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Response of Date Palm (*Phoenix dactylifera* L.) Seedlings to Foliar Application of Silicon under Different Irrigation Regimes

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Abstract. **In Saudi Arabia (SA), date palm seedlings experience aridity stress, which restrict their growth and potentially influence their future productivity. Previous studies showed a potential for the combination between deficit irrigation technique (DI) and silicon (Si) application to reduce irrigation water (IW) and improve water use efficiency (WUE) in various plants. In this study, growth parameters, chlorophyll content, and nutrient uptake were examined in 'Nabtet-Ali' date palm seedlings subjected to Si foliar application as K_2SiO_3 at 0, 5, and 10 mM under 100%, 80%, 0 and 60% of required IW. Seedlings under 100% IW exhibited the highest growth parameters followed by 80% IW and then 60% IW treatment that exhibited the lowest values. Si spray increased Si content in leaves and roots but with no effect on growth parameters. Chlorophyll b increased in plants under 80% and 60% IW; however, total chlorophylls were unaffected by IW regimes. Total chlorophylls remained constant but chlorophyll a/b ratio increased in Si treatments especially at 10 mM, suggesting Si involvements in stress-adaptive response. Seedlings under 100% IW had the highest relative water content (RWC) and membrane stability index (MSI) of leaves. RWC and MSI decreased by reducing IW regime with no effect of Si application. Leaf P, Mg, and Si levels were higher in Si treatments compared with nontreated seedlings, in contrast to K, Ca, and Na that were unaffected, although root P and K contents were higher at 100% and 80% IW. In conclusion, IW level exhibited detrimental effects on seedling growth; however, a limited effect of Si application.**

Expanding date palm cultivation in SA encounters critical challenges including limited IW and high evapotranspiration. Date palms require significant amounts of IW to thrive, despite being able to withstand tough environmental conditions like heat and salinity (Al-Qurashi et al. 2016; Youssef and Awad 2008). Adequate IW is necessary for optimal yield and quality of date palms (Alotaibi et al. 2023; Al-Qurashi et al. 2016; Ismail et al. 2014; Mattar et al. 2021). More than 85% of water consumption was attributed to the agricultural activities in SA (Al-Qurashi et al. 2016; Ismail et al. 2014). Thus, improving agricultural practices and increasing knowledge of water productivity are essential for effectively managing the limited water resources for farming. It was reported that extreme drought levels (40% and 60% ETc) significantly decreased leaf growth, dry weight, and various physiological and biochemical characteristics, in contrast to slight drought level (80% ETc) that induced minor influences on date palms (Ali-Dinar et al. 2023; Al-Qurashi et al. 2016; Ismail et al. 2014). Drought is a major environmental stress that leads to harmful impacts on plant development, growth, biochemical components, metabolic processes, and eventual crop production (Rao et al. 2016; Thorne et al. 2020). The lack of cell wall extension and growth caused by osmotic stress like drought leads to a complete halt or slowdown in plant growth as photosynthetic pigments, stomatal conductance, and CO_2 fixation, leading to a decrease in carbohydrate accumulation (Rao et al. 2016). DI is a technique by which the plants are provided with less water than their optimal needs, resulting in water saving through inducing a controlled level of drought stress, either intermittently or continuously throughout the growing season (Kirda 2002). It was reported that implementing DI on date palms in arid regions can enhance WUE and enhance fruit quality, yet may have a detrimental impact on yield (Al-Qurashi et al. 2016; Ismail et al. 2014; Mattar et al. 2021; Sabri et al. 2017). The practice of combining DI and Si application shows potential water management technique to reduce IW and improve WUE (Hattori et al. 2005; Kirda 2002; Pereira et al. 2002). Although Si is considered an unnecessary element for plant growth and development, Si fertilization provides positive impacts in various crops during the past decades (Alayafi et al. 2022; Tubana et al. 2016). Si fertilization enhanced the stability of plants against salinity and aridity stress by regulating water balance, supporting photosynthesis, maintaining leaf integrity, and preserving xylem vessel structure despite increased transpiration rates (Alayafi et al. 2022; Thorne et al. 2020). It is also accountable for promoting water transportation and root development under stress conditions, as well as maintaining an antioxidant defense system (Hattori et al. 2005; Melo et al. 2003). Previous studies showed that the Si application on fruit trees during dry periods lessened the detrimental effect of drought stress on development, pigmentation, and nutrition (Al-Wasfy 2013; Neumann and Zur-Nieden 2001). Accordingly, the current investigation aimed to evaluate the response of date palm seedlings to Si application under different IW regimes.

Materials and Methods

Experimental procedures. In Feb 2022, date seeds of 'Nabtet-Ali' variety were dipped in water in a water bath at 25 °C with air bubbling during 2 weeks to speed-up seed germination. Following radicle appearance, the seeds were individually transferred into 2-L plastic pots filled with potting compost (Kronen, Poland) and sand in a 1:1 ratio. The seedlings were grown in open air and full sun conditions (25 to 39 °C and relative humidity of 40% to 65%) and irrigated with water (electrical conductivity 0.5 mS·cm^{-1}) two times per week. In Feb 2023, a factorial completely random experimental design was adopted with three irrigation regimes (100%, 80%, and 60% of field capacity) and three levels of Si application (0, 5, and 10 mM) as K_2SiO_3 (SiO2 25% +

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K2O 10%) (Shanghai Macklin Biochemical, Co, LTD, Shanghai, China), in four biological replicates (three seedlings/replicate) per treatment. Si was foliarly applied one time each 2 months with a plastic hand sprayer until the entire seedling was wet. Tween 20, as a wetting agent, at 0.01% was added to all foliar solutions. The seedlings were also fertilized with N–P–K (20–20–20 plus trace elements) at 2.0 g/L water (100 mL/pot) once every 2 months for a period of 12 months. In Feb 2024, seedlings of all treatments were gently lifted out of pots, thoroughly rinsed by distilled water to remove dust on leaves and soil particles on roots, and dried using paper towels. The growth parameters including leaf number, length, and width and root number and length were recorded for each individual seedling in each replicate/treatment. Leaf disks were excised for chlorophyll, RWC, and electrolyte leakage measurements. Afterword, each seedling was separated into two portions, vegetative (above soil) and roots (below soil), with fresh weight calculations followed immediately by oven-drying at 70 °C in paper bags for 72 h for dry weight calculations.

Determination of chlorophyll. Chlorophylls were extracted in disks taken from samples of leaves by dimethyl sulfoxide (DMSO) solution and colorimetry measured as previously described in Youssef and Awad (2008).

RWC measurement. RWCs were calculated in leaf disk samples (0.5 cm diameter; 10 discs/replicate) omitting the midrib as detailed by Hayat et al. (2007).

Electrolyte leakage measurement in leaf disks and MSI calculation. Electrolyte leakage was quantified in leaf discs and expressed as MSI% according to Awad et al. (2017).

Determination of P, K, Mg, Ca, Na, and Si content in leaf and root samples. Samples of dry leaf and root were ground and then digested by H_2SO_4-H_2O_2 as oxidants, lithium sulphate to raise temperature of digestion, and selenium as catalyst (Parkinson and Allen 1975). Phosphorus content was colorimetry quantified (Shelton and Harper 1941). K and Na contents were quantified by the flame emission spectrophotometer and EDTA (ethylenediamine tetraacetic acid) titration was used to quantify the Ca and Mg contents. An inductively coupled plasma atomic emission analyzer (Varian-Vista-MPX, CCD simultaneous ICP-OES Axial, Palo Alto, CA, USA) was used for quantifying Si concentration.

Statistical analysis. The collected data were analyzed statistically (analysis of variance) as a factorial completely randomized design (CRD) including three replications by SAS (2013) software. Least significant differences at $P \leq 5\%$ were applied for comparisons of treatments means.

Results

Growth characteristics of seedlings. Leaf number of 'Nabtit-Ali' date palm seedlings was highest (eight leaves/seedling) at 100% IW followed by 80% IW treatment (6.75 leaves/seedling) and then 60% IW that exhibited the lowest leaf number (six leaves/seedling) (Table 1). Leaf width was significantly higher at 100% IW compared with other treatments. Leaf length was significantly higher at 100% (38.69 cm) and 80% (37.17 cm) IW than at 60% (34.92 cm) IW treatment. Height of the above-soil portion (including stem and leaves) was higher (46.33 cm) at 100% IW than the other IW treatments. Dry matter content was highest (48.34%) at 100% IW followed by 80% IW (43.54%) and then 60% IW treatment (36.20%) that exhibited the lowest dry matter level. On the other hand, Si application did not significantly affect these vegetative growth characteristics of date palm seedlings. The interaction effects between IW and Si treatments on vegetative characteristics were not significant (Table 1). Root number of date palm seedlings was highest (averaged nine roots/seedling) at 100% IW followed by 80% IW treatment (averaged 7.83 roots/seedling) and then 60% IW that exhibited the lowest root number (averaged 6.42 roots/seedling) than the other treatments (Table 2). Root length was highest (82.67 cm) at 100% IW followed by 80% IW (53.58 cm) and 60% IW treatment that exhibited the lowest root length (46.17 cm) than the other treatments. Dry matter content of seedling root was highest (49.96%) at 100% IW followed by 80% IW (41.11%) and 60% IW treatment (34.27%) that exhibited the lowest dry matter level than the other treatments. Si application significantly decreased root number compared with nontreated seedlings. However, both root length and dry matter content were not significantly affected by Si application. The interaction effects between IW and Si factors on root growth characteristics were not significant (Table 2).

Chlorophyll content, RWC, and MSI of date palm seedlings. Chlorophyll a and total chlorophyll in seedling leaves were insignificantly influenced by IW treatments (Table 3). Chlorophyll b was higher at 100% IW compared with the other treatments. However, chlorophyll a/b ratio was higher at the lower IW levels (80% and 60% IW) than 100% IW treatment. RWC was significantly higher at 100% IW compared with the other treatments. MSI of leaf was highest (80.44) at 100% IW followed by 80% IW (76.58) and then 60% IW that exhibited the lowest MSI (72.77) than the other treatments. Si application, especially at 10 mM, significantly increased chlorophyll a/b ratio than nontreated seedlings with no significant effect on chlorophyll a, b, and total chlorophyll. There was no significant interaction effect between IW and Si on chlorophyll components and RWC (Table 3).

Mineral content of seedlings. Leaf P content was significantly higher at 60% IW in comparison with other treatments (Table 4). K content was significantly higher at 100%

Table 1. Effect of irrigation regimes and silicon foliar application on vegetative growth of 'Nabtit-Ali' date palm seedlings.

	Treatments	Leaf number	Leaf width (cm)	Leaf length (cm)	Height above soil (cm)	Dry matter content (%)
Irrigation water (IW)	100%	8.00 a	4.43 a	38.69 a	46.33 a	48.34 a
	80%	6.75 b	3.86 b	37.17 a	41.67 b	43.54 b
	60%	6.00 c	3.71 b	34.92 b	40.75 b	36.20 c
F-test		***	**	*	**	***
LSD (0.05)		*0.37*	*0.23*	*2.20*	*3.91*	*2.85*
Silicon (Si)	0	6.92	3.88	38.08	42.42	42.62
	5 mM	6.92	4.14	36.83	44.25	42.62
	10 mM	6.92	3.98	35.86	42.08	42.83
F-test		*NS*	*NS*	*NS*	*NS*	*NS*
LSD (0.05)		—	—	—	—	—
IW × Si						
F-test		*NS*	*NS*	*NS*	*NS*	*NS*

Comparisons between means were made by the least significant difference (LSD) at $P \leq 5\%$. Means within each column followed by the same letter are not significantly different. *, **, and ***, significant at $P \leq 0.05$, 0.01, and 0.001, respectively; NS, not significant; —, not calculated.

Table 2. Effect of irrigation regimes and silicon foliar application on root growth characteristics of 'Nabtit-Ali' date palm seedlings.

	Treatments	Root number	Root length (cm)	Dry matter content (%)
Irrigation water (IW)	100%	9.00 a	82.67 a	49.96 a
	80%	7.83 b	53.58 b	41.11 b
	60%	6.42 c	46.17 c	34.27 c
F-test		***	***	***
LSD (0.05)		*0.49*	*2.61*	*3.28*
Silicon (Si)	0	8.17 a	59.33	42.31
	5 mM	7.50 b	61.75	42.73
	10 mM	7.58 b	61.33	40.29
F-test		**	*NS*	*NS*
LSD (0.05)		*0.49*	—	—
IW × Si				
F-test		*NS*	*NS*	*NS*

Comparisons between means were made by the least significant difference (LSD) at $P \leq 5\%$. Means within each column followed by the same letter are not significantly different. ** and ***, significant at $P \leq 0.01$ and 0.001, respectively; NS, not significant; —, not calculated.

Table 3. Effect of irrigation regimes and silicon foliar application on chlorophyll components (Chl A, B, Total Chl, and Chl A/B), leaf relative water content (RWC) and leaf membrane stability index (MSI) of 'Nabtit-Ali' date palm seedlings.

	Treatments	Chl A	Chl B	Total Chl	Chl A/B	RWC	MSI
Irrigation water (IW)	100%	1.45	0.73 a	2.18	2.02 b	60.63 a	80.44 a
	80%	1.54	0.65 ab	2.19	2.41 a	46.83 b	76.58 b
	60%	1.49	0.61 b	2.10	2.53 a	46.64 b	72.77 c
F-test		*NS*	**	*NS*	**	***	***
LSD (0.05)		—	*0.09*	—	*0.30*	*3.30*	*1.98*
Silicon (Si)	0	1.49	0.72	2.20	2.12 b	51.42	77.30
	5 mM	1.46	0.65	2.11	2.33 ab	51.56	76.43
	10 mM	1.53	0.62	2.16	2.51 a	51.12	76.06
F-test		*NS*	*NS*	*NS*	**	*NS*	*NS*
LSD (0.05)		—	—	—	*0.30*	—	—
IW × Si							
F-test		*NS*	*NS*	*NS*	*NS*	*NS*	***

Comparisons between means were made by the least significant difference (LSD) at $P \leq 5\%$. Means within each column followed by the same letter are not significantly different. ** and ***, significant at $P \leq 0.01$ and 0.001, respectively; NS, not significant; —, not calculated.

and 80% IW than the low 60% IW treatment. Both Mg and Si contents were significantly higher at 80% IW than the other IW treatments. However, Ca and Na contents were not significantly affected by IW treatments. The content of P was significantly higher at 10 mM Si than the other treatments. Mg and Si contents were significantly higher in Si treatments than the nontreated seedlings. However, leaf K, Ca, and Na contents were not significantly affected by Si application (Table 4). On the other hand, the significant interaction effects between IW and Si on P, K, and Ca declared that, at 80% IW treatment, P content was highest at 10 mM K_2SiO_3 application; however, at 60% IW it was highest at 5 mM K_2SiO_3 treatments (Table 5). K content was highest at 100% and 60% IW with K_2SiO_3 application, in contrast to its content at the 80% IW where Si application exhibited the lowest K content. Ca content was significantly higher at 100% IW with K_2SiO_3 application than non–Si-treated seedlings. However, at 80% and 60% IW, K_2SiO_3 application exhibited no significant effect on leaf Ca content (Table 5). However, the significant interaction between IW and Si on leaf MSI declared that Si application significantly retain higher MSI only at 80 and 60% IW treatments than at 100% IW (Table 5). Root P content was highest at 80% followed by 100% IW and at lowest level at 60% IW treatment (Table 6). K content was significantly higher at 100% IW than the other treatments. Mg content was significantly higher at 60% IW than the other IW treatments. However, Ca content was not significantly affected by IW treatments. Na content was significantly lower at 100% IW than the other treatments. Si content was significantly higher at 80% than the other IW treatments.

K_2SiO_3 application showed no significant effect on root mineral content except for Si that was higher at K_2SiO_3 treatment than the control. Moreover, there were no significant interaction effects between IW and Si on root mineral content (Table 6).

Discussion

The sustainability of agriculture in arid regions faces a significant challenge due to environmental stresses including drought and salinity. The growth and productivity of date palms in such regions are greatly restricted by a lack of IW. In the current study, date palm seedlings were irrigated with three different levels (100%, 80%, and 60% of field capacity) and three levels of Si foliar application (0, 5, and 10 mM). The results revealed that seedlings that received 100% IW exhibited the highest growth characteristics (including leaf and root parameters) followed by 80% IW and then 60% IW treatment that showed the lowest. An optimal level of IW to date palm seedlings is crucial to sustain healthy vegetative growth to establish new orchards with future economical productivity. It is known that intensive irrigation encourages root rot development (Alwahshi et al. 2019) and slows down the growth of roots and causes nutrient deficiencies due to leaching out of nutrients from the rhizosphere, especially in sandy soils that are common in SA. Conversely, inadequate IW causes drought stress that limits tree growth and future productivity (Al-Qurashi et al. 2016; Mattar et al. 2021; Sabri et al. 2017). Thus, in arid regions, additional research is critically required to enhance water utilization for a sustainable agriculture system and to limit IW loss. The higher vegetative growth parameters at 100% IW than the other levels possibly connected with the moisture increase in soil as for water supply. The current data agree with those of Al-Qurashi et al. (2016) on 5-year-old 'Barhee' date palm trees produced via tissue culture procedure and transplanted in an open orchard supplied with different levels of IW as well as those of Arzani and Arji (2002) on young potted olive trees exposed to water stress and DI. Tree growth and yield are greatly decreased in situations in which water consumption is restricted, primarily because of insufficient water supplies. Among the main processes that are hampered by drought are cell elongation, assimilation production rate, and photosynthesis capacity. This may be due to secondary consequences like oxidative stress and damage to proteins and pigments involved in photosynthetic processes, or it may be the consequence of direct restrictions like mesophyll and stomata conductance decrease. Numerous studies indicated that stomatal limitation is a significant inhibitor of photosynthesis under drought stress (Alrasbi et al. 2010; Renninger et al. 2009; Youssef and Awad 2008). Accordingly, various horticultural practices have been suggested on various crops, such as the application of Si, amino acids, and calcium that can enhance plant tolerance ability to IW reduction without limitation in plant growth and yield characteristics (Bassiony et al. 2018; Upadhyaya et al. 2011). Numerous studies have demonstrated the significance of Si in plant biology, where it aids in the plant's ability to mitigate various biotic and abiotic challenges (Agarie et al. 1998; Meunier et al. 2017). It is also recognized for enhancing stability of plants against drought by preserving the water equilibrium of the plant and the xylem channel structure under conditions of heavy transpiration (Agarie et al. 1998; Merwad et al. 2018; Howladar et al. 2018). However, in the current study, Si application increased Si content in both leaves and roots of date palm seedlings but showed no significant effect on vegetative growth including root growth under the different IW treatments. Despite the significant increase of chlorophyll b in leaves under 80% and 60% IW, total chlorophyll insignificantly increased by IW treatments. Chlorophyll a/b ratio of the control seedlings was typical to healthy C_3 plants, but drastically increased with decreasing IW level. The current investigation declared that Si application, especially at 10 mM, efficiently increased chlorophyll a/b

Table 4. Effect of irrigation regimes and silicon foliar application on P, K, Mg, Ca, Na (g/kg dry weight), and Si (mg/kg dry weight) contents in leaf of 'Nabtit-Ali' date palm seedlings.

	Treatments	P	K	Mg	Ca	Na	Si
Irrigation water (IW)	100%	0.30 b	10.34 a	28.94 b	52.39	0.20	0.24 b
	80%	0.30 b	10.28 a	35.72 a	57.00	0.20	0.32 a
	60%	0.39 a	8.62 b	29.89 b	55.61	0.20	0.21 b
F-test		***	***	**	*NS*	*NS*	***
LSD (0.05)		*0.03*	*0.92*	*3.75*	—	—	*0.04*
Silicon (Si)	0	0.32 b	9.82	25.11 c	53.94	0.20	0.12 b
	5 mM	0.32 b	9.85	37.11 a	54.28	0.20	0.30 a
	10 mM	0.36 a	9.58	32.33 b	56.78	0.20	0.33 a
F-test		**	*NS*	***	*NS*	*NS*	***
LSD (0.05)		*0.03*	—	*3.75*	—	—	*0.04*
IW × Si							
F-test		***	**	*NS*	**	*NS*	*NS*

Comparisons between means were made by the least significant difference (LSD) at $P \leq 5\%$. Means within each column followed by the same letter are not significantly different. ** and ***, significant at $P \leq 0.01$ and 0.001, respectively; NS, not significant; —, not calculated.

Table 5. The interaction effects of irrigation regimes and silicon foliar application on leaf P, K, and Ca (g/kg dry weight) and membrane stability index (MSI) of 'Nabtit-Ali' date palm seedlings.

	Irrigation water level			Irrigation water level		
	100%	80%	60%	100%	80%	60%
Silicon application		Leaf P			Leaf K	
0	0.33 cd	0.27 ef	0.36 bc	9.10 bc	10.37 ab	9.98 ab
5 mM	0.28 ef	0.25 f	0.43 a	10.95 a	7.78 c	10.05 ab
10 mM	0.30 df	0.39 b	0.39 b	10.97 a	7.72 c	10.80 a
LSD (0.05)		0.04			1.59	
		Leaf Ca				
0	45.33 c	57.83 a	58.67 a			
5 mM	57.83 a	56.00 ab	49.00 bc			
10 mM	54.00 ab	57.17 a	59.17 a			
LSD (0.05)		7.70				
		MSI				
0	80.55 a	74.45 b	70.29 c			
5 mM	80.57 a	81.05 a	74.28 b			
10 mM	80.19 a	74.24 b	73.75 b			
LSD (0.05)		3.42				

Comparisons between means were made by the least significant difference (LSD) at $P \leq 5\%$. Means within each column followed by the same letter are not significantly different.

ratio than nontreated seedlings with no effect on chlorophyll a, b, and total chlorophyll. This result might suggest the involvement of Si in improving the plant's stress-adaptive response by maintaining a higher chlorophyll a/b ratio. It has been reported that chlorophyll a, b, and total chlorophyll (a + b) contents decreased under drought treatments, whereas the chlorophyll a/b ratio increased in *Lycium ruthenicum* Murr. seedlings (Guo et al. 2016). It is known that the energy transduction core of the photosynthesis system contains chlorophyll a and chlorophyll b is more linked to proteins in the outer antenna complexes, which also capture light energy. The chlorophyll a/b ratio increases could be a component of the plant's stress-adaptive response (Youssef and Awad 2008). Chlorophyll b is involved in light harvesting, while chlorophyll a is usually linked to reaction centers involved in photosynthesis. Under stressful conditions, plants such as date palm seedlings can maximize photosynthetic efficiency by increasing the chlorophyll a/b ratio, which guarantees maximal energy collection at a lower capacity for light harvesting (Youssef and Awad 2008). RWC, which expresses the percentage of water in a leaf as a percentage of the total quantity of water that a leaf can retain at maximum turgor, is a widely used parameter for assessing the water balance in plant leaves. In the present study, seedlings that received 100% IW showed increased RWC in leaf tissues and continued to have more stable cell membranes (higher MSI). Osmotic adjustments and other stress-resilient adaptations can preserve metabolic activity, cell turgidity, and membrane integrity in leaf tissues by maintaining RWC under normal or healthy conditions (Slabbert and Krüger 2014). In this investigation, RWC and MSI decreased as a result of the decrease in IW supply, but neither of these variables was impacted by Si spray. However, our results contradict with previously published studies in which exogenous Si maintained plant cell membrane stability by reduction of lipid peroxidation and/or malondialdehyde in various plant species under stress such as rice (Agarie et al. 1998), grapevine rootstock (Soylemezoglu et al. 2009), wheat (Howladar et al. 2018; Kabir et al. 2016), and cowpea (Merwad et al. 2018). In the current study, leaf P, Mg, and Si contents were higher in Si treatments than the nontreated seedlings, in contrast to K, Ca, and Na that were unaffected; in root, both P and K contents were higher at 100% and 80% IW treatments. In partial confirmation, it was reported that Si was essential for maintaining the mineral balance in plants during stressful conditions by enhancing nutrient uptake and supporting plants to conserve water (Zhu and Gong 2014). Liu et al. (2014) proposed a mechanism by which Si enhances drought stress tolerance of plants that involves increasing the absorption and transport of water into plants through an increase in root hydraulic conductance. This is referred to as Si-mediated upregulation of the transcription of certain aquaporin genes. It was concluded that IW level exhibited detrimental effects on seedling growth; however, with limited effect of Si spray.

Table 6. Effect of irrigation regimes and silicon foliar application on P, K, Mg, Ca, Na (g/kg dry weight) and Si (mg/kg dry weight) contents in root of 'Nabtit-Ali' date palm seedlings.

	Treatments	P	K	Mg	Ca	Na	Si
Irrigation water (IW)	100%	0.36 b	6.20 a	25.50 b	52.00	0.20 b	0.13 b
	80%	0.46 a	5.09 b	23.72 b	47.61	0.30 a	0.32 a
	60%	0.31 c	5.37 b	30.39 a	49.36	0.32 a	0.15 b
F-test		***	**	**	*NS*	***	***
LSD (0.05)		*0.04*	*0.67*	*4.17*	—	*0.04*	*0.05*
Silicon (Si)	0	0.37	5.37	25.00	47.39	0.25	0.10 c
	5 mM	0.36	5.80	27.06	48.69	0.28	0.21 b
	10 mM	0.39	5.49	27.56	52.89	0.28	0.29 a
F-test		*NS*	*NS*	*NS*	*NS*	*NS*	***
LSD (0.05)		—	—	—	—	—	*0.05*
IW × Si							
F-test		*NS*	*NS*	*NS*	*NS*	*NS*	*NS*

Comparisons between means were made by the least significant difference (LSD) at $P \leq 5\%$. Means within each column followed by the same letter are not significantly different. ** and ***, significant at $P \leq 0.01$ and 0.001, respectively; NS, not significant; —, not calculated.

Conclusion

The current investigation declared that IW regimes have detrimental effects on date palm seedling growth, in contrast to Si foliar application that showed only a limited effect. The highest growth parameters were achieved in seedlings under 100% IW followed by 80% IW and the lowest was at 60% IW. Seedlings under 100% IW exhibited higher leaf RWC and MSI. Total chlorophyll content was unaffected by IW level but lowering IW or Si application increased chlorophyll a/chlorophyll b ratio. RWC and MSI decreased by decreasing IW level with no effect of Si application. Si foliar spray increased Si content in leaves and roots while IW and Si spray produced variable results on other mineral contents of both leaves and roots.

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