. Rosa M, Prado C, Podazza G, et al. Soluble sugars—metabolism, sensing and abiotic stress: a complex network in the life of plants. *Plant Signal Behav.* 2009;4;388.
49. Chaves MM, Pereira JS, Maroco J, et al. How plants cope with water stress in the field. Photosynthesis and growth. *Ann Bot.* 2002;89; 907–916.
50. Potters G, Pasternak TP, Guisez Y, et al. Stress-induced morphogenic responses: growing out of trouble? *Trends Plant Sci.* 2007;12(3): 98–105.
51. Bernstein N. Effects of salinity on root growth plant roots. In *Plant Roots: The Hidden Half*, 4th Ed. eds Eshel A, Beeckman T, editors. Boca Raton, FL: CRC Press;2013;36:1–18.