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EFFECT OF DIFFERENT NPK FERTIGATION LEVELS ON GROWTH, YIELD AND NITRATE ACCUMULATION OF SWEET PEPPER PLANTS GROWING IN PLASTIC GREENHOUSE

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ABSTRACT

This experiment was carried out during the two successive seasons of 1999-2000 and 2000-2001 in the unheated plastic house of the Vegetable Crops Department, Faculty of Agriculture, Cairo University. Transplants for sweet pepper (*Capsicum annuum* L. cv. Bruyo hybrid) were arranged in 3 replicates using split-plot design. The treatment of preplanting NPK soil addition was stablished in the main plots and 5 NPK fertigation levels in the sub-main. Generally, it can be observed that plant hieght and total leaf area showed higher significant increases with the third fertigation level (100kg NH_4NO_3+ 50kg H_3PO_4+ 60kg K_2SO_4/plastic house, 540 m^2). Meanwhile, number of leaves as well as dry weights of roots, stems and leaves recorded the highest significant increases with the fifth fertigation level (150kg NH_4NO_3+ 75kg H_3PO_4 + 90kg K_2SO_4) in both seasons. In addition, the third fertigation level showed higher significant increases for early and total yield except, early yield in the second season. Also, concentrations of N and Fe showed significant increases by fifth fertigation level in leaves tissue. Furthermore, the same fertigation level combined with preplanting NPK soil addition increased significantly concentration of Pb in leaves. Howeover, no constant trend could be detected in Ni concentrations between treatments. As regard fruit quality; fruit length, width and size as well as ascorbic acid no significant differences among treatments were recorded. However, total acidity and total soluble solids were increased significantly with increasing fertigation level in both seasons. Also, fruits tissue showed higher concentrations for N, P and K by NPK preplanting soil addition combined with the fifth fertigation level. Furthermore, fruit concentration of Fe and Zn recorded significant increases by increasing fertigation levels. In addition, preplanting NPK soil addition combined with the fifth fertigation level showed the lowest value of Pb concentration in fruits tissue. Moreover, concentration of Ni showed no significant differences among treatments. Furthermore, nitrate concentration was increased significantly by increasing fertigation levels, *vice versa* for total sugars. However, the concentrations of Pb and nitrate accumulation in sweet pepper fruit still less than the critical limits permitted to be found for human consumption.

INTRODUCTION

Sweet pepper (*Capsicum annuum*) is one of the most important vegetable crops grown in Egypt. Egyptian land are suffering from insufficient macro and micronutrients. Application of chemical fertilizers might be a successful tool for improving the chemical conditions of the soil, which in turn could induce stimulative effect on plant growth and productivity, especially with applying chemical fertilizer through drip irrigation water in plastic houses. Fertigation is improved efficiency of fertilizer recovery, minimal fertilizer losses due to leaching and control of nutrient concentration in soil solution.

Tests of nitrate accumulation in Egyptian vegetables showed considerable higher contents of nitrate as compared to those found in vegetables grown in several European countries (Blom-Zandstra, 1989; Kheir *et al.*, 1991; Hanafy Ahmed, 1996 and Hanafy Ahmed *et al.*, 1997 and 2002 a, b and c), in spite the high intensity and long duration of light in Egypt which favours nitrate reduction in plants. Accumulation of nitrate in fruits has many detrimental effects on human health. Nitrite may be accumulated from nitrate after ingestion, causing methaemoglobinemia (Wright and Davison, 1964). The World Health Organization has tentatively fixed the acceptable daily intake of nitrate at 3.65 mg/kg body weight and for nitrite at 0.13 mg/kg (Reinink, 1988). When nitrite ions absorbed into the blood, the Fe^{++} of hemoglobin may be oxidized to Fe^{+++} producing methaemoglobin, which can not transport oxygen. Babies are more susceptible to methaemoglobinemia than older children or adults (Luthrs, 1973). Also, the presence of NO_3 and NO_2 in blood might result in the formation of nitrosamines, which are carcinogenic (Craddock, 1983). Therefore, it is very important to study nitrate accumulation in edible parts (fruits) of sweet pepper plants. Although, sweet pepper fruits contained little nitrate level (< 100 mg/kg) when compared with other vegetables, the accumulation of nitrates was favored by shady growing place, as well as by insufficient light in greenhouses, as a result of reducing nitrate reductase activity (Jaervan, 1994). Thus, the aim of this study was to determine the effect of different levels of fertigated NPK combined with or without preplanting NPK soil addition on the growth, chemical composition, yield and quality of sweet pepper fruits. Also, this study includes an attempt to reduce mineral fertilizer by using fertigation system, which in turn could reduce environmental pollution by heavy metals as well as nitrate accumulation in sweet pepper fruits.

MATERIALS AND METHODS

This experiment was carried out during the two successive seasons of 1999-2000 and 2000-2001 in the unheated plastic house of the Vegetable Crops Department, Faculty of Agriculture, Cairo University. Seeds of sweet pepper (*Capsicum annuum* L. cv. Bruyo hybrid) produced by Bronzima Company (Netherlands), were used in this investigation. Seeds were sown on 20^{th} and 27^{th} of August in 1999 and 2000 year, respectively, in trays (84 cells) filled with 1:1 by volume petmoss and vermiculite media, which is recommended by the National Committee for Protected Cultivation (NCPC), El-Beltagy and Abou-Hadid (1988) for sweet pepper plants. The physical and chemical properties of the soil under study were presented in Table (1). The following procedures were used for the chemical analysis of the soil before cultivation. Soil reaction (pH) was determined by using pH meter 18 Aqua Lytic with a glass electrode (Richard, 1954). Electrical conductivity (EC) of soil extract (1:2.5) was determined using EC meter (YSI) model 32. Available N was extracted by 2 N KCl solution and determined by using the methods described by Markus *et al.* (1982). Available phosphorus was extracted by sodium bicarbonate according to Olsen *et al.* (1954) and estimated colorimetrically as described by King (1951). Available K, Fe, Zn, Mn, Cu, Pb and Ni were extracted by DTPA solution according to the methods reported by Lindsay and Norvell (1978) and Soltanpour and Workman (1979) and determined by using Atomic Absorption Spectrophotometer apparatus PERKIN ELIMER 3300. Organic matter content was determined according to the modified Walkely and Black methods (Richard, 1954). Mechanical analysis was determined at the beginning according to Piper (1950).

The plastic house used was 60 m length, 9 m width and 3.25 m height. The plastic house was divided into 5 beds (ridges), each of 100 cm width, 20 cm height. The organic fertilizer (cattle manure) applied in the bottom of the beds at the rate of 5 m^3 per each plastic house at time of soil preparation, where seedlings were planted 50 cm apart on the two sides of each bed. Thus, 1200 plants were grown per each plastic house (area of 540 m^2). Each square meter contained 2.2 plants. The plastic cover was local UV-treated polyethylene sheet of 7.5 m in width and 200 microns in thickness.

Table (1): Physical and chemical properties of the soil in both seasons.

Season / Properties	1999	2000
Physical properties:		
Clay (%)	22.9	26.1
Silt (%)	36.2	34.6
Fine sand (%)	37.1	36.0
Coarse sand (%)	3.8	3.3
Soil texture	Clay loam	Clay loam
Chemical properties:		
Available N (%)	1.15	0.95
Available P (%)	0.44	0.39
Available K (%)	1.25	1.48
Available Fe (ppm)	40.16	41.09
Available Zn (ppm)	28.90	30.88
Available Mn (ppm)	30.54	36.64
Available Cu (ppm)	15.65	16.42
Available Pb (ppm)	3.3	3.2
Available Ni (ppm)	0.85	0.90
EC (mmohs/cm)	1.11	1.25
p H	8.03	7.89
Organic matter (%)	2.40	2.55

Transplants were shifted after 38 and 40 days in 1999 and 2000 season, respectively to the unheated plastic house. Other agricultural practices, i.e. irrigation, training, pruning as well insects and diseases control were done whenever were necessary according to the recommendation of NCPC. In both seasons, the experiment included the following treatments: - Two groups of basic chemical fertilizer, i.e. with or without soil addition, in the first group, the basal chemical fertilizers were applied before planting as follows: 25 kg ammonium nitrate (33.5% N), 100 kg calcium super phosphate (15.5% P_2O_5) and 50 kg potassium sulphate (48% K_2O)/plastic house (540 m^2) as recommended by NCPC which served as main treatment. For each group, five different levels of NPK fertilizers as ammonium nitrate (33.5% N), phosphoric acid (85% P_2O_5) and potassium sulphate (48% K_2O) were applied *via* drip irrigation started after 2 weeks from transplanting date, these five different fertigation treatments were served as sub-main treatments. Through the growing season, the levels from ammonium nitrate, phosphoric acid and potassium sulphate (kg/plastic house, 540 m^2) were used, respectively, as follows: 50 – 25 – 30 (control), 75 – 37.5 – 45, 100 – 50 – 60, 125 – 62.5 – 75 and 150 – 75 – 90. Each treatment divided into 30 applications, fertigated weekly for 15-20 minutes. Three plants were collected randomly from each replicate during the whole course of growth period at 60, 90 and 120 days after transplanting to determined the following growth characters: Shoot height (cm), Numbers of leaves/plant, Total leaf area/plant (cm^2) which measured by using leaf area meter Li-3000 as well as dry weights of leaves, stems and roots. Determination of N, P, K, Fe, Zn, Mn, Cu, Pb and Ni were carried out on the dry leaves at 60, 90 and 120 days after transplanting. The fine powder (1.0 g) of dry sample was digested by using sulphuric acid and perchloric acid according to Piper (1947). Total nitrogen was determined by using the micro-Kjeldahl method as described by Jackson (1973). Phosphorus was estimated colormetrically by using chlorostannous reduced molybdophosphoric blue colour method according to Chapman and Pratt (1961). Potassium was determined by using flamephotometer 410. Iron, manganese, zinc, copper, lead and nickel were determined by using Atomic Absorption Spectrophotometer. At marketable, green mature stage, all fruits of each plant were harvested starting from 90 days after transplanting. Harvesting period included 7 and 6 pickings in the first and second season, respectively; the following yield parameters were recorded: early yield, the sum of the three first pickings (kg/m^2) and total yield, the all harvesting pickings (kg/m^2). To estimate fruit quality, samples of five fruits at the marketable green stage of the fourth and fifth picking of the first and second season, respectively were chosen randomisely from each subplot with three replicates, where the following the physical and chemical properties were determined: Fruit length, size and diameter, average weight of fruit, ascorbic acid (Vitamin C), total acidity and total soluble solids (T.S.S.) percentages were determined by using Abee refractometer according to A.O.A.C (1975). Total sugars were determined as (mg/g dry weight) of sweet pepper fruit tissues according to Dubois *et al.* (1956). Nitrate determination was carried in fruits dry materials by using the method described by Kamal (1951). The experiments were carried out in split-plot design with three replicates. The presence or absence of the basic chemical fertilizers were occupied the main plots, whereas the fertigation treatments were arranged in sub plots. All data were subjected to the statistical analysis and means were compared according to the L.S.D. test described by Snedecor and Cochran (1980).

RESULTS AND DISCUSSION

1- Vegetative growth characters

Data in Tables (2 and 3) reveal that plant height, number of leaves, total leaf area and dry weights of roots, stems and leaves were significantly increased with preplanting NPK soil addition compared with untreated plants in most of the studied growth samples of sweet pepper plants in the two seasons with some exceptions. Similar trends were obtained by Singh *et al.*, (1999) and Nassar *et al.*, (2001) on sweet pepper plants. On the contrary, Hanafy Ahmed *et al.*, (2002c) found that addition of NPK fertilizers had no effect on most of the studied plant growth parameters.The authors suggested that might be related to the increase of available nutrient of N, P_2O_5 and K_2O in clay loamy soil which gave the preplanting NPK soil addition little effect on the growth characters of sweet pepper plants.

As regard the effect of NPK fertigated levels, data in Tables (2 and 3) indicate that increasing levels of fertigated NPK showed significant increase in number of leaves, total leaf area and dry weights of roots, stems and leaves in the three growth samples of the two successive seasons with some exceptions. While the highest values of plant height and total leaf area were recorded at the higher three fertigation levels when compared with the control fertigation level. These results are in agreement with those obtained by Silva *et al.* (1999) and Guertal (2000) on capsicum plants. Generally, it can be suggested that the great response of sweet pepper concerning growth characters was obtained with NPK fertigated levels between (100 kg NH_4NO_3 + 50 kg H_3PO_4 + 60 kg K_2SO_4, and 150 kg NH_4NO_3 + 75 kg H_3PO_4 + 90 kg K_2SO_4 /plastic house), this might be attributed to the beneficial effect of fertigation system which was significantly superior over conventional method to increase the uptake of available nutrient from N, P_2O_5 and K_2O n oil or sweet pepper plants. Similar conclusion was obtained by Veeranna *et al.* (2000).

Concerning the effect of interaction between preplanting NPK soil addition and various levels of NPK fertigation, the data in Tables (2 and 3) reveal significant increase in all of the studied growth parameters with increasing levels of NPK fertigation combined with NPK soil addition in all growth samples of the two seasons. The highest values of plant height and total leaf area were obtained by the plants treated with the moderate NPK fertigation level (100 kg NH_4NO_3 + 50 kg H_3PO_4 + 60 kg K_2SO_4/plastic house) combined with NPK soil addition. Furthermore, numbers of leaves and dry weights of both roots and stems showed the highest values at the highest NPK fertigation level (150 kg NH_4NO_3 + 75 kg H_3PO_4 + 90 kg K_2SO_4 /plastic house) combined with NPK soil addition. Meanwhile, dry weights of leaves reveal no constant trend of significant increase could be detected with increasing fertigation levels of NPK fertilizers. Generally, it is clear from the present results that, increasing NPK fertilizer significantly affected vegetative growth characters. This might be due to the positive effect of these nutrients (N,P and /or K) on vegetative growth characters. In this respect, regarding nitrogen fertilizer, Abd-El-Baky (2000) and Hassan (2002) working on capsicum plants found positive effect of nitrogen fertilization on vegetative plant growth.

the compound of NPK fertilizers, similar findings were obtained by Maya *et al.* (1997) and Abd- El-Baky (2000) on sweet pepper. In this respect, the effect of phosphorus may be due to its enhancing influence on photosynthesis and respiration as reported by Repla (1979). Furthermore, Edmond *et al.* (1981) added that phosphorus is a part of molecular structural of several vitally important compounds notable nucleic acids (DNA, the two forms of RNA). On the other hand, the highest levels of phosphorus fertilization had the opposite effect on vegetative growth characters. Similar results were obtained by Singh and Srivastava (1988) on chilli plants.

In this respect, Fujinao (1967) mentioned that there was an increase in the amount of inorganic phosphate in guard cells of closed stomata compared to open stomata. Thus, the effects of phosphorus on growth and dry matter accumulation through stomatal behavior may be due to its effect on CO_2 penetration into photosynthesizing cells through guard cells and consequently CO_2 assimilation. In this respect, Radin (1984) working on cotton reported that the effect of phosphorus nutrition on stomatal behaviour may be related to alteration of the balance between ABA and cytokinins. Yoneyama (1988) reported that high P concentration inhibits enzyme reactions and create abnormal osmotic pressure in the cell. Furthermore, Ma and Takahashi (1990) and Mandal and Mandal (1990) reported that application of phosphorus fertilizer at a high dose caused a decrease in the concentration of Zn, Cu, Fe and Mn in both shoots and roots. Various hypotheses have been suggested to explain this phenomenon, which include: (i) Interaction of P with other micronutrients in soil. (ii) Interference of P at the highest level on plant metabolism involving uptake, translocation and utilization of micronutrients. (iii) Imbalance P:Zn, P:Fe and P:Mn ratios due to increased or decreased dry matter production with P application. Similar suggestions were reported by Hanafy Ahmed *et al.* (1996) on faba bean plants.

Regarding potassium fertilization as a part of NPK compound fertilizers, the data in Tables (2 and 3) show that increasing levels of NPK fertilization increased vegetative growth characters in sweet pepper plants. Similar results were obtained by Nassar *et al.* (2001) on sweet pepper plants. Obtained results might be due to the role of this element on many of metabolic processes in plant and consequently on plant growth. In this regard, many studies proved that K plays a major role in many physiological and biochemical possesses such as cell division and elongation. Mengel (1977) reported that absorbed potassium is preferentially translocated towards meristemic tissues. The author also stated that high potassium levels in these cells, result in an increase in turgor pressure, which has a direct influence on cell elongation. In this connection, Hassan (2002) suggested that potassium element is very important in the over all metabolism of sweet pepper plants, enzyme activation, stabilization of the native conformation of enzymes (Mengel and Kirkby, 1978), metabolism of carbohydrates and protein compounds (Smith, 1968). Finally, it could be concluded that moderate levels of fertigated NPK combined with the preplanting NPK soil addition were more competence for sweet pepper growth comparing with the other higher NPK fertigation levels or the other lower ones.

2- Yield and its components

In the two successive seasons, the present results in Table (4) show that fruit number, average fruit weight per plant, early and total yield for sweet pepper plants did not show any significant increase with the application of preplanting NPK soil addition when compared with untreated plants, except average fruit weight per plant for early yield in the second season.. Similar results were obtained by Shrivastava (1996) and Hanafy Ahmed *et al.* (2002c) on capsicum plants. In this respect, it can be suggested that preplanting NPK soil addition treatment had no favorable influence on yield and its component, this might be attributed to use low level of NPK soil addition before transplanting which is not sufficient to make a positive effect on the yield of sweet pepper plants and its components.

With regard to the influence of NPK fertigation levels either alone or in combined with preplanting NPK soil addition on yield and its component, data present in Table (4) reveal that fruits number, average fruit weight as well as early and total fruit yield increased significantly with moderate NPK fertigation level (100 kg NH_4NO_3 + 50 kg H_3PO_4 + 60 kg K_2SO_4 /plastic house) when compared with other levels, with some exceptions. However, the total yield in the second season showed non significant increase among treatments. These results are in harmony with those reported by Bracy *et al.* (1995) and Qawasmi *et al.* (1999) on capsicum plants. The authors mentioned that moderate NPK fertigation levels increased yield and its component compared with the highest NPK levels. Also, they mentioned that this increment was attributed to the increase in both number and average weight of fruits. Furthermore, from the present results, it can be suggested that the enhancement of early yield as a result of the increase of nitrogen, phosphorus and potassium might be attributed to the effect of such nutrients on flowering and fruit setting. Similar suggestion was obtained by Saito *et al.* (1963) and Fisher (1969). On the contrary, Hassan *et al.* (1993) and Siti *et al.* (1993) found that increasing N levels decrease the percentage of fruit set as well as both early and total yield of capsicum plants. In this respect, Lauer and Blevins (1989) working on soybean mentioned that nitrogen supply increased cytokinin and decreased ABA and hence, decrease flower and pod drop. These findings were confirmed by Horgan and Warieng (1980) the authors suggested that phosphorus supply enhance cytokinin contributes to the enhancing effect of phosphorus on flower formation. In addition, Eid *et al.* (1992) reported that the maximum early yield of tomato were obtained in case of appling the highest level of potassium (96 kg K_2O /fed) when compared with 48 and 72 kg K_2O /fed. Similar results were obtained by Hassan (2002) working on sweet pepper plants. On the other hand, Hanafy Ahmed (1986) working on sweet pepper plants reported that potassium deficient plants flowered earlier than those receiving complete nutrient solutions. However, the author mentioned that potassium deficient fruits did not reach the marketable stage at all. Moreover, Tedeschi and Zerbi (1984) reported that yield of sweet pepper depended on the number of fruits per plant and the mean fruit weight rather than the number of flowers, which was less important because abscission of flowers and young fruits were always high. On the other hand, a reverse trend was reported by Basavaraj and Naik

(2000), GuoHua *et al.* (2001), Nassar *et al.* (2001) on capsicum plants. The authors found significant increase in fruits number, average fruit weight per plant as well as early and total yield by increasing levels of NPK fertilization. In this connection, Hanafy Ahmed (1986 and 1997) working on sweet pepper and squash plants, respectively suggested that the increases in fruit yield under sufficient supply of macronutrient (N, P and K) might be attributed to sufficient supply of assimilates from the leaves to the fruits as a result of, a) an increase in available leaf assimilate supply to the fruits, b) an increase in potential sink strength of fruit, and/ or c) an increase in translocation capacity. Thus, it can be suggested that increasing NPK rate stimulates vegetative growth and the consequence acceleration of the reproductive growth.

Table (4): Yield and yield components [fruits number/plant, single fruit weight (g) and yield (kg/m^2)] of sweet pepper plants as affected by different levels of NPK during 1999-2000 and 2000-2001 seasons.

Season		1999-2000								
Yield component		Fruit number			Fruit weight			Yield (kg/m^2)		
	Treatment	+ NPK	- NPK	Mean (B)	+ NPK	- NPK	Mean (B)	+ NPK	- NPK	Mean (B)
Early yield	1 (Control)	3.08	2.80	2.94	195	213	204	1.50	1.49	1.50
	2	2.88	2.93	2.91	200	241	221	1.44	1.77	1.61
	3	3.68	3.98	3.83	230	250	240	2.12	2.49	2.31
	4	3.23	3.03	3.13	239	225	232	1.93	1.70	1.82
	5	2.78	2.38	2.58	218	230	224	1.52	1.37	1.45
	Mean (A)	3.13	3.02		216	232		1.70	1.76	
	L.S.D 0.05	A= N.S. B= 0.92 A×B=1.29			A= N.S. B= 26 3 A×B=37.20			A= N.S. B= 0.54 A×B= 0 76		
Total yield	1 (Control)	18.6	22.6	20.60	127	114	121	5.91	6.44	6.18
	2	26.7	25.22	25.96	138	127	133	9.21	8.00	8.61
	3	28.15	33.30	30.73	167	122	145	11.75	10.60	10.96
	4	22.27	28.05	25.16	133	102	118	7.40	7.15	7.28
	5	24.23	29.85	27.04	98	97	98	5.94	7.24	6.59
	Mean (A)	23.99	27.80		133.4	112.4		8.04	7.80	
	L.S.D 0.05	A=N.S. B= 9.12 A×B=12.90			A=N.S B=42.10 A×B=59.60			A= N.S B= 1 43 A×B= 2.02		
Season		2000-2001								
Early yield	1 (Control)	3.86	3.33	3.60	205	224	215	1.98	1.86	1.92
	2	3.48	2.54	3.01	210	263	237	1.83	1.67	1.75
	3	4.10	4.33	4.22	212	232	222	2.17	2.51	2.34
	4	3.13	3.50	3.32	295	234	265	2.31	2.05	2.18
	5	3.55	3.08	3.32	210	237	224	1.86	1.82	1.84
	Mean (A)	3.62	3.36		226	238		2.03	1.98	
	L.S.D 0.05	A= N S B= 1 01 A×B= 1 43			A= 9 6 B= 15.2 A×B= 21 5			A=N S. B=N S A×B=N S		
Total yield	1	17.80	18.70	18.25	141	126	134	6.27	5.89	6.08
	2	17.50	18.90	18.20	150	137	144	6.56	6.47	6.52
	3	18.90	17.0	17.95	168	186	177	7.94	7.91	7.93
	4	17.60	15.70	16.65	184	154	169	8.10	6.04	7.07
	5	15.50	16.00	15.75	167	154	161	6.47	6.16	6.32
	Mean (A)	17.46	17.26		162	151.4		7.07	6.49	
	L.S.D 0.05	A=N.S B=N.S A×B=N S.			A=N S. B=N S A×B=N S			A=N.S B=1 70 A×B=N S		

Finally, it can be concluded that fruits number, average fruit weight as well as early and total yield of sweet pepper plants positively affected by moderate application level of NPK fertilizer when compared with the higher levels or the lower ones.

3-Plant chemical constituents

As regard the effect of NPK soil addition treatment on macro and microelements concentrations, results obtained in Tables (5 and 6) indicate that leaves of sweet pepper plants showed no significant increase in concentrations of N, P, K, Fe and Mn with the application of preplanting NPK soil addition fertilizer comparing with untreated plants in the two successive seasons with some exceptions. However, the concentration of Zn recorded significant increase with preplanting NPK soil addition in both seasons, except the concentration of Zn in all growth samples of the second season one. Similar results were obtained by Nassar *et al.* (2001) and Hanafy Ahmed *et al.* (2002 c) on capsicum plants.

With regard to the influence of NPK fertigation levels, data obtained in Tables (5 and 6) reveal that concentration of total N,P and K increase significantly in the leaves of sweet pepper plants in the two successive seasons in most of the studied growth samples by increasing levels of fertigated NPK either alone or in combined with the preplanting NPK soil addition up to (150 kg NH_4NO_3 + 75 kg H_3PO_4 + 90 kg K_2SO_4 /plastic house) comparing with the other lower levels or control one with some exceptions. These results are in harmony with those reported by Olsen *et al.* (1993), Qawasmi *et al.* (1999), Guertal (2000), Mohamed and Enzy (2001) and Hassan (2002) on capsicum plants. From the present results, it can be clearly obvious that application of excess nitrogen, phosphorus and potassium had positive influence on sweet pepper leaves concentration of such nutrients. In this respect, it can be suggested that increasing NPK fertilizers level increased nutrients in rooting zone in readily available form, which could increase their uptake, by plants as a result of using fertigation system, which improved efficiency of fertilizer recovery and minimal losses due to leaching. Similar suggestions were obtained by Veeranna *et al.* (2000) on capsicum. Further interpretation was performed in relation to the effect of fertilization on root growth, hence nutrients uptake may affect; a close positive correlation between the number of roots primordial and cytokinin production, were reported by Richards (1981) on tomato. Moreover, the synthesis and export of cytokinin were also affected by N, P and K supply (Horgan and Warieng, 1980). On the other hand, many investigators found no significant increase in N, P and K concentrations by Increasing NPK levels in the different plant organ. Similar trend was obtained by Thomas and Heliman (1964) who mentioned that no phosphorus accumulation was detected in sweet pepper plant with the additions of nitrogen fertilization. In this respect, Haynes (1988) reported that the levels of leaf K and P concentrations in bell pepper plants were not affected by increasing levels of N fertigation. Furthermore, Marschner (1995) mentioned that the leaves and stems of capsicum plants contained less percentages of potassium at the highest levels of phosphorus fertilization.

Table (5): Nitrogen, phosphorus, potassium concentrations (mg/g d.w.), iron, zinc, manganese and copper concentrations (ppm) in the leaves of sweet pepper plants as affected by different levels of NPK during 1999-2000 season.

Chemical composition	Days after transplanting	60			90			120		
	Treatment	+ NPK	- NPK	Mean (B)	+ NPK	- NPK	Mean (B)	+ NPK	- NPK	Mean (B)
N	(Control) 1	26 2	25 4	25 8	28 5	27 4	28 0	30 1	30 0	30.1
	2	26.5	25 6	26.1	28.8	27 7	28 3	31 5	30 1	30 8
	3	26.9	26.5	26 7	29 3	28.7	29.0	32.2	31.4	31.8
	4	27.8	27.5	27.7	29 7	29.3	29.5	33.0	32.4	32.7
	5	29 1	28 8	29.0	31 8	30.7	31.3	34 9	33.8	34.4
	Mean (A)	27.3	26 8		29.6	28.8		32 3	31.5	
	L.S.D 0.05	A=N S B=2 39 A×B=3 37			A=N S B=3.22 A×B=N S			A=N S B=2 56 A×B=3 63		
P	(Control) 1	3.32	3.19	3.26	3.96	3.52	3.74	4 03	3.95	3.99
	2	3.32	3.23	3.28	4.00	3.56	3.78	4.12	4.10	4.11
	3	4.52	3.79	4.16	4.36	4.10	4.23	4 75	4 18	4.47
	4	4 41	4.26	4.34	4.66	4.40	4.53	5.15	5.05	5.10
	5	4.44	4.30	4.37	4.85	4.42	4.64	5.29	5.28	5.29
	Mean (A)	4.00	3.75		4.37	4.00		4.67	4.51	
	L.S.D 0.05	A=N.S B=N.S. A×B=N.S.			A=N.S. B=N.S. A×B=N S.			A=N S B=1.16 A×B=1 64		
K	(Control) 1	28.0	23.3	25.7	23.0	22.6	22.8	17.9	17.3	17.6
	2	29.4	26.7	28.1	24 2	23.8	24.0	18.9	17.4	18.2
	3	29.5	27.8	28.7	24.5	24.3	24.4	19.4	17.4	18.4
	4	29.7	29.0	29.4	25.0	24.7	24.9	20.9	17.6	19.3
	5	29.9	29.7	29.8	26.7	26.1	26.4	20 8	19.2	20.0
	Mean (A)	29.3	27.3		24.7	24.3		19.6	18.2	
	L.S.D 0.05	A=1 67 B=2.63 A×B=3.72			A=N.S. B=N.S A×B=N.S			A=N S B=2.50 A×B=3 50		
Fe	(Control) 1	705	695	700	850	814	832	550	475	513
	2	800	790	795	1050	1030	1040	570	510	540
	3	850	825	838	1100	1075	1088	650	590	620
	4	913	900	907	1240	1220	1230	695	645	670
	5	975	945	960	1290	1265	1278	735	710	723
	Mean (A)	849	831		1106	1081		640	586	
	L.S.D 0.05	A=N S B=62 A×B=87			A=N.S. B=157 A×B=222			A=42 B=66 A×B=93		
Zn	(Control) 1	71	71	71	75	75	75	8.2	80	81
	2	79	75	77	81	77	79	89	86	88
	3	86	77	82	90	82	86	97	89	93
	4	83	77	80	86	80	83	97	83	90
	5	80	77	79	82	79	81	97	83	90
	Mean (A)	80	75		83	79		92	84	
	L.S.D 0.05	A=2.28 B=3.61 A×B=5 10			A=2.26 B=3.57 A×B=5.06			A=3.11 B=4.92 A×B=6 95		
Mn	(Control) 1	118	119	119	108	108	108	103	104	104
	2	120	121	121	110	116	113	105	109	107
	3	120	125	123	112	115	114	105	111	108
	4	123	125	124	112	116	114	106	114	110
	5	123	126	125	113	118	116	108	115	112
	Mean (A)	121	123		111	115		105	111	
	L.S.D 0.05	A=N S B=N S A×B=N S			A=N S B=N S. A×B=N S			A=N S B=N S. A×B=N S		

Table (6): Nitrogen, phosphorus, potassium concentrations (mg/g d.w.), iron, zinc, manganese and copper concentrations (ppm) in the leaves of sweet pepper plants as affected by different levels of NPK during 2000 – 2001 season.

Chemical composition	Days after transplanting	60			90			120		
	Treatment	+ NPK	- NPK	Mean (B)	+ NPK	- NPK	Mean (B)	+ NPK	- NPK	Mean (B)
N	(Control) 1	28.0	27.0	27.5	30 4	27.6	29.0	31.4	29.0	30 2
	2	28.4	27.9	28.2	31.7	28.9	30.3	33.5	31.2	32 4
	3	29.0	28.2	28 6	32.2	29.9	31.1	34.3	32.8	33.6
	4	29.8	28.7	29.3	33.0	30 3	31.7	35.0	33.0	34 0
	5	30.8	30.0	30.4	34.4	33.6	34.0	36.2	34.4	35.3
	Mean (A)	29.2	28.4		32.3	30.1		34.1	32.1	
	L.S.D 0.05	A=N.S. B=N.S A×B=N S.			A=1.23 B=1 95 A×B=2 75			A=1 28 B=2 02 A×B=2 86		
P	(Control) 1	3.39	3.24	3.32	3.45	3.39	3.42	4.20	4.11	4.16
	2	3.55	3.38	3.47	3.75	3.57	3.66	4.25	4.18	4.22
	3	3.75	3.60	3.68	4.13	4.10	4.12	4.73	4.45	4.59
	4	4.64	4.35	4.50	4.75	4.42	4.59	5.23	5.10	5.17
	5	4.70	4.52	4.61	4.80	4.63	4.72	5.37	5.25	5.31
	Mean (A)	4.01	3.82		4.18	4.02		4.76	4.62	
	L.S.D 0.05	=N S. B=0.91 A×B=1.29			=N.S. B=0.56 A×B=0.79			=N.S. B=0.57 A×B=0 81		
K	(Control) 1	27.1	25.2	26.2	22.6	22.0	22.3	18.3	17.7	18.0
	2	28.3	27.5	27.9	23.3	22.3	22.8	19.9	19.3	19.6
	3	28.9	27.3	28.1	24.2	23.1	23.7	21.0	20.3	20.7
	4	28.8	28.4	28.6	24.4	23.8	24.1	22.4	20.7	21.6
	5	30.1	29.8	30.0	26.7	24.2	25.5	22.8	22.2	22.5
	Mean (A)	28.6	27.6		24.2	23.1		20 9	20.0	
	L.S.D 0.05	=N.S. B=N.S. A×B=N.S.			=N.S B=N.S A×B=N.S.			=N.S. B=3.6 A×B=5.1		
Fe	(Control) 1	750	740	745	895	822	859	540	325	433
	2	813	810	812	1078	1063	1071	590	570	580
	3	888	875	882	1158	1175	1167	618	557	588
	4	900	892	896	1218	1205	1212	671	655	663
	5	995	942	969	1333	1315	1324	763	741	752
	Mean (A)	869	852		1136	1116		636	570	
	L.S.D 0.05	A=N.S. B=177 A×B=250			A=N.S. B=120 A×B=170			A=N.S. B=169 A×B=240		
Zn	(Control) 1	76	74	75	77	75	76	83	81	82
	2	82	74	78	83	79	81	86	84	85
	3	89	82	86	95	81	88	104	89	97
	4	83	77	80	89	79	84	95	86	91
	5	77	75	76	86	83	85	97	86	92
	Mean (A)	81	76		86	79		93	85	
	L.S.D 0.05	=N.S. B=N.S. A×B=N.S.			=N.S. B=N.S. A×B=24.08			=N.S. B=N S. A×B=N S.		
Mn	(Control) 1	123	124	124	111	116	114	101	101	101
	2	122	124	123	113	120	117	101	106	104
	3	124	126	125	115	124	120	104	112	108
	4	128	130	129	117	124	121	106	115	111
	5	127	134	131	121	128	125	108	117	113
	Mean (A)	125	128		115	122		104	110	
	L.S.D 0.05	=N.S. B=N S A×B=N S.			=6.10 B=9.70 A×B=13 70			=N.S B=N S A×B=N S		

Also, the author mentioned that the uptake of K^+ was decreased when accompanied by SO^{-2}_4. Golcz (1995) on capsicum noticed that K in the range of 0.12-0.48 g/dm^3 had an antagonistic effect on leaf P content. Moreover, Sergio *et al.* (1994) and Nassar *et al.* (2001) working on capsicum found that increasing levels of K had no effect on concentrations of total P in leaves tissues. Meanwhile, Golcz (1992) working on capsicum stated that increasing N levels decreased K concentration in plant tissues. This result may be referred to the antagonism between N and K. Meanwhile, Kato *et al.* (1993) working on sweet pepper mentioned that heavy application of N did not change appreciably in K contents in plant tissues. Recently, Hanafy Ahmed *et al.* (2002 c) found that 100% or 50% of the recommended NPK fertilizer did not show any significant differences in N, P and K concentrations in sweet pepper leaves.

Finally, it can be concluded that increasing NPK fertigation levels up to (150 kg NH_4NO_3 + 75 kg H_3PO_4 + 90 kg K_2SO_4 /plastic house) combined with preplanting NPK soil addition increased significantly the concentrations of N, P and K in the leaves of sweet pepper plant in most of the studied growth samples of the two seasons when compared with those supplied with the lowest level (50 kg NH_4NO_3 + 25 kg H_3PO_4 + 30 kg K_2SO_4 /plastic house); control level.

Furthermore, data in Tables (5 and 6) indicate that concentrations of Fe increased significantly in the leaves of sweet pepper plants in all growth samples of the two successive seasons by increasing levels of fertigated NPK up to (150 kg NH_4NO_3 + 75 kg H_3PO_4 + 90 kg K_2SO_4 /plastic house) either alone or in combined with preplanting NPK soil addition when compared with corresponding plants supplied with lower levels. Moreover, concentration of Mn did not show any significant differences between treatments, except in the 2nd sample of the second season. In addition, concentration of Zn showed significant increase in the leaves of the plants supplied with the moderate NPK level (100 kg NH_4NO_3 + 50 kg H_3PO_4 + 60 kg K_2SO_4 /plastic house) either alone or in combined with preplanting NPK soil addition treatment, with some exceptions. Anyway, many investigators mentioned that increasing NPK fertilizers levels affect positively micronutrients concentration (Moreno *et al.*, 1996 and Mohamed and Enzy, 2001) on capsicum. In this respect, it may be suggested that increasing levels of NPK fertilizers could enhance the physiological functions of plant cells and in turn the uptake of these nutrients including micronutrients from the soil solution. This conclusion was reported previously by Hanafy Ahmed *et al.* (1997) on jew's mallow and radish plants. On the contrary, Kato *et al.* (1993), Sergio *et al.* (1994) and Hanafy Ahmed *et al.* (2002c) found that application of NPK fertilizer had no effect on the concentrations of micronutrients in capsicum plants.

4- Fruit quality

As regard fruit quality, the results presented in Table (7) reveal that the applications of preplanting NPK soil addition, increasing levels of fertigated NPK and their interaction between treatments showed no significant increases in fruit physical characters (length, diameter and size) of sweet pepper in the two seasons, with some exceptions. Similar results were obtained by Maya *et al.* (1997), Silva *et al.* (1999) and Hanafy Ahmed *et al.* (2002c) on capsicum plants. In this respect, it can be suggested that fruit dimensions appeared to be mainly depended on heredital factors more than on the differences between NPK levels. On the contrary, Abd-El-Baky (2000), Guetral (2000) and Hassan (2002) on capsicum, reported that increasing levels of NPK fertilizer increased significantly fruit dimensions. Furthermore, data in Table (7) show that application of preplanting NPK soil addition, increasing level of fertigated NPK and their interaction had no significant increase on the concentration of vitamin C in the fruits of the two successive seasons. However, data in Table (7) show significant increases in the percentage of T.S.S. and T.A. with increasing levels of fertigates NPK up to moderate rate (100 kg NH_4NO_3 + 50 kg H_3PO_4 + 60 kg K_2SO_4/plastic house) either alone or in combined with preplanting NPK soil addition. Similar results were obtained by Hassan (1997), Maya *et al.* (1997) and Hanafy Ahmed *et al.* (2002 c) on capsicum. In this respect, Midan (1995) and Hanafy Ahmed *et al.* (2002 c) working on sweet pepper plants mentioned that fruit quality; vitamin C, total soluble solids and titrable acidity depend on variety, soil fertility and cultivating date.

Table (7): Fruit length, diameter (cm), size (cm^3), nitrate (ppm), total sugars (mg/g d.w.), vitamin C (mg/100 g f.w.), total acidity (mg/100 g cm^3) and total soluble solids (%) in the fruits of sweet pepper plants as affected by different levels of NPK during 1999-2000 and 2000-2001 seasons.

Season	1999-2000						2000 - 2001					
Fruit quality	Fruit length			Fruit diameter			Fruit length			Fruit diameter		
Treatment	+ NPK	- NPK	Mean (B)	+ NPK	- NPK	Mean (B)	+ NPK	- NPK	Mean (B)	+ NPK	- NPK	Mean (B)
(Control) 1	9.2	10.1	9.7	5.5	5.2	5.4	11.0	11.3	11.2	6.4	6.0	6 2
2	10.5	10.9	10.7	5.9	5.4	5.7	10.8	11.7	11.3	6.7	6.8	6.8
3	10.6	11.0	10.8	5.7	6.0	5.9	11.1	11.8	11.5	6.7	6.5	6.6
4	10.4	10.9	10.7	5.4	5.7	5.6	11.9	11.1	11.5	6.5	6.8	6 7
5	10.7	10.9	10.8	5.5	5.3	5.4	11.8	11.6	11.7	6.5	6.9	6 7
Mean (A)	10.3	10.8		5.6	5 5		11.3	11.5		6.6	6.6	
L.S.D 0.05	A=N.S. B=N.S. A×B=N.S.			A=N.S. B=N.S. A×B=N.S.			A=N.S. B=N.S. A×B=N.S			A=N.S B=N S A×B=0.82		
Fruit quality	Fruit size			Nitrate			Fruit size			Nitrate		
(Control) 1	388	378	383	53.1	49.7	51.4	408	406	407	55.0	54.1	54 6
2	399	393	396	63.5	58.7	61.1	395	411	403	54.5	52.4	53 5
3	379	398	389	68.1	57.6	62.9	385	407	396	62.7	57.1	59.9
4	400	398	399	71.5	69.7	70.6	414	436	425	67.2	59.5	63.4
5	396	381	389	71.1	67.4	69.3	431	416	424	70.7	64.2	67.5
Mean (A)	392	390		65.5	60.6		407	415		62.0	57.5	
L.S.D 0.05	A=N.S. B=N.S A×B=N.S.			A=N.S. B=0.24 A×B=0.34			A=N.S. B= 25.5 A×B=36.1			A=N.S B-0.20 A×B=0 27		
Fruit quality	Total soluble solids			Total sugars			Total soluble solids			Total sugars		
(Control) 1	5.40	4.70	5.05	6.40	6.74	6.57	4.72	4.80	4.76	6.84	7.0	6.93
2	6.30	4.80	5.55	6.34	6.02	6.18	5.30	4.81	5.06	6.14	6.78	6.46
3	6.54	5.70	6.12	5.70	5.84	5.77	6.35	5.30	5.83	5.34	5.88	5.61
4	5.90	5.48	5.69	5.24	5.66	5.45	6.00	5 21	5.61	4.94	5.58	5.26
5	5.85	5.00	5.43	4.94	5.14	5.04	6.00	5.32	5.66	4.28	4.90	4 59
Mean (A)	6.00	5.14		5.72	5.88		5.67	5.09		5.51	6.03	
L.S.D 0.05	A=0.73 B=N.S A×B=1 64			A=N.S B=0.69 A×B=0.98			A=0 57 B=0.90 A×B=1.27			A=0.34 B=0.53 A×B=0 75		
Fruit quality	Vit. C			Total acidity			Vit. C			Total acidity		
(Control) 1	252	250	251	160	165	163	246	240	243	128	152	140
2	264	262	263	172	192	182	258	258	258	152	160	156
3	271	264	268	203	235	219	258	252	255	184	208	196
4	281	282	282	192	199	196	280	271	276	176	171	173
5	286	284	285	160	182	171	282	278	280	128	152	140
Mean (A)	271	268		177	195		265	260		154	169	
L.S.D 0.05	A=N.S B=N.S. A×B=N.S			A=18 B= 30 A×B=44			A=N S B=N.S A×B=N.S			A=N.S B= 32 A×B=46		

As regards macroelements concentration N, P and K, data in Table (8) show that application of preplanting NPK soil addition increased N concentration in sweet pepper fruits, while had no significant increase in concentrations of K and P in both seasons. In addition, data in Table (8) reveal that concentrations of N, P and K in tissues of sweet pepper fruits increased significantly by increasing levels of fertigated NPK up to (150 kg NH_4NO_3 + 75 kg H_3PO_4 + 90 kg K_2SO_4 /plastic house) as single treatment or combined with preplanting NPK soil addition treatment in the two seasons, except K concentration in the first season which showed no significant increase among treatments. Similar results were obtained by Marti and Mills (1991), Olsen *et al.* (1993) and Aliyu (2000) on capsicum. On the contrary, Hanafy Ahmed *et al.* (2002c) found that increasing applications of NPK fertilizer had no significant effect on concentration of total N, P and K in sweet pepper fruits.

As regard microelements concentration, Data in Table (8) indicate that no significant increase could be detected in the concentrations of Fe, Zn and Mn in the fruits of sweet pepper plants in the two seasons, with the application of preplanting NPK soil addition comparing with untreated plants, except concentrations of Fe in the first season which showed significant increase as a result of this treatment. Similar results were obtained by Kato *et al.* (1993) and Hanafy Ahmed *et al.* (2002 c) in sweet pepper fruits. In this respect, it can be suggested that lack response of sweet pepper fruits from micronutrient by the application of preplanting NPK soil addition, might be attributed to low content of micronutrient forms in the NPK fertilizers used. Furthermore, it can be suggested that high value of soil pH which recorded in Table (1) might be cause a reduction in the availability of micronutrients in the root zone for cultivated plants.

Concerning the effect of fertigated NPK levels and interaction treatments, data in Table (7) reveal that increasing levels of fertigated NPK up to (150 kg NH_4NO_3 + 75 kg H_3PO_4 + 90 kg K_2SO_4 / plastic house) as single treatment or combined with preplanting NPK soil addition treatment in the two seasons increased significantly the concentrations of Fe, Zn and Mn in the fruits in both seasons, except total Mn concentration in the second season which showed no significant increase with treatments. Similar results were obtained by Moreno *et al* (1996) and Mohamed and Enzy (2001) on capsicum plants. In this respect, it can be suggested that increasing levels of fertigated NPK cause slightly positive effect on the concentrations of micronutrients in sweet pepper fruits, this might be attributed to using high levels of phosphoric acid through drip irrigation system, which cause slight decrease in soil pH and consequently increased the availability of micronutrients for cultivated plants.

Table (8): Nitrogen, phosphorus, potassium (mg/g d.w.), iron, zinc, manganese, lead and nickel (ppm) concentrations in the fruits of sweet pepper plant as affected by different levels of NPK during 1999-2000 and 2000-2001 seasons.

Season	1999-2000						2000 - 2001					
Chemical omposition	N			P			N			P		
Treatment	+ NPK	- NPK	Mean (B)	+ NPK	- NPK	Mean (B)	+ NPK	- NPK	Mean (B)	+ NPK	- NPK	Mean (B)
(Control) 1	9.9	9.3	9.6	2.82	2.68	2.75	10.8	9.6	10 2	2.76	2 70	2.73
2	11 8	10.1	11.0	2.95	2 89	2.92	12.9	11.0	12.0	2.82	2.74	2 78
3	14.0	12.8	13.4	3.15	3.12	3.14	14.6	13.5	14 1	3 28	3 20	3 24
4	14.3	13.4	13.9	3.87	3.82	3.85	15.5	14.2	14.9	3.75	3 62	3.69
5	16.5	14.8	15.7	3.93	3.95	3.94	17 4	15.9	16.7	4.00	3.85	3.93
Mean (A)	13.3	12.1		3.34	3.29		14.1	12.8		3 32	3.22	
L.S.D 0.05	A=1.03 B=1 63 A×B=2 30			A=N S. B=0 71 A×B=1.01			A=0 83 B= 1 31 A×B=1 86			A=N S B= 0 94 A×B=N S		
Chemical compositio	K			Fe			K			Fe		
(Control) 1	28.8	28.4	28.6	365	333	349	29.0	28.3	28.7	376	345	361
2	30.1	29.2	29.7	435	410	423	31.1	29.7	30.4	428	400	414
3	30.2	30.1	30.2	450	415	433	33 1	31.5	32.3	468	423	446
4	31.3	30 2	30.8	480	465	473	33.7	32.4	33.1	485	450	468
5	31.9	30 8	31.4	495	475	485	35.6	34.0	34.8	490	483	487
Mean (A)	30.5	29.8		445	420		32.5	31.2		449	420	
L.S.D 0.05	A= N S B=N S A×B=N S			A= 19 B= 31 A×B=43			A= N S B= 2.61 A×B=3 69			A= N.S B=75 A×B=106		
Chemical compositio	Zn			Mn			Zn			Mn		
(Control) 1	30	30	30	13	13	13	34	30	32	14	13	14
2	35	32	33	15	16	16	37	33	35	16	16	16
3	38	34	36	15	16	16	40	35	38	16	16	16
4	40	36	38	17	17	17	42	37	40	16	16	16
5	43	38	41	18	18	18	43	38	41	19	19	19
Mean (A)	37	34		16	16		39.2	34.6		16	16	
L.S.D 0.05	A= N.S. B= 8 43 ×B=11 92			A=N S. B= 3 1 A×B=4 4			A=N.S. B=7 01 A×B=9 92			A= N S. B=N.S. A×B=N.S.		
Chemical compositio	Pb			Ni			Pb			Ni		
(Control) 1	3.68	3.15	3.42	1.90	2.22	2.06	3.85	3.50	3.68	2.00	2.53	2.27
2	3.85	3.33	3.59	1.80	1.80	1.80	3.33	3.50	3.42	1.75	1.80	1 78
3	3.50	3.15	3.33	1.87	1.90	1.89	3.33	3.15	3.24	2.20	1.29	1.75
4	3.15	2.98	3.07	1.90	1.90	1.90	3.15	2.98	3.07	1.97	1.91	1.94
5	2.80	2.80	2.80	2.00	1.90	1.95	2.80	2.80	2.80	2.28	1.85	2.06
Mean (A)	3.40	3.08		1.89	1.94		3.29	3.19		2.04	1.87	
L.S.D 0.05	A=0.21 B=0.33 A×B=0 47			A=N.S B=N.S. A×B=N.S			A=N.S B=0.36 A×B=0.51			A=N.S. B=N S. A×B=N.S.		

Similar suggestion was reported by Ristimaki (1999). Moreover, Hanafy Ahmed *et al.* (2002 c) working on sweet pepper concluded that increasing levels of NPK could enhance the physiological functions of plant cell and in turn the uptake of these nutrients including micronutrients from the soil solution.

Concerning heavy metals, data in Table (8) indicate that the application of preplanting NPK soil addition, fertigation treatments and their interactions had no significant increase on the concentrations of Ni in sweet pepper fruit tissues in the two seasons. This may be induce as a result of the lower level of Ni in NPK mineral fertilizers. These results are in harmony with those reported by Hanafy Ahmed *et al.* (2002c) on sweet pepper plants. On the other hand, Ching Fang and KuoNan (1994) on sweet pepper found that application of NPK fertilizers showed higher increase in Ni concentration in fruits than expected but still below the acceptable maximum levels for human consumption. Furthermore, data in Table (8) reveal that the application of preplanting NPK soil addition had no significant effect on the concentration of Pb in sweet pepper fruits. However, concentration of Pb decreased significantly with increasing levels of fertigated NPK either alone or in combined with preplanting NPK soil addition. The highest values of Pb in the first season were obtained with (75 kg NH_4NO_3 + 37.5 kg H_3PO_4+ 45 kg K_2SO_4 /plastic house) and with (50 kg NH_4NO_3 + 25 kg H_3PO_4 + 30 kg K_2SO_4 /plastic house ,control) in the second one. In this respect, it can be suggested that negative relationship could be detected between increasing levels of fertigated NPK and concentration of Pb in the fruits of sweet pepper plants. Similar suggestion was reported by Gaweda (1996) on radish and spinach plants. On the contrary, Uher (1995) working on carrot plants found that increasing the applications of N fertilizers increased significantly concentration of Pb, and the shoots showed excessive Pb contents.

Therefore, it is important here to mentioned that, although by increasing the applications of NPK fertilizer, the concentrations of heavy metals in sweet pepper fruit still less than the critical limits permitted to be found in normal plants or human consumption. These results were confirmed by Abd-El-Maksoud (1993) who reported that the toxicity limits of Pb were 200 ppm in plant and 0.6 ppm/ kg for human body. In addition, Kabata-Pendias and Pendias (1984) reported that the normal range of Ni and Pb was between 0.02-5.0 ppm in plants. In this respect, it can be concluded that, all values of Ni concentration in the fruits of sweet pepper plants were under the normal range.

5-Nitrate accumulation

As regard nitrate concentration, data in Table (7) indicate that application of preplanting NPK soil addition showed no significant differences on the concentration of nitrate accumulation in sweet pepper fruits in the two successive seasons compared with untreated plants. This might be attributed to the little amounts of preplanting NPK soil addition fertilizer which caused low NO_3 concentration in the soil. Similar results were obtained by Stopes *et al.* (1989) in lettuce. On the other hand, Hanafy Ahmed *et al.* (2002 c) working on sweet pepper, mentioned that increasing NPK fertilizers increased significantly nitrate concentration in fruit tissues.

Concerning the effect of NPK fertigation levels on the concentration of nitrate accumulation in sweet pepper fruits, data in Table (7) show significant increase by increasing levels of fertigated NPK up to (150 kg NH_4NO_3 + 75 kg H_3PO_4 + 90 kg K_2SO_4 /plastic house) either alone or in combined with preplanting NPK soil addition. Similar results were obtained by Fontes *et al.* (2000) on tomato. The highest concentration of nitrate accumulation in fruits of sweet pepper plants in both seasons was obtained by the plants supplied with NPK soil addition before transplanting combined with the highest fertigation level (150 kg NH_4NO_3 + 75 kg H_3PO_4 + 90 kg K_2SO_4 /plastic house) followed by the plants supplied with the lower NPK fertigation levels. Generally, it is clear from the data that the rate of nitrate accumulation in sweet pepper fruits is influenced by the dose of NPK application in all treatments. In this respect, Ruiz *et al.* (2000) and Hanafy

Ahmed *et al.* (2002 b and c) pointed out that N supply was one of the most important factor affecting nitrate accumulation in growing plants. These results strongly confirmed the suggestion that several plant species accumulate NO_3 as a result of an excess of N uptake over reduction. Rufty *et al.* (1982) reported that NO_3 is believed to accumulate in a storage pool, presumably in the vacuoles, from which it is not readily available. However, it is important here to mentioned that increasing total nitrogen concentration in fruits of sweet pepper is not necessarily accompanied by increasing nitrate accumulation in the plant. This might be due to the utilization and conversion of nitrogen from the simple form such as nitrate to more complicated one such as proteins and amino acids. Similar suggestion was reported by Hanafy Ahmed (1996) on lettuce plants. However, concerning the effect of phosphorus fertilizer on nitrate accumulation, Barker and Maynard (1971) and Maynard *et al.* (1976) mentioned that phosphate was found to have no or only little effect on the nitrate accumulation. In this respect, Korschunow (1988) on potato, Gao *et al.* (1989) on Chinese cabbage and spinach and Hanafy Ahmed *et al.* (2002a) on rocket plants, indicate that high P concentration inhibit nitrate reductase activity and is accompanied by less nitrate uptake and accumulation .Moreover, many investigators showed that increasing potassium fertilizer level reduced nitrate accumulation in many vegetables (Ni Wu Zhong *et al.*, 1997; Xiu Fengo and Ito, 1998 and Hanafy Ahmed *et al.*, 2002 a). This may may be due to the highest input of photosynthetic products to non-structural osmotic compounds in the vacuole (Matile, 1987) and to the role played by K in osmotic adjustment (Barlow, 1983). On the other hand, Ruiz *et al.* (2000) mentioned that applying the highest rates of N and K led to increase in the absorption and translocation of nitrate to the shoot in capsicum plants. In addition, it can be suggested that increasing the application of potassium sulphate (as a source of sulphate ions) fertilizer might be decreased nitrate accumulation in fruits of sweet pepper as a result of increasing sulphate ions in rhizosphere soil. Similar results and suggestions were obtained by Hanafy Ahmed *et al.* (1997) on jew's mallow and radish plants. In this respect, Maynard *et al.* (1976) reported that sulphur deficiency increased nitrate contents of vegetables. Also, Blom-Zandstra and Lampe (1983) found a negative correlation between nitrate content and the presence of sulphate. Furthermore, from the previous suggestion it can be assumed that using potassium sulphate might decrease pH value of the soil due to increasing sulphur ions which might be increasing the availablility of micronutrients in soil solution. In this connection, Hanafy Ahmed *et al.* (1997 and 2002 a) suggested that there was a negative relationship between micronutrients and nitrate accumulation in jew's mallow, radish and rocket plants. This effect may be due to the role played by these micronutients on nitrate reductase (NR) and nitrite reductase (NiR) activity. In this respect, Crawford and Campbell (1990) reported that nitrate was first transported into the cell and then reduced to ammonium by the consecutive action of two enzymes: NR and NiR. Both enzymes are metalloenzymes that require cofactors: a molybdenum-protein cofactor (MoCo) for NR and an iron-containing hydrochlorin (siroheme) for NiR. Moreover, Mengel and Kirkby (1978) mentioned that manganese is essential in photosystem II and hence in the flow of electrons from water *via* ferredoxin to NiR. Amberger (1979) reported that in zinc deficient plants, an increase in ribonuclease activity and an accumulation of nitrate has been found, indicating that this element is implicated also in nitrate reduction. Concerning total sugar concentrations data in Table (7) indicate that application of preplanting NPK soil addition showed no significant increase in total sugar concentrations in the fruits of sweet pepper plants in the first season , While, in the second one, the data indicate significant increase in concentrations of total sugar by untreated plants. Similar results were obtained by Kocevski *et al.* (1995) on capsicum and Hanafy Ahmed *et al.* (1997)on jew's mallow and radish. Moreover, data in Table (7) data showed that, in the two successive seasons, the total sugar concentrations in the fruits of sweet pepper plants decreased significantly by increasing levels of fertigated NPK either alone or in combined with preplanting NPK soil addition up to (150 kg NH_4NO_3 + 75 kg H_3PO_4 + 90 kg K_2SO_4 /plastic house). In this respect, it can be suggested that there is a negative relationship between increasing NPK fertilizers level and total sugar concentrations. Similar results were obtained by Hanafy Ahmed *et al.* (1997) on jew's mallow and radish plants and Hanafy Ahmed *et al.* (2002 a and c) on sweet pepper and rocket plants, respectively. Furthermore, it is important here to mention that, increasing the level of NPK fertilization increased both fresh and dry weights of sweet pepper plants. Therefore, these decreases in total sugar concentrations which were concomitantance with increases in the fresh and dry weights of sweet pepper plants may be due to that the plants used most of carbon in structural growth, but incorporated relatively less carbon in soluble organic compounds. Similar results and suggestions were obtained by Hanafy Ahmed *et al.* (2002 b) working on lettuce plants. In this respect, it can be suggested that, nitrate accumulation might be increased in the vacuoles to compensate the shortage of sugars. So, it can be concluded that NO_3 accumulation was inversely related to accumulation of sugars. Similar findings were reported by Blom-Zandstra and Lampe (1985) and Hanafy Ahmed (1996) on lettuce, Hanafy Ahmed *et al.* (1997) on jew's mallow and radish as well as Hanafy Ahmed *et al.* (2002 a, b and c) on rocket, lettuce and sweet pepper, respectively. In this respect, Blom-Zandstra *et al.* (1988) mentioned that the lettuce genotype, which had higher nitrate concentration, had also lower concentration of sugars and organic compounds. In addition, the increases in the concentration of total sugar under the lower rates of NPK fertilization may also be explained on the assumption that, as already known, the nitrate accumulation in the vacuoles is not readily available. However, when the nitrogen fertilizer amount was reduced, the nitrate might remove from the vacuoles to sustain the protein synthesis and the plant will store sugars and organic acids to compensate for the declining osmotic value. This suggestion is in a good agreement with that of Blom-Zandstra (1989). Furthermore, another suggestion could be put forward to explain the role played by potassium in enhancing sugars formation and at the same time nitrate assimilation. It is known that, carbohydrates can be stored as organic acids and sugars in the vacuoles; the main component of the organic acids appears to be malate. An inverse relationship was found between nitrate and malate accumulation (Purvis *et* *al.*, 1974 and Neyra and Hageman, 1976). Moreover, Ben Zioni *et al.* (1971) reported that the synthesis of malate in the plant leaves proceeds concomitantly with nitrate reduction and the malate is transferred to the roots balanced by K^+. Generally, it can be concluded that increasing level of NPK mineral fertilizer application increased nitrate accumulation but decreased the total sugar concentrations in fruits of sweet pepper plants.

Finally, it is important here to mention that, although the increase in NPK fertigation levels for sweet pepper plants are required to increase fruit production, the concentration of nitrate accumulation in sweet pepper fruits still less than the critical limits permitted to be found in normal plants or human consumption.

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تأثير المستويات المختلفة من الأسمدة النيتروجينية والفوسفاتية والبوتاسية المضافة مع ماء الرى بالتنقيط على النمو والمحصول وتراكم النترات فى نباتات الفلفل الحلو النامية فى الصوب البلاستيكية.

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أجريت التجربة داخل الصوبة البلاستيكية بمزرعة قسم الخضر - كلية الزراعة جامعة القاهرة - خلال الموسمين المتتالين ١٩٩٩-٢٠٠٠ و٢٠٠٠-٢٠٠١ حيث تمت زراعة الفلفل الحلو صنف برايو فى ثلاثة مكررات باستخدام تصميم القطع المنشقة ، حيث اشتملت القطع الرئيسية على معاملتين إضافة أو عدم إضافة الأسمدة المعدنية الأساسية NPK الموصى بها قبل الزراعة. أما القطع المنشقة فقد اشتملت على خمس معاملات سمادية NPK أضيفت على دفعات طوال موسم النمو مع ماء الرى بالتنقيط. و كان الغرض من التجربة هو دراسة تأثير المعاملات السمادية المختلفة على النمو والمحتوى الكيماوي والجودة لثمار الفلفل الحلو داخل الصوبه الزراعية وكذلك دراسة تأثير مستويات الأسمدة المعدنية المستخدمة على التلوث البيئى الناشىء عن زيادة بعض العناصر الثقيلة أو تراكم النترات فى الثمار. وقد سجلت التجربة بصفة عامة زيادة معنوية فى صفات ارتفاع النبات والمساحة الكلية للأوراق فى مراحل النمو المختلفة بزيادة مستويات التسميد المعدنى مع ماء الرى بالتنقيط وخاصة المستوى التسميدى الثالث (١٠٠ كجم نترات أمونيوم +٥٠ كجم حامض فوسفوريك + ٦٠كجم سلفات بوتاسيوم/صوبة ٥٤٠م٢) أما بالنسبة لصفة عدد الأوراق والوزن الجاف للجذور والسيقان والأوراق فقد أظهرت أعلى معنوية مع المستوى التسميدى الخامس (١٥٠ كجم نترات أمونيوم +٧٥ كجم حامض فوسفوريك + ٩٠ كجم سلفات بوتاسيوم/صوبة) فى حين أظهر المحصول الكلى والمبكر اعلى زيادة معنوية مع المستوى التسميدى الثالث فى كلا الموسمين باستثناء المحصول المبكر فى الموسم الثانى حيث لم تصل الزيادة الى درجة المعنوية . وقد سجل محتوى الأوراق من العناصر المعدنية أعلى زيادة معنوية من النتروجين و الحديد فى كلا الموسمين مع المستوى التسميدى الخامس ، كذلك زاد تركيز عنصر الرصاص معنويا داخل الأوراق مع المعاملة بالإضافة الأرضية من السماد من السماد المعدنى الأساسى قبل الزراعة والمستوى التسميدى الخامس مع ماء الرى بالتنقيط ، بينما لم يسجل عنصر النيكل اتجاه ثابت للزيادة المعنوية خلال الموسمين . أما بالنسبة لصفات الجودة للثمار فقد سجلت النتائج عدم وجود زيادة معنوية لصفة طول وعرض وحجم الثمره وكذلك تركيز حامض الاسكوربيك مع المعاملات السمادية المختلفة خلال الموسمين. بينما زادت الحموضة الكلية والمواد الصلبة الذائبة الكلية معنوياً داخل الثمار مع زيادة معدلات التسميد المعدنى مع ماء الرى بالتنقيط خلال الموسمين . وقد سجلت الإضافة الأرضية من السماد المعدنى الأساسى قبل الزراعة والمعاملة التسميدية الخامسة أعلى زيادة معنوية من تركيزات النيتروجين و الفوسفور و البوتاسيوم والحديد و الزنك داخل أنسجة الثمار فى الموسمين مقارنة بباقى المعاملات. وقد سجلت الإضافة الأرضية من السماد المعدنى الأساسى قبل الزراعة مع المعاملة التسميدية الخامسة اقل انخفاض معنوى من عنصر الرصاص بينما لم يسجل النيكل داخل الثمار في الموسمين فروق معنوية نتيجة المعاملات . فى حين سجلت النترات أعلى زيادة معنوية داخل الثمار بزيادة معدلات التسميد المعدنى مع ماء الرى بالتنقيط وكانت أعلى هذه الزيادات مع المستوى التسميدى الخامس ، فى حين انخفض تركيز السكريات الكلية بزيادة مستويات التسميد مع ماء الرى بالتنقيط . وفى جميع المعاملات لم تصل تركيزات الرصاص او النترات داخل انسجة الثمار الى الحدود السامة للأنسان.