Plant Archives Volume 20 No. 2, 2020 pp. 9516-9524 **e-ISSN:2581-6063 (online), ISSN:0972-5210**

EVALUATION OF SOME FOLIAR TREATMENT ON TOMATO PLANT GROWTH UNDER SALINE CONDITION (HYDROPONIC EXP.)

A. El-Hassanin[1], M. Samak[1], A. Khater[2], Hala Kandil[2] and Amal El-Maghraby[2]

[1]Dept.of Natural Resources, Faculty of African Postgraduate Studies, Cairo University, Egypt.
[2]Plant Nutrition Department, National Research Centre, 33 El Buhouth St., Dokki, Cairo 12622, Egypt.

Abstract

A Hydroponic experiment was carried out in a greenhouse of the National Research Center Dokki, Egypt, to study the effect of some foliar treatments (silica, KNO_3, prolein, Fe, K,B, Algae extract) on enhancing growth of tomato plants under different salinity levels (EC: 2, 4 and 6 dSm^{-1}) using Na Cl. Fresh weight of tomato shoot and root showed reduction responses to salinity stress. All spraying treatments have positive effect on vegetative growth of tomato plants. The spraying with silica possessed the highest treatment effect on shoot and root compared with control. While, the treatment Fe+K+B+Si showed the least effect on plant shoot. All treatments caused an increase in plant moisture content specially silica and prolein. Increasing root/shoot ratio with increasing salinity levels, the level of the salinity 4 dSm^{-1} showed the highest value of root/ shoot ratio. The spraying treatments Si, KNO_3, Fe+K+B gave the highest values of root/shoot ratio under different salinity level, while the treatment Fe+K+B+Si gave the lowest one. As a conclusion, Si and KNO_3 were the best treatment for recovery of plant under saline stress condition.

Key words : Hydroponic, salinity (Na Cl), silica, KNO_3, prolein, Fe, K, B, Algae extract.

Introduction

Tomato *(Solanum lycopersicum)* is one of the most important vegetable plants in the world. Global production is estimated as 163.96 million metric tons, with China and India are the leading producers in 2013 (Faostat, 2015). Tomato is consumed fresh, cooked or after processing; canning process also transforms tomato into juice, pulp, paste, or a variety of sauces (Cuartero and Fernandez, 1999).

Salinity is currently one of the most severe abiotic factors, limiting agricultural production. In arid and semi arid lands, the plants are subjected throughout their life cycle to different stresses; some of these plants can tolerate these stresses in different ways depending upon plant species and type of stress. Excessive salinity reduces the productivity of many agricultural crops including most of the vegetables. Knowledge of salt tolerance in vegetable plants is necessary to increase productivity and profitability of crops grow in a salty environment. According to USDA report, out of all vegetables, tomato is moderately sensitive to salinity. Salt stress has three fold effects which reduces water potential and causes ion imbalance and toxicity (de la Peña and Hughes, 2007). Salt stress affects some major processes such as germination, speed of germination, root/shoot dry weight and Na^+/K^+ ratio in root and shoot (Parida and Das, 2005). Increasing salt stress negatively affected growth and development of tomato plant (Jogendra, *et al.,* 2012). Many studies reported that tomato plants exposed to high concentrations of salt in their root zone suffered reduction in plant growth, fruit size and fruit yield (Mohammad *et al.,* 1998; Scholberg and Locascio, 1999; Magan *et al.,* 2008).

Many elements play an important role in increasing plant tolerance to salinity. Foliar utilization of potassium fertilizer could be effective in adjusting salinity prompted potassium-inadequacy, fundamentally diminishing salinity initiated harm to membranes and increasing biomass production in tomato and strawberry as revealed by (Kaya *et al.,* 2003). Silicon (Si) is the second most abundant element in soil. It has been proven to enhance the quantitative and qualitative traits of plants, especially under environmental stresses, such as salinity, drought, and heavy metal toxicity (Etesami and Jeong, 2018 and Wu, *et al.,* 2015). The mechanism for silicon inhibition of sodium uptake is due to its activation of an H^+-ATP -as enzyme that selectively favors potassium absorption over sodium. (Liang *et al.,* 2003). Increased potassium uptake and decreased sodium uptake by silicon additions are considered to be major mechanisms responsible for better growth of plants under salinity. Boron is involved in many processes including sugar transport, cell wall synthesis and maintenance, membrane integrity, RNA, Indole acetic acid (IAA) and phenol metabolism (Dordas and Brown, 2001). Iron (Fe) is a cofactor for approximately 140 enzymes that catalyze unique biochemical reactions (Brittenham, 1994). Hence, iron fills many essential roles in plant growth and development, including chlorophyll synthesis and chloroplast development (Miller *et al.,* 1995).

Proline is one of nonessential amino acids found in plants, and one of the most important dominant compound produced in response to salt stress (Marin *et al.,* 2010). Its main role is probably to protect plant cells against negative effect of salt by maintaining the osmotic balance, stabilizing sub cellular structure such as proteins and membranes in addition to scavenging (Ashraf and Foolad, 2007).

Blue- green algal extract excretes a great number of substances that influence plant growth and development (Ordog, 1999). These microorganisms have been reported to benefit plants by producing growth promoting regulators, vitamins, amino acids, antibacterial, antioxidants (Abd el-Aty *et al.*, 2014) and antifungal substances (Haggag et al, 2014).

This study aim to evaluate some remediative addietives applied to tomato plants grown in hydroponics under saline conditions in order to minimize the hazards of salinity.

Materials and Methods

A Hydroponic experiment was carried out in a greenhouse of the National Research Center Dokki, Egypt to study the effect of some foliar treatments on enhancing growth of tomato plants under different salinity levels (EC: 2, 4 and 6 dSm^{-1}) using NaCl. The hybrid tomato *(Solanum lycopersicum) Elssia* Sp was cultivated. The seeds were germinated in foam trays Containing 6*9 holes. From the 1^{st} to the 14^{th} day after sowing, the seedlings were irrigated with tap water. From the 14th day, the plants were irrigated with 0.5 g NH_4NO_3 nutrient solution. After two weeks the seedlings was transplant in a small cups (diameter 5 cm and 7 cm high) filled with peatmoss. One seedling were placed in each cup which contained many holes in bottom when the plants reached the stage of 3 to 5 native leaves, they were transplanted to the hydroponic system.

The hydroponic system

The experimental plots were composed of plastic container 1.5 L with cover that have two holes one for cup seedlings and the second for tube of aeration then each seedlings cup was put inside the hole that was made with the container cover immersed in Hoagland's solutions table 1 according to Hoagland and Arnon (1950) and the air tube from the other hole of the cover was inserted. Hoagland solution salinity level has been adjusted to 2, 4 and 6 dSm^{-1} using NaCl.

After one week seven spray treatments were prepared to

- -K 500 ppm as KNO_3,
- Si 8 mML^{-1} as calcium silicate
- Proline 100 ppm
- Algae as extraction 2%
- Fe 10 ppm as Fe-EDTA+ K500 ppm as KNO_3 + B 10 ppm as boric acid
- Fe10 ppm + K500 ppm + B10 ppm + Si mML^{-1} and
- Fe 10 ppm + K500 ppm + B 10ppm+ proline 100 ppm

The seven spray treatments were carried out other than the control, three replications were made for each

Table 1: Preparation of the stock solutions and a full Hoagland solution Component.

	Stock Solution	mL Stock Solution/1 L
Macronutrients		
2M KNO_3	202 g/L	2.5
2M $Ca(NO_3)_2 \cdot 4H_2O$	236 g/0.5 L	2.5
Iron (Sprint 138 iron chelate)	15 g/L	1.5
2M $MgSO_4 \cdot 7H_2O$	493 g/L	1
Micronutrients		
H_3BO_3	2.86 g/L	1
$MnCl_2 \cdot 4H_2O$	1.81 g/L	1
$ZnSO_4 \cdot 7H_2O$	0.22 g/L	1
$CuSO_4 \cdot 5H_2O$	0.08 g/L	1
$H_2MoO_4 \cdot H_2O$ or	0.09 g/L	1
$Na_2MoO_4 \cdot 2H_2O$	0.12 g/L	1
Phosphate		
1M KH_2PO_4 (pH to 6.0)	136 g/L	1

Photos showing how to change the nutrient solution

General photos for hydroponic experience.

treatment, and the Hoagland solution was changed weekly with the original content in the experiment and with the same salt concentration for the primary treatments. Spraying the different treatments was done once every week from the start of the experiment for four weeks. The experiment lasted for 6 weeks, growth parameters were recorded for plants (shoot fresh weight (SFW), root fresh weight (RFW), shoot dry weight (SDW), root dry weight (RDW) and root/shoot ratio was calculated. Also, the percentage of moisture in the shoot and root system was calculated as follows:

(Shoot moisture content, %) = ((SFW-SDW)/SFW) * 100

(Root moisture content, %) = ((RFW-RDW)/RFW) * 100

Results and Discussion

The results showed the effect of some remediate additives sprayed on tomato plants grow (in the hydroponics experiment) under saline conditions for minimizing the hazards of salinity. The plant fresh weight and dry weight were recorded after plant exposure to salinity and spraying treatment.

Results for fresh weight of tomato plants exhibited reduction responses to salinity stress (Table 2). The mean value of tomato plants fresh weight under different salinity levels were 33.57,22.9, and 13.45 gm by an equivalent decrease of 0.0, 31.78, and 59.93% for 2 dSm^{-1}, 4 dSm^{-1} and 6 dSm^{-1}, respectively. Osmotic pressures affect plant growth by restricting the uptake of water by root. Salinity can also affect plant growth because the high concentration of salts in the root solution interferes with balanced absorption of essential nutritional ions by plant (Zeinolabedin, 2012):

As a general average, all spraying treatments had positive effect on vegetative growth of tomato plants,

Table 2: Effect of some foliar treatments on tomato shoot fresh weight (gm) under saline condition (hydroponic system).

Foliar Treatments	Shoot Fresh Weight/gm							
	Salinity levels							
	2 dSm^{-1}		4 dSm^{-1}		6 dSm^{-1}		Mean	
	weight/gm	%	weight/gm	%	weight/gm	%	weight/g	%
Control	26	100%	11.56	100%	3.95	100%	13.83	100
KNO_3	41.06	157.9	27.66	239.27	16.23	410.88	28.31	204.7
Si	47.80	183.8	30.70	265.57	17.83	451.39	32.11	232.18
Prolein	26.03	100.1	25.20	217.99	14.33	362.78	21.85	157.99
Alge	27.03	103.9	25.43	219.98	10.13	256.45	20.86	150.83
Fe+K+B	44.25	170.2	27.60	238.75	12.66	320.5	28.17	203.7
Fe+K+B+Si	23.23	89.3	13.86	119.89	17.76	449.62	18.28	132.2
Fe+K+B+Prol	33.19	127.6	21.43	185.38	14.73	372.91	23.12	167.17
Mean	33.57	129.1	22.9	184.85	13.45	340.06		

Table 3: Effect of some foliar treatments on tomato fresh root (gm) under saline condition (hydroponic experiment).

Foliar Treatments	Root Fresh Weight/gm							
	Salinity levels							
	2 dSm^{-1}		4 dSm^{-1}		6 dSm^{-1}		Mean	
	weight/gm	%	weight/gm	%	weight/gm	%	weight/g	%
Control	7.07	100%	4.2	100	1.3	100	4.19	100
KNO_3	10.27	145.26	6.0	142.8	3.4	261.5	6.56	156.56
Si	14.8	209.33	7.4	176.2	5.0	384.6	9.07	216.47
Prolein	8.06	114.0	6.7	158.6	3.03	233.1	5.93	141.53
Alge	9.6	135.8	6.8	280.9	3.75	288.5	6.72	160.38
Fe+K+B	9.2	130.1	5.9	193.5	3.93	302.3	6.34	151.31
Fe+K+B+Si	8.1	114.1	5.3	126.2	5.46	420.0	6.29	150.0
Fe+K+B+Prol	9.63	136.2	4.9	117.4	4.13	317.7	6.22	148.45
Mean	9.59	135.6	5.90	140.48	3.75	288.46		

especially under salinity levels 4, 6 dSm^{-1}. While there was no positive effect of spray treatments under the salinity rate 2 dSm^{-1} except for Si, KNO_3, Fe+K+B, and Fe+K+B+Prol spraying treatment that caused an increase by 83.8%, 57.9%,70.2% and 27.6% compared with control respectively.

The spraying treatment with silica exhibited the highest effect by 232.18 % as an average compared with control. While, the treatment Fe+K+B+Si showed the least effect 167.17%. Kaya et al. (2006) supported these results which indicated that silicon application increased corn fresh and dry weight and improved grain yield. The silicon partially offset the negative impacts of salt stress due to increasing the tolerance of wheat to NaCl stress by enhancement of relative water content, chlorophyll content and photosynthetic activity (Bybordi, 2014). Silica present in plant cells limits uptake of toxic ions and prevents their translocation to shoots. The beneficial effect of silicon may be related to the depression of water loss by transpiration and consequently reduced rate of passive uptake and transport of minerals (Gao *et al.,* 2006 and Romero-Aranda *et al.,* 2006). Huanli *et al.,* (2015) suggested that silicon application could decrease Na and Cl accumulation and increased antioxidant defense in tomato roots, which improved the root growth and hydraulic conductance, and therefore improved leaf water status and shoot growth. Potassium contributes for tolerance against salinity as it has a competing nature to sodium for binding and maintaining plant water status (Capula-Rodríguez *et al.,* 2016). Significant reductions in fresh and dry weight of tomato shoots were reported in response to salinity stress (Bolarin *et al.,* 1991, 1993).

At the early plant growth stages, the root system may not get well developed to uptake sufficient nutrients from the root media and in a such condition the foliar application of fertilizers could be a good option to supply

Table 4: Effect of some foliar application on tomato shoot dry Weight under saline condition (hydroponic experiment).

Treatments Foliar	Shoot dry Weight (SDW)							
	Salinity levels							
	2 dSm-1		4 dSm-1		6 dSm-1		Mean	
	weight/g	**%	weight/g	**%	weight/g	**%	weight/g	%
Control	4.45	82.9	2.4	79.24	0.85	78.37	2.57	100
KNO_3	5.38	86.89	3.43	87.6	2.4	85.21	3.74	182.05
Si	3.7	92.25	3.55	88.44	3.13	82.44	3.46	298.00
Prolein	4.36	83.25	2.53	89.96	2.23	84.44	3.04	155.24
Alge	3.55	86.86	4.00	84.27	1.9	81.24	3.15	156.65
Fe+K+B	5.15	88.36	3.4	87.68	2.26	82.15	3.60	174.42
Fe+K+B+Si	4.56	80.37	3.86	72.15	3.06	82.77	3.83	207.77
Fe+K+B+Prol	4.96	85.05	3.36	84.32	3.1	78.95	3.81	205.39
Mean	4.51		3.32		2.26			

** (plant moisture content %) = ((SFW-SDW)/SFW) * 100.

Table 5: Effect of some foliar application on tomato root dry Weight under saline condition (hydroponic experiment).

Treatments Foliar	Root dry Weight (RDW)							
	Salinity levels							
	2 dSm-1		4 dSm-1		6 dSm-1		Mean	
	weight/g	*	weight/g	*	weight/g	*	weight/g	%
Control	0.93	86.8	0.84	80.00	0.2	84.6	0.66	100
KNO_3	1.73	83.2	1.43	76.2	1.13	66.8	1.43	216.67
Si	1.62	89.05	1.8	83.8	1.45	71.0	1.62	245.9
Prolein	1.33	83.5	1.4	91.6	0.5	83.5	1.08	163.1
Alge	1.5	84.4	1.46	78.5	0.35	90.7	1.10	167.2
Fe+K+B	1.65	82.1	1.16	80.3	1.4	64.4	1.40	212.6
Fe+K+B+Si	0.98	87.9	0.96	81.9	0.63	88.5	0.86	130.3
Fe+K+B+Prol	1.02	89.4	1.75	64.3	0.86	79.2	1.21	183.3

(Root moisture content %) = ((RFW-RDW)/RFW) * 100*.

the essential nutrients like potassium (K^+) and phosphorous (P^{3+}) to the plants (Mallarino *et al.,* 2001). High NaCl concentration in plant media induces the P^{3+} and K^+ deficiencies in tomato (Adams, 1991). Tal and Shannon (1983) reported that salinity stress reduced elongation rate of the main stem in tomato.

The roots fresh weight of the tomato plant decreased due to the high level of salinity (Table 3). The mean value of tomato root fresh weights under different salinity levels were 9.59, 5.90, and 3.75 gm. The rate of decline was consistent with the decrease in shoot fresh growth, it fell with a rate of 0.0, 38.48% and 60.89% for the levels of salinity 2, 4 and 6 dSm^{-1}, respectively. Salinity adversely affects vegetative growth and reduces yield, fresh and dry weight of shoots and roots because of a combination of osmotic and specific ion effects of Cl- and Na+ (Hajiboland *et al.,* 2010). Many salt ions are toxic to plant cells when present at high concentrations. Typically, the majority of salt stress is caused by sodium chloride (NaCl). The damage is not only caused via toxicity of Na+ and Cl- ions, but also by a water deficit or osmotic stress (Zhu, 2002). Mohammad (1998) suggested that both root length and root surface area per plant were decreased significantly under higher salinity conditions.

As a general average, all spraying treatments have positive effect on vegetative growth of tomato plants root, under different salinity levels 2, 4, and 6 dSm^{-1}. The treatment of silica was the most influential, with an average increase of 116.47% over the control, followed by an algae extract with an increase of 60.38%, then potassium nitrate with an increase 56.56%. While the treatments with proline was the least affected, with an increase of 41.53%.

The most positive treatment was silica, with the most recent effects at the salinity level 6 dSm^{-1} where the latest increase is equivalent to 248.6%. The appearance of individual spraying treatments (Si, KNO_3) were more

Table 6: Effect of some foliar application on tomato root/shoot ratio under saline condition (hydroponic experiment).

Foliar Treatments	Dry root/shoot ratio			
	Salinity levels			
	2 dSm^{-1} S:R	4 dSm^{-1} S:R	6 dSm^{-1} S:R	Mean
Control	0.209	0.350	0.235	0.265
KNO_3	0.322	0.417	0.467	0.405
Si	0.438	0.507	0.463	0.469
Prolein	0.305	0.553	0.224	0.361
Alge	0.423	0.365	0.184	0.324
Fe+K+B	0.320	0.341	0.619	0.427
Fe+K+B+Si	0.215	0.249	0.206	0.223
Fe+K+B+Prol	0.206	0.521	0.277	0.335
Mean	0.305	0.413	0.334	

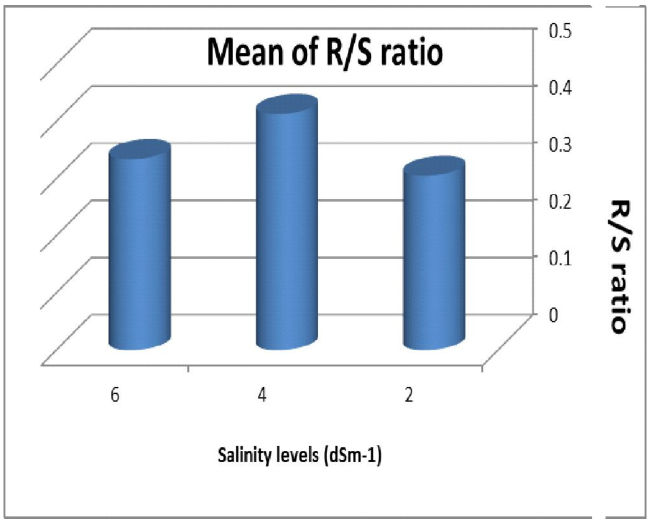

Fig. 1: Tomato root/shoot ratio under different saline condition (hydroponic experiment).

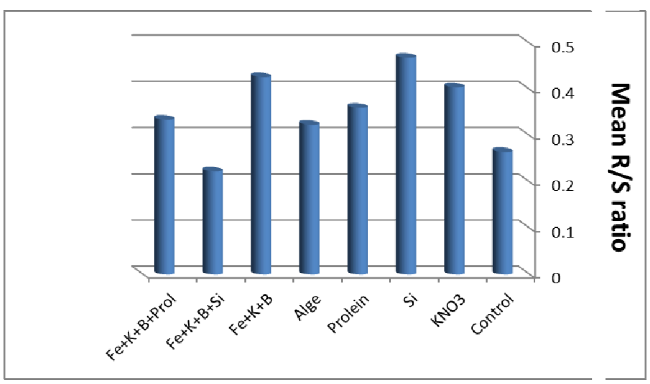

Fig. 2: Effect of foliar application treatment on tomato root/shoot ratio.

positive compared to mixture treatments (Fe+K+B+Si, Fe+K+B, Fe+K+B+Si) for shoot and root fresh weight.

Salinization decreased dry matter weight of tomato plant by 26.38% and 49.89% in the more stressed treatment 4 dSm^{-1} and 6 dSm^{-1}, respectively, compared to control 2 dSm^{-1}. All foliar application treatments caused an increase in dry weight especially under saline condition 4 dSm^{-1} and 6 dSm^{-1}. While there was no positive effect of spray treatments under the salinity rate 2 dSm^{-1} for Si, prolein, algae spring treatment.

The spraying with silica possessed the highest effect treatment by 198% as average compared with control. While, the prolein treatment showed the least effect 55.24%.

Plant moisture content % = shoot fresh weight (SFW) – shoot dry weight (SDW) /shoot fresh weight * 100 was calculated, (Table 4). All treatments caused an increase in plant moisture content specially selenium and prolein. This my be du to increasing water uptake under saline condition or decreasing transpiration. Zhu and Gong (2014) suggested the mechanisms for silicon-mediated alleviation of salt stress to include the following aspects: (1) maintaining the water content; (2) improving the photosynthesis and decreasing the transpiration rate; (3) reducing ion toxicity and minimizing salt-induced oxidative damage; (4) regulating biosynthesis of compatible solutes and levels of plant hormones. Rios *et al.*, (2017) summarized the improvement acts of Si in plant salinity tolerance mainly from the water uptake and a aquaporin's points of view. Recently, progresses have been made in elucidating the alleviation acts of Si in salt-induced osmotic stress (Chen *et al.,* 2014 and Zhu *et al.,* 2015). Romero-Aranda *et al.*, (2006) found that exogenous silicon alleviated the deleterious effect of salt stress by improving the water storage within the leaves, but not by improving plant water uptake or reducing the Na and Cl-accumulations in the plants. Plants subjected to drought, treated with silicon, maintained higher stomatal conductivity, relative water content and water potential. It helps leaves become larger and thicker, thus limiting the loss of water through transpiration and reduces water consumption.

From table 5 salinization decreased mean root dry weight of tomato plant by 39.4% in the more stressed treatment 6 dSm^{-1} compared with control 2 dSm^{-1}. While the mean value of treatment 4 dSm^{-1} (1.35 gm/plant) did not affect the dry weight of the roots compared with control (1.345 gm/plant). Feigin *et al.,* (1987), Shalhevet and Hsiao, (1986) and Smith *et al.,* (1992) reported that growth of tomato is significantly reduced by salinity.

All spray treatments used gave an increase in the dry weight of the root specially silica, potassium nitrate and mixture of (Fe+K+B) which caused an increase of 145.9%, 116.7% and 112.6% of mean root dry weight, respectively. On the other hand, the Prolein, Alge and Fe+K+B+Si, spraying treatment were the least effective. The results showed that the use of silica alone gave a more positive effect compared to mixing it with other elements.

These results agreed with several studies which reported the foliar application of potassium fertilizer has beneficial effect against salt stress on sunflower (Arshadullah *et al.,* 2014), sugar beet (Zaki *et al.,* 2014), eggplant (Elwan, 2010), ryegrass (Tabatabaei and Fakhrzad, 2008), tomato (Amjad *et al.,* 2014; Kaya *et al.,* 2001), sunflower (Jabeen and Ahmad, 2011), endives (Tzortzakis, 2010), and wheat (Bybordi, 2015). Also, beneficial effects of foliar spraying with nutrients under salinity conditions were previously observed in major crops, such as tomato *(Solanum lycopersicum* L.*)* (Topçuoçlu and Kütük 2002), maize *(Zea mays* L.*)* (Hu *et al.*, 2008), and sunflower *(Helianthus annus* L.*)* (Jabeen and Ahmad 2012). Gong *et al.*, (2006) found that silicon significantly reduced Na+ transport to the shoot and promoted the growth of rice plant. Okuma et al, (2004) and Ali, *et al.*, (2007) reported that application of proline is considered as an important agent to maintain osmotic potential of the plant cell and it considered as an antioxidant agent through its role in increasing the ability of plant to tolerate salt stress. Also, Siddique *et al.,* (2015), Ahmad *et al.,* (2015) and Ami*et al.,* (2020) reported that the applications of proline have been beneficial in mustard crops, wheat and rice, respectively.

Root: shoot ratio, the ratio of the amount of plant tissues that have supportive functions to the amount of those that have growth functions. Plants with a higher proportion of roots can compete more effectively for soil nutrients, while those with a higher proportion of shoots can collect more light energy. Large proportions of shoot production are characteristic of vegetation in early successional phases, while high proportions of root production are characteristic of climax vegetational phases.

Data illustrated in table 6 and Fig. (1) exhibted that increasing root shoot ratio with increasing salinity levels; the level of the salinity 4 dSm^{-1} showed the highest value of root /shoot ratio. Root /shoot ratio was higher under plant stress condition (drought, salinity, etc.,), (Nahar, 2011).

The spraying treatments Si, KNO_3, Fe+K+B possessed the highest values of root/shoot ratio (Fig. 2) under different salinity level, while the treatment Fe+K+B+Si gave the lowest one.

The root/shoot ratio is proportional to nutrient supply/ fertilization, with a greater ratio at low nutrient supply (Kang and Van Iersel, 2004). On the other hand, when there is a large and continuous supply of water and nutrients, a small root system may be sufficient (Greenwood, 1983), as shown by plant production in water culture (e.g., the 'Nutrient Film Technique') in commercial horticulture plants with a higher proportion of roots can compete more effectively for soil nutrients, while those with a higher proportion of shoots can collect more light energy. These results are in harmony with Abdoliahil and Jafari (2012) who found that the effects of salinity treatments on root/ shoot (R/S ratio) were significant. Maximum R/S ratio was observed at NaCl 1%. With increasing in salinity levels, R/S ratio increased significantly.

References

Abd El-Aty, A.M., A.A. Mohamed and F.A. Samhan (2014). In vitro antioxidant and antibacterial activities of two fresh water cyanobacterial species, Oscillatoria agardhii and Anabaena sphaerica. *Journal of Applied Pharmaceutical Science*, **4(7):** 069-075.

Abdoliahi, F. and L. Jafari (2012). Effect of NaCl and KNO_3 Priming on seed germination of canola (*Brassica napus* L.) under salinity conditions. *International Journal of Agriculture: Research and Review*, **2(5):** 573-579.

Adams, P. (1991). Effects of increasing the salinity of the nutrient solution with major nutrients or sodium chloride on the yield, quality and composition of tomatoes grown in rockwool. *J. Hortic. Sci*., **66(2):** 201–207.

Ahmad, P., A. Hashem, E.F. Abd-Allah, A.A. Alqarawi, R. John and D. Egamberdieva (2015). Role of Trichoderma harzianum in mitigating NaCl stress in Indian mustard (Brassica juncea L) through antioxidative defense system. *Front. Plant Sci.*, **6:** 868. https://doi.org/10.3389/fpls.2015.00868

Ali, Q., A. Muhammad and A. Habib-Ur-Rehman (2007). Exogenously applied proline at different growth stages enhances growth of two maize cultivars grown under water deficit conditions. *Pak. J. Bot.*, **39(4):** 1133-1144.

Ami, K., S. Planchai, C. Cabassa, A. Guivarc'h, A.A. Very and M. Khelifi (2020). Different proline responses of two Algerian durum wheat cultivars to in vitro salt stress. *Acta Physiol. Plant*, **42:** 21. https://doi.org/10.1007/s11738-019-3004-9.

Amjad, M., J. Akhtar, M.A.U. Haq, S. Imran and S.E. Jacobsen (2014). Soil and foliar application of potassium enhances fruit yield and quality of tomato under salinity. *Turkish J. Biol.*, **38(2):** 208–218.

Arshadullah, M., A. Ali, S.I. Hyder, I.A. Mahmood and B.U. Zaman (2014). Effect of different levels of foliar application of potassium on Hysun-33 and Ausigold-4 sunflower (*Helianthus annuus* L.) cultivars under salt stress. *Biol. Sci.-PJSIR*, **57(1):** 1–4.

Ashraf, M. and M.R. Foolad (2007). Roles of glycine betaine and proline in improving plant abiotic stress resistance. *Environ. Exp. Bot.*, **59:** 206-216.

Bolarin, M.C., E.G. Cuartero, V. Cruz and J. Cuartero (1991). Salinity tolerance in four wild tomato species using vegetative yield salinity response curves. *J. Am. Soc. Hort. Sci.*,**116:** 286-290.

Bolarin, M.C., F. Perez-Alfocea, E.A. Cano, M.T. Estan and M. Carol (1993). Growth, fruit yield and ion concentration in tomato genotypes after pre- and post-emergence salt treatments. *J. Am. Soc. Hort. Sci.*, **118:** 655-660.

Brittenham, G.M. (1994). New advances in iron metabolism, iron deficiency and iron overload. *Current Opinion in Hematology*, **1:** 549-556.

Bybordi, A. (2014). Interactive effects of silicon and potassium nitrate in improving salt tolerance of wheat. *Journal of Integrative Agriculture*, **13(9):**1889–99. doi:10.1016/S2095-3119(13):60639-5.

Bybordi, A. (2015). Influence of exogenous application of silicon and potassium on physiological responses, yield, and yield components of salt-stressed wheat. *Commun. Soil Sci. Plant Anal.*, **46(1):** 109–122.

Capula-Rodríguez, R., L.A. Valdez-Aguilar, D.L. Cartmill, A.D. Cartmill and I. Alia-Tejacal (2016). Supplementary calcium and potassium improve the response of tomato (*Solanum lycopersicum* L.) to simultaneous alkalinity, salinity, and boron stress. *Commun. Soil Sci. Plant Anal.*, **47(4):** 505–511

Chen, S., H. Diekmann, D. Janz and A. Polle (2014). Quantitative X-ray elemental imaging in plant materials at the subcellular level with a transmission electron microscope: applications and limitations. *Materials*, **7:** 3160–3175. doi: 10.3390/ma7043160

Cuartero, J. and R. Fernandez-Munoz (1999). Tomato and salinity. *Scientia Horticulturae*,**78:** 83-125.

de-la Peña, R. and J. Hughes (2007). Improving vegetable productivity in a variable and changing climate. SAT e Journal (ejournal.icrisat.org); **4(1):**1–22.

Dordas, C. and P.H. Brown (2001). Permeability and the mechanism of transport of boric acid cross the plasma membrane of *Xenopus laevis* oocytes. *Journal Biological Trace Element Research*, **81:**127-139.

Elwan, M.W. (2010). Ameliorative effects of di-potassium hydrogen orthophosphate on salt-stressed eggplant. *J. Plant Nutr.*, **33(11):** 1593–1604.

Etesami, H. and B.R. Jeong (2018). Silicon (Si): Review and future prospects on the action mechanisms in alleviating biotic and abiotic stresses in plants. *Ecotoxicol. Environ. Saf.*, **147:** 881–896.

Faostat (2015): <http://faostat.fao.org/site/339/accessed on March, 19, 2015. Cuartero J and Fernandez MR (1999) Tomato and salinity. *Scientia Hort.*, **78:** 83-125.

Feigin, A., I. Rylski, A. Meiri and J. Shalhevet (1987). Response of melon and tomato plants to chloride-nitrate ratio in saline nutrient solution. *J. Plant Nutr.*, **10:** 1787-1794.

Gao, X., Ch. Zou, L. Wang and F. Zhang (2006). Silicon decreases transpiration rate and conductance from stomata of maize plants. *J. Plant Nutr.*, **29:** 1637-1647.

Gong, H.J., D.P. Randall and F.J. Flowers (2006). Silicon deposition in the root reduce uptake in rice (*Oryza sativa* L.) seedling by reducing bypass flow. *Plant Cell Environ.*, **29:** 1970–1979.

Greenwood, D.J. (1983). Quantitative Theory and the Control of Soil Fertility. *New Phytol.*, **94:** 1-18.

Hagag, W., A.M. Abd El-Aty and A.A. Mohamed (2014). The potential effect of two Cyanobacterial species; Anabaena sphaerica and Oscillatoria agardhii against grain storage fungi. *European Scientific Journal*, **10(30):** 1857 – 7881.

Hajiboland, R., A. Aliasgharzadeh, S.F. Laiegh and C. Poschenrieder (2010). Colonization with arbuscular mycorrhizal fungi improves salinity tolerance of tomato (*Solanum lycopersicum* L.) plants. *Plant Soil*, **331:** 313-327.

Hoagland, D.R. and D.I. Arnon (1950). The water-culture method for growing plants without soil. Berkeley, Calif. : University of California, College of Agriculture, Agricultural Experiment Station. Retrieved 1 October 2014.

Hu, Y., Z. Burucs and U. Schmidhalter (2008). Effect of foliar fertilization application on the growth and mineral nutrient content of maize seedlings under drought and salinity. *Soil Sci. Plant Nutr.*, **54(1):** 133–141.

Huanli, L., Z. Yongxing, H. Yanhong, H. Weihua and G. Haijun (2015). Beneficial effects of silicon in alleviating salinity stress of tomato seedlings grown under sand culture. *Acta Physiol Plant*, **37:** 71 DOI 10.1007/s11738-015-1818-7.

Jabeen, N. and R. Ahmad (2012). Improving tolerance of sunflower and safflower during growth stages to salinity through foliar spray of nutrient solutions. *Pakistan J. Bot.*, **44:** 563–572.

Jabeen, N. and R. Ahmad (2011). Foliar application of potassium nitrate affects the growth and nitrate reductase activity in sunflower and safflower leaves under salinity. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, **39(2):** 172.

Jogendra, S., S.E.V. Divakar and S. Vijayata (2012). Effect of salinity on tomato (*Lycopersicon esculentum Mill.*) during seed germination stage. *Physiol. Mol. Biol. Plants*, **18(1):** 45–50.

Kang, J.G. and M.W. Van Iersel (2004). Nutrient solution concentration affects shoot: root ratio, leaf area ratio, and growth of sub-irrigated salvia (*salvia splendens*). *Hort. Sci.*, **39(1):** 49-54.

Kaya, C., B.E. Ak and D. Higgs (2003). Response of salt-stressed strawberry plants to supplementary calcium nitrate and/or potassium nitrate. *J. Plant Nutr.*, **26:** 543–560.

Kaya, C., L. Tuna and D. Higgs (2006). Effect of silicon on plant growth and mineral nutrition of maize grown under water-stress conditions. *J. Plant Nutr.*, **29:** 1469–1480.

Kaya, C., H. Kirnak and D. Higgs (2001). Enhancement of growth and normal growth parameters by foliar application of potassium and phosphorus in tomato cultivars grown at high (NaCl) salinity. *J. Plant Nutr.*, **24(2):** 357–367.

Liang, Y.C., Q. Chen, Q. Liu, W.H. Zhang and R.X. Ding (2003).

Exogenous silicon (Si) increases antioxidant enzyme activity and reduces lipid peroxidation in roots of salt-stressed barley (*Hordeum vulgare* L.). *J. Plant Physiol*., **160:** 1157-1164.

Magan, J.J., M. Gallardo, R.B. Thompson and P. Lorenzo (2008). Effects of salinity on fruit yield and quality of tomato grown in soil-less culture in greenhouses in Mediterranean climatic conditions. *Agric. Water Manag*., **95:** 1041-1055.

Mahajan, S. and N. Tuteja (2005). Cold, salinity and drought stresses: an overview. *Arch. Biochem. Biophys*., **444(2):** 139–158.

Marin, J.A., P. Andreu, A. Carrasco and A. Arbeloa (2010). Determination of proline concentration, an abiotic stress marker, in root exudates of excised root cultures of fruit tree rootstocks under salt stress. Revue des Régions Arides – Numéro spécial – 24 (2/2010) Actes du 3ème Meeting International ‘’Aridoculture et Cultures Oasisennes : Gestion et Valorisation des Ressources et Applications Biotechnologiques dans les Agrosystèmes Arides et Sahariens” Jerba (Tunisie). 15-16-17/12/2009.

Miller, G.W., I.J. Huang, G.W. Welkie and J.C. Pushmik (1995). Function of iron in plants with special emphasis on chloroplasts and photosynthetic activity. In: Abadia, J., (Ed.), Iron Nutrition in Soils and Plants. Kluwer Academic Publishers, Dordecht, 19-28.

Mohammad, M., R. Shibli, M. Ajouni and L. Nimri (1998). Tomato root and shoot responses to salt stress under different levels of phosphorus nutrition. *J. Plant Nutr.*, **21:** 1667-1680.

Mohammad, M., I.R. Shibli, M. Ajlouni and L. Nimrib (1998). Tomato Root and Shoot Responses to Salt Stress Under Different levels of Phosphorus Nutrition. *Journal Plant Nutrition*, **21(8):** 1667-1680.

Nahar, K. and R. Gretzmacher (2011). Response of shoot and root development of seven tomato cultivars in hydroponic system under water stress. *Academic Journal of Plant Sciences*, **4(2):** 57-63.

Okuma, E., Y. Murakami, Y. Shimoishi, M. Tada and Y. Murata (2004). Effects of exogenous application of proline and betaine on the growth of tobacco cultured cells under saline conditions. *Soil Sci. Plant Nutr.*, **50:** 1301-1305.

Ordog, V. (1999). Beneficial effect of microalgae and cyanobacteria in plant/soil- systems, with special regard to their auxin- and cytokinin like activity. International Workshop and Training Course on microalgae biology and biotechnology Mosonmagyarovar, Hungary, June, 13-26.

Parida, A.K. and A.B. Das (2005). Salt tolerance and salinity effects on plant: a review. *Ecotoxical. Environ. Safety*, **60:** 324–349. doi: 10.1016/j.

Rios, J.J., M.C. Martinez-Ballesta, J.M. Ruiz, B. Blasco and M. Carvajal (2017). Silicon-mediated improvement in plant salinity tolerance: The role of aquaporins. *Front. Plant Sci.*, **8:** 948.

Romero-Aranda, M.R., O. Jurado and J. Cuartero (2006). Silicon alleviates the deleterious salt effect on tomato plant growth by improving plant water status. *J. Plant Physiol*., **163:** 847–855. doi:10.1016/j.jplph.2005.05.010. PMID:16904793.

Scholberg, J.M.S. and S.J. Locascio (1999). Growth response of snap bean and tomato as affected by salinity and irrigation method. *Hort. Sci*., **34:** 259-264.

Shalhevet, J. and T.C. Hsiao (1986). Salinity and drought. A comparison of their effects on osmotic adjustment, assimilation, transpiration and growth. *Irig. Sci.*, **7:** 249-264.

Siddique, A.B., M.R. Islam, M.A. Hoque, M.M. Hasan, M.T. Rahman and M.M. Uddin (2015). Mitigation of salt stress by foliar application of proline in rice. Univers. *J. of Agric. Res.*, **3:** 81–88. https://doi.org/10.13189/ujar.2015.030303.

Smith, M.A.L., L.A. Spomer, R.A. Shibli and S.L. Knight (1992). Effect of NaCl salinity on miniature dwarf tomato ‘Micro-Tom’: H. Shoot and root growth responses, fruit production and osmotic adjustment. *Plant Nutr.*, **15:** 2329-2341.

Tabatabaei, S. and F. Fakhrzad (2008). Foliar and soil application of potassium nitrate affects the tolerance of salinity and canopy growth of perennial ryegrass (Lolium perenne var Boulevard). *Am. J. Agric. Biol. Sci*., **3(3):** 544–550.

Tal, M.M. and C. Shannon (1983). Salt tolerance in the wild relatives of the cultivated tomato: Response of Lycopersicon esculenturnMill., L. cheesrnanii,L.peruvian urnand Solanurnpennellii and F, hybrid to salinity. *Aust. J. Plant Physiol.*, **10:**109-117.

Topçuoçlu, B. and C. Kütük (2002). Effects of salinity stress and foliar CaCl2 applications on dry matter, calcium and oxalic acid contents in tomato plant growing in nutrient solution containing different levels of calcium. *Acta. Hortic.*, **573:** 475–481.

Tzortzakis, N. (2010). Potassium and calcium enrichment alleviate salinity-induced stress in hydroponically grown endives. *J. Hortic. Sci*., **37:** 155–162.

Wu, J., J. Guo, Y. Hu and H. Gong (2015). Distinct physiological responses of tomato and cucumber plants in silicon-mediated alleviation of cadmium stress. *Front. Plant Sci*., **6:** 453.

Zaki, N.M., M.S. Hassanein, G.A. Amal, A. Ebtsam and M.M. Tawfik (2014). Foliar application of potassium to mitigate the adverse impact of salinity on some sugar beet varieties. 2: effect on yield and quality. *Middle East J*., **3(3):** 448–460.

Zeinolabedin, J. (2012). The Effects of Salt stress on plant growth. *Technical Journal of Engineering and Applied Sciences*, **2(1):** 7-10.

Zhu, J.K. (2002). Salt and drought stress signal transduction in plants. *Ann. Rev. Plant Biol*., **53:** 247-273.

Zhu, Y.X. and H.J. Gong (2014). Beneficial effects of silicon on salt and drought tolerance in plants. *Agron. Sustain. Dev*., **34:** 455–472.

Zhu, Y.X., X.B. Xu, Y.H. Hu, W.H. Han, J.L. Yin, H.L. Li and H.J. Gong (2015). Silicon improves salt tolerance by increasing root water uptake in *Cucumis sativus* L.. *Plant Cell Rep*., **34:** 1629–1646.