University of Birjand

تنشهای محیطی در علوم زراعی
Environmental Stresses In Crop Sciences
Vol. 14, No. 3, p. 665-674
Fall 2021
http://dx.doi.org/10.22077/escs.2020.2805.1728

Original article

The effect of silicon on phosphorus uptake and wheat growth under moisture stress in a calcareous soil

Z. Zandi Gouharrizi[1], R. Khorasani[2*], A. Halajnia[3]
1. Former graduate student of Soil Science, College of Agriculture, Ferdowsi University of Mashhad, Iran
2. Associate Professor, Department of Soil Science, College of Agriculture, Ferdowsi University of Mashhad, Iran
3. Assistant Professor, Department of Soil Science, College of Agriculture, Ferdowsi University of Mashhad, Iran

Received 17 July 2019; Accepted 7 January 2020

Extended abstract

Introduction

Drought stress is one of the major physical stresses that have adverse effects on plant growth and metabolic processes such as nutrient uptake. Some researchers reported that silicon can improve plant growth and regulation of phosphorus uptake under drought stress. But Gao et al. (2004) did not observe a significant increase in fresh and dry weight under water-deficit stress induced by polyethylene glycol in maize. On the other hand, silicon did not have a significant effect on shoot dry matter and phosphorus concentration in wheat flag leaves under non-stressed condition (Sarto et al., 2014). Therefore, due to the increase in consumption of silicon fertilizer in our country to cope with drought stress, this experiment was conducted to investigate the influence of silicon on phosphorus uptake and wheat growth under water deficient conditions.

Materials and methods

A three-factor experiment was carried out in a completely randomized design with three replications in research greenhouse of ferdowsi university of Mashhad. The experiment factors were three levels of silicon (0, 50 and 150 mg kg^{-1}), three levels of phosphorus (0, 25 and 50 mg kg^{-1}) and two levels of moisture stress (45 and 100% of field capacity). Soil samples were taken from 0-30 cm depth. The pots were filled with 5 kg of soil. Silicon and phosphorus were added to the soil in the form of sodium silicate (Na_2SiO_3) and calcium phosphate ($Ca(H_2PO_4)_2.H_2O$) respectively. Ten seeds of wheat were sown in each pot and then thinned to 3 plants per pot after seedling establishment. Soil moisture was kept at about level of field capacity for two weeks. Moisture stress treatments were imposed by weighing the pots every day. The plants were irrigated with distilled water for 50 days after sowing. Then, harvested, oven-dried and grinded. Soil samples were air-dried and passed through a 2 mm sieve. Shoot fresh and dry weights, silicon and phosphorus concentrations in shoots and silicon concentration in soil samples were measured. Minitab 17 software was used for data analysis. The comparison of means was performed by using Tukey test at 5% probability level.

Results and discussion

According to the results, shoot fresh and dry weights were decreased by 55.4% and 41.5% under moisture stress. Also, concentration and uptake of phosphorus reduced by 13.6% and 49.8% under water

[*]Correspondent author Reza Khorasani; E-Mail: khorasani@um.ac.ir.

deficient conditions. Moreover, application of 25 mg kg^{-1} phosphorus increased the plant fresh and dry weights in both stress and non-stressed conditions. Shoot fresh and dry weights did not change significantly with increasing silicon supply under different soil moisture levels. Silicon application decreased shoot phosphorus cocentration and uptake at field capacity, however, phosphorus concentration and uptake were not significantly affected by silicon at the 45% FC level. The interaction of silicon and moisture stress factors indicated that by increasing silicon concentration in the soil, no significant changes were observed in silicon uptake under stress conditions. Also, silicon concentration and availability in the soil were increased by solubility of soil silicates after plant cultivation. As a result, the effect of silicon on fresh and dry weights, shoot phosphorus concentration and uptake was not significant. Thus, further studies are needed to use silicon in calcareous soils for wheat under moisture stress.

Conclusions

The results showed that moisture stress significantly reduced shoot fresh and dry weights, silicon and phosphorus concentration of shoot and uptake of silicon and phosphorus. But, silicon addition did not alter the silicon uptake. It appears that the concentration of plant-available silicon in soil was increased by solubility of soil silicates after plant cultivation. Thus, plant did not respond to silicon fertilization and application of silicon in soil could not reduce the negative effects of moisture stress. Therefore, the initial concentration of silicon should be considered for silicon fertilizer recommendation to overcome moisture stress constraints in wheat cultivation in calcareous soils.

***Keywords*:** Beneficial nutrient, drought stress, nutrient interactions, plant nutrition

Table 1. Some physical and chemical properties of the soil prior to sowing

Clay	Silt	Sand	pH	EC	FC	Organic Carbon	CCE
----------%----------			-	dS m^{-1}	----------%----------		
16	52.7	31.3	7.30	2.10	15	0.35	13.0

Table 2. The concentration of nutrients in the soil before planting

$P_{ava.}$	$K_{ava.}$	$Si_{ava.}$	Total Nitrogen
----------mg kg^{-1}----------			
5.20	151	45.45	450

Table 3. Variance analysis of the effects of phosphorus (P), silicon (Si) and moisture stress (FC) on fresh and dry weights, silicon concentration and uptake in the shoots

S.O.V	df	Shoot Fresh weight	Shoot dry weight	Shoot silicon concentration	Shoot silicon uptake
P	2	277.66^{*}	5.7912^{*}	144211520^{*}	163.34^{*}
Si	2	15.62^{ns}	0.1363^{ns}	32695621^{*}	67.42^{*}
FC	1	1746.29^{*}	17.6571^{*}	64848486^{*}	1738.25^{*}
Si× P	4	3.4^{ns}	0.0417^{ns}	26436939^{*}	124.38^{*}
FC× P	2	79.68^{*}	0.8849^{*}	82892^{ns}	6.51^{ns}
FC× Si	2	10.6^{ns}	0.2721^{ns}	9551318^{*}	47.82^{*}
FC×Si× P	4	8.95^{ns}	0.2015^{ns}	2233762^{ns}	71.7^{*}
Error	$35^{\dagger}$	6.09	0.1865	1337486	7.18
CV%	-	*16.4*	*19.4*	*17.8*	*19.4*

ns: Non significant, *: Significantly different at P<0.05 level

†: The experiment contains a missing value.

Table 4. Variance analysis of the effects of phosphorus (P), silicon (Si) and moisture stress (FC) on shoot phosphorus concentration and uptake and silicon concentration in soil

S.O.V	df	Shoot phosphorus concentration	Shoot phosphorus uptake	silicon concentration in soil
P	2	13578831*	195.925*	3598.78*
Si	2	874445*	11.592*	7374.35*
FC	1	2673460*	299.344*	587.92*
Si× P	4	1875076*	10.721*	2574.81*
FC× P	2	1076470*	23.519*	195.91ns
FC× Si	2	795152*	3.833*	750.42*
FC×Si× P	4	457562*	2.285ns	998.71*
Error	35†	106882	1.03	64.74
CV%	-	*10.5*	*14*	*8.2*

ns: Non significant, *: Significantly different at P<0.05
†: The experiment contains a missing value.

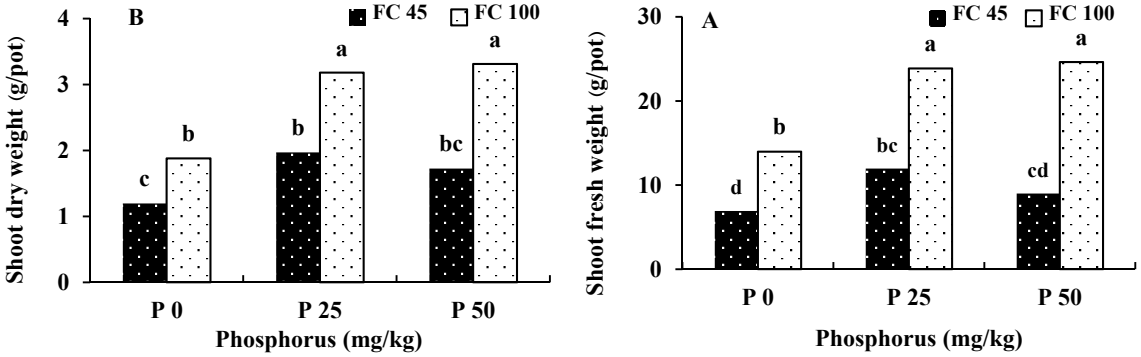

Fig. 1. The interaction of phosphorus and moisture stress on shoot A) fresh weight and B) dry weight

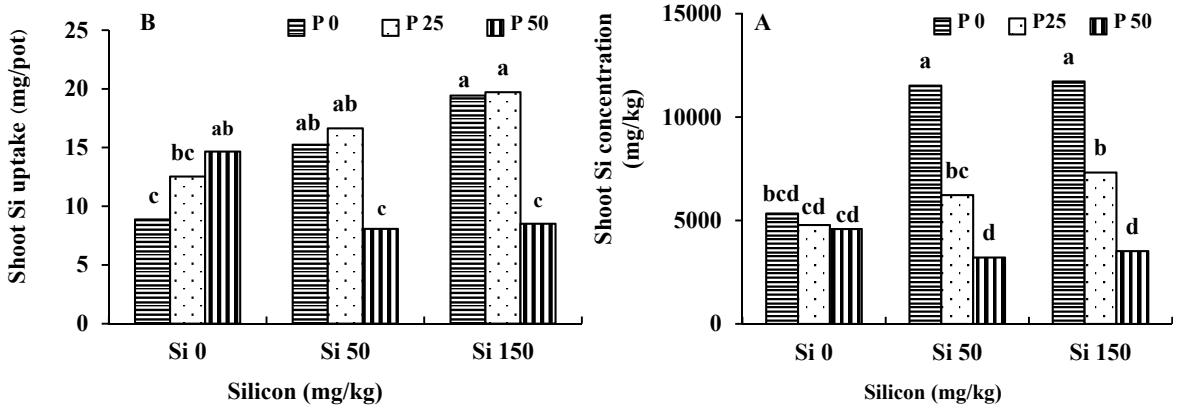

Fig. 2. The interaction of silicon and phosphorus on shoot A) Si concentration and B) Si uptake

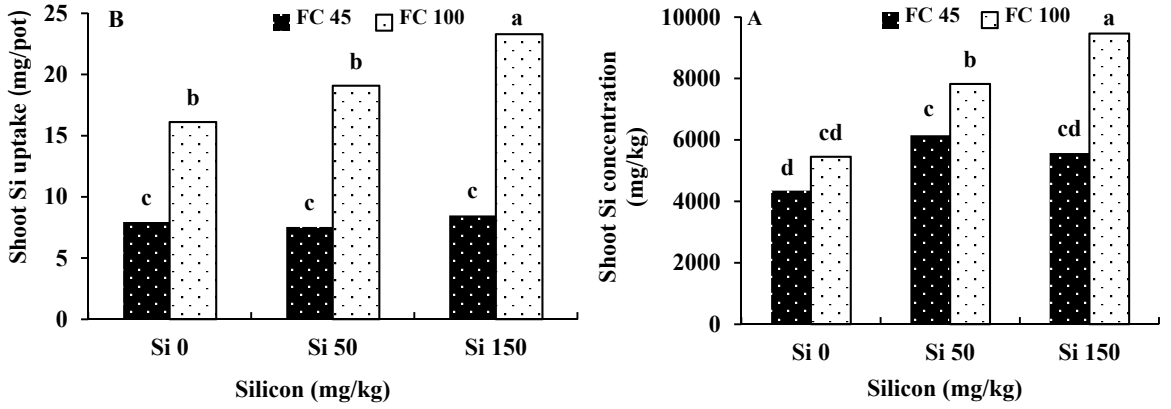

Fig. 3. The interaction of silicon and moisture stress on shoot A) Si concentration and B) Si uptake

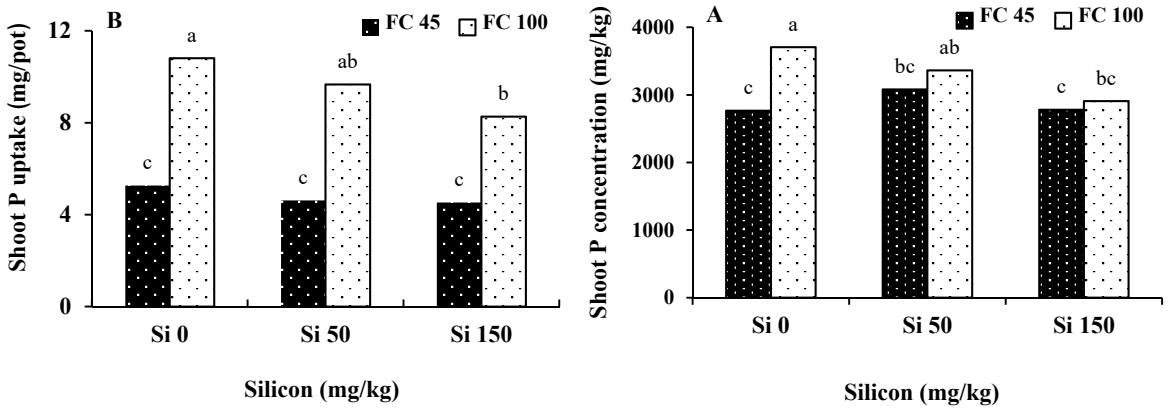

Fig. 4. The interaction of silicon and moisture stress on shoot A) P concentration and B) P uptake

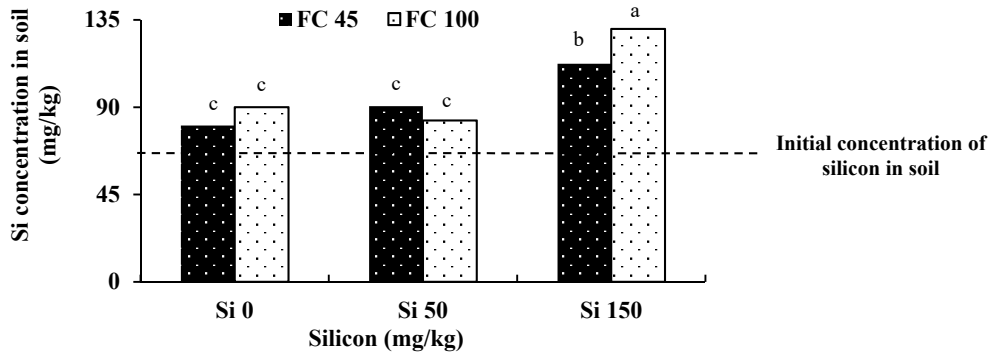

Fig. 5. The interaction of silicon and moisture stress on Si concentration in soil

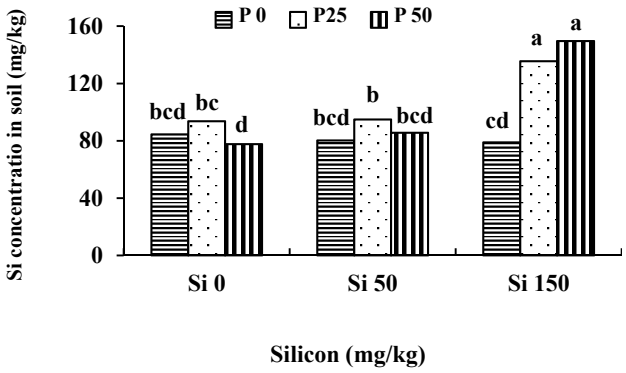

Fig. 6. The interaction of silicon and phosphorus on Si concentration in soil