Assiut J. Agric. Sci., (47) No. (4) 2016 (201-214) *ISSN: 1110-0486*
Website: http://www.aun.edu.eg/faculty_agriculture/ *E-mail: ajas@aun.edu.eg*

Impact of Phosphorus and Sulphur Application on Yield, Phosphorus and Micronutrients Uptake by Wheat Plants

Ezzat M. Ahmed
Soil and Water Dept., Faculty of Agriculture, Assiut University, Assiut, Egypt.

Received on: 20/6/2016 **Accepted for publication on:** 23/6/2016

Abstract

A field experiment was carried out at the Experimental Farm Station of Soils and Water Department, Faculty of Agricultural, Assiut University, during 2013/2014 growth season to investigate the effect of application of phosphorus (P) and sulphur (S) on yield, and the uptake of phosphorus and some micronutrients by wheat plants. The treatments comprised of three P levels (0, 30, 60 kg P_2O_5 fed^{-1}) and three S levels (0, 100, 200 kg S fed^{-1}) in different combinations. Applications of P at 30 and 60 kg P_2O_5 fed^{-1} showed significant increases in the main straw yield of wheat of 4.45 to 10.50%, respectively, over the control. Also, S addition at 100 and 200 kg S fed^{-1} resulted in a significant increase in the main wheat straw yield of 1.51 and 3.11 % over the control, respectively. Moreover, a respective significant increase in the main grain yield of 3.58 to 9.56 % was observed due to application of the two P levels, but both applied S levels caused a respective significant increase in the main grain yield of 1.50 to 3.08 % over the control. The application effect of both P and S was synergistic at all applied levels. Applying P at levels of 30 and 60 kg P_2O_5 fed^{-1} produced an increase in the main P uptake of 23.19 and 54.23 % by wheat straw, respectively, and 11.89 and 28.83% by wheat grains, respectively, over the control. Also, S applications caused similar effect on the main P uptake by both straw and grains. Moreover, the highest applied P level caused increases in main Fe, Zn, Mn and Cu uptakes of 43.32, 48.65, 36.37 and 69.75 %, respectively, by the straw, respectively, and increases in main Zn, Mn and Cu uptakes of 36.37, 16.92 and 75.02%, respectively, by the grains over the control, and decreases in the Fe uptake of 1.63% by grain . In addition, the highest S applied level resulted in increases in the main uptake of Fe, Zn, Mn and Cu of 21.29, 22.52, 53.32 and 58.83%, respectively, by the straw and 15.04, 16.12, 26.18 and 28.16%, respectively, by the grains over the control.

Keywords*: Phosphorus: Sulphur; Wheat; Straw yield; Grain yield; Micronutrient uptake*

Introduction

Wheat is the most important and widely cultivated crop of the entire world. It is the principal food for human beings in most countries. Egypt is one of these countries that depends on wheat as a food and consumes about 9 million ton/year.

Sulphur (S) interacts with phosphorus (P) in the soils which the phosphate ion is more strongly bound to soil compounds than sulphate (Hedge and Murthy, 2005). Applications of phosphorus fertilizer increase the phosphate adsorption on soil constituents, which cause sulphate ions to release into soil solution (Tiwari and Gupta, 2006). Thus, sulphate ions may be subjected to leaching if they are not taken up by plant roots. The application of phosphorus was reported to cause a significant increase

in wheat grain yield, and the highest grain yield was found to be related to the high level of soil phosphorus. (Shuaib *et al.,* 2009).

Alam *et al*. (2003) indicted that the application of phosphorus fertilizer to wheat crop significantly increased the plant height, number of tillers per plant, straw and grain yields as well as the P uptake by grains over the control. A synergistic relationship exists between phosphorus and sulphur at the low applied level of sulphur to wheat (Randhawa and Arora, 2000). Hence, the nature of interaction of both nutrients depends up on the initial soil fertility status, the nutrient applied levels and the crop species.

Phosphorus and sulphur are known to interact with all essential macronutrients and micronutrients (Abdin *et al*, 2003). Additions of sulphur containing fertilizers may result in a soil acidification and eventually may have impacts on the uptake of other nutrients (Havlin *et al,* 2007)**.** Also, a synergistic effect of both applied S and Fe was also reported by Malewar and Ismail (1997). The combined application of both nutrients resulted in a tremendous boost of 101% in Fe availability. A close relationship was observed between Fe and S in plant metabolism (Malewar and Ismail, 1997).

Tufemkci *et al*. (2005) showed that the soil application of phosphorus resulted in increases in the uptake of Zn, Cu, Fe and Mn by plant tissues. However, Bakhshipour *et al*. (2008) found that the P application at a range level of 0 to 35 mg P kg^{-1} caused a decrease in Zn concentration of tea seedlings.

The current study aimed to investigate the effects of both P and elemental S applications on yield and uptake of P, Fe, Mn, Zn and Cu by wheat plants.

Materials and Methods

A field experiment was conducted at the Experimental Farm Station of Soils and water Department, Faculty of Agricultural, Assiut University, situated at a latitude of 27^{o}, 11' N, a longitude of 31^{o} 10' E and 52 m above the sea level during the winter growth season of 2013/2014 to study the effects of phosphorus and sulphur applications on the yield and uptakes of P, Fe, Mn, Zn and Cu by wheat plants. Some soil physical and chemical properties of the experimental site are present in Table 1.

Table 1. Some physical and chemical properties of a representative soil samples of the experimental site before sowing

Particle - size distribution	
Sand (%)	24.20
Silt (%)	62.45
Clay (%)	13.35
Texture grade	Silt loam
pH (1:1 suspension)	7.66
EC 1:1 extract ($dS\ m^{-1}$)	1.07
Total $CaCO_3$ (%)	2.85
Soluble Ions ($mmol\ kg^{-1}$)	
Ca^{++}	4.75
Mg^{++}	1.50
Na^{+}	6.10
K^{+}	1.03
Cl^{-}	4.07
HCO_3^{-}	7.01
$SO_4^{=}$	6.55
$NaHCO_3$-extractable phosphours ($mg\ Kg^{-1}$)	15.55
DTPA-extractable Fe ($mg\ Kg^{-1}$)	4.52
DTPA-extractable Mn ($mg\ Kg^{-1}$)	12.20
DTPA-extractable Zn ($mg\ Kg^{-1}$)	0.45
DTPA-extractable Cu ($mg\ Kg^{-1}$)	0.65

The trial was laid out in a randomized complete block design with a split plot (3 x 3.5 m) arrangement. Phosphorus (P) treatments were in the main plots whereas elemental sulphur (S) ones were in the subplots. There were nine treatments having different combinations including three levels of P (0, 30, 60 kg P_2O_5 fed^{-1}) and three levels of elemental S (0, 100, 200 S kg fed^{-1}). Nitrogen was applied at the level of 75 kg N $fed.^{-1}$ as urea (46.5 % N) and potassium fertilizer was added at the level of 50 kg K_2O $fed.^{-1}$ in the form of potassium sulphate (48% K_2O). Phosphorus treatments were used in the form of triple superphosphate (40 – 48 % P_2O_5). All treatments were replicated three times. The applied different combinations of P and S treatments are shown in Table (2).

Wheat (Sids 12) seeds were sown on Nov. 10, 2013. Phosphorus and sulphur treatments were applied before crop sowing. Crop was grown under surface irrigation. All agricultural practices were done as recommended for wheat crop. The preceding crop was maize. The crop was harvested on May 20, 2014. On that date an area of one square meter was selected in the middle of each plot and its plants were separately collected. The plant samples were dried and then grains and straw yield were recorded.

Representative 50 g samples of both straw and grains were separately collected from the bulk sample of each plot, oven- dried, ground and digested using the H_2SO_4 and H_2O_2 method that was described by Parkinson and Allen (1975). Phosphorus in the digests was determined by spectrophotometer. In addition, Fe, Zn, Mn and Cu in the plant digests were measured using the Inductivity

Coupld Optical Emission Spectrometry (ICP-OES, thermo iCAP 6000 Series). The analysis of variance was carried out according to Gomez and Gomez (1984) using the MSTAT computer software. The means of the treatments were compared using the least significant difference (LSD) test at the 0.01 level of probability.

Table 2. Applied combinations treatments of phosphorus and sulphur.

Treatment	Applied level (kg fed^{-1})	
	P_2O_5	S
T_1 (P_0S_0)	0	0
T_2 (P_0S_1)	0	100
T_3 (P_0S_2)	0	200
T_4 (P_1S_0)	30	0
T_5 (P_1S_1)	30	100
T_6 (P_1S_2)	30	200
T_7 (P_2S_0)	60	0
T_8 (P_2S_1)	60	100
T_9 (P_2S_2)	60	200

Results and Discussion

1- Straw and Grain Yields of Wheat Plants

a) Straw yield

The main application effects of P or elemental S showed significant increases in the straw yield wheat plants (Table 3 and Fig. 1a). The phosphorus application at levels of 30 and 60 kg P_2O_5 fed^{-1} increased the main straw yield by 4.5 and 10.5 %, respectively, compared to the control. Moreover, the application of elemental sulphur at levels of 100 and 200 kg S fed^{-1} increased the main straw yield by 1.5 and 3.2 %, respectively, over the control.

The interaction application effect of P and S showed a significant steady increase in the straw yield of wheat. Table (4) shows that the application of sulphur at levels of 100 and 200 kg S fed^{-1} caused increases in the straw yield of 0.8 and 1.6%, respectively, while adding these two levels of sulphur with 30 kg P_2O_5 fed^{-1} increased these benefits of the straw yield to reach 4.81 and 6.62 %, respectively. Moreover, applying both respective sulphur levels with 60 kg P_2O_5 fed^{-1} produced additional increases in the straw yield to attain 11.3 and 13.6% of the control. Therefore, the combined application of P and S resulted in highly significant increases in the straw yield of wheat (Table 4 and Fig. 1b). The highest wheat straw yield of 2508.14 kg fed^{-1} was obtained with using the T_9 (P_2S_2) treatment (60 kg P_2O_5 and 200 kg S fed^{-1}) while, the lowest one (2207.33 kg fed^{-1}) was recorded with T_1 (P_0S_0) treatment (control). Aulakh *et al*, (1990) and Singh *et al*, (1995) indicated that the nature of P and S interaction depended on their levels of application.

Table 3. Main application effects of P and S on straw and grain yields as well as uptakes of P and Fe, Zn, Mn and Cu by wheat plant

Treatments	Yield		Uptake									
	Straw (kg / fed)	Grains (kg /fed)	P kg/fed		Fe g/fed		Zn g/fed		Mn g/fed		Cu g/fed	
			Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain
P0	2224.66	2483.00	3.19	8.74	152.74	93.18	36.48	81.49	45.88	77.85	20.03	20.38
P1	2313.56	2571.89	3.93	9.78	187.51	110.92	47.99	87.94	58.67	95.98	33.93	28.70
P2	2458.11	2720.33	4.92	11.26	218.91	91.66	54.32	103.41	62.57	91.04	34.00	35.67
$LSD_{0.01}$	5.08	5.44	0.05	0.07	1.01	0.93	0.78	3.37	0.79	0.57	0.52	0.54
S0	2296.67	2553.78	3.36	8.99	164.41	91.20	41.02	82.72	42.98	77.04	22.73	24.50
S1	2331.44	2592.11	4.14	10.09	195.59	99.66	47.52	93.99	58.29	90.62	29.27	28.85
S2	2368.17	2632.33	4.55	10.71	199.42	104.92	50.26	96.13	65.85	97.21	36.00	31.40
$LSD_{0.01}$	5.08	5.44	0.05	0.07	1.01	0.93	0.78	3.37	0.79	0.57	0.52	0.54

The synergistic application effect of P and S may be due to utilization of high quantities of nutrients through the well developed root and shoot systems of the plants. These results confirm the earlier findings of Randhawa and Arora, (2000) on wheat and Choudhary and Dos (1996) on winter maize. In addition, Konde *et al* (1998) reported that the availability phosphorus in the soil causes favorable effects on plant growth.

Table 4. Interaction application effect of P and S on straw and grain yields of wheat plant

Treatment	Straw yield (kg / fed)	Grain yield (kg / fed)
T_1 (P_0S_0)	2207.33	2467.33
T_2 (P_0S_1)	2224.10	2480.67
T_3 (P_0S_2)	2242.50	2501.22
T_4 (P_1S_0)	2274.66	2530.59
T_5 (P_1S_1)	2312.34	2572.31
T_6 (P_1S_2)	2353.57	2621.65
T_7 (P_2S_0)	2408.24	2663.32
T_8 (P_2S_1)	2458.12	2723.29
T_9 (P_2S_2)	2508.14	2774.32
$LSD_{0.01}$	8.81	9.43

b) Grain yield

Applying P at the level of 30 and 60 kg P_2O_5 fed^{-1} showed increases in the main wheat grain yield of 3.58 and 9.56 %, respectively, over the control (Table3 and Fig.1a). Also, element S application at levels of 100 and 200 kg S fed^{-1} resulted in increases in the main wheat grain yield of 1.50 and 3.07 %, respectively, over the control (Fig. 1a)

The interaction of P and S levels increased their beneficial synergistic effect. The grain yield of wheat was increased by only 0.54 and 1.37% over the control when the element S was applied alone at levels of 100 and 200 kg S fed^{-1}, respectively. However, applying these respective S levels with P at a level of 30 kg P_2O_5 fed^{-1} produced increases in the grain yield of 4.25 and 6.25% over the control. Moreover, the addition of both re-

spective S levels with 60 kg P_2O_5 fed^{-1} gave increases in the grain yield of 10.37 and 12.44% (Table 4 and Fig. 1b). The highest grain yield of wheat of 2774.33 kg fed^{-1} was obtained with applying T_9 (P_2S_2) treatment (60 kg P_2O_5 and 200 kg S f^{-1}) but, the lowest one (2467.33 kg fed^{-1}) was recorded for the control treatment (P_0S_0). Similar results were reported by Kachhava *et al* (1997) and Chandra Deo and Khaldelwal (2009).

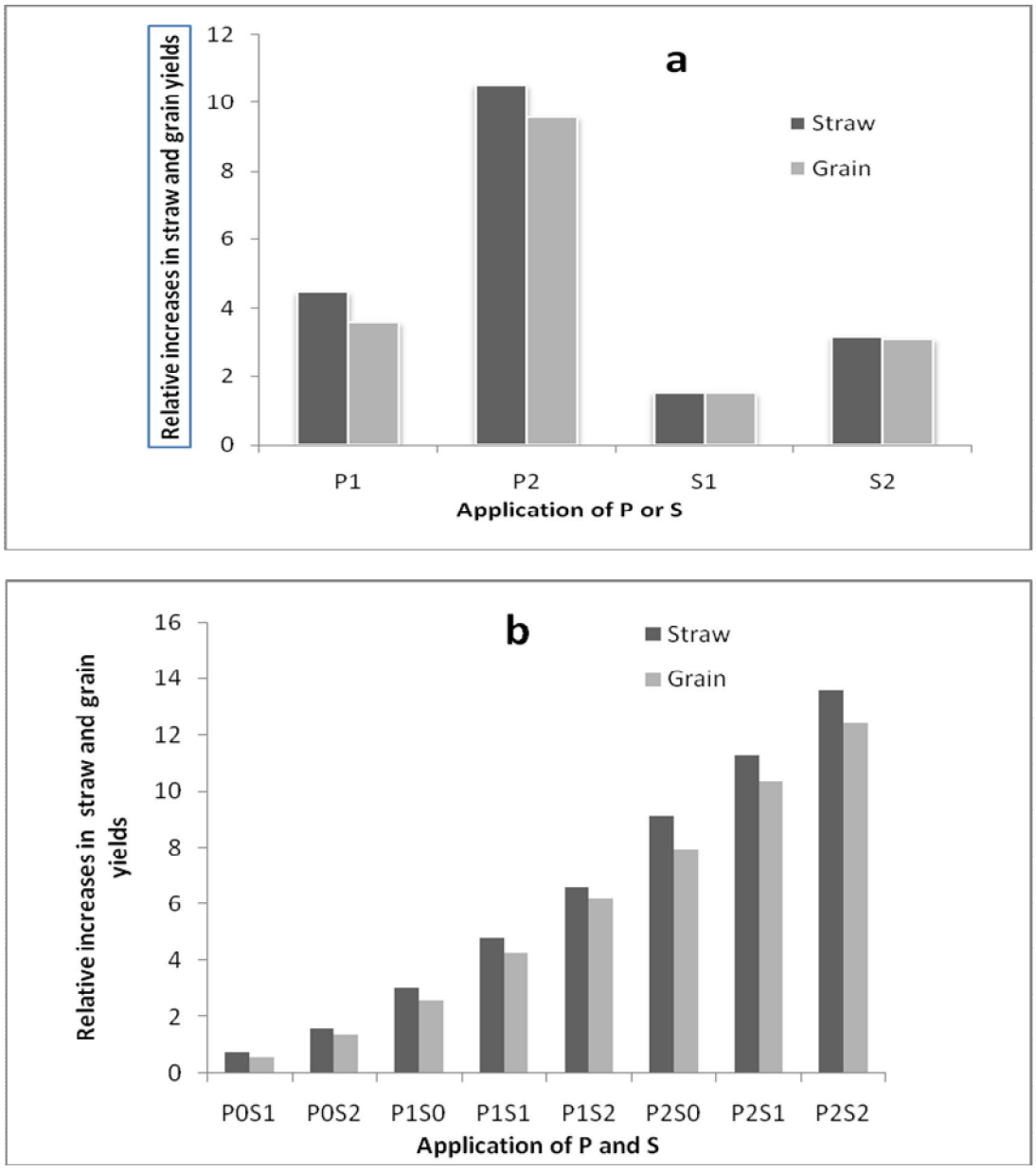

Figure 1: The relative increases in wheat straw and grain yields due to (a) main and (b) interaction application effect of P and S.

The increase in the grain yield may be attributed to the better root development with increasing the levels of these nutrients. Phosphorus

that is constituent of nucleic acid and different types of proteins, might stimulate cell division and increase the plant growth. Choudhary and Das, (1996) also reported a beneficial effect of applying sulphur due to lowering the soil pH and improving the chemical conditions of the soil.

2- Phosphorus Uptake by Wheat Plants.

The applied levels of phosphorus (30 and 60 kg P_2O_5 fed^{-1}) to the soil significantly increased the main P uptake by wheat straw and grains (Table 3 and Fig.2). Similarly, the main P uptake was significantly increased with applying both levels of sulphur (100 and 200 S kg fed^{-1}). The P uptake by wheat straw was increased by 23.19 and 54.23 %, and the P uptake by grains was raised by 11.89 and 28.83 % over the control when P was applied alone to the soil at levels of 30 and 60 kg P_2O_5 fed^{-1}, respectively. Also, elemental S applied alone at levels of 100 and 200 kg S fed^{-1} resulted in increases in the straw P uptake of 23.19 and 35.42 %, respectively, and in the grain P uptake of 12.23 and 19.13 %, respectively, over the control.

The interaction of both factors, P and S produced significant steady increases in P uptakes by both straw and grains (Tables 5 and 6). The P uptake by wheat plants ranged from 2.98 to 5.60 kg fed^{-1} by straw and from 8.32 to 12.25 kg fed^{-1} by grains. Highest P uptakes by straw and grains of 5.60 and 12.25 kg fed^{-1}, respectively, were recorded using T_9 treatment (60 kg P_2O_5 and 200 kg S fed^{-1}). Similar results were indicated by Teotia *et al* (2000) and Islam *et al* (2006) in mungbean**.**

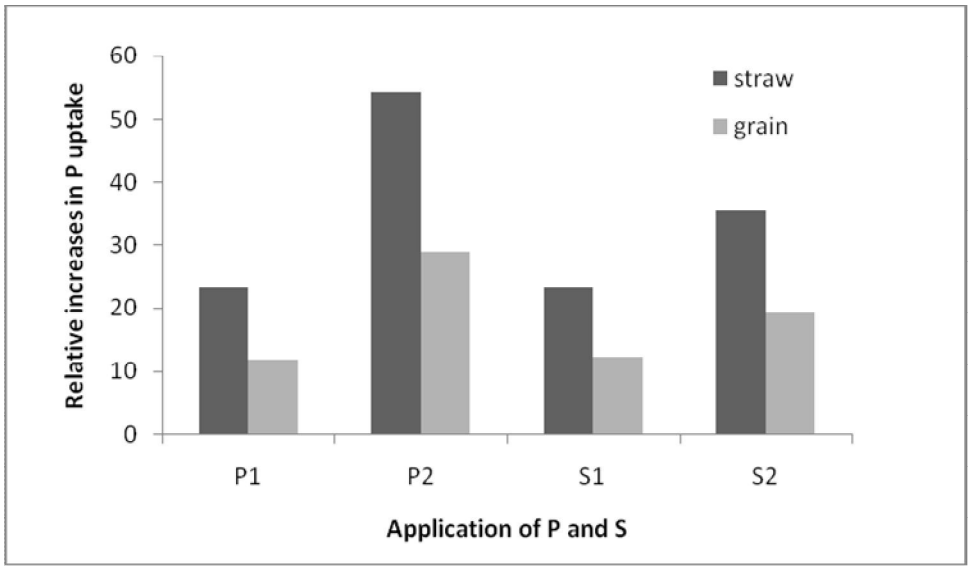

Figure 2: The relative increases in P uptake by wheat straw and grains induced by the application of P and S

Table 5. The application effect of P and S on P, Fe, Zn, Mn and Cu uptakes by straw of wheat plants.

Treatments	Uptake by straw				
	P (kg/fed)	Fe (g/fed)	Zn (g/fed)	Mn (g/fed)	Cu (g/fed)
T_1 (P_0S_0)	2.98	138.33	32.23	37.38	18.10
T_2 (P_0S_1)	3.21	167.99	36.62	46.56	18.68
T_3 (P_0S_2)	3.84	151.89	40.59	53.70	23.32
T_4 (P_1S_0)	3.17	164.99	43.07	44.13	24.57
T_5 (P_1S_1)	3.99	184.37	48.41	57.19	31.45
T_6 (P_1S_2)	4.66	213.17	52.49	74.69	45.89
T_7 (P_2S_0)	3.94	189.11	47.76	47.44	25.52
T_8 (P_2S_1)	5.22	234.41	57.52	71.12	37.69
T_9 (P_2S_2)	5.60	233.19	57.69	69.15	38.79
$LSD_{0.01}$	0.0.01	1.91	1.35	1.36	0.90

Table 6. The application effect of P and S on P, Fe, Zn, Mn and Cu uptakes by grain of wheat plants.

Treatments	Uptake by grain				
	P (kg/fed)	Fe (g/fed)	Zn (g/fed)	Mn (g/fed)	Cu (g/fed)
T_1 (P_0S_0)	8.32	87.51	75.50	72.70	17.77
T_2 (P_0S_1)	8.82	90.17	83.02	75.66	19.10
T_3 (P_0S_2)	9.09	101.37	85.95	85.20	24.26
T_4 (P_1S_0)	8.69	99.63	79.97	85.28	24.04
T_5 (P_1S_1)	9.88	117.04	88.40	99.81	29.58
T_6 (P_1S_2)	10.78	116.09	95.45	102.85	32.49
T_7 (P_2S_0)	9.99	86.47	92.68	73.15	31.70
T_8 (P_2S_1)	11.56	91.23	110.57	96.40	37.85
T_9 (P_2S_2)	12.25	97.28	106.99	103.58	37.45
$LSD_{0.01}$	0.13	1.61	5.84	0.99	0.93

3-Micronutrient Uptakes by Wheat Plants.

a) Iron (Fe) uptake

The application of P at levels of 30 and 60 kg P_2O_5 fed^{-1} increased the main Fe uptake by straw to reach 22.7 and 43.32%, respectively, while, adding S at levels of 100 and 200 kg S fed^{-1} raised the straw main Fe uptake to attain 18.96 and 21.29 %, respectively, over the control (Table 3 and Fig. 3a). Also, elemental S additions at levels 100 and 200 kg S fed^{-1} gave increases in the main Fe uptake by wheat grains of 9.28 and 15.04 %, respectively, over the control. However, addition of P at levels 30 and 60 kg P_2O_5 fed^{-1} produced a 19.04% increase and a 1.63% decreases, respectively, in the main Fe uptake by grains compared to the control.

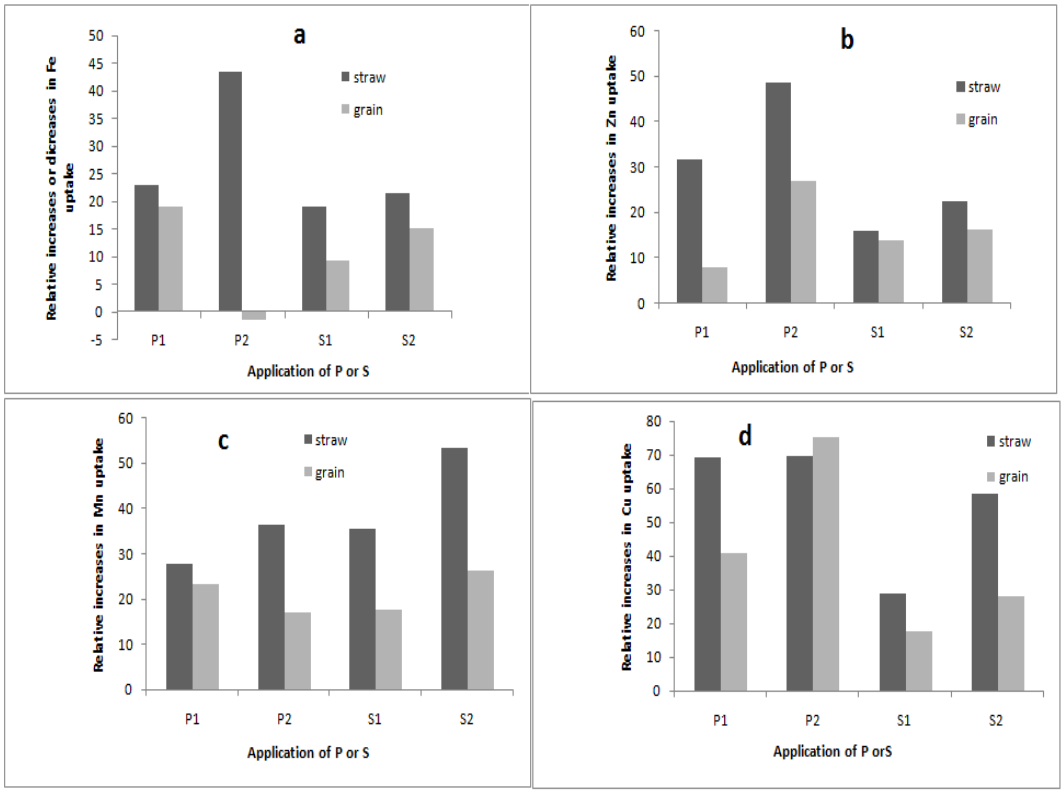

Figure 3: The relative increases or decreases of (a) Fe, (b) Zn, (c) Mn and (d) Cu uptakes by straw and grains induced by the application of P or S

The interaction of P and S levels showed a significant effect on Fe uptake by both straw and grains (Tables 5 and 6). The Fe uptake by wheat straw was increased by only 29.66 and 13.56 g fed^{-1} over the control by the application of 100 and 200 kg S fed^{-1}, respectively, without adding P. However, using 30 kg P_2O_5 fed^{-1} with these respective applied S levels produced Fe uptake by straw of 46.04 and 74.84 g fed^{-1}, respectively, over the control,. Moreover, adding 60 kg P_2O_5 fed^{-1} in a combination with both S levels resulted in 69.08 and 94.84 g fed^{-1}, respectively, of Fe uptake by straw over the control (Table 5). Also, the addition of both respective levels S without applying P increased the Fe uptake by grains by 2.66 and 13.86 g fed^{-1}over the control. However, applying 30 kg P_2O_5 fed^{-1} with100 and 200 kg S fed^{-1} gave Fe uptake by grains of 29.53 and 28.58 g fed^{-1}, respectively. A respective Fe uptake by grains was recorded with adding 60 kg P_2O_5 fed^{-1}combined with both S levels of 3.72 and 9.77 g fed^{-1}.

The addiction of T_6 (P_1S_2) treatment (30 kg P_2O_5 and 200 kg S fed^{-1}) showed the highest Fe uptake by wheat straw (213.17 g fed^{-1}). The lowest Fe uptake by straw (138.33 g fed^{-1}) was recorded for the T_1 (P_0S_0) treatment. Moreover, the highest value (117.04 g fed^{-1}) of Fe uptake by wheat grains was found for the T_5 (P_1S_1) treatment, and the lowest one (86.47 g fed^{-1}) was obtained for the T_7 (P_2S_0) treatment (Table 6).

So, sulphur application resulted in increases in Fe uptake by wheat plants as it was also indicated by Malewar and Ismail (1997). They indi-

cated that the application of 80 mg S kg^{-1} increased the available Fe by 49%. A close relationship exists between Fe and S metabolism in plants.

b) Zinc (Zn) uptake

The application of P or S had significant increases in the main Zn uptake by wheat straw and grains (Table 3). The application of P at levels of 30 and 60 kg P_2O_5 fed^{-1} resulted in an increase in the main Zn uptake by straw of 31.6 and 48.9 %%, respectively. Also, S application at levels of 100 and 200 kg fed^{-1} showed an increase in the main Zn uptake by straw of 15.8 and 22.5 %, respectively. Moreover, the respective increases in the main Zn uptake by grains were 7.9 and 26.8 % due to the applied P levels as well as 13.6 and 16.2 % due to the applied S levels (Table 3 and Fig. 3b).

The results in Tables 5 and 6 showed that the interaction of P and S levels had significant increases in the Zn uptake by straw and grains. Additions of sulphur at 100 and 200 kg S fed^{-1} without applying P showed an increase in the Zn uptake by straw of 4.36 and 8.75 g fed^{-1}, respectively, over the control. However, the combination of 30 kg P_2O_5 fed^{-1} with these levels of S had an increase in the straw Zn uptake of 16.18 and 20.26 g fed^{-1}, respectively, over the control. Moreover, adding 60 kg P_2O_5 fed^{-1} with these S levels caused an increase in the straw Zn uptake of 25.26 and 25.46 g fed^{-1} over the control, respectively. The highest value of Zn uptake by straw (57.69 g fed^{-1}) was observed for the plot receiving the T_9 treatment (60 kg P_2O_5 and 200 kg S fed^{-1}). However, the lowest value of Zn uptake by straw (32.23 g fed^{-1}) was recorded for the T_1 treatment (Table 5). The Zn uptake by wheat grains had increases by 7.52 and 10.45 g fed^{-1} with adding sulphur alone at levels of 100 and 200 kg S fed^{-1}, respectively. However, adding 30 kg P_2O_5 fed^{-1} with these sulphur levels produced respective increases in the grain Zn uptake of 12.90 and 19.95 g fed^{-1} over the control Moreover, applying 60 kg P_2O_5 fed^{-1} with both sulphur levels produced respective increases of 17.18 and 35.07 g fed^{-1} in the grain Zn uptake over the control. The Zn uptake by grains had the highest value of 110.57 g fed^{-1} with using the T_8 treatment and the lowest one of 75.50 g $fed^{-1}$with the T_1 treatment (Table 6).

Due to the acidifying effect of S oxidation, the availability of nutrients like P, Zn, Cu, Fe and Mn is influenced (Hilal *et al*, 1990b). The application of P and S resulted in increases in the uptakes of these nutrients by plants, which may be due to the availability increase of these nutrients in the soil. The high application level of P (60 P_2O_5 fed^{-1}) however, resulted in a decrease in the Zn uptake by wheat grains. This may be either due to the dilution effect when the plant growth rate exceeded that of the Zn uptake or due to the reduction in the translocation of Zn from roots to leaves (Tandon, 2001) .The hypothesis that P application resulted in the formation of insoluble zinc phosphate is not true and many workers have shown that P application has no effect on the available Zn contents of the soil (Tandon, 2001). The induced Zn uptake increase by S application has been reported by Sharma *et al*, (1990) and Babhulkar *et al*, (2000). The in-

crease in Zn uptake may be due to the increase in the root surface area resulting from better growth due to S supply as both sulphur and zinc are known to increase root growth. Babhulkar *et al*, (2000) indicated that Zn and S interaction occurred at both absorption sites and within plants.

c) Manganese (Mn) uptake

Phosphorus applications at levels of 30 and 60 kg P_2O_5 fed^{-1} raised the main straw Mn uptake by 27.9 and 36.3 %, respectively, compared to the control (Table 3 and Fig. 3c). Also, sulphur application at levels of 100 and 200 kg S fed^{-1} resulted in increases in the main straw Mn uptake of 35.6 and 53.1 %, respectively, compared to the control. In addition, both P applied levels showed the respective increases in the main Mn uptake by grains of 23.28 and 16.92 %. Also, both S added levels produced respective increases in the main Mn uptake by grains by 17.62 and 26.18 compared to the control.

There was a significant interaction effect of P and S applications on the Mn uptake by wheat straw and grains (Tables 5 and 6). The highest amount of Mn taken up by wheat straw (71.12 g fed^{-1}) was recorded for the T_8 treatment, while, the lowest one (37.38 g fed^{-1}) was for the T_1 treatment. The Mn uptake by straw was increased by 9.18 and 16.32 g fed^{-1} over the control with applying 100 and 200 kg S fed^{-1} respectively without adding P. However, P additions of 30 kg P_2O_5 fed^{-1} combined with both S levels produced increases in the straw Mn uptake of 19.81 and 37.31 g fed^{-1}, respectively, over the control. However, P additions at 60 kg P_2O_5 fed^{-1} with applying S at both levels gave increases in the straw Mn uptake of 33.74 and 31.77 g fed^{-1}, respectively, over the control.

The application of S_1 and S_2 alone increased the Mn uptake by wheat grains by 2.96 and 12.50 fed^{-1}, respectively, over the control (Table 6). Moreover, the combination of 30 kg P_2O_5 fed^{-1} with both applied S levels increased the grain Mu uptake by 24.11 and 30.15 g fed^{-1}, respectively, over the control. Also, mixing 60 kg P_2O_5 fed^{-1} with S applied levels increased the grain Mn uptake by 23.70 and 30.88 g fed^{-1}. The highest amount of Mn taken up by wheat grains (103.58 g fed^{-1}) was recorded for the T_9 treatment (60 kg P_2O_5 and 200 kg S fed^{-1}) while, the lowest one (72.70 g fed^{-1}) was signed to the T_1 treatment.

So, the application of P had a significant effect on the Mn uptake by wheat plants. The possible mechanism that is responsible for the less uptake of Mn at high nutrient application levels may be that other cations also compete with Mn for the transport across membranes. Applications of S had a significant effect on the Mn uptake by wheat plants. The interaction of S and Mn is least studied. The mechanism that is responsible for the increased Mn uptake is not known. Applications of acid (NH_4^+) forming fertilizer may increase the availability of Mn (Havlin *et al,* 2007).

d) Copper (Cu) uptake.

There was a significant effect on the main Cu uptake by wheat straw and grains due to the applied levels of P or S. The application of P (P_1 and P_2) resulted in increases in the main Cu uptake by wheat straw of 69.3 and

69.7 %, respectively, over the control. Also, S (S_1 and S_2) levels showed increases in this main respect of 28.8 and 58.4 %, respectively, over the control. Furthermore, the application of P levels (P_1 and P_2) resulted in increases in the main Cu uptake by grains of 40.82 and 75.02 %%, respectively, over the control, but S_1 and S_2 application raised the main Cu uptake by grains of 17.75 and 28.16 %, respectively, over the control (Table 3 and Fig.3d).

Both applied levels of P and S had significant effects on the Cu uptake by wheat straw and grains (Table 5 and 6). The maximum value of Cu uptake (45.89 g fed^{-1}) by straw was recorded for the T_6 treatment (30 kg P_2O_5 and 200 kg S fed^{-1}) and the minimum one (18.10 g fed^{-1}) was for the T_1 treatment (Table 5). Also, the highest amount of Cu taken up (37.85 g fed^{-1}) by grains was obtained with the T_8 treatment (60 kg P_2O_5 and 100 kg S fed^{-1}) while, the lowest one (17.77 g fed^{-1}) was with T_1 treatment (Table 6). The induced increase in Cu uptake by wheat plants due to phosphorus applications may be attributed to the increased root growth**.**

Conclusion

The interaction of phosphorus and sulphur application depends on the soil fertility status, levels of applied nutrients, test crop and climatic conditions. The effect of phosphorus and sulphur application was synergistic at all P and S levels. The combination of 60 Kg P2O5 fed^{-1} and 200 kg S fed^{-1} resulted in the highest values of wheat straw and grain yield as well as the highest uptake values of P, Fe, Zn and Cu. This will increase the fertilizer use efficiency and save precious and cost inputs. Also, these will minimize the threats of soil and water pollution.

References

Abdin, M, Z., A. Ahmed, I. Khan, A. Jamal and M. Iqbal. 2003 Sulphur interaction with other nutrients. In. Abrol, Y. P. and A. Ahmed (eds), Sulphur in Plants, p: 359. Kluwer Academic Publication, The Netherlands.

Alam, S. M., S. Azam, S. Ali and M. Iqbal, 2003. Wheat yield and P fertilizer as influenced by rate and integrated use of chemical and organic fertilizer. Pak. J. Soil Sci. 22(2): 72-76.

Aulakh, M. S., N. S. Pasricha and A. S. Azad, 1990 Phosphorus-Sulphur interrelationship for soybean on P and S deficient soil. Soil Sci., 150: 705-709.

Babhulkar, M. S., D. Kar, W. P. Bodole and S. S. Balpande. 2000. Effect of sulphur and Zn on yield, quality and butrient uptake by safflower in Vertisol. J. Ind. Soc. Soil Sci., 48: 541-543.

Bakhshipour, R., E. Kahneh and P. A. Oskoei, 2008. Interaction studies of P and Zn in tea seedlings inoculated with *Arbucular mycorrhizal* fungi. Asian J. Chem., 20: 1175-1178.

Chandra Deo and R. B. Khaldelwal, 2009. Effect of P and S nutrient on yield and quality of chickpea (*cicer arietinum L.*). J. Indain. Soc. Soil Sci., 57: 352-356.

Choudhary, H. P. and S. K. Das, 1996. Effect of P, S and Mo application on yield of rainfed blackgram and their residual effect on safflower, soil and soil and water conservation in eroded soil. J. Indain Soc. Soil Sci., 44:741-745.

Gomez, K. A. and A. A. Gomez, 1984. Statistical Procedures for Agricul-

ture Reseach. Johan Wiley and Sone. New York, U. S. A.

Havlin, J. L., J. D. Beation, S. L. Tisdale and W. L. Nelson. 2007. Soil Fertility and Fertilizer, An Introduction to Nutrient Management, 7th edition p: 221. Pearson Education Inc. Singapore.

Hedge, D. M. and I. Y. L. N. Murthy. 2005. Management of secondary nutrients. Indian J. Fert., 9: 90-100.

Hilal, M.H., H. El-Lakkany and H. El-Sheemy. 1990b. Effect of sulphur and long term fertilizer application program on rhizosphere and yield of peanut in sandy soils. In. Proc. Middle East Sulphur Symposium. P: 217. 12.16 February, 1990, Cairo.

Islam, M. N., S. Hoque and A. Islam, 2006. Effect of PxS interactions on nutrient concentration and yield of wheat, rice and mungbean. J. Indain. Soc. Soil Sce., 54: 86-91.

Kachhava, K. G., D. S. Gawande, O. D. Kohire and S. S. Mane, 1997. Influence of various sources and levels of sulphur on nodulation, yield and uptake of nutrient by chickpea. J. Indian Soc. Soil Sci., 45:590-591.

Konde, B. K., P. M. Managava and R. B. Sonawane, 1998. Effect of *rhizobium loti*, vesicular arbuscular mycorrhizae and P levels on nodulation, yield and nutrient uptake by chickpea (*Cicer arietinum L.*). J. Indian Soc. Soil Sci., 46: 465-467.

Malewar, G. U. and S. Ismail. 1997. Sulphur in balanced fertilization in wesrem India. Proc. The TS/FSI/IFA Sypsosium on Sulphur in Balaced Fertilization. P: 14. New Delhi, India.

Parkinson, J. A., and S. E. Allen, 1975. A wet oxidation procedure suitable for the determination of nitrogen and mineral nutrients in biological material. Comm. Soil Sci. Plant Anal. 6:1-11.

Randhawa, P. S and C. L. Arora. 2000. Phodhporus-sulphur interaction effects on dry matter yield and nutrient uptake by wheat. J. Indian Soc. Soil Sce., 48: 536-544.

Sharma, U. C., 1990. Effect of Zn and S on nutrient uptake and yield of mustard. J. In. Soc. Soil Sci., 38: 696-701.

Shuaib, K., M. Ansar, M. A. Ali, A.Sher, G. Ahmed and M. Rashid, 2003. Effect of phosphorus on the yield and components of wheat variety (Inqlab-91) under rainfed conditions. Sarhad J. Agric. Vol. 25: 21-24.

Singh, V., V. Kumar and S. P. S. Karawasra, 1995. Interaction of sulphurand zinc on dry matter yield, concentration and uptake of sulphur in green gram (*Vigan radiate* L.). Crop Res., 9: 32-41.

Tandon, H. L. S., 2001. Management of nutrient interactions in agriculture, p: 142. Fertilizer Development and Consultation Organization, New Dlhi, India.

Teotia, U. S., V. S. Mehta and P. C. Srivastava, 2000. Phosphours-Sulphur interaction in moongbean (*Vigan radiate L.* Wilczek): I. Yield, phosphours and sulphur contents. Legume Res., 23: 106-109.

Tiwari, K. N. and B. R. Gupta. 2006. Sulphur for sustainable high yield agriculture in Uttar Pradesh. Indian J. Fert., 1: 37-52.

Tufemkci, S., F. Somnez and R. I. G. Sensoy. 2005. Effect of Arbuscular mycorrhiza fungus inoculation and phosphorus and nitrogen fertilization on some plant growth parameters and nutrient contents of chickpea. J. Biol. Sci., 5: 738-743.

تاثير اضافة الفوسفور والكبريت على المحصول وامتصاص الفوسفور والعناصر الصغرى بواسطة نباتات القمح

عزت مصطفى احمد
قسم الاراضى والمياه – كلية الزراعة – جامعة أسيوط

الملخص

أجريت تجربة حقلية فى المزرعة البحثية بقسم الاراضى والمياه – كلية الزراعة – جامعة اسيوط خلال موسم ٢٠١٣/٢٠١٤. وذلك لدراسة تاثير الفوسفور والكبريت على المحصول وامتصاص الفوسفور والعناصر الصغرى بواسطة نباتات القمحوكنت معاملات الفوسفور صفر و ٣٠ و ٦٠ كجم فو٢اه للفدان ومعاملات الكبريت صفر و ١٠٠ و ٢٠٠ كجم كب للفدان. وقد اوضحت النتائج ان اضافة الفوسفور بمعدل ٣٠ و ٦٠ كجم فو٢اه للفدان ادى الى زياد معنوية فى مصول القش بنسبة ٤٥,٤ و ٥٠,١٠ % ، وفى محصول الحبوب بنسبة ٨٥,٣ و ٩,٥٦ % مقرنة بالكنترول. كما ان اضافة الكبريت بمعدل ١٠٠ و ٢٠٠ كجم كب للفدان ادت الى زيادة معنوية فى محصول القش بنسبة ١,٥١ و ٣,١١% ، وفى محصول الحبوب بنسبة ١,٥٠ و ٣,٠٨ % مقارنة بالكنترول. كما ادت اضافة الفوسفور والكبريت الى زيادة معنوية فى امتصاص نباتات القمح للفوسفور والعناصر الصغرى. فاضافة الفوسفور بمعدل ٣٠ و ٦٠ كجم فو٢اه للفدان كانت الزيادة فى نسبة الفوسفور الممتص بواسطة القش هى ٢٣,١٩ و٥٤,٢٣ % وبواسطة الحبوب هى ١١,٨٩ و ٢٨,٨٣ % مقارنة بالكنترول ، كما ادت اضافة الكبريت الى زيادة معنوية فى نسبة الفوسفور الممتص بواسطة القش والحبوب.

ادت اضافة المستوى الاعلى للفوسفور الى زيادة فى كل من الحديد والزنك والمنجنيز والنحاس الممتص بواسطة القش بنسبة ٤٣,٣٢ و ٤٨,٦٥ و ٣٦,٣٧ و ٦٥,٧٥% على الترتيب زيادة عن الكنترول ، كذلك زادت الكمية الممتصة من عناصر الزنك والمنجنيز والنحاس بنسبة ٣٦,٣٧ و١٦,٩٢و٧٥,٠٢ % على الترتيب زيادة عن الكنترول ، وادى الى نقص الحديد الممتص بواسطة الحبوب بنسبة ١,٦٣%. بالاضافة الى ذلك ادت اضافة المستوى الاعلى من الكبريت الى زيادة فى كل من الحديد والزنك والمنجنيز والنحاس الممتصة بواسطة القش بنسبة ٢١,٢٩ و٢٢,٥٢ و٥٣,٣٢ و٥٨,٨٣ % على الترتيب وزادت الكمية الممتصة بواسطة الحبوب بنسبة ١٥,٠٤و١٦,١٢و٢٦,١٨و٢٨,١٦% على الترتيب زيادة عن الكنترول.