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EFFECT OF SULPHUR AND PHOSPHATE FERTILIZATION ON GROWTH YIELD AND FRUIT QUALITY OF PEPPER (*Capsicum annuum,* L.)

a- Vegetative growth and chemical constituents of leaves

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ABSTRACT

Two field experiments were carried out at El-Baramoon Farm, Mansoura Horticultural Research Station, during the summer seasons of 2002 and 2003.The study aimed to investigate the effect of sulphur levels(0, 150 and 300 kg S/fed/), and phosphorus fertilization levels (0,30, 60 and 90 kg P_2O_5/fed.) and their interactions on the vegetative growth parameters (plant height, number of branches, number of leaves, leaf area, fresh wt./plant and dry wt./plant), leaf chlorophyll contents and chemical compositions of sweet pepper cv. California Wonder. All tested vegetative growth parameters increased with the increase in sulphur and phosphorus levels.The increments were significant except those of number of branches per plant. The interaction effects showed that the highest level of sulphur (300 kg S/fed) plus the highest phosphorus level (90 kg P_2O_5/ fed) were of superior effects on all the studied vegetative growth parameters.

Chlorophyll a, b, total chlorophyll and chlorophyll a:b ratio significantly increased with increasing either sulphur or phosphorus application levels, over the control. The interaction effects appeared the highest contents of chlorophyll a,b and total chlorophyll with the highest levels of both sulphur (300 kg S/fed) and phosphorus (90 kg P_2O_5/fed.)

Leaf contents of nitrogen, phosphorus, potassium and sulphur increased significantly with the sulphur and phosphorus fertilization, compared with controls. The increments were in line with the increase in the added sulphur and phosphorus levels. The interaction effects indicated that leaves from plants fertilized with the highest level of sulphur (300 kg S/fed.) plus the highest level of phosphorus (90 kg P_2O_5/ fed) resulted in the highest contents of N, P, K and sulphur.

The highest leaf contents of Fe, Zn and Mn were detected in plants fertilized with sulphur at 300 kg S./fed. and phosphorus at 60 kg P_2O_5/fed. Leaves of plants treated

with sulphur at 300 kg S/fed. combined with phosphorus level at 60 kg P_2O_5/ /fed., had the highest contents of Fe, Zn and Mn.

INTRODUCTION

Sweet pepper (*Capsicum annuum* L.) is an important vegetable and condiment crop grown in tropical and subtropical regions of the world for the purpose of exportation and local markets usage. In Egypt, sweet pepper occupied 22853 faddans in 2005,with a production average of 20.05 ton/fed.* Great efforts have been directed toward improving sweet pepper production and quality mainly to increase the exported yield. Several factors are affecting plant growth, among them the nutritional supplies with sulphur and phosphorus fertilization.

Cited after the Economic and Statistical Departement, Ministry of Agriculture, Egypt, Several investigations pointed to the presence of a good relationship between sulphur and solubility and availability of phosphorus to plants under alkaline soil (Rivera and Irgazarry, 1984).

Increasing sulphur level improved pepper vegetative growth characters, i.e. plant height, No. of leaves and branches and total dry weight/plant (Taylor, *et al*.,1984 , Fenn *et al*., 1987 and Shaheen and Omar, 1989). Pandey and Agrawal (1994) reported that plant height, No. of leaves, leaf area, total (leaf , shoot and plant biomass) of tomato plants were greatly enhanced by sulphur application. They also reported that S treated plants allocated a greater proportion of their assimilates for growth and development of photosynthetic organs.

Many investigators confirmed that application of elemental sulphur increased all growth parameters and leaf chlorophyll content (Topcuoglu and Yalcin, 1997 on tomato ; Sawan and Rizk, 1998 on eggplant ; Hewedy, 1999 on tomato ; Smatanova *et al*., 2004 on pepper and El-Morsy, 2005 on garlic).

Mostafa *et al*., (1990) found that solubility of Fe and Mn was clearly increased in different soil layers as a result of S incorporation with soil.

Elemental sulphur is the most effective of the soil acidulents. By the end of S oxidation process, sulphuric acid is formed and soil pH starts to drop down causing an increase in the availability and uptake of N,P,K,S Ca, Fe, Zn, Mn and other elements in many vegetable crops (Rahman and Hoque, 1994 on eggplant ; Tisdale *et al*., 1995 ; Vinay *et al*., 1995 on garlic ; Topcuoglu and Yalcin, 1997 on tomato ; El-Fayoumy and El-Gamal, 1998 on potato and Kowalska , 2005 on tomato).

Phosphorus is closely concerned with vital growth processes which are essential in all living cells. It is a constituent of nucleic acid and nuclei; it plays a good role in plant metabolism, structure and reproduction processes that can not be replaced by any other element. Phosphorus is indirectly associated with all the biochemical reactions in plants. It is associated with both the accumulation and release of energy for plant metabolic functions. In addition it is known that phosphates are necessary and intimately involved in photosynthesis, in the utilization of sugars, starch and the formation of meristematic tissues (Gardener *et al*., 1985).

Phosphorus application considerably improved vegetative growth of pepper plants. Vegetative growth parameters i.e. plant height, number of leaves, number of branches, leaf area, both fresh and dry weight of shoots and leaf chlorophyll content increased with the increase in the level of applied phosphorus (Reuveni *et al*., 1998 ; Kaya *et al*., 2003 and Alabi, 2006). Many investigators reported that the availability and uptake of N, P, K Ca, Mg, S, Fe, Zn and Mn were markedly increased in pepper plants as a result of increasing P fertilization level (Olsen *et al*., 1993 , Davies *et al*., 1999 , Kaya *et al*., 2003 and Schroeder and Janos, 2005)

Regarding the interaction effect of P and S, many investigators illustrated that application of P and S was of a great effect in maximizing different vegetative growth parameters, chlorophyll content and leaf mineral contents (Shaheen *et al*., 1989 a on broad bean; Olsen *et al*., 1993 on pepper; Gopal *et al.,* 2003. on tomato, and Jaggi *et al.,* 2003 on pepper).

MATERIALS AND METHODS

Two field experiments were carried out at El-Baramoon Farm of Mansoura Horticultural Research Station, during the two successive summer seasons of 2002 and 2003. This work aimed to study the effect of mineral fertilization with different levels of sulphur, phosphorus and their interactions on vegetative growth, leaf chlorophyll contents and chemical compositions of sweet pepper plants(*Capsicum annuum* L. cv. California Wonder), under clay soil.

On March 20th, of both 2002 and 2003 seasons, sweet pepper seeds cv. California Wonder were sawn in the nursery in 2 x 2 m. beds. After six weeks, seedlings were transplanted to the field, 30 cm apart on one side of the ridge. The experimental unit was consisted of 4 rows, each of 4 m long and 0.7 m width, with an area of 11.2 m^2.

Experimental design and treatments:

A complete randomized block design in split plot system, with 3 replications was adopted. Main plots were occupied with sulphur levels (0, 150 and 300 kg S/fed.), whereas phosphorus levels (0, 30, 60 and 90 kg P_2O_5/fed.) were placed in the subplots. The experiment includes 12 treatments, which were the combination of 3 sulphur x 4 phosphorus levels. Sulphur was applied once before transplanting and during soil preparation, whereas phosphorus was applied as Ca-superphosphate (15.5%) in two equal doses, before transplanting and 30 days later.

All plots were fertilized equally with N at 200 kg N/fed. using ammonium sulphate (20.5%N) and 50 kg K_2O/fed. as potassium sulphate (48% K_2O). All plants received similar cultural practices as commonly recommended.

Recorded data:

Vegetative growth:

Three representative plants from each plot were randomly picked up at 90 days after transplanting to measure, plant height (cm), number of branches/ plant, number of leaves/ plant, leaf area/ plant (according to the method of Koller, 1972) and fresh and dry weight/ plant (kg).:

Photosynthetic pigments:

Samples of 0.2 gm fresh leaves were used for extraction and determination of chlorophylls a and b by using spectrophotometer (Mackinny, 1941).

Elemental composition of leaves:

Leaf samples were used to determine, total nitrogen (%), phosphorus (%), potassium (%) and sulphur concentration (%), according to Black (1983), Watanab and Olsen (1965), Jackson (1965) and Page (1982), respectively. Meanwhile, Fe, Mn and Zn were measured in the same leaf samples, using atomic absorption spectrophotometer, according to the method of Chapman and Partt (1961).

All collected data were statistically subjected to analysis of variance and means were separated using Least significant difference test as described by Snedecor and Cochran (1980).

Mechanical and chemical analysis of the experimental soil were conducted at Mansoura Center of Soil Improvement, Mansoura, Egypt, according to methods of Black (1965) and Page (1982). The analysis data are shown in Table (1).

Table (1): Physical and chemical analysis of the experimental soil, during 2002 and 2003 seasons.

Soil properties	Season	
Soil properties	2002	2003
Physical analysis		
Coarse sand%	1.92	2.12
Fine sand%	22.57	22.79
Silt %	26.11	25.96
Clay %	49.40	49.13
Soil type	Clay	Clay
Chemical analysis		
Total nitrogen %	0.12	0.15
Available P (ppm)	7.15	7.95
Exchangeable K (ppm)	215	229
$CaCO_3$%	2.80	2.75
Organic matter %	1.90	2.10
EC (mmhos/cm, 25ºC)	1.25	1.29
pH (1:2:5 w/v)	8.02	7.90
Soluble anions (meq/L)		
Cl^-	3.49	3.43
HCO_3	3.15	3.18
CO_3^-	0.00	0.00
SO_4^-	5.11	5.18
Soluble cations (meq/L)		
Ca^{++}	4.00	3.97
Mg^{++}	1.29	1.27
Na	1.19	1.22
K	5.27	5.33
Available micronutrients (ppm)		
Fe	3.59	3.63
Zn	1.31	1.29
Cu	0.53	0.55
Mn	1.48	1.43

RESULTS AND DISCUSSION

Vegetative growth parameters:

Effect of sulphur

The effect of sulphur and phosphorus levels and their interactions on plant height, number of branches, number of leaves, leaf area/plant, fresh weight and dry weight/plant are shown in Tables (2 and 3).

Data presented in Table (2) show that plant height and number of leaves were significantly increased with increasing sulphur levels from zero up to 300 kg. S/fed. However, the increase in number of branches did not reach the level of significance. This was true in both seasons of the study.

Table (2). Effect of sulphur, phosphorus and their interactions on plant height (cm) No. of branches and No. of leaves, during 2002 (S1) and 2003 (S2) seasons.

Characters		**Plant height (cm)**		**No. of branches**		**No. of leaves**	
Season		**S1**	**S2**	**S1**	**S2**	**S1**	**S2**
Treatment							
S (kg S/fed)							
Control		63.33	59.49	10.20	9.08	39.65	41.20
150		70.95	66.16	10.41	9.38	53.19	50.61
300		77.24	69.17	10.66	10.29	65.30	61.79
L.S.D. (5%)		2.53	1.24	N.S	N.S	2.95	3.41
P (kg P_2O_5/fed)							
Control		62.13	57.05	9.90	8.60	24.37	32.57
30		67.95	64.63	10.10	9.08	45.70	48.92
60		73.99	67.63	10.67	9.94	64.64	59.98
90		77.95	70.44	11.02	10.72	76.16	66.33
L.S.D. (5%)		1.84	1.75	N.S	N.S	3.86	2.26
Interactions							
S levels (kg S/fed)	**P Levels (kg P_2O_5/fed)**						
~~Control~~	Control	57.25	54.23	9.80	8.38	14.31	25.18
~~Control~~	30	61.75	59.38	9.95	8.50	30.81	39.42
~~Control~~	60	65.33	60.10	10.19	9.13	51.92	46.28
~~Control~~	90	69.00	64.25	10.85	10.30	61.56	53.93
~~150~~	Control	63.03	58.18	9.93	8.46	26.38	32.19
~~150~~	30	67.00	64.13	9.97	8.62	41.46	48.17
~~150~~	60	75.40	70.25	10.82	9.75	66.38	56.36
~~150~~	90	78.38	72.08	10.93	10.70	78.55	65.73
~~300~~	Control	66.13	58.75	9.97	8.96	32.41	40.33
~~300~~	30	75.10	70.40	10.39	10.12	64.82	59.18
~~300~~	60	81.25	72.53	11.00	10.93	75.61	68.29
~~300~~	90	86.48	75.00	11.29	11.15	88.36	79.34
L.S.D. (5%)		3.18	3.03	N.S	N.S	6.69	3.91

Results of Table (3) declare that leaf area/plant, fresh weight and dry weight/plant, increased significantly concurrently with the increase of sulphur levels from zero, 150 up to 300 kg S/fed. The increase in vegetative growth parameters could be due to the fact that sulphur increased the capacity of plant in building metabolites (Shaheen *et al*. 1989a) on or to the helpful effect of sulphur on activating vegetative growth, which in turn increased the number of leaves and branches (Omar *et al*. 1990).

Results are in harmony with the findings of Shaheen and Omar (1989) on sweet pepper ; Lopez-Moreno *et al*. (1996) on tomato; Sawan and Rizk (1998) on egyplant; Hewedy (1999) on tomato ; Gopal *et al*. (2003) on tomato; Smatanova *et al*. (2004) on pepper and El-Morsy (2005) on garlic.

Effect of phosphorus:

Data presented in Table (2) show that plant height and number of leaves increased significantly with increasing phosphorus levels. This increase was corresponding to the increase in P rate from zero up to 90 kg P_2O_5/fed. Number of branches was not significantly increased with increasing phosphorus levels compared with control. This was true in the two seasons of the study.

Data shown in Table (3) indicate that application of phosphorus levels markedly increased leaf area/plant, fresh weight as well as dry weight/plant. Plants received P-fertilizer were generally better than those of the control. Tincrease in the rate of applied P from 30 to 90 kg P_2O_5/fed caused stimulative effect on plant growth and the highest two levels (60 and 90 kg P_2O_5/fed.) were the superior treatments, where they significantly increased leaf area/plant and shoot fresh and dry weights/plant. This was evident in both seasons. The positive effect of phosphorus on vegetative growth may be due to the beneficial effect of P-element on the activation of photosynthesis and metabolic processes of organic compounds in plants and hence increasing plant growth (Gardener *et al*., 1985). These results are in agreement with those of Shaheen et al.,(1989 b); Lopez-Moreno *et al*. (1996); Reuveni *et al*. (1998); Nigri *et al*. (1999); Broschat and Klock (2000); Kaya *et al*. (2003) and Alabi (2006). They all concluded that P-supplementation to pepper plants improved their growth parameters i.e. plant height, number of leaves, shoot fresh and dry weights and leaf area/plant.

Effect of interaction:

Data in Table (2) cleare that application of S and P in combination exhibited significant increase in plant height and number of leaves. However, the increase in number of branches as a result of S + P application was not significant in the two seasons. Data presented in Table (3) show that leaf area/plant, fresh weight and dry weight increased significantly with the increase in the combined sulphur and phosphorus levels. It is clear from the Data of Tables (2 & 3) that the highest rates (300 kg S + 90 kg P_2O_5/*fed*) gave the best results in all studied parameters. The increase in plant growth parameters could be due to the effect of sulphur element on soil pH reduction, to the point that helps in increasing the availability of some nutrient elements such as P, Fe, Zn, Mn and Cu which were reflected on plant uptake and growth (Dahdouh *et al*. (1993) ; Mehana (1994); Mehana and Farag (2000) and El-Morsy (2005). Similar results were obtained by Olsen *et al*. (1993) who indicated that application of P + S increased the dry weight of leaves and stems of bell pepper. Hewedy (1999) on tomato; Mahmoud (2000) on eggplant, found that application of S (1000 kg/fed) in combination with 0.2% P gave the highest records for number of branches and plant height. Youssef (2002) found that application of 50 kg S/fed + 60 kg P/*fed* improved plant height and number of leaves/plant. Gopal *et al*. (2003) illustrated that the highest P and S levels restored growth of tomato plants.

Table (3). Effect of sulphur, phosphorus and their interactions on leaf area/plant (m^2), fresh weight/plant (gm) and dry weight/plant (gm) during 2002 (S_1) and 2003 (S_2) seasons.

Characters		**Leaf area (m^2) /plant**		**Fresh wt./plant (gm)**		**Dry wt./plant (gm)**	
Season		**S1**	**S2**	**S1**	**S2**	**S1**	**S2**
Treatment							
S (kg S/fed)							
Control		0.248	0.277	167.21	152.38	45.87	39.49
150		0.271	0.302	224.04	232.88	60.37	61.81
300		0.296	0.335	267.51	263.45	71.47	67.67
L.S.D. (5%)		0.006	0.006	5.83	15.45	2.59	2.18
P (kg P_2O_5/fed)							
Control		0.230	0.273	144.63	127.74	39.19	33.00
30		0.258	0.295	205.34	189.21	54.29	49.77
60		0.286	0.313	246.69	253.93	67.32	66.16
90		0.311	0.338	281.70	294.07	76.09	76.38
L.S.D. (5%)		0.004	0.007	8.81	12.72	2.89	3.50
Interactions							
S levels (kg S/fed)	**P Levels (kg P_2O_5/fed)**						
	Control	0.218	0.258	89.93	75.25	25.12	19.18
Control	30	0.236	0.274	156.28	112.31	43.11	29.12
Control	60	0.263	0.286	193.35	181.82	53.15	47.25
Control	90	0.274	0.290	229.29	240.15	61.92	62.42
Control	Control	0.224	0.269	150.13	135.53	40.16	35.10
150	30	0.268	0.291	190.48	206.68	51.28	55.63
150	60	0.275	0.312	257.35	279.16	69.63	75.93
150	90	0.315	0.335	298.21	310.15	80.41	80.60
150	Control	0.247	0.291	193.83	172.44	52.30	44.72
300	30	0.271	0.319	269.25	248.63	68.47	64.55
300	60	0.319	0.342	289.37	300.18	75.29	
300	90	0.345	0.389	317.59	331.91	85.95	86.13
L.S.D. (5%) 300		0.008	0.012	15.26	22.03	5.00	6.06

Photosynthetic leaf pigments:

Effect of sulphur:

The effect of sulphur on chlorophyll a, b, total chlorophyll and chlorophylls a/b ratio are presented in Table (4). Data declared that chlorophyll a, b, total and a/b ratio significantly increased with increasing sulphur application levels. These results may be due to the beneficial effect of the sulphur as one of many elements required for plant growth and its necessary for the formation of protein and chlorophylls (Morris *et al*., 1984 and Hewedy 1999). The essential role of S in the synthesis of chlorophyll has been observed by Dietz (1989) on spinach where he suggested that the reduction in chlorophyll a and b in case of S deficiency, might be due to accelerated breakdown of chlorophyll and decomposition of chloroplasts under low S conditions. The obtained results are in accordance with those of, Topcuoglu and Yalcin (1997) on tomato, Sawan and Rizk (1998) on eggplant and Gopal *et al*. (2003) on tomato.

Effect of phosphorus:

Results of Table (4) illustrate that chlorophyll a, b, total and a/b ratio increased significantly with increasing phosphorus levels. This was true in the two seasons. These results are coincided with those of Kaya *et al*. (2003) and El-Tohamy *et al*. (2004) confirmed that application of phosphate to the root zone of pepper plants increased chlorophyll content over the control.

Effect of interaction:

Data in Table (4) indicated that the leaves of plants treated with the highest levels of both sulphur (300 kg/fed) and phosphorus (90 kg/fed) had the highest contents of chlorophyll a, b and total chlorophyll, in the two seasons.

Table (4). Effect of sulphur, phosphorus and their interactions on chl.a, chl. b, total chl. (mg/100 gm D.W.) and a/b ratio, during 2002 (S_1) and 2003 (S_2) seasons.

Characters		Chl.a (mg/100 gm D.W)		Chl.b(mg/100 gm.D.W)		Total chl.(mg/ 100gm.D.W)		a/b ratio	
Season		**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**
Treatments									
S (kg S/fed)									
Control		2.23	2.54	1.32	1.47	3.55	4.01	1.69	1.73
150		2.53	2.81	1.37	1.50	3.90	4.31	1.85	1.87
300		3.10	3.48	1.52	1.62	4.62	5.10	2.04	2.15
L.S.D. (5%)		0.07	0.09	0.03	0.03	0.09	0.12	0.01	0.04
P (kg P_2O_5/fed)									
Control		2.36	2.74	1.29	1.45	3.65	4.19	1.83	1.89
30		2.47	2.85	1.34	1.50	3.81	4.35	1.84	1.90
60		2.71	2.95	1.44	1.53	4.15	4.48	1.88	1.93
90		2.93	3.22	1.54	1.64	4.47	4.86	1.90	1.96
L.S.D. (5%)		0.05	0.06	0.03	0.02	0.08	0.08	0.01	0.01
Interactions									
S levels (kg S/fed)	**P levels (kg P_2O_5/fed)**								
Control	Control	2.00	2.40	1.21	1.41	3.21	3.81	1.65	1.70
Control	30	2.15	2.51	1.29	1.46	3.49	3.97	1.67	1.72
Control	60	2.27	2.56	1.34	1.48	3.61	4.04	1.69	1.73
Control	90	2.48	2.70	1.46	1.55	3.94	4.25	1.70	1.74
150	Control	2.32	2.66	1.28	1.44	3.60	4.10	1.81	1.85
150	30	2.41	2.74	1.31	1.47	3.72	4.21	1.84	1.86
150	60	2.60	2.81	1.40	1.49	4.00	4.30	1.86	1.89
150	90	2.81	3.03	1.47	1.59	4.28	4.62	1.88	1.91
300	Control	2.78	3.17	1.37	1.51	4.15	4.68	2.02	2.10
300	30	2.87	3.31	1.41	1.56	4.28	4.87	2.04	2.12
300	60	3.27	3.50	1.59	1.61	4.86	5.11	2.06	2.17
300	90	3.50	3.93	1.69	1.79	5.19	5.72	2.10	2.20
L.S.D (5%)		0.09	0.11	0.05	0.04	0.14	0.15	0.01	0.02

The lowest chlorophyll contents appeared in the leaves of control plants. Gopal *et al*. (2003) indicated that P and S at low rates drastically reduced the concentration of chlorophylls a and b in tomato plants, and reduced Hill reaction activity in either low P or low S. This might be due to involvement of S in chlorophyll synthesis and thus indirectly affecting photosynthesis. However, the lowered Hill activity in S deficiency was raised by combining with P. Similar results were obtained by Lauer *et al*. (1989) on soybean.

Leaf contents of macroelements:

Effect of sulphur:

Data in Table (5) show that nitrogen, phosphorus, potassium and sulphur contents in the leaves were significantly increased with the increase in soil application of sulphur levels as compared with control plant leaves. The high N, P, K and S contents in the treated plants could explain the enhancement in the vegetative growth of these plants as reported in Table (1) due to the essential role of these macro elements in the various metabolic processes. This was evident in the two seasons.

Results of the first season showed higher potassium leaf content than those of the second one. These increments were observed with the different levels of sulphur and with the leaves of untreated plants.

The increments of N, P, K and S contents in the leaves as a result of S application had explained by El-Fayoumy and El-Gamal (1998) on potato, where they stated that S-application significantly increased P-extracted from soil and available P in the surface layers. They also confirmed that, P absorption and uptake by plants was increased by S application rates. Rahman and Hoque (1994) on eggplant and Youssef (2002) on pea, reported that addition of sulphur decreased pH of soil extract and increased the availability of many elements in rooting zone, which in turn increased their absorption by plants. Pandey and Agrawal (1994) ; Topcuoglu and Yalcin (1997) on tomato ; Radwan and Tawfik (2004) ; El-Ghamry *et al.,* (2005) on potato and Kowalska (2005) on tomato came to the same conclusion.

Effect of phosphorus:

Data presented in Table (5) declare that nitrogen, phosphorus, potassium and sulphur percent in the leaves increased significantly with increasing phosphorus levels. The increments were corresponded with each level of phosphorus application. These results are in agreement with those of Davies *et al*. (1999) on *Capsicum annuum*, El-Morsy *et al*. (2002) on potato, Kaya *et al*. (2003) and Muthumanickam (2003) on pepper plant. They all concluded that increasing phosphorus application level, increased the availability of NPK elements.

Effect of interaction:

The interaction effects of sulphur and phosphorus on the leaf nitrogen contents (Table 5) indicated that the leaves of plants treated with the highest sulphur level (300 kg S/*fed*) and the highest phosphorus level (90 kg P_2O_5/*fed*) gained the highest nitrogen (4.15% and 4.23%), and phosphorus (0.656% and 0.686%) contents in the first and second seasons, respectively, compared with control plants that contained the lowest nitrogen (3.13% and

3.33%) and phosphorus (0.311% and 0.354%) contents in the first and second seasons, respectively.

The increase in P content in the leaves may be due to the influence of S, which plays an important role in increasing availability and uptake of phosphorus (Yousry *et al*., 1984 and Gendy *et al*., 1995), by increasing the level of phosphorus from the bulk soil to rhizosphere and stimulating its uptake by reducing soil pH (Khater, 1981 and Al-Rawi and Tajuldeen, 1985). Furthermore, sulphur plays a role in improving soil water relations and increasing root growth and roots penetration depth (Hilal, 1990, El-Fayoumy, 1996) on faba bean and Mazrouh, (2000), on tomato.

The interaction effects of sulphur and phosphorus on potassium and sulphur contents displayed a similar trend to those of nitrogen and phosphorus, as reported above. The obtained results are in agreement with those of Olsen *et al*. (1993) on bell pepper; Mahmoud (2000) and Youssef (2002) who stated that the combined application of P and S to bell pepper plants progressively increased N, P, K, Ca, Mg and S.

Table (5): Effect on sulphur, phosphorus and their interactions on macro element contents of sweet pepper leaves, during 2002 (S_1) and 2003 (S_2) seasons.

Characters		N%		P%		K%		S%	
Season		S1	S2	S1	S2	S1	S2	S1	S2
Treatments									
S (kg S/fed)									
Control		3.45	3.58	0.394	0.429	2.81	2.47	0.12	0.14
150		3.64	3.78	0.462	0.500	2.83	2.63	0.19	0.21
300		3.79	3.96	0.556	0.582	3.07	2.80	0.25	0.28
L.S.D. (5%)		0.05	0.06	0.021	0.009	0.12	0.09	0.01	0.02
P (kg P_2O_5/fed)									
Control		3.28	3.47	0.359	0.401	2.43	2.14	0.12	0.15
30		3.50	3.70	0.466	0.482	2.77	2.47	0.17	0.19
60		3.77	3.92	0.513	0.542	3.07	2.83	0.21	0.24
90		3.97	4.01	0.544	0.590	3.35	3.10	0.25	0.26
L.S.D. (5%)		0.06	0.03	0.020	0.014	0.07	0.05	0.02	0.01
Interactions									
S levels (kg S/fed)	P levels (kg P_2O_5/fed)								
Control	Control	3.13	3.33	0.311	0.354	2.36	2.01	0.07	0.09
Control	30	3.31	3.49	0.387	0.408	2.75	2.29	0.11	0.13
Control	60	3.59	3.70	0.433	0.455	2.90	2.64	0.14	0.16
Control	90	3.79	3.81	0.446	0.498	3.25	2.93	0.15	0.18
150	Control	3.28	3.50	0.356	0.394	2.45	2.11	0.12	0.15
150	30	3.50	3.69	0.462	0.481	2.62	2.45	0.16	0.18
150	60	3.82	3.95	0.498	0.538	2.93	2.89	0.21	0.24
150	90	3.96	4.00	0.530	0.587	2.93	2.89	0.21	0.24
300	Control	3.42	3.59	0.411	0.455	2.48	2.29	0.18	0.20
300	30	3.70	3.91	0.549	0.556	2.94	2.67	0.23	0.25
300	60	3.89	4.11	0.608	0.632	3.38	2.95	0.28	0.31
300	90	4.15	4.23	0.656	0.686	3.49	3.28	0.34	0.35
L.S.D. (5%)		0.06	0.06	0.035	0.025	0.13	0.09	0.03	0.03

Leaf contents of microelements:

Effect of sulphur:

Data in Table (6) display that iron, Zinc and manganese contents of the leaves were significantly increased as a result of increasing sulphur application. The increments were corresponded with the increase in the levels of sulphur. This was true in the two seasons of study.

The obtained results may be attributed to the positive effect of sulphur on the availability of micronutrients for plant uptake, through forming compounds which are capable in reducing soil pH, and this in turn increases water penetration and improves soil structure which had a positive effect on the availability of nutrients such as P, Fe, Zn, Mn and Cu (Hattar, 1983 and Shaheen and Omar, 1989).

Similar results were obtained by Topcuoglu and Yalcin (1997) who found that Zn, Mn, Cu and active Fe contents were increased in leaf petiole of tomato plants as a result of sulphur application. El-Fayoumy and El-Gamal (1998) and Youssef and Amer (2002) reported that S application increased the availability and uptake of Fe, Mn, Zn and Cu in the leaves of potato. and pea plants.

Effect of phosphorus:

Results in Table (6) indicate that phosphorus fertilization had positive effect on the iron contents of pepper leaves. Data show that iron, zinc and manganese contents increased in the leaves of the treated plants over the control and the highest values were obtained with the medium level (60 kg P_2O_5/ *fed*). This was evident in both seasons of study. Such data also reveal that the reduction in the Fe content at (90 kg P_2O_5/*fed*) compared with those of the medium level (60 kg P_2O_5/fed.) was significant ,however, this reduction in Zn and Mn contents did not reach the level of significance. These results were confirmed by those of Sreenivasa *et al*. (1993), on Chili Pepper and Davies *et al*. (1999) on bell pepper who indicated that shoot Zn, Cu, Mn and Fe contents increased as applied P increased. Similar conclusion with Zn contents was obtained by Muthumanickam (2003) on black pepper.

Effect of interaction:

The interaction effects of sulphur and phosphorus levels on iron content (Table 6) indicated that leaves of plants treated with the highest level of sulphur (300 kg S/*fed*) and the medium level of phosphorus (60 kg P_2O_5/*fed*) gained significantly the highest contents of iron (251 and 232 ppm) in the first and second season, respectively, compared with those of control (141 and 111 ppm). Results of Table (6) also show that leaves of plants received (300 kg S/*fed*) and (60 kg P_2O_5/*fed*) contained the highest levels of Zn (61 and 59 ppm)and Mn (79 and 71 ppm),), in the first and second seasons, respectively,

compared with control leaves that showed the lowest Zn contents (29 and 25 ppm), and Mn (44 and 39 ppm),contents in the first and second season, respectively. However, differences in Zn and Mn contents, between treated and control plants, did not elevate to the significance level.

The combined effects of sulphur and phosphorus on leaf contents of microelements was confirmed by Fenn *et al*. (1990) and Singh *et al*. (1995).

who stated that application of S and P to soil, reduced soil pH and and increased the availability and uptake of P, Fe, Zn, Mn and Cu.

Table (6). Effect of sulphur, phosphorus and their interactions on microelement contents of sweet pepper leaves, during 2002 (S1) and 2003 (S2) seasons.

Characters		Fe (ppm)		Zn (ppm)		Mn (ppm)	
Season		S1	S2	S1	S2	S1	S2
Treatment							
S (kg S/fed)							
Control		166	151	38	33	49	43
150		199	177	45	41	63	53
300		232	204	53	50	72	63
L.S.D. (5%)		8.28	3.60	3.51	5.37	3.12	5.01
P (kg P_2O_5/fed)							
Control		174	150	36	32	55	46
30		192	174	42	38	60	52
60		221	201	53	50	66	59
90		209	185	50	47	64	55
L.S.D (5%)		5.79	4.47	4.23	4.33	3.55	3.39
Interactions							
S levels (kg S/fed)	P Levels (kg P_2O_5/fed)						
Control	Control	141	111	29	25	44	39
Control	30	152	150	35	30	49	41
Control	60	192	178	47	42	53	48
Control	90	179	166	42	38	50	45
150	Control	178	159	38	32	59	47
150	30	190	173	42	39	62	52
150	60	220	195	53	49	68	60
150	90	211	183	50	47	65	54
300	Control	203	180	43	39	63	52
300	30	235	200	50	46	71	63
300	60	251	232	61	59	79	71
300	90	239	206	59	56	77	67
L.S.D (5%)		10.02	12.49	N.S.	N.S.	N.S.	N.S.

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تأثير استعمال الكبريت المعدني و التسميد الفوسفاتي علي نمو و محصول و جودة ثمار الفلفل الحلو

أ- النمو الخضري و المحتوي الكيماوي للأوراق

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أجريت تجربتان حقليتان في مزرعة البرامون التابعة لمحطة بحوث البساتين بالمنصورة خلال الموسم الصيفي لعامي ٢٠٠٢, ٢٠٠٣ بهدف دراسة تأثير إضافة مستويات من الكبريت (صفر – ١٥٠ – ٣٠٠ كجم كبريت للفدان) و معدلات من التسميد الفوسفاتي (صفر – ٣ – ٦٠ – ٩٠ كجم فو٢ا٥ للفدان) وتفاعلاتها علي النمو الخضري (طول النبات – عدد الأفرع – عدد الأوراق – مساحة الأوراق – و الوزن الطازج و الجاف للنبات و محتوي الأوراق من الكلوروفيل و كذلك المحتوي الكيماوي للأوراق و ذلك في نباتات الفلفل الحلو صنف كاليفورنياووندر.

- أظهرت النتائج زيادة القياسات الخضرية مع زيادة معدل إضافة كل من الكبريت و الفوسفور و كانت الزيادة معنوية لجميع القياسات ماعدا عدد الأفرع علي النبات
- أظهر تفاعل الكبريت مع الفوسفور أن المعدل الأعلى للكبريت (٣٠٠ كجم كبريت للفدان)+ أن المعدل الأعلى للفوسفور (٩٠ كجم فو٢ا٥ للفدان) كان أكثر المعاملات تأثيرا علي قياسات النمو الخضري بالمقارنة بباقي المعاملات و ذلك خلال عامي الدراسة
- زاد محتوي الأوراق من كلوروفيل ا ,ب و الكلوروفيل الكلي و نسبة كلوروفيل ا/ب زيادة معنوية مع زيادة أي من الكبريت أو الفوسفور المضاف عنة في أوراق نباتات المقارنة و ظهرت أعلي القيم لهذه المكونات في أوراق النباتات التي عوملت بالمعدل الأعلى للكبريت (٣٠٠ كجم/ فدان) + المعدل الأعلى للفوسفور (٩٠ كجم/ فدان).
- أظهر محتوي الأوراق من عناصر النيتروجين , الفوسفور , البوتاسيوم و الكبريت زيادة معنوية مع زيادة معدل إضافة كل من الكبريت و الفوسفور عنة في أوراق نباتات المقارنة. وكانت الزيادة متمشية مع زيادة كل من الكبريت و الفوسفور المضاف.
- أظهر تفاعل الكبريت مع الفوسفور أعلي محتوي لهذه العناصر في أوراق النباتات التي تم تسميدها بالمعدل الأعلى لكل من الكبريت و الفوسفور.
- ظهر أعلى محتوي للأوراق من عناصر الحديد , المنجنيز في أوراق النباتات التي تم تسميدها بالمعدل الأعلى للكبريت (٣٠٠كجم/ فدان) أو مع المعدل المتوسط من الفوسفور (٦٠ كجم/ فدان) كما أظهر تفاعل الكبريت مع الفوسفور أعلى محتوى لهذه العناصر في أوراق النباتات التي تم تسميدها بالمعدل الأعلى للكبريت (٣٠٠كجم/ فدان) مع المعدل المتوسط للفسفور (٦٠ كجم/ فدان.