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RESEARCH ARTICLE

SILICON ALLEVIATES ADVERSE EFFECT OF DROUGHT STRESS INDUCED BY POLYETHYLENE GLYCOL (PEG 8000) ON SEED GERMINATION AND SEEDLING GROWTH OF DURUM WHEAT VARIETIES

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ABSTRACT

The effect of Silicon treatments on 11 durum wheat (*Triticum durum* Desf.) seed germination under *in vitro* drought stress conditions was studied. The laboratory experiment was performed using a factorial completely randomized design with three levels of drought stress (0, 100 and 200 g/l PEG8000) and five Silicon concentrations (0, 5, 10, 15 and 20 mg/l Si) with three replications for each treatment. Fresh weight, dry weight, germination percentage, seedling length and vigor index were measured under the experiment conditions. Variance analysis results (ANOVA) showed highly significant ($p<0.001$) differences between treatments and varieties for all traits. It was observed that PEG concentrations decrease seed germination and seedling growth traits and that adding Si mitigates PEG effects as a significant increase especially with highest Si concentrations (15 and 20 mg/l). Silicon increase fresh weight, dry weight, germination percentage, seedling length and vigor index by 25 %, 21.42 %, 12.67 %, 17.45 %, 164.67 % and 143.12 % when the Si concentration was 0 mg/l and 20 mg/l respectively. It is concluded that Si addition is beneficial to improve durum wheat seed germination and plant growth under drought stress.

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INTRODUCTION

Seed germination and seedling growth are among the most important plants growth stages for plant establishment. In arid and semi arid area, these stage are extremly affected by abiotic stresses mainly drought (Almaghrabi, 2012; Siddiqui and Al-Whaibi, 2014; Jorenush and Rajabi, 2015). In these cases, Silicon can alleviates environmental stresses effects. In nature, Silicon is always coupled to an oxygen molecule and thereby forms SiO2 and considered as a functional nutrient (Bouzoubaâ, 2005). In the biosphere Silicon exists mostly in three forms: amorphous (Si); silica gel and ortho silicic acid (OSA: Si (OH_4)). The OSA is a neutral, small molecule with low solubility (0.05 - 5 mg Si/L); its stability depends on pH, concentration and temperature (Sommer *et al*., 2015).

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Meena *et al*. (2014) showed that Si is absorbed by plants in the form of monosilicic acid, also called orthosilicic acid $[H_4SiO_4]$ from the soil. Sugarcane absorbs the biggest amount of silicon (300–700 kg of Si ha-1), followed by rice (150–300 kg of Si ha-1), and wheat (50–150 kg of Si ha-1). Silicon fertilization has the potential to mitigate the adverse effects of environmental stress and to decrease soil nutrient depletion. So, it reduces use of phytosanitary and NPK fertilizers (Guntzer *et al*., 2012). It improves soil fertility by advanced water, physical and chemical soil characteristics. Under water deficit, Silicon is recommended to keep the mineral equilibrium (Shi *et al*., 2014). Silicon effects yield by its deposition under the leaf epidermis, so it results a physical mechanism of defense, phenols production causing phytoalexin production, decreases water losses (transpiration) and increases plant photosynthesis capacity (Ahmad *et al*., 2012). Toledo *et al*. (2012) reported that silicon advantageous effects were observed especially in Si accumulating-grasses. Si levels in wheat and oat, is higher than 1%. Beneficial effects of

Silicon (Si) on plants are well illustrated (Guntzer *et al*., 2012 and Almutairi, 2016). Nevertheless, information about silicon effects, under water stress conditions, on seed germination are not so available (Shi *et al*., 2014). The aim of the current study was to evaluate the effect of silicon on durum wheat seed germination under drought stress induced by the chemical product poly ethylene glycol (PEG8000).

MATERIAL AND METHODS

Plant materials and treatments

Eleven durum wheat cultivars were used in the study: Maâli, Mahmoudi, Om rabiaa, Karim, Nasr, Salim, Maghrbi, Ben bechir, Souri, Agili glabre and Azizi. Seeds were initially sterilized with 12% sodium hypochlorite for 5 min and then rinsed twice with distilled water for 5 min each rinse and then transferred to 90-mm diameter plastic Petri dishes (10 seeds per dish) on filter paper moistened with fifteen different solutions. Experiment was performed using a factorial completely randomized design with three levels of drought stress (0, 100 and 200 g/l PEG8000) and five Silicon concentrations (0, 5, 10, 15 and 20 mg/l Si) with three replications for each treatment. This experiment was conducted in a germination programmed incubator with constant temperature at 22 ±2 C and relative humidity of 50%, and the culture lasted for 7 days. Every morning, 3 ml of each solution was added into the corresponding Petri dish.

Treatments

PEG and Silicon treatments were imposed simultaneously:

- T0 : 0 (PEG) + 0 (Si) ; T1 : 0 (PEG) + 5 mg (Si)
- T2 : 0 (PEG) + 10 mg (Si) ; T3 : 0 (PEG) + 15 mg (Si)
- T4 : 0 (PEG) + 20 mg (Si) ; T5 : 100 g/l (PEG) + 0 (Si)
- T6 : 100 g/l (PEG) + 5 mg (Si) ; T7 : 100 g/l (PEG) + 10 (Si)
- T8 : 100 g/l (PEG) + 15 mg (Si) ; T9 : 100 g/l (PEG) + 20 (Si)
- T10 : 200 g/l (PEG) + 0 (Si) ; T11 : 200 g/l (PEG) + 5 mg (Si)
- T12 : 200 g/l (PEG) + 10 mg (Si) ; T13 : 200 g/l (PEG) + 15 mg (Si)
- T14 : 200 g/l (PEG) + 20 mg (Si)

Measurements

Two germination parameters: finally germination percentage and germination energy. Seeds were considered to be germinated when the radicle emerged through the seed coat and reached more than 2 mm in length. Germination energy was the percentage of germinated seeds unregistered after 4 days of the experiment relative to the total number of seeds tested (Ruan *et al*., 2002).

Germination percentage = (total number of seeds germinated/total number of seeds observed) × 100

Four seedling growth parameters: seedling fresh weight, seedling dry weight, seedling (root+ shoot) length and vigor index which is calculated by the following formula (Vashisth and Nagarajan, 2010).

Vigor index = germination % × mean of seedling length (shoot + root)

Statistical analysis

Data were statistically analyzed with SPSS software ver. 16.0 (IBM SPSS Statistics; SPSS Inc., SPSS for Windows, 2007, Chicago, USA) software. Means comparison was performed using Tukey's multiple range test at the 0.05 and 0.01 level.

RESULTS AND DISCUSSION

Growth parameters of all 11 durum wheat cultivars: Fresh weight, dry weight, germination percentage, germination energy, seedling length (shoot + root) and vigor index are represented in Table 1.

Table 1. Variance analysis of fresh weight, dry weight, germination percentage, germination energy, seedling length (shoot + root) and vigor index of 11 durum wheat varieties under 15 treatments

Variance Sources	df	Fresh weight (g)	Dry weight (g)	Germination percentage	Germination energy	Seedling length (cm)	Vigor index
Treatments	14	73.92***	19.47***	25.13***	23.95***	399.81***	130.39***
Varieties	10	27.83***	19.74***	38.95***	45.49***	32.61***	50.82***
Treatments × varieties	140	2.42***	1.52**	2.42***	2.64***	3.17***	3.30***

Significance level: ** :p<0.01;*** :p<0.001.

Table 2. Means comparison of different treatments for all studied traits

			Variance sources					
			Fresh weight (g)	Dry weight (g)	Germination percentage	Germination energy	Seedling length (cm)	Vigor index
Treatments	0 g/l PEG	0 mg Si (T0)	0.74 bcd	0.18 a	67.12 abc	61.21 abc	22.23 abc	1413.77 abc
		5 mg Si (T1)	0.81 abc	0.19 a	68.03 abc	62.27 abc	23.12 abc	1463.78 ab
		10 mg Si (T2)	0.85 ab	0.20 a	68.18 abc	63.71 abc	24.20 a	1563.09 a
		15 mg Si (T3)	0.85 ab	0.20 a	70.91 a	65.00 ab	23.56 ab	1560.86 a
		20 mg Si (T4)	0.89 a	0.20 a	69.70 ab	66.06 a	23.69 ab	1565.56 a
	100 g/l PEG	0 mg Si (T5)	0.61 d	0.12 c	52.42 de	48.18 def	2.64 d	138.90 e
		5 mg Si (T6)	0.69 cd	0.14 bc	56.06 cd	52.42 cde	21.07 c	1113.85 d
		10 mg Si (T7)	0.69 cd	0.14 bc	56.36 cd	53.64 bcd	20.90 c	1187.87 cd
		15 mg Si (T8)	0.79 abc	0.17 ab	57.58 bcd	54.55 abcd	20.69 c	1156.14 cd
		20 mg Si (T9)	0.73 cd	0.18 a	60.61 abc	57.58 abcd	21.70 bc	1284.51bcd
	200 g/l PEG	0 mg Si (T10)	0.21 e	0.12 c	34.85 f	31.21 g	1.20 d	58.98 e
		5 mg Si (T11)	0.23 e	0.12 c	35.45 f	33.94 g	1.85 d	93.83 e
		10 mg Si (T12)	0.24 e	0.12 c	42.42 ef	40.00 fg	1.56 d	70.91 e
		15 mg Si (T13)	0.30 e	0.12 c	41.21 ef	39.39 fg	2.14 d	101.33 e
		20 mg Si (T14)	0.33 e	0.13 c	43.64 ef	41.52 efg	23.63 ab	1068.36 d

Means with similar letter(s) in each trait are not significantly different.

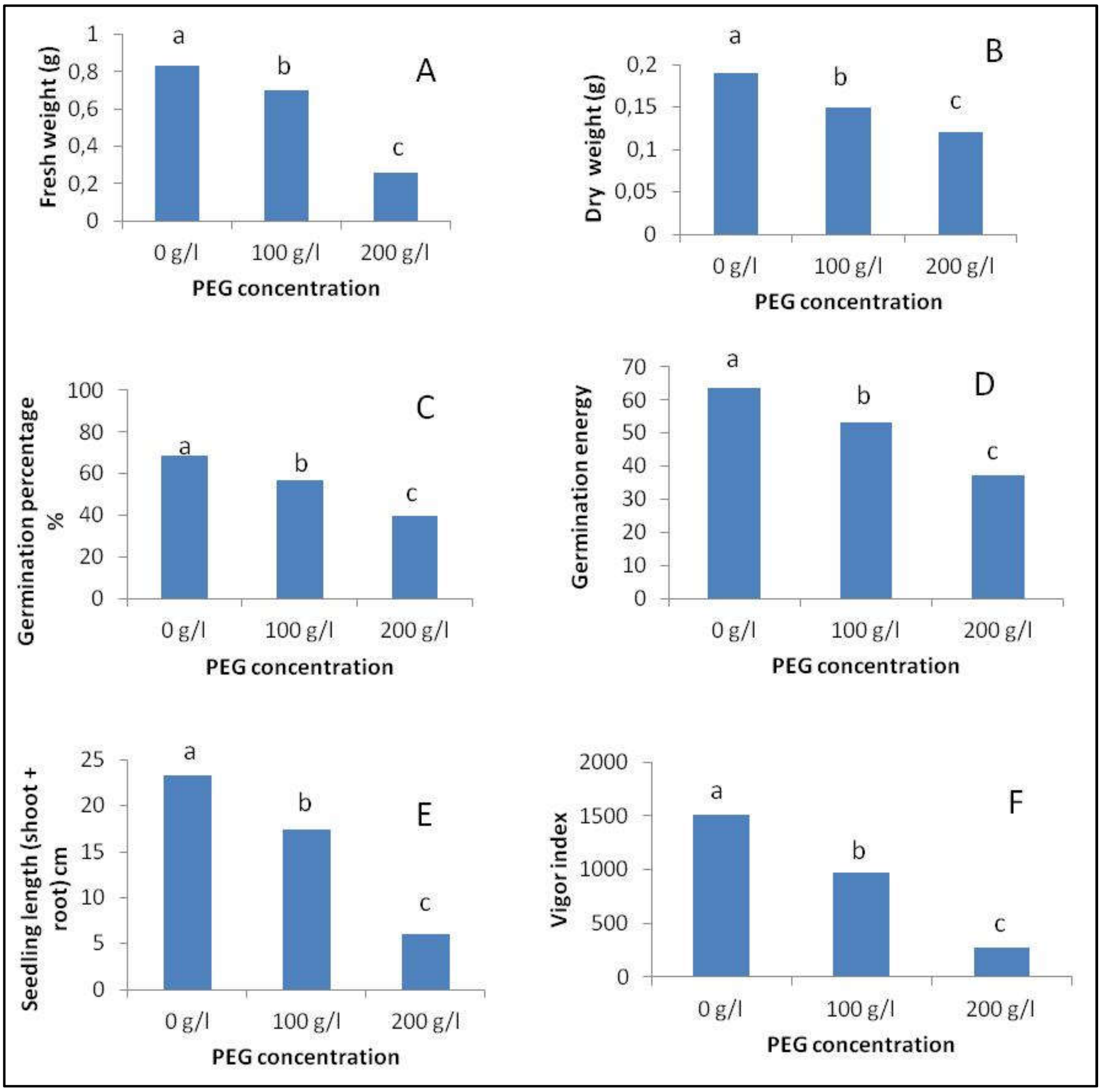

Figure 1. Polyethylene (PEG 8000) levels effects on fresh weight (A), dry weight (B), germination percentage (C), germination energy (D), seedling length (E) and vigor index (F) of 11 durum wheat varieties

All these traits were highly significant ($P < 0.001$) affected by Si treatments and varieties. Also, a significant ($p<0.01$; $p<0.001$) interaction between treatment and varieties was observed for these traits. Increasing water stress level reduce significantly all studied traits, lowest values of fresh weight (0.25 g),dry weight (0.12 g), germination percent (39.52 %), germination energy (37.21), seedling length (6.08 cm) and vigor index (278.58) were obtained under 200 g/l PEG8000 (Figure 1). Compared to the no stressed regimes, Bouzoubaâ (2005) concluded that drought stress application reduces significantly germination percentage, root fresh weight and root dry weight. Indeed, Chachar *et al*. (2014) which reported that seed vigor index is among the most sensitive traits to water stress. In this experiment, vigor index increase by 443.25 % from 200g/l to 0 g/l PEG8000. In this context, Abdoli and Saeidi (2012) showed also that water stress decreased seedling vigor index from 21.2 to 16.5 percent in nine wheat cultivars. In our study, increasing PEG concentrations level during growth seedling restrains wheat seedling developmental traits and survival. Same results are obtained by Almaghrabi (2012) and Barzegar Ghajari *et al*. (2015). Adding silicon to the medium of durum wheat seed germination under PEG levels causes an improvement on seed germination and seedling growth characteristics (Table 2 and Figure 2). In fact, Silicon increase fresh weight, dry weight, germination percentage, seedling length and vigor index by 25 %, 21.42 %, 12.67 %, 17.45 %, 164.67 % and 143.12 % when the Si concentration was 0 mg/l and 20 mg/l respectively (figure 2).This influence is more effective under highest Si concentration (15 and 20 mg/l). These results corroborate with those of Hmeed *et al*. (2013) which reported that Si efficiently improved germination energy, seedling vigor index, shoot length and root length under drought stress induced by polyethylene glycol, in wheat. In this study, Silicon enhances drought plant tolerance in juvenile stage (germination and seedling stage).

According to Rizwan *et al*. (2015) Si increased germination, plant development, and biomass accumulation by increasing photosynthesis under water stress conditions. This nutriment augment water uptake and helps plant to more dry weight and higher yield production (Ahmed, 2013). Similar results were also founded by Liu *et al*. (2014) in Sorghum bicolor L. These beneficial effects could be due to the increase of plant mineral nutrients, gas exchange modification which return to osmotic adjustment, stress reduction and gene expression modification in plants.

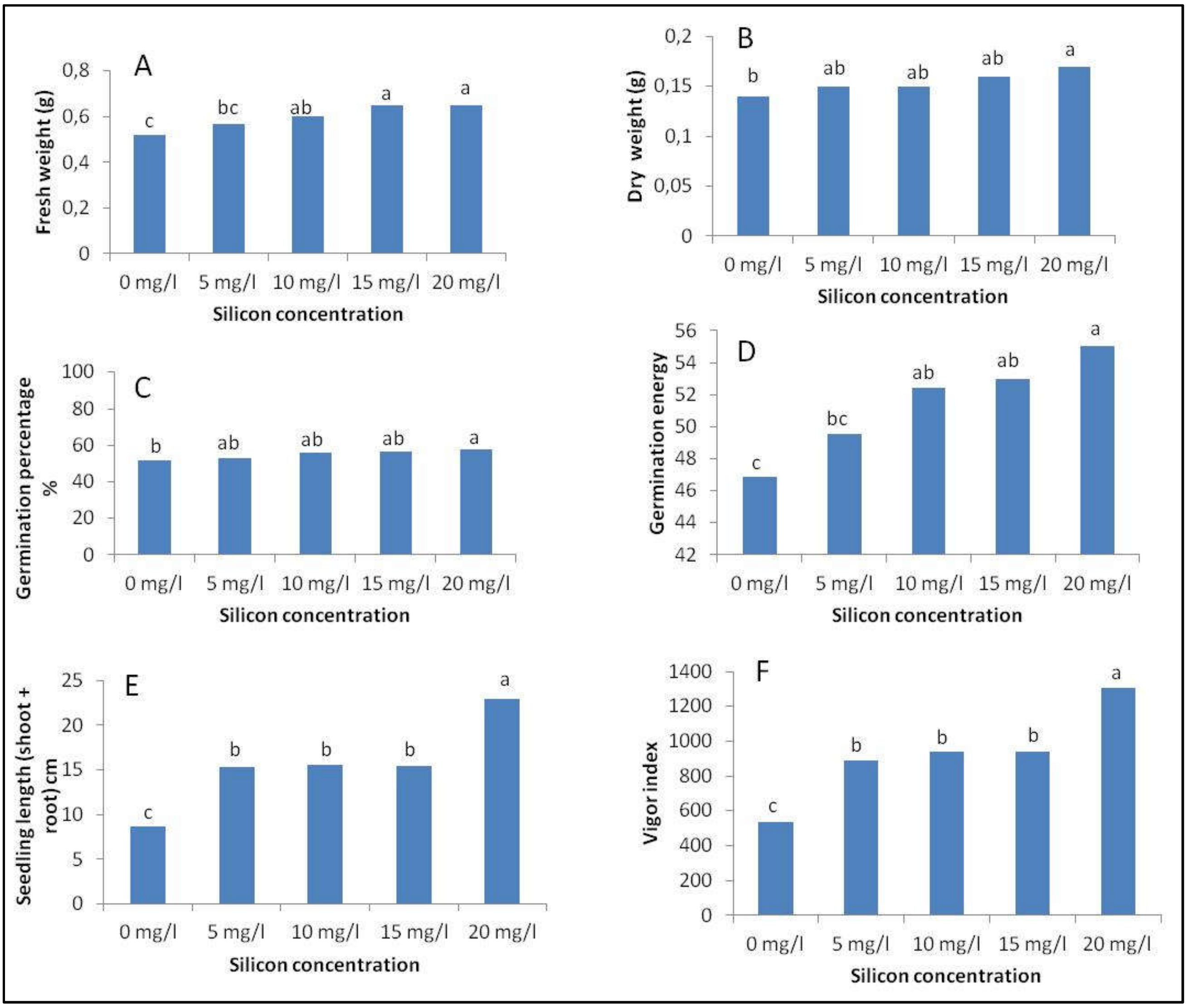

Figure 2. Effect of Silicon levels on fresh weight (A), dry weight (B), germination percentage (C), germination energy (D), seedling length (E) and vigor index (F) of 11 durum wheat varieties

Conclusion

The use of Silicon alleviates drought stress effects on durum wheat varieties. It increases fresh weight, dry weight, germination percentage, germination energy, seedling length and vigor index. These effects must be more studied and explained by physiological plant response.

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