Using silicon for increasing the tolerance mango cv. Ewaise transplants to drought

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Abstract: Mango cv. Ewaise transplants were exposed to four water deficits namely 25, 50, 75 and 100 of field capacity with or without silicon at 150 mg/ kg^{-1} soil as an attempts for alleviating the adverse effects of drought on growth and nutritional status of young mango trees. A great decline was observed on all growth characters, leaf water content %, plant pigments, total carbohydrates % as well as concentrations and uptake of N, P, K, Mg and Si of mango grown under drough conditions (25 and 50 % field capacity). Soil addition of silicon at 150 mg/ kg^{-1} soil was favourable in counteracting these inferior effects. H_2O_2 content was greatly enhanced with water deficit treatment and the vice versa was obtained with using silicon. The effect either increase or decrease was associated with reducing field capacity from 100 to 25 %. It is preferable for soil addition of silicon at 150 g/ kg^{-1} soil in young mango cv. Ewaise orchards grown under arid conditions.

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1. Introduction

Drought stress usually case great decline on yield of fruit crops. It is responsible for enhancing reactive oxygen species and at the same time reducing the antioxidant defense system. Water deficit results in lowering and some times stopping photosynthesis, cell division and the biosynthesis of all plant pigments and organic foods **(Alvi and Sharif, 1995 and Iturbe-Omaetxe *et al*., 1998).** With the shortage of the available water nowadays under Egyptian conditions any attempt conducted to promote water use efficiency is appreciated. Various studies showed that using silicon was beneficial for counteracting the adverse effects of water stress on growth and nutritional status of the plants. It is also known that silicon increases drought tolerance in plants by maintaining plant water balance, photosynthesis activity, erectness of leaves and structure of xylem vessels under higher transpiration rates. Also, its responsible for encouraging water transport and root growth under unfavourable conditions and antioxidants defense system and **(Matoh *et al*., 1991; Epstein, 1999; Alvarez and Datnaff , 2001; Aziz *et al*., 2002; Melo *et al*., 2003 and Hattori *et al*., 2005).**

Previous studies showed that using silicon in fruit orchards under drought conditions were accompanied with alleviating the adverse effects of drought on growth, plant pigments as well as nutritional status of the plants **(Matichenov *et al*., 2000; Kanto, 2002; Ma and Takahashi, 2002; Neumenn and Zur- Neiden, 2011; Gad El- Kareem, 2012 and Al- Wasfy, 2012 and 2013).**

The target of this study was elucidating the beneficial effects of using silicon on growth and nutritional status of Ewaise mango transplants grown under drought conditions.

2. Material and Methods

This pot trial was conducted in greenhouse located at Faculty of Agriculture, Minia Univ. Minia Governorate during 2011 and 2012 seasons on 240 4-year old Ewaise mango cv. (*Mangifira indica* L.) transplants onto seedling rootstocks. Each seedling was planted in plastic pots 40 cm in diameter and 40 cm. in height, filled with 8.0 kg air dried sandy loamy soil (69.0, 24.2 and 6.8 % of sand, silt and clay, respectively), containing 0.85 of organic matter 0.05 % of N, 17.6 mg/ kg^{-1} P and 180.0 mg/kg^{-1} K. The soil pH was 7.97 and the EC was 1.41 dS m^{-1}. Each pot was fertilized annually with 10.0 g N, 3.0 P_2O_5 and 8.0 g K_2O (according to **Duran- Zuazo *et al*., 2004).** The plant height (cm.) and stem diameter (cm.) was adjusted to 35.0 cm and 0.90 cm at the start of experiment, respectively (zero measurement).

The present study included the following eight treatments:-

1. Non water salinization with using salicylic acid (SA).
2. Water salinization at 10 mM NaCl without SA.
3. Water salinization at 20 mM NaCl without SA.
4. Water salinization at 40 mM NaCl without SA.
5. Non water salinization with using SA at 0.55 mM.
6. Water salinization at 10 mM NaCl + SA.
7. Water salinization at 20 mM NaCl + SA.
8. Water salinization at 40 mM NaCl + SA.

Each treatment was replicated three times, ten seedlings per each. Randomized complete design was adopted. The selected plastic pots kept inside glass greenhouse under natural light. Soil was allowed to equilibrate in the greenhouse for ten days before planting the seedlings. The seedlings were irrigated with non- salinized tap water every four days at field capacity (soil moisture content reached 15 % by weighting). After one month from planting the seedlings they were irrigated with saline water (caused by NaCl) at 0.0 (0.0 g^{-1} NaCl), 10.0 (0.36 g^{-1} NaCl), 20.0 (0.72 g^{-1} NaCl) and 40.0 mM (1.44 g^{-1} NaCl) seedlings were separated into two groups, the first was sprayed with salicylic acid at 0.55 mM (0.1 g^{-1} / Iw) and the other one was left without spraying salicylic acid was dissolved in distilled water and the pH was adjusted at 6.5 with NaOH. It was applied three times at one month after carrying out saline water and at one month intervals. Irrigation with saline irrigation was done at field capacity as previously mentioned. For preventing salt accumulation in the plastic pots, it is preferable for using non- salinized water irrigation at field capacity in between involved saline water for leaching salt. At the end of experimental (last week of Sept.) the following measurements were recorded:

1. Plant height (cm.) from the surface of soil.
2. Stem diameter 20 cm above ground (cm.).
3. Each seedling was separated into shoots and roots for measuring averages fresh and dry weights of shoots and root (g/ plant). The ratio between fresh roots and shoots was calculated. Then plant dry weight (g.) was recorded.
4. Leaf water content % was measured by drying the leaves at 80 °C for 48 hours and calculated as follows leaf water content = $\frac{F.W \times 100}{F.W}$

where F.W and d.W were fresh and dry weights, respectively.

5. H_2O_2 was assayed according to the method of **He *et al.* (2005).** Leaves were homogenized in ice bath with 0.1 % (w/v) TCA. The extract was centrifuged at 12,000 × g for 15 min, after which to 0.5 ml of the supernatant was added 0.5 ml of 10 mM potassium phosphate buffer (pH 7.0) and 1 ml of 1 M KI, and the absorbance was read at 390 nm. The content of H_20_2 was given on a standard curve.
6. Plant pigments namely chlorophylls a & b and total carotenoids were determined according to the procedures of **Arnon (1949) and Wettstein (1957)**.
7. Total carbohydrates % in the leaves by using phenol and sulphoric acid method (**A.O.A.C., 1995**).
8. Visual assessment of the symptoms.

The severity of the plants condition was classified as follows: a) Plants without symptom (WS).
b) Very mild chlorosis (VMC).
c) Partial mild chlorosis (PMC).
d) Burns on the margins and apices of leaves (BMA).
e) Sever damage with leaf drop and plant death (SDD).

9. K^+/ Na^+ was calculated by dividing K^+ by Na^+
10. Percentages of N, P, K, Mg and Na were determined on the dried whole plant (according to **Piper, 1950**) and uptake of these nutrients by each seedling (g/ plant) was calculated by multiplying of each neutral by dry weight of whole plant (g/ plant).

Proper statistical analysis was done using new L.S.D at 5 % (according to **Mead *et al*., 1993).**

3. Results and Discussion

1- Growth characters:

It is clear from the data in Table (1) that varying water deficit treatments significantly altered all growth characters namely plant height, stem diameter as well as fresh and dry weights of shoots and roots, Root/ shoot and plant dry weight. A gradual and significant reduction on these growth characters was observed with increasing water deficit from 100 to 25 % field capacity. Irrigation at 100 % field capacity with or without using silicon gave the maximum values. It is worth to mention that using silicon (Si) under drought conditions (at percentages of field capacity lower than 100) significantly was accompanied with enhancing all growth character in relative to non- application of Si under the same conditions. Using well water at 100 % field capacity accompanied with soil addition of Si at 150 g/ kg^{-1} soil succeeded in producing the maximum values of the investigated growth characters. Irrigation with water at 25 % field capacity gave unfavourable effects on growth characters but with using Si these inferior effects were significantly reduced. These results were true during both seasons.

These results are in agreement with those obtained by **Lux *et al*. (2003)** as well as **Al- Wasfy (2012) and (2013).**

2- Leaf water content %:

It can be stated from the data in Table (2) that irrigation at 25 to 75 % field capacity (drought conditions) with or without Si significantly was followed by a reduction on the leaf water content % comparing with using water at 100 % field capacity. The reduction was associated with reducing field capacity from 100 to 25 %. Using Si via soil to mango cv. Ewaise transplants grown under drought conditions significantly was very effective in counteracting the reducing effect of water deficit on leaf water content. The maximum values were recorded on the plants that irrigation with 100 % field capacity plus application of Si. Using water at 25 % field capacity gave the lowest values. These results were true during both seasons.

These results are in harmony with those obtained by **Aziz *et al*. (2002); Tahir *et al*. (2006) and Al-**

Wasfy (2013).

3- H_2O_2 content:

It is clear from the data in Table (2) that H_2O_2 content was significantly increased in the seedlings grown under drought conditions (25 to 75 % field capacity). There was a gradual reduction on H_2O_2 content with increasing field capacity from 100 to 25 %. Using Si in combined with water deficit was favourable than using water deficit in reducing H_2O_2 content. The lowest values of H_2O_2 content were obtained in response to irrigation with water at 100 % field capacity. The highest water deficit (25 % field capacity) especially under non- application of Si resulted in the maximum values. Similar results were obtained during both seasons.

These results are in harmony with those obtained by **Matoh *et al*. (1991) and Alvi and Sharif (1995).**

4- Plant pigments, total carbohydrates % as well as concentrations and uptake of N, P, K, Mg and Si:

As shown in Tables (2 & 3 & 4 & 5), plant pigments namely chlorophylls a & b, total carotenoids and total chlorophylls, total carbohydrates % as well as concentrations and uptake of N, P, K, Mg and Si were adversely affected by drought conditions even with the application of Si in relative to using water at 100 % field capacity with or without Si. Under water stress conditions, using silicon was significantly essential for alleviating the inferior effects of water deficit on plant pigments, total carbohydrates % and plant uptake of nutrients. The maximum values were recorded due to irrigation at 100 % field capacity plus application of Si. Irrigation with deficit water at 25 % field capacity without using Si gave the lowest values. These results were true during both seasons.

These results are in conformity with those obtained by **Baligar *et al*., (2001); Melo *et al*., (2003); Hattori *et al*., (2005) and Al- Wasfy (2013).**

Table (1): Some growth characters of Ewaise mango transplants grown with or without silicon at three levels of water content during 2011 and 2012 seasons.

Treatment	Plant height (cm.)		Stem diameter (cm.)		Shoot fresh weight/ plant (g.)		Shoot dry weight/ plant (g.)		Root fresh weight/ plant (g.)		Root dry weight/ plant (g.)	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
Irrigation at 100 % F.C without silicon	121.0	131.9	1.62	1.69	810	851	146	153	267	272	46.0	49.0
Irrigation at 75 % F.C without silicon	118.7	129.9	1.41	1.48	751	791	134	142	248	262	44.6	47.2
Irrigation at 50 % F.C without silicon	110.9	121.0	1.25	1.32	711	761	128	145	235	252	42.3	45.4
Irrigation at 25 % F.C without silicon	81.5	91.9	1.09	1.16	601	650	108	117	198	215	35.6	38.7
Irrigation at 100 % F.C + 150 mg Si/ kg^{-1} soil	131.3	141.9	1.77	1.84	860	933	155	168	284	307	51.1	55.3
Irrigation at 75 % F.C + 150 mg Si/ kg^{-1} soil	126.9	137.3	1.57	1.64	801	851	144	153	265	281	47.7	50.6
Irrigation at 50 % F.C + 150 mg Si/ kg^{-1} soil	119.9	128.0	1.41	1.48	761	811	137	146	251	268	45.2	48.2
Irrigation at 25 % F.C + 150 mg Si/ kg^{-1} soil	88.9	99.9	1.21	1.25	641	691	122	125	212	228	38.2	41.1
New L.S.D at 5 %	**1.7**	**1.7**	**0.06**	**0.07**	**21.0**	**20.8**	**5.9**	**6.2**	**8.0**	**8.2**	**2.0**	**2.2**

F.C = Field capacity

Table (2): Root/ shoot, plant dry weight, leaf water content, H_2O_2 content and chlorophylls a & b of Ewaise mango transplants grown with or without silicon at three levels of water content during 2011 and 2012 seasons.

Treatment	Root/ shoot (F.W basis)		Plant dry weight (g.)		Leaf water content %		H_2O_2 content (µ mol/ g^{-1} dw)		Chl. a (mg/ g^{-1} F.W)		Chl. b (mg/ g^{-1} F.W)	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
Irrigation at 100 % F.C without silicon	0.33	0.32	192.0	202.0	77.0	78.3	4.1	4.3	16.4	15.0	7.1	7.5
Irrigation at 75 % F.C without silicon	0.33	0.33	178.6	189.2	74.0	74.9	5.0	5.4	15.0	13.5	6.0	6.3
Irrigation at 50 % F.C without silicon	0.33	0.33	170.3	190.4	71.0	71.8	8.9	9.3	12.0	10.5	5.0	5.4
Irrigation at 25 % F.C without silicon	0.33	0.33	143.6	155.7	61.0	61.8	15.9	16.2	8.0	6.4	3.3	3.7
Irrigation at 100 % F.C + 150 mg Si/ kg^{-1} soil	0.33	0.33	206.1	223.3	80.0	80.7	3.0	3.3	18.5	17.0	9.4	9.8
Irrigation at 75 % F.C + 150 mg Si/ kg^{-1} soil	0.33	0.33	191.7	203.6	77.0	77.9	4.1	4.4	17.1	16.0	8.0	8.4
Irrigation at 50 % F.C + 150 mg Si/ kg^{-1} soil	0.33	0.33	182.8	194.2	74.0	74.3	5.3	5.6	14.9	13.5	7.0	7.3
Irrigation at 25 % F.C + 150 mg Si/ kg^{-1} soil	0.33	0.33	160.2	166.1	65.0	65.0	7.1	7.5	10.1	8.5	4.5	4.8
New L.S.D at 5 %	**NS**	**NS**	**11.1**	**11.4**	**3.0**	**2.9**	**0.3**	**0.4**	**0.6**	**0.7**	**0.3**	**0.4**

F.C = Field capacity

Table (3): Total carotenoids and percentages of carbohydrates, N, P, K & Mg in the whole plant of Ewaise mango transplants grown with or without silicon at three levels of water content during 2011 and 2012 seasons.

Treatment	Total carotenoids (mg/ g^{-1} F.W)		Total carbohydrates %		N %		P %		K %		Mg %	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
Irrigation at 100 % F.C without silicon	4.5	4.0	16.0	16.7	1.62	1.71	0.25	0.30	1.31	1.40	0.71	0.69
Irrigation at 75 % F.C without silicon	4.0	3.5	14.9	15.6	1.41	1.50	0.21	0.26	1.12	1.21	0.65	0.63
Irrigation at 50 % F.C without silicon	2.5	2.0	12.0	12.7	1.15	1.25	0.14	0.19	0.99	1.08	0.55	0.53
Irrigation at 25 % F.C without silicon	1.5	1.0	9.1	9.8	1.01	1.11	0.08	0.12	0.91	1.00	0.41	0.38
Irrigation at 100 % F.C + 150 mg Si/ kg^{-1} soil	5.2	4.7	18.1	18.8	1.83	1.92	0.32	0.35	1.41	1.50	0.77	0.75
Irrigation at 75 % F.C + 150 mg Si/ kg^{-1} soil	4.6	4.1	16.0	16.7	1.55	1.65	0.27	0.31	1.23	1.33	0.71	0.69
Irrigation at 50 % F.C + 150 mg Si/ kg^{-1} soil	2.9	2.4	14.1	14.8	1.40	1.50	0.20	0.24	1.09	1.17	0.60	0.58
Irrigation at 25 % F.C + 150 mg Si/ kg^{-1} soil	1.8	1.3	11.2	12.0	1.14	1.29	0.14	0.16	0.97	1.06	0.47	0.45
New L.S.D at 5 %	**0.3**	**0.3**	**0.5**	**0.6**	**0.06**	**0.07**	**0.03**	**0.03**	**0.03**	**0.03**	**0.04**	**0.04**

F.C = Field capacity

Table (3): Si content and uptake of N, P, K, Mg & Si of Ewaise mango transplants grown with or without silicon at three levels of water content during 2011 and 2012 seasons.

Treatment	Si (mg/ g^{-1} dr)		N uptake (g/ plant)		P uptake (g/ plant)		K uptake (g/ plant)		Mg uptake (g/ plant)		Si uptake (g/ plant)	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
Irrigation at 100 % F.C without silicon	6.5	7.1	3.11	3.45	0.48	0.61	2.51	2.83	1.36	1.39	1.25	1.43
Irrigation at 75 % F.C without silicon	5.5	6.0	2.52	2.84	0.38	0.49	2.00	2.29	1.16	1.19	0.98	1.14
Irrigation at 50 % F.C without silicon	3.9	4.5	1.96	2.38	0.24	0.36	1.69	2.06	0.94	1.01	0.66	0.86
Irrigation at 25 % F.C without silicon	2.1	2.7	1.45	1.73	0.11	0.19	1.31	1.56	0.59	0.59	0.30	0.42
Irrigation at 100 % F.C + 150 mg Si/ kg^{-1} soil	11.5	12.1	3.77	4.29	0.66	0.78	2.91	3.35	1.59	1.67	2.37	2.70
Irrigation at 75 % F.C + 150 mg Si/ kg^{-1} soil	10.0	10.5	2.97	3.36	0.32	0.63	2.36	2.71	1.36	1.40	1.92	2.14
Irrigation at 50 % F.C + 150 mg Si/ kg^{-1} soil	8.5	9.0	2.56	2.91	0.37	0.47	1.99	2.27	1.10	1.13	1.55	1.75
Irrigation at 25 % F.C + 150 mg Si/ kg^{-1} soil	6.3	6.7	1.83	2.14	0.27	0.27	1.55	1.76	0.75	0.75	1.01	1.11
New L.S.D at 5 %	**0.5**	**0.6**	**0.55**	**0.51**	**0.07**	**0.08**	**0.15**	**0.18**	**0.15**	**0.16**	**0.17**	**0.15**

F.C = Field capacity

4. Discussion

It was suggested that silicon could increase drought tolerance of plants **(Epstein, 1999 and Ma, 2004)**. Plantation in drought conditions resulted in inhibiting plant photosynthesis through reducing internal CO_2 concentrations and stomatal conductance **(Matoh *et al*., 1991 and Gong *et al*., 2005).** Drought conditions increase the formation of reactive oxygen species such as superoxide, H_2O_2 and OH (**Sudhakar *et al*., 2001**). Plants posses efficient antioxidant defense systems for scavenging reactive oxygen species. The major antioxidant enzymes were superoxide dismutase, catalase, peroxidase and acid phosphlipase. Glycolate oxidase plays an important role in maintaining a high glutathione reducase/ reduced glutathione ratio in plants **(Liang *et al*., 2003 and Zhu *et al*., 2004).** Drought conditions increase the formation of reactive oxygen species that oxidizes photosynthetic pigments, membrane lipids, proteins and nucleic acids **(Smirnoff, 1993; Alscher *et al*., 1997; Yordanov *et al*., 2000 and Egert and Tevini, 2002).** Plants with high levels of constitutive or induced antioxidants have been reported to have greater resistance to this oxidative damage **(Sudhakar *et al*., 2001).** In the present study, drought stress inhibited the activates of antioxidant enzymes and included the accumulation of H_2O_2 which caused protein decomposition and oxidization, lipids peroxidation and decrease in photosynthetic pigment contents **(Gong *et al*., 2005).** Previous studies showed that Si increases the activities of antioxidant enzymes in the leaves that protect plant tissues from oxidative damage under drought conditions **(Gong *et al*., 2003b).**

Silicon is also known to increase drought tolerance in plants by maintaining plant water balance, photosynthetic activity, erectness of xylem vessels structure. A silicon- cuticle double layer formed on the leaf epidermal tissue is responsible for the action of Si in enhancing water potential. Also, Si is responsible for stimulating water transport and root growth **(Hattori *et al.*, 2005).**

Conclusion

It is beneficial for using silicon at 150 g/ kg^{-1} for mango cv. Ewaise transplants growing under drough conditions for producing vigorous plants.

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