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EFFECT OF GIBBERILLIC ACID AND A MIXTURE OF MICRONUTRIENTS (NUTARMINE) ON EARLINESS, HEAD YIELD, AND PRE AND POSTHARVEST QUALITY OF GLOBE ARTICHOKE (*Cynara scolymus* L.)

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ABSTRACT

Globe artichoke plants were grown perennially at Kaha Experimental Station during the two successive seasons of 2000/2001 and 2001/2002, to study the influence of GA3 at 50, 100, 150, and 200 ppm, Nutarmine (a mixture of microelements) and their combination on plant growth, earliness, head yield, and chemical constituents of head receptacles. The effect of packaging method on storability of heads was also investigated using flower heads produced by plants sprayed with the combination of 150 ppm GA_3 and Nutarmine.

Data revealed that number of leaves per plant significantly increased only by Nutarmine treatment. Number of offshoots per plant significantly increased by GA_3 at 150 ppm, and Nutarmine, each alone or when combined together. GA_3, Nutarmine or their combination did not affect dry weight of leaves per plant.

GA_3 at 200 ppm was significantly the best for induction of blooming earliness. Highest significant incraase in percentage early yield was achieved by GA3 at 150 ppm combined with Nutarmine. Percentage late yield increased significantly by Nutarmine treatment only.

In early yield, GA_3 at 150 ppm combined with Nutarmine resulted in the highest significant increase in number of flower heads per plant, average head weight and total weight of heads per plant, while the combination of GA_3 at 200 ppm with Nutarmine resulted in the highest significant increase in receptacle weight. GA_3 levels, Nutarmine or their combination did not affect flower head diameter or receptacle diameter.

In late yield, The highest significant increase in number of flower heads per plant, average head weight, weight of flower heads per plant, average receptacle weight were resulted by the combination of GA_3 at 150 ppm with Nutarmine. However, none of GA_3 levels, Nutarmine or their combinations affect flower head diameter or receplacle diameter.

All tested treatments, except GA_3 at 200 ppm, significantly increased reducing sugars of receptacle, while non-reducing sugars and inuline contents were not affected by any treatment. The increase in GA_3 concentration, either alone or when combined with Nutarmine, was accompanied with increament in receptacle phenol contents. All treatments enhanced the accumulation of GA_3, and there was a gradual increase in GA_3 contents of the receptacle, associated with the increase in GA_3 concentration, either when GA_3 was alone or combined with Nutarmine. All determined micro-elements, i.e., Mn, Fe, Cu, B, and Zn, significantly increased by the presence of Nutarmine alone or when combined with GA_3

In the storability study, results indicated that prolonging storage period resulted in a remarkable increase in percentage weight loss, decay, fiber contents and discoloration of cut ends, while it caused a reduction in the values of visual quality and

texture of flower heads, regardless packaging treatments. Individually wrapping heads with stretch film and lining treatments were better than control treatments, but using the stretch film was more significantly effective in improving storage quality features, i.e., weight loss %, decay %, discoloration of cut ends, Fiber %, visual quality and texture.

INTRODUCTION

Globe artichoke (*Cynara scolymus* L.) is one of the most important vegetable crops grown for both local consumption and export. great attention is giving recently by the Egyptian government to promote globe artichoke production to satisfy the increased demands for local and foreign markets. The demands for export to European markets increase during the period from November to February. Thus, factors affecting the early production and storability during this period are of major importance for promoting globe artichoke exportation to European markets since the peak of production occurs usually during March to May. Among these factors gibberellins, plant growth regulators, have received the most attention. Gibberellins found to affect vegetative growth of globe artichoke (El-Gridly, 1994; El-Gazar *et al.*, 1995; El-Shal, 1998), earliness (El-Abagy, 1993; Mauromicale and Lerna, 1995; Miguel *et al*, 1997; Garcia *et al.*, 1999; Mauromicale and Lerna, 2000), and yield and quality of produced heads (Elia *et al.*, 1994; Abou-Hadid *et al.*, 1995; Kocer and Eser, 1999). Another important factor that did not investigate intensively on globe artichoke, but found to have a remarkable effect on the growth, yield and quality of many other vegetable crops, is micronutrients (Panigrahi *et al.*, 1990, on cauliflower; Eid *et al.*, 1991, on garlic; Singh and Riwari, 1996, on onion; Patil, 2001, on okra; Rai *et al.*, 2002, on tomato; Yakout and Greish, 2002, on faba bean). In addition to the previously mentioned factors, it has been found that wrapping and packaging methods have a great influence on quality of stored globe artichoke heads (Ferreyra *et al.*, 1994; Passam *et al.*, 1999).

The present study aims at investigating the effects of gibberellic acid (GA3) and Nutarmine on inducing earliness and improving yield and quality of globe artichoke heads, as well as studying the effect of packaging method on keeping quality of stored heads, for both export and local consumption.

MATERIALS AND METHODS

Two field experiments were carried out at Kaha Experimental Station of the Horticultural Research Institute, Agricultural Research Center, during the two successive seasons of 2000/2001 and 2001/2002. The experiments were designed to investigate the effects of foliar spraying with gibberellic acid (GA_3) and Nutarmine; a ready made mixture of micronutrients containing 8.1% Mn, 7.5% Fe, 3.2% Cu, 4.5% Zn, 1.45% B, 0.046% Mo and 15% total sulfur, on inducing earliness and improving yield and quality of globe artichoke. One year old plants of local cultivar (Balady) cultivated in 1999, were growing perennially and used in the two conducted experiments. Each cropping cycle of the perennial globe artichoke was initiated after the end of harvesting of preceding season during May, by stopping irrigation, then

cutting off dried plants 5 to 8 cm below soil surface to stimulate the development of new shoots. By the end of July, the plants were re-irrigated. The tested treatments included GA_3 at 50, 75, 150 and 200 ppm, each alone or combined with Nutarmine. In addition, Nutarmine was applied to plants as a separate treatment. Nutarmine was used at 2 kg/500 liter of H_2O/feddan, regardless of being alone or in combination with different GA_3 concentrations. GA3 treatments were applied twice at two weeks intervals, starting six weeks after first irrigation (when the plants reached approximately 25 cm in diameter). Nutarmine treatment was applied 45 and 75 days after first irrigation.

The experiments were set up in randomized complete blocks with three replicates. Each replicate contained ten treatments (plots). Each plot was 25 m^2 in area, and consisted of 5 rows, each 5 meter long and 1 meter width, with one meter in-row spacing. The growing plants were subjected to regular inter-cultural practices as well as disease and pest control programs recommended by the Ministry of Agriculture for commercial globe artichoke production.

Studied Characteristics

1- Plant growth parameters:

A randomly chosen sample of 5 plants / plot was picked up 120 days after first irrigation and at the end of growing season to count number of leaves, number of offshoots per plant and to determine weight of dry leaves /plant at 120 days after first irrigation.

2- Yield and flower head traits:

Mean number of days from first irrigation up till 25% plant blooming was recorded and used as an indicator for earliness. All flower heads of plants in each plot were harvested and counted during the periods from November-February and March-May, to study yield distribution and to determine early and late yields. Yield was calculated as number of heads per plant and as fresh weight of heads per plant. A random sample of 10 heads was taken from each plot to determine average weight and diameter of head, as well as weight and diameter of receptacle (edible part), for both early and late yields.

3- Chemical constituents:

Total soluble solids (T.S.S) were measured by using refractometer, reducing and non-reducing sugars, inuline, phenols and gibberellins, in head receptacles of early yield were determined according to the methods described by Forsee (1938), Morell (1941), Winton and Winton (1958), A.O.A.C. (1975), and Seeley and Powell (1974), respectively. The micronutrients; Mn, Fe, Cu, B, and Zn were determined using the atomic absorption spectrophotometer. The micronutrients and Gibberellins were determined in receptacles of early yield in the second season only.

In the storability study, random compact and uniform flower heads, harvested from plants sprayed with the combination of GA_3 at 150 ppm and Nutarmine at marketable stage, and transferred directly to vegetable handling department at the Horticultural Research Institute. Flower stack were cut 15

cm below the base and heads were then either individually wrapped with polyvinyl chloride stretch film (Proback Comp., Italy) before being packed in a standard carton of 35x25x8 cm in dimensions, or packed in the standard cartons that were lined with polypropylene film, or packed unwrapped in the standard cartons. Treatments were arranged in a randomize complete blocks design, with three replicates (cartons), each contained ten flower heads. All treatments were stored at 0°C and a relative humidity of 95% for 1, 2, 3, or 4 weeks, respectively. Samples were subsequently evaluated for percentage weight loss, percentage decay, discoloration of cut ends, percentage fiber contents, visual quality and texture, which were measured according to the methods of Ezzat *et al.* (1997), El-Seifi (1997), Rodov *et al.* (2000), A.O.A.C. (1975), Aharoni *et al.* (1996), and Hardenburg (1971), respectively.

Collected data were statistically analyzed by Analysis of Variance using SAS program (SAS, 1985) with means separated by Least Significant Difference (LSD) test according to Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Vegetative growth:

Data presented in Table (1) show that the effect of tested treatments on number of leaves at 120 days after first irrigation or at the end of the season was consistent through the two conducted experiments. Results proved that GA_3, either alone or combined with Nutarmine, decreased number of leaves per plant or did not significantly affect them in both tested stages. Nutarmine alone increased significantly number of leaves per plant compared with control. In this regard, Foti *et al.* (1981) reported that spraying globe artichoke with 40 ppm GA_3 diminished number of leaves.

Number of offshoots per plant, Table (1), increased significantly and consistently, regardless sampling time and season, when plants were treated with 150 ppm GA_3 either alone or in combination with Nutramine, or when plants treated with Nutarmine alone. Also, GA_3 at 200 ppm, alone or in combination with Nutarmine increased number of offshoots per plants, but only after 120 days from first irrigation, in both sasons. Similar results were obtained by Schrader (1994) who pointed out that GA_3 treatment of globe artichoke plants increased number of offshoots, but decreased plant size and vigor, and he attributed the promotive effect of GA_3 on globe artichoke offshoots to its ability to cause more lateral branching of the main stem of plants. The positive results of Nutramine on vegetative growth of plants might be due to the essential roles of micronutrients in higher plants, where they are involved in many important metabolic fuctions such as transport of carbohydrates, regulation of meristematic activity, photosynthesis, respiration and energy production and protein metabolism. Such functions would directly or indirectly contribute to plant growth (Srivastva and Gupta, 1996).

Data of dry weight of leaves per plant, presented in Table (1), indicated that GA_3, Nutarmine or their combinations had insignificant effect on dry weigtit of leaves per plant compared with control during the two seasons.

Table (1): Vegetative growth characteristics of globe artichoke plants (Balady cv.) as affected by GA_3 concentrations, Nutarmine and their combinations in 2000/2001 (I) and 2001/2002 (II)seasons.

Treatment	NO. of leaves / plant				NO. of offshoots / plant				Dry weight of leaves / plant (g)	
	120 days after first irrigation		End of season		120 days after first irrigation		End of season			
	I	II	I	II	I	II	I	II	I	II
Control	42.9	41.3	109.0	111.5	3.6	3.6	6.7	5.2	12.53	12.36
50 ppm GA3	40.7	40.9	100.5	100.4	3.5	3.2	6.7	5.5	12.40	12.15
100 ppm GA3	44.3	42.0	104.9	101.4	3.3	3.1	7.0	5.9	12.13	12.37
150 ppm GA3	41.0	40.3	106.7	104.5	4.1	4.1	8.0	5.6	12.20	12.23
200 ppm GA3	42.2	42.1	109.1	105.5	4.2	4.3	5.9	5.2	12.13	12.11
50 GA3 + Nut.	39.7	42.5	101.4	105.1	3.7	3.7	6.4	6.3	12.76	12.76
100 GA3+Nut.	41.3	41.5	105.0	110.6	3.5	3.5	6.6	6.5	12.26	12.41
150 GA3+Nut.	39.7	39.4	101.8	108.6	4.1	4.3	7.8	6.8	12.23	12.40
200 GA3+Nut.	42.2	38.9	110.9	106.4	4.5	4.5	4.9	5.2	12.33	12.40
Nutarmine	44.8	43.1	120.1	128.1	3.9	4.0	7.2	5.6	12.33	12.26
LSD (5%)	1.65	1.71	3.03	2.94	0.2	0.3	0.5	0.3	0.46	0.52

percentage early and late yield of globe artichoke plants (Balady cv.).
Similarly, Mansour (1983) pointed out that GA_3 at 25 to 100 ppm had insignificant effect on dry weight of leaves per plant "Balady" globe artichoke cultivars.

Blooming earliness and yield distribution:

The effect of GA_3 levels, Nutarmine and their combinations on blooming earliness and percentage early and late yields is illustrated in Table (2). Results proved that spraying globe artichoke plants with GA_3 at different tested concentrations resulted in a highly significant improve in blooming earliness in both seasons, compared with control. The highest concentration of GA_3 (200 ppm) resulted in blooming 22.8 and 23.2 days earlier than control in the first and second seasons, respectively. The combinations of GA_3 with Nutarmine had a similar effect to that of GA_3 levels alone on blooming earliness. Nutarmine alone significantly induced blooming earlier than control, 9.8 and 14.4 days in the first and second seasons, respectively, but was significantly less effective compared with GA_3 treatments alone or in combinations with Nutarmine.
The obtained results are in agreement with those obtained by Garcia *et al.* (1994) who pointed out that foliar applications of GA_3 at 50 ppm as a single spray, or a single spray of 50 ppm followed by 25 ppm a month later, advanced harvesting date by an average of 20 days. Similar reports about the effect of GA_3 on inducing earliness of globe artichoke were also introduced by Miguel *et al.* (1997) and Kocer and Eser (1999). The increase in earliness induced by GA_3 application may be attributed to the fact established by Lang (1965) who pointed out that gibberellins applied to certain plant species induced them to flower without a low temperature treatment.

Table 2: Effect of GA_3, Nutramine and their combinations on blooming earliness and percentage early and late yield of globe artichoke plants (Balady cv.) in 2000/2001 (I) and 2001/2002 (II)seasons.

Treatment	No. of days to 25% blooming		% early yield*		% Late yield*	
	I	II	I	II	I	II
Control	100.20	100.96	20.4	19.7	79.6	80.3
50 ppm GA3	80.63	80.83	51.1	48.5	48.8	51.5
100 ppm GA3	81.13	78.80	52.3	46.9	47.7	53.1
150 ppm GA3	84.33	78.43	49.2	49.4	50.8	50.6
200 ppm GA3	77.36	77.73	38.8	47.8	61.2	52.2
50 GA3+Nut.	79.76	80.96	48.5	47.1	51.5	52.9
100 GA3+Nut.	81.76	80.50	52.1	46.0	46.9	54.0
150 GA3+Nut.	80.26	78.46	52.4	50.5	47.6	49.6
200 GA3+Nut.	81.43	77.30	38.9	45.5	61.1	54.5
Nutarmine.	90.36	86.60	26.9	24.8	73.1	75.2
LSD (5%)	2.59	2.77	8.09	7.32	4.94	4.63

*Based on total number of produced heads

Percentage early yield presented in Table (2) significantly increased by GA_3 foliar spray treatments compared with control, when applied alone or combined with Nutarmine. This was true regardless the used concentration and in both seasons. Highest percentage early yield resulted from the application of 150 ppm GA_3 combined with Nutarmine, in both seasons. On the other hand, spraying the plants with Nutarmine alone did not significantly affect percentage early yield in both seasons. The effect of GA_3 on increasing percentage early yield may be attributed to their significant effects on inducing blooming earliness. Similarly Schrader (1994) used GA_3 on perennial artichoke to accelerate maturity, and he found that application of 20 ppm GA_3 three times at 2 weeks intervals significantly increased percentage early yield. The insignificant effect of micronutrients on early yield was reported previously in several vegetable crops by Arora *et al.* (1990) and Petrikova (1991), on tomato; and by Panigrahi *et al.* (1990), on cauliflower.

Percentage late yield (Table 2) behaved appositively to percentage early yield in terms of responding to GA_3 concentrations, Nutarmine and their combinations. Percentage late yield significantly decreased when plants sprayed with GA_3 alone or in combination with Nutarmine, compared with control. Nutarmine alone also increased significantly the percentage late yield compared to all GA_3 treatments and their combinations with Nutarmine, but it was less effective than control. The obtained results of percentage late yield were consistent through the two successive seasons. The positive effect of Nutarmine on percentage late yield may be due to the involvement of microelements in several important metabolic process which directly affect vegetative growth and subsequently yield production in globe artichoke. Similar effects of micronutrients on vegetables were reported on okra by Medhi and Kakati (1994) and on tomato by Gupta *et al.* (2002).

Yield and flower head traits

Data related to characteristics of flower head, receptacle and yield/plant for the early yield are presented in Table (3). Results show that number of flower heads produced per plant increased significantly by all tested treatments compared with control, but the highest increase resulted from the combination of GA_3 at 150 ppm with Nutarmine , in both seasons. This treatment showed 281.4% and 295.2% increment in number of heads of early yield over the control, in the first and second seasons, respectively.

As for the weight of flower head of early yield, data indicate that all tested treatments, except Nutarmine which insignificantly increased flower head weight in the first season, increased significantly weight of flower heads compared with control. The highest significant increase resulted from the combination of GA_3 at 150 ppm with Nutarmine, in both seasons. The increase amounted to 106.9% and 106.1% over the control in the first and second seasons, respectively.

The weight of heads per plant for the early yield was significantly increased by all tested treatments, but the highest was produced by the combination of GA_3 at 150 ppm with Nutarmine, in both seasons compared with control. The significant increase in weight of heads per plant early yield by this combination could be attributed to the significant increase in both number of heads per plant and head weight, but because the percentage increase in head number per plant was much greater than percentage increase in head weight (about 2.63 and 2.78 folds in the first and second seasons, respectively), it can be concluded that the significant increase in early yield per plant.was mainly due to the increase in number of heads per plant. The effect of GA_3 in this respect could be attributed to its ability to cause cell elongation or expansion through affecting the extensibility of the cell wall (Lockhart, 1965) or by affecting the process of cell division, where it had been reported that GA_3 can increase the size of the meristematic region and also can increase the proportion of cells which
are undergoing division (Loy, 1977).These effects of GA_3 on cell division can be accounted for by an effect on cell cycle, where Liu and Loy (1976) indicated that GA_3 reduced the duration of the cell cycle in watermelon seedlings by nearly 30%. Nutarmine also contributed to the increase in flower head yield per plant through increasing the photosynthetic pigment contents (Bahr, 1990) and enzyme activity, which in turn enhanced plant metabolism and increased nutrient uptake through roots after foliar fertilization (Baier and Baierova, 1999). These factors reflected positively on weight of heads in early yield.

As regards of flower head diameter in early yield, data in Table (3) show that GA_3 alone at 50 or 100 ppm and the combination of 50 ppm with Nutarmine, decreased head diameter in the first season only. However, flower head diameter was not affected by any GA_3 concentrations alone or in combination with Nutarmine in the second season. Nutarmine alone significantly reduced flower head diameter through out the two seasons. The obtained results are in agreement with those of Mansour (1983) who found that GA_3 application at 25 ppm reduced head diameter.

Table (3): Effect of GA_3 concentrations, Nutarmine and their combinations on flower head and receptacle traits, and yield/plant for the early yield of globe artichoke plants (Balady cv.) in 2000/2001 (I) and 2001/2002 (II) seasons.

Treatments	Flower head								Receptacle			
	Number/plant		Weight/ head (gm)		weight/ plant (kg)		Diameter (cm)		Weight (gm)		Diameter (cm)	
	I	II	I	II	I	II	I	II	I	II	I	II
Control	4.3	4.1	192.5	195.0	0.828	0.799	7.0	7.2	41.6	44.4	4.2	5.1
50 ppm GA3	10.8	11.2	201.3	200.8	2.174	2.249	6.4	7.0	42.9	45.7	4.1	4.7
100 ppm GA3	11.4	11.2	200.3	201.2	2.283	2.253	6.4	6.9	44.7	50.0	4.3	4.7
150 ppm GA3	12.0	11.6	196.0	199.6	2.352	2.315	6.7	7.2	42.0	51.3	4.3	5.3
200 ppm GA3	9.6	11.7	198.7	204.5	1.907	2.392	7.0	7.3	44.7	51.7	4.2	5.1
50 GA3+Nut.	10.3	11.5	203.8	203.6	2.099	2.341	6.4	7.2	41.3	47.4	4.2	4.8
100 GA3+Nut.	11.7	11.2	203.2	201.8	2.377	2.260	6.7	6.9	41.8	48.3	4.3	4.8
150 GA3+Nut.	12.1	12.1	205.7	206.9	2.488	2.503	6.8	7.3	44.6	52.0	4.3	5.4
200 GA3+Nut.	10.0	11.9	202.7	206.1	2.024	2.452	7.1	7.3	45.7	52.8	4.3	5.3
Nutarmine	5.3	5.3	194.8	201.7	1.032	1.069	6.5	6.1	41.9	50.6	4.2	5.2
LSD (5%)	0.74	0.68	6.13	3.18	0.196	0.189	0.36	0.38	2.28	2.92	N.S.	0.41

As for the effect of Nutarmine, similar results were obtained by Panigrahi *et al.* (1990) who pointed out that micronutrients did not affect cauliflower size.

Data of receptacle weight of early yield, presented in Table (3), indicate that GA_3 at 100 or 200 ppm alone or the combinations of GA_3 at 150 or 200 ppm with Nutarmine, significantly and consistently increased receptacle weight in both seasons, compared with control. Other tested treatments, except GA_3 alone at 50 ppm, resulted in a significant increase in receptacle weight, but this was true in the second season only. Nutarmine alone significantly increased receptacle weight in the second season only. The obtained results can be explained by the fact reported by Liu and Loy (1976) and Loy (1977) who indicated that GA_3 can enhance cell division and cell enlargement. At the same time, Nutarmine, as a mixture of micronutrients, increased the amount of metabolites accumulated in these cells by increasing photosynthetic pigment contents and increasing nutrient uptake through roots Bair and Baierova (1999). Similar results were obtained by Garcia *et al.*(1999) and by Kocer and Eser (1999), on globe artichoke.

Results in Table (3) also show that receptacle diameter was not affected by GA_3, Nutarmine or their combinations in both seasons. Similar results were obtained by Mansour (1983) who pointed out that there were no appreciable effect for GA_3 foliar application on receptacle diameter of globe artichoke.

Data of flower head and receptacle characteristics of late yield are presented in Table (4). Concerning number of produced flower heads per plant, data show that all tested concentrations of GA_3 and their combinations with Nutarmine significantly increased number of flower heads per plant, compared with control in both seasons. The highest significant effects were due to the combinations of 200 or 150 ppm GA_3 with Nutarmine, respectively. Nutarmine alone was effective in increasing number of flower heads per plant, but this effectiveness was significant in the first season only.

The average flower head weight of late yield was clearly affected by GA_3 foliar applications alone or in combination with Nutarmine. Data illustrated in Table (4) indicate that in the first season, GA_3 at 150 or 200 ppm or the combinations of GA_3 at 100, 150 or 200 ppm with Nutarmine significantly increased flower head weight. In the second season, all tested GA_3 levels and their combinations with Nutarmine increased significantly the flower head weight. The highest significant increase, in both seasons, resulted from the combinations of GA_3 at 200 or 150 ppm GA_3 with Nutarmine, respectively. Nutarmine alone increased flower head weight, but this increase was significant in the first season only.

Weight of heads per plant of late yield (Table 4) significantly increased by all GA_3 levels, either alone or in combination with Nutarmine, in both seasons. Highest weight of heads of late yield per plant was produced by the combination of GA3 at 150 or 200 ppm with Nutarmine. Nutarmine alone significantly increased fresh weight of late yield per plant, but in the first season only. The obtained results are in harmony with those obtained by Elia *et al.* (1994), and Schrader (1994) who concluded that GA_3 treatments increased number of heads, average head weight and total yield of globe artichoke.

Table (4): Effect of GA3 concentrations, Nutarmine and their combinations on flower head and receptacle traits and yield/ plant for the late yield of globe artichoke plants (Balady cv.) in 2000/2001 (I) and 2001/2002 (II) seasons.

treatments	Flower head								Receptacle			
	Number/plant		Weight/ head (gm)		weight/ plant (kg)		Diameter (cm)		Weight (gm)		Diameter (cm)	
	I	II	I	II	I	II	I	II	I	II	I	II
Control	19.7	20.8	138.5	136.8	2.728	2.845	7.0	6.7	34.9	33.7	4.7	4.2
50 ppm GA3	20.7	23.1	137.1	139.2	2.817	3.215	6.01	6.0	30.8	34.2	4.6	3.9
100 ppm GA3	21.7	22.3	137.9	140.0	2.992	3.122	6.3	6.1	40.5	35.4	4.7	4.0
150 ppm GA3	24.4	23.5	140.3	139.6	3.423	3.280	7.0	6.0	40.3	37.8	4.6	4.1
200 ppm GA3	23.7	24.4	141.3	141.0	3.504	3.440	7.1	6.4	38.4	38.7	4.5	4.1
50 GA3+Nut.	21.2	24.3	138.6	140.8	2.938	3.421	6.5	6.2	41.4	36.0	4.6	4.0
100 GA3+Nut.	22.0	24.4	140.4	141.0	3.088	3.440	6.6	6.3	41.2	35.1	4.5	4.1
150 GA3+Nut.	25.8	26.1	143.3	143.2	3.697	3.737	6.8	6.4	45.5	41.0	4.5	4.2
200 GA3+Nut.	24.8	25.9	142.7	141.6	3.539	3.667	6.7	6.7	44.1	40.6	4.5	4.2
Nut.	21.0	21.4	140.2	137.1	2.944	2.933	6.8	6.4	44.2	40.2	4.8	4.2
L.S.D at 5%	0.80	1.23	1.54	1.72	0.198	0.204	0.30	0.31	5.72	1.39	N.S.	N.S.

However, the obtained results disagreed with those of Miguel *et al.*(1997) who found no effect for GA_3 on average head weight or total yield of globe artichoke. Also, the effect of Nutarmine was similar to the results obtained by Rai *et al* (2002) who reported significant increase in tomato fruit number and weight and total yield as a response to foliar spray of micronutrient mixture.

As for flower head diameter, data in Table (4) show that GA_3 at 50 and 100 ppm alone or in combination with Nutarmine, significantly reduced head diameter in both seasons. In addition, GA_3 at 150 ppm also significantly decreased head diameter, but only in the second season. Other tested treatments did not affect head diameter in both seasons, compared with control. The reduction in globe artichoke head diameter was reported previously by Mansour (1983) who indicated that GA_3 treatment resulted in a decrease in head diameter.

Concerning receptacle weight of late yield, data in Table (4) indicated that GA_3 at 100, 150 and 200 ppm, in the second season only, the combinations of any tested GA_3 level with Nutarmine and Nutarmine alone, in both seasons, increased significantly the receptacle weight, compared with control. The highest significant increase in receptacle weight was resulted from the combinations of GA_3 at 150 or 200 ppm with Nutarmine, and from spraying the plants with Nutarmine alone, in both seasons. Similar results were obtained by Garcia *et al.* (1999) who indicated that GA_3 at 50 ppm increased receptacle weight.

With regard to receptacle diameter of late yield, data in Table (4) proved that all tested treatments insignificantly affected receptacle diameter in comparison with check treatment. The obtained results were consistent through the two seasons and were in agreement with those obtained by Mansour (1983) who indicatede that there were no significant effect for GA_3 foliar application on receptacle diameter of globe artichoke.

The effect of GA_3 concentrations, Nutarmine and their combinations on chemical constituents of head receptacles of early yield is presented in Table (5) Results indicate that total soluble solids were not affected by GA_3, Nutarmine or their combinations, in the two seasons compared with the control. The obtained results are in harmony with those obtained by Garcia *et al.* (1994) who found that GA_3 as one spray of 50 ppm followed by one of 25 ppm a month later, did not significantly affect the receptacle total soluble solids. However, Abou-Hadid *et al.* (1995) reported that globe artichoke heads subjected to 60% shading and 100 ppm GA_3 resulted in the higher T.S.S., compared with control. As for the effect of Nutarmine, similar results were obtained by Petrikova (1991) who found that spraying tomato plants with cytozyme (containing chelated micronutrients) did not affect tomato fruit total soluble

solids.Results of reducing and non-reducing sugars indicate that all tested treatment, except GA_3 alone at 200 ppm, significantly increased reducing sugars of receptacles in the two seasons. However, non-reducing sugars were not affected by any of the tested treatments in the two seasons.

Table (5): Effect of GA_3 concentrations, Nutarmine and their combinations on chemical constituents of globe artichoke receptacles (Balady cv.) of early yield in 2000/2001 (I) and 2001/2002 (II)seasons.

Treatments	T.S.S. (%)		Red. Sugars (%)		Non-red. sugar (%)		Inuline (%)		Phenols (%)	
	I	II	I	II	I	II	I	II	I	II
Control	9.26	9.31	0.75	0.75	0.13	0.12	1.37	1.41	0.32	0.33
50 ppm GA3	9.03	9.20	0.80	0.80	0.11	0.11	1.32	1.32	0.33	0.33
100 ppm GA3	9.40	9.25	0.81	0.80	0.12	0.11	1.32	1.36	0.36	0.34
150 ppm GA3	9.16	9.23	0.80	0.78	0.12	0.12	1.38	1.37	0.37	0.36
200 ppm GA3	9.14	9.21	0.77	0.76	0.11	0.12	1.34	1.36	0.38	0.37
50 GA3 + Nut.	8.98	8.90	0.81	0.79	0.12	0.12	1.40	1.33	0.36	0.36
100 GA3 + Nut.	9.36	9.31	0.81	0.80	0.12	0.12	1.38	1.34	0.36	0.34
150 GA3 + Nut.	8.83	9.25	0.80	0.79	0.11	0.11	1.36	1.36	0.36	0.35
200 GA3 + Nut.	9.03	9.40	0.83	0.81	0.12	0.12	1.32	1.39	0.37	0.35
Nutarmine	9.30	9.35	0.81	0.80	0.11	0.12	1.39	1.38	0.34	0.33
LSD (5%)	N.S.	N.S.	0.03	0.03	N.S.	N.S.	N.S	N.S.	0.02	0.02

Similar trend was reported by Garcia *et al.* (1999) and Kocer and Eser (1999), who pointed out that high concentrations of GA_3 (75 ppm or higher) insignificantly affected reducing sugars, but low concentrations of GA_3 (50 ppm or lower) increased significantly the reduced sugars of the receptacles. The obtained trend of Nutarmine on reducing and non-reducing sugars is similar to the results of Medhi and Kakati (1994), who reported a remarkable increase in reducing sugars as a response of spraying okra plants with a mixture of micronutrients, while the non-reducing sugars insignificantly responded to micronutrients.

Concerning the effect of GA_3, Nutarmine and their combinations on inuline percentage, data in Table (5) clearly show that all tested treatments had insignificant effect on receptacle inuline contents. The obtained results are in harmony with those of Miguel *et al* (1997) who sprayed globe artichoke plants with GA_3 or GA_2, each at 30 ppm, but did not find any significant effect on inuline percentage.

Data related to percentage phenols in receptacles indicated that increasing the concentration of GA_3 was associated with increasing in percentage phenols. This increase was insignificant at 50 ppm GA_3, but was significant at all other higher tested GA_3 concentrations, compared with control. Results also showed that all combinations of GA_3 with Nutarmine resulted in a significant increase in percentage phenols, compared with control. However, Nutarmine alone did not significantly affect percentage phenols. The described results were consistent through the two seasons.

Similarly, Geibel *et al.* (1994) reported that treating celery plants with GA_3 prior to storage, resulted in a significant increase in psoralens, a natural phenol. Also, Agwah *et al.* (1994) soaked onion seeds immediately before planting in GA_3 at 50 or 100 ppm, and he found that phenol contents in seeds of the new generation were significantly higher in the case of 100 ppm GA_3 treatments than in the case of 50 ppm treatment.

The effect of GA_3 levels, Nutarmine and their combinations on gibberellins and microelement contents of head receptacles of early yield (in the second season only) is presented in Table (6). Results indicate that receptacle contents of gibberellins increased significantly by all tested treatments compared with control. Amount of gibberellins accumulated as a result of spraying the plants with any tested GA_3 concentration alone was significantly higher than the amount resulted from combining GA_3 levels with Nutarmine, or Nutarmine alone. Nutarmine alone increased the contents of gibberellins compared with control, but it was less effective than any GA_3 level alone or when combined with Nutarmine.

As for receptacle micronutrient contents, data in Table (6) show a significant increase in Mn, Fe, Cu, B and Zn as a result of spraying globe artichoke plants with Nutarmine alone or in combination with GA_3 levels, compared with control or GA_3 alone at any level. The highest concentration of each determined microelement were detected in plants treated with Nutarmine alone. The obtained results are in agreement with those obtained by Patil (2001) on okra, by Panigrahi *et al.* (1990) on cauliflower, and by Petrikova (1991) on tomato.

Table (6): Effect of GA_3 concentrations, Nutarmine, and their combinations on Gibberellins and microelement contents of globe artichoke receptacles (Balady cv.) of the early yield during the second season 2001/2002.

Treatments	GA (ng/g. Fw)	Mn (mg/kg)	Fe (mg/kg)	Cu (mg/kg)	B (mg/kg)	Zn (mg/kg)
Control	25.53	165.00	231.00	9.53	37.50	40.53
50 ppm GA3	89.53	164.33	232.00	8.40	36.13	40.60
100 ppm GA3	93.10	167.00	223.30	10.0	35.83	42.20
150 ppm GA3	93.10	157.00	224.33	8.30	37.93	39.20
200 ppm GA3	95.23	160.33	234.0	9.20	36.70	42.86
50 GA3+ Nut.	62.70	272.00	282.66	11.96	41.83	50.66
100 GA3+ Nut.	65.20	270.00	293.00	12.26	42.33	51.80
150 GA3 + Nut.	71.76	265.30	278.33	11.83	42.56	48.53
200 GA3 + Nut.	72.20	257.66	243.66	12.43	42.93	49.53
Nutarmine	61.46	371.66	300.33	12.63	43.73	52.16
LSD (5%)	4.41	4.14	2.95	0.70	1.20	1.28

Storability study

Data in Table (7) reveal that prolonging storage period resulted in a remarkable increase in percentage weight loss, percentage decay, discoloration of receptacle cut ends, and percentage fiber contents, while it caused a clear reduction in the values of visual quality and texture of globe artichoke flower heads. These results were true and consistent, regardless the packaging treatments, in both seasons.

Table (7): Effect of interaction between packaging treatments and *storage periods on* tested storage parameters of globe artichoke flower buds during storage at 0°C.

Packaging Treatment	Weight loss %				Decay %				Discoloration of cut ends[1]			
	1w*	2w	3w	4w	1w	2w	3w	4w	1w	2w	3w	4w
	2000/2001											
St. Film**	1.12	2.27	2.74	3.75	1	1	1.25	2.0	1.00	2.00	2.25	2.75
Lining	7.77	15.0	18.5	19.8	1	1	1.50	4.5	1.25	2.50	2.75	3.50
Control	10.9	18.2	21.7	23.3	1	1	2.25	5.0	1.75	2.50	3.00	4.00
LSD (5%)	2.03	1.73	2.65	4.20	ns	ns	0.24	0.78	0.32	0.31	0.74	0.63
	20001/2002											
St. film	1.04	1.75	2.48	2.29	1	1	2.00	2.7	1.25	2.00	2.75	3.00
Lining	5.37	8.23	12.3	16.3	1	1	2.50	4.0	1.25	2.50	3.50	3.75
Control	8.18	11.0	15.8	21.8	1	1	3.00	4.5	1.50	2.50	3.70	4.00
LSD (5%)	1.46	2.05	1.71	1.65	NS	NS	0.25	0.37	0.17	0.33	0.40	0.53

Packaging treatmen	Fiber %				Visual quality[2]				Texture[3]			
	1w	2w	3w	4w	1w	2w	3w	4w	1w	2w	3w	4w
	2000/2001											
St. Film**	0.50	0.53	0.57	0.60	9.00	8.50	7.50	5.0	5.00	4.50	4.00	3.75
Lining	0.62	0.70	0.74	0.80	7.50	5.50	5.50	2.5	4.50	4.00	3.50	2.00
Control	0.68	0.77	0.81	0.88	6.00	4.00	1.75	1.0	4.00	4.00	3.00	1.00
LSD (5%)	0.09	0.12	0.17	0.15	1.24	0.83	1.05	0.70	ns	ns	1.23	0.85
	20001/2002											
St. film	0.47	0.50	0.53	0.55	9.00	8.75	7.00	5.00	5.00	5.00	3.75	3.25
Lining	0.56	0.60	0.66	0.72	8.25	7.00	6.50	3.00	4.25	4.75	3.50	2.50
Control	0.62	0.65	0.73	0.80	7.00	5.00	2.00	1.00	4.00	4.25	2.50	1.50
LSD (5%)	0.08	0.06	0.11	0.14	0.68	0.46	0.25	1.35	NS	NS	0.94	0.61

*** W = weeks** **** St. film= Stretch film**

1- Discoloration score: 1= none, 2= slight, 3= moderate, 4= moderately severe, 5= severe

2- Visual quality score: 9= excellent, 7= good, 5= fair, 3= poor, 1= unusable

3-Texture score: 1= very soft, 2= soft, 3= moderately firm, 4= firm, 5= very firm and turgid

Data in Table (7) also show that individually wrapping heads with stretch film, or lining cartons significantly reduced percentage weight loss, compared with control, but using the stretch film was more effective. Similar results were obtained by Passam *et al.* (1999) who enclosed globe artichoke heads in polyethylene and stored them at 2 and 10°C, and found that wrapping decreased water loss which subsequently reduced weight loss. Data related to percentage decay (Table 7) demonstrated that the lowest percentage decay, after the third and fourth weeks of storage at °C was associated with heads wrapped with stretch film. These results may be due to high permeability of the stretch film, the feature that prevents humidity accumulation and allows good gas exchange, which subsequently help in keeping cell turgidity and minimizing fungi and bacterial infection (Kader *et al.*, 1989).

Concerning the discoloration of receptacle cut ends, data in Table (7) show that head wrapping with stretch film significantly minimized discoloration of receptacle cut ends, compared with lining and control treatments, at any storage period. These results are consistent with the known effect of modified atmosphere packaging in reducing the activity of polyphenoloxidase enzyme, which catalyze the oxidation reaction leading to discoloration (Wiley, 1994).

As for fiber contents, data in Table (7) indicate that individually wrapping heads with stretch film significantly reduced percentage fiber contents, compared with lining and control treatments, at any tested storage period. These finding agreed with those of Omar (2003) on baby corn.

Data in Table (7) also show that individually wrapping heads with stretch film significantly maintained visual quality better than lining or control treatments. Lining treatment was also significantly better than control treatments in keeping the visual quality of heads. The obtained results are in line with those of Kader *et al.* (1989), who indicated that packaging vegetables with polymeric films retards deterioration and enhances maintenance of market quality.

Regarding texture, results illustrated in Table (7) demonstrate that packaging treatments did not affect head texture in the first two weeks of storage at °C. However, when storage period was prolonged to 3 or 4 weeks, results indicated that wrapping heads with stretch film, significantly minimized the reduction in texture values, compared with control treatments. These results are in harmony with those of Kader *et al* (1989).

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تأثير حمض الجبريليك وخليط من العناصر الصغرى (نيوترامين) على التبكير والمحصول والجودة فى نورات الخرشوف

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تم زراعة نباتات الخرشوف المعمرة فى محطة بحوث قها خلال الموسمين المتتالين ٢٠٠٠/٢٠٠١ ، ٢٠٠١/٢٠٠٢ وذلك لدراسة تأثير حمض الجبريليك بتركيزات ٥٠ ، ١٠٠ ، ١٥٠ ، ٢٠٠ جزء فى المليون ، خليط من العناصر الصغرى (نيوترامين) وخليط من كليهما على نمو النباتات ، التبكير ، محصول النورات ، والمحتوى الكيماوى للجزء المأكول . كما تم دراسة تأثير طرق التعبئة على القدرة التخزينية للرؤوس والناتجة من المعاملة بخليط من حمض الجبريليك بتركيز ١٥٠ جزء فى المليون مع النيوترامين .

وقد أظهرت البيانات أن عدد الأوراق / نبات زاد معنويا عند المعاملة بالنيوترامين فقط . أما عدد الخلفات / نبات فقد زاد معنويا بواسطة المعاملة بحمض الجبريليك عند تركيز ١٥٠ جزء فى المليون. وكذلك عند المعاملة بالنيوترامين أو بخليط من كليهما . ولم يؤثر حمض الجبريليك أو النيوترامين أو مخلوطهما على الوزن الجاف للأوراق / نبات .

وكان حمض الجبريليك بتركيز ٢٠٠ جزء فى المليون الأفضل فى إستحداث الإزهار المبكر . وكانت أعلى نسبة مئوية للإنبات فى المحصول المبكر نتجت من المعاملة بخليط من حمض الجبريليك عند ١٥٠ جزء فى المليون مع النيتوترامين . أما المحصول المتأخر فقد زاد معنويا عند المعاملة بالنيوترامين فقط .

فى المحصول المبكر أحدث الخليط من حمض الجبريليك بتركيز ١٥٠ جزء فى المليون مع النيوترامين زيادة معنوية فى عدد النورات لكل نبات ، وفى متوسط وزن النورة ، الوزن الكلى للنورات/نبات ، بينما أدى الخليط من حمض الجبريليك بتركيز ٢٠٠ جزء فى المليون مع النيوترامين إلى أعلى زيادة معنوية فى وزن الجزء المأكول .

فى المحصول المتأخر أدت المعاملة بخليط من حمض الجبريليك بتركيز ١٥٠ جزء فى المليون مع النيوترامين إلى أعلى زيادة معنوية فى عدد النورات/نبات ومتوسط وزن النورة ، وزن النورات/نبات ومتوسط وزن الجزء المأكول . على الرغم من أن مستويات حمض الجبريليك ، والنيوترامين أو كليهما لم يكن لها تأثير على قطر النورة أو قطر الجزء المأكول .

وقد زادت كل المعاملات المدروسة ، ما عدا حمض الجبريليك بتركيز ٢٠٠ جزء فى المليون ، محتوى الجزء المأكول من السكريات المختزلة ، فى حين لم يكن لها أى تأثير على السكريات الغير مختزلة والأنيولين . فزيادة تركيز حمض الجبريليك سواء كان بمفرده أو مخلوطا مع النيوترامين مصاحبا لزيادة فى محتوى الجزء المأكول من الفينولات . وقد زادت كل المعاملات المدروسة من تراكم حمض الجبريليك وكان هناك زيادة تدريجية فى محتوى الجزء المأكول من حمض الجبريليك عند زيادة تركيز حمض الجبريليك المستخدم سواء كان بمفرده أو مخلوطا مع النيوترامين . وقد زادت الكميات المقدرة من العناصر الصغرى ، المنجنيز والحديد والنحاس والبورن والزنك معنويا عند معاملة النباتات بالنيوترامين سواء بمفرده أو مخلوطا مع حمض الجبريليك .

عند دراسة القدرة التخزينية، أكدت النتائج أن زيادة فترة التخزين أدت إلى زيادة معنوية فى النسبة المئوية للفقد فى الوزن ، % للتالف ، % للمحتوى من الألياف ، والتغير فى لون الجزء المقطوع . فى حين أنه حدث إنخفاض فى قيم جودة المظهر والقوام فى النورات ، بغض النظر عن معاملات التعبئة المدروسة . التغليف الفردى للنورات بواسطة استرتيش فيلم ومعاملة تبطين صناديق الحفظ كان أفضل من معاملة الكنترول ولكن معاملة التغليف الفردى للنورات كانت أكثر معنويه فى تحسين صفات الجودة التخزينية مثل الفقد فى الوزن ، % للتالف ، تغير فى لون الجزء المقطوع ، % للألياف ، جودة المظهر وكذلك القوام .