J. Agric. Sci. Mansoura Univ., 25 (11): 7259 - 7266, 2000.

EFFECT OF SILICON APPLICATION ON P-ZN INTERACTION AND THEIR EFFECT ON GROWTH AND NUTRIENT UPTAKE BY WHEAT GROWN IN SANDY SOIL

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ABSTRACT

To study the effect of silicon application on P-Zn interaction in sandy soils and their effects on the growth of wheat, a pot experiment was conducted in greenhouse with wheat, *Triticum aestivum L.* variety Sahel 1. Phosphorus was applied as Super phosphate 15.5% P_2O_5 at rates of 0, 50 and 100 Kg P/feddan and zinc as $ZnSO_4.7H_2O$ at rates of 0, 10 and 20 Kg Zn/feddan. Silicon was added as $Na_2SiO_3.5H_2O$ at rates of 0 and 300 Kg Si/feddan. The results showed that dry matter yield was significantly higher with Si-treated soil than with Si-untreated soil. Application of 50 Kg P/feddan, significantly increased the dry matter yield of wheat over control while the rate of 100 Kp/feddan caused a decrease in the dry matter yield over 50 Kg P/feddan, in both Si-treated and untreated soil. In both cases also, zinc application at the rate of 20 kg/feddan increased dry matter yield especially at the rates of 0 and 50 kg P/feddan.

The concentrations and uptake of P and Zn increased with the application of P and Zn, respectively. Zn concentration was decreased by increasing both levels of P. Silicon concentration in plant was decreased by raising rate of P from 0 to 50 or 100 kg/feddan, on the other hand, it was a slightly increased with 20 Kg Zn/feddan. The uptake of Si and Zn by wheat plant was higher with Si-treated soil than untreated soil. These results give evidence of the beneficial effect of silicon element on the P-Zn interaction and growth of wheat in sandy soils.

INTRODUCTION

Phosphorus-Zinc interaction has been reported in soil and crops. Observations that higher available P in soil often aggravates Zn deficiency symptoms have been explained and summarized by Loneragan *et al*., (1979). Three different factors may be responsible for this: 1) “dilution” of Zn in plants by the increase in growth induced by phosphorus fertilizers, 2) inhibition of Zn uptake by the cations (Ca^{++} in particular) added with phosphorus fertilizers, and 3) phosphorus enhanced Zn adsorption on the soil constitments like hydroxides and oxides of iron and aluminum and $CaCO_3$. Others have noted that Zn-deficient plants can have high concentrations of P that are potentially toxic, and concluded that P toxicity symptoms have been mistakenly ascribed to Zn deficiency (Christensen and Jakson, 1982 and Loneragan and Webb, 1993). Although the connection between Zn deficiency and phosphorus toxicity is not yet fully understood, there is substantial evidence that Zn affects phosphorus metabolism in the roots

(Loughman, *et al.*, 1982) and increases the permeability of the plasma membranes of wheat root cells to phosphorus. Lonergan and Webb (1993) have argued that Zn deficiency induced P toxicity is an artifact caused by the very high concentrations of P (e.g. 200-1000 µM) used in most nutrient solutions. To their knowledge, there has never been a clearly documented case of P toxicity under field conditions, where soil solutions P concentrations are typically < 5 µM (Barber, 1995).

Silicon is among the beneficial element for the growth of some plants. This effect may occur for one or more reasons of the following: 1) increasing the resistance to fungal diseases (Leusch and buchenauer, 1988), 2) reducing the water loss by cuticular transpiration, and increasing resistance against lodging and pests (Okuda and Takahashi, 1961 and Marschner, 1995), 3) increase light efficiency by increasing the rigidity and angle of the leaf blades (Yoshida *et al.*, 1969), 4) increasing the release of P from adsorbed forms by silicate ions (Silva, 1971; Scheffer *et al.,* 1982; and EL-Beshbeshy 1990, 1994 and 2000) and 5) preventing the Zinc visual chlorosis (Marschner *et al*., 1990).

Very little work has been done on P and Zn interaction in relation to Si supply. Therefore, the objective of this work is to study the interaction effect of P and Zn in sandy soil treated with silicon and to illustrate their effects on the growth of wheat plants in these soils.

MATERIALS AND METHODS

The soil sample used in this study was collected from the surface layer (0-30 cm) of a newly-reclaimed sandy soil from east Nile area at Minia City, Egypt. The soil analytical data are given in Table (1). The collected soil was air-dried, crushed and sieved through 2 mm-plastic mesh and potted in 4 kg plastic pots. The treatments consisted of all possible combinations of three levels of P (0, 50 and 100 kg/feddan) as Super phosphate 15.5% P_2O_5, and three levels of Zn (0, 10 and 20 kg/feddan) as $ZnSO_4.7H_2O$, each being replicated six times in a randomized complete block design. Three replications have received silicon at the rate of 300 kg/feddan as $Na_2SiO_3.5H_2O$ (water glass) and the remained replications did not receive silicon. Zinc, phosphorus and silicon were added to the soil in pot treatments and mixed well. Twelve seeds of wheat *Triticum aestivum L.* (var. Sahel 1) were sown in each pot and after germination were thinned to eight healthy plants and allowed to grow in the greenhouse. All pots received nitrogen and potassium each at the rate of 100 kg/feddan as NH_4NO_3 and K_2SO_4, respectively

The plants were harvested after 50 days, washed several times in running tap water, followed by distilled water, dried in oven at 70^{o}C and weighed. The plant samples were ground in a stainless steel grinder and digested in sulphuric acid and hydrogen peroxide. Phosphorus, silicon and zinc were determined in the Service Laboratory for Soil, Water and Plant Analysis of Minia University using the standard methods. Phosphorus was determined colorimetrically using the mixed reagents [reducing agent, metol

(P-methyle aminophenosulphate), sodium sulphite, meta-bisulphate and ammonium molybdate] then measured using a Spectrophotometer, while silicon was determined by a Silico-molybdate method (Fox et al., 1967b and Kilmer, 1965). Zinc was determined using an Atomic Absorption Spectrophotometer.

Table (1): Some physical and chemical properties of the experimental soil.

Particle size distribution				pH	$CaCO_3$	N	CEC	P	Fe	Zn	Mn	Cu
Sand %	Silt %	Clay %	Soil texture	1:2.5	%	%	meq / 100g soil	ppm				
89	4.5	6.5	sandy	8.46	8.24	0.02	3.05	5.0	1.8	0.73	0.64	1.3

RESULTS AND DISCUSSION

Dry matter yield

The effect of various rates of P and Zn with or without Si on dry matter yield of wheat is illustrated in Table 2. Dry matter was markedly increased when the P rate was elevated from 0 to 50 kg/feddan. The dry matter yield was significantly higher with Si- treated soil than Si-untreated soil. The effects of P and Si addition on the dry matter yield are in a good agreement with those previously reported by Kundu *et al.,* (1986). EL-Beshbeshy (1994) and Ahmad, (1996).

The effect of Zn, however, varied considerably depending on the added rate of P. At zero P rate, for example, increasing rates of Zn from zero to 10 kg/feddan increased dry matter from 1.54 to 2.02 g/pot without silicon application, the corresponding values with Si were 2.35 and 2.60 g/pot, respectively. On the other hand, the same increase of zinc (from zero to 10 kg/feddan) reduced dry matter as P rate was increased to 100 kg/feddan. The obtained results are in agreement with those reported by Parker (1997) who found that wheat yields were markedly depressed by increasing rate of applied zinc.

Table (2): Dry matter yield and P content in wheat plants as affected by P and Zn in the absence and presence of Si

Treatments		Dry matter (g/pot)		P Con. %		P-Uptake (mg/pot)	
		-Si	+Si	-Si	+Si	-Si	+Si
P_o	Zn_0	1.54 b	2.35 c	0.17 d	0.18 d	2.62 c	4.23 d
	Zn_1	2.02 b	2.60 c	0.18 d	0.18 d	3.64 c	4.68 d
	Zn_2	1.76 b	2.11 c	0.17 d	0.17 d	2.99 c	3.59 d
P_1	Zn_0	4.38 a	4.60 a	0.31 c	0.28 c	13.58 b	12.88 c
	Zn_1	4.28 a	4.56 a	0.35 bc	0.29 c	14.98 b	13.22 c
	Zn_2	4.35 a	4.56 a	0.34 bc	0.33 c	14.79 b	15.05 bc
P_2	Zn_0	3.99 a	4.51 a	0.39 b	0.41 ab	15.56 b	18.49 a
	Zn_1	3.88 a	4.04 b	0.47 a	0.40 b	18.24 a	16.16 b
	Zn_2	3.91 a	4.04 b	0.50 a	0.46 a	19.55 a	18.58 a
L.S.D 0.05		0.47	0.37	0.05	0.05	2.19	2.38

Different letters within one column denote significant differences at 5% level.

Statistical analysis of dry matter results showed a significant effect of both P and Si and their interactions, While Zn treatments did not show significant effect (Table 4).

Table (3): Silicon and zinc content in wheat plants as affected by P and Zn in the absence and presence of Si.

Treatments		Si conc. mg/g		Si-uptake mg/pot		Zn Conc. (ppm)		Zn uptake (µg/pot)	
		-Si	+Si	-Si	+Si	-Si	+Si	-Si	+Si
P_o	Zn_0	20.67 b	28.93 a	31.83 d	67.99 cd	45.70 c	39.00 c	70.38 c	91.65 c
	Zn_1	23.23 a	28.63 a	46.92 d	74.44 de	50.00 b c	45.00 bc	101.00 c	117.00 bc
	Zn_2	22.15 ab	28.61 a	38.98 d	60.37 e	91.70 a	65.30 a	161.39 b	137.78 b
P_1	Zn_0	17.50 c	20.28 b	76.65 ab	93.29 a	20.30 d	23.70 d	88.91 c	109.02 bc
	Zn_1	18.23 c	19.48 b	78.02 a	88.83 ab	44.67 c	41.30 bc	191.19 b	188.33 a
	Zn_2	18.23 c	20.33 b	79.30 a	92.70 a	38.00 c	48.30 bc	165.30 b	220.25 a
P_2	Zn_0	16.50 c	19.42 b	65.84 bc	87.58 b	18.30 d	26.30 d	73.02 c	118.61 bc
	Zn_1	16.75 c	19.27 b	64.99 c	77.85 bcd	60.00 b	47.30 bc	232.80 a	191.09 a
	Zn_2	16.76 c	19.27 b	65.53 bc	77.85 bc	41.00 c	52.00 b	160.31 b	210.08 a
L.S.D.0.05		1.64	1.06	10.73	11.87	11.35	11.54	36.19	39.3

Different letters within one column denote significant differences at 5% level.

P, Zn and Si concentrations:

Tables (2 and 3) shows the effects of P, Zn and Si (as soil application) on the concentrations of P, Zn and Si in wheat plants. P concentration in plant tissue was increased progressively with increasing P rates. Only at 100 kg P feddan^{-1}, P concentration increased by increasing rate of Zn from zero to 10 kg/feddan. Supply of Si decreased P concentration in plants. This decrease can be only partially explained by a dilution effect, i.e. increase in dry weight. At all rates of P, Zn concentrations increased significantly by elevated Zn rate from zero to 10 kg/feddan. This effect of zinc on both Zn and P concentration is in a good agreement with the results obtained by Parker (1997). On the other hand, the increasing rate of P significantly reduced both Zn and Si concentrations in plant. In a previous study EL-Beshbeshy (2000) found that Si concentration in corn plant decreased by increasing P in nutrient solution. Holah (1989) revealed that the use of sodium silicate resulted in an increase in Si content of rice. Marschner et al (1990) found that Si concentration is higher in the P deficient plants. The reduction of Zn concentration in plant as a result of Si application has been reported by many investigators (Bowen, 1972; Elawad et al, 1982 and Holah, 1989).

Results of ANOVA (Table 4) show that P concentration in wheat was affected by P, Zn and Si, but no significant effect otherwise. A highly significant effect of P, Zn and their interactions on Zn concentration, but no significant effect for Si and its interaction with Zn. Moreover, P and Si and their interactions significantly effected Si concentration only.

P, Zn and Si uptake

Regarding the effect of different treatments on P, Zn and Si uptake, it is evident from the results in tables (2 and3) that P uptake by wheat plants increased steadily and sharply by increasing P application rate. Average value of P uptake significantly increased from 3.54 mg / pot to 13.99 and 17.47 mg / pot by P application at rates of 0, 50 and 100 kg/feddan (Table 4). At all P rates, Zn application had no significant effect on P uptake. The effect of Si on P uptake varied considerably depending on the P rate. Without phosphorus application for example, the uptake of P by wheat was higher in the presence of Si, while, by increasing rates of P to 50 or 100 kg $feddan^{-1}$ Si application had no effect on P uptake. In this connection, Russel, (1973) showed that the addition of soluble silicate to a soil had a beneficial effect when available P was deficient. Evidently, at P rates of 50 or 100 kg P/feddan, addition of Zn at the rate of 10 kg/feddan increased Zn uptake significantly in the absence of Si. This results are in agreement with Holah (1989) who found that the use of sodium silicate increased Zn uptake by rice plants. On the other hand, the highest values for Zn uptake were obtained at 20 kg Zn $feddan^{-1}$, in the presence of Si. It is also evident from the results that at all levels of P or Zn , the silicon uptake was significantly higher in the presence of Si.

Table (4): Significance of the influence of P, Zn and Si on dry matter, and P, Zn and Si content in wheat plants.

Source of variation	Significance						
	D.M	P Conc.	Zn Conc.	Si Conc.	P Uptake	Zn uptake	Si uptake
Phosphorus	**	**	**	**	**	**	**
P 0	2.06 c	0.18 c	54.95 a	25.93 a	3.62 c	113.20b	53.42c
P 1	4.46 a	0.32 b	36.99 c	19.01 b	14.08 b	160.50a	84.80a
P 2	4.06 b	0.43 a	40.47 b	18.05 c	17.36 a	164.32a	73.27b
Zinc	NS	*	**	NS	*	**	NS
Zn 0	3.56 a	0.32 b	25.82 c	19.81 a	11.23 b	91.93 b	70.53a
Zn 1	3.56 a	0.33 ab	47.82 b	20.18 a	11.82 ab	170.23 a	71.84a
Zn 2	3.46 a	0.36 a	53.40 a	19.98 a	12.43 a	184.77a	69.12a
Silicon	*	NS	NS	**	NS	*	**
Si 0	3.34 b	0.35 a	41.40 a	18.23 b	11.77 a	138.26b	60.90b
Si 1	3.71 a	0.32 a	41.44 a	21.59 a	11.88 a	153.76a	80.10a
P x Zn	NS	NS	**	NS	NS	**	NS
P x Si	*	NS	**	**	NS	NS	NS
Si x Zn	N.S	NS	NS	NS	NS	*	NS
P x Zn x Si	NS	NS	*	NS	NS	*	NS

**** Significant at 0.01 Level   * Significant at 0.05 Level   NS not significant**
Different letters within one column denote significant differences at 5% level.

Analysis of variance (Table, 4) showed that P uptake was significantly affected by P and Zn, but no significant effect otherwise. Zinc uptake was affected by P, Zn, and Si and all interactions except P x Si. Also, Si uptake was affected significantly by both Si and P application.

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تأثير إضافة السليكون على تفاعلات الفوسفور والزنك وتأثيرهما على النمو والكمية الممتصة من العناصر بواسطة نباتات القمح في الأراضي الرملية

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لدراسة تأثير إضافة السليكون على تفاعلات الفوسفور مع الزنك وتأثيرهما على النمو والكمية الممتصة من العناصر المغذية بواسطة نبات القمح في الأراضي الرملية ، تم زراعة القمح صنف ساحل (1) في تجربه أصص يحتوي كل أصيص على 4 كيلو جرام من أرض رملية عوملت بثلاث مستويات من الفوسفور صفر،50،100 كيلو جرام فوسفور للفدان من سماد سوبر فوسفات ، وثلاث مستويات من الزنك صفر،10،20 كيلو جرام زنك للفدان من كبريتات الزنك ، ومستويين من السليكون صفر ،300 كيلوجرام سليكون للفدان من سليكات الصوديوم. ولقد أوضحت النتائج ما يلي:

1. إضافة السليكون أدى إلى زيادة معنوية فى محصول المادة الجافة لنباتات القمح مع كل معاملات الفوسفور والزنك مقارنة بالمعاملات التي لم تعامل بالسليكون.
2. التسميد بمعدل50 كيلو جرام فوسفور للفدان أدى إلى زيادة معنوية في محصول المادة الجافة لنباتات القمح مقارنة بمعاملة المقارنة ، وكذلك إضافة الزنك حتى 20 كيلو جرام زنك للفدان ، وكان أفضل محصول عند 50 كيلو جرام فوسفور ، 20 كيلو جرام زنك للفدان.
3. أدت زيادة معدلات إضافة كل من الفوسفور والزنك إلى زيادة في التركيز والكمية الممتصة من كل منهما، بينما انخفض تركيز الزنك عند زيادة معدلات إضافة كل من الفوسفور والسليكون، كما أن زيادة تركيز الفوسفور أدى إلى خفض تركيز السليكون في النباتات بصفة عامة، كما أن المعاملة بالسيليكون أدت أيضاً إلى خفض تركيز الفوسفور في النبات.
4. بالرغم من انخفاض تركيز الزنك في النباتات التي نمت في التربة المعاملة بالسليكون إلا أن الكمية الممتصة بواسطة نباتات القمح زادت في معظمها زيادة معنوية.

وتشير النتائج في مجملها إلى أن إضافة السليكون بالرغم من أنه ليس عنصراً أساسياً في تغذية النبات إلا أنه يعطي نتائج إيجابية في تقليل أثر التفاعل بين الفوسفور والزنك في التربة والنبات ، وفي الوقت نفسه كان مشجعاً على زراعة محصول القمح في الأراضي الرملية.