J. Agric. Sci. Mansoura Univ., 32 (3): 2225 - 2242, 2007

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

b-Effect on yield, fruit quality and nutrient components

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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 interaction on yield components (number of fruits/plant, average fruit weight, fruit yield/plant, early and total yield/ *fed*.), fruit physical characteristics (fruit length, fruit diameter, fruit shape index, flesh thickness and dry matter %), fruit chemical compositions (TSS, carotenoids, Vit. C, total acidity) and fruit mineral contents i.e. N, P, K, S, Fe, Zn. and Mn of sweet pepper cv. California Wonder. The obtained results showed that all the previous parameters were increased with the increase of sulphur levels from zero up to 300 kg/fed compared with control. The increments were significant except those of number of fruits/ plant in the two seasons, fruit shape index in the second season, flesh thickness in both seasons which showed no significant differences. All tested fruit parameters were significantly increased with the addition of phosphorus compared with control However, the differences among treatments were not significant in each of No. fruits/plant, fruit shape index and flesh thickness in both seasons. Results also declared that the highest contents of Fe, Zn and Mn were noticed with 60 kg P_2O_5/ *fed* then decreased with 90 kg P_2O_5/ *fed* and the differences in Mn contents were insignificant. 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*.) had superior effects on all the studied parameters, except that Fe, Zn and Mn contents which gave their highest contents with 300 kg S/*fed* plus 60 kg P_2O_5/ *fed*.

INTRODUCTION

Sweet pepper (*Capsicum annuum* L.) is an important vegetable and popular 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 an average of 20.05 ton/fed.*Sweet pepper fruits are known to be very rich in vitamins, especially vitamins ”A” and “C”. It is also a good source of B-carotene. Green fruits contain chlorophyll A and chlorophyll B, which are probably synthesized denovo during chloroplast development (Rajput and Poruleker,1998).

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* Cited from the Economic and Statistical Departement, Ministry of Agriculture, Egypt, 2005

Increasing sweet pepper production and improving fruit quality are important to increase the exported yield. Several factors affect plant growth, yield and fruit quality of pepper, among them the nutritional supplies with sulphur and phosphorus fertilization, since several investigations indicated a good relationship between sulphur and solubility of phosphorus under alkaline soils (Rivera and Irgazarry, 1984).Sulphur is a constituent of amino acids methionine and cystine. The vitamins biotin and thiamine contain sulphur, and the structure of proteins is determined to a considerable extent by sulphur groups. As with other essential elements S plays a unique role in plant metabolism. Sulphur was reported to improve yield and quality of sweet pepper (Shaheen and Omar, 1989). Sulphur is important to increase the yield components and quality of other vegetables (Youssef, 2002 on pea ; Radwan and tawfik , 2004 on potato and Smatanova *et al.*, 2004 on spinach and pepper).

Topcuoglu and Yalcin (1997) reported that S application increased total S, N, P, K, Ca, Mg, Zn, Mn, Cu and active Fe contents in tomato leaf petiole and fruit tissues. El-Fayoumy and El-Gamal (1998) indicated that S application increased the availability and uptake of P, Fe, Mn, Zn, Cu and also increased vitamin C, carotene, starch and protein in potato tubers.

Phosphorus is a constituent of nucleic acid and nuclei; P plays a good role in plant metabolism, structure, and reproduction that can not be replaced by any other element. The phosphate esters in plant growth has particular role in the conversion of carbohydrates and in the metabolism of starch. Furthermore, phosphorus is important for the ripening of seeds and fruits. Davies *et al.,* (1999), Murgan *et al.*(2002) and Jaggi *et al.,* (2003) concluded that phosphorus application increased pepper yield and improved fruit quality.

Concerning the combined effect of S and P Olsen *et al.,* (1993) reported that P and S fertilizers was of great importance to maximize fresh wt. of bell pepper marketable fruits. Also, Jaggi *et al.*, (2003) and sarker *et al.*,(2003) confirmed the positive effect of both S and P application on the yield and fruit quality of pepper therefore, this study aimed to improve yield and quality of pepper fruits through S and P application.

MATERIALS AND METHODS

Two field experiments were carried out at El-Baramoon Farm of Mansoura Horticultural Research Station, during summer seasons of 2002 and 2003 to study the effect of different levels of sulphur, phosphorus and their interaction on fruit yield and its components as well as chemical compositions of fruits. On March 20th, of both 2002 and 2003 seasons, sweet pepper seeds cv. California Wonder were sown in the nursery in 2 x 2 m. beds. After six weeks, seedlings were transplanted to the field, 30 cm a part 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 blocks design in split plot system, with 3 replications was adopted. Main plots were occupied with sulphur levels (0,

150 and 300 kg/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% P_2O_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). Also, all plants received similar cultural practices as commonly recommended.

Recorded data:

The following measurements and determinations were carried out in both seasons:

Fruit yield and its components:

All harvested fruits from the each plot, were used to calculate the following parameters:

Number of fruit per plant, average fruit weight (gm), fruit yield (gm) per plant, early yield (ton) per faddan: It was considered as the summation of the first four harvests according to El-Gandour, (1965).

Total fruit yield (ton)per faddan: calculated based on fruit yield/plot.

Fruit physical characteristics: including fruit length, L, (cm), fruit diameter ,D, (cm), fruit shape index (L/D) and flesh thickness (cm) were determined.

Dry matter content: Fresh samples were allowed to dry in oven at 70^{o}C for 48 h. until constant weight, and percent of dry matter was calculated.

Fruit chemical properties:

A representative samples of 20 fruits were taken from each plot to determine the following properties.

Total soluble solids percentage (TSS%): determined by a hand refractometer.

Total carotenoids: Total carotenoid contents of fruits were determined and calculated according to the method of Kirck and Allan (1965).

Vitamin C and acidity: determined by titration against 2,4,6-dichlorophenol indophenol and phenolphytheline, respectively, according to methods of A.O.A.C (1970).

All collected data were subjected to statistical analysis of variance for split-plot design, and means were separated using Least significant difference test as mentioned by Snedecor and Cochran (1980).

Table (1) show mechanical and chemical analysis of the experimental soil which conducted at Mansoura Center of Soil Improvement, according to methods of Black (1965) and Page(1982.

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

Soil properties	Season	
	2002	2003
A- 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
B- Chemical analysis		
Total nitrogen %	0.12	0.15
Available phosphorus (ppm)	7.15	7.95
Exchangeable potassium (ppm)	215	229
$CaCO_3$%	2.80	2.75
Organic matter %	1.90	2.10
EC (mmhos/cm, 25^{o}C)	1.25	1.29
pH (1:2:5 w/v)	8.02	7.90
C- 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
D- Soluble cations (meq/L) Ca^{++}		
Ca^{++}	4.00	3.97
Mg^{++}	1.29	1.27
Na	1.19	1.22
K	5.27	5.33
F- 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

Effect of sulphur and phosphorus levels on fruit yield.

Effect of sulphur:

Data presented in Table (2) show that number of fruits/plant increased with increasing sulphur levels although the differences did not reach the level of significance in both seasons of study. Results in the same table reveal significant increase in both average fruit weight and yield of fruits/plant with each increase in sulphur level. The increase in yield /plant over the control were 15.07%, 31.31% and 10.28%, 26.79% with 150 and 300 kg S/fed in the first and second seasons, respectively. It could be concluded that application of sulphur had a stimulative effect on the growth and yield of sweet pepper. This might explained the importance of S in improving yield and quality by influencing the S containing amino acids, which are the building blocks of proteins, and along with starch are responsible forformation of fruits (Arora and Luchra, 1970 and Gopal *et al.*, 2003,). Results in Table (2)

also indicated that both early and total yield/ *fed*. were significantly increased with the increase in sulphur level compared with controls. The increments were associated with the increase in the sulphur levels in both seasons. The favorable effects of sulphur may be due to the fact that it is essential element for metabolism especially protein synthesis (Freney *et al.*, 1978 and Russell, 1988). Furthermore, S is considered as a fungicide and it affects soil nematodes, soil born diseases and some other plant pests (Hilal *et al.*, 1990 a). Each of S and P elements has a distinct effect on improving the yield and its components (Mazrouh, 2000) on tomato. These results are in harmony with those of Shaheen and Omar (1989), Shaheen *et al.* (1989 b) on sweet pepper, Hewedy (1999), Gopal *et al.* (2003) both on tomato and Smatanova *et al.* (2004) on spinach and pepper.

Effect of phosphorus:

Data in Table (2) indicate that number of fruit/plant increased with the increase in phosphorus levels, although these increments were not significant in both seasons. It is clear from such data that average fruit weigh and yield of fruits/plant were significantly increased with each increase in phosphorus levels. This was obviously occurred in the two seasons. The increments in the yield were 22.35%; 29%, 49.76%; 25.68%, 31.83% and 48.98% for the 30, 60 and 90 kg P_2O_5/fed. in the first and in the second seasons, respectively. This may be due to the role of phosphorus as an essential component of many organic compounds in plant, which indirectly may reflect positively on yield (Marschner, 1995).

Results of Table (2) also show that early yield and total yield/ *fed.* were significantly increased with the increase in the added P levels.

Table (2). Effect of each of sulphur and phosphorus on yield and its components of sweet pepper plants during 2002 (S1) and 2003 (S2) seasons.

Characters	No. of fruits/plant		Average fruit weight (gm)		Yield/plant (gm)		Early yield (ton /fed)		Total Yield (ton /fed)	
Season	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**
Treatments										
kg S/fed										
Control	11.86	11.81	54.04	56.44	640.91	666.56	7.46	7.98	11.55	11.97
150	12.67	12.74	58.21	57.70	737.52	735.10	8.41	8.72	13.01	13.32
300	14.01	13.76	60.07	61.42	841.58	845.14	9.96	10.01	15.07	15.25
L.S.D. at 5%	N.S	N.S	1.04	0.88	11.99	18.11	0.13	0.31	0.54	0.47
kg P_2O_5/fed										
Control	10.93	11.07	54.12	53.50	591.53	592.25	6.91	7.28	10.45	10.85
30	12.76	12.55	56.72	59.31	723.75	744.34	8.24	8.56	12.90	13.31
60	13.22	13.07	57.72	59.92	763.06	780.76	8.92	9.22	13.75	14.07
90	14.47	14.38	61.22	61.36	885.85	882.36	10.39	10.56	15.74	15.81
L.S.D. at 5%	N.S	N.S	1.14	1.08	12.08	9.20	0.12	0.26	0.45	0.53

The highest total yield gained from plants fertilized with P at 90 kg P_2O_5 /fed. The increment in pepper fruit yield as a result of phosphorus application may be due to its role in vital growth processes, which are

essential in all living cells and plays an important role in plant metabolism. It is also important for root development, the ripening of seeds and fruits as well as for the efficient functioning and utilization of nitrogen (Russell, 1988 and Mazrouh, 2000). These results are in accordance with those of Nigri *et al.* (1999), Murugan *et al.* (2002), Yusdar and Hanafi (2002), Kaya *et al.* (2003) and Muthumanickam (2003). Who concluded that yield and quality of pepper plants improved with increasing P levels.

The effect of sulphur and phosphorus interaction:

Data in Table (3) show that the interaction effects of S and P on number of fruits /plant were not significant within the various, levels throughout the two seasons. In contrary, these interaction effects on average weight of fruit and yield per plant in the two seasons were significant. The highest values were observed in plants treated with sulphur at 300 kg S/*fed* and phosphorus at 90 kg P_2O_5/*fed*. The lowest yield values were gained from the control plants in the two seasons of study, the other treatments showed intermediate values. Mazrouh (2000) and Gopal *et al.* (2003) confirmed that application of P and S together increased average fruit weight and yield of tomato.

Data in Table (3) also declared that the highest early yield/ *fed*., was gained from plants received the highest level of both sulphur (300 kg/*fed*) and phosphorus (90 kg/*fed*) i.e. 12.71 and 12.27 tons /*fed*., in the first and second seasons, respectively. The lowest early yield was harvested from the control plants, i.e. 5.88 and 6.58 tons per fed., in the first and second seasons, respectively.

Table (3). Effect of interaction of sulphur and phosphorus on yield and its components of sweet pepper plants, during2002 (S1) and 2003 (S2) seasons.

Characters		No of fruits/plant		Average wt. of fruit (gm)		Yield/plant (gm)		Early yield/fed (ton)		Total yield/fed (ton)	
Season		S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
Treatments											
S levels (kg S/fed)	P levels (kgP_2O_5 /fed)										
	Control	10.10	10.40	48.90	50.35	493.89	523.64	5.88	6.58	8.77	9.44
	30	12.22	12.11	53.62	57.56	655.24	697.05	7.58	8.11	11.96	12.32
	60	12.41	12.30	55.44	59.53	688.01	732.22	8.17	8.27	12.58	12.93
	90	12.70	12.42	58.21	58.33	739.27	724.46	8.22	8.95	12.89	13.18
150	Control	10.51	10.70	56.00	53.24	588.56	569.67	6.80	7.05	10.25	10.60
	30	12.54	12.33	57.61	57.62	722.43	710.45	8.09	8.21	12.54	12.92
	60	13.13	13.11	58.60	58.71	769.42	769.69	8.54	9.16	13.54	13.85
	90	14.52	14.81	60.64	61.25	880.49	907.11	10.23	10.46	15.71	15.93
300	Control	12.19	12.12	57.45	56.90	700.31	689.63	8.05	8.21	12.32	12.53
	30	13.53	13.21	58.92	62.75	797.19	828.93	9.04	9.35	14.19	14.70
	60	14.12	13.80	59.11	61.53	834.63	849.11	10.04	10.22	15.12	15.44
	90	16.20	15.91	64.80	64.51	1049.76	1026.35	12.71	12.27	18.64	18.32
L.S.D. at (5%)		N.S	N.S	1.97	1.88	20.93	15.93	0.21	0.46	0.78	0.92

Concerning the total yield, it is clear that plants fertilized with the highest sulphur level plus the highest phosphorus level gave the highest yield which were (18.64 and 18.32 tons/fed) in the first and second seasons, respectively. The control plants gave the lowest total yield (8.77 and 9.44 tons/fed), in the first and second seasons, respectively. This increase in yield of pepper as a result of the combined effects of S and P reflects the synergistic role of both elements on the yield and quality (Gopal *et al.*, 2003) on tomato. Those results were confirmed by Niranjana and Devi (1990) and Olsen *et al.* (1993), on pepper.

Candilo *et al.* (1994) stated that combining S at 450 kg/ha with P at 250 kg P_2O_5/ha increased the marketable yield of tomato over the control or those of each element alone. Similar results also were obtained by Mazrouh (2000) on tomato, and Jaggi *et al.* (2003) on chili pepper. Sarker *et al.* (2003) conclude that along with increasing P and S levels, number and weight of fruits and total yield of pepper plant markedly increased.

The effect on fruit physical characteristics:

Effect of sulphur:

Data in Table (4) show that fruit length and fruit diameter were significantly increased over the control and among the treatments as a result of increasing sulphur application levels. This was clear in the two seasons.

Data in Table (4) also indicate that sulphur application levels resulted in insignificant increase in fruit shape index and flesh thickness in both seasons of study.

The dry matter percentage significantly increased with the increase in sulphur application levels. The increases were associated with each increase in sulphur level. This was evident in the two seasons. The important role of sulphur in photosynthesis and protein synthesis which reflected on the fruit parameters and the dry matter percentage was confirmed b Arora and Lunchra, 1970). Those results are in harmony with those of Shaheen and Omar (1989), Shaheen *et al.* (1989b) on sweet pepper, Topcuoglu and Yalcin (1997) on tomato, Youssef (2002) on pea plants and Gopal *et al.* (2003) on tomato.

Effect of phosphorus:

Results of Table (4) reveal that fruit length and fruit diameter were increased significantly with the increase in phosphorus levels. This was evident throughout the two seasons. Concerning the fruit shape index and flesh thickness, data indicated that they were not significantly affected by the application of phosphorus at the various levels during the two seasons. Dry matter percentage (Table 4) was increased with the increase in phosphorus level. The increments were significant in the two seasons. These results declared the role of phosphorus in the activation of photosynthesis and metabolic processes of organic compounds and hence increasing plant growth and this in turn reflect the positive effect on fruits and yield (Gardener *et al.*, 1985 and Marschner, 1995). These results are coincide with those of Maya *et al.* (1997), Davies *et al.* (1999), Murugan *et al.* (2002), Yusdar and Hanafi (2002), Kaya *et al.* (2003), Muthumanickam (2003) who concluded that fruit physical characteristics of pepper plants were improved with increasing P levels.

Table(4). Effect of each of sulphur and phosphorus on fruit physical characteristic of sweet pepper during 2002 (S1) and 2003 (S2) seasons.

Characters	Fruit length (cm)		Fruit diameter (cm)		Fruit shape index		Flesh thickness (cm)		Dry matter %	
Season	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**
Treatments										
(kg S/fed)										
Control	9.13	9.34	7.38	7.88	1.24	1.19	0.16	0.17	5.29	5.15
150	9.68	10.60	7.77	8.93	1.25	1.19	0.18	0.19	5.58	5.42
300	10.64	11.46	8.10	9.47	1.31	1.21	0.20	0.21	6.04	5.93
L.S.D. at 5%	0.55	0.82	0.53	0.43	0.05	N.S	N.S	N.S	0.15	0.12
(kg P_2O_5/fed)										
Control	8.57	9.25	7.02	7.76	1.22	1.19	0.16	0.18	5.28	5.11
30	9.10	10.25	7.12	8.64	1.28	1.21	0.17	0.19	5.53	5.35
60	10.39	10.80	8.10	9.07	1.28	1.19	0.19	0.20	5.82	5.70
90	11.20	11.37	8.77	9.58	1.28	1.19	0.21	0.22	5.91	5.84
L.S.D. at 5%	0.59	0.83	0.64	0.50	N.S	N.S	N.S	N.S	0.11	0.13

Effects of interaction:

Data presented in Table (5) illustrate the effects of interaction between sulphur and phosphorus treatments on fruit length, fruit diameter, fruit shape index, flesh thickness and dry matter percentage. The interaction effects of the two nutrients indicated that the longest fruits (12.0 and 12.37 cm) in the first and second seasons, respectively, were harvested from the plants received the highest sulphur level (300 kg/fed) plus the highest phosphorus level (90 kg/fed). The shortest fruits were harvested from control plants. The differences among the various treatments were not significant in the two seasons. Fruit diameter, fruit shape index and flesh thickness followed similar trend to those of fruit length throughout the two seasons.

Data in Table (5) show that dry matter % was significantly increased with the increase of S and P levels in both seasons. The highest sulphur level plus the highest phosphorus level gave the highest dry matter percentages (6.13 and 6.11%), in the first and second seasons, respectively. The lowest values (5.00 and 4.89%) were obtained from fruits of control plants. The other treatments gained intermediate values in this regard. These results are partially in agreement with those of Mazrouh (2000) and Gopal *et al.* (2003) both on tomato.

Table (5). Effect of interaction of sulphur and phosphorus on yield and its components of sweet pepper plants during 2002 (S1) and 2003 (S2) seasons.

Characters		Length of fruit (cm)		Diameter of fruit (cm)		Fruit shape index		Fleshy thickness (cm)		Dry matter %	
Season		S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
Treatments											
Interactions											
S levels (kg S/fed)	P levels (kg P_2O_5/fed)										
Control	Control	7.81	8.20	6.84	6.90	1.14	1.19	0.14	0.16	5.00	4.89
	30	8.20	9.18	6.90	7.80	1.19	1.18	0.15	0.17	5.11	4.95
	60	10.00	9.90	7.40	8.20	1.35	1.21	0.17	0.18	5.43	5.28
	90	10.50	10.10	8.40	8.63	1.25	1.17	0.18	0.19	5.61	5.49
150	Control	8.70	9.55	7.00	8.00	1.24	1.19	0.16	0.18	5.12	4.93
	30	9.00	10.28	7.15	8.51	1.26	1.21	0.17	0.19	5.39	5.20
	60	9.92	10.90	8.00	9.21	1.24	1.18	10.19	0.20	5.81	5.63
	90	11.10	11.66	8.92	10.00	1.24	1.17	0.21	0.22	6.00	5.93
300	Control	9.20	10.00	7.21	8.39	1.28	1.19	0.17	0.19	5.73	5.51
	30	10.11	11.80	7.31	9.60	1.38	1.23	0.19	0.20	6.10	5.90
	60	11.25	11.60	8.90	9.80	1.26	1.18	0.20	0.22	6.21	6.19
	90	12.00	12.37	9.00	10.11	1.33	1.22	0.23	0.25	6.13	6.11
L.S.D. at 5%		N.S.	N.S	N.S	N.S	N.S	N.S	N.S	N.S	0.19	0.22

The effect on fruit chemical properties:

Effect of sulphur:

Data presented in Table (6) indicate that fruit contents of carotenoids, total soluble solids and Vit C were significantly increased more than controls, as a result of sulphur application. There was a positive relationship between the increase in sulphur levels and the increase in fruit contents of carotenoids, TSS and Vit. C. This was observed in both seasons. Similar results were obtained by Hewedy (1999) on tomato and El-Morsy (2005) on Garlic.

Results of Table (6) also reveal that total acidity was significantly increased as a result of sulphur fertilization, in the two seasons, but the differences between the two sulphur levels were not significant. The increase in carotenoids, T.S.S., Vit. C and total acidity indicated that nutritional values of fruits of sulphur treated plants, were more than those of untreated ones. El-Fayoumy and El-Gamal (1998) on potato came to similar conclusion.

Effect of phosphorus:

Data in Table (6) declare that fruit contents of the carotneoids were significantly increased with each increase in the level of phosphorus starting from zero, 30, 60 and up to 90 kg/fed. The differences between all treatments were significant, in the two seasons of study. Data also indicated that total soluble solids were increased with increasing phosphorus levels. It is noticed that the differences between treatments were not significant, except those between each of the control and30 kg/fed., or 90 kg/fed in the first season. In the second season no significant differences were observed between the

control and 30 kg/fed but the significance was clear between the lowest level of P (30 kg/fed) and the highest level (90 kg/fed).

Data in Table (6) also show that Vit. C contents were increased with increasing phosphorus levels and the differences between all treatments were highly significant, in both seasons. On the other hand, total acidity was significantly increased with increasing phosphorus level from zero up to 60 kg/fed then it decreased with the highest level (90 kg/fed). The promoting effect of phosphorus level on Vit. C and T.S.S. were confirmed by Uddin and Begum (1990) on Chili pepper, Koceveski *et al.* (1995), Murugan (2001) on pepper and El-Morsy *et al.* (2002) on potato.

Effects of interaction:

Data presented in Table (6) declare that the highest carotenoids contents (3.27 and 3.09 mg/dm^2) were obtained from the fruits of plants fertilized with the highest level of sulphur (300 kg/fed) and the highest level of phosphorus (90 kg/fed), in the first and second seasons, respectively. The lowest values (1.95 and 1.79 mg/dm^2) were observed in the fruits of control plants. The other different treatments showed intermediate values.

Table (6): Effect of sulphur, phosphorus and their interactions on fruits characteristics of sweet pepper plants, during 2002 (S1) and 2003 (S2) seasons

Characters		Carotenoids (mg/dm^2)		TSS%		Vit. C% (mg/ 100 g F.W.)		Total acidity %	
Season		**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**
Treatments									
S (kg S/fed)									
Control		2.47	2.30	2.31	2.53	56	69	0.267	0.277
150		2.83	2.74	2.73	2.91	73	94	0.301	0.315
300		2.93	2.90	2.94	3.09	94	101	0.311	0.323
L.S.D. at 5%		0.05	0.08	0.12	0.17	5.17	6.58	0.019	0.015
P (kg P_2O_5/fed)									
Control		2.18	2.28	2.51	2.69	55	64	0.265	0.278
30		2.76	2.55	2.60	2.77	66	78	0.282	0.300
60		2.95	2.79	2.71	2.91	82	92	0.316	0.327
90		3.10	2.98	2.82	3.01	94	119	0.308	0.316
L.S.D. at 5%		0.07	0.08	0.21	0.16	4.12	5.03	0.014	0.012
Interactions									
S levels (kg S/fed)	**P levels (kgP_2O_5 /fed)**								
	30	2.35	2.19	2.29	2.53	43	60	0.239	0.258
	60	2.71	2.45	2.34	2.59	68	76	0.292	0.281
	90	2.89	2.79	2.41	2.61	80	98	0.312	0.325
150	Control	2.19	2.36	2.53	2.73	52	71	0.279	0.291
	30	2.97	2.64	2.68	2.79	65	89	0.295	0.311
	60	3.03	2.93	2.79	3.00	82	95	0.320	0.345
	90	3.13	3.05	2.91	3.11	96	123	0.310	0.313
300	Control	2.39	2.70	2.78	2.93	81	79	0.292	0.300
	30	2.95	2.81	2.83	2.99	90	85	0.313	0.330
	60	3.11	3.00	3.00	3.14	97	105	0.335	0.345
	90	3.27	3.09	3.15	3.31	108	138	0.303	0.310
L.S.D. at 5%		0.12	0.13	N.S	N.S	7.13	8.71	0.024	0.021

The interaction effects of sulphur and phosphorus on the T.S.S. showed no significant differences among various treatments ,however, the highest values in this concern (3.15 and 3.31%) were observed in fruits of plants fertilized with S at 300 kg/fed plus P at 90 kg/fed. The lowest T.S.S. values (2.21 and 2.41%) were noticed with the control fruits, in the first and second seasons. The differences among the other interactions were not significant in the two seasons. Data in Table (6) also reveal that Vit. C followed similar trend to those of carotenoids and the interaction effects were significant in the two seasons.

Regarding the S * P interaction effects on total acidity data of the same table indicated that the lowest total acidity values (0.225 and 0.243%) were observed in the control fruits in the first and second seasons, respectively. On the other hand, the highest total acidity values (0.335 and 0.345%) was observed in fruits of plants received S at 300 kg/fed plus P at 60 kg/fed, in the first and second seasons, respectively. The differences among the other treatments were significant in the two seasons of study. These results are partially in agreement with those of Niranjana and Devi (1990) on pepper, Candilo *et al.* (1994), Mahmoud and Amara (2000) and Mazrouh (2000) on tomato.

The effect on fruits mineral contents:

Macro-elements content in fruits:

Effect of sulphur:

Results in Table (7) declared that nitrogen, phosphorus, potassium and sulphur contents were increased significantly in fruits of plants received sulphur fertilization levels, compared with controls. The increments among the different treatments were significant in both seasons of study. The results are in agreement with the findings of Topcuoglu and Yalcin (1997) who reported that elemental sulphur application to the soil increased S, N, P and K in tomato fruits. El-Fayoumy and El-Gamal (1998) stated that applying S to the soil increased phosphorus concentration and uptake by potato tubers. Recently, El-Morsy (2005) confirmed that, N, P and K were significantly increased in garlic cloves with increasing sulphur application level.

Effect of phosphorus:

Data presented in Table (7) show that each of nitrogen, phosphorus and potassium contents were significantly increased in fruits of treated plants compared with the untreated ones. The increase in fruit contents of the three elements were associated with each increase in P level from zero and up to 90 kg P_2O_5/ fed. This was evident in the two seasons of study.

Sulphur content increased was significantly with the increase in phosphorus level, compared with control. The differences among various concentrations in both seasons were significant, except those between the medium level (60 kg P_2O_5/*fed*) and the highest levels (90 kg P_2O_5/*fed*), in the first season. Murugan *et al.* (2002) and Alabi (2006) reported that increasing phosphorus levels improved P, K and Mg contents of pepper fruits.

Effects of interaction:

Data in Table (7) show the interaction effects of sulphur and phosphorus on fruit contents of nitrogen, phosphorus, potassium and

sulphur. Data show that fruits from the untreated plants had the lowest values of nitrogen percentage (0.82 and 0.97%), while the highest level of sulphur plus the highest level of phosphorus gave the highest values (1.64 and 1.61%), in the first and second seasons, respectively. The other treatments gained intermediate values, in both seasons of study.

Such data indicated that the highest fruit contents of phosphorus ,potassium and sulphur were obtained from plants fertilized with the highest level of both sulphur and phosphorus in the first and second seasons, respectively. On the other hand, the control fruits showed the lowest values in the first and second seasons, respectively. The other different treatment gained intermediate values. The interaction effects among other treatments were significant in the two seasons.

Table (7): Effect of sulphur, phosphorus and their interactions on fruit macronutrient contents of sweet pepper fruits, during 2002 (S1) and 2003 (S2) seasons.

Characters		**N%**		**P%**		**K%**		**S%**	
Season		**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**
Treatments									
S (kg S/fed)									
Control		1.08	1.17	0.160	0.162	1.66	1.50	0.07	0.09
150		1.34	1.35	0.181	0.196	1.98	1.76	0.11	0.13
300		1.43	1.41	0.210	0.222	2.08	1.87	0.14	0.15
L.S.D. (5%)		0.07	0.04	0.008	0.009	0.06	0.03	0.01	0.02
P (kg P_2O_5/fed)									
Control		0.95	1.06	0.150	0.157	1.46	1.33	0.07	0.09
30		1.24	1.25	0.171	0.178	1.79	1.56	0.10	0.11
60		1.40	1.42	0.198	0.208	2.03	1.86	0.12	0.14
90		1.54	1.53	0.216	0.229	2.35	2.09	0.13	0.16
L.S.D (5%)		0.06	0.02	0.005	0.006	0.05	0.04	0.02	0.02
Interactions									
S levels (kg S/fed)	**P levels (kgP_2O_5 /fed)**								
Control	Control	0.82	0.97	0.126	0.115	1.26	1.18	0.04	0.06
	30	1.01	1.08	0.145	0.138	1.61	1.31	0.06	0.08
	60	1.10	1.22	0.175	0.179	1.79	1.65	0.08	0.10
	90	1.39	1.42	0.193	0.215	2.00	1.84	0.09	0.12
150	Control	0.96	1.10	0.148	0.163	1.52	1.38	0.07	0.10
	30	1.30	1.28	0.176	0.184	1.83	1.61	0.10	0.11
	60	1.51	1.49	0.193	0.208	2.10	1.93	0.13	0.15
	90	1.59	1.55	0.208	0.229	2.47	2.13	0.15	0.17
300	Control	1.06	1.11	0.177	0.194	1.61	1.43	0.11	0.14
	30	1.42	1.39	0.191	0.213	1.94	1.75	0.13	0.15
	60	1.60	1.55	0.225	0.238	2.19	2.00	0.15	0.17
	90	1.64	1.61	0.247	0.243	2.58	2.29	0.16	0.19
L.S.D. (5%)		0.10	0.04	0.009	0.100	0.10	0.08	N.S	N.S

Singh *et al.* (1995) found that S and other nutrients tended to increase with balanced P&S fertilizers and application of S and P to the soil led to increase the availability of both elements on potato plants. Gopal *et al.* (2003) found that the presence of minimum concentration of P facilitates the availability and translocation of sulphur in tomato. They suggested that both

the nutrients are mobile and with maturity, the translocation is fast and smooth to top parts of plants and accumulated in the fruits of tomato. Also, Kuchawar *et al.* (2005) reported that the highest content of N, P, K, S in fruits were gained from the highest rates of both elements i.e.90 kg P_2O_5/*fed* and 60 kg S/fed.

Micro-element content in fruits:

Effect of sulphur:

Data in Table (8) show the effect of sulphur fertilization on the fruit Fe, Zn and Mn contents. Results indicated that fruit contents of Fe significantly increased with the addition of sulphur fertilizers, compared with control. The increases were associated with the increase in applied sulphur in both seasons of study.

Zinc in the fruits were increased with increasing the applied sulphur compared with control in both seasons. The increments were not significant among all treatments, except those between the control and 150 kg S/ *fed*. in the second season and between control and 300 kgP_2O_5/ *fed*. in the two seasons.

Mn content in the fruits showed similar trend to those of Fe in the two seasons except that the differences between control and the lowest level in the second season were not significant. This increments may be due to the positive effect of sulphur on the availability of micronutrients by forming compounds which reduced soil pH and this in turn increase their uptake by plants.

The obtained results are in agreement with those of Topcuoglu and Yalcin (1997) who reported that total Zn, Mn, Fe contents were generally increased in tomato fruit tissues as a result of sulphur application. El-Fayoumy and El-Gamal (1998) and Radwan and Tawfik (2004) showed that S application at the level of 0.03% caused the highest significant increase in Fe, Mn, Zn and Cu concentration in potato tissues, tubers and leaves.

Effect of phosphorus:

Data in Table (8) show that fruit content of Fe was increased significantly with the application of tested phosphorus levels, compared with controls. Fe of fruits increased with increasing phosphorus level up to 60 P_2O_5 kg/*fed* and then decreased significantly with the level of 90 kg P_2O_5/*fed* although remained significantly higher than control fruits. Concerning Zn and Mn contents the trend was similar to those of Fe except that the differences among various treatments were not reach the level of significance, also with 90 kg P_2O_5/*fed*, the reduction in fruit content was not significant. (Murugan *et al.*, 2002) reported that increasing P level from 30 up to 60 kg/ha improved some micronutrient content of pepper fruit. Alabi, 2006 also found that increasing P level from 25 and up to 125 kg P_2O_5/fed., increased pepper fruit contents of Zn, Mn and Fe

Effect of interaction:

Data presented in Table (8) show the interaction effects of sulphur and phosphorus levels on micronutrients contents in pepper fruits. Results indicated that, interaction of S and P at the highest level of S (300 kg S/*fed*) and the medium level of P (60 kg P_2O_5/*fed*.) gave the highest fruit contents of

Fe. The differences between the other treatments were significant in both seasons Data also declare that the interaction effects of S and P on fruit contents of Zn and Mn followed the same trend of Fe except that the differences among treatments were not significant. The control fruits showed the lowest values of Fe, Zn and Mn. This was evident in the two seasons. The combined effect of S and P were confirmed by Fenn *et al.*(1990) and Olsen *et al.* (1993).. Also Singh *et al.* (1995) used 0, 25 or 50 kg S/ha with 80 kg P_2O_5 /hato fertilize potato plants. and found that Mg, Cu and Fe contents tended to increase with balanced P and S fertilizers.

Table (8). Effect of sulphur, phosphorus and their interactions on micronutrients contents of sweet pepper fruits during 2002(S1) and 2003(S2) seasons.

Characters		**Fe (ppm)**		**Zn (ppm)**		**Mn (ppm)**	
Season		**S1**	**S2**	**S1**	**S2**	**S1**	**S2**
Treatments							
S (kg S/fed)							
Control		64	57	16	13	15	12
150		71	64	18	16	17	14
300		80	74	20	17	19	18
L.S.D. (5%)		2.16	1.67	2.17	2.46	1.16	3.01
P (kg P_2O_5/fed)							
Control		61	52	16	13	16	13
30		70	63	18	15	17	15
60		81	74	20	18	19	17
90		76	71	18	16	17	15
L.S.D. (5%)		3.32	2.29	2.46	2.53	N.S	N.S
Interactions							
S levels (kg S/fed)	**P Levels (kgP_2O_5/fed)**						
Control	Control	49	44	14	11	14	11
	30	60	53	16	13	15	13
	60	78	68	18	16	17	15
	90	72	65	17	14	15	12
150	Control	61	50	16	13	16	13
	30	68	62	19	16	18	14
	60	80	73	20	19	19	16
	90	76	71	18	16	18	16
300	Control	73	63	19	15	18	17
	30	82	75	21	17	19	18
	60	85	81	23	19	21	20
	90	81	77	20	18	18	19
L.S.D. (5%)		5.73	3.47	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
ب- التأثير علي المحصول و صفات الثمار و المكونات الغذائية للثمار

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أجريت تجربتان حقليتان فى مزرعة البرامون محطة بحوث البساتين بالمنصورة خلال الموسم الصيفي لعامي (٢٠٠٢ ، ٢٠٠٣) و ذلك بغرض دراسة تأثير الكبريت بمستويات (صفر , ١٥٠ و٣٠٠ كجم/ فدان) والفوسفور بمستويات (صفر , ٣٠ , ٦٠ و٩٠ فو٢ اه /فدان) و تفاعلاتهما على المحصول و مكوناته

(عدد الثمار للنبات – متوسط وزن الثمرة – وزن الثمار للنبات – المحصول المبكر و المحصول الكلي للفدان) – الصفات الطبيعية للثمار (طول الثمرة – قطر الثمرة – دليل شكل الثمرة – سمك لب الثمرة) المكونات الكيميائية للثمار (الكاروتين - المواد الصلبة الذائبة الكلية – فيتامين ج – الحموضة الكلية) و كذلك محتوي الثمارمن العناصر الغذائية (النيتروجين – الفوسفور – البوتاسيوم – الكبريت – الحديد – الزنك – المنجنيز) و ذلك في نباتات الفلفل الحلو (صنف كاليفورنيا ووندر).

أظهرت النتائج المتحصل عليها زيادة جميع القياسات السابق الإشارة إليها مع زيادة معدل الكبريت المضاف من صفر إلى ٣٠٠ كجم/ فدان عنها في نباتات المقارنة و كانت الزيادة معنوية في جميع القياسات ما عدا عدد الثمار/ نبات في الموسمين, دليل شكل الثمرة في الموسم الثاني و سمك لب الثمرة في الموسمين حيث كانت الزيادة بها غير معنوية.

أظهرت كل قياسات الثمار تحت الدراسة زيادة معنوية نتيجة للتسميد الفوسفاتي بينما كانت الفروق بين المعاملات غير معنوية في بعض الصفات مثل عدد الثمار/ نبات - دليل شكل الثمرة و سمك لب الثمرة في الموسمين.

أظهرت النتائج أيضا أن أعلي محتوي من كل من الحديد , الزنك و المنجنيز لوحظ مع المعدل المتوسط من الفوسفور (٦٠ كجم فو٢ اه / فدان) ثم نقص مع المعدل الأعلي (٩٠ كجم فو٢ اه / فدان).

أظهر تفاعل الكبريت مع الفوسفور أن المعدل الأعلى للكبريت المضاف (٣٠٠ كجم /فدان) بالإضافة إلى المعدل الأعلى للفوسفور (٩٠ كجم /فدان) أعطى اعلي تأثيرا في كل الصفات التي تم دراستها ماعدا محتوي كل من الحديد , الزنك و المنجنيز الذي أعطي اعلي محتوي مع المستوي الأعلى للكبريت (٣٠٠كجم / فدان) + المستوي الأوسط للفوسفور ٦٠ كجم فو٢ اه / فدان).