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EFFECT OF BIOFERTILIZER TYPES UNDER VARYING NITROGEN LEVELS ON VEGETATIVE GROWTH, HEADS YIELD AND QUALITY OF GLOBE ARTICHOKE (*Cynara scolymus, L.*)

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ABSTRACT

Two field experiments were carried out during the winter seasons of 2000/2001 and 2001/2002 at the Agricultural Experimental Station (at Abeis) Alexandria University, to investigate the response of globe artichoke plants cv. French, to the inoculation with Halex$_2$ and Microbein biofertilizers under varying N levels (0, 45, 90 and 135 kg N fed^{-1}). The results indicated that increasing N applied rate was accompanied with significant increases in plant height, number of off-shoots and leaves plant^{-1}, and leaf dry matter content. Moreover, leaf's mineral contents (N, P and K) were positively and significantly responded to N application. It was also noticed that yield characters (number and weight of heads plant^{-1}) increased as a result of N application up to 90 kg N fed^{-1}.Application of 135 kg N fed^{-1} improved most head quality characteristics (head's weight, length, diameter, dry matter, TSS and K content). However, the differences between 90 and 135 kg N fed^{-1} were not found significant in terms of total carbohydrates of head and receptacle weight. Inoculation of globe artichoke stumps with the biofertilizer Halex$_2$ or Microbein led to significant increases in vegetative growth characters, leaf's mineral contents and yield potential (early and total heads yield). Head quality characteristics were greatly improved due to the biofertilizer treatments. Microbein appeared to be more effective than Halex$_2$ in this respect. The application of 90 kg N fed^{-1}, combined with Microbein biofertilizer, seemed to be the most efficient treatment combination, which gave a balanced vegetative growth, a higher early and total heads yield as well as a good quality. Moreover, this particular treatment combination was more beneficial in changing yield pattern distribution of globe artichoke heads compared to all other treatments.

INTRODUCTION

Globe artichoke is considered as one of the most important vegetable crops in Egypt, for local consumption and exportation, either fresh or processed. It gained an important nutritional value due to its high contents of phenolic compounds, flavonoids, inulin, heparaxal, fibers and many minerals (Lattanzio and Sumere, 1987).Its extracts contain also cynarin, which has effects on hepatobitary diseases, hyperlipidaemia, dropsy, rheumatism and cholesterol metabolism (Adzet *et al.,* 1987 ; Hammouda *et al.,* 1993a). In addition, leaves, stems and industry residues are used for cattle feed (Hammouda *et al.,* 1993b). Egypt has the potential to develop an excellent export industry in artichoke (Schrader, 2001). The production areas around Alexandria, Behira and Giza Governorates have favorable climatic conditions to grow good quality artichoke for export marketing. The major production of globe artichoke in Egypt is obtainable usually during the months of March and April, but the optimum export window to European countries is the period from November up to February (Abdel-Al and Moustafa, 1973 ; Abd El-Fattah *et al.*, 1998). The early production through this period represents a vital importance, since the demand for either export or local market is great and the prices are high which affects the net income of globe artichoke production (Okàsha *et al.,* 1997). Nowadays, in Egypt, a great attention is given in Egypt for promoting globe artichoke production to satisfy the increased demands of local fresh market, developing processing industry and rapidly growing exportation. Therefore, the modification or redistribution of the yield pattern of artichoke coupled with increasing yield potential, by any way, would be of a great interest. Globe artichoke is a sensitive plant to nutritional balance due to its huge vegetative growth and high productivity; besides, it is a perennial crop with a long life cycle (Rubatzky and Yamaguchi, 1997).

Nitrogen nutrition is one of the paramount factors influencing growth and reproductive development of globe artichoke. The effects of N fertilizer on vegetative growth and yield potential were extensively studied by several investigators and reflected much confliction on N rates (60-150 kg N fed^{-1}) required for optimum head production and quality (Gerakis and Honoma, 1969; El-Shal *et al.*, 1993a; Pomares *et al.*, 1993; Pedreno *et al.*, 1996; El-Seifi *et al.*, 1997; Schrader and Mayberry, 1997; Abd El-Fattah *et al.*, 1998; Feleafel, 2005). Gerakis and Honoma (1969) found a marked response to N application which increased the foliage fresh weight of globe artichoke and accelerated the appearance of bolters when applied up to 200 Ib N / acre. However, El-Shal *et al.* (1993b) mentioned that N application at 60 kg fed^{-1} exerted some increases on leaf area, leaves fresh and dry weights, heads productivity and accelerated earliness of artichoke. Salamah (1997) found that the growth characters of globe artichoke were markedly increased due to the application of 114 kg N fed^{-1}. Abd El-Fattah *et al.* (1998) reported that the application of N fertilizer up to 80 kg N fed^{-1} increased leaf dry matter content, mineral contents, early and total yield. Recently, Feleafel (2005) showed that the addition of 150 kg fed^{-1} reflected positive influences on number of basal shoots, plant height, early and total yield of globe artichoke plants. Unlikely, Foti *et al.* (2000) demonstrated that earliness and total yield were better by the additional of 80 kg N fed^{-1}. On the other extreme, Schrader and Mayberry (1997) reported that artichokes require less fertilizer than most other vegetable crops to produce top yields. For maximum yields in most circumstances, growers in USA apply 45-90 kg N fed^{-1}. Many other investigators concluded that there was no yield response to N application above 80 kg N fed^{-1} (El-Adgham, 1974; Pomares *et al.*, 1993; Pedreno *et al.*, 1996; Abd El-Fattah *et al.*, 1998 ; Foti *et al.*, 2000). Therefore, judicious application of N fertilizer is an important cultural practice to improve the yielding ability of globe artichoke crop. Furthermore, the excessive use of N fertilizer increases generally the total cost of crop production and creates pollution of agro-ecosystem (Fisher and Richter, 1984). Under these circumstances, supplementing or substituting the inorganic fertilizers with organic sources, especially those of microbial origin, is of great interest and so urgent. Little information on the effect of biofertilzer application or the interaction between the bio-and-chemical fertilization on globe artichoke plants is available (Abd El-Fattah, 1998; Sorial *et al.*, 1998). Sorial *et al.* (1998) reported that the application of biofertilizer (Promote) stimulated the vegetative growth, raised leaf's mineral contents as well as increased early and total yield of artichoke heads. They added that the biofertilizer improved some head quality characteristics and changed the yield pattern distribution of globe artichoke plants.

The present study was conducted to investigate the effect of biofertilizer types under varying levels of N on vegetative growth, head yield and quality characteristics of globe artichoke plants under the prevailing conditions of Alexandria Governorate.

MATERIALS AND METHODS

The main effects of nitrogen fertilizer levels and biofertilizer types as well as their interactions on the vegetative growth, mineral contents, yield and quality of globe artichoke cv. French were investigated throughout two field experiments; executed at the Experimental Station Farm (at Abeis), Fac. Of Agric., Alex. Univ.; during the two winter seasons of 2000/2001 and 2001/2002. Preceding the initiation of each experiment, soil samples at 25cm depth were collected from each experimental site and analyzed, according to Page *et al*. (1982). The results of the analyses are given in Table (1).

Table (1): Some important physical and chemical properties of the experimental sites in 2000/2001 and 2001/2002 winter seasons

Seasons	Physical properties				Chemical properties							
	Sand (%)	Silt (%)	Clay (%)	Texture	EC. (dsm^{-1})	PH	O.M. (%)	N (%)	P (ppm)	K ($meqL^{-1}$)	$CaCo_3$ (%)	So_4 (%)
2000/2001	22.1	37.8	40.1	Clay loam	3.18	8.02	0.72	0.12	141	0.082	1.6	074
2001/2002	22.4	36.4	41.2	Clay loam	3.12	7.90	0.76	0.10	152	0.085	1.4	0.68

Nitrogen fertilizer treatments contained three different levels; 45, 90 and 135 kg N fed^{-1} as well as the unfertilized control. Biofertilizer treatments included seed inoculation with two variant types of biofertilizers; Halex-2 and Microbein; as well as the uninoculated control. There were twelve treatment combinations in total. The biofertilizer Halex-2; a mixture of non-symbiotic N-fixing bacteria of genera *Azotobacter*, *Azospirllum* and *klebsiella*; was obtained from the Biofertilization Unit, Plant Pathology Department, Fac. of Agric., Alex. Univ.; whereas, the biofertilizer Microbein; a mixture of non-symbiotic N-fixing bacteria of genera *Azotobacter*, *Azospirillum* and *klebsiella* as well as the phosphate dissolving bacteria *Baccillus*; was obtained from the Biofertilization Unit, Ministry of Agriculture, Egypt. Seed pieces (stumps) of globe artichoke plants were planted in 4 ridges of 1.2 m width and 6 m length at 0.75 m plant distances on July 16, 2000 and July 18, 2001. The area of the smallest experimental unit was 28.8 m^2. Two guard rows were left between each two adjacent main plots and one guard row was left between each two adjacent sub-plots to protect against side effects. Each nitrogen rate was equally divided and side dressed at 60, 90 and 120 days after planting. The first N application, in all treatments, was in the form of ammonium sulphate (20.6% N); whereas, the later ones were in the form of ammonium nitrate (33.5% N). Halex-2 biofertilizer was utilized at the rate of 200 g, according to recommendations of the Biofertilization Unit, Plant Pathology Department, Fac. of Agric., Alex. Univ.; whereas, Microbein biofertilizer was utilized at the rate of 20 kg fed^{-1}, according to the recommendations of the Ministry of Agriculture, Egypt. The inoculation process was performed by immersing the stumps (previously treated with the fungicide Topsin M-70 at the rate of 2g per liter for 20 minute) in a Halex-2 or Microbein cells suspension ($4x10^7$ cells ml^{-1}) containing 5% Arabic gum, for 30 minutes just before planting. The inoculation process was again repeated three weeks later as a side dressing beside the seed pieces. Stumps of the uninoculated control were dipped in distilled water containing 5% Arabic gum. The experimental layout was a split-plots system in a randomized complete blocks design, with three replications. Nitrogen fertilizer levels were arranged as the main plots, while the biofertilizer types were randomly distributed in the sub-plots. All experimental units received identical levels of potassium and phosphorus fertilizers. Calcium super phosphate at the rate of 200 Kg fed^{-1} (15.5% P_2 O_5) was base dressed before planting and potassium sulphate (48% K_2O) at the rate of 150 Kg fed^{-1}. was equally divided and side dressed at the same times of N application. All other agricultural practices were adopted whenever they were necessary and as commonly recommended for the commercial production of globe artichoke. Harvesting started in the first season on November 22 and continued until May24, 2001. Meanwhile; in the second season, the harvesting extended from November 24 to May 27, 2002.

Data Recorded

1-Vegetative growth characters

Measurements of morphological characters were taken using five randomly selected plants from the outer ridges in each sub-plot at the blooming stage. The measurements of plant height, number of off-shoots and leaves plant^{-1} and leaf dry matter content were recorded.

2-Leaf's mineral contents

Leaf samples for chemical determinations were collected from the youngest fully expanded mature leaves of 10 randomly selected plants at blooming stage. Contents of N, P and K were determined using Microkjeldahal procedure for N, ammonium stannous chloride method for P (A.O.A.C., 1992) and flame photometer for K (Black, 1965).

3-Early and total heads yield

Early yield plant^{-1} was estimated as the number and weight of all harvested heads during the four months of Nov., Dec., Jan. and Feb. Total yield plant^{-1} was determined as number and weight of all harvested heads throughout the entire harvesting period.

4- Yield pattern distribution

Yield pattern distribution was determined and expressed as percentage of monthly produced heads per plant relative to the total number of harvested heads throughout the entire harvesting period.

5- Heads quality characteristics

At the peak of harvesting period (March), head quality characters were considered and the following measurements and determinations were achieved; average head weight, length and diameter, receptacle weight, head dry matter content, total soluble solids (TSS) in the edible portions, using a hand refractometer, total carbohydrates and K content in the edible portions, as outlined by Malik and Singh (1980) and Black (1965), respectively.

Appropriate analyses of variance on data of each experiment were performed using Costat Software (1985). Comparisons among the means of the various treatment combinations were carried out, using the revised least significant difference test at p=0.05, illustrated by El-Rawy and Khalf- Allah (1980).

RESULTS AND DISCUSSION

Vegetative growth characters

Data presented in Table (2) showed that the application of N fertilizer, irrespective of the used level, significantly, increased plant height, number of off-shoots plant^{-1}, number of leaves plant^{-1} and leaves dry matter content, relative to the unfertilized control, in both seasons of 2000/2001 and 2001/2002. It was noticed that increasing N application up to 135 Kg fed^{-1} progressively and significantly increased No. of off-shoots plant^{-1} and leaf dry matter content. However, plant height and No. of leaves plant^{-1} recorded the highest.

with the application of 90 kg N fed^{-1}. Such a positive response of N applied levels on all studied vegetative characters could be due to that the available amount of N to plants in the soil was relatively low (Table, 1). The enhancing effect of N on plant growth might be attributed to its vital contribution to several biochemical processes related to growth, in the plants, and to its active role on assimilating the photosynthetic reaction (Marschner, 1994). The present results matched well with those obtained by El-Shal *et al.* (1993a), Salamah (1997) and El-Seifi *et al.* (1997), who reported that increasing the applied N rate from 40 up to 120 kg fed^{-1} exerted increases on the vegetative growth characters of globe artichoke plants grown under the condition of newly reclaimed soils.

Treating the globe artichoke seed pieces before planting with the Halex$_2$ or Microbein biofertilizers was responsible for significant increases on plant height, No. off-shoots and leaves plant^{-1} and leaf dry matter content over the unionculated control, in both seasons (Table, 2). The inoculation with the biofertilizer Microbein gave significantly longer plants, more No. off-shoots and higher content of leaf dry matter than Halex$_2$, in both seasons. However, the differences between Halex$_2$ and Microbein in terms of number of leaves plant^{-1} were not significant. The beneficial effects of the two investigated biofertilizers on the studied vegetative growth traits of globe artichoke might be related to the promoting effects of the non-symbiotic N_2-fixing bacteria on morphology and / or physiology of the root system; resulting in a more efficient utilization of available nutrients in the soil and 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 of IAA, gibberellins and cytokinins, and synthesized 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 nutrients and water from the soil.

Table (2): Vegetative growth characters and leaf dry matter content of globe artichoke plants, as affected by nitrogen fertilizer levels and biofertilizer types, during the winter seasons of 2000/2001 and 2001/2002

Treatment		2000/2001				2001/2002			
N levels (KgN/fed)	Biofertilizer types	Plant height (cm)	No. off-shoots $plant^{-1}$	No. leaves $plant^{-1}$	Leaf dry matter content (%)	Plant height (cm)	No. off-shoots $plant^{-1}$	No. leaves $plant^{-1}$	Leaf dry matter content (%)
0		75.8C	7.9D	64.57D	13.51D	86.0C	8.2D	65.16D	14.27D
45		79.1B	8.4C	70.28C	14.40C	89.6B	8.6C	69.75C	15.03C
90		87.2A	9.4B	78.93A	15.45B	94.8A	9.5B	83.89A	15.86B
135		87.6A	9.8A	75.16B	16.24A	96.6A	10.0A	77.90B	16.77A
	Control	77.6C	7.7C	66.22B	13.3C	87.0C	8.0C	68.03B	13.88C
	Halex2	81.8B	8.2B	76.42A	14.48B	91.7B	8.6B	78.38A	15.18B
	Microbein	87.7A	10.6A	74.08A	16.90A	97.6A	10.6A	76.14A	17.38A
0	Control	73.3i	7.1d	60.85f	11.93g	81.9g	7.49	60.45g	12.63g
	Halex2	76.0gh	7.3d	67.04de	13.60f	87.9e	7.6g	68.86ef	14.40f
	Microbein	78.0fg	9.4b	65.88ef	15.00d	88.2de	9.6cd	66.16f	15.77d
45	Control	75.1gh	7.3d	68.42cde	12.67g	86.2f	7.7g	66.45f	13.43g
	Halex2	79.3ef	7.8cd	71.86c	14.13ef	89.5d	8.4ef	70.73de	14.80ef
	Microbein	83.0cd	10.0b	70.58cd	16.40c	93.2be	9.7c	72.09d	16.87c
90	Control	81.0de	8.1c	67.21de	14.27ef	87.9de	8.5e	72.22d	14.37f
	Halex2	85.0bc	8.3c	88.90a	14.67cd	94.5b	8.9de	94.60a	15.40de
	Microbein	95.0a	11.8a	80.68b	17.40b	101.9a	11.1b	84.86b	17.80b
135	Control	81.0de	8.1c	68.43cde	14.43ef	91.9c	8.5e	73.00d	15.07def
	Halex2	87.0b	9.6b	77.86b	15.50cd	94.9b	9.5d	79.34c	16.13c
	Microbein	94.7a	11.8a	79.19b	18.80a	103.2a	12.0a	81.46c	19.10a

Values marked with the same alphabetical letter(s), within a comparable group of means, do not significantly differ, using revised L.S.D. test at 0.05 level.

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 Sorial *et al.* (1998), who indicated that the application of Promote biofertilizer; mixtures of fungus and yeast; stimulated significantly plant height, number of leaves plant^{-1} and leaf dry matter content of globe artichoke plants.

The interaction effects between the various levels of N fertilizer and biofertilizer types on vegetative growth characters were found significant, in both seasons (Table, 2). At any level of N, inoculation artichoke seeds (stumps) with the biofertilizer Halex$_2$ or Microbein increased plant height, No. off-shoots and leaves plant^{-1} and leaf dry matter content compared to the uninoculated ones. Nevertheless, the Microbein was superior in this respect. The combined treatment of 90 Kg N fed^{-1} and the inoculation with the Microbein biofertilizer was the most beneficial treatment combination for all vegetative growth characters and leaf dry matter content except for No. leaves plant^{-1} as it recorded significantly higher mean values than those of the highest N rate (135 kg N fed^{-1}) alone. However, the highest significant No. leaves plant^{-1} was gained from the application of 90 kg N fed^{-1} combined with Halex$_2$ biofertilzer.

Leaf's mineral contents

Results of Table (3) illustrated a progressive significant increase on leaf N content with the application of N up to 135 kg N fed^{-1}; whereas, gradual increases in leaf P and K contents occurred when N applied rate reached up to 90 kg fed^{-1}.Raising N level over 90 kg fed^{-1} did not significantly reflect any effect on leaf's K content; but it, significantly, deceased leaf's P content. The obtained results seemed to agree with those of Salamah (1997), who reported that leaf N, P and K contents of globe artichoke increased gradually with increasing the

Table (3): Leaf's mineral contents of globe artichoke plants as affected by N levels and biofertilizer types during the winter seasons of 2000/2001 and 2001/2002

Treatment		2000/2001			2001/2002		
N levels (KgN/fed)	Biofertilizer types	N (%)	P (%)	K (%)	N (%)	P (%)	K (%)
0		2.462D	0.253C	1.527C	2. 715D	0.257C	1.503C
45		2.967C	0.284B	2.042B	2.879C	0.285B	1.967B
90		3.259B	0.296A	2.207A	3.204B	0.298A	2.155A
135		3.430A	0.284B	2.330A	3.373A	0.285B	2.293A
	Control	2.674B	0.271B	1.865C	2.573B	0.272B	1.826C
	Halex2	3.203A	0.261B	1.969B	3.189A	0.262B	1.929B
	Microbein	3.212A	0.306A	2.246A	3.368A	0.310A	2.185A
0	Control	1.977e	0.244a	1.325e	1.870e	0.247a	1.318e
	Halex2	2.727cd	0.240a	1.405e	2.690cd	0.240a	1.365e
	Microbein	2.683cd	0.276a	1.852d	3.587cd	0.285a	1.827d
45	Control	2.513d	0.272a	1.898cd	2.417d	0.273a	1.825cd
	Halex2	3.197ab	0.264a	1.973bcd	3.120ab	0.265a	1.917bcd
	Microbein	3.190ab	0.315a	2.256ab	3.100ab	0.317a	2.160ab
90	Control	3.007bc	0.287a	2.053bcd	2.893bc	0.288a	1.998bcd
	Halex2	3.367ab	0.281a	2.175-abc	3.407ab	0.282a	2.146ab
	Microbein	3.403ab	0.319a	2.394a	3.313ab	0.323a	2.322a
135	Control	3.197ab	0.279a	2.184abc	3.113ab	0.280a	2.163abc
	Halex2	3.520a	0.260a	2.323a	3.537a	0.260a	2.288a
	Microbein	3.573a	0.314a	2.481a	3.470a	0.314a	2.429a

Values marked with the same alphabetical letter(s), within a comparable group of means, do not significantly differ, using revised L.S.D. test at 0.05 level.

level of N application from 95 to 285 kg N ha^{-1}. Sorial *et al.* (1998), working on globe artichoke, indicated that application of N fertilizer up to 80 kg N fed^{-1}, significantly, increased the leaf mineral content of N, P and K.

Data arranged in Table (3) indicated that the inoculation with the biofertilizer $Halex_2$ or Microbein, significantly increased the leaf contents of N, P and K compared to the uninoculated control, in both seasons. The exception was for leaf's P content, where, the effect of inoculation with the biofertilizer $Halex_2$ did not differ from the uninoculated one. Biofertilization with leaf's K content was significantly more effective than $Halex_2$ on leaf's mineral contents, except leaf's N content, where their effects were similar. The promoting effects of the biofertilizers, $Halex_2$ and leaf's K content on the nutritional status of the leaves could be related to the role of biofertilizer on improving the availability of nutrients and to the modification of root growth, morphology and physiology, through hormonal exudates of biofertilizers bacteria, resulting in a more efficient absorption of available nutrients (Jagnow *et al.*, 1991).The adequate influence of Microbein rather than $Halex_2$ on leaf P content probably due to the presence of phosphate dissolving bacteria as a component of Microbein ,which perhaps devoted a more efficient absorption of P. Similar findings on the effect of biofertilization on leaf mineral content of globe artichoke were reported by Sorial *et al.* (1998).

The interaction effects between N application levels and biofertilizer types exhibited some significant differences on leaf's N and K content, in both seasons (Table, 3). Leaf's P content, however, was not significantly affected. At any N level, inoculation with either $Halex_2$ or Microbein, increased leaf's N and K contents relative to the uninoculated ones, but with different rates.

Early and total heads yield

Data in Table (4) exhibited that the application of N, irrespective of the level used, increased significantly the early and total heads yield plant^{-1} expressed as number and weight of heads, compared to the unfertilized control treatments, in both seasons. Application of 90 kg N fed^{-1} out-yielded the low N level (45 kg N fed^{-1}). Raising N applied rate from 90 to 135 kg N fed.$^{-1}$ did not appear to improve number and weight of early and total heads yield plant^{-1},in both seasons. The positive effects of N application on globe artichoke yield might be attributed to its role on activating the vegetative growth (Table, 2) and to the accumulation of mineral contents in leaves; which, in turn enhanced the production of more photosynthetic substances required for head formation and development. Similar findings were recorded by Gerakis and Honoma (1969), who found a marked response to N application which accelerated the appearance of bolters (heads). El-Seifi *et al.* (1997) reported that soil dressing with 120 kg N/fed is recommended for increasing globe artichoke productivity and earliness under newly reclaimed soil conditions. Salamah (1997) and Foti *et al.* (2000) demonstrated that earliness and total heads yield were better by 200 kg ha^{-1} (80 kg fed^{-1}). Pomares *et al.* (1993) and Pedreno *et al.* (1996), also, showed that there was no yield response to N application above 200 kg ha^{-1}.

Inoculation globe artichoke stumps with the two biofertilizer types; Halex$_2$ and Microbein exerted positive remarkable influences on number and weight of early and total heads yield plant^{-1} compared to the uninoculated ones, in both growing seasons (Table, 4). Number and weight of early heads yield plant^{-1} as well as number of total heads yield plant^{-1} were similar whether the inoculation process was performed either with Halex$_2$ or Microbein, in both seasons. However, Microbein-treated stumps produced significantly heavier weight of total heads yield plant^{-1}than Halex$_2$- treated ones, in both seasons. The more promoting influences of Microbein than Halex$_2$ might be

Table (4): Early and total heads yield of globe artichoke plants as affected by N fertilizer levels and biofertilizer types during the winter seasons of 2000/2001 and 2001/2002

Treatment		2000/2001				2001/2002			
N levels (Kg N/fed.)	Biofertilizer types	Early yield heads plant^{-1}		Total heads yield plant^{-1}		Early heads yield plant^{-1}		Total heads yield plant^{-1}	
		Number	Weight (g)	Number	Weight (kg)	Number	Weight (g)	Number	Weight (kg)
0		2.49C	500.7C	14.83C	2.79C	2.81C	564.8C	12.42C	3.01C
45		4.18B	611.0B	20.41B	3.05B	4.60B	661.2B	17.40B	3.46B
90		5.29A	736.0A	23.18A	3.38A	6.07A	778.8A	19.78A	3.71A
135		5.74A	728.5A	23.24A	3.54A	6.28A	785.3A	20.54A	3.61A
	Control	2.96B	559.6B	17.29B	2.76B	3.04B	596.3B	14.06B	2.96B
	Halex2	5.23A	683.5A	21.75A	3.32A	5.89A	745.4A	19.43A	3.69A
	Microbein	5.10A	689.2A	22.21A	3.49A	5.90A	751.0A	19.09A	3.70A
0	Control	1.65c	419.8f	13.94c	2.16f	1.34b	471.3f	11.18b	2.32f
	Halex2	2.89bc	534.1e	15.42c	2.96de	3.73a	601.6d	13.43a	3.26cd
	Microbein	2.94bc	548.1e	15.12c	3.24bc	3.37a	621.6d	12.66ab	3.46cd
45	Control	3.45bc	537.5e	19.09b	2.71e	3.88a	574.6e	15.57cd	2.81e
	Halex2	4.78b	628.8d	21.83ab	3.29cd	4.98a	697.3b	18.27b	3.69bc
	Microbein	4.32bc	666.8c	20.31b	3.15c	4.93a	711.6b	17.22bcd	3.87ab
90	Control	3.44bc	631.1d	18.63b	2.96de	3.52c	664.6c	15.11bcd	3.20d
	Halex2	6.37a	792.5a	25.63a	3.47bc	7.28b	841.3a	22.09a	3.86ab
	Microbein	6.06a	784.5a	25.28a	3.70ab	7.42a	830.6a	22.15a	4.07a
135	Control	3.29bc	649.8cd	17.48b	3.22cd	3.40c	674.6c	14.39d	3.52c
	Halex2	6.88a	778.1ab	24.10a	3.55bc	7.55b	841.3a	22.81a	3.93ab
	Microbein	7.06a	757.5b	28.14a	3.85a	7.88a	840.0a	24.33a	3.39cd

Values marked with the same alphabetical letter(s), within a comparable group of means, do not significantly differ, using revised L.S.D. test at 0.05 level.

explained on the basis that Microbein is a multi-inoculation containing three different genera of non-symboitic N-fixing bacteria; *Azotobacter*, *Azospirillum*, *Klebsiella* as well as one genera of phosphate dissolved bacteria; *Baccillus*; while, $Halex_2$ contained the three different genera of non-symbiotic N-fixing bacteria; *Azotobacter*, *Azospirillum* and *Klebsiella.* The obtained results confirmed the previous findings of Sorial *et al.* (1998), who found that application of a biofertilizer caused some significant increases on earliness, early and total yield of globe artichoke. Moreover; Abd El-Fattah (1998) reported that soil inoculation with the biofertilizer Phosphorien increased early and total yield of artichoke.

The interaction of N levels by biofertilizer types had significant effects on early and total heads yield plant^{-1} of globe artichoke plants, in both seasons (Table, 4). At the different N levels, the inoculation with $Halex_2$ or Microbein biofertilizers led to some significant increases, but with variable rates, in both early and total yield plant^{-1}, either as number or weight of heads. The treatment combination of 90 kg N fed^{-1} with the inoculation by $Halex_2$ or Microbein biofertilizers gave higher mean values for early and total heads yield plant^{-1} than those attained at the highest N rate (135 kg N fed^{-1}) alone. The results mean that 90 kg N fed^{-1} was sufficient to meet the requirements of globe artichoke when the seeds were inoculated either with the biofertilizers $Halex_2$ or Microbein.

Yield pattern distribution

The yield pattern distribution of globe artichoke heads throughout the entire harvesting period (November to May), expressed as percentage of number of monthly produced heads relative to the total number of heads yield is given in Table (5) and Fig (1). The unfertilized (control) produced a low percentage till the end of February. At 0, 45, 90 and 135 kg N fed^{-1}, percentages of the produced heads yield plant^{-1} throughout Nov. – Feb. (early heads yield) were 16.79, 20.48, 22.82 and 24.69% in 2000/2001 season, while averaged

Table (5): Yield pattern distribution of globe artichoke heads throughout the harvesting period, expressed in terms of percentage to total heads yield as affected by N fertilizer levels and biofertilizer types during the winter seasons of 2000/2001 and 2001/2002

Treatment / Month		2000/2001							2001/2002						
N levels (Kg N/fed.)	Biofertilizer types	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
0		018	2.21	4.81	9.59	34.83	45.03	3.36	0.22	2.54	5.59	14.27	33.41	39.25	4.72
45		0.35	4.15	6.46	9.52	35.75	39.24	4.53	0.41	4.60	7.37	14.65	32.00	36.27	4.70
90		0.45	4.77	7.82	9.78	36.23	38.67	2.28	0.41	4.92	8.44	16.91	31.72	35.74	1.86
135		0.47	5.65	8.34	10.23	36.63	36.59	2.09	0.45	4.92	8.71	16.49	31.64	34.46	3.33
	BF_0*	0.29	3.30	5.19	8.35	36.67	41.98	4.22	0.32	3.82	6.16	11.32	36.23	38.55	3.60
	BF_1	0.37	4.63	7.91	11.14	35.32	37.87	2.76	0.37	4.08	7.91	18.39	30.27	35.10	3.88
	BF_2	0.49	4.66	7.45	10.36	35.58	38.49	2.97	0.50	4.84	8.68	16.89	30.52	35.18	3.39
0	BF_0	0.00	1.13	2.22	8.49	36.67	48.08	3.41	0.00	1.22	2.98	7.79	38.86	44.28	4.87
	BF_1	0.22	2.46	6.18	9.88	33.66	44.35	3.25	0.30	3.18	6.22	18.07	31.16	36.25	4.82
	BF_2	0.32	3.04	6.02	10.06	34.12	43.35	3.09	0.36	3.22	6.34	16.70	31.69	37.22	4.47
45	BF_0	0.24	3.98	4.57	9.28	34.91	40.83	6.19	0.26	4.08	5.18	15.40	36.14	34.28	4.66
	BF_1	0.34	4.20	7.12	10.24	36.78	38.41	2.91	0.28	3.28	6.12	17.58	29.96	38.12	4.66
	BF_2	0.48	4.28	7.46	9.05	36.26	37.37	4.06	0.68	6.44	10.82	10.69	30.17	36.42	4.78
90	BF_0	0.36	3.98	5.78	8.34	37.38	40.68	3.48	0.38	5.21	7.98	9.73	35.03	37.44	4.23
	BF_1	0.47	5.00	8.70	10.68	35.62	36.85	2.68	0.42	4.72	8.68	19.13	30.02	34.67	2.35
	BF_2	0.52	5.32	8.98	9.15	35.68	38.35	2.00	0.44	4.82	8.64	19.60	30.11	35.12	1.27
135	BF_0	0.33	4.10	8.08	6.31	38.43	40.88	1.87	0.36	4.76	8.48	10.03	34.88	38.21	3.28
	BF_1	0.46	6.86	9.62	11.61	35.22	34.05	2.18	0.48	5.12	8.72	18.78	29.94	33.62	3.70
	BF_2	0.62	5.98	7.32	11.17	36.24	36.52	2.15	0.52	4.88	8.92	18.07	30.11	34.48	3.02

*BF_0 : Uninoculated (control) BF_1 : $Halex_2$ BF_2 : Microbein

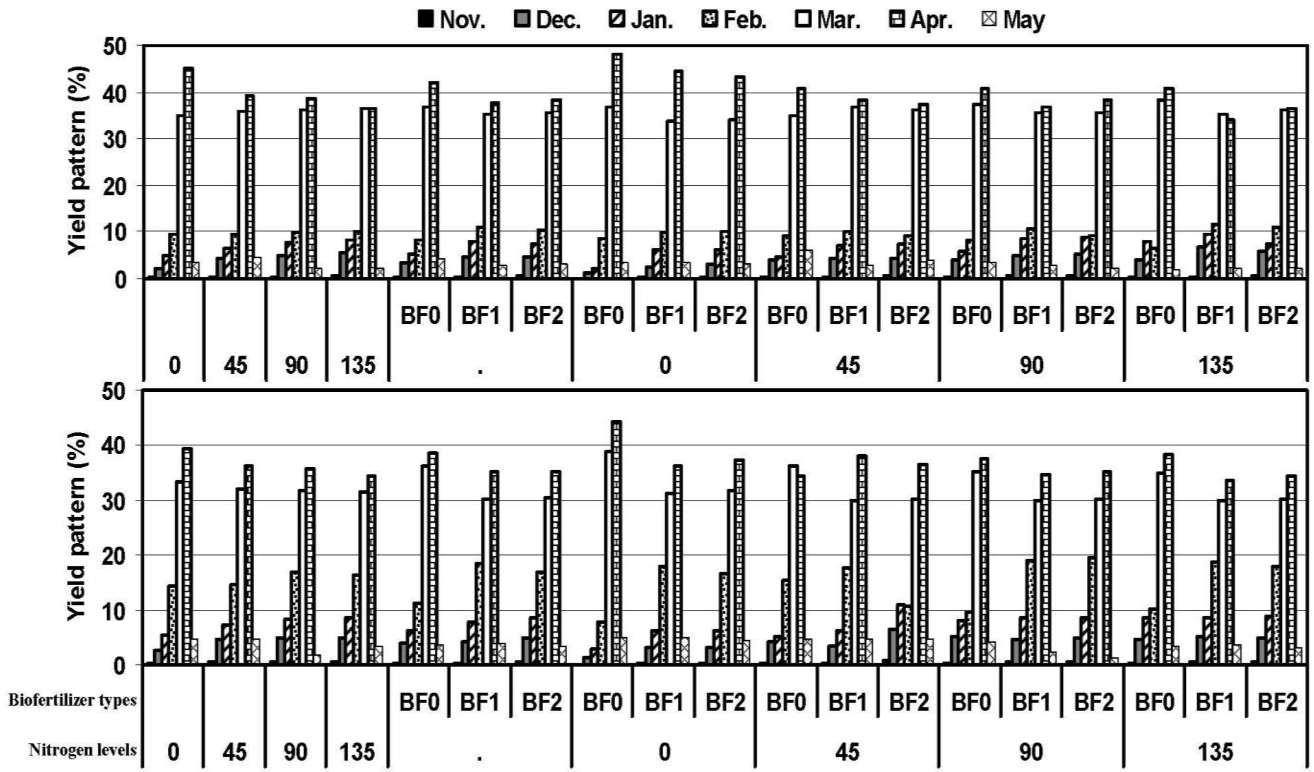

Fig. (1): Yield pattern of globe artichoke heads throughout the harvesting period as affected by N fertilizer levels and biofertilizer types during the winter seasons of 2000/2001 and 2001/2002

Treatment: 1- Nitrogen levels 0, 45, 90 and 135 kg N fed^{-1}. 2- Bifertilizer types: BF_0: Uninoculated, BF_1 : $Halex_2$, BF_2: Microbein

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22.62, 26.44, 30.68 and 30.57% in 2001/2002 season, respectively. Meanwhile, percentages of the produced heads yield plant^{-1} throughout the same period (Nov. – Feb.) due to uninoculated and Halex$_2$ and Microbein treated plants were 17.13, 24.05 and 22.96% in 2000/2001 season and 21.62, 30.75 and 30.91% in 2001/2002 season, respectively. These findings mean that both nitrogen fertilization levels and biofertilizer types changed the yield pattern distribution to be more earlier in which high prices are offered.

It is worthy to mention that the application of N at 90 or 135 kg N fed accompanied with Halex$_2$ or Microbein biofertilizer caused a good shifting in the yield pattern of globe artichoke towards November to February and redistributed the yield pattern to meet somewhat the requirements of exportation demands. Results obtained by El-Abagy (1993), Abd El-Fattah *et al.* (1998), Sorial *et al.* (1998) and Feleafel (2005) seemed to confirm the obtained results.

Head quality characteristics

Data recorded in Table (6) showed that the application of N was responsible for significant improvements on head quality characteristics, expressed as head's weight, length, diameter, dry matter content, total soluble solids (TSS), total carbohydrate (COH), K content and receptacle weight, compared to the unfertilized control, in both growing seasons. Increasing N level from 0 to 90 and furtherly to 135 kg N fed^{-1} reflected significant and successive increases on most head quality characteristics with the exception in heads receptacle weight and total carbohydrates, ;where the differences between 90 and 135 kg N fed^{-1} were insignificant. The positive effects of N application on head quality characteristics seemed to be expected on the ground that nitrogen enhanced vegetative growth, as previously mentioned (Table, 2), and caused the accumulation of minerals (N, P and K) in leaves (Table, 3);which, in turn, increased carbohydrate assimilation and their translocation to the reproductive tissues (heads) resulting in improving their quality. Similar results were recorded by Abd El-Fattah *et al.* (1998), who indicated that increasing the application

Table (6): Head quality characteristics of globe artichoke plants as affected by N fertilizer levels and biofertilizer types during the winter seasons of 2000/2001 and 2001/2002

Treatment		2000 / 2001								2001 / 2002							
N levels (KgN/fed)	Biofertilizer types	Head weight (g)	Head length (cm)	Head diameter (cm)	K (%)	Head dry matter (%)	T.S.S. (%)	Total COH (%)	Receptacle weight (g)	Head weight (g)	Head length (cm)	Head diameter (cm)	K (%)	Head dry matter	T.S.S. (%)	Total COH (%)	Receptacle weight (g)
0		224.0D	8.1D	7.7D	2.452D	15.37D	10.2D	1.207C	55.8C	226.5D	8.4D	8.0D	2.399D	15.28D	11.1D	1.302C	63.8C
45		235.1C	8.6C	8.2C	2.720C	16.13C	11.2C	1.221B	59.1B	238.4C	8.8C	8.4C	2.675C	16.50C	12.4C	1.317B	67.4B
90		238.7B	9.6B	9.2B	2.911B	16.96B	11.9B	1.240A	67.0A	244.0B	9.7B	9.3B	2.885B	17.55B	13.0B	1.337A	72.6A
135		241.7A	10.0A	9.6A	3.010A	17.83A	12.4A	1.238A	67.6A	247.8A	10.2A	10.1A	2.967A	18.34A	13.7A	1.337A	74.5A
	Control	223.9B	7.9C	7.5C	2.668C	14.98C	10.1C	1.208C	57.6C	229.5B	8.2C	8.1C	2.627C	15.18C	10.8C	1.304C	64.8C
	Halex2	239.6A	8.4B	8.1B	2.734B	16.26B	11.7B	1.214B	61.8B	243.3A	8.8B	8.4B	2.699B	16.58B	13.0B	1.313B	69.5B
	Microbein	241.1A	10.9A	10.6A	2.917A	18.49A	12.6A	1.258A	67.7A	244.8A	10.8A	10.4A	2.868A	19.00A	13.9A	1.352A	74.4A
0	Control	216.8a	7.3d	6.9d	2.289f	13.73g	7.8f	1.197a	53.3i	221.8a	7.6e	7.2g	2.262f	13.03a	8.3h	1.293a	59.7g
	Halex2	226.4a	7.5d	7.1d	2.382f	15.50c	10.9de	1.203a	56.0gh	228.1a	7.8e	7.4g	2.330f	15.70f	12.1ef	1.299a	65.7e
	Microbein	228.7a	9.6b	9.2b	2.684e	16.87de	12.0bc	1.220a	58.0fg	229.6a	9.8d	9.4cd	2.605e	17.10d	12.8cd	1.315a	66.0de
45	Control	222.4a	7.5d	7.1d	2.673e	14.53f	10.0e	1.208a	55.1gh	226.7a	7.9e	7.5g	2.618e	14.77g	10.5g	1.302a	64.0f
	Halex2	240.5a	8.0d	7.6cd	2.698de	15.90d	11.5cd	1.211a	59.3ef	243.2a	8.6e	8.2ef	2.659de	16.23ef	13.0cd	1.310a	67.3d
	Microbein	242.3a	10.2b	9.8b	2.791cde	17.97be	12.3abc	1.243a	63.0cd	245.4a	9.9c	9.5c	2.748cde	18.50e	13.6bc	1.339a	71.0be
90	Control	226.2a	8.3c	7.9c	2.855bcd	15.47de	10.9de	1.224a	61.0de	232.5a	8.7e	8.3e	2.820bcd	16.37f	11.6f	1.322a	65.7de
	Halex2	244.8a	8.5c	8.1c	2.889bc	16.50b	12.0bc	1.227b	65.0bc	249.4a	9.1d	8.7de	2.872bc	16.77de	13.3cd	1.326a	72.3b
	Microbein	245.1a	12.0a	11.6a	2.989b	18.90a	12.9ab	1.270a	75.0a	250.1a	11.3b	10.9b	2.962b	19.50b	14.1b	1.362a	79.7a
135	Control	230.2a	8.3c	7.9c	2.855bcd	16.17c	11.8cd	1.202a	61.0de	236.8a	8.7d	9.3e	2.806bcd	16.53def	12.7de	1.301a	69.7c
	Halex2	246.6a	9.8b	9.4b	2.969b	17.13b	12.2bc	1.216a	67.0b	252.4a	9.7d	9.3d	2.937b	17.60c	13.4bcd	1.315a	72.7b
	Microbein	248.4a	12.0a	11.6a	3.205a	20.20a	13.3a	1.297a	74.7a	254.2	12.2a	11.8a	3.158a	20.90a	15.1a	1.394a	81.0a

Values marked with the same alphabetical letter(s), within a comparable group of means, do not significantly differ, using revised L.S.D. test at 0.05 level.

of N from 40 to 120 kg N fed^{-1} resulted in producing heavier head weight, larger head diameter and more contents of TSS and dry matter, over those of the control plants. Salamah (1997) reported that increasing N fertilization up to 95 kg N ha^{-1} (38.5 kg fed^{-1}) was associated with improvements on head quality, expressed as head weight and length as well as receptacle diameter. However, raising N rate from 190 to 380 kg N ha^{-1} (77 to 154 kg N fed^{-1}) did not reflect any further improvement on these traits.

Inoculation of seed pieces of globe artichoke either with $Halex_2$ or Microbein recorded significantly the higher mean values for head's weight, length, diameter, dry matter, TSS, total carbohydrates, K and receptacle weight, than those of the uninoculated control (Table, 6). Biofertilization with Microbein was significantly more effective than $Halex_2$ on all head quality characteristics; except the head weight in the first season, where their effects were insignificant. The obtained results agreed, in general, with those of Sorial *et al.* (1998), who reported some enhancing effects on some head quality characteristics ;i.e., head weight, head diameter, TSS and dry matter content as a result of inoculation with a biofertilizer.

Some interaction effects between N levels and biofertilizer types on most head quality characteristics were found significant (Table, 6). Head weight and total carbohydrates, however, were not affected. The comparisons among the various treatment combinations, in general, exhibited that the treatment combination of 90 kg N fed^{-1} and inoculation with Microbein was the most economical and beneficial treatment in most head quality characteristics especially in the first season. An exception was noticed for head's K content; whereas, the application of 135 kg N fed^{-1} coupled with Microbein biofertilizer recorded the highest mean values.

Conclusively, it is recommended to use biofertilizer Microbein or $Halex_2$ with a moderate supply level of nitrogen fertilizer (90 kg N fed^{-1}) in order to increase early and total heads yield of globe artichoke plants as well as to improve head quality characteristics. Moreover, such a treatment combination can modify the production pattern of artichoke head to meet the demands for the export markets.

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الملخص العربي

تأثير نوع السماد الحيوي تحت مستويات مختلفة من النيتروجين على النمو الخضري ومحصول وجودة نورات الخرشوف

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قسم الخضر – كلية الزراعة – جامعة الإسكندرية

أجريت دراسة حقلية لمدة عامين خلال الموسم الشتوي لعامي 2001/2000، 2002/2001 بالمزرعة التجريبية لكلية الزراعة – جامعة الإسكندرية بأبيس وذلك لدراسة مدى استجابة نباتات الخرشوف الصنف الفرنساوي للتلقيح بالأسمدة الحيوية هالكس $_2$ وميكروبين تحت مستويات مختلفة من التسميد الأزوتي (صفر، 45، 90، 135 كجم نيتروجين للفدان). أوضحت النتائج أن زيادة معدل التسميد الأزوتي قد أدى إلى زيادة معنوية في ارتفاع النبات وعدد الفسائل الجانبية والأوراق والمحتوى الجاف للأوراق، وكذلك فإن المحتوى المعدني (ن، فو، بو) قد استجاب بالزيادة معنوياً للتسميد الأزوتي، بالإضافة إلى ذلك فقد لوحظ أن مكونات المحصول (عدد ووزن النورات لكل من للمحصول المبكر والكلي) قد ازدادت بزيادة التسميد الأزوتي حتى 90 كجم/ فدان. ولقد أشارت النتائج أيضاً أن إضافة المعدل الأزوتي 135 كجم/فدان قد أدى إلى تحسين معظم صفات الجودة (وزن وطول وقطر والمحتوى الجاف والمواد الصلبة الذائبة ونسبة البوتاسيوم في النورات)، في حين لم تكن الاختلافات بين 90و 135 كجم ن/فدان معنوية فيما يتعلق بالمحتوى الكلي من الكربوهيدرات ووزن التخت النوري.

ولقد بينت النتائج أن تلقيح قطع تقاوي الخرشوف بالسماد الحيوي هالكس $_2$ أو ميكروبين قد أدى إلى زيادة معنوية في النمو الخضري ومحتوى الأوراق من العناصر المعدنية والمحصول المبكر الكلي (كعدد أووزن للنورات)، ولقد أدت معاملات السماد الحيوي إلى تحسين صفات الجودة للنورات. وقد وجد أن إضافة السماد الأزوتي عند مستوى 90 كجم ن / فدان مع التلقيح الحيوي الميكروبية كان أفضل المعاملات العاملية كفاءة، حيث أعطت نمو خضريا متوازنا وأعلى محصول مبكر وكلي بالإضافة لأفضل مواصفات جودة. وعلاوة على ذلك، كانت هذه المعاملة أكثر المعاملات فائدة لتغير توزيع المنحنى المحصولي بالمقارنة بالمعاملات العاملية الأخرى. وتشير الدراسة بصفة عامة أن التلقيح بالسماد الحيوي يكون أعلى كفاءة مع المستوى المعتدل من الأزوت (90 كجم ن/ فدان) مقارنة بالمستوى المرتفع منه (135 كجم ن/ فدان).