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THE ROLE OF POTASSIUM SILICATE ON THE VEGETATIVE GROWTH OF *PRUNUS ARMENIACA* C.V QAISI SEEDLINGS IRRIGATED WITH SALTY WATER

Basheer Hachim Mahdi* **and Shyamaa Salman Neamah**
Department of Horticulture and Landscape, Faculty of Agriculture, University of Kufa, Najaf, Iraq, Email: bashertayf@gmail.com

Abstract

Seedlings of apricot (*Prunus armeniaca* L.) c.v Qaisi were treated with three concentrations of potassium silicate (0, 1, and 2 ml.L^{-1}) during 2022 season and irrigated with three levels of salty water (1.5, 2 and 2.5 dsm^{-1}) to determine the role of potassium silicate on the vegetative growth of these seedlings. Results showed that treated apricot seedlings with potassium silicate that irrigated by salty water was affected the average of seedling height, stem diameter, branches number, leaves number, leaf area, fresh and dry weight of total vegetative. The outcomes of current study indicated that using studied factors was improved the growth of seedlings which will be reflected on the quality of apricot fruits.

Key words: *Prunus armeniaca*, potassium silicate, salty water, vegetative growth.

Introduction

Apricot (*Prunus armeniaca* L.) is considered deciduous stone fruit that belong to *Prunus* genus and Rosaceae family, its native home is China and Siberia and from there moved to Italy then to the rest of the world (Westwood 1989). The nutritional importance of apricot fruits presented in its high content of A vitamin and niacin in comparison with other fruits as it used as fresh food or to make jam or juice, it can also be dried and canned as well as sweet apricot kernels are used in making sweets and in extracting oil from bitter seeds (El-Issa and Batha 2012). Salinity of soils is considered one of the main problems that face plant production in arid and semi-arid regions causing a significant decrease in the growth and yield of plants growing in those soils. Among the most dissolved salts common in Iraqi soils are sodium, magnesium and calcium chlorides, sodium and magnesium sulfates as sodium chloride salt is the most common and widespread in most Iraqi saline soils. Also, the salinity of irrigation water is one of the most important reasons that impede agricultural development in areas that do not adopt rain-fed irrigation as a main method in agriculture (Al-Zubaidy 1989). Silicon is one of the important elements as it has a role in many physiological processes of the plant including improving the effectiveness of photosynthesis, protein and carbohydrate content, increasing the effectiveness of the roots to absorb nutrients, and reducing the toxicity of the sodium ion by reducing its flow from the soil solution to the plant then reducing the osmotic pressure inside the cells in addition to increasing the ratio of potassium to sodium, increasing the effectiveness of antioxidant enzymes and reducing toxic elements (Guerriero et al. 2016). Potassium is considered one of macro nutritional elements which is necessary for plant and its concentration can be increased in the dry matter of plant, also plants need its single positively charged ion in greater quantities than other nutrients except nitrogen

(Bergmann 1983). The addition of potassium to the plant increases its ability to tolerate salinity (Jiping and Jian 1997). Thus, current study is conducted to determine the role of spraying potassium silicate on reducing the damages of different levels of salty water on the growth parameters of apricot seedlings.

Materials and methods

Experiments were conducted in 2022 season in the nursery of certified seedlings, Directorate General for Horticulture and Forestry, Hindia/ Karbala province from 15/3/ 2022 to 15/9/2022. 135 of two years old apricot seedlings c.v Qaisi were selected, homogeneous in height and size inlaid on 2kg plastic bags. Seedlings were shifted into 10kg plastic pots contain loamy soil mixed with peat moss in 3:1 ratio and put under woody shade. Samples of soils from these pots were collected and mixed well then analyzed to determine its chemical and physical properties (Table 1) and also samples of irrigation water were analyzed for its chemical properties (Table 2). All service operations were carried out on seedlings including irrigation, removing of weeds and pest control periodically throughout the experiment period.

Table 1. Chemical and physical characteristics of soil before planting.

<table>
<tr><th colspan="2">Texture</th><th>Value</th><th>Unit</th></tr>
<tr><td colspan="2">Sand</td><td>720</td><td rowspan="3">$g.kg^{-1}$</td></tr>
<tr><td colspan="2">Silt</td><td>110</td></tr>
<tr><td colspan="2">Clay</td><td>170</td></tr>
<tr><td colspan="2">Soil texture</td><td colspan="2">Loamy-Sandy</td></tr>
<tr><th colspan="2">Type of analysis</th><th>Value</th><th>Unit</th></tr>
<tr><td colspan="2">pH of soil</td><td>7.1</td><td>----</td></tr>
<tr><td colspan="2">Electric conductivity (EC)</td><td>0.56</td><td>$dS.m^{-1}$</td></tr>
<tr><td rowspan="3">Dissolved cat-ions</td><td>K^{+}</td><td>0.22</td><td rowspan="4">$ml.mol.L^{-1}$</td></tr>
<tr><td>Na^{+}</td><td>1.23</td></tr>
<tr><td>Ca^{++}</td><td>0.39</td></tr>
<tr><td rowspan="2">Dissolved an-ions</td><td>Cl^{-}</td><td>0.12</td></tr>
<tr><td>CO_3^{-2}</td><td>Nill</td><td>----</td></tr>
<tr><td colspan="2">Exchange Capacity CEC</td><td>38.4</td><td>----</td></tr>
<tr><td colspan="2">Organic material</td><td>6.5</td><td>$g.kg^{-1}$</td></tr>
</table>

A factorial experiment with three blocks was carried out in 15/3/2022 using Randomized Complete Block Design (RCBD) with two main factors, the first factor was spraying three concentrations of potassium silicate fertilizer (0, 1 and 2 $ml.L^{-1}$) and the second factor was three levels of irrigation by salty water (1.5, 2 and 2.5 $dS.m^{-1}$) then treatments were applied as follows:

T1: Salty irrigation water (1.5 $dS.m^{-1}$) + no spraying with potassium silicate (control)
T2: Salty irrigation water (1.5 $dS.m^{-1}$) + spraying with 1 $ml.L^{-1}$ of potassium silicate
T3: Salty irrigation water (1.5 $dS.m^{-1}$) + spraying with 2 $ml.L^{-1}$ of potassium silicate

T4: Salty irrigation water (2 $dS.m^{-1}$) + no spraying with potassium silicate
T5: Salty irrigation water (2 $dS.m^{-1}$) + spraying with 1 $ml.L^{-1}$ of potassium silicate
T6: Salty irrigation water (2 $dS.m^{-1}$) + spraying with 2 $ml.L^{-1}$ of potassium silicate
T7: Salty irrigation water (2.5 $dS.m^{-1}$) + no spraying with potassium silicate
T8: Salty irrigation water (2.5 $dS.m^{-1}$) + spraying with 1 $ml.L^{-1}$ of potassium silicate
T9: Salty irrigation water (2.5 $dS.m^{-1}$) + spraying with 2 $ml.L^{-1}$ of potassium silicate

Means were compared using the least significant difference (L.S.D.) at 5% level of significance ($P>0.05$) (AL–Rawi and Khalf 2000).
After that, the average of increasing in (seedling height, branches number, stem diameter, leaves number and the mean of total leaf area were measured.

Table 2. Some chemical characteristics of irrigation water used in the study.

Chemical characteristic	**Unit**	**Treatment (salinity of irrigation water $dS.m^{-1}$)**		
Electrical conductivity (EC)	$dS.m^{-1}$	1.5	2	2.5
pH	**-**	7.92	7.52	8.1
Calcium	$mmol.L^{-1}$	0.42	3.78	4.4
Magnesium	$mmol.L^{-1}$	0.14	1.62	3.6
Sodium	$mmol.L^{-1}$	2.48	3.14	6.2
Potassium	$mmol.L^{-1}$	0.21	0.12	0.16
Chloride	$mmol.L^{-1}$	3.60	3.88	6.21
Sulphate	$mmol.L^{-1}$	3.13	4.47	8.12
Bicarbonate	$mmol.L^{-1}$	-	2.15	3.81
Sodium adsorption ratio (SAR)	$(mmol.L^{-1})^{2/1}$	1.14	1.35	2.36

Results

Tables 3, 4, 5, 6 and 7 results indicated that different treatments of salty irrigation water, spraying potassium silicate and their interaction were affected the vegetative growth parameters of apricot seedlings (c.v Qaisi) and decreased it rapidly. There were significant differences in the average of seedling height when it treated with different levels of salty irrigation water as the 1.5 $dS.m^{-1}$ was excedded and gave the highest average of seedling height amounted 43.22 cm $seedling^{-1}$ compare to the lowest average 30.73 cm $seedling^{-1}$ recorded in 2.5 $dS.m^{-1}$ treatment (Table 3). There were also significant differences in the average of seedling height when it treated with potassium silicate when 2ml.L-1 concentration was exceeded and gave the highest average of seedling height amounted 37.57cm $seedling^{-1}$ compare to the lowest average 34.44 cm $seedling^{-1}$ in control treatment. The interaction between spraying potassium silicate and salty irrigation water was significantly affected seedling height when the treatment 1.5 $dS.m^{-1}$ of salty water + no spraying with potassium silicate gave the highest average of increasing in the seedling height up to 46.36cm.seedling^{-1} compared to the lowest seedling height 27.55cm.seedling^{-1} recorded in the treatment 1.5 dS.m^{-1} of salty water + spraying with 2ml.L^{-1} of potassium silicate. Results also showed that there were significant differences in the main stem diameter when the seedlings irrigated with different levels of salty water as the treatment of 1.5 dS.m^{-1} was gave the highest increasing in the main stem diameter amounted 5.59mm compared to 3.30mm in 2 dS.m^{-1} treatment (Table 4). Spraying potassium silicate also achieved significant differences in the stem diameter when the treatment of 2ml.L^{-1} of potassium silicate was gave the highest average of main stem diameter amounted 4.53mm in comparison with the lowest average 4.08mm in control treatment. The interaction between spraying potassium silicate and salty irrigation water was significantly affected average of increasing in main stem diameter of apricot seedlings. The treatment 1.5 dS.m^{-1} of salty water + no spraying with potassium silicate gave the highest average of stem diameter amounted 6.17mm compared to 1.5 dS.m^{-1} of salty water + spraying with 2ml.L^{-1} of potassium silicate which gave the lowest average reached 2.46mm. Table 5 showed that there were significant differences in the average of branches number when the seedlings were irrigated with different levels of salty water. The treatment 1.5 dS.m^{-1} of salty water was gave the highest increasing in the average of total branches number amounted 5.99branch seedling^{-1} compared to the lowest average 3.92branch seedling^{-1} at 2.5 dS.m^{-1} of salty water. Spraying potassium silicate was achieved significant differences in branches number as the treatment of 2ml.L^{-1} of potassium silicate gave the highest average reached 5.99branch seedling^{-1} compared to 5.5branch seedling^{-1} in control treatment. The interaction treatment 1.5 dS.m^{-1} of salty water + no spraying with potassium silicate gave the highest average of branches number amounted 8.26branch seedling^{-1} compared to 1.5 dS.m^{-1} of salty water + spraying with 2ml.L^{-1} of potassium silicate which gave the lowest average reached 3.05branch seedling^{-1}. There were significant differences in the average of leaves number when the seedlings were irrigated with different levels of salty water. The treatment 1.5 dS.m^{-1} of salty water was gave the highest increasing in the average of leaves number amounted 289.88leaf seedling^{-1} compared to the lowest average 224.47leaf seedling^{-1} at 2.5 dS.m^{-1} of salty water. Spraying potassium silicate was achieved significant differences in leaves number as the treatment of 2ml.L^{-1} of potassium silicate gave the highest average reached 272.63leaf seedling^{-1} compared to 237.68leaf seedling^{-1} in control treatment. The interaction treatment 1.5 dS.m^{-1} of salty water + no spraying with potassium silicate gave the highest average of leaves number amounted 294.5leaf seedling^{-1} compared to 1.5 dS.m^{-1} of salty water + spraying with 2ml.L^{-1} of potassium silicate which gave the lowest average reached 173.9leaf seedling^{-1}. Table 7 results indicated that there were significant differences in the average of leaf area when the seedlings of apricot were irrigated with different levels of salty water. The treatment 1.5 dS.m^{-1} of salty water was gave the highest increasing in the average of leaf area amounted 36.85cm^2 compared to the lowest average 26.63cm^2 at 2.5 dS.m^{-1} of salty water. Spraying potassium silicate was achieved significant differences in leaf area as the treatment of 2ml.L^{-1} of potassium silicate gave the highest average reached 34.56cm^2 compared to 29.43cm^2 in control treatment. The interaction treatment 1.5 dS.m^{-1} of salty water + no spraying with potassium silicate gave the highest average of leaf area amounted 38.55cm^2 compared to 2 dS.m^{-1} of salty water + spraying with 1ml.L^{-1} of potassium silicate which gave the lowest average reached 22.74cm^2. There were significant differences in the average of fresh weight of total vegetative when the seedlings were irrigated with different levels of salty water (Table 8). The treatment 1.5 dS.m^{-1} of salty water was gave the highest increasing in the average of fresh weight of total vegetative amounted 96.0gm seedling^{-1} compared to the lowest average 78.67gm seedling^{-1} at 2.5 dS.m^{-1} of salty water. Spraying potassium silicate was achieved significant differences in fresh weight of total vegetative as the treatment of 2ml.L^{-1} of potassium silicate gave the highest average reached 89.93gm seedling^{-1} compared to 84.14g seedling^{-1} in control treatment. The interaction treatment 1.5 dS.m^{-1} of salty water + no spraying with potassium silicate gave the highest average of fresh weight of total vegetative amounted 99.16gm seedling^{-1} compared to 1.5 dS.m^{-1} of salty water + spraying with 2ml.L^{-1} of potassium silicate which gave the lowest average reached 73.42gm seedling^{-1}. Table 9 indicated that there were significant differences in the average of dry weight of total vegetative when the seedlings were irrigated with different levels of salty water. The treatment 1.5 dS.m^{-1} of salty water was gave the highest increasing in the average of dry weight of total vegetative amounted 45.03gm seedling^{-1} compared to the lowest average 35.92gm seedling^{-1} in control treatment. Spraying potassium silicate was achieved significant differences in dry weight of total vegetative as the treatment of 2ml.L^{-1} of potassium silicate gave the highest average reached 41.57gm seedling^{-1} compared to 38.98g seedling^{-1} in control treatment. The interaction treatment 1.5 dS.m^{-1} of salty water + no spraying with potassium silicate gave the highest average of dry weight of total vegetative amounted 44.13gm seedling^{-1} compared to 1.5 dS.m^{-1} of salty water + spraying with 2ml.L^{-1} of potassium silicate which gave the lowest average reached 33.20gm seedling^{-1}.

Table 3. The role of potassium silicate, salty water and their interaction on the average of height (cm seedling^{-1}) of apricot seedlings c.v Qaisi.

Salty water dS.m^{-1}	Potassium silicate (ml.L^{-1})			The average of salty water effect
	0	1	2	
1.5	46.36	29.41	27.55	43.22
2	43.95	36.46	29.54	34.72
2.5	39.33	38.29	35.10	30.73
The average of potassium silicate effect	34.44	36.65	37.57	
LSD (0.05)	Potassium silicate = 0.59 Salty water = 0.59 Interaction = 1.03			

Table 4. The role of potassium silicate, salty water and their interaction on the average of main stem diameter (mm) of apricot seedlings c.v Qaisi.

Salty water dS.m^{-1}	Potassium silicate (ml.L^{-1})			The average of salty water effect
	0	1	2	

1.5	6.17	3.61	2.46	5.59
2	5.77	4.35	3.22	4.16
2.5	4.85	4.53	4.22	3.30
The average of potassium silicate effect	4.08	4.44	4.53	
LSD (0.05)	Potassium silicate = 0.10 Salty water = 0.10 Interaction = 0.18			

Table 5. The role of potassium silicate, salty water and their interaction on the average of branches number (branch $seedling^{-1}$) of apricot seedlings c.v Qaisi.

Salty water $dS.m^{-1}$	Potassium silicate ($ml.L^{-1}$)			The average of salty water effect
	0	1	2	
1.5	8.26	4.15	3.05	7.67
2	7.64	5.29	3.98	5.18
2.5	7.11	6.11	4.75	3.92
The average of potassium silicate effect	5.15	5.63	5.99	
LSD (0.05)	Potassium silicate = 0.16 Salty water = 0.16 Interaction = 0.28			

Table 6. The role of potassium silicate, salty water and their interaction on the average of leaves number (leaf $seedling^{-1}$) of apricot seedlings c.v Qaisi.

Salty water $dS.m^{-1}$	Potassium silicate ($ml.L^{-1}$)			The average of salty water effect
	0	1	2	
1.5	296.17	243.26	173.60	289.88
2	291.07	269.84	238.65	262.47
2.5	282.40	274.31	261.17	224.47
The average of potassium silicate effect	237.68	266.52	272.63	
LSD (0.05)	Potassium silicate = 3.41 Salty water = 3.41 Interaction = 5.90			

Table 7. The role of potassium silicate, salty water and their interaction on leaf area (cm^2) of apricot seedlings c.v Qaisi.

Salty water $dS.m^{-1}$	Potassium silicate ($ml.L^{-1}$)			The average of salty water effect
	0	1	2	
1.5	38.23	27.32	22.74	36.85
2	36.46	34.70	24.66	32.39
2.5	35.87	35.15	32.68	26.69
The average of potassium silicate effect	29.43	31.94	34.56	
LSD (0.05)	Potassium silicate = 0.51 Salty water = 0.51 Interaction = 0.88			

Table 8. The role of potassium silicate, salty water and their interaction on the average fresh weight of vegetative growth (gm $seedling^{-1}$) of apricot seedlings c.v Qaisi.

Salty water $dS.m^{-1}$	Potassium silicate ($ml.L^{-1}$)			The average of salty water effect
	0	1	2	
1.5	99.16	79.43	73.83	96.01
2	95.40	87.40	75.39	85.45
2.5	93.45	89.52	86.80	78.67
The average of potassium silicate effect	84.14	86.06	89.67	
LSD (0.05)	Potassium silicate = 0.80 Salty water = 0.80 Interaction = 1.39			

Table 9. The role of potassium silicate, salty water and their interaction on the average dry weight of vegetative growth (gm $seedling^{-1}$) of apricot seedlings c.v Qaisi.

Salty water $dS.m^{-1}$	Potassium silicate ($ml.L^{-1}$)			The average of salty water effect
	0	1	2	
1.5	46.47	36.75	33.74	45.03
2	44.83	40.75	34.25	39.55
2.5	43.80	41.15	39.77	35.92
The average of potassium silicate effect	38.98	39.94	41.57	
LSD (0.05)	Potassium silicate = 0.41 Salty water = 0.41 Interaction = 0.71			

Discussion

The effect of the salinity of irrigation water on vegetative parameters of apricot seedlings c.v Qaisi.

It can be noted in Tables 3, 4, 5, 6 and 7 results that there was significant decreasing in the vegetative characteristics including seedlings height, branches number and stem diameter when the seedlings of apricot were irrigated with salty water. The decreasing may attribute to increasing of salinity in soil solution directly which affected negatively and inhibited enzymes activity in plant cells and disruption of the nutritional balance or due to dysfunction of cellular membranes as well as through its effect on the processes of photosynthesis, respiration and electron transport pathways. This decrease may be occurred due to the indirect effects of salinity through affecting the soil properties and thus the growth of seedlings. The high osmotic pressure of the soil solution at the high salinity levels of the irrigation water causes a deficit in the absorption of water which works to reduce the opening pressure of the cells and affects the softness of its wall and the lack of breadth, elongation of it thus reducing the height of the plant (Nilsen and Orcutt 2000). The decrease in the number of leaves and the leaf area occurred as a result of high salinity (Cramer et al. 1985), also salinity leads to a defect in the growth of leaves and their small size and then reduces the process of photosynthesis (Zheng et al. 2009). The outcome showed that the leaf area was affected rapidly by the salinity of irrigation water as when the salinity of this water increased, the leaf area is decreased. In addition to the lack of transfer of nutrients and growth hormones from the roots to the rest of the plant parts due to the low amount of water absorbed and this leads to a decrease in the elongation and the area of the leaf cells, thus the plant works in such conditions to produce growth inhibitors (ABA acid and ethylene) to resist salt stress. These growth inhibitors impede growth and expand the leaves to remain small and eventually fall off, in addition to the role of ABA acid in reducing the opening of stomata and a decrease in the penetration of carbon dioxide which leads to a decrease in the efficiency of carbon metabolism and a decrease in processed carbohydrates (Grattan and Grieve 1998). This effect on leaf growth is an early response to salt tolerance in plants when exposed to salt stress (Munns and Termaat 1986). The high levels of salinity lead to defoliation due to the accumulation of growth inhibitors in the detachment area as a result of resistance to salt stress represented by sodium and chloride ions which contributes to the decrease in leaf area (Greenway and Munns 1980). The decrease in the number of leaves as a result of the increase in the salinity levels of the irrigation water leads to a decrease in the plant branches as a result of the accumulation of toxic ions. The salinity also works to slow down the vegetative and root growth as a result of inhibiting the action of stimulating hormones such as gibberellins and activate the action of obstructing hormones such as abscisic acid (Taiz and Zeiger 2006).

The role of potassium silicate on vegetative parameters of apricot seedlings c.v Qaisi.

Spraying potassium silicate on the seedlings of apricot was affected the vegetative parameters as it increase seedlings height, branches number and leaf area when the concentration of this fertilizer was increased due to the fact that potassium silicate is one of the means that works to increase salt tolerance of the plant by increasing the Na^{++}: K^{+} ratio under salt stress conditions.

The role of silicon in reducing salinity damage may be attributed to its effect in increasing the effectiveness of the root system and reducing the speed of transpiration as well as increasing the effectiveness of ion-carrying proteins presented in the outer plasma membrane and thus improving the process of ionic balance (Liang et al. 2006). The effect of potassium silicate in increasing the characteristics of vegetative growth may be due to its role in maintaining good water content through partial closure of stomata, reducing transportation, increasing the readiness of nutrients and then dividing and elongating cells and increasing growth (Zargar et al. 2019). The silicon element has an active role in increasing the light transmittance to the mesophyll cells in the leaves which leads to an increase in the efficiency of photosynthesis and processed carbohydrates (Adrian 2004; Sacala 2009), which leads to increase vegetative parameters (Gaur et al. 2020) as well as it decreased the environmental stress in plant and encourage the increasing of photosynthesis products (Patil et al. 2017; Santi et al. 2018).

References

Adrian, J. 2004. Potassium nutrition in North Great Plains: News and views by potash and

AL–Rawi, K. M. and Khalf, A. M. 2000. Design and Analysis of Agricultural Experiments. College of Agriculture University of Mosel, Iraq.

Al-Zubaidy, A. H. 1989. The salinity of water: Theoretical and practical basis. University of Baghdad, Ministry of Higher Education and Scientific Research of Soil Science Hekma House.

Bergmann,W. 1983. Ernahrungsstorungen beiKulturpflanzen.Veb Gustav Fischer Verlag Jena, DDR.

Cramer, G. R., Läuchli, A., and Polito, V. S. 1985. Displacement of Ca2+ by Na+ from the plasmalemma of root cells: A primary response to salt stress. *Plant physiology*, 79(1): 207-211.

El-Issa, E. and M. Batha. 2012. Deciduous Fruit Production. First Edition, Damascus.

Gaur, S., J. Kumar, D. Kumar, D. K. Chauhan, S. M. Prasad and P. K. Srivastava 2020. Fascinating impact of silicon and silicon transporters in plants: A review. Ecotoxicology and Environmental Safety 202: 110885.

Grattan, S. R., and Grieve, C. M. 1998. Salinity–mineral nutrient relations in horticultural crops. *Scientia horticulturae* 78(1-4): 127-157.

Greenway, H. and Munns, R. 1980. Mechanisms of salt tolerance in Non-halophytes. *Annual review of plant physiology* 31(1): 149-190.

Guerriero, G., Hausman, J. F., and Legay, S. 2016. Silicon and the plant extracellular matrix. Frontiers in plant science 7: 463.

Jiping, L. and K.Z. Jian.1997. An Arabidopsis mutan that requires increasedcalcium for potassium nutrition and salt tolerance . Proc.Nati Acad. Sci.USA. (23): 14960-14964.

Liang, Y.C., Su, W. C., Zhu, Y.-G. and Christie, P. 2006. Mechanisms of silicon mediated alleviation of abiotic stresses in higher plants: a review. Environ. Pollut., 147: 422–428.

Munns, R. and Termaat, A. 1986. Whole plant response to salinity. Functional Plant Biology, 13(1): 143-160.

Orcutt, D. M. and Nilsen, E. T. 2000. The physiology of plants under stress: soil and biotic factors. John Wiley & Sons.

phosphate Institute (PPI), Canada.

Sacala, E. 2009. Role of silicon in plant resistance to water stress. Journal elementol, 14(3): 619-630.

Westwood, M.N. 1989. Temperate Zone Pomology (Translated by Y.H. Yousif). Mousel University.

Zargar, S. M., R. Mahajan, J. A. Bhat, M. Nazir and R. Deshmukh .2019. Role of silicon in plant stress tolerance: opportunities to achieve a sustainable cropping system. Biotech 9(3): 73.

Zheng, C., Jiang, D., Liu, F., Dai, T., Jing, Q. and Cao, W. 2009. Effects of salt and waterlogging stresses and their combination on leaf photosynthesis, chloroplast ATP synthesis, and antioxidant capacity in wheat. *Plant Science* 176(4): 575-582.