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EFFECT OF PHOSPHORUS, ZINC AND SULPHUR APPLICATION ON THE GROWTH CHARACTERS, P AND ZN UPTAKE, YIELD COMPONENTS OF WHEAT PLANT GROWN ON CALCAREOUS SOIL

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ABSTRACT

A field experiment was conducted over two successive seasons (2006/2007 and 2007/2008) at Borg El-Arab area, on North western of Egypt and about 65 km from Alexandria city, to study the effect of phosphorus, sulphur and zinc applications on P and Zn uptake, growth, yield and its components of wheat plant (*Triticum aestivum* L.) CV. Sakha 69. Phosphorus rates were 0, 60 and 120 kg P_2O_5 ha^{-1}, as superphosphate, and zinc application rates were 0, 5 and 10 kg ZnO ha^{-1} as ($ZnSO_4.7H_2O$) either without or with one sulphur application rate (100 kg S ha^{-1}). The used soil type was Aridisols (Calciorthids); calcareous sandy clay loam soil. The results obtained showed that plant height and dry weight/plot were responded to P and Zn treatments and this response was significantly increased in the presence of sulphur application. The P uptake by roots was significantly increased with increasing P rates, when combined with added Zn without of S application, at the booting (ZGS 31) and soft dough stages (ZGS 45). On the other hand, in the presence of S, there were insignificant increase of P uptake by roots and significant increase of P uptake by shoots with increasing of P rates when combined with increasing of Zn rates as compared with the control. The Zn uptake was significantly increased in roots and significantly decreased in the shoots with increasing of P and Zn rates without S application as compared to the control. Whereas, plots that treated with S gave the highest shoot Zn uptake. Increasing P and Zn rates significantly increased grains P and Zn uptake and the highest uptake values were obtained in plots that treated with P, Zn and S. The application of P and Zn without S did not significantly increase the yield and its components as compared with the control. The highest values of yield and its components were obtained at the highest rates of P and Zn that combined with 100 kg S ha^{-1}, and those values were 548, 794, 3.38, 4.72, 15.88, 20.60, 22.91 and 13.28 for number of spikes/m^2, weight of spikes (g/m^2), grain index (g), grain yield (ton ha^{-1}), straw yield (ton ha^{-1}), biological yield (ton ha^{-1}), harvest index (%) and protein percentage, respectively.

INTRODUCTION

Wheat occupies about 33% of the total winter crop area in Egypt and is the major staple crop, consumed mainly as bread (Kherallah et al., 2000). More than one-third of the daily caloric intake of Egyptian consumers and 45% of their total daily protein consumption is derived from wheat (Kherallah et al., 2000).

Zinc deficiency has been reported to be the most widespread micro-nutritional disorder of the food crops in many areas of the world (Kanwar and Youngdahl, 1985). Global studies initiated by FAO and some projects recorded Zn deficiency in 50% of the soil samples collected from 25 countries (FAO, 2002; IFPRI, 2002 and IFPRI, 2004). Zinc deficiency is common on neutral and calcareous soils with high pH, as well as intensively cropped soils, soils with high available phosphorus and sandy soils (Rammah, 1989; IFAD, 1991 and FAO, 2002).

Wheat response to zinc applications on calcareous soils showed varying magnitude of intensity from many wheat growing countries (Sillanpaa, 1982 and Sillanpaa, 1990). In other wheat producing regions, zinc applications have proved as beneficial for wheat production on Zn-deficient soils. Zinc deficiency is common on calcareous soils with high available phosphorus and silicon. (Singh *et al.,* 2005).

Heavy applications of phosphorous fertilizers to soils, low in available zinc, can also induce zinc deficiency (Mengel and Kirkby, 2001). Mechanisms of P induced Zn deficiency was suggested by Parker et al., (1992) who reported that decreased solubility of soil Zn may result from enhanced sorption of Zn by hydrous oxides, and to the dilution effect due to the increase in dry matter production. Bergman (1992) found that high P levels inhibit translocation of Zn^{+2} to shoot, and Zn levels in the leaves are mostly effected, while Zn^{+2} uptake by the root were less affected.

Zhu *et al*., (2001) demonstrated that an increase in available P in soil was associated with lower Zn concentrations in shoots and there was inverse relationship between shoot P and Zn concentrations. Correction of Zn deficiency via fertilization is not always successful due to agronomic and economic factors. Some of these factors include reduced availability of Zn due to topsoil drying, subsoil constraints, disease interactions, and cost of fertilizer in developing countries (Graham and Rengel, 1993).

When calcareous soil wheat producers, at Borg El-Arab region, reviewed soil test reports, they often find that DTPA-extractable zinc levels are below 0.3 ppm. Consultants and researchers agree these levels seem “pretty low”, but questions about the effect of Zn fertilization on plant tissue concentrations and uptake of Zn with P fertilizer application to calcareous soil need to be answered.

In recent years, S-deficiency has become an increasing problem for agriculture resulting in decreased crop quality parameters and yield (Hawkesford, 2000). Attention has been paid for application of elemental sulphur to soils to correct soil alkalinity. Elemental sulphur is oxidized by soil microorganisms to sulphuric acid, which in turn lowers soil pH, improve soil structure and increases the availability of certain macro- and micronutrients (El-Shahawy, 2004).

The objective of this study, therefore, was to evaluate the interaction effects of P and Zn, with and without S application on the growth characters, P and Zn uptake, and yield components of wheat plant grown on Zn-deficiency calcareous soil for two successive seasons

MATERIALS AND METHODS

Sit of field experimental:

A field experiment was conducted during two successive winter seasons (2006/2007 and 2007/2008) at Borg El-Arab area (North western coastal zone of Egypt) about 65 km west Alexandria city. The soil type of this area is Aridisols (Calciorthids) with sandy clay loam texture.

Soil characteristics:

Composite surface soil samples (0-30 cm) were collected from experimental area prior to sowing, air-dried and ground to pass a 2-mm sieve. The mean values of the main soil chemical and physical characteristics are presented in Table (1).

Particle size distribution of soil (sand, silt and clay) was determined by the pipette method (Gee and Bauder, 1986). The amount of total carbonate was measured by Calcimeter method (FAO, 1970). The soil pH and electrical conductivity (E.C) were determined in 1:2.5 soil: water suspension and saturated soil paste extract, respectively, as described by Richards (1954). The soil CEC was determined by saturating the soil with 1 M NaOAc at pH 8.2 according FAO (1970). The amount of available P was extracted by Olsen method with 0.5 M $NaHCO_3$ at pH 8.5 and P was colorimetrically measured by ascorbic acid/ammonium molybdate method according Page et al. (1982). The amount of available K was extracted by 1.0 M NH_4OAc K was measured by flame photometer (FAO, 1970). The amounts of NO_3-N and organic matter (OM) were determined according Page et al., (1982). Soil testing of S was extracted by $Ca(H_2PO_4)_2$ and $CaCl_2$ for the determination of free + adsorbed SO_4^{-2} and free SO_4^{-2}, respectively (Tabatabai, 1982) and the extracted SO_4^{-2} was colorimetrically measured as described by Hesse (1972). Soil testing of Zn was determined by DTPA extraction (Lindsay and Norvell, 1978). The amounts of total N, P and Zn in plant tissues were determined according to Chapman and Pratt (1961). The Zn concentration was measured by Perkin Elmer atomic absorption spectrophotometer Model 2380.

Table (1): The mean values of the main chemical and physical properties of the experimental field soil before sowing.

Soil variable	Mean	Soil variable	Mean
EC, dS m^{-1} (sat. soil paste ext.)	3.6	NO_3-N	30.0 ppm
pH (1:2.5, soil : water)	8.40	{$Ca(H_2PO_4)_2$ + $CaCl_2$}-S	22.0 ppm
O.M, (%)	0.55	Particle size distribution:	
Total Carbonate (%)	19.3	Sand	21
$NaHCO_3$-P (µg P/g soil)	6.5	Silt	63
$NaHCO_3$-K (µg K/g soil)	160.0	Clay	16
C.E.C (me/100 g soil)	112.0	Texture	SCL *
DTPA-Zn (µg Zn/g soil)	0.30		

*Sandy Clay Loam

Field Experimental Design and Treatments:

The field experiment was carried out in a split-plot design with four replicates. The main plots were subjected to phosphorus treatments (0, 60 and 120 kg P_2O_5 ha^{-1}) and the sub-plots were subjected to zinc treatments (0, 5 and 10 kg ZnO ha^{-1}) either without S application or with 100 kg S ha^{-1} as elemental sulphur. The area of each sub plot was 10.5 m^2 (3.0 m wide and 3.5 m in length). The sowing was done using drill hand machine on 25 September in the first season and 28 September in the second season. The harvested area of sub plot was 8.4 m^2 (2.4 m in width and 3.5 m in length) to determine yield of grains and straw.

The P treatments were applied at the rates of 0, 60 and 120 kg P_2O_5 ha^{-1} as superphosphate (15.5 % P_2O_5) and Zn treatments were applied at the rates of 0, 5 and 10 kg ZnO ha^{-1} as fine granular $ZnSO_4.7H_2O$ (28.2 % ZnO). While sulphur was applied at rate of 100 kg S ha^{-1} as elemental sulphur, which was added to sub plots that treated with Sulphur.

The distributions of treatments were:

1. Control: without adding any treatments.
2. 60 kg P_2O_5 ha^{-1}, 5 kg ZnO ha^{-1} and 0 kg S ha^{-1}, (P_{60}-Zn_5-S_0).
3. 60 kg P_2O_5 ha^{-1}, 10 kg ZnO ha^{-1} and 0 kg S ha^{-1}, (P_{60}-Zn_{10}-S_0).
4. 60 kg P_2O_5 ha^{-1}, 5 kg ZnO ha^{-1} and 100 kg S ha^{-1}, (P_{60}-Zn_5-S_{100}).
5. 60 kg P_2O_5 ha^{-1}, 10 kg ZnO ha^{-1} and 100 kg S ha^{-1}, (P_{60}-Zn_{10}-S_{100}).
6. 120 kg P_2O_5 ha^{-1}, 5 kg ZnO ha^{-1} and 0 kg S ha^{-1}, (P_{120}-Zn_5-S_0).
7. 120 kg P_2O_5 ha^{-1}, 10 kg ZnO ha^{-1} and 0 kg S ha^{-1}, (P_{120}-Zn_{10}-S_0).
8. 120 kg P_2O_5 ha^{-1}, 5 kg ZnO ha^{-1} and 100 kg S ha^{-1}, (P_{120}-Zn_5-S_{100}).
9. 120 kg P_2O_5 ha^{-1}, 10 kg ZnO ha^{-1} and 100 kg S ha^{-1}, (P_{120}-Zn_{10}-S_{100}).

Cultural Practices

The experimental area was ploughed, rolled and divided into plots and then the P and Zn fertilizers were added to surface layer (0-15cm) of experimental units while sulfur was applied as broadcast, a week before sowing. Wheat *(Triticum aestivum* L.) Sakha 69 variety was planted at a rate of 120 kg per hectare. The seed germination test was 90%.

The agricultural practices and irrigation schedule of the wheat plant were done according to the recommendations of the Ministry of Agriculture and Land Reclamation (MALR). However, to provide for maximum yield, irrigation management levels were maintained to soil moisture does not drop below 65 per cent of the water holding capacity of soil of the root zone during the growing seasons.

Sampling:

Plant samples were collected from the center of each plot. Three plant samples were taken at three stages of plant growth according to Zadoks Growth Stage ZGS (Zadoks *et.al*., 1974) and Feekes Scale (Miller, 1992) as follows:

1- Vegetative growth stage and the secondary root system were developing, at 33 days after sowing (33 DAS), after most tillering had been formed (5 tillers); elongation of stem and the first node was detectable in stem (ZGS 31, Feekes 6).

2- The booting stage, at 55 days after sowing (55 DAS). The head was fully developed, but had not yet emerged from the leaf sheath below the flag leaf and before beginning flowering stage (ZGS 45, Feekes 10).

3- The soft dough stage; kernels of spiked panicle were developing after pollination, the kernel begins filling and accumulating starch and protein rapidly and its dry weight was increased. This stage was at 75 days after sowing (75 DAS) (ZGS 85, Feekes 11.2).

At harvest, the plant samples were taken on March 2007 and 2008 for both successive seasons. The plant samples (from one square meter) were taken randomly from the middle area of each plot (three replicates) to determine plant height "cm", dry weight "g/plot", number of spikes/m^2, weight of spikes "g/m^2", grain index "g" (100 grain weight). In addition, grain yield "ton ha^{-1}", straw yield "ton ha^{-1}", biological yield "ton ha^{-1}" were determined for the whole area of experimental units. The other three replicates were taken for the determination of the yield and then converted to yield per hectare and harvest index (grain yield/ biological yield × 100).

The samples of plant materials were subjected to washing by tap water then by distilled water and dried gently by spreading on soft paper sheets to remove excess water, placed in paper bags, and dried in a forced-air oven at 70° C for 48 hrs before recording the data of the growth characters and plant tissue analysis of elements. The oven-dried plant materials were ground in a Wiley mill to pass through a 1-mm sieve and analysis for N, P and Zn according to Chapman and Pratt (1961).

Crude protein content of grains was calculated by multiplying N percent by the conversion factor 6.25 (El-Moatasem et al., 1993). The statistical analysis of the obtained data was carried out according to the method described by Gomez and Gomes (1984).

RESULTS AND DISCUSSION

Table (1) showed that the experimental soil of Borg El-Arab area had relatively low of total soluble salts ($E.C_e$= 3.6 dSm^{-1}), and very low of both O.M (0.55%), low available P (6.5 μg P g^{-1} soil), available K (160 μg K g^{-1} soil), low sulfate ion, and very low available Zn (0.3 μg Zn g^{-1} soil). It is clear that the soil is Zn-deficient and generally infertile for wheat production.

Some plant growth characters:

Tables 2 and 3 showed the response of plant length and dry weight/plant of wheat plant, at the different growth stages for an average of two seasons (2006/2007 and 2007/2008). Data recorded in Table (2) show that, irrespective of Zn rates, P fertilizer significantly increased plant height and dry weight/plant as compared with the control at the different growth stages. This may be attributed to the role of P in plant metabolism processes, root growth and proliferation of plants that increase nutrient uptake. It is obvious that the increase of nutrients absorption by plant lead to an increase in its dry weights (Mengel and Kirkby. 2001). The results also showed that P and Zn treatments significantly increased the growth characters in the presence of sulphur at all growth stages. Also the effect of P was more pronounced when Zn was added in the presence of S. This positive effect of sulphur may be due to its oxidation by soil microorganisms to sulphuric acid that decreases soil pH, improves soil structure and increases the availability of certain nutrient elements. Abd El-Fattah *et al*.(1996) mentioned similar explanation. The highest values of plant height and dry weight/plot were obtained with the treatment: 120 kg P_2O_5 ha^{-1} and 10 kg ZnO ha^{-1} plus of 100 kg S ha^{-1}, which recorded of 91 cm and 40.8 g/plant, and 119 cm and 125.8 g/plant, respectively at soft dough stage (ZGS 85) and harvest (Table, 3).

Table (2): The mean values of plant height and dry weight of the three growth stages (ZGS 31, ZGS 45 and ZGS 85) of wheat plant grown in the two seasons (1st and 2nd) as affected by phosphorus, sulphur and zinc treatments.

Treatments *			Plant height (cm)						Dry weight (g/ m^2)						Harvest stage			
			ZGS 31		ZGS 45		ZGS 85		ZGS 31		ZGS 45		ZGS 85		Plant height (cm)		Dry weight (g/plant)	
P	S	Zn	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
0	0	0	17	19	33	37	50	46	5.2	5.0	6.2	6.4	20.6	23.0	60	64	53.3	51.1
		5	18	21	40	38	53	55	5.1	5.3	7.3	7.7	22.0	22.8	63	69	50.5	51.1
		10	20	22	36	38	55	57	5.1	5.3	7.5	7.7	22.8	23.2	68	72	51.0	53.0
	100	0	22	24	37	39	56	58	5.2	5.4	6.4	6.8	22.8	23.4	69	73	52.8	53.6
		5	24	26	40	42	54	58	5.0	5.4	7.5	7.9	22.0	22.4	69	71	53.1	54.5
		10	26	28	41	43	53	55	5.3	5.6	7.4	7.8	22.9	23.5	66	70	53.7	54.7
60	0	0	22	24	42	46	62	64	5.4	5.6	8.0	8.4	27.0	27.4	79	83	60.0	64.0
		5	23	25	43	47	64	66	5.7	5.9	8.3	8.5	25.1	25.9	73	77	63.0	66.0
		10	27	29	46	48	65	67	5.3	3.5	8.7	8.9	25.0	25.6	70	74	66.1	67.7
	100	0	30	34	47	51	75	79	6.1	6.5	8.0	8.4	29.1	29.7	78	82	66.0	67.0
		5	34	36	50	54	80	82	6.4	6.8	8.6	9.0	29.0	29.8	89	93	75.0	75.8
		10	40	42	56	60	81	83	6.6	6.7	9.3	9.7	33.5	34.1	97	101	83.9	84.9
120	0	0	28	30	49	51	67	71	6.3	6.5	8.2	8.4	26.4	27.0	74	78	68.0	68.8
		5	21	25	48	50	74	76	5.9	6.1	8.1	8.3	25.9	26.1	75	82	71.5	72.5
		10	20	22	45	47	75	81	5.7	5.9	8.3	8.5	21.8	22.2	81	87	72.7	73.7
	100	0	33	37	52	56	77	79	5.9	6.1	9.8	10.3	31.5	32.5	90	96	87.9	89.3
		5	38	42	57	59	83	87	6.6	7.0	13.5	14.1	38.5	39.1	108	114	97.7	99.1
		10	45	47	62	66	90	92	9.0	9.4	18.2	19.0	40.3	41.3	115	123	124.8	126.8

*** Treatments= P: kg P_2O_5/ha, S: kg S/ha and Zn: kg ZnO/ha.**

Table (3): The average values of plant height and dry weight of wheat plant at the three different growth stages for the two grown seasons as affected by phosphorus, sulphur and zinc treatments.

Treatments *			Growth stage						Harvest stage	
			Plant height (cm)			Dry weight (g/ m^2)			Plant height (cm)	Dry weight (g/plant)
P	S	Zn	ZGS 31	ZGS 45	ZGS 85	ZGS 31	ZGS 45	ZGS 85		
0	0	0	18	35	48	5.1	6.3	21.8	62	52.2
		5	20	39	54	5.2	7.5	22.4	66	50.8
		10	21	37	56	5.2	7.6	23.0	70	52.0
	100	0	23	38	57	5.3	6.6	23.1	71	53.2
		5	25	41	56	5.2	7.7	22.2	70	53.8
		10	27	42	54	5.4	7.6	23.2	68	54.2
60	0	0	23	44	63	5.6	8.2	27.2	81	62.0
		5	24	45	65	5.8	8.4	25.5	75	64.5
		10	28	47	66	5.4	8.8	25.3	72	66.9
	100	0	32	49	77	6.3	8.2	29.4	80	66.5
		5	35	52	81	6.6	8.8	29.4	91	75.4
		10	41	58	82	6.7	9.5	33.8	99	84.4
120	0	0	29	50	69	6.4	8.3	26.7	76	68.4
		5	23	49	75	6.0	8.2	26.0	79	72.0
		10	21	46	79	5.8	8.4	22.0	84	73.2
	100	0	35	54	78	6.0	10.1	32.0	93	88.6
		5	40	58	85	6.8	13.8	38.8	111	98.4
		10	46	64	91	9.2	18.6	40.8	119	125.8
LSD(0.05)			7.28	8.92	20.8	0.64	1.88	3.36	7.80	4.85

*** Treatments= P: kg P_2O_5/ha, S: kg S/ha and Zn: kg ZnO/ha.**

Phosphorus uptake:

Table (4) show that P uptake was increased in roots and shoots with increasing P rates, as compared to the control at all growth stages. The P uptake by roots was significantly increased with increasing P rates combined with added Zn in the absence of S application, at the booting (ZGS 45) and soft dough (ZGS 85) stages. This result was not noticed at the first growth stage (ZGS 31). This may be due to the small size of roots. The results also showed that the P uptake by roots in presence of S was markedly but not significantly increased, where P rates and combined with increased Zn rates at all growth stages.

Table (4): The average values of P and Zn uptake by roots and shoots of wheat plant at the three different growth stages (ZGS 31, ZGS 45 and ZGS 85) for the two grown seasons as affected by phosphorus, sulphur and zinc treatments.

Treatments *			P uptake, mg/plot						Zn uptake, mg/plot						Grain, at harvest	
			Roots			Shoots			Roots			Shoots				
P	S	Zn	ZGS 31	ZGS 45	ZGS 85	ZGS 31	ZGS 45	ZGS 85	ZGS 31	ZGS 45	ZGS 85	ZGS 31	ZGS 45	ZGS 85	P uptake, mg/plot	Zn uptake, mg/ plot
0	0	0	18	32	43	33	59	65	0.63	0.79	1.03	1.33	1.62	2.52	174.5	2.86
		5	22	39	48	31	55	58	0.66	0.83	1.53	1.39	1.79	2.50	181.2	3.22
		10	29	43	54	34	51	70	0.70	0.87	1.62	1.48	1.84	2.55	180.4	3.66
	100	0	21	38	43	35	60	73	0.70	0.79	1.58	1.50	2.00	2.64	198.2	4.11
		5	23	40	49	48	62	76	0.72	0.81	1.64	1.62	2.21	2.92	224.1	4.65
		10	29	43	55	53	68	80	0.68	0.83	1.71	1.74	2.28	2.91	232.6	5.15
60	0	0	33	59	78	58	79	91	0.85	1.42	1.98	0.99	1.38	2.88	255.4	4.35
		5	35	66	82	34	60	76	1.15	1.73	2.51	0.70	1.11	2.40	274.2	4.66
		10	38	68	91	32	48	62	1.47	1.99	3.10	0.41	0.84	1.75	286.6	5.02
	100	0	30	46	58	59	89	97	0.89	0.98	2.02	1.64	1.86	2.75	335.5	5.25
		5	33	50	60	62	99	105	0.62	0.76	1.60	1.94	2.28	3.31	436.4	5.90
		10	35	54	65	82	103	111	0.45	0.47	1.12	2.25	2.38	3.82	540.4	6.76
120	0	0	35	70	85	68	89	99	0.89	1.26	2.06	1.02	1.26	2.78	266.2	4.20
		5	41	74	89	44	63	84	1.22	1.58	2.59	0.72	1.16	2.32	272.2	4.88
		10	48	79	94	41	41	76	1.54	1.85	3.14	0.42	0.89	1.58	280.2	5.33
	100	0	29	52	68	60	100	104	0.95	1.72	2.16	2.10	2.82	3.14	344.5	5.99
		5	38	57	70	69	109	118	0.68	1.52	1.76	2.42	3.11	3.68	353.3	6.75
		10	44	60	72	74	118	135	0.42	1.32	1.34	2.85	3.42	4.86	454.8	7.45
LSD(0.05)			18.3	26.5	18.9	23	10.2	9.0	0.30	0.28	0.51	0.28	0.26	0.44	88.2	2.30

*** Treatments= P: kg P_2O_5/ha, S: kg S/ha and Zn: kg ZnO/ha.**

Table (4) also showed that in the presence of S, P uptake by shoots was significantly increased with increasing Zn rates up to 10 kg ZnO ha^{-1}, at the booting (ZGS 45) and soft dough (ZGS 85) stages as compared with the control. This may be due to the role of Zn as a co-factor in the enzymatic reactions and stimulating the plant growth. Similar finding are obtained by Abd El-Maksoud *et al*. (1993). Similar interpretation was obtained by Gendy *et al*. (1995) and El-Shahawy (2004). Whereas, when the S fertilizer was not applied, P uptake by shoots was significantly decreased with increasing Zn rate to 10 kg ZnO ha^{-1}. These results may be due to combination of P with Zn and its accumulation in roots, while S application prevented P accumulation in roots and increased its translocation to shoots of wheat plant. Similar explanation was mentioned by Zhu *et al*. (2001) and Abd El-Hafez *et al*., (2007).

Zinc uptake:

Table (4) showed that Zn uptake by roots was significantly increased while it significantly decreased by shoots with the increasing P and Zn rates, especially in plots that did not receive S, as compared with the control. This trend was clear with the progress of plant growth. Zhu *et al*., (2001) suggested that the increased P supply induced a higher physiological P-enhanced Zn requirement or physiological inactivation of Zn in plant tissues. On the other hand, opposite trend was obtained with S application. In the presence of S, Zn uptake by roots was insignificantly decreased and Zn uptake by shoots was significantly increased. Khan and Zende (1977) reported that the negativity of (r) values from roots to the leaves and the depression in the mobility of Zn and P due to their applications revealed that the Zn-P interactions originate in the plant roots, thereby retarding the translocation of each to upper plant parts. As well as, this behavior revealed that the mechanism of this phosphorus-zinc interaction occurs primarily in plant roots, rather than in the soil, and excessive concentrations of phosphorus in the plant roots result in the binding of zinc within root cells. The zinc becomes part of the “fabric” of the root and, therefore, becomes unavailable for transport to shoots and leaves, where it is needed for normal plant growth. Similar explanation was mentioned by Zhu *et al*., (2001) and Abd El-Hafez *et al*., (2007).

Table (4) also showed that plots that received 100 kg S ha^{-1} significantly increased Zn content in shoots and which indicates Zn translocation to the shoots. The Zn uptake was increased from 1.75 mg/plot at rates of 60 kg P_2O_5 ha^{-1}, 10 kg ZnO ha^{-1} plus 0 kg S ha^{-1} to 4.86 mg/plot at rates of 120 kg P_2O_5 ha^{-1}, 10 kg ZnO ha^{-1} plus 100 kg S ha^{-1} at the growth stage (ZGS 85). The results also showed that with S application the highest Zn uptake by shoots was obtained. This may be due to the role of S to decrease of soil pH, improve soil structure and increases the availability of certain nutrient elements. Similar interpretation was obtained by Gendy *et al*., (1995) and El-Shahawy (2004). Several researchers have studies had suggested that phytosiderophores also can play a role in Zn nutrition and thus, quite possibly, Zn efficiency (Hacisalihoglu and Kochian, 2003). With regard to the role of pytosiderophores in Zn nutrition, Zhang *et al*. (1991) reported that Zn deficient graminaceous species released pytosiderophores and thus increased the mobilization of Zn and Fe in soil.

Uptake of P and Zn by grains:

Table (4) showed that P and Zn uptake by grains of wheat plant had increased with increasing of P and Zn rates. The significant increase and highest uptake values, for P and Zn, were obtained in plots that treated with S. Application of P and Zn, up to 120 kg P_2O_5 ha^{-1} and 10 kg ZnO ha^{-1} plus of 100 kg S, enhanced P and Zn uptake by grains. On the other hand, lower values were obtained in the control (Table, 4). The stimulating effects of phosphorus and zinc on their uptake by grains may be due to their direct effect on enhancing photosynthesis activity in plant. Similar results were obtained by El-Ashmoony (1991), El-Shafie (1994) and Abd El-Kader *et al*. (2007).

Yield and its components:

Tables 5 and 6 showed that application of P and Zn in the absence of S did not significantly increase the yield and its components as comparison with the control. However, the significant increase of the yield parameters and its components were observed by the interaction between P, and Zn plus S application (the plots that were treated with S in addition P and Zn). These results agree with those obtained by Abd El-Fattah *et al*. (1990), Singh *et al*. (2005) and Amal *et al*. (2006). This trend could be due to that addition of S had increased the availability of P and Zn and increased soil supply of P and Zn to plant. As well as, addition of S to soil decreased the soil capacity to fix the added P (Tisdal *et al*., 1992).

Table (5): The mean values of wheat yield characters at harvest stage for the two growth seasons (1st and 2nd) as affected by phosphorus, sulphur and zinc treatments.

Treatments *			yield characters															
			No. of spikes/ m^2		Weight of spikes, g/ m^2		Grain index, g		Grain yield, ton ha^{-1}		Straw yield, ton ha^{-1}		Biological yield, ton ha^{-1}		Harvest index, %		Protein, %	
P	S	Zn	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
0	0	0	448	472	711	721	2.01	2.21	4.18	4.32	14.30	14.54	18.48	18.86	22.62	22.91	10.45	10.59
		5	457	479	720	736	2.10	2.22	4.22	4.34	14.54	14.74	18.76	19.08	22.49	22.75	10.60	10.72
		10	465	483	722	740	2.13	2.21	4.31	4.41	14.71	14.93	19.02	19.34	22.66	22.80	10.78	10.86
	100	0	460	482	719	731	2.19	2.27	4.25	4.37	14.75	14.95	19.00	19.32	22.37	22.62	10.90	10.98
		5	470	486	730	744	2.20	2.30	4.31	4.45	14.85	15.07	19.16	19.52	22.49	22.80	11.05	11.15
		10	471	489	740	752	2.22	2.34	4.39	4.47	14.85	15.07	19.24	19.54	22.82	22.88	11.20	11.32
60	0	0	470	494	749	760	2.13	2.25	4.43	4.53	14.64	14.84	19.07	19.37	23.23	23.39	11.08	11.16
		5	480	496	751	765	2.18	2.26	4.45	4.55	14.72	14.88	19.17	19.43	23.21	23.42	11.11	11.25
		10	485	497	760	770	2.20	2.28	4.49	4.59	14.79	14.91	19.28	19.5	23.29	23.54	11.27	11.37
	100	0	502	518	769	777	2.31	2.41	4.56	4.66	15.25	15.45	19.81	20.11	23.02	23.17	11.67	11.79
		5	518	524	780	788	2.33	2.45	4.60	4.72	15.41	15.55	20.01	20.27	22.99	23.29	12.06	12.18
		10	529	541	790	800	2.42	2.52	4.68	4.76	15.50	15.58	20.18	20.34	23.19	23.40	12.50	12.58
120	0	0	480	500	757	765	2.10	2.30	4.49	4.57	14.79	14.87	19.28	19.44	23.29	23.51	11.09	11.19
		5	486	502	760	772	2.21	2.35	4.50	4.62	14.81	14.95	19.31	19.57	23.30	23.61	11.20	11.30
		10	490	508	765	775	2.28	2.36	4.53	4.62	14.90	15.08	19.43	19.7	23.31	23.45	11.32	11.44
	100	0	510	528	770	782	2.62	2.74	4.59	4.67	15.50	15.60	20.09	20.27	22.85	23.04	12.11	12.21
		5	521	539	776	786	2.80	2.96	4.60	4.68	15.63	15.73	20.23	20.41	22.74	22.93	12.58	12.66
		10	541	555	790	798	3.32	3.44	4.70	4.74	15.83	15.93	20.53	20.67	22.89	22.93	13.21	13.35

*** Treatments= P: kg P_2O_5/ha, S: kg S/ha and Zn: kg ZnO/ha.**

As clear in Table (6) that the highest values of yield and its components were obtained at highest rates of P and Zn fertilizers combined with 100 kg S ha^{-1}. the highest values were 548, 794, 3.38, 4.72, 15.88, 20.60, 22.91 and 13.28 for number of spikes/m^2, weight of spikes (g/m^2), grain index (g), grain yield (ton ha^{-1}), straw yield (ton ha^{-1}), biological yield (ton ha^{-1}), harvest index (%) and protein percentage, respectively.

Table (6): The average values of wheat yield characters at harvest stage for the two growth seasons as affected by phosphorus, sulphur and zinc treatments.

Treatments *			Characters							
P	S	Zn	No. of spikes/ m^2	Weight of spikes, g/ m^2	Grain index, g	Grains yield, ton ha^{-1}	Shoots yield, ton ha^{-1}	Biological yield, ton ha^{-1}	Harvest index, %	Protein, %
0	0	0	460	716	2.11	4.25	14.42	18.67	22.76	10.52
		5	468	728	2.16	4.28	14.64	18.92	22.62	10.66
		10	474	731	2.17	4.36	14.71	19.07	22.86	10.82
	100	0	471	725	2.23	4.31	14.82	19.13	22.53	10.94
		5	478	737	2.25	4.38	14.85	19.23	22.78	11.10
		10	480	746	2.28	4.43	14.96	19.39	22.85	11.26
60	0	0	482	754	2.19	4.48	14.74	19.22	23.31	11.12
		5	488	758	2.22	4.50	14.80	19.30	23.32	11.18
		10	491	765	2.24	4.54	14.85	19.39	23.41	11.32
	100	0	510	773	2.36	4.61	15.35	19.96	23.10	11.73
		5	522	784	2.39	4.66	15.48	20.14	23.14	12.12
		10	535	795	2.47	4.72	15.54	20.26	23.30	12.54
120	0	0	490	761	2.20	4.53	14.83	19.36	23.40	11.14
		5	494	766	2.26	4.56	14.88	19.44	23.46	11.25
		10	499	770	2.32	4.58	14.99	19.57	23.40	11.38
	100	0	519	776	2.68	4.63	15.55	20.18	22.94	12.16
		5	530	781	2.88	4.64	15.68	20.32	22.83	12.62
		10	548	794	3.38	4.72	15.88	20.60	22.91	13.28
LSD(0.05)			45.60	56.82	0.28	0.42	0.46	0.98	0.72	0.98

*** Treatments= P: kg P_2O_5/ha, S: kg S/ha and Zn: kg ZnO/ha.**

Relative variation of yield:

Table 7 showed that the values of the relative variation of the dry weight with respect to the control (P=0, S=0 and Zn=0) showed that negative values (-2.7 an -0.4 % for the treatments: P=0, S=0 and Zn=5, and P=0, S=0 and Zn=10, respectively). This indicates that was most of applied Zn to the soil has been changed to unavailable form and did not improve plant growth expressed in dry weight. At Zn treatment of 5 kg ZnO ha^{-1}, the relative decrease of dry weight was 7.2 % and with 10 kg ZnO ha^{-1} the relative decrease was 0.4, which indicates the tow rates no positive effects on plant yield and in order to increase plant yield, higher Zn rates should be application.

Application of 100 kg S ha^{-1} had increased the plant dry weight as indicated by the values of the relative increase (1.9, 27.4, and 69.7 % for 0 kg ZnO ha^{-1}). This points out to the stimulating action of S on plant growth. With increasing Zn application in combination with 100 kg S ha^{-1}, the relative increases of dry weight were 1.9, 3.1 and 3.8 % for 0, 5, and 10 kg ZnO ha^{-1} respectively (Table, 7).

Application of 60 kg P_2O_5 ha^{-1} with Zn treatments increased the relative dry weight to values of 18.8, 23.6 and 28.2 % with 0, 5, and 10 kg ZnO ha^{-1}, respectively. These values were 31.0, 37.9 and 40.2 % for 0, 5, and 10 kg

ZnO ha^{-1}, respectively with 120 kg P_2O_5 ha^{-1}. These results indicate that application of P in combination with Zn to calcareous soil increased the growth of wheat plant expressed as dry weight (Table, 7).

Table (7): The Relative variation of the control with P, S and Zn treatments for wheat plant grown in calcareous soil.

Treatments *			Relative variation of the control %
P	**S**	**Zn**	
0	0	0	--
		5	-2.7
		10	-0.4
	100	0	1.9
		5	3.1
		10	3.8
60	0	0	18.8
		5	23.0
		10	28.2
	100	0	27.4
		5	44.4
		10	61.7
120	0	0	31.0
		5	37.9
		10	40.2
	100	0	69.7
		5	88.5
		10	141.0

*** Treatments= P: kg P_2O_5/ha, S: kg S/ha and Zn: kg ZnO/ha.**

Application of S in combination with 60 kg P_2O_5 ha^{-1} increased the relative yield by values of 27, 44.4 and 61.7 % with 0, 5 and 10 kg ZnO ha^{-1}, respectively. These relative increases were 69.7, 88.5 and 141.0 % with 120 kg P_2O_5 ha^{-1} in combination 100 kg S ha^{-1} plus 0, 5 and 10 kg ZnO ha^{-1}, respectively.

It is interesting to notice that application of 120 kg P_2O_5 ha^{-1} produce lower relative dry weight (31.0, 37.9 and 40.2 %) without S application and with 0, 5, and 10 kg ZnO ha^{-1}, respectively, than with S application (69.7, 88.5 and 141.0 %, respectively). The same trend was found with application of 60 kg P_2O_5 ha^{-1} without S application (18.8, 23.6 and 28.2 %, respectively) and with S application (27, 44.4 and 61.7 % with 0, 5 and 10 kg ZnO ha^{-1}, respectively). These results reveal the role of S application for improving wheat plant growth and that S had stimulated the role of both P and Zn for plant growth (Table, 7).

It is clear from these results that 120 kg P_2O_5 ha^{-1}, 100 kg S ha^{-1} and 10 kg ZnO ha^{-1} had produced the highest relative dry weight with the respect to control.

Conclusion:

The obtained results showed that application of Zn-fertilizer in combination with P and S application to the Zn-deficient calcareous soil had improved the growth characters of wheat plant grown on this soil especially.

High P fertilizer rate alone had increased markedly but not significantly grains yield while applying 100 kg ha^{-1} in combination with 120 kg P_2O_5 ha^{-1} had increased significant grains yield and all wheat yield components. Also, application of Zn in combination with S significantly increased all growth components and grain yield. The results showed that applications of 120 kg P_2O_5 ha^{-1} in combination with 10 kg ZnO ha^{-1} and 100 kg S ha^{-1} had produced high significant yields of wheat plant grown in infertile calcareous soil.

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تأثير أضافة الفوسفور والكبريت والزنك على أمتصاص الفوسفور والزنك والنمو والمحصول ومكوناته لنبات القمح (*Triticum aestivum* L.) النامى فى الارض الجيرية

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أقيمت تجربة حقلية خلال الموسمين المتتالين 2007/2006 و 2008/2007 فى منطقة برج العرب، شمال غرب جمهوري مصر العربية لدراسة تأثير أضافة الفوسفور والكبريت والزنك على أمتصاص الفوسفور والزنك، والنمو وصفات المحصول ومكوناته (القش والسنابل) لنبات القمح (*Triticum aestivum* L.) صنف سخا 69 . كان معدل أضافة الفوسفور: صفر – 60 – 120 كجم/هكتار فى صورة سوبرفوسفات ، بينما معدل أضافة الزنك: صفر – 5 – 10 كجم/هكتار كاكسيد الزنك مع عدم أضافة او أضافة دفعة واحدة من الكبريت المعدنى (100 كجم/هكتار).

أظهرت أهم النتائج أستجابة طوال النبات، والوزن الجاف/نبات لمعدلات الأضافة من الفوسفور والزنك وأزدادت الأستجابة معنوياً فى القطع التى عوملت بأضافة الكبريت. وفى القطع الغير معاملة بالكبريت ازدادت قيم أمتصاص الفوسفور فى الجذور معنوياً بزيادة معدل أضافة الفوسفور مرتبطاً بأضافة الزنك، أما فى القطع التجريبية المعاملة بالكبريت كانت الزيادة غير معنوية. وازدادت معنوياً قيم أمتصاص الفوسفور بواسطة السيقان كلما زاد معدل اضافة الفوسفور والزنك معا. أمتصاص الزنك أزداد معنويا فى الجذور ونقص معنويا فى السيقان مع زيادة معدل أضافة الفسفور والزنك معا فى القطع الغير معاملة بأضافة الكبريت، بينما القطع المعاملة بالكبريت أعطت أعلى قيم لأمتصاص للزنك بواسطة السيقان. بزيادة معدل الفسفور والزنك معا أزدادت قيم أمتصاص الفوسفور والزنك فى الحبوب، وكانت أعلى قيم فى القطع المضاف اليها الكبريت. أدت أضافة معدلات الفوسفور والزنك الى زيادة المحصول ومكوناته وكانت الزيادة غير معنوية فى القطع الغير معاملة بأضافة الكبريت، ومعنوية فى القطع المعاملة بأضافة الكبريت، وتحققت أعلى قيم بأضافة أعلى معدل فسفور وأعلى معدل زنك بجانب أضافة الكبريت كالتالى: عدد السنابل 548/م^2 ، وزن السنابل 794 (جم/ م^2) ، الدليل الحبي 3.38 (جم) ، محصول الحبوب 4.72 **(طن/هكتار) ، محصول القش 15.88 (طن/هكتار) ، المحصول الحيوي 20.60 (طن/هكتار) ، دليل الحصاد 22.91 (%) ، النسبة المئوية للبروتين 13.28 (%).**