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EFFECT OF NPK AND BIOERTILIZER TYPES ON VEGETATIVE GROWTH, TUBER YIELD AND QUALITY OF POTATO

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ABSTRACT

Two field experiments were carried out during the summer seasons of 2000 and 2001, at the Experimental station Farm, Faculty of Agriculture, Alexandria University, at Abies, to investigate the response of potato plants cv. Alpha, to two biofertilizer types (Nitrobein and Halex-2) under four varying percentages NPK; 25%, 50%, 75% and100% from the commercial recommended rates (180-60-96 Kg N-P-K fed^{-1}). The results indicated that increasing NPK applied rate or inoculation with Halex-2 biofertilizer was accompanied with significant increases in plant height, number of branches and leaves, fresh weight and leaf area plant^{-1} . The mineral contents of leaves (N-P-K) were positively and significantly responded as a result of increasing NPK application percent. Halex-2 appeared to be more effective than Nitrobein in this respect. Moreover, yield potential; i.e., total yield fed^{-1}, number of tubers plant^{-1} and average tuber weight were increased due to the application of 75% of the recommended NPK or biofertilizer inoculation treatments, particularly Halex-2 biofertilizer. The treatments enhanced most tuber quality characteristics (percentages of large and medium tuber sized, T.S.S. and total carbohydrates). Application of 75% of the recommended NPK level combined with Halex-2 biofertilizer appeared to be the most commercial and efficient treatment combination which gave balanced vegetative growth and higher yield potential with a best tuber quality. This particular treatment significantly produced higher yield (the increment in the total yield fed^{-1} was 19.8%, as average of the two seasons) than that obtained from the application of 180- 60- 96 Kg NPK fed^{-1} without

biofertilizer, as well as saved 25% from potato plants requirements of NPK fertilizers.

INTRODUCTION

Potato (*Solanum tuberosum*, L.) is one of the most popular food crops. In Egypt, it occupies an important position among vegetable crops for local consumption, processing, and exportation.

Nutrition is essential in determining potato yield and quality, as well as influencing the potato plant's ability to withstand negative effects from pests, water, temperature, and other stresses. Nitrogen, along with Phosphorus and potassium, are classified as primary macronutrient, which are needed in relatively large quantities and are often deficient in crops not receiving fertilizer application (Marschner, 1986). Fertilizer requirements of potato are quite high due to its high yielding potential per unit area and time. Nitrogen is a constituent of all proteins, many metabolic intermediates, and of nucleic acids (Goh and Haynes, 1986; Salisbury and Ross, 1991). Potatoes are known to be heavy feeders of nitrogen (Singh, 1995; Veeranna *et al.,* 1997). Moreover, phosphorus (P) is used in the plant for energy storage and transfer, maintenance and transfer of genetic code, and is structural component of cells and many biochemicals. Phosphorus deficiencies result in poor root growth, stunted top growth, reduced yield and crop quality, and delayed maturity. Also, potassium plays a major role in many physiological and biochemical processes as cell division and elongation, enzyme activation, synthesis of simple sugars and starch and accelerating translocation of carbohydrate necessary for tuber formation and development (Marschner, 1986). Many investigators illustrated that vegetative growth and tuber yield and quality characters of potato plants were increased by increasing NPK rates (Awad ,1997; Ashour and Sarhan, 1998; Hammad and Abdel-Ati ,1998 and Arisha and Bardisi 1999).

The excessive use of inorganic fertilizers represents the major cost in plant production and creates pollution of agro-ecosystem, as well as deterioration of soil fertility (Fischer and Richter, 1984). Under these circumstances, substitution of inorganic fertilizer with organic source is needed, especially those of microbial origin. The favorable effects of biofertilizer on vegetative growth, tuber yield and quality characters of potato have been reported by many investigators (Choudhary *et al*., 1984; Terry *et al*., 1996; Abdel–Ati *et al*.,1996; El-Gamal, 1996; Ashour *et al*., 1997 ; Awad *et al.* ,2002). Ghoneim and Abdel-Razik (1999) reported that treating potato tuber seeds with biofertilizer (Halex-2) improved most vegetative growth characters and yield potential of potato. Little information is available on the magnitude of potato responses to biofertilizer application or on the interactions between bio-and-chemical fertilization on potato plants.

The present study was conducted to investigate the effect of biofertilizer types under varying levels of NPK on vegetative growth, tuber yield and quality characteristics of potato plants under the prevailing conditions of Alexandria.

MATERIALS AND METHODS

Two field experiments were carried out, during the two summer seasons of 2000 and 2001 at the Agricultural Experimental Station Farm (at Abis), Faculty of Agriculture, Alexandria University, to find out the response of potato plants cv. “Alpha” to inoculation with Nitrobein and Halex-2 biofertilizers under varying NPK rates. Preceding the initiation of each experiment, soil samples of 30 cm depth were collected and analysed according to the published procedures of Page *et al.*(1982). Results indicated that the experimental site had total N = 0.18 and 0.15 % , P= 0.12 and 0.15% , exchangeable K = 20 and 22 meq $L.^{-1}$, E . C = 3.32 and 3.28 ds. $m.^{-1}$, pH = 7.89 and 8.15 and organic matter = 0.89 and 0.98 % in 2000 and 2001 , respectively . Each experiment included twelve treatments, representing all combinations of four NPK rates; 25%, 50%, 75% and 100% from the commercial recommended level (180-60-96 Kg NPK fed^{-1} , according to the recommendations of the Ministry of Agriculture, Egypt.) and three biofertilizer treatments, i.e., inoculation with two variant types of biofertilizers; Nitrobein and Halex-2, as well as the non-inoculated; control.

The biofertilizer Halex-2; a mixture of non-symbiotic N-fixing bacteria of genera *Azotobacter*, *Azospirillum* and *klebsiella*; was obtained from the Biofertilization Unit, Plant Pathology Department, Fac. Agric., Alex. Univ.; whereas, the biofertilizer Nitrobein; a single strain of non-symbiotic N-fixing bacteria of genus *Azospirillum*; was obtained from the Biofertilization Unit, Ministry of Agriculture, Egypt. Halex-2 and Nitrobein biofertilizers were utilized at the rate of 200 and 500 g fed^{-1}, respectively. The inoculation process was performed by immersing the tuber seeds in a Halex-2 or Nitrobein cells suspension containing 5% Arabic gum, for 15 minutes just before planting. The inoculation process was again repeated six weeks later as a side dressing beside the seed pieces. Tuber seeds of the uninoculated control were dipped in distilled water containing 5% Arabic gum for the same time. Imported potato tuber seeds were used. Seed tuber pieces were sown in rows 4 m long, 0.7m apart and 25 cm between hills, on January 28 and 31, 2000 and 2001, respectively. The experimental layout was a split–plot system in a randomized complete blocks design with three replications. NPK rates; 45-15-24, 90-30-48, 135-45-72 and 180-60-96 kg NPK fed^{-1}, were randomly arranged in the main plots, meanwhile, biofertilizer treatments were randomly distributed in the sub–plots. Each sub-plot consisted of 3 rows and each two adjacent plots were separated by a guard row. Nitrogen application was achieved in the form Ammonium sulphate (20.5 % N) at three equal applications; 6, 8 and 10 weeks after planting. P as calcium superphosphate (15.5% P_2O_5) was broadcasted, as single placement, during soil preparation; while, K as potassium sulphate (48% K_2O) was applied in two equal applications; 8 and 10 weeks after planting. Recommended agriculture practices were followed as commonly used in the commercial production of potato

Data Recorded

Vegetative growth characters; a random sample of five potato plants was taken from the first row of each sub-plot, after 90 days of planting to measure plant height (cm), count number of main stems and leaves, determine leaf area (cm^2), and weigh fresh weight (g) plant^{-1}.

Mineral contents of leaves; from the some plant sample taken for recording the vegetative features, random samples of the youngest expanded mature leaves, were collected, washed with distilled water, weighed, oven dried at 70 °C till constant weight. The dried leaf materials were grind and homogenized, wet digested; using concentrated sulfuric acid and H_2O_2, and the contents of N, P and K were determined according to the methods described in FAO (1980).

Tubers yield and quality characters; harvest was carried out 120 days after planting. The harvested tubers from the 2nd and 3rd rows of each experimental unit were weighed, counted, graded into three sizes according to their diameter; small (< 30 mm), medium (30- 60mm) and large (> 60mm), as well as potato cull. Number and weight of tuber plant^{-1} in addition to total tuber yield fed^{-1} and average tuber weight were calculated. At the same time, tuber sample from each sub-plot was saved, to determine total soluble solids (T.S.S) using a hand refractometer, total carbohydrates as outlined by Malik and Singh (1980) and tuber dry matter content.

All obtained data of the present study were, statistically, analyzed according to the design applied using Costat software (1985). The comparisons among means of the different treatments were carried out, using the Revised L.S.D. test as illustrated by El-Rawi and Khalf-Allah (1980).

RESULTS AND DISCUSSTION

Vegetative Growth Characters

The results presented in Table 1, generally, clarified the presence of significant increments on all studied vegetative growth characters of potato plants as a result of increasing the rates of NPK application, in 2000 and 2001 seasons. The gradual increment of NPK application up to the rates of 135-45-72 kg NPK fed^{-1} resulted in significant increases on plant height, number of branches and leaves, vegetative fresh weight and leaf area plant^{-1}. However, in both seasons, the differences between 135-45-72 and 180-60-96 kg NPK fed^{-1} did not reflect any beneficial effect on vegetative growth traits. The enhancing effects of NPK on vegetative growth might be attributed to their vital contribution in several metabolic process in plants, related to growth (Marschner, 1994) and to their role in increasing meristemic activities and consequently the vegetative growth of potato plants (Awad *et al.* ,2002). These results are in accordance with those obtained by Arisha and Bardisi (1999) and El-kader (2002) who found that increasing NPK levels have an important role in enhancing the vegetative growth of potato plant.

Concerning the effect of inoculation potato tuber seeds with biofertilizer, data in Table (1) showed that Halex-2 biofertilizer, significantly, gave higher magnitudes of plant height, number of leaves, vegetative fresh weight and leaf area of potato plant than the Nitrobein or the non-inoculated control, in both seasons. However, number of branches plant^{-1} was not affected. The beneficial effects of biofertilizers on vegetative growth traits of potato may be related to the promotion effects of the non-symbiotic N_2-fixing bacteria on morphology and / or physiology of the root system; which, perhaps, resulted in a more efficient utilization of available nutrients in the soil, favoring the vegetative growth to go more forward. Jagnow *et al*. (1991) and Noel *et al*. (1996) pointed out that the non-symbiotic N_2-fixing bacteria, *Azotobacter* and *Azospirillum*, produced adequate amounts IAA, gibberellins and cytokinins, and synthesized of some vitamins. Moreover, they increased the surface area per unit root length and enhanced the root hair branching with an eventual increase on the uptake of nutrient and water from the soil. Carletti *et al*. (1996) demonstrated that the plants, inoculated with *Azospirillum*, displayed an increase on total root length by 150%, compared to the uninoculated control. Furthermore, Apte and Shende (1981) reported that the inoculation substances might change the microflora in the rhizosphere and affect the balance between harmful and beneficial organisms. Similar findings were recorded by Choudhary *et al*.(1984), Terry *et al*.(1996) and Ashour *et al*.(1997).

The interaction effects of various NPK rates and biofertilizer types on the growth characters growth of potato plants were found significant, in both seasons (Table 1). The best significant result for the plant height, number of leaves, fresh weight and leaf area plant^{-1} were attained due to the combined application of 135-45-72 kg NPK fed^{-1}

with the biofertilizer Halex- 2, in both seasons. Meanwhile, it was also noticed that the highest mean values of number of branches plant^{-1} was recorded as a result of the application of 135-45-72 kg NPK fed^{-1} in the presence of Nitrobein. These results appeared to be in close agreement with previous results reported by El-Gamal (1996) and Hammad and Abdel-Ati (1998).

Table (1):Effect of NPK level, inoculation with biofertilizer and their interaction on vegetative growth characters of potato plants during the summer seasons of 2000 and 2001.

Treatments		2000					2001				
N-P-K rate kg fed^{-1}	Biofertilizer	Plant height (cm)	No. branches plant^{-1}	No. Leaves plant^{-1}	Fresh Weight plant^{-1} (g)	Leaf Area plant^{-1} (cm^2)	Plant height (cm)	No. branches plant^{-1}	No. leaves plant^{-1}	Fresh Weight Plant^{-1} (g)	Leaf Area Plant^{-1} (cm^2)
45-15-24		55.9B	3.30B*	36.7C	291.5D	570.2D	53.5B	3.32B	37.6C	300.0D	573.3D
90-30-48		57.5B	3.42B	40.5B	314.4C	683.4C	55.1B	3.44B	40.2B	329.6C	660.1C
135-45-72		58.9A	3.88A	43.0A	395.4A	855.8A	61.2A	3.82A	43.2A	394.6A	937.8A
180-60-96		59.3A	3.47B	41.1B	367.7B	758.0B	61.6A	3.48B	40.0B	356.2B	816.3B
	Control	50.6C	3.48A	35.3C	303.5C	607.6C	50.3C	3.39A	34.4C	304.8C	617.0C
	Nitrobein	56.5B	3.52A	41.5B	348.5B	724.6B	57.3B	3.55A	41.6B	348.4B	756.6B
	Halex-2	66.6A	3.56A	44.2A	374.7A	818.3A	66.0A	3.60A	44.9A	382.0A	867.0A
45-15-24	Control	45.8g	3.20b	30.0h	272.7i	487.4f	44.8f	3.17c	30.9i	268.6g	450.0h
	Nitrobein	59.7c	3.28ab	39.3ef	293.0h	565.0e	52.9d	3.19c	39.8f	310.9f	619.8f
	Halex-2	62.3b	3.43ab	40.9e	308.8g	658.3d	62.9b	3.59abc	42.1de	320.6ef	650.2f
90-30-48	Control	48.6f	3.50ab	34.6g	292.4h	585.8e	48.0e	3.34bc	33.8h	313.6f	561.9g
	Nitrobein	55.8d	3.37ab	41.2de	319.5f	687.8d	53.2b	3.57abc	40.9ef	327.7e	668.2ef
	Halex-2	68.1a	3.41ab	45.8ab	331.4e	776.5c	64.1b	3.40abc	46.1ab	347.6d	750.3cd
135-45-72	Control	52.8e	3.85ab	37.6f	308.0g	696.6d	51.2d	3.84ab	37.1g	319.7ef	710.7de
	Nitrobein	54.9de	3.93a	44.2bc	408.0b	898.1b	64.6b	3.89a	45.0bc	367.7c	948.6b
	Halex-2	69.1a	3.86ab	47.2a	470.1a	972.9a	67.9a	3.74ab	47.6a	496.3a	1154.0a
180-60-96	Control	55.3d	3.36ab	39.2ef	341.0e	660.7d	57.2c	3.22c	35.9g	317.5f	745.3cd
	Nitrobein	55.7d	3.50ab	41.1de	373.5d	747.5c	58.7c	3.55abc	40.7ef	387.5b	789.8c
	Halex-2	66.9a	3.56ab	43.1cd	388.5c	865.8b	69.0a	3.66abc	43.6cd	363.5c	913.7b

*Values followed by the same letter (s) through the main effects and interaction, are not significantly different, using revised LS.D test at 0.05 level.

Mineral Contents of Leaves

Data in Table (2) show the influence of varying NPK rates on the mineral contents of potato leaves. Nitrogen, P and K percentages in potato leaves, significantly, increased as the NPK rates increased up to 180-60-96 kg NPK fed^{-1}, in both seasons. This could be due to the positive effect of phosphorus on root growth, which leads to more absorption of nutrients (Marschner, 1986). Similar results were obtained by Sharma and Grewal (1991), Awad (1997), Arisha and Bardisi (1999), Awad *et al.* (2002) and El-kader (2002) .

Table (2) shows also that inoculation potato tuber seeds with the biofertilizers, Halex-2 and Nitrobein, significantly increased leaf N, P and K percentages in potato leaves compared to the untreated control, in both seasons. Biofertilization with Halex-2 was significantly more effective than Nitrobein on increasing N and P percentages in potato leaves, in the two growing seasons. In relation to the potassium content of potato leaves, the results indicated that the differences between Halex-2 and Nitrobein were not significant, in both seasons. The promoting effects of Halex-2 biofertilizer could be attributed to the role of non-symbiotic N_2 fixing bacteria on the availability of nutrients and modification of root growth morphology resulting in more efficient absorption of available nutrients (Jagnow *et al.*, 1991).These results are in agreement with those reported by El-Gamal (1996) , Hammad and Abdel-Ati (1998), Sherif *et al. (*2000) and Awad *et al.* (2002) who found that N, P and K contents of potato foliage were increased significantly by Microbein biofertilizer containing *Azotobacter, Azospirillum* and P-solubilizing bacteria.

Significant differences were obtained for the interaction effects between NPK rates and biofertilizer treatments on N, P, and K contents of potato leaves, in both seasons (Table, 2). At any NPK rate, inoculation potato tuber seeds with Halex-2, generally, tended to increase N, P, and K contents of potato leaves. Fertilizing potato plants with the highest NPK rate (180-60-96 kg NPK fed^{-1}) and inculcation with Halex-2 seemed to be the best treatment combination as it gave the highest values of N, and P contents in potato leaves, while the plants which inculcated with Halex-2 and received 135-45-72 kg NPK fed^{-1} rate gave the highest values of K contents in potato leaves, in the two growing seasons. These results were, generally, in accordance with those reported by Awad et *al.*, (2002).

Table (2): Effect of NPK level, inoculation with biofertilizer and their interaction on the percentage of N , P and K in leaves of potato plants during the summer seasons of 2000 and 2001.

Treatments		2000			2001		
N-P-K rate kg fed^{-1}	Biofertilizer	N (%)	P (%)	K (%)	N (%)	P (%)	K (%)
45-15-24		1.84C	0.178D	3.12C	1.70C	0.172D	2.92C
90-30-48		2.20B	0.216C	4.22B	2.20B	0.232C	3.97B
135-45-72		2.39B	0.318B	5.25A	2.47B	0.489B	4.47A
180-60-96		2.78A	0.442A	4.91A	2.93A	0.479A	4.89A
	Control	2.03B	0.187C	3.61B	2.10C	0.203C	3.39B
	Nitrobein	2.25B	0.256B	4.61A	2.31B	0.280B	4.17A
	Halex-2	2.63A	0.423A	4.91A	2.56A	0.441A	4.63A
45-15-24	Control	1.65h	0.125j	2.48h	1.55e	0.133j	2.21g
	Nitrobein	1.73gh	0.175i	3.17g	1.67de	0.166h	2.97f
	Halex-2	2.15ef	0.233g	3.73f	1.89d	0.217f	3.59e
90-30-48	Control	1.94fg	0.138j	3.55fg	1.95cd	0.150i	3.50e
	Nitrobein	2.12ef	0.189hi	4.16e	1.99cd	0.198g	3.84e
	Halex-2	2.53cd	0.322d	4.95d	2.66b	0.350d	4.57cd
135-45-72	Control	2.12f	0.196h	4.25e	2.24c	0.208fg	3.55e
	Nitrobein	2.35de	0.272f	5.70ab	2.59b	0.317e	4.91bc
	Halex-2	2.71bc	0.488b	5.80a	2.59b	0.522b	4.97b
180-60-96	Control	2.43d	0.291e	4.17e	2.67b	0.322e	4.29d
	Nitrobein	2.80b	0.387c	5.40bc	3.02a	0.439c	4.96bc
	Halex-2	3.12a	0.649a	5.17cd	3.11a	0.675a	5.41a

*Values followed by the same letter (s) through the main effects and interaction, are not significantly different, using revised LS.D test at 0.05 level.

Tubers Yield Characters

Data in Table (3) illustrated the response of potato tubers yield to varying NPK rates. The results, clearly, showed that increasing NPK applied dose up to 135-45-72 kg NPK fed^{-1} led to significant progressive increases in all studied yield characters of potato plants expressed as total tubers yield fed^{-1}, tuber yield plant^{-1}, number of tuber plant^{-1} and average tuber weight, in the two growing seasons. Results, also, revealed that all potato tubers yield characters, significantly, decreased with raising NPK applied rates over 135-45-

72 kg NPK fed^{-1}, in the two growing years. The enhancing effect of applying NPK to a particular level on tuber yield characters could be explained on the basis that, NPK fertilization encourage the vegetative growth (Table 1) to go forward and probably accelerated the photosynthetic rate, so number of tubers and tuber weight ,were increased. These results appear to be in close agreements with the findings of Nandekar *et al.* (1991), Singh *et al*. (1992), Awad (1997), Ali (2002), Awad *et al.* (2002) and El-kader (2002) .

Inoculation potato tuber seeds with the two biofertilizer types; Halex-2 and Nitrobein exerted positive remarkable influences on the yield characters of potato plants expressed as total yield fed^{-1}, tuber yield plant^{-1}, number of tuber plant^{-1} and average tuber weight, as compared to the non-inoculated ones, in both growing seasons (Table 3). Halex-2, significantly, exceeded Nitrobein in total tubers yield fed^{-1}, tubers yield plant^{-1}, number of tubers plant^{-1}. The differences between Halex-2 and Nitrobein with respect to average tuber weight were not significant. These increments might be attributed to the non-symbiotic bacteria present in biofertilizers which have beneficial effects on morphology and / or physiology of the root system enhancing N_2–fixation and mineral uptake, so encourage the vegetative growth (Table 1) to go forward which, in turn, promoted the synthesis of more photosynthates required for tuber formation and development. The more promoting influences of Halex -2 than Nitrobein might be explained on the basis that Halex-2 contained the three different genera of non-symbiotic N-fixing, bacteria, *Azotobacter, Azospirillum* and *Klebsiella,* while Nitrobein contans a single strain of non-symbiotic N-fixing bacteria of genus *Azospirillum*. The obtained results confirmed the previous findings of Ashour *et al*., 1997 and Awad *et al.* (2002) who found that application of Microbein biofertilizer (*Azotobacter, Azospirillum* and phosphor solubilizing bacteria) caused significant increases in total tubers yield, number of tubers plant^{-1} and average tuber weight of potato.

The comparisons presented in Table (3) illustrated the presence of some significant interaction effects between different NPK rates and biofertilizers treatments, on all studied tuber yield characters, in both seasons. The comparisons among the twelve interactive treatments, generally, indicated that, the combination treatment of 135-45-72 kg NPK fed^{-1} (75% from the recommended level) and Halex-2 was the most economical and beneficial treatment which gave significantly the highest mean value for most of the tuber yield characters of potato plants i.e., total tubers yield fed^{-1}, tubers yield plant^{-1} and number of tubers plant^{-1}, in both years. The increment in total yield fed^{-1}, was 19.8%, as average of the two seasons, over the application of 180- 60-96 Kg NPK fed^{-1} without biofertilizer. On the other hand, the combination treatment of Nitrobein either with 180-60-96 or 135-45-72 kg NPK fed^{-1} gave significantly the highest mean value for average tuber weight, in the first and second seasons, respectively. Similar results were recorded by El-Gamal (1996), Hammad and Abdel-Ati (1998) and Awad *et al.* (2002).

Tubers Quality Characters

Data presented in Table (4) illustrated that application of NPK up to 135-45-72 kg NPK fed^{-1} rate significantly increased the percentages of large and medium tuber size grade (> 60 and 30-60 mm in diameter), as well as percentages of T.S.S and total carbohydrates, in both seasons. The exception was in the second season where values of total carbohydrates percentage, at the different NPK rates, were not significant. The reverse was true for the percentages of tuber size grade < 30 mm in diameter (small) and culls. Meanwhile, increasing the rate of NPK up to 180-60-96 kg NPK fed^{-1} recorded the best content of tuber dry matter, in both seasons. Similar results were obtained by Kumar *et al.* (1992) who found that increasing NPK rate up to 125% of the recommended fertilizer rate of 150-60-60 kg NPK ha^{-1}, increased yield of large tubers.

Inoculation potato tuber seeds with the biofertilizer Halex-2 significantly increased the percentages of large and medium sized

Table (3): Effect of NPK level, inoculation with biofertilizer and their interaction on tubers yield characters of potato plants during the summer seasons of 2000 and 2001.

Treatments		2000				2001			
N-P-K Rate kg fed^{-1}	Biofertilizer	Total Yield (ton fed^{-1})	Tuber Yield plant^{-1} (g)	No. of Tuber plant^{-1}	Average Tuber weight (g)	Total Yield (ton fed^{-1})	Tuber yield plant^{-1} (g)	No. of Tuber plant^{-1}	Average Tuber weight (g)
45-15-24		14.13D	785.5D	7.93D	99.1A	13.72D	753.9C	7.70D	97.9A
90-30-48		15.03C	843.5C	8.33C	101.3A	14.85C	796.2C	8.42C	94.6B
135-45-72		17.37A	1022.7A	10.17A	100.6A	17.48A	1059.4A	9.64A	109.9A
180-60-96		16.70B	894.9B	9.92B	90.2B	16.45B	841.8B	8.89B	94.7B
	Control	14.01C	792.2C	8.11B	97.7B	14.11C	746.5C	8.05B	92.7B
	Nitrobein	15.91B	883.8B	8.72B	101.4A	15.68B	857.8B	8.39B	104.4A
	Halex-2	17.50A	984.0A	9.68A	101.7A	17.09A	984.1A	9.55A	103.0A
45-15-24	Control	12.40g	687.9g	7.34f	94.2i	12.15h	655.7j	7.66g	85.6j
	Nitrobein	14.35ef	799.9ef	7.94e	100.2de	14.05fg	770.2gh	7.49g	102.8d
	Halex-2	15.65d	868.8cd	8.48d	102.5b	14.95de	835.8de	7.97fg	104.9c
90-30-48	Control	13.75f	759.6f	7.64ef	99.4g	13.85g	725.3i	7.51g	96.6g
	Nitrobein	14.95de	862.2cd	8.47d	101.8bc	14.70efg	795.8fg	8.76cd	90.8h
	Halex-2	16.40c	908.7c	8.88c	102.3b	16.00c	867.6d	8.99c	96.5g
135-45-72	Control	14.45ef	881.2cd	8.80cd	100.2ef	14.75ef	855.1de	8.41def	101.7e
	Nitrobein	17.85b	997.1b	9.97b	100.0fg	17.80b	1037.5b	9.07c	114.4a
	Halex-2	19.80a	1190.0a	11.75a	101.3cd	19.90a	1285.5a	11.45a	112.3b
180-60-96	Control	15.45d	840.2de	8.67cd	96.9h	15.70cd	750.1hi	8.64cde	86.8i
	Nitrobein	16.50c	875.9cd	8.48d	103.3a	16.15c	827.8ef	8.24ef	100.5f
	Halex-2	18.15b	968.6b	9.61b	100.9de	17.50b	947.7c	9.78b	96.9g

*Values followed by the same letter (s) through the main effects and interaction, are not significantly different, using revised LS.D test at 0.05 level.

tubers as well as percentages of dry matter, T.S.S. and total carbohydrates over those inoculated with the biobfertilizer Nirobein or the non-inoculated control, in both growing seasons (Table 4). The reverse trend was noticed for the small and cull sized tubers, in both experiments of 2000 and 2001 seasons. These results appeared to be in close agreement with previous results reported by Frommel *et al*. (1993), Abdel-Ati *et al*. (1996), El-Gamal (1996) and Ghoneim and Abdel-Razik (1999).

Concerning, the interaction effect of NPK rates and biofertilizer treatments on potato tuber quality characters, data in Table (4) showed that there were some significant differences between all interactive treatments. At any NPK rate, inoculation potato tuber seeds with Halex-2 or Nitrobein, generally, tended to increase percentages of large and medium sized tubers and dry matter percentage compared to those of the non-inoculated one, in both seasons. The combined treatment of application 135-45-72 kg NPK fed^{-1} and inoculation potato tuber seeds with Halex-2 was the most beneficial treatment for increasing percentages of large and medium sized tubers as well as decreasing small and cull sized tubers, in both seasons. The exception was that in 2000 season, where the best significant result for medium sized tubers was attained due to the combined application of 90-30-48 kg NPK fed^{-1} with the biofertilizer Halex-2. Total soluble soilds and total carbohydrates, however, were not significantly affected, in the two growing seasons.

Generally, it could be concluded that inoculation potato tuber seeds with Halex-2 biofertilizer and application of 75% of the recommended NPK level (180-60-96 kg NPK fed^{-1}) increased the productivity of potato tuber and improved tuber quality characteristics, as well as saved 25% from potato requirement of NPK fertilizers.

Table (4): Effect of NPK level, inoculation with biofertilizer and their interaction on tuber quality of potato plants during the summer seasons of 2000 and 2001.

Treatments		Tuber size grade (%)				Tuber matter (%)	T.S.S %	Total carbohydrates %
N-P-K rate kg fed^{-1}	Biofertilizer	Large (> 60 mm) in diameter	Medium (30-60 mm) in diameter	Small (<30 mm) in diameter	Cull			
2000								
45-15-24		25.33C	28.33B	22.62A	23.72A	22.08B	18.15C	16.36B
90-30-48		32.77B	32.68A	20.40B	14.15B	18.85D	18.71B	16.57B
135-45-72		38.82A	32.38A	16.08C	12.75C	21.12C	18.99A	16.79A
180-60-96		39.05A	31.28A	17.65C	12.02C	23.11A	19.00A	17.02A
	Control	30.64C	28.34C	21.08A	19.94A	21.55B	18.47C	16.47C
	Nitrobein	34.26B	31.40B	19.20B	15.14B	19.64C	18.69B	16.67B
	Halex-2	37.08A	33.78A	17.29C	13.95B	22.69A	18.98A	16.91A
45-15-24	Control	23.15g	26.20g	24.05a	26.80a	22.15b	17.85a	16.14a
	Nitrobein	26.70f	37.55f	23.60a	12.13f	20.55d	18.08a	16.36a
	Halex-2	26.15f	31.25d	20.20c	22.40b	23.55a	18.52a	16.56a
90-30-48	Control	30.10e	28.75e	22.40b	18.75d	18.70e	18.59a	16.42a
	Nitrobein	31.70e	33.25c	20.20c	14.85e	17.60f	18.72a	16.49a
	Halex-2	36.50d	36.05a	18.60e	8.85h	20.25d	18.85a	16.81a
135-45-72	Control	31.75e	29.55e	18.50e	20.20c	21.75c	18.61a	16.45a
	Nitrobein	39.55b	33.05c	15.45h	11.95f	18.85e	19.01a	16.84a
	Halex-2	45.15a	34.55b	14.30i	6.00i	22.75b	19.25a	16.98a
180-60-96	Control	37.55cd	28.85e	19.35d	14.25e	23.60a	18.83a	16.78a
	Nitrobein	39.10bc	31.75d	17.55f	11.60f	21.55c	18.86a	16.97a
	Halex-2	40.50b	33.25c	16.05g	10.20g	24.20a	19.28a	17.30a
2001								
45-15-24		26.35C	28.73B	22.45A	22.47A	19.07C	19.46C	16.97A
90-30-48		32.67B	32.45A	21.35A	13.53B	23.05A	19.84B	17.15A
135-45-72		37.38A	32.73A	16.55B	13.34B	21.51B	20.03A	17.39A
180-60-96		37.77A	32.45A	16.72B	13.06B	23.20A	20.15A	17.58A
	Control	29.23C	27.95C	21.03A	21.75A	22.16A	19.77B	17.11B
	Nitrobein	34.06B	32.09B	19.43B	14.42B	20.24B	19.86B	17.30A
	Halex-2	37.34A	34.74A	17.35C	10.57C	22.73A	20.00A	17.41A
45-15-24	Control	24.35j	25.15g	25.15a	25.35a	19.80f	19.49a	16.74a
	Nitrobein	26.95i	28.30e	23.35b	21.40b	17.90g	19.39a	17.08a
	Halex-2	27.75h	32.75c	18.85de	20.65b	19.50f	19.50a	17.08a
90-30-48	Control	29.75g	30.05d	23.10b	17.10d	23.05cd	19.58a	16.94a
	Nitrobein	32.30f	32.25c	21.55c	13.50e	21.85e	19.94a	17.14a
	Halex-2	35.95e	35.05b	19.40d	9.60g	24.25ab	19.99a	17.38a
135-45-72	Control	30.25g	26.55f	17.70f	25.50a	22.55cde	19.92a	17.30a
	Nitrobein	38.05d	35.05b	16.75g	10.15g	19.15f	19.97a	17.38a
	Halex-2	43.85a	36.60a	15.20i	4.35i	22.85cde	20.19a	17.49a
180-60-96	Control	32.55f	30.05d	18.15ef	19.25c	23.25bc	19.99a	17.47a
	Nitrobein	38.95c	32.75c	16.05gh	12.25f	22.05de	20.15a	17.58a
	Halex-2	41.80b	34.55b	15.95h	7.70h	24.30a	20.32a	17.70a

* Values followed by the same letter (s) through the main effects and interaction, are not significantly different, using revised LS.D test at 0.05 level.

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الملخص العربي

تأثير التسميد النتروجيني والفوسفوري والبوتاسي وأنواع السماد الحيوي على النمو الخضري ومحصول وجوده درنات نباتات البطاطس

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أجريت دراسة حقلية خلال الموسم الصيفي لعامي 2000 و2001، بالمزرعة التجريبية ـ كلية الزراعة – جامعة الإسكندريةـ بأبيس، لدراسة استجابة نباتات البطاطس الصيفي صنف ألفا، لثلاث معاملات من التسميد الحيوي(غير ملقح، هالكس ـ 2، نيتروبين) تحت أربعة معدلات مختلفة من السماد النتروجيني والفوسفوري والبوتاسي (25% ،50% ،75% ،100% من المعدل الموصى في الإنتاج التجاري وهو180 – 60 – 96 كجم ن- فو$_2$أ$_5$ - بو$_2$أ للفدان). أوضحت الدراسة إن زيادة معدل التسميد المعدني من النتروجين والفوسفور والبوتاسيوم أو التلقيح بالسماد الحيوي (هالكس -2) كان مصحوباً بزيادة معنوية في ارتفاع النبات وعدد الافراع والأوراق للنبات والوزن الطازج والمساحة الورقية للنبات، وكذلك فان المحتوى المعدني للأوراق من (ن ، فو، بو) قد استجاب معنويا لكلا العاملين ولقد تميز السماد الحيوي هالكس ـ 2 بتفوق واضح عن النيتروبين، علاوة على ذلك ، فان الجهد المحصولي معبرا عنه بمحصول الفدان ، ومحصول الدرنات للنبات، وعدد الدرنات للنبات، ومتوسط وزن الدرنة، قد استجاب بالزيادة كنتيجة لزيادة مستوى النتروجين والفوسفور والبوتاسيوم حتى 135- 45- 72كجم ن- فو$_2$أ$_5$ - بو$_2$أ للفدان أو بمعاملة التلقيح الحيوي خاصة الهالكس ـ 2 ولقد أشارت الدراسة أيضا إن زيادة معدلات السماد المعدني أو معاملة التلقيح الحيوي قد أدت إلى تحسين معظم صفات الجودة (النسبة المئوية للدرنات الكبيرة والمتوسطة ، المواد الصلبة الذائبة والكربوهيدرات الكلية). ولقد وجد إن إضافة السماد الكيماوي عند مستوى 75% من المعدل الموصى به وهو 135ن - 45 فو$_2$أ$_5$ - 72 بو$_2$أ كجم للفدان مع التلقيح بالسماد الحيوي (هالكس -2) كان أفضل المعاملات كفاءة حيث أعطت أعلي نموا خضري متوازنا وأعلي محصول مع أفضل جودة لدرنات البطاطس مقارنة بالمتحصل عليه من أضافه 180ن – 60 فو$_2$أ$_5$ - 96بو$_2$أ كجم للفدان بدون تسميد حيوي، حيث بلغت الزيادة فى محصول الدرنات للفدان 19.8% كمتوسط لموسمي الزارعة ، بالإضافة إلى أنها وفرت 25% من الاحتياجات السمادية لنبتات البطاطس من النيتروجين و الفوسفور و البوتاسيوم.