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INFLUENCE OF VESICULAR ARBUSCULAR MYCORRHIZAE INOCULATION, NK FERTILIZATION AND MICRONUTRIENTS FOLIAR APPLICATION ON GROWTH, YIELD AND QUALITY OF POTATOES

BY

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ABSTRACT

This work was carried out in two successive summer plantations of 2004 and 2005 on potatoes cv. Spunta at Abou Awad village, Aga, Dakahlia Governorate, to study the influence of Vesicular Arbuscular Mycorrhizal (VAM) fungi, nitrogen and potassium fertilization at rates of 50, 75 and 100% of recommended rate/fed. with foliar spraying of micronutrients (Fe150, Zn 75, and Mn 75 ppm) and their interactions on plant growth, yield and its components, as well as chemical composition .

Application of the tested rates of nitrogen and the potassium induced significant increase in vegetative characteristics (plant height, foliage fresh and foliage dry weight) total tuber yield (t/fed), number of tubers/plant and tuber weight/plant, tuber dry matter, starch and nitrate content in tuber, as well as N,P and K concentrations in the leaves and micronutrients in the leaves (Fe, Mn and Zn) in both seasons.

Similarly, plant height, chlorophyll content, foliage fresh and dry weights, total yield (t/fed), number of tubers, tuber weight/plant, tuber dry weight, starch and nitrate content in tuber, NPK concentration in leaves and tubers, micronutrient content (Fe, Zn and Mn) in leaves gave the highest values with inoculation by VA Mycorrhizal fungi and some micronutrients .

The interaction between NK, VAM fungi and micronutrient gave the highest values of vegetative growth characteristics, number of tubers/plant, NPK in leaves and tubers and micronutrients (Zn and Mn) in leaves when potatoes was fertilized with 100% NK of the recommended rate and inoculate with VAM fungi plus foliar spraying by micronutrients (Fe, Zn and Mn).as well as total yield (t/fed), tuber weight/plant, tuber dry weight, starch content in tuber, Mn and Zn in leaves, while The lowest content of nitrate in tubers was found when plants were applied with 50 (%) NK of recommended rate with inoculation by VA Mycorrhizal fungi.

Generally, the best results were obtained when potato received 75 % of NK of the recommended rate, inoculated by VA Mycorrhizal fungi and sprayed with micronutrients at dose of Fe 150, Mn 75 and Zn 75 ppm. This treatment resulted in the highest total tuber yield and its components and reduced chemical fertilizer inputs.

Key words: Vesicular Arbuscular Mycorrhizal fungi, NK fertilizer, Micronutrients, Potatoes.

INTRODUCTION

Potato (*Solanum tuberosum* L.) is one of the most important vegetable crops in Egypt. It gained a considerable importance as an export crop to European markets and one of the national income resources. Taking the economical point into account, the high prices of chemical fertilizers may increase the production costs of potato production.

It is essential to use vesicular arbuscular mycorrhizae (VAM) as a biofertilizer to improve soil fertility and increase uptake of nutrients, especially N and P (Rechcigl, 1995). Mycorrhizal fungi are often associated with the roots of plants grown under conditions of low soil fertility. This relationship increases the ability of plants to absorb nutrients such as phosphorus, potassium, copper and zinc. Mycorrhizal colonization not only increases phosphorus uptake of many plants but also increases nitrogen (N) uptake in some species as well (Smith and Read, 1997)

Muromtsev *et al.* (1988) proved that shoot growth of some crops, including potatoes, increased in the presence of endomycorrhizal fungi. Iqbal *et al.* (1995) denoted that inoculation of potatoes with VAM fungi increased and improved plant growth compared with the untreated ones. Rai *et al.* (1990) stated that total yield of potato increased by 4.2 and 5.5 % by inoculation of plants with *Glomus mosseae* and *Glomus fasciculatum*, respectively. Linderman (1994) and Niemira *et al.* (1995) indicated that VA Mycorrhizae enhance productivity of potatoes.

Ghosh and Das (1998) pointed out that plant height and number of shoots/plant of potato increased considerably when plants were inoculated with both VAM and phosphate solubilizating bacteria. Hammad and Abdel-Ati (1998) and Adbel-Naem *et al.* (1999) mentioned that potato tubers of plants inoculated with *Azospirillum* and/or VAM fungi gave higher content of dry matter, NP concentration and uptake value. On the other hand, the same authors observed the reduction of nitrate contents of potato tubers via biofertilization with *Azospirillum* and VA-Mycorrhizal fungi. Vasatka and Gryndler (1999) found that inoculation of potato plants with VAM fungi increased the weight of the biggest tuber and the total weight of tubers. Awad (2002) revealed that inoculation of potato seed tubers with VAM fungi before planting markedly increased vegetative growth characteristics, total tuber yield, dry matter/plant and starch content in tubers.

Davies *et al.* (2005a and b) found that potato plants inoculated with mycorrhiza had greater plant growth and tuber yield than the non- inoculated. Saif

EL-Deen (2005) found that inoculation of sweet potato with VAM fungi led to significant increases in vegetative growth parameters, total yield. NPK contents in leaves and tuber roots.

Nitrogen is vitally an important plant nutrient and is frequently the most efficient of all nutrients. Brijlal and Sharma (1995) recorded that the application of K up to 75 kg/ha increased tuber yield compared with the control. Meena and Gupta (1996) found that the maximum plant height and dry matter were recorded with the application of 120 kg N/ha. Application of N fertilizers increased vegetative growth as well as yield and its components (Gaber and Srag, 1998; Ghoneim and Abdel-Razik, 1999; Tabatabel and Malakouti, 1999). El-Sawy *et al.* (2000) showed that application of K at 50 or 100 kg K_2O/fed has significantly increased stem length and number of leaves/plant of potato. Allison *et al.* (2001) indicated that potassium fertilizer had a significant effect on DM yield at rate 105 kg/ha. Belanger *et al.* (2002) recorded that nitrogen fertilization significantly increased both total and marketable yields, fresh weight and tuber N content.

Nofal (1998) and Nofal *et al.* (1998) reported that foliar fertilization with chelated micronutrients (2.8 % Fe, 2.8% Zn, 2.8 % Mn at 800 g/fed) gave the highest tuber yield and significantly affected N, K, Fe, Mn and Cu. Radwan and Tawfik (2004) reported that vegetative growth parameters and tuber yield significantly were increased by foliar application with Mn or Zn at 100 ppm while NPK contents of potato leaves and tubers were significantly increased with foliar spray by Mn and Zn at 200 ppm. Furthermore, starch content and specific gravity were increased.

The objectives of this study were to determine the effect of inoculation with arbuscular mycorrhizal fungi, NK fertilization rates and foliar application of micronutrients on growth, yield and quality of potatoes as well as to investigate the possibility of reducing of the mineral fertilizer application and avoid environmental pollution.

MATERIALS AND METHODS

This study was conducted during the two summer plantation of 2004 and 2005 at Abou Awad village, Aga, Dakahlia Governorate, Egypt.

Potato seed pieces tubers cv. Spunta (imported from Netherlands) average weight about 50 g .Each subplot was comprised of 4 ridges, 5 m length, 0.75 width 0.25 m spacing between plants, the subplot area was 15 m^2 . Planting dates were 15 and 18 on January in the first and second seasons, respectively.

Some physical and chemical properties of the experimental soil at the depth of 0-30 cm are shown in Table (1).

Vesicular arbuscular mycorrhizal fungi (VAM) were obtained from Mycology and Disease survey. Dept, Plant Pathology Res. Inst., Agric. Res. Center, Giza.

Table (1): Some physical and chemical properties of the experimental soil

Sand %	Silt %	Clay %	Texture	O.M %	$CaCO_3$ %	pH	Available nutrients (ppm)					
							N	P	K	Fe	Zn	Mn
25.4	32.0	41.0	Clayey	1.6	3.6	7.9	21.6	14.4	165	3.54	1.85	1.74

The inoculate suspension of VAM fungi as biofertilizer was diluted at rate of 1 to 200 before addition. Multi VA Mycorrhizal (*Glomus* spp & *Gigaspora* spp.). were used. The spore count was found to be 145 spore/ml.

Micronutrients: A mixture of compound cheated micronutrients, *i. e.*, Fe-EDTA (13%), Mn-EDTA (13%) and EDTA (15%).

Inorganic phosphorus was added in the form of calcium superphosphate (15.5 % P_2O_5) once during soil preparation at the rate of 75 kg P_2O_5/fed.

The experimental design

The experimental was split plot design with three replicates. Nitrogen and potassium with three levels (50, 75 and 100% kg/fed of the recommended rates/fed, i.e., 90 kg N + 48 kg K_2O, 135 kg N + 72 kg K_2O and 180 kg N + 96 kg K_2O/fed) were randomly distributed in main plots, ammonium nitrate (33.5%N)was added three equal rates after 4,6 and 8 weeks from planting date and potassium sulfate (48% K_2O) was added twice, one half with the first rates and second half with third rates of N fertilizer. subplots occupied for control, inoculated with vesicular arbuscular mycorrhizal (VAM) fungi (growing plants were inoculated with VAM) beside the plants with 100 ml/plant at 42 and 56 days after planting), mixture of micronutrients (Fe 150, 75 Mn and 75 Zn ppm) alone and mixture of micronutrients with inoculation (VAM) fungi the mixture of micronutrients were applied twice at 7 and 9 weeks after planting.

Data Recorded

1. Vegetative growth characteristics

Six plants were taken randomly from each plot at 75 days after planting (DAP) to determine: plant height (cm), number of main stems/plant and chlorophyll contents measured by a Minolta SPAD chlorophyll meter (Yadava, 1986).Chlorophyll reading were taken on the fifth leaf from the plant apex, foliage fresh weight (g)/plant and dry weight/plant (%).

2. Yield and its components

Total tuber yield (ton/fed), number of tubers/plant and tuber weight/plant were determined at harvest time (105 days after planting).

3. Tuber Quality

At harvest time, random samples of tubers were dried at 70°C until constant weight for dry matter (%) determination of starch content in tubers (%), Nitrate content in tubers (ppm dry weight basis) as recommended by Singh (1988).

4. Chemical Composition

The contents of N,P,K, Fe, Zn and Mn was determined in the fourth leaf from the plant top at 75 days after planting and NPK in tubers at harvesting time. Total nitrogen, phosphorus and potassium were determined according to the method described by Bremner and Mulvaney (1982), Fe, Zn and Mn were measured using atomic absorption spectorophotometer.

5. Assessment of mycorrhizal development

For VA mycorrhizal fungi analysis of roots, 1.0 cm root segments from five plants per treatment were sampled at harvest and pooled to assess colonization percentage (Phillips and Hyman, 1970). For spore counts, samples consisting of 100 g of soil from 5 plants per treatment were processed through glycerol floatation and spore extraction methods (Schenck, 1982).

Statistical analysis

Data were statistically analyzed and the means were compared by using LSD test as described by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

1. Vegetative growth characteristics

a- Effect of nitrogen and potassium rates

Data presented in Table (2) indicate that the vegetative growth of potato, *i. e.*, plant height, foliage fresh and dry weight were increased significantly by the addition N and K fertilizers in both seasons, and chlorophyll content in the first season only. However the number of stems/plant were not significantly influenced by nitrogen and potassium rate in both seasons. These results might be due to the role of nitrogen since it is a primary component of all nucleic acids, proteins, amino acids and chlorophyll . On the other hand, potassium is necessary for the activation of some enzyme systems, the translocation of carbohydrates, and for osmosis regulation. Therefore, N and K enhances the amount of metabolites necessary for building plant organs consequently the vegetative growth of plants (Westermann, 2005). The obtained results are in general agreement with those reported by Gaber and Srag (1998), Arisha and Bardisi (1999), Tabatabel and Malakouti (1999), and Belanger *et al.* (2002).

b- Effect of VA mycorrhizal fungi and micronutrients

Data in Table (2) show that inoculation of potatoes with VA mycorrhizae and foliar application of micronutrients either alone or in combination led to significant increases in plant height, chlorophyll content, fresh and dry weight compared with the control. Whereas, number of main stems/plant was not significantly affected in the second season only. The superiority effect of VA mycorrhizae could be explained on the basis of their role in growth supplying the nutrient and water uptake, disease resistance and greatly increased the rate of photosynthesis and phytohormones such as gibberllins, auxins and cytokinins which promoted plant growth as well as increased radiation interception and subsequent greater biomass production (Ali, 1999; Davies *et al.*2005 a and b). Similar results were obtained by Hammad and Abdel-Ati (1998). Awad (2002) found that inoculation of potatoes with VA mycorrhizae increased vegetative plant characteristics compared with untreated plant. The positive effect of micronutrients on vegetative growth characteristics might be due to their effects on transport of carbohydrates and regulation of meristematic activity, such functions would directly or indirectly contributed to plant growth (Srivastva and Gupta, 1996).

c- The interaction between N K and VA mycorrhizae and micronutrient

Data in Table (2) illustrate that the interactions between N K rates, VA mycorrhizae and micronutrients had insignificant effects on number of main stems/plant, fresh weight/plant, plant height in the second season and chlorophyll content in the first season (2004), however it affected significantly the application of 75 % NK, VA mycorrhizae and micronutrient gave the highest values dry weight in both seasons.

2. Yield and its components

a- Effect of nitrogen and potassium rates

Data illustrated in Table (3) show that total tuber yield (t/fed) and tuber weight/plant were significantly increased with increasing nitrogen and potassium rates in both seasons. The highest values of total yield and tuber weight/plant were produced when potato plant received 75% N + 75 % K_2O/fed. However, the highest number of tubers/plant was obtained at 100% N + 100 % K_2O/fed .These results might be due to the increase vegetative growth and dry matter contents (Table 2). It may also be stated that the sufficient application and the efficient absorption of N and K were coupled together to promote the production of more photosynthesis required for good tuber yield and its components. These results are in agreement with those reported by Brijlal and Sharma (1995), Vos (1997) and Meyer and Marcum (1998).

b- Effect of VA mycorrhizal fungi and micronutrient

The results in Table (3) reveal that colonization of potatoes with VA Mycorrhizae or the addition of micronutrient singly or combined significantly increased total tuber yield (t/fed), number of tubers/plant and tuber weight/plant compared with untreated plants, in the two seasons. The highest total yield was obtained by inoculated with VA Mycorrhizae combined with micronutrient addition. The percentage of increment in total tubers yield/fed. was 26.35 % and 26.38 in both seasons, respectively . These results might be attributed to be that the symbiotic fungi increase nutrients and water uptake, photosynthesis process which led to produce vigorous plant and yield components. These are in agreement with those obtained by Pfleger and Linderman (1994), Niemera *et al.* (1995), Hammad and Abdel Ati (1998), Abdel-Naem *et al.* (1999), Vasatka and Gryndler (1999), Awad (2002) and Davies *et al.* (2005a & b). They found that inoculation with VA mycorrhizae increased weight and size of tubers. Moreover, effect of micronutrient (Fe, Zn and Mn) on yield and its components might be attributed to their positive photosynthetic process and as an activator for IAA oxidase and carbohydrate assimilation. Nofal (1998) reported that foliar fertilization with chelated micronutrients gave the highest tuber yield.

Table (2): Vegetative growth characteristics as affected by NK rates, micronutrients, inoculation with VA mycorrhizae and their interactions during the two summer plantations 2004 and 2005.

Treatments	Characteristics	Plant height (cm)		Chlorophyll (SPAD unit)		No. of main Stems/plant		Fresh weight g/plant		Dry weight %	
		2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
NK rates											
	50%	46.62	44.48	53.83	52.83	2.50	2.50	273.00	267.75	11.45	11.37
	75%	52.50	48.12	55.50	54.63	2.64	2.50	313.83	306.25	13.11	13.13
	100%	54.92	52.49	53.78	53.04	2.69	2.55	306.33	301.08	12.92	12.84
	LSD 5%	0.80	1.30	0.76	NS	NS	NS	14.74	7.12	0.16	0.17
(VAM) & Micronutrients											
	Control	46.75	44.62	51.91	50.99	2.37	2.22	258.78	256.44	11.50	11.52
	Mycorrhizae (VAM)	52.47	49.95	54.44	53.51	2.63	2.55	306.56	299.67	12.95	12.88
	Micronutrients	49.88	46.83	54.19	54.10	2.59	2.66	296.78	289.78	12.20	12.13
	(VAM) + Micronutrients	56.30	52.05	56.93	55.41	2.85	2.63	328.78	320.89	13.32	13.26
	LSD 5%	0.91	1.35	0.84	0.74	0.32	NS	9.36	8.28	0.16	0.19
NK x (VAM) & Micronutrients											
50%NK	Control	44.20	42.14	51.53	50.77	2.22	2.11	225.00	223.33	10.17	10.06
	Mycorrhizae (VAM)	47.31	45.43	53.89	52.50	2.66	2.66	291.00	283.67	11.95	11.90
	Micronutrients	44.60	43.13	54.27	53.53	2.55	2.77	278.00	270.33	11.63	11.55
	(VAM) + Micronutrients	50.38	47.22	55.60	54.54	2.55	2.44	298.00	293.67	12.04	11.98
75%NK	Control	46.48	44.08	52.48	51.43	2.33	2.33	276.67	274.33	12.19	12.47
	Mycorrhizae (VAM)	54.39	50.73	55.15	54.78	2.55	2.44	320.33	312.00	13.52	13.43
	Micronutrients	52.15	45.85	55.10	54.64	2.66	2.55	309.67	302.33	12.61	12.56
	(VAM) + Micronutrients	57.00	51.80	59.26	57.65	3.00	2.66	348.67	336.33	14.14	14.05
100% NK	Control	49.57	47.63	51.72	50.77	2.55	2.22	274.67	271.67	12.13	12.05
	Mycorrhizae (VAM)	55.72	53.70	54.27	53.23	2.66	2.55	308.33	303.33	13.40	13.29
	Micronutrients	52.88	51.50	53.20	54.13	2.55	2.66	302.67	296.67	12.37	12.29
	(VAM) + Micronutrients	61.53	57.13	55.95	54.03	3.00	2.77	339.67	332.67	13.77	13.74
	LSD 5%	1.58	NS	NS	1.28	NS	NS	NS	NS	0.28	0.33

Table (3): Total tuber yield and its components as affected by NK rates, micronutrients, inoculation with VA Mycorrhizae and their interactions during the summer plantations 2004 and 2005.

Treatments \ Characteristics		Total yield ton/fed		No.of tuber/plant		Tuber weight g/plant	
		2004	2005	2004	2005	2004	2005
NK rates							
50%		12.01	11.94	4.12	3.93	596.01	572.62
75%		15.46	15.36	4.93	4.82	782.28	767.30
100%		15.03	14.91	5.18	5.13	761.83	743.00
LSD 5%		0.26	0.24	0.32	0.42	22.49	29.34
(VAM) & Micronutrients							
Control		12.37	12.24	4.11	4.07	639.76	619.52
Mycorrhizae (VAM)		14.64	14.54	4.67	4.60	726.62	708.04
Micronutrients		14.03	14.02	4.71	4.50	701.28	681.07
(VAM) + Micronutrients		15.63	15.47	5.48	5.34	785.82	768.60
LSD 5%		0.24	0.27	0.20	0.22	21.10	22.39
NK x (VAM) & Micronutrients							
50% NK	Control	9.81	9.75	3.43	3.34	493.40	481.67
	Mycorrhizae (VAM)	12.74	12.64	4.15	4.00	613.63	585.33
	Micronutrients	12.01	11.99	4.31	3.87	595.07	566.36
	(VAM) + Micronutrients	13.49	13.37	4.59	4.49	681.93	657.10
75% NK	Control	13.73	13.63	4.52	4.39	699.70	683.47
	Mycorrhizae (VAM)	15.91	15.81	4.90	4.83	798.87	787.02
	Micronutrients	15.09	15.04	4.67	4.58	768.43	755.03
	(VAM) + Micronutrients	17.13	16.94	5.63	5.48	862.10	843.70
100% NK	Control	13.59	13.35	4.38	4.49	726.17	693.43
	Mycorrhizae (VAM)	15.27	15.17	4.97	4.96	767.37	751.77
	Micronutrients	15.01	15.02	5.15	5.04	740.33	721.80
	(VAM) + Micronutrients	16.27	16.10	6.21	6.05	813.43	805.00
LSD 5%		0.42	0.47	0.35	NS	36.54	NS

c- The interaction between N K rates, VAM fungi and micronutrient

Concerning the interaction between N K rate, VAM fungi and micronutrient on potatoes yield and its components, data in Table (3) reveal that there was significant effect on total tuber yield in both season and number of tuber/plant and tuber weight/plant in the first season only. The maximum total yield was obtained when potato plants were fertilized with 75% NK, inoculated with VA mycorrhizae and foliar sprayed by micronutrient compared with untreated ones. The percentage increased in total tuber yield/fed was 19.72 % and 20.60 %in the first and second season, respectively Similar results was reported with Saif EL-Deen (2005).

3. Tuber quality

a- Effect of N and K rates

The results in Table (4) demonstrate that tuber dry weight and starch percentages and nitrate content were significantly affected by addition of N K rates in the two growing seasons. The highest values of dry matter and starch content were obtained at 75% N K_2O of the recommended rate/fed . While the lowest level of nitrate in potato tubers (85.58 and 73.58 ppm, in both seasons, respectively) was recorded in the potato tuber applied with 50 % N K_2O of the recommended rate/fed. On the other hand, the highest level of nitrate (116.33 and 101.67 ppm) was detected in potato tubers produced with 100 % N K_2O of the recommended rate/fed. These results may be due to the relationship between NO_3^- N concentration which increased with increasing nitrogen fertilization (Belanger *et al.*, 2002).

Table (4): Dry matter, starch and nitrate contents in tuber as affected by NK rates, micronutrients, inoculation with VA Mycorrhizae and their interactions during the summer plantations 2004 and 2005.

Characteristics / Treatments		Dry weight %		Starch % in tubers		Nitrate content in tubers(ppm)	
		2004	2005	2004	2005	2004	2005
NK rates							
50%		17.08	16.93	11.77	11.47	85.58	73.58
75%		18.34	18.19	12.99	12.84	105.08	94.75
100%		18.05	17.91	12.62	12.44	116.33	101.67
LSD 5%		**0.17**	**0.12**	**0.25**	**0.24**	**3.39**	**2.49**
(VAM) & Micronutrients							
Control		16.51	16.33	11.28	10.91	116.00	102.00
Mycorrhizae (VAM)		17.92	17.76	12.99	12.80	88.22	78.22
Micronutrients		17.86	17.73	12.24	12.07	105.78	90.33
(VAM) + Micronutrients		19.01	18.89	13.33	13.21	99.33	89.44
LSD 5%		**0.26**	**0.23**	**0.27**	**0.17**	**4.03**	**3.24**
NK x (VAM) & Micronutrients							
50% NK	control	16.20	15.99	10.48	9.97	101.00	85.00
	Mycorrhizae (VAM)	17.68	17.54	12.43	12.19	64.33	57.33
	Micronutrients	16.70	16.58	11.47	11.23	92.00	78.33
	(VAM) + Micronutrients	17.75	17.60	12.70	12.48	85.00	73.67
75% NK	control	16.73	16.57	11.82	11.59	119.67	109.00
	Mycorrhizae (VAM)	18.12	18.00	13.42	13.18	92.00	85.33
	Micronutrients	18.58	18.43	12.77	12.67	107.33	95.00
	(VAM) + Micronutrients	19.93	19.78	13.97	13.91	101.33	89.67
100% NK	Control	16.60	16.43	11.53	11.18	127.33	112.00
	Mycorrhizae (VAM)	17.95	17.73	13.12	13.02	108.33	92.00
	Micronutrients	18.29	18.18	12.50	12.32	118.00	97.67
	(VAM) + Micronutrients	19.34	19.30	13.33	13.23	111.67	105.00
LSD 5%		**0.44**	**0.38**	**NS**	**NS**	**6.98**	**5.62**

b- Effect of VA mycorrhizal fungi and micronutrient

Presented data in Table (4) show also, that the effect of inoculation with VAM fungi and foliar spraying of micronutrient each alone or in combination significantly affected on percentage of dry matter and starch in potato tubers in both seasons. The highest percentages of dry matter and starch in potato tuber were obtained by inoculation with VAM and micronutrients application. These results may be attributed to improving mineral nutrition uptake and increasing the photosynthetic efficiency (Awad, 2002, Davies *et al.*, 2005a & b). Moreover, micronutrient efficiency involvement in one or more of important biological functions such as synthesis of chlorophyll, electron transport system, protein synthesis and IAA oxidase. These results are in agreement with those of Nofal *et al.* (1998), Radwan and Tawfik (2004) and Hiller (2005).

c- The interaction between N K rates, VA mycorrhizae and micronutrient

Data presented in Table (4) show that the interaction between N K rate with inoculation by VAM fungi as biofertilizers and foliar spraying micronutrient caused significant increase on percentage of dry matter and nitrate content (ppm) potato tubers in both seasons. However, no significant effect on starch percentage potato tuber in the two growing seasons. These results are in line with Saif EL-Deen (2005) who found that inoculation of sweet potato with VAM fungi and micronutrient application gave the highest significant increase in dry matter and total carbohydrates.

4- Chemical composition

a- Effect of nitrogen and potassium rates

Data in Table (5) clearly illustrate that the addition of nitrogen and potassium significantly affected the contents N P and K in the leaves and tubers The highest values of these macronutrients were obtained from the application of 100 % N K of recommended rate, in the two seasons.

Data in Table (6) indicate that Fe, Zn and Mn contents in the leaves were significantly increased by increasing the N and K_2O rates. Potato plants fertilized with 100 % N and K of recommended rate gave the highest value of Fe, while potato plant fertilized with 75 % N and K_2O of recommended rate/fed gave the highest value of Zn and Mn contents compared with 50 % of recommended rate in both seasons. These results may be due to the effect of N and K_2O on plant growth and consequently on the efficiency of the root in absorbing various nutrients. The obtained results are in agreement with those reported by Allison *et al.* (2001) and Westermann (2005).

b- Effect of VA mycorrhizal fungi and micronutrient

As regard to the effect of VA Mycorrhizae and micronutrients on chemical composition of the leaves and the potato tuber, data in Table (5) indicate that the inoculation with VA Mycorrhizae combined with foliar application of micronutrients caused the highest significant increase in N P K of both leaves and tubers compared with the untreated control.

Table (5): Percent N, P and K in the leaves and tubers as affected by NK rates, micronutrients, inoculation with VA Mycorrhizae and their interactions during the summer plantations 2004 and 2005.

Characteristics / Treatments		N% in leaves		N% in tubers		P% in leaves		P% in tuber		K% in leaves		K% in tubers	
		2004	2005	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
NK rates													
50%		1.77	1.71	1.46	1.40	0.323	0.313	0.274	0.253	1.87	1.86	1.65	1.62
75%		2.11	1.93	1.94	1.90	0.405	0.391	0.345	0.310	2.23	2.22	2.08	2.02
100%		2.41	2.31	2.01	1.95	0.501	0.485	0.424	0.397	2.49	2.48	2.11	2.06
LSD 5%		**0.07**	**0.20**	**0.031**	**0.043**	**0.016**	**0.010**	**0.014**	**0.020**	**0.058**	**0.081**	**0.040**	**0.044**
(VAM) & Micronutrients													
Control		1.84	1.80	1.56	1.51	0.324	0.313	0.264	0.247	1.93	1.92	1.72	1.68
Mycorrhizae (VAM)		2.20	2.09	1.92	1.84	0.439	0.429	0.383	0.347	2.32	2.31	2.07	2.03
Micronutrients		2.03	1.96	1.75	1.71	0.386	0.366	0.320	0.290	2.13	2.11	1.84	1.79
(VAM) + Microelements		2.31	2.08	1.99	1.93	0.489	0.478	0.423	0.396	2.41	2.40	2.15	2.10
LSD 5%		**0.060**	**0.189**	**0.054**	**0.058**	**0.014**	**0.018**	**0.019**	**0.017**	**0.050**	**0.059**	**0.048**	**0.048**
NK x (VAM) & Micronutrients													
50% NK	Control	1.54	1.55	1.15	1.11	0.227	0.223	0.183	0.177	1.66	1.65	1.50	1.47
	Mycorrhizae (VAM)	1.85	1.78	1.56	1.48	0.370	0.363	0.330	0.303	1.94	1.93	1.67	1.63
	Micronutrients	1.75	1.68	1.43	1.38	0.297	0.277	0.237	0.210	1.86	1.82	1.59	1.56
	(VAM) + Micronutrients	1.92	1.84	1.71	1.61	0.397	0.390	0.347	0.320	2.03	2.02	1.83	1.81
75% NK	Control	1.92	1.83	1.74	1.67	0.350	0.337	0.290	0.260	1.98	1.97	1.81	1.76
	Mycorrhizae (VAM)	2.25	2.13	2.07	2.00	0.440	0.430	0.377	0.337	2.49	2.46	2.27	2.20
	Micronutrients	2.01	1.96	1.87	1.84	0.373	0.353	0.317	0.283	2.13	2.11	1.95	1.89
	(VAM) + Microelements	2.25	1.79	2.11	2.07	0.457	0.443	0.397	0.360	2.33	2.32	2.29	2.22
100% NK	Control	2.06	2.00	1.79	1.74	0.397	0.380	0.320	0.303	2.15	2.13	1.84	1.81
	Mycorrhizae (VAM)	2.49	2.37	2.13	2.05	0.507	0.493	0.443	0.400	2.53	2.55	2.28	2.25
	Micronutrients	2.34	2.24	1.94	1.91	0.487	0.467	0.407	0.377	2.41	2.40	1.98	1.91
	(VAM) + Micronutrients	2.76	2.62	2.17	2.12	0.613	0.600	0.527	0.507	2.87	2.85	2.34	2.26
LSD 5%		**0.104**	**NS**	**NS**	**NS**	**0.025**	**0.031**	**0.032**	**0.029**	**0.086**	**0.103**	**0.083**	**0.082**

Table (6): Contents of Fe, Zn and Mn in potato leaves as affected by NK rates, micronutrients, inoculation with VA Mycorrhizae and their interactions during the summer plantations 2004 and 2005.

Treatments \ Characteristics		Fe in leaves ppm 2004	Fe in leaves ppm 2005	Mn in leaves ppm 2004	Mn in leaves ppm 2005	Zn in leaves ppm 2004	Zn in leaves ppm 2005
NK rates							
50%		73.25	69.92	43.08	41.33	62.67	60.00
75%		90.42	87.67	62.42	59.33	75.00	72.25
100%		108.25	104.08	58.08	55.50	69.42	66.08
LSD 5%		2.12	4.65	1.68	0.60	2.20	1.89
(VAM) & Micronutrients							
Control		69.44	66.44	32.33	30.00	46.22	43.56
Mycorrhizae (VAM)		87.67	84.00	49.33	47.67	61.00	58.11
Micronutrients		95.89	92.56	61.44	58.33	77.11	74.67
(VAM) + Micronutrients		109.56	105.89	75.00	72.22	91.78	88.11
LSD 5%		3.15	4.09	2.62	2.45	2.73	3.23
NK x (VAM) & Micronutrients							
50% NK	Control	44.67	41.33	28.67	26.33	40.00	38.00
	Mycorrhizae (VAM)	71.00	67.00	42.00	41.33	57.33	54.67
	Micronutrients	82.00	79.00	48.33	46.00	73.00	70.33
	(VAM) + Micronutrients	95.33	92.33	53.33	51.67	80.33	77.00
75% NK	Control	73.67	70.00	33.67	31.67	50.33	47.00
	Mycorrhizae (VAM)	88.00	86.00	55.00	52.67	64.67	60.00
	Micronutrients	94.00	91.67	72.33	67.33	84.00	82.67
	(VAM) + Micronutrients	**106.00**	**103.00**	**88.67**	**85.67**	**101.00**	**99.33**
100% NK	Control	90.00	88.00	34.67	32.00	48.33	45.67
	Mycorrhizae (VAM)	104.00	99.00	51.00	49.00	61.00	59.67
	Micronutrients	111.67	107.00	63.67	61.67	74.33	71.00
	(VAM) + Micronutrients	127.33	122.33	83.00	79.33	94.00	88.00
LSD 5%		5.45	7.08	4.54	4.24	4.73	5.59

Data in Table (6) reveal that inoculation with VA mycorrhizae as biofertilizer mixture with foliar spraying had significant positive effect on Fe, Zn and Mn in leaves of potato in the two seasons compared with the control. The superiority effect of VAM fungi may be due to extending the effective volume from which plant roots take up nutrients. This process is most important for ions that move the root by diffusion. Moreover,it may attributed to the effect of micronutrients on stimulating biological activities, i.e., enzyme activity, rate of photosynthetic products and increasing nutrient uptake through roots after application. (Radwan and Tawfik, 2004, Hiller *et al.*, 2005 and Davies *et al.*, 2005a & b).

c- The interaction between N K rates, VAM fungi and micronutrient

Results in Table (5) reveal that the interaction between N K rate, VAM fungi and micronutrient on contents of N, P and K in leaves and tubers of potato plants was significant. The highest values N, P and K in the leaves and tubers obtained when plants fertilized with 100 % NK, inoculated with VA mycorrhizae in the presence of foliar addition of micronutrients. However, N content in tubers in both seasons and leaves in second season was not significant.

Data in Table (6) show that the interaction among N K rate, VAM fungi and foliar application of micronutrient on micronutrients in the leaves of potato plants, had significant effect on micronutrients (Fe, Zn and Mn), in both seasons. The maximum values of Fe, Zn and Mn were recorded at of N and K_2O fertilizers of recommended rate under inoculation by VA mycorrhizae with application of micronutrients (Fe, Zn and Mn) .

5. Assessment of mycorrhizal development

The obtained results in Table (7) demonstrate that percentage of potato plant root colonization with VA mycorrhizal fungi were greater at used 75 % N K with inoculation by VA mycorrhizal and foliar application of micronutrient on potato plants, followed by 75 % N K with inoculation by VAM fungi alone, while the highest values of number of spores in rhizosphere were noticed when potato plants ware fertilized at the rate of 75 % NK of recommended rates under inoculation with VA mycorrhizae compared to control. Similar results were reported by (Davies *et al.*2005 a and b).

Table (7): Percentage of potato roots colonization with mycorrhizae and number of spores g/soil in the rhizosphere.

Treatments		Colonization %	No. Spores/g soil
50% NK	Control	42..4	28
	Mycorrhizae (VAM)	66.5	74
	Micronutrients	60.0	58
	(VAM) + Micronutrients	70.6	73
75% NK	Control	46.2	37
	Mycorrhizae (VAM)	72.3	98
	Microelement	56.4	66
	(VAM) + Micronutrients	79.8	85
100% NK	Control	40.2	33
	Mycorrhizae (VAM)	65..4	62
	Micronutrients	593	54
	(VAM) + Micronutrients	66.8	59

CONCLUSION

Generally, the obtained results indicated that colonization of potatoes with mycorrhizal fungi serve as a biofertilizer, when combined with foliar spraying with mixture of Fe 150, Zn 75 and Mn 75 ppm and application at the rate of 135 kg N + 72 kg K_2O/fed gave the highest total tuber yield. Hence, there are excellent opportunities to utilize and manipulate mycorrhizal fungi to enhance crop productivity and reduced agricultural chemical inputs. Beneficial mycorrhizal fungi are one of the important cornerstones of sustainable agricultural system. They can make plants more efficient in utilizing available soil water, fertility and plant productivity.

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تأثير التلقيح بفطر الميكوريزا ومعدلات من التسميد الأزوتي والبوتاسى والرش ببعض المغذيات الصغرى على النمو والمحصول والجودة فى البطاطس

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تم إجراء تجربتين حقليتين ناجحتين في عروتين حقليتين متتاليين ٢٠٠٤ و٢٠٠٥ على محصول البطاطس صنف سبونا بقرية أبو عوض – أجا – بمحافظة الدقهلية ، لدراسة تأثير التلقيح بفطر الميكوريزا وثلاثة معدلات من التسميد النيتروجيني والبوتاسى هى ٥٠ ، ٧٥ ، ١٠٠ % من المعدل الموصى به للفدان ، مع الرش الورقى ببعض المغذيات الصغرى (حديد ١٥٠ ، زنك ٧٥ ، منجنيز ٧٥ جزء في المليون) ، معا وتفاعلاتهم على النمو والمحصول ومكوناته بالإضافة إلى المحتوى الكيميائى. وأظهرت النتائج المتحصل عليها ما يلي:

أدت إضافة معدلات من النيتروجين والبوتاسيوم إلي حدوث زيادة معنوية فى الصفات الخضرية (طول النبات ، الوزن الطازج للنبات والنسبة للوزن الجاف)

والمحصول الكلى (طن/فدان) ، وعدد ووزن الدرنات للنبات والنسبة المئوية للمادة الجافة والنشا ومحتوى النترات فى الدرنات بالإضافة إلى تركيز النيتروجين والفوسفور والبوتاسيوم فى الأوراق والدرنات وكذلك المغذيات الصغرى (حديد – زنك – منجنيز) في الأوراق في كلا الموسمين.

أوضحت النتائج أيضا أن التلقيح بفطر الميكوريزا مع الرش بالمغذيات الصغرى (حديد – زنك – منجنيز) أدت إلى زيادة فى طول النبات ومحتوى الكلوروفيل فى الأوراق والوزن الطازج للنبات والنسبة المئوية للوزن الجاف والمحصول الكلى (طن/فدان) وعدد ووزن الدرنات للنبات والنسبة المئوية للمادة الجافة والنشا ومحتوى النترات فى الدرنات وتركيز النيتروجين والفوسفور والبوتاسيوم ومحتوى العناصر الصغرى فى الأوراق .

و قد أعطت التفاعلات بين النيتروجين والبوتاسيوم والتلقيح بفطر الميكوريزا مع الرش و بعض المغذيات الصغرى أعلى قيم للصفات الخضرية وعدد الدرنات للنبات ومحتوى النيتروجين والفوسفور والبوتاسيوم فى الأوراق والدرنات والعناصر الصغرى (زنك – منجنيز) فى الأوراق عند تسميد محصول البطاطس بـ ١٠٠ % من النيتروجين والبوتاسيوم مع التلقيح بفطر الميكوريزا + الرش بالعناصر الصغرى (حديد – زنك – منجنيز). وكذلك المحصول الكلى (طن/فدان) ووزن الدرنات للنبات ومحتوى المادة الجافة والنشا فى الدرنات والزنك والمنجنيز فى الأوراق . بينما كانت أقل القيم فى محتوى النترات فى الدرنات عند معدل ٥٠ % من المعدل الموصى به مع التلقيح بفطر الميكوريزا.

و بصفة عامة فإن أحسن النتائج التي حصل عليها هي تسميد محصول البطاطس بـ ٧٥ % من النيتروجين والبوتاسيوم من المعدل الموصى به للفدان (١٣٥ كجم ن + ٧٢ كجم بو٢أ) مع التلقيح بفطر الميكوريزا والرش ببعض العناصر الصغرى عند (١٥٠ حديد ، ٧٥ زنك ، ٧٥ منجنيز جزء في المليون). حيث أعطت أعلى القيم للمحصول الكلى ومكوناتة مع ترشيد أستخدام التسميد المعدنى.