Current Science International Volume : 06 | Issue : 02| April-June|2017
ISSN 2077-4435 Pages: 445-457

Growth, yield and nutritional quality of sweet pepper plants as affected by potassium and phosphate fertilizers varying in source and solubility

Amira M. Hegazi[1], Amal M. El-Shraiy[1] and Ghoname A. A.[2]

[1] *Agric. Botany Department, Faculty of Agriculture, Ain Shams Univ., Cairo, Egypt*
[2] *Vegetable Research Department, National Research Center, Dokki, Cairo, Egypt*

Received: 08 February 2017 / Accepted: 14 May 2017 / Publication Date: 28 June 2017

ABSTRACT

The effects of phosphorus fertilization and foliar potassium on plant growth and fruit quality of sweet pepper plants were evaluated at a private farm located in Khatatba, Giza, Egypt, during two successive seasons (2014 and 2015) to investigated the impact of different sources of phosphate monoammonium phosphate (MAP), monopotassium phosphate (MKP), urea phosphate (UP) and calcium superphosphate (SP)) and foliar application of potassium as K_2O (0, 100 and 200 ppm) on growth, nutrient content, photosynthetic pigments, ascorbic acid, total acidity, protein and fruit yield of sweet pepper plants (*Capsicum annuum* L.) cv. Gedeon,. The results showed that growth of pepper plants were affected according to the source of phosphate, application of MKP recorded the highest values of plant height, number of leaves and branches, plant fresh and dry weights as well as plant yield, meanwhile MAP gave remarkable improvement of plant growth and fruits characters as compared to control (adding SP). Application of UP recorded the least effectiveness on plant growth and yield parameters compared with SP as phosphorus source. An increase in photosynthetic pigments and minerals nutrition (N, P, K and Ca %) was recorded parallel to the increase of phosphorus availability (with MAP and MKP application). Foliar spray of K showed an enhancement of fruits number and weight, as well as total acidity and vitamin C concentrations. Therefore, an adequate management of fertilization with P and additive amounts of foliar K could improve yield and fruit quality of pepper plants as a result of stimulation of growth, and amelioration of some biochemical analysis

Key words: phosphate fertilizers, monoammonium phosphate (MAP), urea phosphate (UP), monopotassium phosphate (MKP), potassium fertilizers, pepper and yield

Introduction

Bell pepper (*Capsicum annuum* L.) plant cultivated in almost all parts of the world as an important fruit vegetable. It has occupied an essential rank in Egyptian agriculture due to its high income and nutritional values for human health (Ghoname *et al*. 2010). Pepper is a respectable source of numerous antioxidant compounds. For example, pepper fruits contain more than 20 different carotenoids, abundant phenolic compounds (including flavonoids) and vitamin C (Igbokwe *et al*, 2013 and Deepa *et al*, 2006). So, eating of one medium-size pepper provides double the daily requirement of vitamin C (Hasler, 1998).

Phosphorus (P) is an essential macronutrient that can limit normal plant as it constitutes about 0.2% of plant dry weight (Schachtman *et al.*, 1998). Phosphorus is considered as an integral part of the cellular activities of living organisms and contributes to several vital functions in the plant, such as early root and seedling growth, improving winter hardiness, promotion of early heading and uniform maturity, increasing seed formation and quality, and increasing water-use efficiency. Moreover, it is involved in many plant functions, including storage and transfer of energy, cell division, photosynthesis, transformation of sugars and starches, regulation of some enzymes, nutrient transport within the plant, transport of carbohydrates, and transfer of genetic characteristics from one generation to another (Taiz *et al.*, 2015). Deficiency of phosphorus affects not only plant growth and development and crop yield, but also the fruit quality and the seeds formation (Njira and Nabwami, 2015). Effectiveness and availability of phosphorus to plants depends on many factors like pH,

Corresponding Author: Amira M. Hegazi, Agric. Botany Department, Faculty of Agriculture, Ain Shams Univ., Cairo, Egypt. E-mail: amirahegazi@yahoo.com

physicochemical properties of the soil, dominant climate and soil content of organic matter and sources of P fertilizer (Gupta *et al.*, 1985; El-Bassiouny *et al.,* 2012).

In Egypt, superphosphates and rock phosphate considered the main sources of P used for agricultural production for a long time but recently other alternative fertilizers of P became available such as monopotassium phosphate (MKP), monoammonium phosphate (MAP), and urea phosphate (UP) which can be used to manage P fertilization especially during production of short life vegetables such as snap bean (El-Bassiouny *et al.,* 2012). These sources present distinct solubility traits and nowadays are popular in several countries due to their high P nutrient content and its excellent physical properties (Chien *et al.*, 2009; (Rosen and Spiegelman, 2014).

The use of UP as high soluble P fertilizer is essential to overcome the precipitation problem associated with common triple super phosphate (TSP) especially if drip irrigation system is used since TSP precipitate in the irrigation line and clog the apertures. Moreover, using UP through drip lines aid in acidifying the soil (reduced about 0.5 unit), and increased available P levels around the drip apertures. Due to high P mobility in the 20 cm around emitters, it is recommended to split UP application to provide the longest residual and best distribution of available P in a calcareous soil. (Rubeiz *et al.*, 1991). On the other hand using MAP as a source of P increased canola growth when compared to triple superphosphate (TSP) (Thomas and Rengel, 2002). Furthermore, fruit weight and number of flowers and fruits correlated positively with the increase of potassium rates. Potassium fertilization has been associated with increased plant growth and yield, fruit quality. About, two-thirds of the K uptake is allocated to fruits (Hidetoshi, 2007). Potassium also increases production of beneficial compounds such as protein, lycopene, ascorbic acid, total soluble solids, titratable acidity, but reduces sugar levels (Si-Smail *et al*., 2007; (Almeselmani, 2010). It was also shown to reduce the internal white tissues and increase the redness of fruits, thus reducing the incidence of yellow shoulder in tomato fruits (Gunter, 2010). Finally, it was shown to have a positive impact on the number of stems per plant, stem diameter, and plant height (Si-Smail *et al*., 2007). Potassium may also affect capsaicin accumulation, via its positive effects on fruit development (Oka *et al.*, 2004) and (Leal-Fernández *et al.*, 2013). (Zhang *et al.*, 2009) found that both green fruit and blossom-end rot fruit yield decreased with increasing application of K fertilizer.

Materials and Methods

Plant Material

The study was conducted as field experiment to evaluate the effect of different phosphorus sources (monoammonium phosphate (MAP), monopotassium phosphate (MKP), urea phosphate (UP) and calcium superphosphate (CSP) as control in combination with potassium foliar application at (0, 2 and 4 ml/ L of liquid potassium (37.5% K_2O, Kafr El Zayat Pesticides & Chemicals Co., Egypt) on growth and productivity of bell pepper (*Capcicum annum* L.) cv. Gedeon during 2014 and 2015 seasons at a private farm located in Khatatba, Giza, Egypt. In both seasons, seedlings were transplanted on 2nd week of March in a sandy soil field (sand physical properties was 89.4% sand, 6.9% silt, and 3.7% clay with a pH of 7.8, EC of 1.68 dS/m). The normal agricultural practices were used for the sweet pepper production, i.e. irrigation, fertilization (except for P sources), diseases and pest control were followed according to the recommendation of the Egyptian Ministry of Agriculture.

Treatments

The experiment tested the effect of four P-sources (Monoammonium phosphate (MAP; 12 N - 61 P -0 K); Monopotassium phosphate (MKP; 0 N -52 P -34 K); Urea phosphate (UP; 17 N -44 P -0 K); Calcium superphosphate (SP; 15% P_2O_5) in combination with three potassium foliar applications at (0, 100 and 200 ppm of potassium oxide) started at one month after transplanting with 2 week-intervals (the amount of solution sprayed for each treatment was 200 ml/m^2).

All plants received their phosphorus needs in equal amounts (125 kg P_2O_5/ha). The total quantity of calcium superphosphate was added one time before transplanting, while MAP, MKP, and UP were added in two equal portions at 15 and 30 days after transplanting with irrigation water. The amounts of N, K and Ca in the different fertilizers were subtracted from the total amounts needed; thus the final amounts of these elements were equal in all treatments.

Data Recorded

Vegetative growth parameters

Five plants were chosen randomly from each sub-plot at 90 days after transplanting and transferred to laboratory to record the following data: (plant height (cm); number of leaves and branches per plant, plant fresh and dry weight).

Fruit yield and yield component:

The fruits were harvested five times when having attained full size for fresh use. Total number of fruits per plant and total fruit yield per plant (g/plant) were also recorded.

Chemical content:

a- Determination of vitamin C

Fruit samples were randomly taken at harvesting time to determine vitamin C (ascorbic acid) content in the fruit as mg per 100g fresh weight and total acidity by (hand Refractometer) according to method described by A.O.A.C. (1990).

b- Determination of photosynthetic plant pigments

Carotenoids, chlorophyll a, b and total chlorophyll concentrations in fully expanded leaves were measured three times at 30, 60 and 90 days after transplanting
Also, carotenoids and total chlorophyll concentrations in pepper fruits were measured three times at 30, 60 and 90 days after transplanting. Chlorophylls and carotenoids were extracted using 10 ml N, N dimethyl formamide according to the method of Moran, 1982. Formulae and coefficients used for the determination of chlorophylls were described by Lichtenthaler and Wellburn, (1983) the carotenoids were determined spectrophotometrically at 470 nm (CT 200 spectrophotometer) using the formula of (Shlyk, 1971)The data was expressed as mg/g fresh weight.

c- Determination of protein

Bovine serum albumin V was used as a standard to determine protein concentration in both leaves and fruits extracts according to the method proposed by Bradford (1976).

d- Determination of mineral nutrients

Leaf and fruits samples were oven dried at 68°C for 72 hours, then fine grinded and used to determine mineral contents on a dry weight basis. Total nitrogen and phosphorus contents were determined using Kieldahl method and colorimetric method using spectrophotometer (SPECTRONIC 20D, Milton Roy Co. Ltd., USA), respectively, according to the procedure described by Cottenie, (1980). Potassium content was measured using flame photometer method (JENWAY, PFP-7, ELE Instrument Co. Ltd., UK) as described by Chapman and Pratt, (1982)Calcium was measured with atomic absorption spectrophotometer (FAO, 1980.).

Experimental design and statistical analysis

The experiment was arranged in a split plot design with four replicates, where phosphorus fertilization sources were arranged randomly within the main plots, while potassium foliar application treatments were distributed in the subplots. Treatments were statistically analyzed and means separation was carried out using Least Significant Difference (LSD) at $P < 0.05$ according to the method described by Gomez and Gomez (1984). The determination of bio-chemical compounds and nutrient elements was carried out in the first experimental season.

Results and Discussion

Phosphorus is a common component of organic compounds in plants, that phosphorus deficiency significantly reduced plant growth (Marschner, 1997). (Rai, 1984)reported an increase in the leaves protein content of maize in response to phosphorus application. Potassium is one of the major macronutrients, contributing up to 6% of plant dry weight (Shabala, 2003) and it is considered to be a key factor for fruit quality ((Hartz *et al.*, 2005)). The findings about the influence of K on pepper fruit quality are related to nutritional quality (Flores *et al.*, 2004). Responses of pepper plants to the application of different P sources and foliar K on plant growth, biochemical changes and yield components were studied.

Effect of Different phosphorus sources and sprayed potassium on:

I- Vegetative growth and yield characters:

Data presented in Table 1 revealed that vegetative growth parameters were affected by the phosphorus sources, as application of monoammonium phosphate (MAP) significantly gave the highest values of evaluated vegetative parameters, e.g. plant height, number of leaves and branches per plant, fresh and dry weights of plant, this enhancement of growth increased gradually with the increase of the concentration of sprayed K. Meanwhile, urea phosphate (UP) gave the lowest values of untraditional sources of phosphate compared with calcium super phosphate (SP). There was partly an identical effect of monopotassium phosphate (MPK) on these growth attributes with monoammonium phosphate. Phosphorus involved in several key plant functions, including cell division, storage and transfer of energy, photosynthesis, regulation of some enzymes, transformation of sugars and starches, nutrient transport within the plant, transport of carbohydrates, and transfer of genetic characteristics from one generation to another (Taiz *et al.*, 2015). Increasing the availability of P led to growth improvement and consequently the yield properties as number of fruits, fruits fresh weight, fruit length and fruit diameter (Table 2). Potassium is not a component of any plant compounds or structures, but it acting as a part in many important regulatory roles in the plant, i.e. osmo-regulation process, regulation of plant stomata and water use, translocation of sugars and formation of carbohydrates, energy status of the plant, the regulation of enzyme activities, protein synthesis and many other processes needed to sustain plant growth and reproduction (Hsiao and Lauchli, 1986). Fruit yield, fruit number per plant, fruit length, fruit diameter and moisture percent of pepper responded positively and significantly to increasing phosphorous availability and potassium concentration; but they had no significant effect on moisture percent of fruit. The lowest fruit yield and fruit number per plant were obtained with SP as a source of phosphorus whereas the highest was obtained with MAP and MKP (Table 2). Generally in this study increasing P availability increased fruit yield, and yield components. This result is in agreement with observation of (Baghour *et al.*, 2001)who reported that vegetative growth yield and quality of pepper significantly improved through phosphorous fertilization. This could be attributed to the important role of this nutrient affecting growth and yield. Regarding fruit moisture, it is obvious that it reduced as affecting with K concentration which led to long shelf life for pepper fruits, as potassium enhanced translocation of sugars and formation of carbohydrates, protein synthesis and many other processes needed to sustain plant growth and reproduction (Hsiao and Lauchli, 1986).

Table 1: Effect of phosphorus sources and sprayed potassium on some vegetative characters of sweet pepper plants (combined analysis of 2014 and 2015 seasons).

Phosphorus source (T)	Potassium conc. (K) ppm	plant length (cm)	No. of leaves	No. of branches	plant FW (g)	plant DW (g)	Mean
		1st Season					
SP (control)	K0	32.00	77	3	333.21	158.61	120.76
	K100	35.20	84.70	3.30	366.53	174.47	132.84
	K200	41.60	92.40	3.90	402.36	190.33	146.12
	Mean	36.27	84.70	3.40	367.37	174.47	
MAP	K0	46.00	136	5	883.64	237.81	261.69
	K100	49.00	157	6	905.61	345.52	292.63
	K200	55.00	166	6	987.68	388.62	320.66
	Mean	50.00	153.00	5.67	925.64	323.98	
MKP	K0	35.00	91	4	580.08	211.91	184.40
	K100	39.00	104	5	692.51	242.31	216.56
	K200	43.00	112	5	866.13	258.51	256.93
	Mean	39.00	102.33	4.67	712.91	237.58	
UP	K0	33.00	80	4	317.13	176.16	122.06
	K100	37.00	86	4	319.81	178.94	125.15
	K200	41.00	96	4	320.65	188.21	129.97
	Mean	37.00	87.33	4.00	319.20	181.10	
	LSD0.5% K	1.39	2.69	1.03	3.12	1.06	
	LSD0.5% T	0.95	1.12	1.06	2.13	1.01	
	LSD 0.5% K*T	0.74	0.94	0.47	1.06	0.09	
		2nd season					
SP (control)	K0	38.40	85	3	345.97	174.47	129.37
	K100	42.24	93.17	3.63	371.03	191.92	140.40
	K200	49.92	101.64	4.29	389.74	209.37	150.99
	Mean	43.52	93.17	3.74	368.91	191.92	
MAP	K0	55.20	150	6	795.28	213.61	243.94
	K100	58.80	173	7	815.05	327.94	276.34
	K200	66.00	183	7	888.91	349.12	298.77
	Mean	60.00	168.31	6.80	833.08	296.89	
MKP	K0	42.00	100	5	538.94	233.10	183.79
	K100	46.80	114	6	761.76	266.54	239.11
	K200	51.60	123	6	779.52	284.36	248.94
	Mean	46.80	112.59	5.60	693.41	261.33	
UP	K0	39.60	88	5	348.84	158.54	127.96
	K100	44.40	95	5	351.79	161.05	131.33
	K200	49.20	106	5	352.72	169.39	136.34
	Mean	44.40	96.08	4.80	351.12	162.99	
	LSD0.5% K	1.13	2.45	1.01	2.98	1.04	
	LSD0.5% T	0.88	1.09	1.01	2.11	1.01	
	LSD 0.5% K*T	0.64	0.88	0.33	1.01	0.05	

Table 2: Effect of phosphorus sources and sprayed potassium on fruit yield components of sweet pepper plants (combined analysis of 2014 and 2015 seasons).

phosphorus sources (T)	Potassium conc. (K) ppm	No. of Fruits/plant	Fruits FW /plant (g)	Fruit Length (cm)	Fruit Diameter (cm)	Total Fruit Moisture (%)	Mean
SP (control)	K0	49	2450	6.98	3.65	90.12	519.53
	K100	54	2700	7.68	3.97	89.78	571.09
	K200	61	3050	8.98	4.01	88.02	642.82
	Mean	54.67	2733.33	7.88	3.88	89.31	
MAP	K0	104	5200	9.75	5.96	92.34	1081.73
	K100	108	5400	10.78	6.54	91.45	1123.35
	K200	129	6450	11.67	6.92	88.95	1337.99
	Mean	113.67	5683.33	10.73	6.47	90.91	
MKP	K0	90	4500	8.14	4.98	91.45	938.38
	K100	95	4750	8.74	5.12	89.74	989.72
	K200	101	5050	9.89	5.87	88.76	1051.64
	Mean	95.33	4766.67	8.92	5.32	89.98	
UP	K0	66	3300	7.12	4.98	90.34	693.20
	K100	75	3750	7.98	5.25	88.94	785.43
	K200	88	4400	8.11	5.77	87.89	918.44
	Mean	76.33	3816.67	7.74	5.33	89.06	
	LSD0.5% K	3.87	5.98	1.08	NS	2.34	
	LSD0.5% T	4.87	6.13	1.11	NS	2.65	
	LSD 0.5% K*T	2.08	3.98	0.86	NS	1.77	

II- Chemical composition

Photosynthetic pigments

Data in Table 3 and 4 illustrated the effect of different phosphorus sources and sprayed potassium on chl a, chl b, total chl and carotenoids in leaves and fruits respectively of sweet pepper plants after 30, 60 and 90 days. Table 3 and 4 showed that sweet pepper plants fertilized with MAP significantly increased chl a, chl b, total chlorophyll and carotenoids concentrations in plant leaves and total chlorophyll and carotenoids in fruits over all other treatments followed by MPK and finally UP as compared with SP. These results obtained that the availability of phosphorus affected the chlorophylls and carotenoids concentrations in both leaves and fruits of pepper plant. On the other hand, plants sprayed with high level of K (200 ppm) showed a remarkable improvement of plant photosynthetic pigments as compared with the other levels (0 and 100 ppm). Plants fertilized with MAP in combination with three levels of potassium indicated that carotenoids and total chlorophyll increased with increasing potassium levels as compared with control plants. Increasing potassium sprayed rates from 0 to 200 ppm significantly increased all chemical composition, i.e. total chlorophyll, N, P and K in leaves and vitamin C content in fruits. In general, the highest and lowest values of measured chemical composition of sweet pepper plants were recorded by plants which received 100 and 200 ppm. These results may be due to the role of potassium in plant metabolism and many important regulatory processes in the plant. Also, it could be increased mineral uptake by plants (Hsiao and Läuchli, 1986 and Marschner, 1995). Results also revealed that photosynthetic pigments concentration increasing at 60 days from planting, this increase was remarkable with plants received MAP or MKP with 200 ppm K then 100 ppm. On the contrary, photosynthetic pigments degradation after 90 days were obvious when plants received SP and without K spraying (0 ppm K).

Table 3: Effect of phosphorus sources and sprayed potassium on photosynthetic pigments in leaves of sweet pepper plants

phosphorus sources (T)	Potassium conc. ppm (K)	Chl a (mg/g FW)	Chlb (mg/g FW)	Cart (mg/g FW)	T Chl (mg/g FW)	Mean	Chl a (mg/g FW)	Chl b mg/g FW)	Cart. (mg/g FW)	T Chl (mg/g FW)	Mean	Chl a (mg/g FW)	Chl b (mg/g FW)	Cart (mg/g FW)	T Chl (mg/g FW)	Mean
		30 days					60 days					90 days				
SP (control)	K0	1.78	0.95	1.90	7.06	2.92	4.10	1.08	2.94	7.63	3.94	1.81	0.37	2.56	3.01	1.94
	K100	2.31	1.23	2.47	9.18	3.80	5.34	1.36	3.83	9.91	5.11	2.15	0.49	3.33	3.92	2.47
	K200	2.67	1.42	2.85	10.59	4.38	6.16	1.45	4.42	11.44	5.87	2.35	0.56	3.84	4.52	2.82
	Mean	2.25	1.20	2.40	8.94		5.20	1.30	3.73	9.66		2.10	0.47	3.24	3.82	
MAP	K0	7.57	1.68	9.55	15.81	8.65	8.69	2.42	10.64	24.57	11.58	7.25	2.60	10.84	16.36	9.26
	K100	8.35	2.00	11.98	17.63	9.99	8.95	2.65	12.09	25.88	12.39	8.96	3.36	11.64	17.68	10.41
	K200	9.32	2.50	13.70	19.30	11.21	9.72	2.94	13.87	27.92	13.61	10.12	5.84	12.64	18.04	11.66
	Mean	8.41	2.06	11.74	17.58		9.12	2.67	12.20	26.12		8.78	3.93	11.71	17.36	
MKP	K0	7.32	1.66	4.98	13.48	6.86	6.16	1.89	5.59	15.88	7.38	6.04	1.44	5.13	13.39	6.50
	K100	7.88	1.74	5.12	14.35	7.27	7.70	2.54	7.14	21.99	9.84	6.99	1.56	6.65	14.62	7.45
	K200	8.57	1.87	8.79	16.54	8.94	8.48	2.88	9.40	23.14	10.97	7.23	1.77	8.02	15.70	8.18
	Mean	7.92	1.76	6.30	14.79		7.45	2.44	7.38	20.34		6.75	1.59	6.60	14.57	
UP	K0	7.32	1.54	4.49	12.48	6.46	6.01	1.68	5.34	16.72	7.44	4.65	1.93	3.98	12.61	5.79
	K100	7.79	1.60	5.06	13.20	6.91	6.04	1.79	7.01	18.63	8.37	5.97	1.73	4.17	13.97	6.46
	K200	7.88	1.70	7.79	14.56	7.98	7.60	2.12	7.51	21.14	9.59	6.47	1.32	6.50	14.78	7.27
	Mean	7.67	1.61	5.78	13.41		6.55	1.86	6.62	18.83		5.70	1.66	4.89	13.79	
	LSD0.5% K	0.12	0.235	0.87	0.89		0.15	0.238	0.98	1.01		0.09	0.21	0.75	0.97	
	LSD0.5% T	0.65	0.54	1.31	1.45		0.77	0.64	1.55	1.67		0.65	0.51	1.32	1.64	
	LSD 0.5% K*T	0.24	0.31	0.58	0.64		0.35	0.45	0.68	0.98		0.29	0.31	0.59	0.84	

Table 4: Effect of phosphorus sources and sprayed potassium on photosynthetic pigments in fruits of sweet pepper plants.

hosphorus sources (T)	Potassium conc. ppm (K)	Cart (mg/g FW)	T Chl (mg/g FW)	Mean	Cart (mg/g FW)	T Chl (mg/g FW)	Mean	Cart (mg/g FW)	T Chl (mg/g FW)	Mean
		30 days			60 days			90 days		
SP (control)	K0	1.33	8.47	2.45	2.06	9.15	2.80	2.68	11.90	3.64
	K100	1.73	11.01	3.19	2.68	11.90	3.64	3.48	15.47	4.74
	K200	1.99	12.71	3.68	3.09	13.73	4.20	4.02	17.84	5.47
	Mean	1.68	10.73		2.61	11.59		3.39	15.07	
MAP	K0	7.46	18.97	6.61	6.29	27.03	8.33	7.84	32.12	9.99
	K100	8.46	21.15	7.40	8.87	28.47	9.34	9.87	35.74	11.40
	K200	8.98	23.16	8.04	10.02	30.71	10.18	11.35	37.74	12.27
	Mean	8.30	21.10		8.39	28.74		9.69	35.20	
MKP	K0	3.14	14.98	4.53	3.21	15.58	4.70	4.18	17.69	5.47
	K100	3.22	15.85	4.77	5.00	17.47	5.62	6.87	21.61	7.12
	K200	5.46	16.06	5.38	6.58	19.89	6.62	8.55	27.13	8.92
	Mean	3.94	15.63		4.93	17.65		6.54	22.14	
UP	K0	2.71	12.25	3.74	3.74	20.07	5.95	4.87	22.07	6.73
	K100	3.55	13.93	4.37	4.91	25.86	7.69	5.38	26.23	7.90
	K200	4.79	14.92	4.93	5.26	26.57	7.96	6.84	28.01	8.71
	Mean	3.68	13.70		4.63	24.16		5.69	25.44	7.78
	LSD0.5% K	0.68	0.98		0.87	1.001		1.04	1.03	
	LSD0.5% T	1.23	2.34		1.65	2.35		1.7	2.67	
	LSD 0.5% K*T	0.98	1.03		0.94	1.06		0.88	1.11	

Leaf and fruit nutrients

Data in Table 5 showed the effect of different phosphorus sources and potassium sprayed on the nutrients percentages of N, P, K and Ca in plant leaves and fruits of sweet pepper plants. Data in Table 5 clearly indicated that fertilization with MAP significantly increased N, P, K and Ca, percentage in sweet pepper leaves and fruits over all other treatments followed by MPK and UP. In the contrary, plants received SP recorded the lowest values of studied plant nutrients. Phosphorus supply results in absorption of water and higher concentration of mineral nutrients from soil as it increases root-shoot ratio and enhanced the growth of lateral roots (Hammond *et al.*, 2004). Plants sprayed with high level of K (200 ppm) showed a remarkable improvement of plant nutrients content in leaves and fruits as compared with the other levels (0 and 100 ppm).

These results may be due to the role of potassium in plant metabolism and many important regulatory processes in the plant. Also, it could be increased mineral uptake by plants (Hsiao and Läuchli, 1986 and Marschner, 1995).

Table 5: Effect of phosphorus sources and sprayed potassium on N, P, K and Ca in leaves and fruits of sweet pepper plants

Phosphorus sources (T)	Potassium conc. ppm (K)	Leaves				Mean
		N	P	K	Ca	
		%				
SP (control)	K0	1.29	1.03	1.06	1.01	1.10
	K100	1.74	1.11	2.64	1.11	1.65
	K200	1.82	1.16	3.41	1.21	1.90
	Mean	1.62	1.10	2.37	1.11	
MAP	K0	2.42	1.03	4.14	1.75	2.34
	K100	2.51	1.04	4.59	1.98	2.53
	K200	2.71	1.29	5.66	2.01	2.92
	Mean	2.55	1.12	4.80	1.91	
MKP	K0	2.01	1.11	3.93	1.38	2.11
	K100	2.13	1.24	4.6	1.67	2.41
	K200	2.24	1.35	4.07	1.88	2.39
	Mean	2.13	1.23	4.20	1.64	
UP	K0	1.89	1.07	2.41	1.15	1.63
	K100	1.89	1.28	3.24	1.36	1.94
	K200	1.97	1.42	3.63	1.65	2.17
	Mean	1.92	1.26	3.09	1.39	
	LSD0.5% K	0.05	0.061	0.34	0.01	
	LSD0.5% T	0.12	0.21	0.14	0.03	
	LSD 0.5% K*T	0.005	0.08	0.09	0.008	
		Fruits				
SP (control)	K0	1.13	0.16	2.09	1.08	1.12
	K100	1.19	0.19	2.13	1.1	1.15
	K200	1.23	0.21	2.18	1.12	1.19
	Mean	1.18	0.19	2.13	1.10	
MAP	K0	1.77	0.39	2.55	1.17	1.47
	K100	1.84	0.42	2.59	1.21	1.52
	K200	1.94	0.48	2.64	1.25	1.58
	Mean	1.85	0.43	2.59	1.21	
MKP	K0	1.36	0.32	2.19	1.13	1.25
	K100	1.42	0.35	2.21	1.15	1.28
	K200	1.49	0.39	2.29	1.18	1.34
	Mean	1.42	0.35	2.23	1.15	
UP	K0	1.26	0.24	2.09	1.08	1.17
	K100	1.29	0.27	2.13	1.11	1.20
	K200	1.33	0.29	2.15	1.13	1.23
	Mean	1.29	0.27	2.12	1.11	
	LSD 0.5% K	0.01	0.042	0.14	0.001	
	LSD 0.5% T	0.08	0.12	0.04	0.003	
	LSD 0.5% K*T	0.004	0.06	0.08	0.002	

Protein, Vit C concentration and total acidity percentage

Table 6 and Figure 1 represented the protein concentration in both leaves and fruits of sweet pepper plants received phosphorus from different sources and sprayed with three levels of potassium. From data recorded in Table 6, it could be found that MAP as a source of P improved protein concentrations in both leaves and fruits of sweet pepper plants. On the other hand, the protein concentration increased with the increase of K sprayed as compared with control plants (didn't receive any sprayed K)

Table 6: Effect of phosphorus sources and sprayed potassium on N, P, K and Ca in leaves and fruits of sweet pepper plants

Phosphorus sources (T)	Potassium conc. ppm (K)	Protein in leaf (mg/g FW)	Protein in fruit (mg/g FW)
SP (control)	K0	3.25	3.90
	K100	4.71	5.65
	K200	5.88	7.06
	Mean	4.61	5.54
MAP	K0	9.63	10.87
	K100	9.88	12.86
	K200	10.34	13.41
	Mean	9.95	12.38
MKP	K0	7.75	9.30
	K100	8.58	10.30
	K200	8.88	11.66
	Mean	8.40	10.42
UP	K0	6.45	6.74
	K100	6.63	7.96
	K200	7.63	9.16
	Mean	6.90	7.95
	LSD0.5% K	1.06	1.34
	LSD0.5% T	1.09	1.25
	LSD 0.5% K*T	1.88	1.09

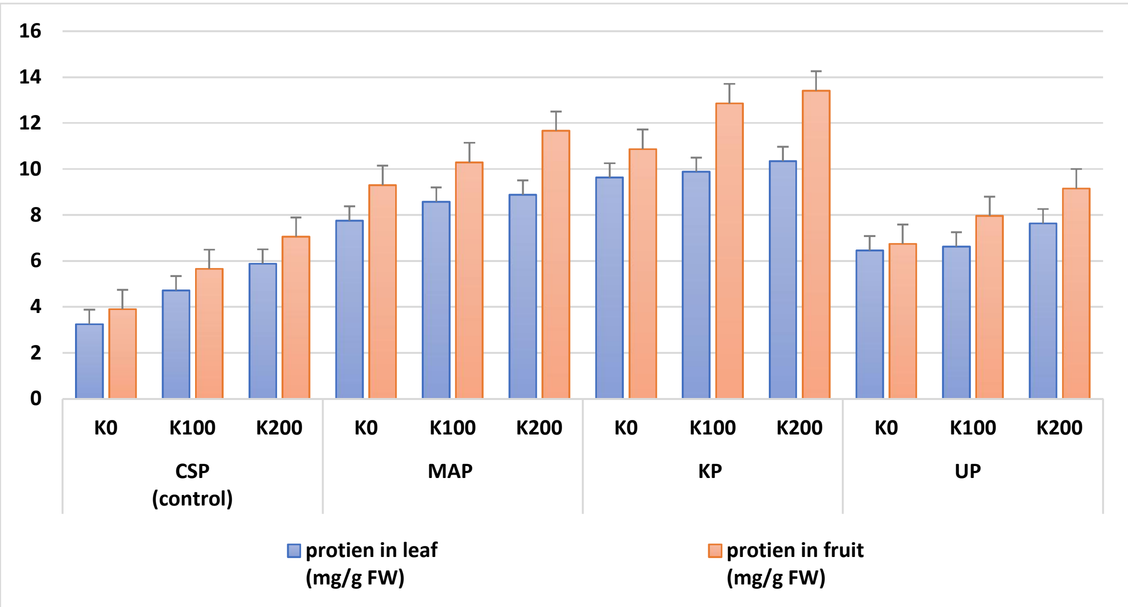

Fig. 1: Total soluble protein in leaves and fruits

Table 7 showed the concentration of Vit C and the total acidity in sweet pepper fruits as affected by different phosphorus sources and K foliar sprayed. The best results were recorded with MAP as P source followed by MKP and finally UP as compared with SP. Foliar spray with 200 ppm K resulted in high accumulation of ascorbic acid (Vit C) and remarkable reduction in total acidity followed by 100 ppm of K. Data presented in Table (7) and Figure (2) indicated that the highest values of vitamin C concentration and the lowest total acidity in fruits were recorded with the combination with fertilization of MAP as a source of phosphorus and foliar spray with 200 ppm of K.

This response may be due to factors in the soil affecting phosphorus availability (Eltelib *et al.*, 2006). It is known that supply of phosphorus is usually associated with a significant increase in number and mass of roots which results in absorption of higher concentration of mineral nutrients from soil including nitrogen resulting in increased growth and total chlorophyll. In this respect, MAP which is characterized by high phosphorus content and high water solubility gave the highest contents of plant pigments, nutrients, protein and Vit C. Increasing potassium sprayed rates from 0 to 200 ppm significantly increased vitamin C content in fruits. In general, the highest values of measured chemical composition of sweet pepper plants were recorded by plants which received 200 ppm of K. These results may be due to the role of potassium in plant metabolism and many important regulatory processes in the plant. Also, it could be increased mineral uptake by plants (Hsiao and Läuchli, 1986 and Marschner, 1995).

Table 7: Effect of phosphorus sources and sprayed potassium on total acidity and Vit C in fruits of sweet pepper plants

Phosphorus sources (T)	Potassium conc. ppm (K)	TA %	VitC (mg $100g^{-1}$)	Mean
SP (control)	K0	1.89	59.84	30.87
	K100	1.49	65.83	33.66
	K200	1.35	83.78	42.57
	Mean	1.58	69.82	
MAP	K0	2.46	93.36	47.91
	K100	1.94	102.69	52.31
	K200	1.76	130.70	66.23
	Mean	2.05	108.92	
MKP	K0	2.27	86.18	44.22
	K100	1.79	94.79	48.29
	K200	1.62	120.65	61.13
	Mean	1.89	100.54	
UP	K0	2.36	89.77	46.06
	K100	1.86	98.74	50.30
	K200	1.69	125.67	63.68
	Mean	1.97	104.73	
	LSD0.5% K	0.28	1.78	
	LSD0.5% T	0.15	1.13	
	LSD 0.5% K*T	0.02	1.02	

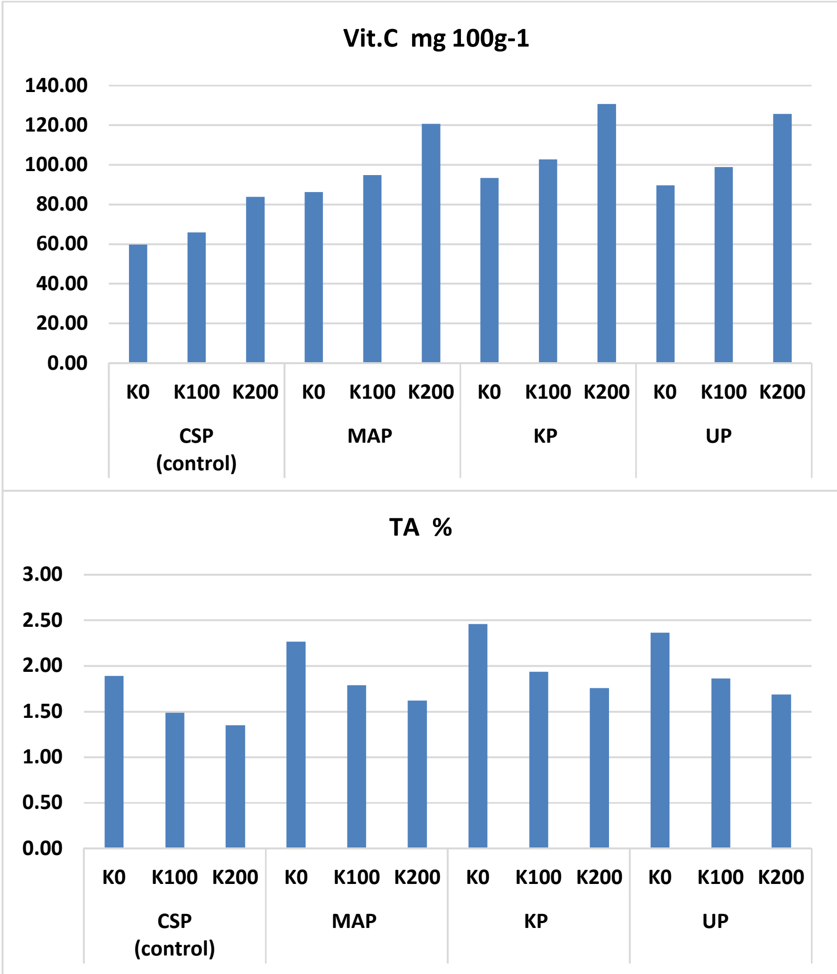

Fig. 2: Effect of phosphorus sources and sprayed potassium on total acidity (TA) and Vit C in fruits of sweet pepper plants

Generally, it could be concluded that application of the soluble sources of P fertilizers (MAP and MKP) significantly increased vegetative growth parameters, yield, photosynthetic pigments, mineral nutrients and protein concentrations in both leaves and fruits of sweet pepper plants as compared with traditional sources (SP). Moreover, foliar spray of K significantly increased all studied data in sweet pepper plants compared with unsprayed plants, especially at high concentration (200 ppm).

References

Eltelib A., Muna A. Hamad and E. Ali, 2006. The Effect of Nitrogen and Phosphorus Fertilization on Growth, Yield and Quality of Forage Maize (*Zea mays* L.). Journal of Agronomy, 5: 515-518.

A.O.A.C., 2007. Official Methods of Analysis. 18th ed. Association of Official Agricultural Chemists, Washington, DC, USA.

Almeselmani, M., 2010. Effect of High temperature on physiological characters and yield attributes of wheat genotypes. In International Conference on Agricultural Productivity Increase: Challenges and Means of Developments, pp 28-30.

Baghour, M., D. Moreno, J. Hernandez, N. Castilla and L. Romero, 2001. Influence of root temperature on phytoaccumulation of As, Ag, Cr, and Sb in potato plants (*Solanum tuberosum* L. var. Spunta). Journal of Environmental Science and Health, Part A, 36 (7): 1389-1401.

Bradford M.M., 1976. A rapid and sensitive method for the quantitation of microgram quantities of protein utilizing the principle of protein-dye binding. Analytical Biochemistry. 72: 248– 254.

Chapman, H. and F. Pratt, 1982. Determination of Minerals by Titration Method Methods of Analysis for Soils, Plants and Water 2nd Edn., California University. Agriculture division, USA: 169-170.

Chien, S.H., L.I. Prochnow and H. Cantarella, 2009. Recent developments of fertilizer production and use to improve nutrient efficiency and minimize environmental impacts. Advances in Agronomy, 102: 267-322, DOI: 10.1016/S0065-2113(09)01008-6.

Cottenie, A., 1980. Soil and plant testing as a basis of fertilizer recommendations,

Deepa, N., Ch. Kaur, B.Singh and H.C. Kapoor, 2006. Antioxidant activity in some red sweet pepper cultivars. J. Food Comp. Anal., 19, 572–578.

El-Bassiouny A.M, A. A. Ghoname, M. E. El-Awadi, Z. F. Fawzy and N. Gruda, 2012. Ameliorative Effects of Brassinosteroids on Growth and Productivity of Snap Beans Grown Under High Temperature. Gesunde Pflanzen:64:175–182

Eltelib, H. A., M. A. Hamad and E. E. Ali, 2006. The effect of nitrogen and phosphorus fertilization on growth, yield and quality of forage maize (*Zea mays* L.). Journal of Agronomy,

FAO Soils Bulletin 38/1. Soil and Plant Testing and Analysis. 250 p. 1980.

Flores, H., M. Puech, F. Hammer; O. Garrido and O. Hernandez, 2004. GIRAFFE multiple integral field units at VLT: A unique tool to recover velocity fields of distant galaxies. Astronomy & Astrophysics, 420 (3): L31-L34.

Ghoname, A.A., M.A. El-Nemr; A.M.R Abdel-Mawgoud and W. A. El-Tohamy, 2010. Enhancement of Sweet Pepper Crop Growth and Production by Application of Biological, Organic and Nutritional Solutions. Research Journal of Agriculture and Biological Sciences, 6(3): 349-355.

Gunter, C.C., 2010. Potassium application timing and method for the reduction of yellow shoulder in processing tomato. Acta Hort. (ISHS) 852:291-296

Gupta, A.P., S.S. Khanna and N.K. Tomar, 1985. Effect of sodicity on the utilization of phosphatic fertilizers by wheat. Soil Sci., 139(1): 47–52.

Hammond, J.P., M.R. Broadley and P.J. White, 2004. Genetic responses to phosphorus deficiency. Ann. Bot., 94 (3): 323-332, DOI:10.1093/aob/mch156.

Hartz, T., P. Johnstone, D. Francis and E. Miyao, 2005. Processing tomato yield and fruit quality improved with potassium fertigation. HortScience, 40 (6): 1862-1867.

Hasler, C.M., 1998. Functional foods: Their role in disease prevention and health. Food Technol., 52, 63–69.

Hidetoshi, A., 2007. Changes in nutrient absorption during growth of cherry tomato in hydroponic culture. Bull. Fukuoka Univ. Educ., 56(3): 9–13.

Hsiao, C. and A. Läuchli, 1986. Role of potassium in plant-water relation. In:Advances in plant nutrition 2nd ed., pp. 281312.,Tinker And A. Läuchli (eds.). Praeger, New York

Hsiao, T. and A. Lauchli, 1986. Role of potassium in plant-water relations. Advances in plant nutrition (USA),

Igbokwe, G.E., G.C.Aniakor and C.O. Anagonye, 2013. Determination of β-Carotene & Vitamin C content of Fresh Green Pepper (*Capsicum annnum*), Fresh Red Pepper (*Capsicum annum*) and Fresh Tomatoes (*Solanum lycopersicum*) Fruits. Bioscientist, 1, 89–93.

Leal-Fernández, C., H. Godoy-Hernández, C. Núñez-Colín, J. Anaya-López, S. Villalobos-Reyes and J. Castellanos, 2013. Morphological response and fruit yield of sweet pepper (*Capsicum annuum* L.) grafted onto different commercial rootstocks. Biological agriculture & horticulture, 29 (1): 1-11.

Lichtenthaler, H. K. and A. R. Wellburn, 1983. Determinations of total carotenoids and chlorophylls a and b of leaf extracts in different solvents. *In*. Portland Press Limited

Marschner, H., 1997. Mineral nutrition of higher plants. London: Academic Press.

Marschner, H., 1995. Mineral nutrition of higher plants. second edition. London: Academic Press.

Moran, R., 1982. Formulae for determination of chlorophyllous pigments extracted with N, N-Dimethylformamide. Plant Physiology. 69: 1376-1381.

Njira, K. O. and J. Nabwami, 2015. A review of effects of nutrient elements on crop quality. African Journal of Food, Agriculture, Nutrition and Development, 15 (1): 9777-9793.

Oka, Y., A. Nakamura, H. Watanabe and K. Touhara, 2004. An odorant derivative as an antagonist for an olfactory receptor. Chemical senses, 29 (9): 815-822.

Rai, A., 1984. A house divided: The origin and development of Hindi/Hindavi. Oxford University Press, USA

Rosen, E. D. and B. M. Spiegelman, 2014. What we talk about when we talk about fat. Cell, 156 (1): 20-44.

Rubeiz, I. G., Z. U. Naja and M. N. Nimah, 1991. Enhancing late and early yield of greenhouse cucumber with plastic mulches. Biological agriculture & horticulture, 8 (1): 67-70.

Schachtman, D. P., R. J. Reid and S. M. Ayling, 1998. Phosphorus uptake by plants: from soil to cell. Plant Physiology, 116 (2): 447-453.

Shabala, S., 2003. Regulation of potassium transport in leaves: from molecular to tissue level. Annals of botany, 92 (5): 627-634.

Shlyk A.A., 1971. Determination of chlorophyll and carotenoids in extracts of green leaves. In: Biochemical Methods in Plant Physiology. Moscow. Nauka: 154–170.

Taiz, L., E. Zeiger, I. M. Møller and A. Murphy, 2015. Plant physiology and development. Sinauer Associates, Incorporated

Thomas, B. and Z. Rengel, 2002. Di-ammonium phosphate and mono-ammonium phosphate improve canola growth when banded in a P-fixing soil compared with triple superphosphate. Crop and Pasture Science, 53 (11): 1211-1218.

Zhang, J.; P. Yedlapalli and J. W. Lee, 2009. Thermodynamic analysis of hydrate-based pre-combustion capture of CO_2. Chemical Engineering Science, 64 (22): 4732-4736.