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Full Length Research Paper

Combined effect of NPK levels and foliar nutritional compounds on growth and yield parameters of potato plants (*Solanum tuberosum L.*)

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Field experiment was conducted to study the effect of NPK levels and foliar nutritional compounds on growth yield, chemical constituents and nutrients content of potato plants grown in newly reclaimed soil. The obtained results could be summarized as follows: Increasing the NPK levels significantly increased all the growth, and yield parameters (except for number of aerial stem, plant), photosynthetic pigments, chemical constituents of potato tuber at harvest, and macro and micronutrients in potato shoots and tubers. The highest values of the mentioned parameters were obtained by using the highest NPK (120:80:100) as compared with the other two NPK levels (Medium: 102:68:85 and low: 90: 60: 75). Foliar application with folifertile, Byfolane and fetrilon combi significantly increased growth and yield parameters, photosynthetic pigments, chemical constituents and nutrients content of shoots and tubers as compared with the control treatment. The highest effective treatment in this respect was folifertile followed by Byfolane and fetrilon combi in decreasing order. The interaction between NPK levels and foliar nutritional compounds significantly affected leaves number (LN)/plant, chl. b and chl. a + b, tuber yield, mono sugars, carbohydrate and L-ascorbic acid as well as p, Mn and Cu concentration in shoots, and N and Fe in tubers. The interaction did not significantly affect the other studied parameters.

Key words: Foliar compounds, nutrients content, potato NPK chemical constituents, interactions.

INTRODUCTION

Potato (*Solanum tuberosum*) is one of the most important and favorite vegetable crop grown in Egypt. Its economic importance arises from the fact that large amount of this crop is exported yearly. Potato is a staple food in the diet of the world's population and also being used as animal feed (Dancs et al., 2008). Although potato is considered as a starchy food, it is also included in the category of vegetables by its micronutrient content, Robert et al. (2006) suggested that consumption of cooked potatoes (consumed with skin) may enhance antioxidant defense and improve the lipid metabolism, these effects could be interesting for prevention of cardiovascular diseases. Potato tubers have been successfully used for high-level production of recombinant antibodies accumulated up to 2% of total soluble tuber protein, also antibodies specific activity did not decrease during tuber storage (Artsaenko et al., 1998). Potatoes could be used as an important dietary source of the carotenoid zeaxanthin which accumulates in the human macula lutea and protects retinal cells from blue light damage. However, zeaxanthin intake from food sources is low. Increasing zeaxanthin in common food such as potatoes by traditional plant breeding or by genetic engineering could contribute to an increased intake of this carotenoid and, consequently, to a decreased risk of age-related macular degeneration (Bub et al., 2008).

Fertilization either mineral and/or organic and foliar

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fertilizers considered the most important agricultural practices, which affects the growing period of plant foliage and tuber formation as well as the quality of produced yield (Gabr et al., 2001; Bekhit et al., 2005).

The necessity of nitrogen (N), phosphorus (P) and potassium (K) for growth has been demonstrated by several investigators, since N supply was desirable for vegetative growth, dry matter accumulation as well as nutrients uptake by potato plants (El-Ghamriny and Saeed, 2007a). As P is a part of molecular structure of nucleic acid (DNA and RNA), the energy transfer compounds, cell membranes and phosphoproteins so it has a great importance in physiological processes inside the plant, moreover, (p) has a role in plant life through energy storage and transfer, it acts as a linkage unit and has a vital metabolic role as an important structural component of wide varieties of biochemical materials including nucleic acids, coenzymes, phosphoproteins, phospholipid and sugar phosphates (Daniel et al., 1998). Furthermore, (k) is a mobile element in plant tissues and it plays an important role in photosynthesis through carbohydrate metabolism, osmotic regulation, nitrogen uptake and translocation of assimilates, also it has a role in physiological processes in plant respiration, transpiration, translocation of sugars and carbohydrates and enzyme transformation (Kelling et al., 1998).

In this concern Kolbe et al., 1990) found that different NPK-ratios led to maximum yield and tuber quality of potato, they added that it is possible to demonstrate characteristic differences between the effect of N-fertilization and varied N-concentrations on tuber yield and composition.

Nitrogen, p and k as macronutrients are commonly applied to soil. This method of application is usually accompanied with some losses through leaching. Excessive irrigation as well as the fixation of phosphorus are considered to be one of the growers mistakes which aggravate N, P and K losses from soil.

In higher pH soil as that in Egyptian soils, it is known that micronutrients as well as some macronutrients may be limiting. Foliar products containing multi-nutrients may correct these deficiencies giving increases in growth and development. Foliar applications are often the most effective economical way to correct plant mineral deficiency (Kannan, 1986), especially when sink competition for carbohydrates between plant organs take place and nutrient uptake from the soil is restricted (Marschner, 1986).

There are many compounds used in foliar fertilization products, chelated compounds made from natural organic materials may have advantages since they are more ecological safe and have more prolonged and efficient action. Agriculturally, a foliar application of nutrient solution is particularly useful when the uptake of nutrients from the soil is growth limiting (Swietlik and Faust, 1994).

It was advisable in this investigation to study the effect of NPK levels and some foliar nutritional compounds on growth, yield and chemical composition of potato plants (*Solanum tuberosum* cultivar Diamant) grown under the newly reclaimed soil conditions.

MATERIALS AND METHODS

Field experiments were carried out in the experimental farm of Salah El-Din, El-Bostan, Nobaria, El-Behera Governorate which belongs to the National Research Center, Giza (Egypt). Some physical and chemical properties of the soil in the experimental sites were noted (Table 1).

The experiment included 12 treatments which were the combination between three NPK levels and three foliar nutritional compounds, Folifertile, Byfolane and Fetrilon combi. The three NPK levels were high (120:80:100), medium (102:68:85) and low (90:60:75).

The treatments were arranged in a split plot design with three replications. The NPK levels were randomly arranged in the main plots and the foliar nutritional compounds were randomly distributed in the sub plots. Chemical composition and concentration of the different nutritional compounds used in foliar feeding are presented (Table 2).

Spraying with nutritional compounds were carried out six times by 15 days intervals during the growth period at rate of 400 L./Fed., control plants were sprayed with tap water. Other agricultural processes were followed according to normal practice in the region. Potato tubers were sown on January 15th at 20 cm apart. The source of fertilizers was ammonium sulfate (20.6% N), triple superphosphate (37% P_2O_5) and potassium sulfate (48% K_2O), respectively. One third of NPK fertilizers were added at the time of soil preparation along with farmyard manure at the rate of 40 m^3 /feddan. The two third of NPK were divided into six equal portions and added at 10 days intervals beginning one month after planting.

Data recorded

Growth parameters

Random samples of five plants were taken from every plot at 90 days after planting, for measuring: stem length, number of areal stems/plant, number of leaves/plant, dry weight of roots/plant, dry weight of shoots/plant, total dry weight of roots and shoots.

Photosynthetic pigment

Disc sample from the fourth upper leaf of potato plants was randomly taken from every experimental unit, 90 days after planting, to determine chlorophyll a, b and chl. a + b also carotenoids and total pigments, according to the method described by Wetteslein (1957).

Yield and its components

At harvest time, 115 to 120 days after planting, following parameters were calculated: No. of tubers/plant, tuber yield/plant, average tuber weight and total yield (ton/fed.)

Chemical composition and nutrients status at harvest

Crude protein, mono sugars, starch, carbohydrate, total soluble solids (T.S.S) and ascorbic acid as well as macro and micronutrients in shoots and tubers were determined as described by, Cottenie et al. (1982), and A.O.A.C. (2000).

Table 1. Some physical and chemical properties of the experimental soil, according to Ryan et al. (1996).

a) Te(a) Texture,, pH, EC, O.M%, $CaCO_3$							
Sand %	**Silt %**	**Clay%**	**Texture**	**pH 1:2.5**	**EC dsm^{-1}**	**O.M%**	**$CaCO_3$**
86.0	8.0	6.0	sandy	7.45	0.89	0.35	1.8

(b) Soluble cations and anions (meq/L 1:5) and available nutrients (ppm)

Na^+	k^+	Ca^{++}	Mg^{++}	CO_3^-	HCO_3^-	Cl^-	SO_4^{--}	N	P	K	Fe	Mn	Zn	Cu
2.77	0.07	4.5	1.00	-	2.35	2.01	3.98	50.0	9.5	64.8	3.12	0.67	0.48	0.39

Table 2. Nutritional compounds composition and concentration percentage.

Compound	Composition												
	N	**P_2O_5**	**K_2O**	**S**	**Mg**	**Fe**	**Mn**	**Zn**	**Cu**	**Mo**	**B**	**Co**	**Reco. Conc.**
Folifertile	22	21	17	0.167	0.076	0.730	0.0395	0.0068	0.0076	0.0050	0.0033	0.002	0. 30
Byfolane	11	8.0	6.0	-	-	9.018	0.016	0.006	0.0066	0.0095	0.0013	-	0.20
Fetrilon combi	-	-	-	-	-	1.5	4.5	3.0	-	-	-	-	0.15

Statistical analysis

The proper statistical analysis of all data carried out according to Gomez and Gomez (1984). The differences between treatments mean were compared using the least significant differences at 5% LSD level.

RESULTS AND DISCUSSION

Vegetative growth and photosynthetic pigments

Effect of NPK levels

Data concerning the effect of mineral NPK levels on vegetative growth parameters at potato plants that is stem length, No. of aerial stem/plant, No. of leaves/plant, dry weight of roots and shoots/plant as well as dry weight of total plant are presented in (Table 3). The present result indicated that application of NPK levels significantly increased all the previous parameters except No. of aerial stem/plant which did not significantly affected. The highest NPK level (120:80:100) gave the highest values for all mentioned parameters as compared with other two NPK levels (Medium 102:68:85 and low 90:60:75). The necessity of N, P and K for growth has been demonstrated by several investigators, since nitrogen supply was desirable for vegetative growth, dry matter accumulation as well as nutrient uptake by potato plants (El-Ghamriny and Saeed, 2007a). The increase in plant growth may be attributed to the beneficial effects of nitrogen on stimulating the merestimatic activity for producing more tissues and organs, since it plays major roles in the synthesis of structural proteins and other several macro molecules, in addition to its vital contribution in several biochemical processes that related to plant growth (Marschner, 1995). Also, nitrogen may be contributed with the activation of cell division and cell elongation (Medani et al., 2000). The promating effect of growth parameters could be attributed to phosphorus as structural part of high energy compounds (Sarg, 2004). It is also a constituent of the cell nucleus and is essential for cell division and the merestimatic tissues development (Frank, 2002).

The obtained results of growth parameters in this investigation are in good agreement with those obtained by El-Arquan et al. (2002), El-Ghamriny and Saeed (2007a), Kamel et al. (2008), Rafla et al. (2009) on different crops. NPK levels significantly affected the phototosynthetic pigments of potato plants (chl. a chl. b, chl. a+b, carotenoids and total pigments). The obtained results took the same trend of those obtain for

Table 3. Effect of NPK levels and some foliar compounds on growth and photosynthetic pigments (mg/g dry weight) in potato shoots 90 days after sawing.

Treatment e		Vegetative growth Vegetative growth						Photosynthetic pigments				
		Stem length (cm)	No. of aerial stem/ plant	No. of leaves/ plant	D. wt. of roots /plant	D. wt of shoots gm/plant	D. wt. of total plant (gm)	Chl. a	Chl. b	Chl. a+b	Carotenoids	Total pigments
NPK levels												
L		25.44	2.91	32.68	4.45	27.41	31.86	2.43	1.69	4.11	1.67	5.78
M		27.14	3.08	34.66	4.85	29.38	34.23	2.57	1.83	4.39	1.75	6.14
H		28.68	3.10	36.89	5.28	31.39	36.67	2.68	1.96	4.63	1.89	6.52
LSD. at 5%		0.42	NS	1.19	0.23	1.36	1.22	0.11	0.07	0.12	6.07	0.11
Foliar compounds												
Control		24.86	2.41	32.27	4.24	26.99	31.23	2.34	1.65	3.99	1.67	5.67
FF.		30.49	3.79	37.93	5.69	32.62	38.31	2.79	2.09	4.87	1.92	6.80
By.		27.18	3.04	35.06	4.94	29.92	34.87	2.61	1.82	4.43	1.75	6.18
Fet.		25.83	2.88	33.70	5.56	28.04	32.60	2.84	1.74	4.22	1.72	5.94
LSD at 5%		0.51	0.47	0.55	0.12	1.01	1.06	0.06	0.05	0.08	0.05	0.10
NPK levels×foliar compounds												
L	Control	23.03	2.60	29.50	3.83	25.57	29.46	2.27	1.57	3.83	1.60	5.43
	FF.	28.70	3.47	36.57	5.30	30.07	35.37	2.60	1.86	4.46	1.80	6.25
	By.	25.90	2.83	33.14	4.57	27.63	32.20	2.47	1.66	4.13	1.66	5.79
	Fet.	24.13	2.73	31.50	4.10	26.37	30.47	2.37	1.66	4.03	1.62	5.65
M	Control	24.93	2.63	32.73	4.30	27.23	31.53	2.33	1.66	3.99	1.68	5.67
	FF.	30.63	3.86	37.47	5.67	32.03	37.70	2.83	2.07	4.90	1.87	6.77
	By.	26.90	3.07	34.59	4.80	30.27	37.07	2.63	1.85	4.48	1.75	6.23
	Fet.	26.10	2.83	33.84	4.63	28.00	32.63	2.47	1.73	4.20	1.71	5.90
H	Control	26.60	1.99	34.57	4.60	28.17	32.77	2.43	1.72	4.16	1.75	5.96
	FF.	32.13	4.10	39.77	6.10	35.77	41.87	2.93	2.33	5.27	2.11	7.38
	By.	28.73	3.23	37.47	5.47	31.87	37.33	2.73	1.94	4.68	1.85	6.52
	Fet.	27.27	3.07	35.77	4.93	29.77	34.70	2.60	1.83	4.43	1.84	6.28
LSD. at 5%		NS	NS	0.95	NS	NS	NS	NS	0.09	0.13	NS	0.17

NPK levels: L= Low (90:60:75), M= Medium (102:68:85) , H= High (120:80:100). Foliar compounds: FF. =Folifertile, By.=Byfolane, Fet.= Fertrilon combi.

the growth parameters. The highest values were obtained by using the highest NPK levels comparing to the other two levels. It is conspicuous that increasing NPK levels significantly increased pigments content in potato shoots at 90 day. The increases in the photosynthetic pigments in shoots may be attributed to the important role of (P) in the potential activity of photosynthesis. Moreover, it has a metabolic activating role to large number of enzymatic reactions depending on phosphorylation (Nassar et al., 2005). Marschner (1995) found that the favourable effect of NPK on

photosynthetic pigments may be also due to N which is a constituent of chlorophyll molecule, amino acids and proteins acting as structural compounds of the chloroplast, correspondingly, an enhancement of protein synthesis and chloroplast formation leads to an increase in chlorophyll. It seems that NPK treatment significantly increased carotenoids in potato shoots, these results are in agreement with those obtained by Bijana et al. (2005) and Kamel et al. (2008) who found that carotenoids in wheat leaves increased significantly by increasing NPK levels.

Effect of foliar compounds

Data indicated that foliar application with the investigated compounds (folifertile, byfolane and fetrilon combi) significantly increased all the growth characters and photosynthetic pigments as compared with the control treatment (Table 3). The highest effective treatment in this respect was that of folifertile followed by byfolane and fetrilon combi in decreasing order. The highest effect of folifertile might be attributed to its higher content of macro and micronutrients than the other two used foliar compounds (Table 2). In addition folifertile contains Mg element, which plays important physiological and biological role in chlorophyll formation, activation of enzymes, synthesis of protein, carbohydrate metabolism and energy transfer, as well as it acts as a catalyst in many oxidation reduction reactions in plant tissues (Saad and El-Kholy, 2000). This means that spraying potato plants with the foliar compounds significantly encourage the capability of plants to produce vigorous vegetative growth characters. Also, these foliar compounds play a great role in plant metabolism such as photosynthesis, respiration and other metabolic process (Ahmed et al., 2002), which in turn produced more carbohydrate, and chlorophyll, leading to enhancements of plant height, leaves number and branches in bean plant (El-Kabany, 2000). The obtained results in this investigation are in good agreement with those obtained by Abd-El-Fatah and El-Ghinbihi (2001) and Helal Fawzeia et al. (2006) who stated that significant increment in faba bean plant height and number of branches/ plant was obtained due to the foliar spraying with micronutrients, leads to growth increase as compared with control plants.

Effect of interaction between NPK levels and foliar compounds

The data obtained in Table 3 indicated that the interaction between NPK levels and foliar nutritional compounds on growth parameters and photosynthetic pigments did not significantly affected most of the parameters under study except leaves No./plant, chl. b and chl. a+b which were significantly affected by the interaction. However the highest values of growth and photosynthetic pigments were obtained by applying the higher level of NPK and sprayed with folifertile compound, on the other hand, the lowest values were attained by using the lowest level of NPK and sprayed with tap water.

Yield and its components and some chemical constituents of potato tubers

Effect of NPK levels

Data presented in Table (4) indicated that increasing the NPK levels significantly increased yield parameters. This result is supported by El-Zeiny and Maha (2004) who found that increasing N levels application up to 95 kg /Fed. Significantly increased stripped stalk and juice, total biomass and forage yield of sweet sorghum. The increasing yield of potato plant can be explained by the important fact of phosphorus as a constituent compound in most metabolic processes (El-Arquan et al., 2002). Moreover, the effect of NPK on increasing yield is due to K which is a co-factor (enzyme activator) for different enzymes and it helps to maintain electro-neutrality in plant cell.

In this concern Lindhaver and Fekete (1990) mentioned that starch synthesis in potato tubers grown at varied k nutrition was investigated with particular regard to the activity of selected enzymes (sucrose synthase, UDP-D-glucose pyrophosphatase, starch phosphorylase, amylases) independence on tuber K content, they added that the activity of enzymes related to tuber Kcontent did not differ significantly, starch and k content of tubers increased with progressing age. Comparing our results in Tables 3, 4 and 5, it is obvious that the positive correlations between the rates of K uptake, starch production and growth indicate that the dynamic phase of K supply to the tubers is of greater importance for starch synthesizing processes, than the influence of total K content. The obtained results agree with those obtained by Moustafa et al. (2005) mentioned that increasing NPK levels significantly increased the growth parameters, yield and its components as well as nutrient uptake of sugar beet and sweet sorghum plants.

The chemical constituents of potato tubers at harvest were significantly increased by increasing NPK levels (Table 4), El-Ghamriny and Saeed (2007b), and Kamel Nadia et al. (2008) proved that NPK application significantly increased reducing, nonreducing and total sugar as well as carbohydrates, starch, and protein contents in wheat grains. Same trend was found by Karcomarczyk et al. (1999) who reported that increasing NPK to 450 kg N and from 50 to 100% of the recommended rate enhanced more carbohydrate and protein accumulation in plants.

Effect of foliar compounds

The obtained results in Table (4) indicated that foliar compounds under investigation (folifertile, Byfolane and fetrilon combi) application significantly increased the yield and

Table 4. Effect of NPK levels and some foliar compounds on yield and chemical composition (%) of potato tubers at harvest time.

Treatment		Yield VV Yeild its component				Chemical composition Chemical c					
		No. of tubers/ plant	Tuber yield/plant (gm)	Average tuber wt. (gm)	Tuber yield (ton/fed)	Crude protein	Mono sugars	Starch	Carbohydrate	Total soluble solids	L-Ascorbic acid
NPK levels											
L		4.51	510.69	107.58	14.32	11.15	3.58	65.26	76.78	4.45	14.49
M		4.88	537.17	110.70	15.39	12.05	3.69	67.34	78.40	4.60	14.83
H		5.36	573.63	113.78	16.60	12.77	3.83	69.17	80.23	4.73	15.36
LSD. at 5%		0.19	14.49	2.06	0.85	0.06	0.23	0.61	0.92	0.09	0.08
Foliar compounds											
Control		4.39	505.04	106.88	14.36	1 0.73	3.49	65.41	76.32	4.25	14.41
FF.		5.49	589.54	115.89	16.69	13.91	4.01	69.97	81.13	4.88	15.61
By.		5.12	548.96	111.66	15.75	12.31	3.79	67.43	79.44	4.66	14.94
Fet.		4.67	518.44	108.31	14.96	11.00	3.58	66.22	76.98	4.56	14.61
LSD at 5%		0.15	13.00	3.34	0.28	0.06	0.20	0.55	0.66	0.10	0.13
NPK levels × foliar compounds											
L	Control	4.03	486.07	105.11	13.33	9.90	3.41	63.17	75.23	3.96	13.98
	FF.	4.91	537.57	112.05	15.50	12.83	3.86	67.70	78.40	4.79	14.93
	By.	4.80	525.80	106.98	14.73	11.50	3.57	65.53	77.80	4.55	14.66
	Fet.	4.31	493.33	106.19	13.73	10.37	3.50	64.63	75.70	4.48	14.38
M	Control	4.40	499.73	106.02	14.07	10.90	3.50	66.03	76.65	4.27	14.32
	FF.	5.53	586.10	114.98	16.50	14.00	3.93	70.17	80.90	4.86	15.66
	By.	5.00	535.77	113.62	15.90	12.41	3.72	67.03	78.83	4.67	14.76
	Fet.	4.59	527.07	108.18	15.07	10.87	3.59	66.13	77.20	4.58	14.59
H	Control	4.73	529.33	109.52	15.67	11.40	3.57	67.03	77.07	4.53	14.93
	FF.	6.03	644.97	120.63	18.06	14.90	4.24	72.03	84.10	5.00	16.23
	By.	5.57	585.30	114.38	16.60	13.03	3.83	69.73	81.70	4.75	15.40
	Fet.	5.09	534.93	110.57	16.07	11.75	3.66	67.90	78.03	4.64	14.87
LSD. at 5%		NS	14.94	NS	NS	NS	0.34	NS	1.17	NS	0.22

NPK levels: L= Low (90:60:75), M= Medium (102:68:85) , H= High (120:80:100). Foliar compounds: FF. =Folifertile, By.=Byfolane, Fet.= Fertrilon combi.

its components as compared with the control treatment. The highest values of all the previous studied parameters were obtained by using folifertile followed by Byfolane, fetrilon combi and control in decreasing order. It is clear from the above results that foliar compounds increased signifi-cantly the average weight of tuber as well as the weight of tubers /plant as compared with control treatment. This effect means that foliar nutrition application led to an increase in plant yield through dry matter accumulation in the economic parts of potato tuber. Results agree with El-Zeiny (2002) found

that vegetative growth, data affected by foliar compounds which in turn increased carbohydrate, cell division and enlargement leading to more yield.

Generally, data indicated that different nutrient compounds favored the increase of vegetative and productive growth as well as yield and components of potato plants (Tables 3 and 4). The changes in the level of mineral nutrition of the above ground organs of plant are not attributed to the foliar absorption itself but to the effect of nutrients uptake by root system (Shereverga, 1959)

The results is supported by Abd- El-Hadi et al. (1998), on wheat, potato and sugar cane, El-Tohamy et al. (2007) on Snap beans and Hussein et al. (2008) on Fodder beet plants, they reported that foliar spray of micronutrients enhanced growth and increased the dry matter accumulation in different crops. The content of crude protein, monosugars, starch, carbohydrate, total soluble solids (T.S.S) and L. Ascorbic acid in plant tubers were significantly increased by using the three different foliar nutritional compounds comparing with the control treatment (Table 4), the highest values of the chemical composition were obtained by applying folifertile, Byfolan, fetrilon combi in decreasing order respectively.

The superiority of folifertile to other nutritional compounds is due to its higher content of macro and micronutrients especially nitrogen and suphur (Table 2), nitrogen may have affect on the uptake and photosynthetic surface, through increasing the number of cells / leaf and number of leaves / plant (El-Baz, 1967). Also, Dancs et al. (2008) indicated that sulphur could increase methionine content of tubers by co-expressing a gene involved in methionine synthesis, led to rich of storage protein in potato tubers.

It seems that when foliar nutritionals were used, the photosynthetic activity was stimulated, leading to enhancement of chemical constituents as crude protein, starch, carbohydrate, L-ascorbic acid and T.S.S in shoots which were afterwards translocated to the tubers. These effects may also due to the presence of micronutrients in the foliar compounds as Zn, Cu, Mn and B. Abou-Zied (1979) concluded that trace elements of folifertile might be mediated via the enzymatic systems responsible for biosynthetic apparatus, and thus rising sugars and nitrogen in intact plants. Furthermore, El-Bassiony et al. (2006) concluded that spraying sweet pepper plants with mixture of Fe, Mn and Zn led to increase in ascorbic acid (vitamin c), total acidity and as compared with the control treatment.

Effect of interaction between NPK levels and foliar compounds

The interaction between the NPK levels and the foliar nutritional compounds significantly affected weight of tubers/plant and percentage of mono sugars, carbohydrate and L-ascorbic acid, but did not affect other parameters of yield as well as the chemical constituents of potato plants (Table 4). The highest values of yield parameters and chemical constituents were obtained when the highest level of NPK was applied and sprayed potato plants with folifertile compound, while the lowest values were attained by using the lowest NPK level and sprayed plants with tap water.

Nutrients content in potato shoots and tubers at harvest

Effect of NPK levels

Data recorded in Table (5) indicated that all the studied nutrients in shoots and tubers of potato plants significantly increased with different levels of the added NPK levels. The highest level of NPK application gave the highest values of macro (N, P and K) as well as micronutrients (Fe, Mn, Zn and Cu) as compared with the medium and lowest levels of NPK. In this connection Abdalla (2002) found that N, protein, P and K contents of faba bean leaves were increased by increasing P level from 100 to 200 kg superphosphate/Fed.

Results are in agreement with those obtained by Moustafa et al. (2005), El-Ghamring and Saeed (2007 a, b) and Kamel, et al. (2008) who stated that increasing NPK levels significantly increased nutrients content and uptake of sugar beet, potato and wheat plants respectively. Also, Rohily et al. (2010) found that leaf nutrient concentrations were at or above the optimum levels for high yield, their study insured that, soil application rates of NPK at pre-planting were sufficient to produce an economical potato yield.

Generally macro and micronutrients in potato tubers were much lower than those obtained in potato shoots. In this case Abdel-Fattah et al. (2001) showed that the concentrations of P, K, Mn, Fe, Zn, Cu, Pb, Ni, Cd and Co in potato tubers were much lower than that in vegetative part especially after 90 days from planting.

Effect of foliar compounds

Data presented in Table (5) reveal that macro (N, P and K) and micronutrients (Fe, Mn, Zn and Cu) content in both vegetative shoots and tubers of potato plants at harvest were significantly higher by applying different foliar compounds than that of control treatment, except, nitrogen content in shoots and tubers as well as Cu content in shoots which their increase did not attain the level of significance at 5%. Highest values of N, P, K and Cu in shoots and tubers of potato plants were obtained by using folifertile as compared with other treatments. On the other hand the highest content of Fe, Mn and Zn, in shoots and tubers were attained by using fetrilon combi followed by folifertile, Byfolane and control in decreasing order. In this concern, Ahmed et al. (1998) stated that spraying macro and/or micro nutrients significantly

Table 5. Effect of NPK levels and foliar compounds on macronutrients (%) and micronutrients (ppm) content in potato shoot and tubers at harvest time.

Treatment		Shoot							Tuber						
		Macronutrients %			Micronutrients (ppm)				Macronutrients %			Micronutrients (ppm)			
		N	P	K	Fe	Mn	Zn	Cu	N	P	K	Fe	Mn	Zn	Cu
NPK levels															
L		3.31	0.350	4.68	121.31	68.07	32.22	21.15	1.77	0.340	2.63	40.08	12.17	26.25	7.08
M		3.50	0.389	4.93	124.87	71.89	34.62	23.38	1.88	0.360	2.72	42.17	13.50	29.34	7.92
H		3.64	0.415	5.09	128.29	76.89	36.98	26.79	1.99	0.378	2.84	45.33	15.08	30.00	8.75
LSD. at 5%		0.11	0.018	0.06	0.840	0.880	0.380	0.410	0.06	0.020	0.02	0.380	0.460	0.550	0.73
Foliar compounds															
Control		3.32	0.361	4.68	119.99	66.98	30.72	21.11	1.76	0.342	2.62	31.33	10.00	19.78	4.89
FF		3.74	0.417	5.26	126.60	73.90	35.62	28.11	2.17	0.386	2.93	46.56	14.44	31.22	10.00
By		3.53	0.388	4.91	121.72	69.94	32.75	24.51	1.84	0.364	2.71	43.78	13.00	29.56	9.89
Fet.		3.37	0.373	4.76	130.98	78.31	39.31	21.35	1.75	0.350	2.68	48.44	16.89	33.56	6.89
LSD at 5%		0.09	0.002	0.08	0.740	0.640	0.600	0.640	0.05	0.002	0.03	0.58	0.69	0.63	0.55
NPK levels × foliar compounds															
L	Control	3.20	0.320	4.50	117.07	62.57	27.97	18.87	1.68	0.330	2.54	27.33	8.67	17.67	4.33
	FF.	3.57	0.390	5.00	123.17	69.97	33.67	24.67	1.96	0.363	2.79	44.33	12.67	28.33	8.67
	By.	3.37	0.357	4.63	117.83	64.40	30.23	21.17	1.74	0.343	2.62	42.00	12.00	27.33	9.00
	Fet.	3.20	0.330	4.57	127.17	75.33	37.00	19.87	1.69	0.333	2.58	46.67	15.33	31.67	6.33
M	Control	3.33	0.370	4.70	120.00	66.43	31.00	20.63	1.78	0.342	2.61	32.00	9.670	20.33	5.000
	FF.	3.73	0.413	5.33	126.13	73.17	35.43	27.83	2.20	0.385	2.92	46.00	14.67	32.67	10.33
	By.	3.53	0.387	4.93	122.07	70.00	32.90	23.87	1.80	0.365	2.69	43.00	12.67	30.67	9.670
	Fet.	3.40	0.387	4.77	131.27	77.97	39.13	21.17	1.75	0.349	2.65	47.67	17.00	33.67	6.670
H	Control	3.43	0.393	4.83	122.90	71.93	33.20	23.83	1.82	0.353	2.70	34.67	11.67	21.33	5.330
	FF.	3.93	0.443	5.43	130.50	78.57	37.77	31.83	2.34	0.410	3.07	49.33	16.00	32.67	11.00
	By.	3.70	0.420	5.17	125.27	75.43	35.13	28.50	1.97	0.383	2.80	46.33	14.33	30.67	11.00
	Fet.	3.50	0.403	4.93	134.50	81.63	41.80	23.00	1.82	0.367	2.90	51.00	18.33	35.33	7.670
LSD. at 5%		NS	0.004	NS	NS	1.110	NS	1.110	0.09	NS	NS	1.00	NS	NS	NS

NPK levels: L= Low (90:60:75), M= Medium (102:68:85) , H= High (120:80:100). Foliar compounds: FF. =Folifertile, By.=Byfolane, Fet.= Fertrilon combi.

increased the leaf content of the sprayed element. In most cases the greatest content of N, P, K, Mg, Zn, Mn, Fe and Cu was presented in leaves picked from trees sprayed with micro and macro-nutrients together. They added foliar fertilizer namely fetrilon combi proved to be the best effect on Fe, Mn and Zn content in their experiment condition and they attributed this favourable effect to the higher content of fetrilon combi from Fe, Mn and Zn nutrients than the other foliar compounds. This means that foliar application of fertilizers induced increases in mineral status of plants and

is considered a useful way to correct the deficiency of nutrients specially under newly cultivated areas (Darwish et al., 2002); Thalooth et al., 2005, 2006; Gobarah et al., 2006).

Effect of interaction between NPK levels and foliar compounds

The interaction between NPK level and foliar nutritional compounds significantly affected P, Mn and Cu content in potato shoots, while it significantly affected N and Fe content of tubers and did not affect other nutrients in shoots and tubers of potato plants (Table 5).

The higher content of N, P, K and Cu in shoots and tubers were obtained by applying highest NPK level and spraying with folifertile compound, while the highest values of Fe, Mn and Zn contents in shoots and tubers were attained by using the higher level of NPK and sprayed by fetrilon combi. The lowest values of all nutrients content in shoots and tubers were obtained by spraying potato plants with tap water and using lowest level of NPK.

Conclusion

It can be concluded that foliar application of nutritional compounds under investigation had a beneficial role and appears to be of great importance in enhancing growth, yield and chemical constituents of potato plants. Folifertile showed the highest effect and fetrilon combi showed the lowest, while Byfolane showed a moderate effect in this respect. Combination between the highest NPK levels (120: 80: 100) and folifertile spraying, showed the most beneficial effects on potato yield.

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