Department für Pflanzenwissenschaften

Lehrstuhl für Gemüsebau

Studies on the Effect of Some Agricultural Treatments on Growth and Productivity of Artichoke (*Cynara cardunculus* var. *scolymus* (L.) Fiori) and their Relation to Earliness and Physical and Chemical Characters of Heads

Mahmoud Abd-Elmoneim Abd-Elsalam Sharaf-Eldin

Vollständiger Abdruck der von der Fakultät Wissenschaftszentrum Weihenstephan für Ernährung, Landnutzung und Umwelt der Technischen Universität München zur Erlangung des akademischen Grades eines Doktors der Agrarwissenschaften genehmigten Dissertation.

Vorsitzender:	Univ.-Prof. Dr. G. Forkmann
Prüfer der Dissertation:	
	1. Univ.-Prof. Dr. W. H. Schnitzler
	2. Univ.-Prof. Dr. G. Wenzel

Die Dissertation wurde am 08.04.2002 bei der Technischen Universität München eingereicht und durch die Fakultät Wissenschaftszentrum Weihenstephan für Ernährung, Landnutzung und Umwelt am 21.05.2002 angenommen.

Acknowledgement

I would like to express my deep gratitude and sincere appreciation to my supervisor Prof. Dr. W. H. Schnitzler for his permanent support, kind encouragement and the scientific advises throughout my research in Germany.

Also, I would like to express my deepest thanks and gratitude to my Egyptian supervisors Prof. Dr. Ibrahim Ibrahim El-Oksh, Professor of Vegetable Crops, Horticulture Department, Faculty of Agriculture, Ain Shams University and Prof. Dr. Abd El-Fattah Mohamed Razin, Professor of Medicinal and Aromatic plants, Medicinal and Aromatic Plants Department, National Research Centre, for their kind support, valuable advises, continuous help, sincere criticism and constructive ideas.

I am very much indebted to Dr. Gerda Nitz for her untiring help, understanding and her correct guidance, as well as for her freedom in discussions and constructive criticism in chemical analyses.

Moreover, I thank all my colleagues at the Chair of Vegetable Science of the Technische Universität München in Freising-Weihenstephan. Deep thanks are also given to Dr. Abdelaaty A. Shahat, Pharmaceutical Sciences Department, National Research Centre for his kind cooperation and patience in discussing and explaining chemical issues, as well as many thanks to Mrs. Mechthild Mayershofer for professional technical assistance.

I am extremely thankful to Mr. G. Reiter and Mr. U. Grotz for their cooperation in the field trials. Also, I would like to express my appreciation to ICSC-World Laboratory for their financial support.

Moreover, my thanks to my family who provided the proper conditions to finish this study.

LIST OF ABBREVIATIONS

%	percent
&	and
CLAC	The Central Laboratory for Agricultural Climate
cm	centimeter
cv.	cultivar
DM	dry matter
DWD	Deutscher Wetterdienst (German weather service)
e.g.	for example
etc.	et cetera
Fig.	figure
Figs.	figures
FW	fresh weight
g	gram
GA3	gibberellic acid
ha	hectare
HPLC	High Performance Liquid Chromatography
i.e.	id est (that is)
Kg	kilogram
mg	milligram
mm	millimeter
nm	nanometer
oz	ounce
ppm	part per million
R^2	level of determination
RH	relative humidity
TSS	total soluble solids
UV	ultraviolet
vs.	versus

LIST OF TABLES

LIST OF FIGURES

1. Introduction

1.1 Globe artichoke as a vegetable crop

Globe artichoke (*Cynara cardunculus* var. *scolymus* (L.) Fiori) is a large immature flower rich in medicinal substances. It is considered one of the most important vegetable crops in the countries bordering the Mediterranean basin including Egypt. The world production of globe artichoke increased from 1205 to 1290 million tons from 1999 to 2000 (Behr, 2001).

1.2 Globe artichoke as a medicinal plant

Globe artichoke has important nutritional values related to its high content of phenolic compounds such as flavonoids, but also due to inulin, fibres and minerals. Phenolic compounds such as cynarin are derivatives of caffeic acid. Extracts containing cynarin (1,5-dicaffeoylquinic acid) have effect on hepatobiliary diseases, hyperlipidaemia, dropsy, rheumatism and cholesterol metabolism. Dichloromethane and ethanol extracts of leaves have also antibacterial properties.

1.3 Globe artichoke in Egypt and in Germany

Nowadays, in Egypt and Germany (Bavaria) more attention is given to promoting globe artichoke production to satisfy the increased demands of local consumption as well as for exportation. High quality artichoke buds with early production of flower heads during the period from December to February (in case of Egypt) and in summer months (in case of Germany) have major importance for promoting the local market and export. Most artichoke plantation areas in Egypt cultivate the local cultivar “Balady” which is very heterozygous and its heads have poor quality, not suitable for exportation. “Green Globe” variety is a seeded cultivar which is suited under German conditions.

1.4 Objectives of this research work

The early harvest period from December to February for globe artichoke in Egypt is economically interesting because in most European countries there is no production during these months, except in southern Italy and Spain, but they are also a big consumer for globe artichoke. The earlier the harvest the higher the prices in the market. In Egypt the highest market prices are obtained from December to February.

In order to accelerate the head production and obtain increased benefits from higher prices, exogenous gibberellic acid (GA3) application is proposed. Applications of GA3 is a common practice to achieve earliness. In this way, cold requirements can be substituted by GA3 for early triggering of the flowering process. Additionally, the best quality is achieved prior to the hotter months of the year.

Globe artichoke is mainly propagated by vegetative propagation (stump cuttings) with the problem of virus diseases and also with low percentage of plant survival (only around 60-70 %). This method often causes physiological, pathological and economical disadvantages. Some of them can be avoided, or reduced by rooted offshoot propagation. Rooted offshoot propagation can reduce the cost of purchasing expensive F1 hybrid seeds each new season. Recently, seed grown cultivars, open pollinated or hybrids, are more readily available.

The aim of this research work was to produce early, high yield and good quality globe artichokes of the cultivar Imperial Star (IS) by applying different gibberellic acid (GA3) treatments, both on seedlings and on directly seeded plants in the field with studies on the physical and chemical characters of harvested heads. Furthermore, rapid increase of clean offshoots from healthy mother plants for globe artichoke propagation of new selections should be made available.

2. Review of literature

2.1 Gibberellic acids

Gibberellic acids are naturally occurring plant hormones. These growth hormones are used in agriculture as plant regulators to stimulate both cell division and cell elongation that affect leaves as well as stems (eventually affecting fruit development and fruit set). Applications of Gibberellic acids can also hasten plant maturation and seed germination. Because they are naturally occurring compounds and have a nontoxic mode of action in target plants, gibberellic acid and related isomers have been classified as agrochemicals. The following compounds are considered collectively under the term ‘’Gibberellic Acids’’: Gibberellic Acid (GA3) $C_{19}H_{22}O_6$; related isomers known as Gibberellins (GA4) $C_{20}H_{26}O_5$ and (GA7) $C_{20}H_{24}O_5$; and the salt of the acid, potassium gibberellate $C_{19}H_{21}KO_6$. Various investigators have reported effects of gibberellic acid (GA3) on globe artichoke plants, but results are variable (De Malach et al., 1976; Foury, 1977; El-Baz et al., 1979; Lin et al., 1991; Elia et al., 1994b; Schrader, 1994; Garcia et al., 1999 and Mauromicale & Ierna, 2000).

2.2 Genetic and botanical origin of globe artichoke

Foury (1969) studied the floral biology of nine globe artichoke cultivars. He found that all cultivars were very heterozygous and by self fertilization showed a wide range of forms. The progenies of different parents were quite distinct. Furthermore, Foury (1989a) mentioned that the origin of the genus Cynara is Mediterranean while its taxonomy and phylogeny are controversial. As a crop, this vegetable is relatively recent (about 1st century) but very few of the 90 cultivars are cultivated. Interspecific crosses are frequently fertile. Little improvement of inflorescence structure has occurred and wild species are not yet being utilized as sources of disease resistance.

Also, Lanteri et al. (2001) concluded that globe artichoke is a vegetable native to the Mediterranean basin. Its commercial production is mainly based on perennial cultivation of vegetatively propagated clones, which are highly heterozygous and segregate widely when progeny tested. A taxonomic revision of the genus Cynara produced 8 species and 4 subspecies, viz. C. algarbiensis, C. auranitica, C. baetica including subsp. baetica and subsp. maroccana (formerly know as C. hystrix), C. cardunculus including subsp. cardunculus and subsp. flavescens, C. cornigera, C. cyrenaica, C. humulis (formerly sometimes in the genus Bourgaea) and C. syriaca. The cultivated artichoke (formerly C. scolymus) and cardoon are both included in C. cardunculus. One species, C. tournefortii is excluded from Cynara (Wiklund, 1992).

The genetic affinities between the cultivated globe artichoke Cynara cardunculus var. scolymus [C. scolymus] and its wild relatives were tested by means of a crossing programme (Rottenberg and Zohary, 1996). The following wild taxa were involved: (1) wild cardoon C. cardunculus var. sylvestris; (2) C. syriaca; (3) C. cornigera; (4) C. algarbiensis; (5) C. baetica (= C. alba); and (6) C. humilis. Only the wild cardoon was found to be fully cross-compatible and fully infertile with C. scolymus. In contrast, all other five wild Cynara species turned to be almost fully or fully cross-incompatible with C. scolymus, and the few interspecific F1 hybrids recovered were partly or almost fully sterile. These findings establish wild cardoon as the wild ancestor of the cultivated globe artichoke.

Similar results were obtained by Rottenberg et al. (1996) on the genetic affinities between the cultivated artichoke Cynara cardunculus var. scolymus [C. scolymus] and its wild relatives were assessed by tests of 20 enzyme systems (28 loci). Six representative cultivars and the following wild taxa were examined: (1) wild cardoon C. cardunculus var. sylvestris; (2) C. syriaca; (3) C. cornigera (= C. sibthorpiana); (4) C. algarbiensis; (5) C. baetica (= C. alba); and (6) C. humilis. Twenty-one out of the 28 loci tested were polymorphic (mainly between species). The genetic identity between the cultivars and the wild cardoon forms ranged from 0.92 to 0.96; while that between these two taxa and the five other wild Cynara species ranged between 0.67 and 0.79. This also implicates that wild cardoon C. cardunculus is the wild ancestry of the cultivated artichoke.

2.3 Vegetative growth characters

Globe artichoke is an annual plant, also grown perennially in many commercial areas. When grown from seed as well as by vegetative propagation, it produces a rosette of leaves followed by the growth of a flower stem. The roots and the underground part of the stem become fleshy and form a storage organ. After flowering, the rosette dries and dies. The development of axillary buds on the rhizome of the mother plants produce a cluster of new rosettes for a ratoon crop. Thus, a healthy and proliferate plant canopy is very important for high yield and head quality.

In progenies raised from seed it was evident that separate genetical factors were responsible for the spineless of leaves and bracts. Violetto Di Procida artichoke cultivar produced less number of offshoots compared with Masedo and Spinosa Sardo (Deidda, 1968). Ibrahim (1980) conducted a comparative study on eleven Italian artichoke cultivars and concluded that leaves varied in texture, shape, length and lobbing. Bull artichoke cultivar known to be cold resistant, has a simple leaf shape and dense trichomes on both leaf sides.

The globe artichoke plant grows to a height of 60-160 cm according to the cultivar. Sims et al. (1977) mentioned that globe artichoke plants grow to a height of 60 to 120 cm or more while the number of offshoots per plant can be twelve or more in older plants. Flower head diameter vary from 15 to 20 cm. Globe artichoke can be a perennial plant. Grown from a seed (achene), it produces a rosette of leaves on compressed stem followed by growth of a flowering stem. The stem produces a terminal bud, two or three smaller secondary buds, several still-smaller tertiary buds, etc. (Ryder et al., 1983). Italian *Cynara scolymus* cultivar, Tema 2000 which is moderately vigorous, reaches a height of only 80-90 cm (Tesi, 1994). Schrader and Mayberry (1992) mentioned that plant height of Imperial Star plants was 145 cm and has broad climatic adaptability, in both coastal and desert production areas of Southern California. Similar results were published by Regents of the University of California (1994) with mature plants of Imperial Star averaging 145 cm in height and 150 cm in diameter, having a semierect habit and best suited for cropping in sandy clay loams with optimum temperature range of 7-25 °C.

2.4 Methods of propagation (offshoots, stump cuttings and seeds) vs. yield

Vegetative propagation is the more common method for globe artichoke (De Vos, 1992). According to Morison et al. (2000), globe artichoke is currently multiplied mainly by vegetative means, but the planting by seeds could lead to easier cropping practices and improved yields. This is especially true with hybrid plants which could be produced from crosses of the two genetic male-sterility systems available.

Early yield obtained from artichoke plants raised from offshoots was higher than those obtained from plants raised from stumps, but differences in total yield were not significant. The highest early yield was obtained by planting in mid-July, and the highest total yield by plating in August in Egypt (Hamdi, 1953). Similar results were obtained by Ibrahim et al. (1981) in USA, early yield of offshoot-planted artichoke was seven times that of stump-planted artichoke. Yield/plant of both stump-planted and offshoot-planted globe artichoke decreased as spacing decreased, but total yield per unit area increased. However, these finding were not confirmed by Abdalla et al. (1995) who compared globe artichoke cv. El-Balady grown from offshoots with those grown from stem pieces. Heads were harvested every 5-7 days. With regard to earliness (first 2 weeks of harvest), total and marketable (head diameter >10 cm) yields, plants in their second year tended to produce more and larger heads than those in their first year, although differences were not always significant. In terms of the same parameters, stem pieces generally gave better results than offshoots.

Furthermore, Aboul-Nasr (1995) in Egypt carried out a study on globe artichoke cv. El-Balady and found that the third planting date with offshoots (mid-September, early October or mid-October) had the highest plant stand due to best rooting but the lowest plant height and numbers of early, marketable and total heads. Mid-September planting date resulted in the most early, marketable and total heads. Old crown pieces (stump cuttings) exceeded offshoots in terms of all the studied parameters.

On the other side, Foury (1989b) mentioned that the recent trend away from vegetative propagation to propagation by seed in artichoke cultivation has drawn attention to seed quality. A review of the literature demonstrate that artichoke seeds are able to germinate over a wide range of temperatures (3-4 to 35-39 °C) and exhibit neither photoperiodic sensitivity nor dormancy. In this connection, Schrader et al.(1992) reported that significant yield increases were achieved when a seed-propagated, thornless artichoke cultivar was developed for winter production in coastal and desert regions of Southern California and Arizona. Growers occasionally use transplants to obtain earlier production. Furthermore, in a trial on an alluvial soil near Zaragoza, Spain, the performance of 3 clones of globe artichoke cv. Tudela (ITG, INIA-D and CNA 303) propagated by offshoots was compared with that of INIA-D plants derived from 2 different stages of in vitro propagation (first-year plants and second-year cuttings) and with cv. Imperial Star propagated by seed. Imperial Star performed best in terms of survival rate, yield earliness and total yield (Gil-Ortega et al., 1995).

Gil-Ortega et al. (1998) conducted a comparative study on four artichoke cultivars and concluded that the globe artichoke cultivar Imperial Star, grown from seed, was comparable to 3 cv. Tudela clones (ITG, INIA-D and CAN-303) vegetatively propagated from stumps (stem bases, partially dried and +/- roots). Micropropagated plants of Tudela clone INIA-D were also included. In the first season for early spring and for total yield of Imperial Star (17.1 and 33.8 t/ha, respectively) was clearly superior to Tudela clones (for which the highest yield for spring and total yield was 13.6 and 25.3 t/ha, respectively). In the second season, autumn yields were greater for the vegetatively propagated Tudela clones than for Imperial Star or the micropropagated INIA-D plants, although total yields were still greatest for Imperial Star.

Another study conducted by Miguel et al. (1997) on globe artichoke grown from seed (cv. Green Globe) or propagated by cuttings or micropropagation (cv. Blanca de Tudela), they mentioned that GA3 (30 ppm) and GA2 (30 ppm) applications advanced harvesting date in all treatments, but particularly in micropropagated plants where the harvesting date advanced by almost one month (compared with a few days in other plants). Yields were higher in cv. Green Globe than in cv. Blanca de Tudela. No significant difference was observed between yields of Blanca de Tudela plants propagated by cuttings or micropropagation. Average head weight was similar in all treatments (143.5-163.5 g), regardless of cultivar, method of propagation or GA3 application. Application of GA3 or GA2 had no significant effect on yields. Although the highest yields were recorded from Green Globe plants it is suggested that there could be problems marketing Green Globe heads in Spain as they differ morphologically from Blanca de Tudela heads.

2.5 Offshoot production

As mentioned under 2.4, globe artichoke plants raised from offshoots have some advantages, Mauromicale and Copani (1990) conducted a study to increase the number of offshoots and concluded that, compared with the untreated controls, earthing up or removing the apex on the mother plant increased the number and weight of suckers (offshoots).

2.6 Globe artichoke cultivars and head characteristics

Shape and size of heads, ripening time and yield/plant proved to be the parameters principally used in selection of artichoke cv. (Elia and Miccolis, 1996). A study conducted by Deidda (1968) concluded that Masedu artichoke cultivar was earlier and its heads were more uniform during the production, but it had smaller and poorer flavoured heads than Spinoso Sardo cultivar. As for marketable yield, only 50 % of the buds produced on Violetto di Toscano were large enough for fresh use, while about 80% of Bianco Tarantino buds are suitable for fresh use (Ryder et al., 1983). Basnitzki and Zohery (1987) mentioned that seeded plants of Talpiot globe artichoke has green globe heads with very thick, fleshy receptacles.

Furthermore, Imperial Star is a seeded artichoke cultivar, thornless with distinctive glossy bracts that are slow to spread open with increasing maturity. The marketable yields of Imperial Star (yield of buds with basal diameters of at least 8.9 cm.) were superior to those of Green Globe Improved and Texas Hill (Schrader and Mayberry, 1992). Similar results were obtained in the USA, and published by Regents of the University of California (1994) where Imperial Star closely resembles Texas Hill in overall appearance, but has more consistent bud and head characteristics, and produces a greater weight and number of primary and secondary flower heads. However, Gil-Ortega et al. (1998) concluded that seed-grown Imperial Star heads were less uniform than those of the Tudela clones (ITG, INIA-D and CAN-303), but almost all were considered marketable, and they were slightly larger than those of Tudela. Elia et al. (1994b) studied four artichoke cultivars, namely 044, 137, 223 and 271. Cultivar 271 had significantly smaller heads than the others. Another study conducted by Tesi (1994) describes Tema 2000 as an Italian *Cynara scolymus* variety, selected from the cultivar Terom. It forms ovate flower heads, 9-11 cm long and 140-200 g in weight, having a compact heart with large fleshy receptacle and slow floral differentiation. The main head of Etrusco is compact, deep purple in colour, weighs 380-500 g and has very fleshy bracts (Papalini et al., 1997). The main head of Moro di Corneto is dark violet, has many bracts and weighs 500-550 g.

Harvesting periods vary according to the cultivars. Mean yield per plant was 521, 376, 323.5 and 206.5 g in Romanesco, Catanese, Violetto de Provenza and Domaca Viska, respectively (Bucan and Goreta, 1998). A recent study conducted by Mauromicale and Raccuia (2000) in Italy found that the delay of maturation time caused a linear increase in head weight and width and a slight decrease in length on both 'Violet de Provence' and 'Violet Margot' and a linear decrease in head weight, width and length on 'Violetto di Sicilia'. The ratio length/width of head, weight receptacle/weight head and scape length for the three cultivars decreased with the delay of maturation from November to March. Another study conducted by Mauromicale et al. (2000b) reported the variations of some head characteristics of globe artichoke (*Cynara scolymus* L.) in relation to their development stage, defined as height of the central flower buds of the central part of receptacle. Two cultivars for spring production, 'Romanesco' from Italy and 'Blanc Hyèrois' from France have height of the flower buds on receptacle increased and head fresh weight (whole or of its fractions bracts and receptacle), size (length and width), and DM content linearly and significantly increased.

2.7 Gibberellic acid and head characteristics

As regard to the effect of GA3 on head length and diameter of artichoke, Snyder et al. (1971) found that GA3 treatments at rates of 25, 50, and 100 ppm produced smaller size artichoke heads compared with the control plants. Similar results were obtained by Mansour (1983), GA3 at 50 and 100 ppm reduced head length of artichoke plants (French cv.). However, these findings were not confirmed by Bekhit et al. (1985) who reported that application of GA3 plus urea had no significant effect on length or diameter of artichoke heads. Abou-Hadid et al. (1995) in Egypt mentioned that the shading plus gibberellic acid treatment was superior, giving the highest head quality and quantity (weight and number) in both seasons compared to shading or gibberellic acid alone. Shading plus gibberellic acid was the best treatment with respect to storage behaviour; artichoke heads had low weight loss and decay, and high TSS and DM contents.

2.8 Globe artichoke cultivars and yield

The cultivar is the most important factor that affects the yield of globe artichoke but there are many factors else, such as plant spacing, planting date, the method of propagation as well as sufficient chilling of plants (Hamdi, 1953; El-Baz et al., 1979; Rodrigo et al., 1979; Ibrahim et al., 1981; Baggett et al., 1982; Bianco and Dellacecca, 1982; Pandita et al., 1988; Miccolis et al., 1989; Miccolis et al., 1990; Foti and Mauromicale, 1994 and Calabrese et al., 1994). Furthermore, some other agricultural practices such as early irrigation and covering houses were found to be affecting globe artichoke yields (Eser et al., 1985 and Dellacecca et al., 1987). We will go through these factors in details.

El-Baz et al. (1979) in Egypt mentioned that a selected French strain gave the best quality of heads between December and February while selected Balady produced the yield later in March. Also Rodrigo et al. (1979) evaluated five introduced artichoke cultivars in Spain, i.e., Murcia, Amposta, Tudela, San Juan de Enova and Tudela X Amposta. The earliest and most productive cultivars were Tudela X Amposta and San Juan de Enova. In all tested cultivars, early yield (November to early March) was about 15-25 % of the total crop. Artichoke harvested during this time were more suitable for the fresh market.

Yields of globe artichoke (cv. Green Globe Improved and ARA-85-7-10) were low; 6 months were required from transplanting to first harvest, and about 20 % of the plants were killed by a bacterial rot (tentatively identified as Erwinia sp.). The limited number of flower buds produced was of high quality (Maynard and Howe, 1986). In another study conducted by Basnitzki and Zohary (1987), Talpiot artichoke heads mature late and can be harvested 3 or 4 times during April and May. Talpiot gives yield of 13-16 tons of fresh heads/hectare, the same yield have been obtained from clonal varieties Violet de Provence and Blanc de Hyeres. Welbaum and Warfield (1992) concluded that the average bud yield/plant was 12 for Imperial Star (IS) cultivar and 9 for Green Globe (GG). The average bud weight was 77 and 80 g for IS and GG, respectively. Tema 2000 (Italian *Cynara scolymus* variety) yielded 11 heads/plant. Spinoso Sardo gave a similar yield of heads (10.5 per plant) but with a markedly lower head weight. The other variety (Violetto di Provenza) gave only 7 heads/plant. Tema 2000, which is an early variety, has good frost resistance (Tesi, 1994). Cultivation and seed production of globe artichoke cv. Green Globe were investigated in Uttrarakhand, India, by Khan et al. (1999) during 1994-95. Plants could be harvested 225 days after planting. Mean yield/plant and mean yield/m^2 were 475 g and 1.55 kg, respectively.

2.9 Effect of some agricultural practices on globe artichoke yield

Plant spacing of 1 X 0.6 m generally increased total weight and number of buds/ha, but reduced number and weight of buds/plant compared to spacing of 1 X 1 m or 1 X 2 m. Average weight/bud was unaffected by plant spacing. Total yield was similar to California production of clonally produced artichoke, but buds were smaller (Baggett et al., 1982), USA. Another study conducted by Elia et al. (1994a) using the new seed-propagated globe artichoke cultivars 044, 137 and 271, concluded that the double row spacing of 170 X 70 X 70 cm and the single row spacing (120 X 70 cm) resulted in the highest yield, but the wider-spaced double row bed may be preferable for access by cultivation machinery. Cultivar 271 produced the highest and earliest yield of small heads and cultivar 044 had the shortest harvesting season. Furthermore, Elia et al. (1991) in Italy mentioned that the best sowing time for Talpiot cv. was summer (30 Aug.), when the yield was about twice that in autumn (16 Oct.). On the other hand, spring sowing (7 Mar.) produced no yield of the same year. Increasing plant density reduced the number of heads/plant, while the yield per unit of area increased. Plant densities of >2.5 plants/m^2 reduced the number of productive plants.

Covering houses with 0.2 mm clear polyethylene in Italy, produced the earliest crop, which could be harvested 20-30 days before the untreated control, but the yield was much reduced (Dellacecca et al., 1987). Similar results were obtained by Garcia et al. (1998) who achieved earlier harvests with high market prices by protected cultivation, or by exogenous applications of gibberellic acid. Moreover, additional revenue was obtained by selling leaves to industry for the extraction of cynarin, a pharmacological compound.

In order to improve yields of Sakiz cv. during the winter months in Turkey, early yield was improved by early irrigation (in the first week of Aug.) and by double GA3 (30 ppm) application but total yield and bud size were unaffected. Early irrigation was found to be more practical than GA3 treatment (Eser et al., 1985).

2.10 Chilling requirements and flowering

Globe artichoke plants are biennial when grown from seeds (Hill, 1993). This 2-year cycle requires milder winters than they do happen in Connecticut, but it has been shown that the growth cycle can be shortened to 5-6 months by seed vernalization (moist chilling) and GA3 application to young plants. These techniques enabled satisfactory flower bud production on plants grown as annuals. Seeds of Green Globe were moist-chilled (4 weeks at 2.2-3.3 °C) in Feb. or Mar. The seedlings from the first batch were raised in a greenhouse and transplanted in the field in early May; they produced 90 % of their flower buds between early July and mid-Aug. The second batch were grown in a cold frame and transplanted in early June; they produced 90 % of their flower buds from mid-July to the end of Sep. Average yield of globe artichoke cv. Green Globe ranged from 9780 buds/acre in the first year to 26 680/acre in the second.

Schrader (1994) concluded that in the central coastal region of California, globe artichoke are grown as perennials. In contrast, in the southern coastal region they are raised as annuals, taking advantage of the warm winter climate and favourable winter market prices. In addition, Welbaum (1994) mentioned that globe artichoke is usually propagated vegetatively because plants grown from seed lack uniformity. Furthermore, in much of the USA, only a small percentage of plants grown from seed flower during the first season due to insufficient chilling for vernalization. In the new cultivars, all Imperial Star (IS) and Green Globe Improved (GG) plants flowered after receiving 1356 h of chilling at <10 °C. With 205 h of chilling, 83 % of IS plants flowered compared with 25 % for GG. No Talpiot (TP) or Grand Beurre (GB) plants flowered after 528 h of chilling. Moreover, Mauromicale and Ierna (1995) concluded that regardless of sowing date, Orlando plants produced heads the next spring, confirming that in the Mediterranean environment seed-grown cultivars have to be exposed to the winter season or part of it to meet their cold requirement for flower initiation.

2.11 Gibberellic acid and yield

Second half of September in Israel was the best time to spray with GA3 for advancing harvest in the cv. Violet de Provence; late September to early October was the best time for Camus de Bretagne. In Camus the response was greatest when two GA3 treatments with 200 or 250 ppm were given; in a year without frost, harvesting was then advanced from April to December/January (De Malach et al., 1976). In addition, Foury (1977) concluded that Gibberellic acid treatment of the globe artichoke cv. Blanc Hyerois appeared to increase the number of leaves slightly, but the effect was rarely significant. Only the earliest spray (14 October) could be considered of practical importance, since it advanced the date at which the buds turned colour by 37 days and the start of harvest by 18 days. Such responses can be modified by the latitude at which the crop was grown. In Egypt, GA3 treatment at 50 and 75 ppm increased the early yield in Selected French but had no effect on the total yield (El-Baz et al., 1979). Furthermore, Basnizki et al. (1986) in Israel, used GA3 at 60 and 120 ppm on artichoke plants and indicated that application of gibberellic acid may cause head deformation of artichoke plants.

Another study conducted by Lin et al. (1991) on the globe artichoke cv. Green Globe concluded that the application of GA3 at 45 ppm in Feb. and Mar. was the most effective treatment in terms of bolting earliness, bolting percentage and flower bud yield. It was concluded that GA3 could be used to compensate for the insufficient chilling conditions in Feb./Mar. in Taiwan. Zaki et al. (1991) in Egypt mentioned that GA3 foliar application within its three doses (50, 100 and 200 ppm) on globe artichoke cv. Herious showed the most enhancing effect on both early and total yield of flower heads as compared with either CCC (500, 1000 and 2000 ppm) or NAA (100, 200 and 400 ppm). For exportation, the application of 200 ppm GA3 may be recommended as the most effective treatment to improve flower head earliness and its quality. However, for improving the total yield, 50 ppm GA3, 500 ppm CCC or 200 ppm NAA may be advisable.

Single sprays (80 ppm GA3) at 90 or 120 days after sowing (DAS) or double sprays at 90+120 DAS on globe artichoke cv. 044 resulted in earlier harvest dates and significantly increased yield compared with controls. Number of heads per ha decreased as sowing date was delayed (except for cv. 137). GA3 treatment (60 ppm) tended to increase yield, although less so for later sowing dates. The duration of harvest was reduced with delay in sowing date and by GA3 treatment, more so in cv. 271 than the other two F1 hybrid cultivars 137 and 223 (Elia et al., 1994b), southern Italy.

Garcia et al. (1994) in Argentina mentioned that in 2 years of trials with globe artichoke cultivar Nato, early (Apr./May) foliar applications of GA3 (one spray of 50 ppm or one spray of 50 ppm followed by one of 25 ppm a month later) significantly increased early yield compared with control. This advanced harvesting date by an average of 20 days. A 50 ppm spray in April followed by a 25 ppm spray, each (50 & 25 ppm) at the next 4 months had similar effects. However, sprays applied later (June/July) did not do the same. GA3 is currently used on perennial artichoke to accelerate maturity, being applied 12 weeks after transplanting (6 weeks before first expected harvest).

In another study in USA, GA3 at 20 and 40 ppm and GA4+GA7+benzyladenine, each at 20 ppm applied 9 or 12 weeks after transplanting to an annual crop of cv. Imperial Star did not produce the required earliness and uniformity. However, application of 20 ppm GA3 three times at 2 week intervals significantly increased early, total and large bud yields, with application beginning 4 weeks after transplanting being the most effective (Schrader, 1994).

Mauromicale and Ierna (1995) in Italy studied the effects of GA3 (0, 1, 2 or 3 plant applications at 60 ppm, at the 8, 8+15 or 8+15+25 leaf stages, respectively) and sowing date (from 1 July to 10 August) on the timing of production and head yield of globe artichoke cv. Orlando, a new seed-grown F1 hybrid. GA3 application replaced the cold requirement, allowing autumnal production. GA3's effectiveness, however, was more evident in early sowings than in later ones. A combination of early sowings (1 and 10 July) and GA3 application (2 or 3 times) resulted in a pattern of head production of Orlando similar to that of Violetto di Sicilia (VS), a typical, early, vegetatively-propagated cultivar, with harvesting starting at the end of Oct. and continuing until mid-May. In addition, the total cumulative yield at the end of cycle was significantly higher in Orlando than in VS. When sowing was delayed until 10 Aug., harvesting of GA3-treated plants was delayed until the early spring (Feb./Mar.).

The same concentration of GA3 as above was used by Mauromicale et al. (1996) in Italy on globe artichoke cultivars Orlando and Violetto di Sicilia when planted on 10 or 22 August or 11 September 1991 to study the effects of spraying with 60 ppm GA3 twice or 3 times at the 10 to 11 leaf stage. The crop was irrigated with 3840 micro S/cm salt water. Orlando matured later than Violetto di Sicilia but produced higher yields: 8 heads/plant compared with only 4.4. Planting Orlando early (10 August) with GA3 treatment resulted in earlier maturation and higher yields than Violetto di Sicilia from mid-March onwards. Heads of Orlando tended to be heavier than those of Violetto di Sicilia.

In Argentina the production of globe artichoke is concentrated from August to October. Garcia et al. (1999) conducted a trail to investigate the use of gibberellic acid (GA3) sprays to bring crop maturity forward to the months of higher prices. Twenty-one cultivars were used, grouped according to their precocity. In 1994 and 1995, GA3 was applied at 50 ppm in April and at 25 ppm in May. The application of GA3 in 1994 brought production forward 52 days for the group I cultivars (the earliest), 6 days for group II and only 3 days for group III (the latest), extending the harvesting period by 60, 8 and 3 days, respectively. A similar trend was observed in 1995. There were no significant differences in other variables (yield parameters, head characteristics, etc). Application of GA3 generated an increase in gross revenue, which varied depending on year and cultivar group.

Calabrese and Bianco (2000) mentioned the possibility of autumn production in central Italy with GA3 treatments: harvests started 85 and 118 days after planting, in early and late cultivars, respectively. Number of buds per hectare varied among cultivars in the range from 218 000-175 000. The mean weight of primary buds reached 150 g in all cultivars. Furthermore, Mauromicale and Ierna (2000) concluded that anticipating the harvest time from April to November in Sicily (Southern Italy), early sowing or 2 or 3 consecutive GA3 applications generally decreased the head weight, increased the head length/width ratio, and the stalk length. These effects did not affect the market suitability of Orlando heads. They were less evident on heads of

Violetto di Sicilia, a traditional, vegetatively propagated cultivar that usually produces heads from November to April.

Kocer and Eser (1999) in Turkey studied the rooted offshoots of globe artichoke cv. Sakiz, applied with GA3 at 30 ppm once or twice. Offshoots at the vegetative growth stage were used for planting. Higher early and total yields were obtained instead of using offshoots at flowering (heading) stage. Applying 30 ppm GA3 improved early yields, with a double application being more effective than a single application. On the other hand, Elia et al. (1998) in Italy mentioned that seed treatment with gibberellic acid was not effective with the late cultivars Talpiot and 044. These cultivars should be sown in late July. Artichoke heads continued to increase in size and change in colour as harvesting was delayed.

2.12 Chemical constituent of artichoke and pharmacological use

Artichoke is a species of great pharmacological interest because of its coleretic and hepato-regenerative action induced by the aqueous extracts of leaves (Paun et al., 1996; Wagenbreth, 1996; Walker, 1996; Gebhardt, 1997; Gebhardt and Fausel, 1997; Megias et al., 1997 and Gebhardt, 1998).

Leaves of the globe artichoke and cardoon are used medicinally. Analysis of bitter substances yielded the sesquiterpenes cynaropicrin, grosheimin and cynaratriol (Bernhard, 1982). Ryder et al. (1983) mentioned that globe artichoke has reputed medicinal value. Certain extracts may have beneficial effects on gastro-intestinal activity, blood-clotting time capillary resistance, and heart activity, as well as neutralising effect on certain toxic substances. Also Onisei et al. (1988) reported that artichoke is a species of great pharmacological interest because of its coleretic and hepato-regenerative action induced by the aqueous extracts of leaves. Although the food or eating qualities of the receptacles and bud scales determine its growth as a vegetable in the Mediterranean area, it is also cultivated in Romania for medicinal purposes. In addition, *Cynara scolymus* is used popularly as anti-snake venom with anti-inflammatory activity in Brazil (Ruppelt et al., 1991).

Leaf extracts of artichoke (AE) are reported to reduce serum cholesterol (Gebhardt, 1995). This study was conducted to investigate whether Hepar-SL(R) forte, a commercial preparation of AE exhibits a direct effect on hepatic cholesterol biosynthesis. Incorporation of 14C-labelled acetate into the non-saponifiable fraction was measured using primary cultures of rat hepatocytes. A highly significant concentration-dependent inhibition of cholesterol biosynthesis was detected within 2 h of incubation with 0.01-1.0 mg extract/ml. No cytotoxic effects were observed at these concentrations. It is suggested that AE acts on the serum cholesterol level via choleretically-induced elimination as well as via an inhibitory effect on de-novo cholesterol synthesis. Furthermore, Yasukawa et al. (1996) concluded that two taraxastane-type hydroxy triterpenes, taraxasterol and faradiol, isolated from the flowers of two Compositae plants, *Cynara scolymus* (artichoke) and *Chrysanthemum morifilolium* (chrysanthemum), respectively, showed strong inhibitory activity against 12-O-tetradecanoylphorbol-13-acetate (TPA) induced inflammation in mice. At 2.0 mumol/mouse, these compounds inhibited markedly the tumor-promoting effect of TPA (1 microgram/mouse) on skin tumor formation following initiation with 7,12-dimethylbenz[alpha]anthracene (50 micrograms/mouse).

The review by Kraft (1997) discusses the mechanisms of action, effects, and tolerability and contraindications of artichoke (*Cynara scolymus*) leaf extract. In various molecular, cellular and in vivo test systems, artichoke leaf extracts show antioxidative, hepatoprotective, choleretic and anti-cholestatic effects as well as inhibiting actions on cholesterol biosynthesis and LDL oxidation. Recently, active ingredients responsible for the main effects have been identified. Thus, luteolin seems to be of crucial importance for the inhibition of hepatocellular de novo cholesterol biosynthesis. The anti-dyspeptic actions are mainly based on increased choleresis. Regarding clinical data, lipid-lowering, antiemetic, spasmolytic, choleretic and carminative effects have been described, along with good tolerance and a low incidence of side effects. Due to its specific mechanisms of action, the future use of artichoke leaf extract for the prevention of arteriosclerosis can be expected.

Elevated serum cholesterol is a universally accepted major risk factor for coronary heart disease. Beneficial effects of artichoke (*Cynara scolymus*) extract for serum cholesterol reduction have been reported. Results from controlled clinical trials of artichoke extract for serum cholesterol reduction, the safety data, and the evidence relating to the mechanism of action are reviewed. Computerised literature searches were performed to identify all controlled clinical trials of artichoke extract for serum cholesterol reduction. Databases included Medline, Embase, Biosis, CISCOM and the Cochrane Library. One placebo-controlled clinical trial met all the inclusion/exclusion criteria. It suggested beneficial effects of artichoke extract for the reduction of serum cholesterol in healthy volunteers. Adverse reactions were mild and infrequent. Mechanism of action seemed biologically plausible and supported by rigorous studies. Lipid-lowering effects of artichoke extract are supported by findings in vitro and in animal experiments (Pittler and Ernst, 1998). Fintelmann (1999) studied globe artichoke extract and a complex of digestive symptoms and concluded that the tolerance to a globe artichoke leaf extract (Hepar-SL, 320 mg/pill) was monitored in 203 German patients for 5.7-34 weeks (average of 23 weeks) and the average daily intake was 5 pills. No adverse effects were found and 98.5 % of patients showed very good to good tolerance according to the opinion of doctors.

2.12.1 Phenolic compounds

Two major compounds in globe artichoke are the salts of chlorogenic acid and cynarin. These were isolated from artichoke extracts and found to account for approximately 29 % of the induced sweetness (Bartoshuk et al., 1972). Lattanzio (1977) mentioned that elution with 50 degree ethanol in pH 4 phosphate buffer achieved the best separation of chlorogenic acid, cynarin, caffeic acid, scolymoside and cynaroside with UV spectrophotometric determination at 325 nm. Aubert and Foury (1981) mentioned that chlorophyll and anthocyanin pigments in the bract epidermis give the globe artichoke capitulum a purple-violet colour, the intensity of these pigments varies with the cultivar. At a late ripening stage internal bracts and the flower also contain anthocyanin. Iglesias et al. (1985) extracted mature leaves (cv. Tudela) were extracted with aqueous and alcoholic solvents by various methods, at different temperatures. Presence of more than 30 % alcohol inhibited the isomerization reactions of the chlorogenic and 1,3 dicaffeylquinic acids which occurred in an aqueous medium. Greatest cynarin, cryptochlorogenic acid and neochlorogenic acid contents were obtained by extraction in boiling water. El-Negoumy et al. (1987) isolated from artichoke flowers eleven flavonoid glycosides of apigenin, luteolin, naringenin and isorhamnetin. The leaves, stems, involucral bracts and receptacles contained only four flavonoid glycosides.

Ben et al. (1992) examined germinating seeds of representative cv. and breeding stocks of globe artichoke (*Cynara scolymus* L.) for their content of total phenolics, chlorogenic acid, and 1,5 dicaffeoylquinic acid (cynarin). Content of these phenolic compounds in the germinating seeds varied considerably between different genetic lines. However, it was higher than that reported in artichoke leaves. It was concluded that compared to the traditional extraction from leaves [used for preparation of bitter tasting aperitifs], germinating seeds offer a richer and more dependable source for cynarin supply.

Moreover, globe artichoke has interesting nutritional characteristics related to its high content of phenolic compounds, flavonoids, inulin, fibre and minerals. Phenolic compounds are derivatives of caffeic acid. Extracts containing cynarin (1,5-dicaffeoylquinic acid) have effects on hepatobiliary diseases, hyperlipidaemia and cholesterol metabolism. The pharmaceutical industry mainly uses leaves. *Cynara scolymus* (globe artichoke) contains caffeoylquinic acids which have cholagogic properties (Zapesochnaya et al., 1992 and Mauri et al., 2000).

Also Dranik et al. (1996) mentioned that the globe artichoke, *Cynara scolymus*, possesses both food value and medicinal properties. The main active components of the plant are mono- and dicaffeoylquinic acids, flavonoids and sesquiterpenes. Medicinal preparations from the leaves clearly possess choleretic and diuretic activity and lower the level of cholesterol in the blood. The most suitable raw material for the formulations of medicinal preparations is fresh leaves gathered in the first year after sowing. But Heckers et al. (1977) mentioned that mean serum cholesterol and triglyceride concentrations were not significantly changed within 3 months. Cynarin, administered per oz, has no hypolipidaemic effect in familial Type II hyperlipoproteinaemia. Adzet and Puigmacia (1985) studied choleraic and cholagogic action of *Cynara scolymus* L. extracts and their hepatotropic activity when faced with acute intoxication by carbon tetrachloride. This activity has always been attributed to phenolic compounds present in the extract and in particular to its caffeoylquinic derivatives. The same investigator Adzet et al. (1987) in Spain reported that globe artichoke is used in folk medicine to treat liver complaints. While the contained polyphenolic compounds (cynarin, isochlorogenic acid, chlorogenic acid, luteolin-7-glucoside, caffeic acid and quinic acid) were tested and found that only cynarin and to a lesser extent, caffeic acid showed hepatoprotective activity. In addition, Debenedetti et al. (1993) concluded that the caffeoylquinic acids content of nine Argentine medicinal plants used for their digestive and hepatoprotective properties was studied by HPLC. Their content was compared to that of a leaf extract of artichoke, *Cynara scolymus* L., which has known cholagogue, choleretic and hepatoprotective activities. Detection of high percentages in the studied plants (nine Argentine medicinal plants and globe artichoke) could justify their traditional medicinal use and the proposed analytical method provided an excellent contribution to their quality. Furthermore, globe artichoke leaves have diuretic properties, and are used in the treatment of dropsy and rheumatism.

In a Romanian artichoke strain, flavonoid and polyphenol contents varied with plant age. Plants 9 to 10 months-old were most suited for pharmaceutical preparations, since leaves contained 0.53-2.39 % flavonoids, and 1.22-1.40 % polyphenols (Hammouda et al., 1993a). The same investigators have reported that apigenin-7-0-glucoside, luteolin, cynaroside and scolymoside were isolated from the leaves of globe artichoke cultivated in Egypt. Globe artichoke extracts are used in traditional medicine in Egypt for their choleretic, ureolytic, diuretic and hypocholesterolaemic properties (Hammouda et al., 1993b).

Globe artichoke heads (cv. Catanese) showed an initial increase in the content of phenolic compounds, especially caffeic acid, regardless of the time of harvest. Subsequently, the level of phenolic compounds decreased with time. Pattern and level of this decrease depended on storage temperature and time of harvest (Lattanzio et al., 1989). Another study, conducted by Leoni et al. (1990) concluded that polyphenol oxidase was extracted and purified from artichoke hearts and best substrates were 5-0-caffeoylquinic acid and caffeic acid. The optimum pH was in the range 5.0-7.0 for 5-0-caffeoylquinic acid and 6.5-8.0 for caffeic acid.

Wagenbreth (1995) concluded that the analytical results showed significant losses of caffeoylquinic acid (CCS) with rising drying temperatures. The highest decrease was measured with short time exposition of leaves to 105 ^{0}C, but the flavonoids were more stable at elevated temperatures than CCS. Still growing leaves contained higher amounts of CCS than adult leaves, whereas the older leaves showed a higher content of flavonoids. An overnight decrease in the content of CCS and a subsequent increase until afternoon or evening was characteristic. The nightly decrease was up to 31 %. The maximum content occurred in the afternoon, giving ranges between 3,0 and 4,6 % of the dry mass.

2.12.2 Sugar fractions

One of the most important components in artichoke plant is inulin. In this connection, Teeuwen et al. (1992) in Netherlands concluded that inulin is a non-structural carbohydrate which naturally occurs in some 30.000 different plants including many edible crops. The majority of these plants stock inulin in their roots and tubers. Inulin, a fructose polymer naturally occurring in thousands of plant species has a rich history of nutritional use. It served as a staple food to entire populations and is still consumed widely today. Furthermore, Loo et al. (1995) mentioned that globe artichoke is used in the Western diet because of the presence of inulin and oligofructose. Experimental results are given to show that inulin derivatives have antiarrythmic, anti-tuberculosis, anticarcinogenic, anti-coagulating and fibrinolytic activities (Reshetnik et al., 1998). All varieties of artichoke contain the same vitamins and minerals such as: vitamins C, B1, B2, B3, and Inulin which helps those suffering from diabetes, liver problems, high blood pressure and other bowel disorders (Unisse, 1994).

Green Globe had the highest reducing sugar content (3.9 %) and a high percentage of water-soluble polysaccharides (34.3 %). The varieties Di Teramo and Spinaso Sardo had the highest contents of water-soluble polysaccharides (38.2 %) and total N/crude protein (15.8 %), respectively (Pandita et al., 1988). Globe artichoke has a long (50-60 days) flowering period and yields 0.250-0.720 mg sugar/flower (Cirnu, 1988). Flavour of Imperial Star is slightly sweeter and milder than that of Green Globe Improved (Schrader and Mayberry, 1992). Agwah et al. (1990) found that the inulin content of the edible portion was relatively higher in the early yield.

Different GA3 treatments resulted in significant increase in inulin content (Mansour, 1983 and Bekhit et al., 1985).

2.12.3 Protein content

Globe artichoke (*Cynara scolymus*) dried leaves and ensiled residues had crude protein of 8.93 and 9.77 %, respectively (Hernandez Ruiperez et al., 1992). Mauromicale et al. (2000b) concluded that crude protein increased in receptacle and decreased in bracts, crude fibre increased in both receptacle and bracts. Regardless of head development stage and in both cultivars (Blanc Hyèrois and Romanesco), receptacle contained more crude protein than bracts. In addition, Moharram et al. (1981) mentioned that the globe artichoke bracts, discarded during canning or freezing, contained 4.36 % crude protein in which the predominant amino acids were: isoleucine + leucine (13.1 %), histidine (8.2 %), glutamic acid (5.9 %), serine (5.9 %) and phenylalanine (5.35 %). The extracted protein has value as a food additive.

Globe artichoke by-product was considered a good potential food source because it showed a good amino acid profile and the highest levels of in vitro protein digestibility (DIVP) of 76.4 % (Lopez et al., 1999).

2.12.4 Other chemical compounds and pharmacological uses

Antibacterial properties of the dichloromethane and ethanol extracts of leaves of *C. scolymus* (collected from Brazil) were investigated by (Mossi et al., 1999). He concluded that the dichloromethane extract (5 mg/ml) completely inhibited growth of *Staphylococcus aureus*, *Bacillus cereus* and *B. subtilis* with bactericidal effects. Fractions exhibiting antibacterial properties were isolated, but the active chemical compounds were not identified.

Atherinos et al.(1962) isolated from the receptacles and leaves of a Egyptian artichoke cultivar taraxasterol, Y-taraxasterol, stigmasterol, B-sitosterol, and a new trihydroxy-steroid sappogenin, cysarogenin. In addition, seven pigments were separated from extracts of the outer bracts of globe artichoke and the 3 main pigments identified as cyanidin-3-caffeyl glucoside, cyanidin-3-caffeyl-sophoroside, and cyanidin-3-dicaffeyl-sophoroside. Different varieties only differed in the proportions of the pigments, which were also affected by the maturity (Pifferi and

Vaccari, 1978). In addition, globe artichoke (cv. Green Globe) were of good nutritive value, 1.45 % minerals, 13.09 % carbohydrates, 0.82 % fat, 1.46 % fibre (Khan et al., 1999).

2.12.5 Fatty acids in globe artichoke seeds

Globe artichoke seeds contained 28 % of a fatty oil with a pleasant aroma and flavour. The physical and chemical constants of the oil are given. Lauric, myristic, palmitic, stearic, palmitoleic, oleic, linoleic and linolenic acids were found in the triacyl glycerides. Oleic and linoleic acids made up 44 and 40 % of the total, respectively. In the monoacyl glyceride fraction the same 8 fatty acids were present, with oleic and linoleic acids representing 21.2 and 6.3 % of the total (Kuliev et al., 1985).

Fatty acid composition of oil from globe artichoke (*Cynara scolymus* L.) seeds was determined by GLC by Choudhary and Kaul (1992), the oil contain linoleic acid (50.33 %), oleic acid (41.6 %), palmitic acid (1.35 %) and stearic acid (6.59 %). The oil contain 91.4 % essential polyunsaturated and 9 % saturated fatty acids making it a good edible oil. The unripe globe artichoke (*Cynara scolymus*) flower-heads are not removed but left on the plants at the end of the harvest cycles. These waste flower-heads contain oil-bearing seeds which may have practical applications. Extraction, characterisation and some possible non-food industrial applications of artichoke seed oils are described by Miceli and Leo (1996). Seeds of globe artichoke showed the highest crude protein content of 21.6 % (Foti et al., 1999).

2.12.6 Globe artichoke as animal feed

After a review of previous studies on the nutritive value of leaves and bracts of artichoke (*Cynara scolymus*) it is suggested that despite relatively low contents of amino acids, artichoke bracts may be used as a constituent of diets for dairy and beef cattle. Potassium, iron, manganese and copper are relatively high and energy value was estimated at 0.76 feed unit/kg DM. It is concluded that, in cattle diets, artichoke bracts have a nutritive value similar to that of maize silage (Galvano and Scerra, 1983). On the other hand, leaves, stems and industry residues are used for cattle feeding (Pecaut, 1992). During and at the end of globe artichoke season in Egypt there are a big amounts of residual leaves which can be used for animal feed. Leaves from the Romanian clone can be harvested three times during the growing season, while the Egyptian clone can only be harvested once (at the end of the cultivation season), and the highest number of leaves was obtained from the Romanian clone (Hammouda et al., 1993a).

Hence, Bonomi et al. (1998) studied three groups of 1000 male Arbor Acres broiler chicks, 1 day old. They were given soyabean oilmeal diets containing 0, 2 or 4 % dried *C. scolymus* leaf meal replacing dried lucerne meal, until 60 days of age. Final mean liveweight was 2800, 2838 and 2983 g, average daily gain was 48, 49 and 52 g, and feed conversion efficiency was 2.42, 2.39 and 2.30, respectively. Carcass dressing percentage was 67.50, 67.91 and 68.82 % while meat yield was 36.95, 37.28 and 38.62 %, respectively. The inclusion of artichoke leaf meal in broiler diets did not affect meat quality or health status of the chicks. Stoev (1998) mentioned that the relative weight of liver and kidneys in chicks increased after administration of globe artichoke leaves. The same investigator concluded that globe artichoke (*Cynara scolymus* L.) extract and Robel FAE (poly-extract of Bulbus allii sativa and Semini rosae canina) have a high protective activity against OTA (ochratoxin A) toxicity in chicks (Stoev et al., 1998).

Another study, conducted by Bonomi (1999) used dehydrated artichoke leaf meal in rabbit rations. The by-product, included in the mixed feeds at doses of 5 % and 10 %, in substitution of dehydrated lucerne meal, improved weight gain (resp. 4 % and 7 %), the feed utilization (resp. 3 % and 5 %), carcass (resp. 2.5 % and 5 %), rear quarters (resp. 5 % and 8 %), loin (resp. 5.5 % and 10 %) and meat yield (resp. 4 % and 7 %).

Furthermore, from a body weight of 50 kg, 45 male Italian Friesian calves were fed a standard diet (group 1, controls) or a diet containing 5 or 10 % artichoke leaf meal (groups 2 and 3 respectively). For calves in the 3 groups, daily gain during the 120-day feeding period averaged 0.71, 0.78 and 0.84 kg respectively ($P<0.05$), and the amount of feed consumed per kg gain was 2.6, 2.43 and 2.37 kg respectively. There were no significant differences between the groups in blood protein concentration, but the faecal fat content was lower in experimental animals than in controls, 3.41 and 3.25 % respectively vs. 3.72 (Bonomi et al., 1999a).

In addition, Bonomi et al. (1999b) studied the use of dehydrated artichoke leaf meal in the diets of ducks, when included in mixed feeds at 6 %, in place of dehydrated lucerne meal, an improvement in live weight gain (8.00 %), feed utilization (7.50 %), dressing percentage (6.50 %), meat yield (13.00 %), skin quality (-18.00 %), meat fat (-25.00 %), abdominal and subcutaneous fat (-25.30 %) and skin pigmentation was observed.

3. Materials and Methods

3.1 First experiment in Egypt with globe artichoke plants grown from seedlings for GA3 effect

3.1.1 Materials

This research work was carried out at National Research Centre (NRC) Experimental Station (30°05´N, 31°22´E), located at about 22 m altitude, in the north of Egypt, Al-Gizah Governorate during two successive seasons in 1998-1999 and 1999-2000. The seeds of Imperial Star (IS) globe artichoke cultivar were supplied by Sun Seed Company, California, USA. The main weather information for Cairo, Egypt and Freising, Germany concerning temperature (T), sunshine (SH) and rainfall (RF) is given in table 1.

Table 1: Average values of main weather variables in Cairo and Freising for comparison

	Cairo			Freising		
Month	**T (°C)**	**SH (h)**	**RF (mm)**	**T (°C)**	**SH (h)**	**RF (mm)**
January	13.5	213	5.2	-1.4	93.8	61.4
February	14.9	222	3.5	1.6	98.4	39.2
March	17.5	243	2.4	5.8	95.4	134.2
April	21.0	279	1.1	6.5	133.4	52.6
May	24.5	315	0.6	15.0	263.4	60.2
June	27.1	372	0.1	14.2	223.7	104.5
July	27.7	357	0.0	17.3	248.4	57.7
August	27.6	333	0.0	17.9	242.4	114.5
September	25.9	309	0.0	10.6	75.1	112.8
October	23.4	297	1.0	11.7	154.3	52.5
November	19.1	228	3.4	1.9	60.0	68.4
December	15.1	201	6.6	-1.7	79.0	59.5
Total	21.4	3369	23.9	8.28	1767.3	917.5

Source: Meteorological data of Cairo (CLAC, Egypt) and Freising (DWD, Germany), Average values from 1998 to 2000 in Cairo and for 2001 in Freising

Seeds were sown in trays of 3.2x3.2x4.5 cm cell size in a medium of peat and sand (1:1) in June in a screen-house. After four weeks, the seedlings were transplanted into pots of 14 cm diameter sprayed with nutrient solution [1 g/litre] of (KRISTALON 15-5-30-3+MICRO) at age of 5 and 7 weeks. The 8 weeks old globe artichoke seedlings were transplanted in the field on August 9, 1998 for the first season trial and on August 7, 1999 for the second season. Soil type was clay loam, pH (7.9-8.3).

Fertilization was as follow: 90 kg P_2O_5/ha (calcium superphosphate 15.5 % P_2O_5) was soil-incorporated two weeks before transplanting, 200 kg N/ha (ammonium sulphate 20.5 % N) was side dressed in 5 doses: first dose was 40 days after transplanting, second at the heading stage plus 65 kg K_2O/ha (potassium sulphate 49 % K_2O), third before the first harvest, fourth and fifth one and two months after first harvest. Furrow irrigation was used every 7-10 days.

3.1.2 Experimental plan

The experimental design was laid out in complete randomised block design (CRB) with three replications. Each experimental plot consisted of four rows. Each row was 5 meters long and with 125 cm width. Planting distance were 100 cm apart. There were 20 plants in each plot and 60 plants per treatment. Each replicate consisted of four treatments, i.e. spraying with aqueous solution of 60 ppm gibberellic acid (GA3) after 4, 6 and 8 weeks from transplanting in addition to untreated check plants (control with water only).

The experiment was conducted in Egypt with plant samples collected for all the chemical analyses done in laboratories of the Chair of Vegetable Science, Department for Plant Sciences, Technische Universität München in Freising-Weihenstephan, Germany **(3.1.5 for more details).**

3.1.3 Treatments

Plants were sprayed (trip wet) with aqueous solution of GA3 at 60 ppm as follow:
Treatment 1 (T1): GA3 was sprayed 4 weeks after transplanting date.
Treatment 2 (T2): GA3 was sprayed 6 weeks after transplanting date.
Treatment 3 (T3): GA3 was sprayed 8 weeks after transplanting date.
(C.): untreated check plants (control) with water only.

3.1.4 Evaluation parameters

3.1.4.1 Vegetative growth characters

Plant height and number of leaves per plant were taken two weeks after each GA3 treatment. Plant height, number of leaves per plant, number of offshoots per plant and width and length of 5th leaf as a representative sample were taken on the same day of the first harvest of flower bud (picking). The plant height was measured from the soil surface up to the highest point of the plant. The 5th leaf was counted starting from the first green leaf at the bottom of the plant up to the top of the plant.

3.1.4.2 Early and total yield

Early yield was calculated for the first three pickings over 34-39 days as harvesting done every 14-18 days in both seasons. Heads were harvested with 5 cm stem. All heads were harvested and total yield per plant was calculated. The total harvesting period was for 119-123 days in both 1998/1999 and 1999/2000 seasons.

3.1.4.3 Head parameters

Heads of each picking in each plot was taken for determining the following parameters:

1. Head length.
2. Head diameter.
3. Head stem diameter.
4. Head fresh weight.
5. Number of removed (discarded) bracts, preparing the edible part.
6. Edible part (receptacle) diameter.
7. Fresh weight of edible part.

3.1.5 Chemical analysis for some chemical constituents

3.1.5.1 Sample preparation

The chemical constituents were determined in samples of the 5^{th} leaf of each plot taken on the same day of the first picking and sample of receptacle (edible part) from the seven pickings in each plot. The leaves and edible part were separated and sliced in pieces of about 1 cm and mixed thoroughly. The plant material was air dried for 7 days and subsequently samples of about 200 g from each plot were packed in dark glass bottles and stored in a desicator for further analysis preparation. In Germany all samples were dried again for three days at 70 °C except the plant material which was analysed for phenolic compounds, since high temperatures during the process of drying will lead to significant losses of caffeoylquinic acid (Wagenbreth, 1995). The samples were ground with a Culatti MFC grinder equipped with a 1-mm sieve, packed airtight in dark glass bottles and stored in a desicator at room temperature for chemical analyses. All organic solvents and chemical reagents were of analytical grade from ACROS, Belgium. A HITACHI spectrophotometer, model U-3200, was used for all colorimetric measurements (see colorimetric analysis, below).

3.1.5.2 Analysis of total sugar

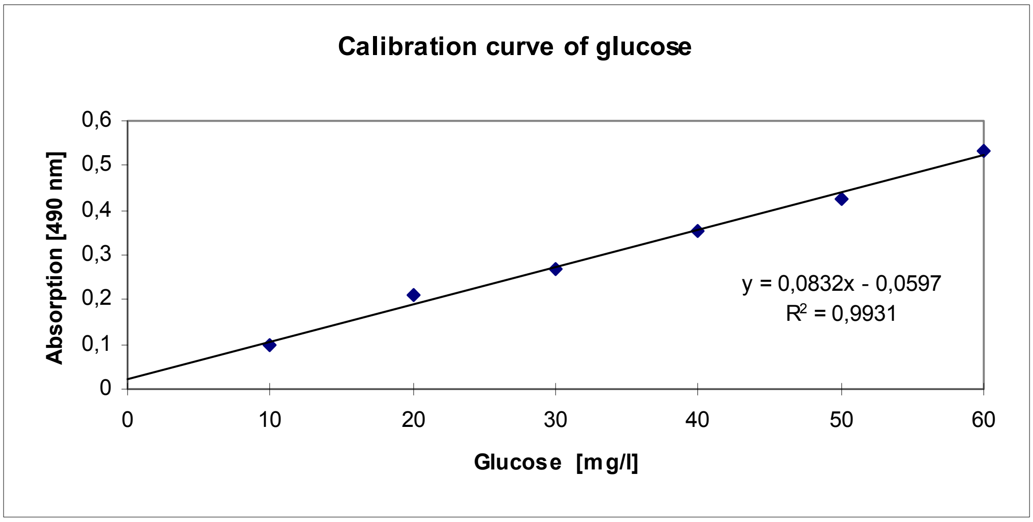
Total sugar both in leaves and edible part were determined colorimetrically using the phenol-sulfuric method (Dubois et al. 1956). This method involves two stages: dehydration of sugar with concentrated H_2SO_4 to furfural and hydroxymethylfurfural, and condensation of these substances with phenol to produce a yellow colour. The intensity of the colour is proportional to the carbohydrate concentration.

- **Extraction**

A powdered sample of 0.2 g was extracted with 25 ml 1 N HCl under reflux for six hours. Afterwards, the mixture was filtered and the filtrate was treated with a 12.5 % solution of lead acetate. The remaining lead was precipitated by adding NaH_2PO_3 to the solution. Finally, the soluble protein free sugar solution was transferred to a 250 ml volumetric flask and filled up with distilled water.

- **Colorimetric analysis**

1 ml of the prepared sugar solution was mixed with 1 ml of a freshly distilled solution of 5 % phenol in a test tube. To this mixture 5 ml of concentrated H_2SO_4 was carefully added. The tubes were allowed to stand for 10 minutes for reaction, then they were shaken thoroughly and placed for 10 to 20 minutes in a water bath at 25 to 30 °C before readings were taken. The formed yellow colour is stable for several hours. The absorbance of the characteristic yellow-orange colour was measured at a wavelength of 490 nm. Blanks were prepared by substituting distilled water for the sugar solution. The total sugar was determined as glucose of which a calibration curve with 10 to 60 mg/l was prepared.



3.1.5.3 Analysis of reducing sugar

Reducing sugar such as glucose, fructose, galactose, lactose, and maltose were determined colorimetrically in leaves and edible part of the artichoke according to the method of Bell (1955). For this, a powdered sample of 0.5 g was extracted with 50 ml of 80 % ethanol for 6 hours. Afterwards, ethanol was removed with a rotary evaporator in vacuo and the remaining aqueous extract was treated with an excess of a 12.5 % lead(II)-acetate solution for 15 minutes in order to precipitate the soluble protein. The excess of Pb^{2+} was removed by adding NaH_2PO_4 to the extract. Finally, the precipitate was filtered off and the filtrate was transferred to a 100 ml volumetric flask and filled up with distilled water. The measurement of the reducing sugar was determined with the phenol-sulphuric acid method as described under **(3.1.5.2)**.

3.1.5.4 Analysis of inulin

The content of inulin was determined volumetrically in the leaves and edible part according to the method of Winton and Winton (1958).

- **Extraction**

Exactly 1.0 g of the powdered sample was weighed into a 100 ml Erlenmeyer flask and treated with about 40 ml ethanol to remove soluble carbohydrates. After filtration, the filtrate was discarded and the residue was extracted three times with 20-25 ml boiling water and kept at 85 °C with continuous magnetic stirring on a hot plate for 15 min. Afterwards, the extracts were combined and treated with an excess of a 12.5 % lead(II)-acetate solution for protein precipitation. The further clean-up steps followed according to the sugar extraction.

- **Preparation of Folin reagent**

35 g molybdic acid and 5 g sodium tungstate were solved in 200 ml distilled water. To the mixture 200 ml of a 10 % NaOH solution was added and heated vigorously for about 30 min. After cooling to room temperature, 125 ml of a 85 % phosphoric acid solution was added and adjusted to 500 ml.

- **Volumetric analysis**

A titre of 0.01 N potassium permanganate solution was used in a micro burette. Samples of 50 ml were prepared (three replicates), in which potassium permanganate solution was continuously dropped. The titration was finished when a faint rose colour in the solution appeared. In present of a high inulin concentration the colour of the end-point is a faint yellow.
For inulin calculation the following relationship is valid

1 mg of inulin = 1.85 ml of 0.01 N potassium permenganate solution.

3.1.5.5 Total protein content

Total protein were determined in the leaves and edible part according to the method of Kjeldahl (Kalra, 1998).

3.1.5.6 Analysis of chlorogenic acid and cynarin

Caffeoylquinic acid derivatives were determined in leaves and edible part by High Performance Liquid Chromatography (HPLC) based on the method reported by Adzet & Puigmacia (1985).

Extraction

1.0 g of globe artichoke powder was extracted with 100 ml boiling water for 2 h. After filtration (White Ribbon Filter Paper Circles/Ashless, ∅ 50 mm, 589/2, provided by Schleicher & Schuell, Germany) the extract was cooled to room temperature, transferred to a volumetric flask and adjusted to 100 ml with distilled water. Before injection into HPLC, an aliquot of the solution was filtered through a 0.45 µm membrane filter. The determinations were made in triplicate.

The used HPLC equipment and conditions:

Gradient pump:	P 580 A LPG, Dionex
Autosampler:	Gina 50, Dionex
Column:	PAK 201 TP 54 RP-18, 250 x 4.6 mm (5 µm), VYDAC
Guard column:	PAK 201 TP^{TM} RP-18, 5 x 4.6 mm (5 µm), VYDAC
Detection:	DAD 340 S, Dionex
Wavelength:	330 nm
Eluent:	**A:** H_2O/CH_3COOH (98:1)
	B: CH_3CN/ CH_3COOH (98:1)
Flow rate:	1.0 ml/min
Column temperature:	25 °C
Injection volume:	40 µl
Analysis time:	35 min
Software:	Chromeleon 6.0, Dionex

For HPLC measurements, the used program for the gradient elution was as follow:

Time (min)	Eluent A (%)	Eluent B (%)
0	100	0
15	88	12
24	80	20
29-35	10	90

Identification of caffeoylquinic acid derivatives was done by comparison of their retention times and characteristic UV-spectra with that of chlorogenic acid. The content of cynarin (1,5-dicaffeoylquinic acid) was determined as chlorogenic acid.

3.1.5.7 Analysis of anthocyanin

Anthocyanin was determined in the outer bracts of artichoke heads which were separated to get the edible part of the head for second and third harvesting according to the method described by Du and Francis (1973). The method briefly consisted of the following steps:

- Extraction of the powdered sample (1.0 g) with 1 % HCl in MeOH at room temperature for 24 hours.
- Filtration and adjusting to 100 ml; from which a small aliquot was diluted with the solvent at the ratio 1:20.

Measuring of the absorption at a wavelength of 542 nm using a HITACHI spectrophotometer.

3.2 Second experiment in Egypt with globe artichoke plants grown by direct seeding in the field for GA3 effect

All trials were carried out at National Research Centre (NRC) Experimental Station, Al-Gizah Governorate during the two successive seasons 1998-1999 and 1999-2000. Seeds of the globe artichoke cultivar Imperial Star (IS) were sown directly into the field, on 9th and 7th of August for the first and second seasons, respectively. Plants were sprayed with GA3 as mentioned under 3.1.3 for the first experiment. All agricultural practices and all chemical analyses were done as mentioned under 3.1.5 for the first experiment. Data on vegetative growth, yield and its components and chemical analyses were recorded as shown in the first experiment.

3.3 Third experiment in Germany for rapid increase of offshoots for globe artichoke propagation

3.3.1 Materials

Seeds of Green Globe cultivar were supplied by Juliwa, Heidelberg, Germany. Green Globe (Juliwa) is the main seeded cultivar distributed in Germany. Seeds were kept in the incubator for two days at 25 °C and 95-98 % RH to enhance even seed germination. After incubation, seeds were sown on May 2nd, 2001 in trays with 77 cells (7x11 cells) using TKS1 (**T**orf**k**ultur**s**ubstrat) substrate. Subsequently, the trays were held in the greenhouse at day/night temperatures of 20 °C/18 °C until transplanting. Seedlings were irrigated on ebb-flood tables with nutrient solution [1 g/litre] of (Flory-8NK, 20-16-1.5) for best transplant quality. Four weeks later when the seedlings had 3-4 true leaves, they were transplanted directly into the field. Soil type was silty loam, pH (5.9-6.4). Irrigation was done each 7-12 days using a drip irrigation system. Fertilization was added through the drip irrigation system with 300 N/ha in equal proportions over seven applications.

3.3.2 Experimental plan

Cultivation was carried out in the Research Station in Dürnast in field Glaslaker 1, Chair of Vegetable Science, Technische Universität München. The research station in Freising (48°24´N, 11°42´E) is at about 372 m altitude, in the south of Germany. The main weather information for Freising-Weihenstephan concerning temperature (T), sunshine (SH) and rainfall (RF) is given in table (1). The planting distance was 150 cm between rows and 50 cm from plant to plant in the rows. Rows were covered with black PE mulch. The experimental design was laid out in complete randomised block design (CRB) with three replications. The area of the each plot was approximately 21 m^2. There were 25 plants in each plot and 75 plants per treatment.

3.3.3 Treatments

Pinching (apex removal) treatments were performed when the plants were 12 weeks old from sowing date or 8 weeks in the field:

Treatment 1 (P1): cutting back the plant completely near the soil surface (apex removed).

Treatment 2 (P2): removing the apex and keeping one true leaf on the plant.

Treatment 3 (P3): removing the apex and keeping three true leaves on the plant.
Control (C.): untreated check plants (control without pinching).

3.3.4 Observation parameters

During the growing period of the seedlings, observations concerning plant height and the number of leaves were carried out. The plant height was measured from the soil surface up to the highest point of the plant. After transplanting, growth observations were recorded as under **(3.3.5)**.

3.3.5 Evaluation parameters

3.3.5.1 Number of offshoots

The numbers of offshoots per plant were recorded after one, four and ten weeks for each treatment.

3.3.5.2 Leaf length of offshoots

The leaf length of the offshoots were measured after one, four and ten weeks from start of each treatment. The plant length was determined from the longest green leaf from its attached point with the plant stem (crown) to the leaf tip, at the upper side of the leaf.

3.3.5.3 Offshoot diameters

The offshoot diameters were measured after ten weeks from start of each treatment. The offshoot diameters were sized from the attached point between the leaves and the offshoot stem.

3.3.5.4 Tap root length of the mother plant

After ten weeks the tap root length of the mother plant were measured for each treatment as follow: five plants from each plot were taken out (with all offshoots) with the surrounding soil of the roots. At this relatively young stage of the plant the root system was still quite limited. The soil surrounding the rooting system was removed and washed by using low water pressure. Afterwards, only the tap root length of the mother plant was measured from the tip of the rooting system and the plant stem (crown).

3.3.5.5 Root length of the offshoots

The root length of the offshoots for each treatment were measured after ten weeks of each treatment as done in **(3.3.5.4)**. The root length of the offshoots of each plant was measured for the longest root from its attached point with the crown to the root tip.

3.4 Statistical data analysis

All collected experimental data was statistically analysed with CoStat Version 3.03, an interactive statistics program for computers. F-test and the Least Significant Difference (LSD) were used for the comparison between treatment means at 5 % probability level.

4. Results

4.1 First experiment

4.1.1 Plant height and number of leaves recorded after GA3 treatments

The GA3 application two weeks after T1 resulted in significant plant height increase of T1 compared to the other two treatments and was similar to control (tables 2 & 3). On the contrary, T1 plants had the lowest number of leaves of all treatments as well as of control. The plant height two weeks after GA3-T2 was increased in T1 and even significantly in T2. T3 produced no effect and was similar to control. But the number of leaves decreased by GA3 with the lowest value in T2 and highest value in T1. T3 plants produced same effect as in control.

Two weeks after GA3-T3 the plant height was positively influenced by GA3 with the highest increase in T2 & T3, followed by T1 and the lowest value in the untreated control. The number of leaves in T1 plants recorded the highest number followed by T2, then control plants and the lowest number in T3.

Untreated control was in all stages always inferior to the GA3-treatments, mainly two weeks after T3 in both seasons.

Table 2: Effects of GA3 treatments on vegetative growth of globe artichoke plants grown from seedlings during 1998-1999 season

Treatments	Two weeks after T1		Two weeks after T2		Two weeks after T3	
	Plant height	No. of leaves	Plant height	No. of leaves	Plant height	No. of leaves
T1	36.70 a	3.83 b	40.63 a	5.63 a	46.40 b	6.53 a
T2	20.20 b	4.40 a	41.40 a	4.86 b	47.73 a	6.20 ab
T3	19.33 b	4.20 a	28.40 b	5.20 ab	48.40 a	5.20 c
C.	19.20 b	4.30 a	27.30 b	5.10 ab	38.30 c	5.73 bc

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)

Table 3: Effects of GA3 treatments on vegetative growth of globe artichoke plants grown from seedlings during 1999-2000 season

Treatments	Two weeks after T1		Two weeks after T2		Two weeks after T3	
	Plant height	No. of leaves	Plant height	No. of leaves	Plant height	No. of leaves
T1	37.60 a	4.13 b	41.53 a	5.73 a	47.10 b	6.56 a
T2	20.90 b	4.70 a	42.10 a	4.96 b	48.63 a	6.20 ab
T3	20.03 b	4.50 a	28.90 b	5.30 ab	49.10 a	5.50 c
C.	19.70 b	4.60 a	27.80 b	5.20 ab	38.80 c	5.76 bc

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)

4.1.2 Vegetative growth characteristics

The plant height in tables 4 and 5 increased with GA3 treatments, in T2 and even significantly in T3. T1 produced no effect and was similar to control. The number of leaves and the length & width of the 5th leaf remained unchanged by all three treatments. But the number of offshoots was positively influenced by GA3 with the highest increase in T1 treatment, followed by T2, then T3 and the lowest number in the untreated control.

Table 4: Effects of GA3 treatments on vegetative growth at first harvesting day of globe artichoke plants grown from seedlings during 1998-1999 season

Treatments	Plant height (cm)	No. of leaves	No. of offshoots	5th leaf	
				Length (cm)	Width (cm)
T1	103.00 b	7.25 a	4.75 a	101.58 a	43.33 a
T2	107.58 ab	7.41 a	3.75 b	103.08 a	42.83 a
T3	109.16 a	7.58 a	3.44 c	107.16 a	47.50 a
C.	102.00 b	7.83 a	2.91 d	100.00 a	44.41 a

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)

Table 5: Effects of GA3 treatments on vegetative growth at first harvesting day of globe artichoke plants grown from seedlings during 1999-2000 season

Treatments	Plant height (cm)	No. of leaves	No. of offshoots	5^{th} leaf	
				Length (cm)	Width (cm)
T1	105.91 b	7.58 a	5.00 a	103.58 a	45.33 a
T2	110.58 ab	7.91 a	4.00 b	105.08 a	44.08 a
T3	112.16 a	7.83 a	3.66 c	109.16 a	46.08 a
C.	105.83 b	7.58 a	3.16 d	102.33 a	44.41 a

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)

4.1.3 Head parameters

For characterisation of artichoke quality it is important to evaluate the flower heads, not only of the main or centre head but also of the following orders.

Tables 6 and 7 have only T2 (only T2 plants produced early main head) because this GA3 treatment produced the earliest harvest. Data are presented for morphological evaluation of head length and diameter as well as head stem diameter and also other physical characteristics for quality such as total head fresh weight, number of removed bracts (to prepare the edible part), diameter and fresh weight of edible part. Only very minor differences appeared in the 1998/1999 and 1999/2000.

The following tables 8 to 19 depict the morphological-physical traits for the artichoke heads from the second to the seventh category in both seasons under evaluation.

Table 6: Physical characteristics of the main flower head for globe artichoke grown from seedlings during 1998-1999 season

Treat-ments	Head length cm.	Head diameter cm.	Head stem diameter cm.	Head fresh weight g.	No. of removed bracts	Edible part diameter cm.	Edible part fresh weight g.
T2	16.50	10.50	3.11	755.33	29.00	7.50	194.00

T2 = GA3 treatment 6 weeks after transplanting date. These values are means

Table 7: Physical characteristics of the main flower head for globe artichoke grown from seedlings during 1999-2000 season

Treat-ments	Head length cm.	Head diameter cm.	Head stem diameter cm.	Head fresh weight g.	No. of removed bracts	Edible part diameter cm.	Edible part fresh weight g.
T2	16.70	10.60	3.09	758.45	29.33	7.90	196.00

T2 = GA3 treatment 6 weeks after transplanting date. These values are means

The three GA3 treatments did not supply any significant differences for the second head except for T2 where the edible part appreciatively increased in edible part diameter and fresh weight. Head fresh weight was lowest in control plants compared to all the three GA3 treatments (tables 8 & 9).

GA3 treatments did not result in any significant differences for the third head except for T1 where the fresh weight significantly increased in the head and edible part (tables 10 & 11).

However, control plants recorded for the fourth head the highest value in head stem diameter and number of removed bracts. The other head parameters remained unchanged for all three treatments (tables 12 & 13).

Table 8: Physical characteristics of the second cut head for globe artichoke grown from seedlings during 1998-1999 season

Treat-ments	Head length cm.	Head diameter cm.	Head stem diameter cm.	Head fresh weight g.	No. of removed bracts	Edible part diameter cm.	Edible part fresh weight g.
T1	16.58 a	9.80 a	2.86 a	806.60 a	28.60 a	7.25 b	119.00 ab
T2	16.35 a	9.93 a	2.83 a	726.00 a	30.30 a	8.70 a	135.00 a
T3	14.55 a	10.20 a	2.93 a	683.30 a	28.60 a	7.40 b	111.00 ab
C.	15.75 a	9.10 a	2.66 a	446.30 b	27.00 a	7.16 b	92.60 b

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)

Table 9: Physical characteristics of the second cut head for globe artichoke grown from seedlings during 1999-2000 season

Treat-ments	Head length cm.	Head diameter cm.	Head stem diameter cm.	Head fresh weight g.	No. of removed bracts	Edible part diameter cm.	Edible part fresh weight g.
T1	16.68 a	9.90 a	2.75 a	815.70 a	28.70 a	7.36 b	120.70 ab
T2	16.55 a	9.89 a	2.72 a	735.30 a	30.50 a	8.76 a	137.60 a
T3	14.95 a	10.17 a	2.85 a	692.30 a	28.90 a	7.39 b	112.30 ab
C.	15.85 a	9.19 a	2.69 a	457.60 b	27.30 a	7.21 b	93.70 b

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)

Table 10: Physical characteristics of the third cut head for globe artichoke grown from seedlings during 1998-1999 season

Treat-ments	Head length cm.	Head diameter cm.	Head stem diameter cm.	Head fresh weight g.	No. of removed bracts	Edible part diameter cm.	Edible part fresh weight g.
T1	15.66 a	9.80 a	2.70 a	669.60 a	30.60 a	7.40 a	124.30 a
T2	15.16 a	9.50 a	2.60 a	371.30 b	27.00 a	7.10 a	101.00 b
T3	15.83 a	9.90 a	2.40 a	337.60 b	27.00 a	6.83 a	94.30 b
C.	16.16 a	9.70 a	2.30 a	368.30 b	28.00 a	7.43 a	95.60 b

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)

Table 11: Physical characteristics of the third cut head for globe artichoke grown from seedlings during 1999-2000 season

Treat-ments	Head length cm.	Head diameter cm.	Head stem diameter cm.	Head fresh weight g.	No. of removed bracts	Edible part diameter cm.	Edible part fresh weight g.
T1	15.78 a	9.70 a	2.78 a	675.53 a	30.00 a	7.53 a	123.60 a
T2	15.27 a	9.60 a	2.66 a	376.36 b	27.30 a	7.26 a	104.30 b
T3	15.91 a	9.80 a	2.57 a	347.76 b	27.60 a	6.96 a	96.00 b
C.	16.23 a	9.60 a	2.43 a	371.63 b	28.60 a	7.50 a	98.30 b

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)

Table 12: Physical characteristics of the fourth cut head for globe artichoke grown from seedlings during 1998-1999 season

Treat-ments	Head length cm.	Head diameter cm.	Head stem diameter cm.	Head fresh weight g.	No. of removed bracts	Edible part diameter cm.	Edible part fresh weight g.
T1	15.16 a	9.26 a	2.03 b	278.33 a	26.33 b	6.26 a	80.00 a
T2	14.00 a	9.03 a	2.03 b	268.33 a	30.00 ab	6.23 a	85.00 a
T3	14.66 a	9.43 a	2.26 ab	295.00 a	29.66 ab	6.46 a	98.33 a
C.	15.66 a	9.40 a	2.66 a	360.00 a	31.00 a	6.83 a	106.66 a

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)

Table 13: Physical characteristics of the fourth cut head for globe artichoke grown from seedlings during 1999-2000 season

Treat-ments	Head length cm.	Head diameter cm.	Head stem diameter cm.	Head fresh weight g.	No. of removed bracts	Edible part diameter cm.	Edible part fresh weight g.
T1	15.23 a	9.33 a	2.12 b	285.46 a	26.46 b	6.37 a	87.33 a
T2	14.19 a	9.10 a	2.13 b	275.39 a	30.03 ab	6.31 a	89.46 a
T3	14.73 a	9.51 a	2.35 ab	302.16 a	29.73 ab	6.53 a	102.53 a
C.	15.71 a	9.49 a	2.75 a	367.13 a	31.10 a	6.91 a	109.73 a

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)

The three GA3 treatments did not supply any significant differences for the fifth head parameters except for T3 where the head fresh weight appreciatively increased (tables 14 & 15).

All head parameters were not affected by GA3 treatments in the sixth head except the edible part diameter and fresh weight were significantly affected by GA3 with the highest increase in T3 and the lowest value in T2 (tables 16 & 17).

For the seventh head the head length, number of removed bracts and edible part fresh weight remained unchanged by all the three GA3 treatments. But head and stem diameter was affected by GA3 with the lowest value in T3 compared to the other two treatments and also to control. Head fresh weight of T2 & control plants recorded the highest value and the lowest weight was in T1 & T3. The edible part diameter was affected by GA3 with the highest increase in T2 & T3 and the lowest diameter in T1 & the untreated control (tables 18 & 19).

Table 14: Physical characteristics of the fifth cut head for globe artichoke grown from seedlings during 1998-1999 season

Treat-ments	Head length cm.	Head diameter cm.	Head stem diameter cm.	Head fresh weight g.	No. of removed bracts	Edible part diameter cm.	Edible part fresh weight g.
T1	13.00 a	8.46 a	1.80 a	210.66 b	27.00 a	6.26 a	84.00 a
T2	13.00 a	8.66 a	1.76 a	211.00 b	28.66 a	6.20 a	85.00 a
T3	13.33 a	8.70 a	1.83 a	242.33 a	28.00 a	6.20 a	81.66 a
C.	14.16 a	8.53 a	1.90 a	228.33 ab	28.00 a	6.26 a	82.00 a

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)

Table 15: Physical characteristics of the fifth cut head for globe artichoke grown from seedlings during 1999-2000 season

Treat-ments	Head length cm.	Head diameter cm.	Head stem diameter cm.	Head fresh weight g.	No. of removed bracts	Edible part diameter cm.	Edible part fresh weight g.
T1	13.19 a	8.53 a	1.86 a	217.79 b	27.33 a	6.33 a	87.33 a
T2	13.13 a	8.76 a	1.79 a	219.13 b	28.00 a	6.29 a	89.17 a
T3	13.43 a	8.83 a	1.87 a	251.46 a	28.66 a	6.26 a	84.63 a
C.	14.21 a	8.66 a	1.93 a	235.57 ab	28.36 a	6.31 a	86.39 a

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)

Table 16: Physical characteristics of the sixth cut head for globe artichoke grown from seedlings during 1998-1999 season

Treat-ments	Head length cm.	Head diameter cm.	Head stem diameter cm.	Head fresh weight g.	No. of removed bracts	Edible part diameter cm.	Edible part fresh weight g.
T1	13.00 a	9.16 a	1.33 a	211.33 a	35.00 a	6.50 b	84.00 c
T2	13.00 a	9.00 a	1.50 a	224.00 a	35.00 a	5.80 c	70.00 d
T3	12.83 a	9.33 a	1.40 a	219.00 a	36.00 a	7.00 a	104.00 a
C.	12.00 a	9.00 a	1.50 a	210.33 a	35.00 a	6.70 b	94.00 b

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)

Table 17: Physical characteristics of the sixth cut head for globe artichoke grown from seedlings during 1999-2000 season

Treat-ments	Head length cm.	Head diameter cm.	Head stem diameter cm.	Head fresh weight g.	No. of removed bracts	Edible part diameter cm.	Edible part fresh weight g.
T1	13.23 a	9.26 a	1.46 a	220.56 a	34.00 a	6.60 b	87.33 c
T2	13.36 a	9.13 a	1.53 a	235.23 a	34.00 a	5.90 c	73.66 d
T3	12.96 a	9.46 a	1.49 a	228.16 a	35.00 a	7.10 a	107.36 a
C.	12.63 a	9.16 a	1.57 a	219.43 a	34.00 a	6.80 b	97.23 b

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)

Table 18: Physical characteristics of the seventh cut head for globe artichoke grown from seedlings during 1998-1999 season

Treat-ments	Head length cm.	Head diameter cm.	Head stem diameter cm.	Head fresh weight g.	No. of removed bracts	Edible part diameter cm.	Edible part fresh weight g.
T1	12.50 a	8.46 a	1.20 ab	140.66 b	35.00 a	6.30 b	70.00 a
T2	12.16 a	8.43 a	1.13 ab	182.00 a	35.00 a	6.60 a	75.00 a
T3	11.83 a	7.40 b	0.96 b	138.00 b	35.00 a	6.70 a	70.00 a
C.	12.33 a	8.53 a	1.26 a	181.00 a	35.00 a	6.20 b	70.00 a

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)

Table 19: Physical characteristics of the seventh cut head for globe artichoke grown from seedlings during 1999-2000 season

Treat-ments	Head length cm.	Head diameter cm.	Head stem diameter cm.	Head fresh weight g.	No. of removed bracts	Edible part diameter cm.	Edible part fresh weight g.
T1	12.63 a	8.56 a	1.22 ab	147.36 b	35.00 a	6.41 b	73.26 a
T2	12.26 a	8.53 a	1.15 ab	189.23 a	35.00 a	6.71 a	78.33 a
T3	11.96 a	7.50 b	0.98 b	145.66 b	35.00 a	6.80 a	75.16 a
C.	12.66 a	8.66 a	1.28 a	188.33 a	35.00 a	6.31 b	74.66 a

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)

4.1.4 Yield

Only T2 of the three GA3 treatments had a significant effect on number of early heads per plant (table 20 and Fig. 1).

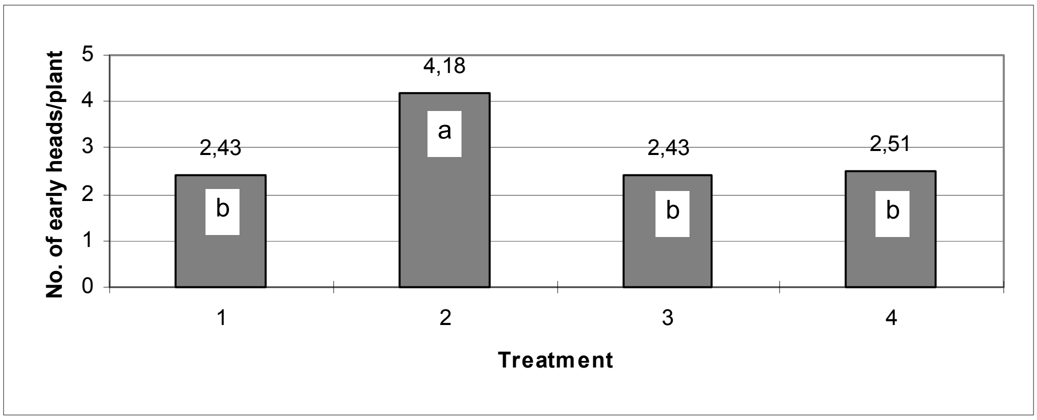
On the other hand, no significant increase was found in number of heads per plant and average number of heads per hectare of the three treatments in both tested seasons and were similar to control (tables 20+21).

The three GA3 applications had a significant increase in early yield per plant, average early yield per hectare, total yield per plant and also average total yield per hectare in T2 in the two successive seasons (tables 20+21 and Fig. 2).

Table 20: Early and total yield of globe artichoke grown from seedlings during 1998-1999 season

Treat-ments	No. of early heads/ plant	No. of heads/ plant	Average no. of heads/ha	Early yield Kg/plant	Average early yield ton/ha	Total yield Kg/plant	Average total yield ton/ha
T1	2.33 b	16.25 a	130 000 a	1.48 b	11.84 b	2.32 b	18.56 b
T2	4.08 a	19.03 a	152 240 a	1.85 a	14.80 a	2.74 a	21.92 a
T3	2.33 b	18.41 a	147 280 a	1.02 c	8.16 c	1.92 c	15.36 c
C.	2.41 b	17.00 a	136 000 a	0.82 c	6.56 c	1.79 c	14.32 c

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)



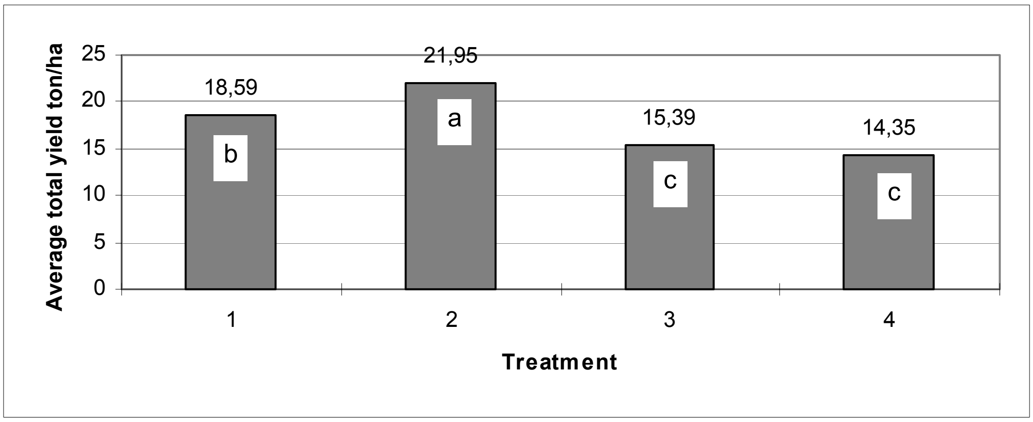
T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date, T4 = control
(means with the same letter are not significantly different)

Figure 1: Number of early heads per plant of globe artichoke grown from seedlings during 1999-2000 season

Table 21: Early and total yield of globe artichoke grown from seedlings during 1999-2000 season

Treat-ments	No. of heads/plant	Average no. of heads/ha	Early yield Kg/plant	Average early yield ton/ha	Total yield Kg/plant
T1	16.35 a	130 019 a	1.58 b	11.94 b	2.35 b
T2	19.16 a	152 259 a	1.95 a	14.90 a	2.79 a
T3	18.51 a	147 299 a	1.12 c	8.26 c	1.95 c
C.	17.13 a	136 019 a	0.92 c	6.66 c	1.82 c

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)



T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date, T4 = control
(means with the same letter are not significantly different)

Figure 2: Average total yield of globe artichoke grown from seedlings during 1999-2000 season

4.1.5 Chemical constituent of leaves

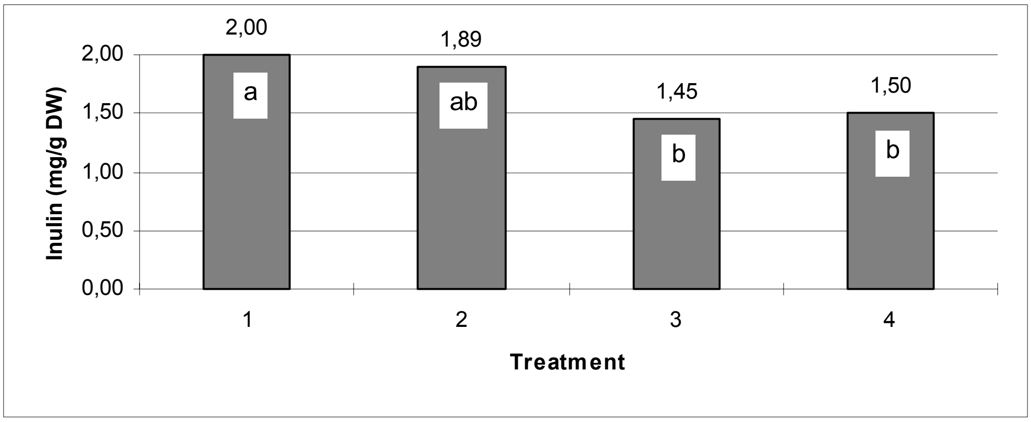
Total sugar content in leaves of globe artichoke increased significantly in T3 due to GA3 application. There were also significant differences among the three treatments in reducing sugar content. In this respect, the highest value was obtained by T2 while the lowest value was recorded in T1 in both tested seasons. On the other hand, T1 recorded the highest inulin content (tables 22+23 and Fig. 3).

There was a significant increase in total protein content in the control plants compared to the other three treatments. On the other hand, chlorogenic acid content of T1 plants increased significantly compared to the other two treatments and was similar to control. T1 recorded the highest value of cynarin content and was similar to control. The lowest values of cynarin content were obtained in T2 & T3 plants (tables 22+23 and Fig. 4).

Table 22: Chemical content in leaves of globe artichoke grown from seedlings during 1998-1999 season

Treat-ments	Total Sugar %	Reducing Sugar %	Inulin (mg/g DW)	Total protein %	Chlorogenic acid %	Cynarin %
T1	9.47 b	3.18 d	1.97 a	17.11 ab	0.536 a	0.202 a
T2	11.56 ab	5.14 a	1.86 ab	14.60 b	0.259 b	0.185 b
T3	14.00 a	3.66 c	1.42 b	15.89 b	0.283 b	0.185 b
C.	10.95 b	3.86 b	1.47 b	18.86 a	0.381 b	0.200 ab

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)



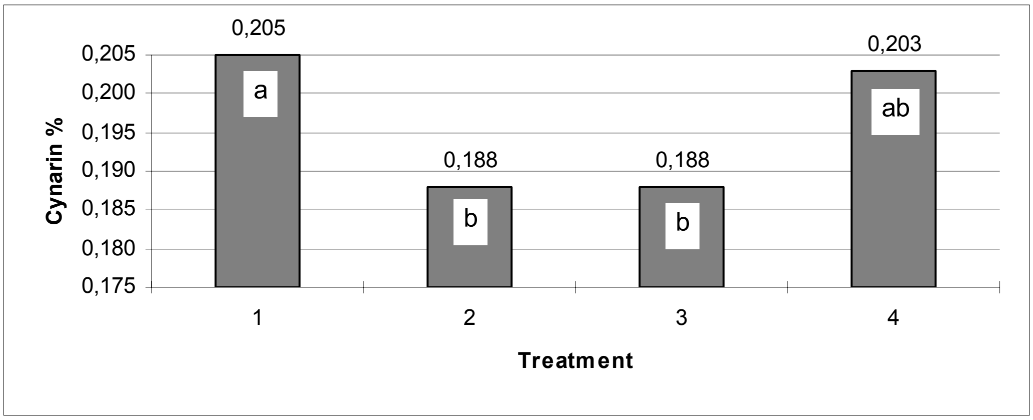
T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date, T4 = control
(means with the same letter are not significantly different)

Figure 3: Inulin content in leaves of globe artichoke grown from seedlings during 1999-2000 season

Table 23: Chemical content in leaves of globe artichoke grown from seedlings during 1999-2000 season

Treat-ments	Total Sugar %	Reducing Sugar %	Total protein %	Chlorogenic acid %
T1	9.54 b	3.25 d	17.20 ab	0.539 a
T2	11.63 ab	5.21 a	14.69 b	0.262 b
T3	14.07 a	3.73 c	15.98 b	0.286 b
C.	11.02 b	3.93 b	18.95 a	0.384 b

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)



T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date, T4 = control
(means with the same letter are not significantly different)

Figure 4: Cynarin content in leaves of globe artichoke grown from seedlings during 1999-2000 season

4.1.6 Chemical constituent of the edible part

For nutritional values of artichoke it is important to evaluate the chemical constituent of the edible part, not only of the main or centre head but also of the following orders.

Since T2 produced the earliest harvest, tables 24 and 25 present only T2 (only T2 plants produced early main head) GA3 treatment for the chemical constituent of total and reducing sugars as well as inulin & protein and also other chemical content for medicinal usage such as chlorogenic acid and cynarin. Only minor differences appeared in the collected data within the two seasons of 1998/1999 and 1999/2000.

Table 24: Chemical content in the edible part of the main flower head of globe artichoke grown from seedlings during 1998-1999 season

Treat-ments	Total Sugar %	Reducing Sugar %	Inulin (mg/g DW)	Total protein %	Chlorogenic acid %	Cynarin %
T2	16.85	10.39	1.49	26.58	0.079	0.069

T2 = GA3 treatment 6 weeks after transplanting date. These values are means

Table 25: Chemical content in the edible part of the main flower head of globe artichoke grown from seedlings during 1999-2000 season

Treat-ments	Total Sugar %	Reducing Sugar %	Inulin (mg/g DW)	Total protein %	Chlorogenic acid %	Cynarin %
T2	16.92	10.46	1.56	26.67	0.082	0.072

T2 = GA3 treatment 6 weeks after transplanting date. These values are means

The following tables 26 to 37 and Figs. 5 to 16 depict the chemical constituent contents for the artichoke heads (edible part) from the second to the seventh category in both seasons under evaluation.

Total sugar content in edible part of second head increased significantly in T2 in the two successive seasons owing to treating plants with GA3 (tables 26+27).

For the reducing sugar content in the edible part, the highest value was obtained by GA3 application in T3 plants and the lowest value was in the control plants (tables 26+27).

The inulin content was negatively influenced by GA3 with the highest decrease in T1 & T3 plants, followed by T2 and the highest inulin content was in the untreated control (table 26 and Fig. 5).

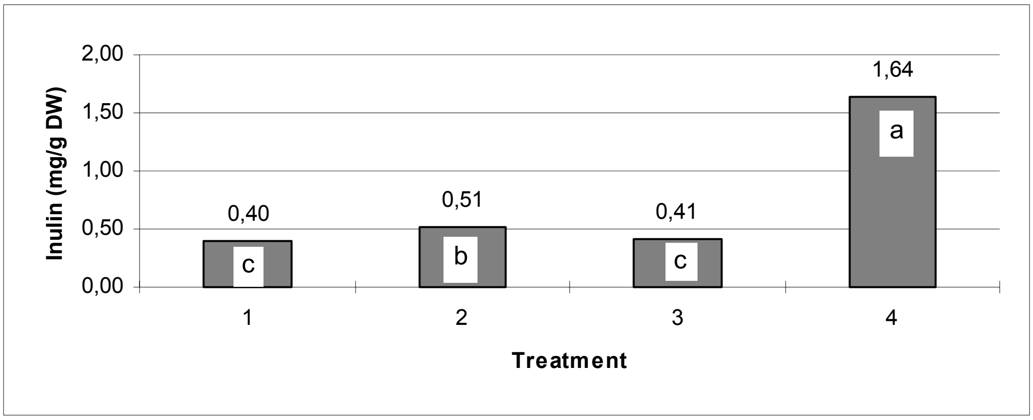
Total protein content increased significantly in T3 plants due to GA3 application while the lowest value was recorded in the control plants (tables 26+27).

GA3 applications had a significant decrease in chlorogenic acid and cynarin content in the edible part, with the lowest value in T2 plants in the two seasons of 1998/1999 and 1999/2000. The highest value was in the control plants (tables 26+27 and Fig. 6).

Table 26: Chemical content in the edible part of the second flower head of globe artichoke grown from seedlings during 1998-1999 season

Treat-ments	Total Sugar %	Reducing Sugar %	Inulin (mg/g DW)	Total protein %	Chlorogenic acid %	Cynarin %
T1	18.11 d	7.92 c	0.33 c	23.31 b	0.024 b	0.032 b
T2	20.30 a	8.20 b	0.44 b	18.91 c	0.008 d	0.016 c
T3	19.58 b	8.98 a	0.34 c	24.08 a	0.017 c	0.030 b
C.	18.30 c	7.64 d	1.57 a	17.86 d	0.029 a	0.036 a

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)



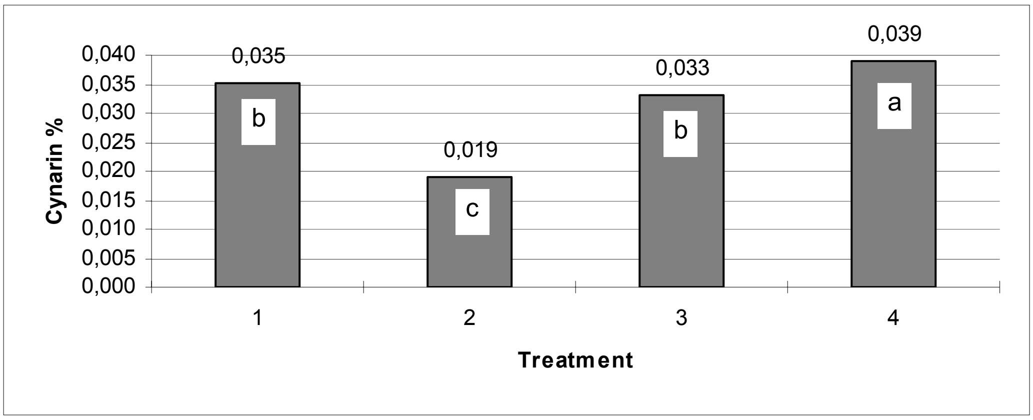
T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date, T4 = control
(means with the same letter are not significantly different)

Figure 5: Inulin content in the edible part of the second flower head of globe artichoke grown from seedlings during 1999-2000 season

Table 27: Chemical content in the edible part of the second flower head of globe artichoke grown from seedlings during 1999-2000 season

Treat-ments	Total Sugar %	Reducing Sugar %	Total protein %	Chlorogenic acid %
T1	18.20 d	8.01 c	23.40 b	0.027 b
T2	20.39 a	8.29 b	19.00 c	0.011 d
T3	19.57 b	9.07 a	24.17 a	0.020 c
C.	18.39 c	7.73 d	17.95 d	0.032 a

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)



T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date, T4 = control
(means with the same letter are not significantly different)

Figure 6: Cynarin content in the edible part of the second flower head of globe artichoke grown from seedlings during 1999-2000 season

For the third head total sugar content in edible part of globe artichoke increased significantly in T1 in the two tested seasons.

Also reducing sugar content of the edible part had the highest value in T1 plants and the lowest value was in the T3 plants (tables 28+29).

The highest content of inulin was in T2 plants, followed by control, then T3 and the lowest inulin content was in T1 plants (table 28 and Fig. 7).

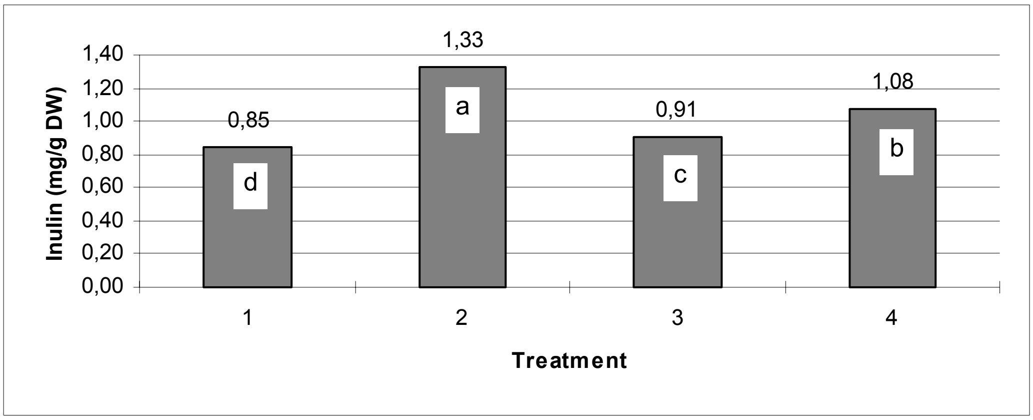
Total protein content increased significantly in all GA3 treatments, with the highest value in T3 plants due to GA3 application and the lowest value was recorded in the control plants (tables 28+29).

The three GA3 applications had a significant decrease in chlorogenic acid and cynarin content in the edible part with the lowest value recorded in T1 plants for chlorogenic acid and in T3 plants for cynarin content. The highest value was obtained in the control plants (tables 28+29 and Fig. 8).

Table 28: Chemical content in the edible part of the third flower head of globe artichoke grown from seedlings during 1998-1999 season

Treat-ments	Total Sugar %	Reducing Sugar %	Inulin (mg/g DW)	Total protein %	Chlorogenic acid %	Cynarin %
T1	24.71 a	9.81 a	0.81 d	25.24 c	0.011 d	0.033 b
T2	20.37 b	8.90 b	1.29 a	26.40 b	0.024 b	0.031 b
T3	12.43 d	7.64 d	0.87 c	28.04 a	0.017 c	0.015 c
C.	13.94 c	7.75 c	1.04 b	23.42 d	0.032 a	0.051 a

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)



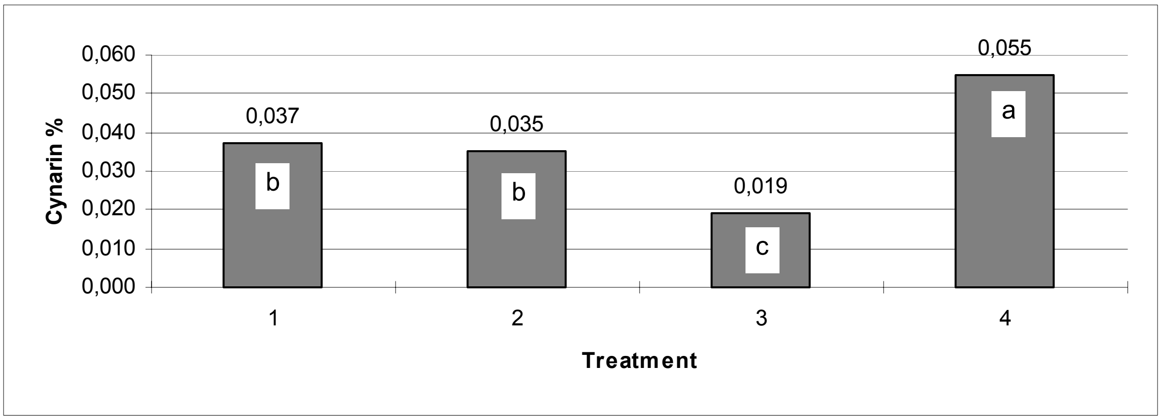
T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date, T4 = control
(means with the same letter are not significantly different)

Figure 7: Inulin content in the edible part of the third flower head of globe artichoke grown from seedlings during 1999-2000 season

Table 29: Chemical content in the edible part of the third flower head of globe artichoke grown from seedlings during 1999-2000 season

Treat-ments	Total Sugar %	Reducing Sugar %	Total protein %	Chlorogenic acid %
T1	24.78 a	9.88 a	25.29 c	0.015 d
T2	20.44 b	8.97 b	26.45 b	0.028 b
T3	12.50 d	7.71 d	28.09 a	0.021 c
C.	14.01 c	7.82 c	23.47 d	0.036 a

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)



T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date, T4 = control
(means with the same letter are not significantly different)

Figure 8: Cynarin content in the edible part of the third flower head of globe artichoke grown from seedlings during 1999-2000 season

Total sugar content in edible part of the fourth head increased significantly in T2 in both tested seasons.

Reducing sugar content of the edible part had the highest value in T1 plants and the lowest value was obtained in the T3 plants (tables 30+31).

Inulin content was highest in T3 plants, followed by T2, then control plants and the lowest content of inulin was obtained in T1 plants (table 30 and Fig. 9).

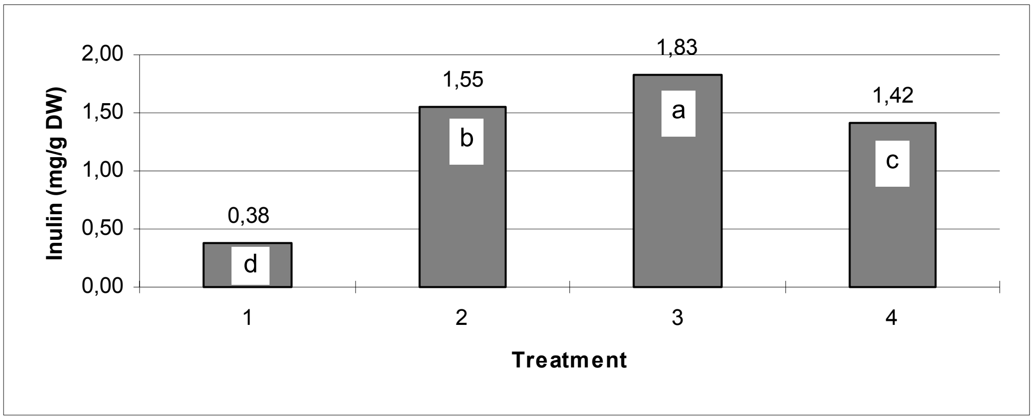
Total protein content increased significantly in all GA3 treatments with highest value in T1 plants due to GA3 application and the lowest value was recorded in the control plants (tables 30+31).

The chlorogenic acid and cynarin content in the edible part were negatively influenced by GA3 with the highest decrease in T1 plants, followed by T2+T3 and the highest content was in the untreated control (tables 30+31 and Fig. 10).

Table 30: Chemical content in the edible part of the fourth flower head of globe artichoke grown from seedlings during 1998-1999 season

Treat-ments	Total Sugar %	Reducing Sugar %	Inulin (mg/g DW)	Total protein %	Chlorogenic acid %	Cynarin %
T1	23.22 b	9.69 a	0.35 d	23.67 a	0.018 c	0.023 c
T2	24.29 a	8.66 b	1.52 b	20.60 c	0.022 b	0.028 b
T3	16.40 d	7.89 d	1.80 a	22.14 b	0.023 b	0.032 b
C.	17.29 c	7.94 c	1.39 c	18.79 d	0.029 a	0.043 a

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)



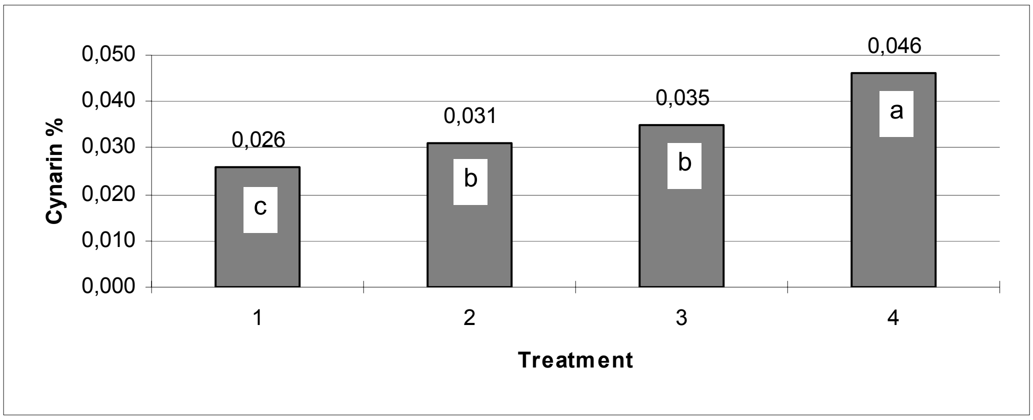
T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date, T4 = control
(means with the same letter are not significantly different)

Figure 9: Inulin content in the edible part of the fourth flower head of globe artichoke grown from seedlings during 1999-2000 season

Table 31: Chemical content in the edible part of the fourth flower head of globe artichoke grown from seedlings during 1999-2000 season

Treat-ments	Total Sugar %	Reducing Sugar %	Total protein %	Chlorogenic acid %
T1	23.28 b	9.75 a	23.72 a	0.021 c
T2	24.35 a	8.72 b	20.65 c	0.025 b
T3	16.46 d	7.95 d	22.19 b	0.026 b
C.	17.35 c	8.00 c	18.84 d	0.032 a

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)



T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date, T4 = control
(means with the same letter are not significantly different)

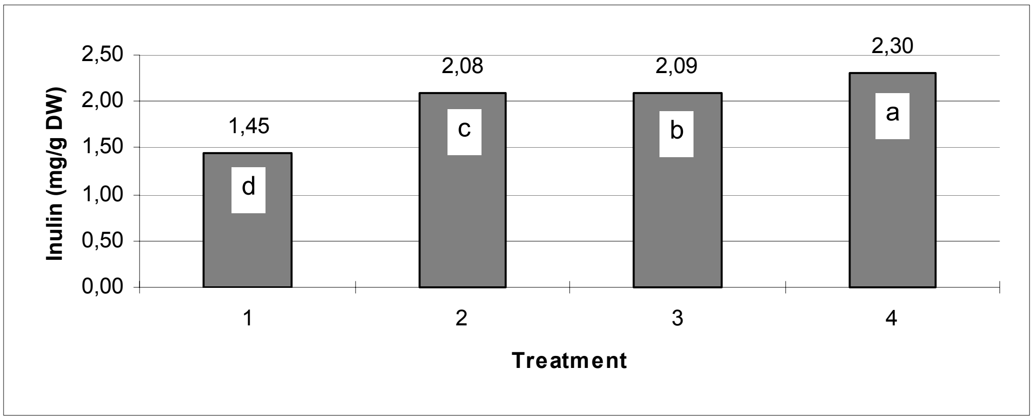
Figure 10: Cynarin content in the edible part of the fourth flower head of globe artichoke grown from seedlings during 1999-2000 season

For the fifth head the highest content of total sugar, reducing sugar, inulin, total protein, chlorogenic acid and cynarin was obtained in plants of T3, T1, control, T1 and the control plants for both chlorogenic acid and cynarin, respectively (tables 32+33 and Figs. 11+12).

Table 32: Chemical content in the edible part of the fifth flower head of globe artichoke grown from seedlings during 1998-1999 season

Treat-ments	Total Sugar %	Reducing Sugar %	Inulin (mg/g DW)	Total protein %	Chlorogenic acid %	Cynarin %
T1	15.99 d	8.43 a	1.41 d	26.85 a	0.050 b	0.026 d
T2	18.97 b	8.17 b	2.04 c	23.51 b	0.025 d	0.041 c
T3	19.36 a	7.74 d	2.05 b	19.76 d	0.037 c	0.051 b
C.	18.67 c	7.83 c	2.26 a	21.33 c	0.058 a	0.060 a

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)



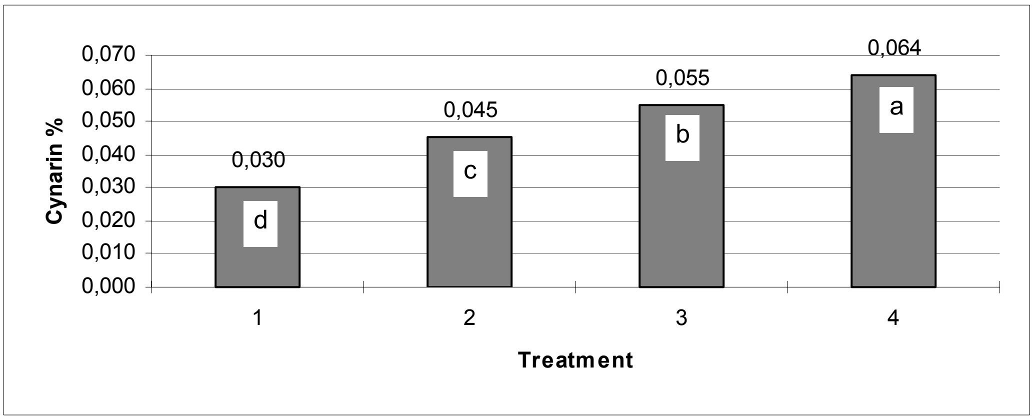
T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date, T4 = control
(means with the same letter are not significantly different)

Figure 11: Inulin content in the edible part of the fifth flower head of globe artichoke grown from seedlings during 1999-2000 season

Table 33: Chemical content in the edible part of the fifth flower head of globe artichoke grown from seedlings during 1999-2000 season

Treat-ments	Total Sugar %	Reducing Sugar %	Total protein %	Chlorogenic acid %
T1	16.03 d	8.47 a	26.89 a	0.054 b
T2	19.01 b	8.21 b	23.55 b	0.029 d
T3	19.40 a	7.78 d	19.80 d	0.041 c
C.	18.71 c	7.87 c	21.37 c	0.062 a

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)



T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date, T4 = control
(means with the same letter are not significantly different)

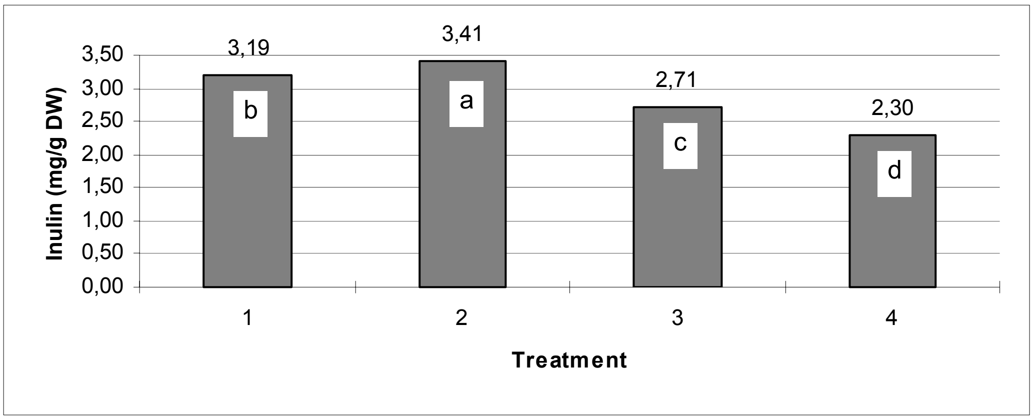
Figure 12: Cynarin content in the edible part of the fifth flower head of globe artichoke grown from seedlings during 1999-2000 season

T2 recorded the highest contents of reducing sugar, inulin and total protein for the sixth head. The highest total sugar content was obtained in T1 plants. GA3 applications negatively influenced the chlorogenic acid content with the lowest value in T1 plants and the highest in the untreated control. Cynarin was highest in control plants and was similar to T2 (tables 34+35 and Figs. 13+14).

Table 34: Chemical content in the edible part of the sixth flower head of globe artichoke grown from seedlings during 1998-1999 season

Treat-ments	Total Sugar %	Reducing Sugar %	Inulin (mg/g DW)	Total protein %	Chlorogenic acid %	Cynarin %
T1	27.06 a	7.49 b	3.15 b	15.98 c	0.011 d	0.025 b
T2	20.04 c	9.17 a	3.17 a	17.26 a	0.028 b	0.039 a
T3	13.82 d	6.51 d	2.67 c	16.67 b	0.023 c	0.025 b
C.	24.57 b	6.76 c	2.26 d	14.15 d	0.032 a	0.040 a

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan’s multiple test)



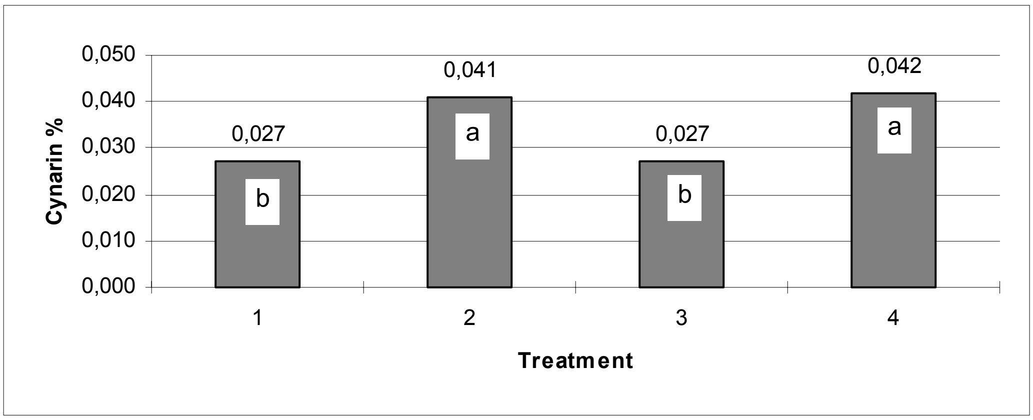
T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date, T4 = control
(means with the same letter are not significantly different)

Figure 13: Inulin content in the edible part of the sixth flower head of globe artichoke grown from seedlings during 1999-2000 season

Table 35: Chemical content in the edible part of the sixth flower head of globe artichoke grown from seedlings during 1999-2000 season

Treat-ments	Total Sugar %	Reducing Sugar %	Total protein %	Chlorogenic acid %
T1	27.12 a	7.55 b	16.04 c	0.013 d
T2	20.10 c	9.23 a	17.32 a	0.030 b
T3	13.88 d	6.57 d	16.73 b	0.025 c
C.	24.63 b	6.82 c	14.21 d	0.034 a

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)



T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date, T4 = control
(means with the same letter are not significantly different)

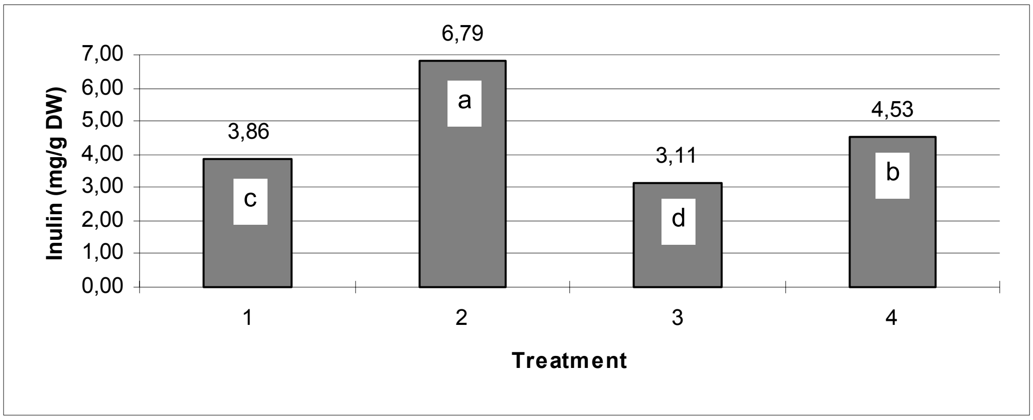
Figure 14: Cynarin content in the edible part of the sixth flower head of globe artichoke grown from seedlings during 1999-2000 season

GA3 treatments had a different influences in the chemical constituent of the seventh head, with the highest contents of total sugar and inulin obtained in T2 plants. T1 produced the highest amount of reducing sugar and chlorogenic acid. Total protein and cynarin was highest in T3 plants (tables 36+37 and Figs. 15+16).

Table 36: Chemical content in the edible part of the seventh flower head of globe artichoke grown from seedlings during 1998-1999 season

Treat-ments	Total Sugar %	Reducing Sugar %	Inulin (mg/g DW)	Total protein %	Chlorogenic acid %	Cynarin %
T1	14.04 d	12.96 a	3.83 c	13.87 b	0.033 a	0.031 b
T2	21.93 a	7.86 d	6.76 a	9.35 d	0.025 b	0.017 d
T3	16.81 b	8.59 c	3.08 d	14.57 a	0.020 c	0.043 a
C.	16.01 c	9.00 b	4.50 b	12.53 c	0.024 bc	0.028 c

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)



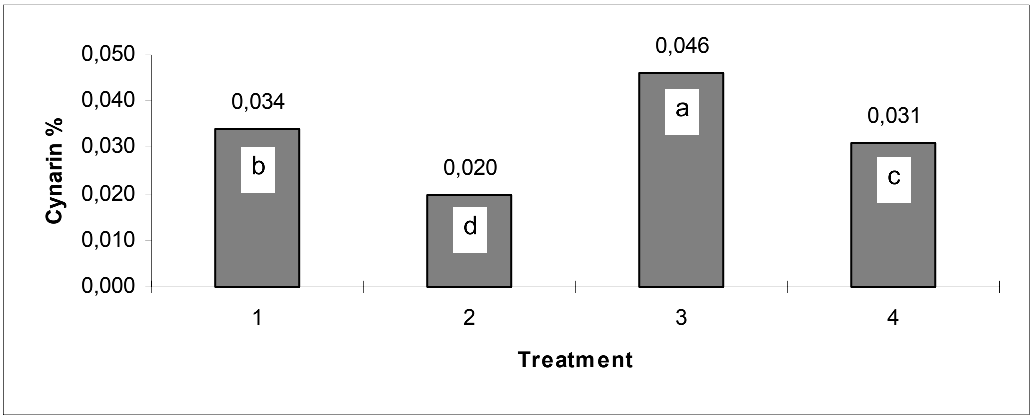
T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date, T4 = control
(means with the same letter are not significantly different)

Figure 15: Inulin content in the edible part of the seventh flower head of globe artichoke grown from seedlings during 1999-2000 season

Table 37: Chemical content in the edible part of the seventh flower head of globe artichoke grown from seedlings during 1999-2000 season

Treat-ments	Total Sugar %	Reducing Sugar %	Total protein %	Chlorogenic acid %
T1	14.11 d	13.03 a	13.92 b	0.036 a
T2	22.00 a	7.93 d	9.40 d	0.028 b
T3	16.87 b	8.66 c	14.62 a	0.023 c
C.	16.08 c	9.07 b	12.58 c	0.027 bc

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)



T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date, T4 = control
(means with the same letter are not significantly different)

Figure 16: Cynarin content in the edible part of the seventh flower head of globe artichoke grown from seedlings during 1999-2000 season

4.1.7 Anthocyanin content of the bracts

Significant differences were recorded among the three treatments in anthocyanin content in the bracts. In this respect, the highest values were recorded in T1 plants in the second head and in control plants in the third head. While, the lowest values were obtained in T3 & T1 plants in the second and third head, respectively in the two tested seasons (table 38).

Table 38: Anthocyanin content (mg/100 g DW) in the bracts of the second and third flower head of globe artichoke grown from seedlings

Treatments	1998-1999 season		1999-2000 season	
	Second head	Third head	Second head	Third head
T1	9.911 a	9.374 d	10.513 a	9.976 d
T2	9.302 c	10.018 b	9.904 c	10.620 b
T3	9.034 d	9.589 c	9.636 d	10.191 c
C.	9.660 b	10.429 a	10.262 b	11.031 a

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after transplanting date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)

4.2 Second experiment

4.2.1 Plant height and number of leaves recorded after GA3 treatments

The GA3 application two weeks after T1 resulted in significant plant height increase of T1 compared to the other treatments and was also similar to control. But number of leaves remained unchanged by all three treatments two weeks after each and was similar to control (tables 39 & 40).

T2 increased the plant height two weeks after gibberellic acid, followed by T1. T3 plants produced no effect and plants were similar to control.

Two weeks after GA3-T3 treatment, the plant height was positively influenced by GA3 with the highest increase in T2 & T3, followed by T1 and the lowest value in the untreated control.

Untreated control was in all stages always inferior to the GA3-treatments, mainly two weeks after T3 in both seasons.

Table 39: Effects of GA3 treatments on vegetative growth of globe artichoke plants grown by direct seeding during 1998-1999 season

Treatments	Two weeks after T1		Two weeks after T2		Two weeks after T3	
	Plant height	No. of leaves	Plant height	No. of leaves	Plant height	No. of leaves
T1	27.63 a	4.43 a	29.43 b	5.26 a	36.50 b	5.40 a
T2	17.96 b	4.86 a	35.86 a	4.93 a	41.26 a	5.40 a
T3	17.63 b	4.30 a	23.06 c	4.83 a	43.30 a	5.10 a
C.	17.73 b	4.33 a	23.06 c	4.73 a	33.53 c	5.40 a

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after sowing date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)

Table 40: Effects of GA3 treatments on vegetative growth of globe artichoke plants grown by direct seeding during 1999-2000 season

Treatments	Two weeks after T1		Two weeks after T2		Two weeks after T3	
	Plant height	No. of leaves	Plant height	No. of leaves	Plant height	No. of leaves
T1	28.53 a	4.73 a	30.13 b	5.56 a	37.20 b	5.70 a
T2	18.66 b	5.16 a	36.76 a	5.23 a	42.16 a	5.70 a
T3	18.33 b	4.60 a	23.56 c	5.13 a	44.10 a	5.10 a
C.	18.43 b	4.63 a	23.56 c	5.03 a	34.03 c	5.40 a

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after sowing date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)

4.2.2 Vegetative growth characteristics

The vegetative growth characteristics of globe artichoke plants such as plant height, number of leaves, number of offshoots and length of the 5th leaf remained unchanged by all the three GA3 treatments and was similar to the untreated control plants. T1 produced the highest width of the 5th leaf compared to the other treatments (tables 41 & 42).

Table 41: Effects of GA3 treatments on vegetative growth at first harvesting day of globe artichoke plants grown by direct seeding during 1998-1999 season

Treatments	Plant height (cm)	No. of leaves	No. of offshoots	5th leaf	
				Length (cm)	Width (cm)
T1	106.25 a	7.58 a	4.08 a	104.58 a	47.50 a
T2	105.66 a	7.66 a	4.50 a	108.00 a	39.08 b
T3	99.41 a	7.58 a	3.66 a	100.58 a	37.50 b
C.	106.00 a	7.41 a	3.58 a	106.66 a	40.83 b

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after sowing date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)

Table 42: Effects of GA3 treatments on vegetative growth at first harvesting day of globe artichoke plants grown by direct seeding during 1999-2000 season

Treatments	Plant height (cm)	No. of leaves	No. of offshoots	5th leaf	
				Length (cm)	Width (cm)
T1	108.25 a	7.91 a	4.33 a	106.58 a	48.16 a
T2	107.66 a	7.83 a	4.75 a	110.00 a	41.25 b
T3	101.08 a	7.75 a	3.91 a	102.58 a	39.50 b
C.	108.00 a	7.58 a	3.83 a	108.66 a	42.16 b

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after sowing date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)

4.2.3 Head parameters

Evaluating the morphological-physical characteristics for quality of the flower heads of globe artichoke is important for good marketing.

Only T2 and T3 plants produced early main head therefore, tables 43 and 44 show only these treatments for morphological evaluation of head length and diameter as well as head stem diameter and other physical characteristics for quality of head fresh weight, number of removed bracts (to prepare the edible part), edible part diameter and fresh weight. Only very minor differences were noted in the 1998/1999 and 1999/2000 seasons.

Table 43: Physical characteristics of the main flower head of globe artichoke grown by direct seeding during 1998-1999 season

Treat-ments	Head length cm.	Head diameter cm.	Head stem diameter cm.	Head fresh weight g.	No. of removed bracts	Edible part diameter cm.	Edible part fresh weight g.
T2	16.00	9.30	2.40	274.60	32.60	6.60	81.50
T3	15.65	9.03	2.43	277.60	30.00	6.33	79.00

T2 and T3 = GA3 treatments 6 and 8 weeks after sowing date. These values are means

Table 44: Physical characteristics of the main flower head of globe artichoke grown by direct seeding during 1999-2000 season

Treat-ments	Head length cm.	Head diameter cm.	Head stem diameter cm.	Head fresh weight g.	No. of removed bracts	Edible part diameter cm.	Edible part fresh weight g.
T2	16.35	9.43	2.53	279.66	32.43	6.73	83.52
T3	15.90	9.16	2.56	282.63	30.66	6.46	81.12

T2 and T3 = GA3 treatments 6 and 8 weeks after sowing date. These values are means

The following tables 45 to 70 depict the morphological-physical traits for the artichoke heads from the second to the sixth category in both seasons under evaluation.

The three GA3 treatments did not supply any significant differences for the second head except for T1 where the head length appreciatively increased, but also the number of removed bracts (tables 45 & 46).

GA3 treatments did not result in any significant differences for the third head for all head parameters (tables 47 & 48).

However, T1 plants recorded for the fourth head the highest head and edible part diameters as well as fresh weight. The number of removed bracts was highest in T2 plants and the other head parameters remained unchanged by all three treatments (tables 49 & 50).

Table 45: Physical characteristics of the second flower head of globe artichoke grown by direct seeding during 1998-1999 season

Treat-ments	Head length cm.	Head diameter cm.	Head stem diameter cm.	Head fresh weight g.	No. of removed bracts	Edible part diameter cm.	Edible part fresh weight g.
T1	16.00 a	8.60 a	2.40 a	301.00 a	35.00 a	6.30 a	80.00 a
T2	14.00 b	8.56 a	2.20 a	247.66 a	28.00 ab	6.60 a	70.00 a
T3	14.66 ab	8.33 a	2.00 a	225.66 a	24.00 b	5.93 a	62.00 a
C.	15.33 ab	7.76 a	2.03 a	212.66 a	24.33 b	5.63 a	55.00 a

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after sowing date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)

Table 46: Physical characteristics of the second flower head of globe artichoke grown by direct seeding during 1999-2000 season

Treat-ments	Head length cm.	Head diameter cm.	Head stem diameter cm.	Head fresh weight g.	No. of removed bracts	Edible part diameter cm.	Edible part fresh weight g.
T1	16.12 a	8.77 a	2.46 a	310.33 a	35.00 a	6.36 a	83.66 a
T2	14.13 b	8.73 a	2.33 a	256.36 a	28.33 ab	6.66 a	72.30 a
T3	14.78 ab	8.46 a	2.06 a	234.66 a	24.36 b	5.98 a	64.00 a
C.	15.45 ab	7.93 a	2.00 a	221.63 a	24.66 b	5.69 a	57.33 a

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after sowing date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)

Table 47: Physical characteristics of the third flower head of globe artichoke grown by direct seeding during 1998-1999 season

Treat-ments	Head length cm.	Head diameter cm.	Head stem diameter cm.	Head fresh weight g.	No. of removed bracts	Edible part diameter cm.	Edible part fresh weight g.
T1	14.00 a	8.56 a	2.03 a	233.33 a	33.66 a	5.86 a	63.33 a
T2	15.66 a	8.86 a	2.13 a	258.33 a	35.00 a	6.23 a	85.00 a
T3	14.50 a	8.66 a	1.86 a	230.00 a	34.00 a	6.46 a	76.66 a
C.	13.33 a	8.33 a	2.10 a	211.66 a	31.00 a	5.76 a	61.66 a

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after sowing date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)

Table 48: Physical characteristics of the third flower head of globe artichoke grown by direct seeding during 1999-2000 season

Treat-ments	Head length cm.	Head diameter cm.	Head stem diameter cm.	Head fresh weight g.	No. of removed bracts	Edible part diameter cm.	Edible part fresh weight g.
T1	14.33 a	8.68 a	2.10 a	242.36 a	34.33 a	5.99 a	70.66 a
T2	15.96 a	8.98 a	2.20 a	267.00 a	35.66 a	6.36 a	92.33 a
T3	14.83 a	8.78 a	1.93 a	239.66 a	34.93 a	6.59 a	83.60 a
C.	13.63 a	8.45 a	2.17 a	220.33 a	32.63 a	5.89 a	68.56 a

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after sowing date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)

Table 49: Physical characteristics of the fourth flower head of globe artichoke grown by direct seeding during 1998-1999 season

Treat-ments	Head length cm.	Head diameter cm.	Head stem diameter cm.	Head fresh weight g.	No. of removed bracts	Edible part diameter cm.	Edible part fresh weight g.
T1	13.50 a	9.06 a	1.96 a	228.66 a	35.00 ab	6.80 a	99.50 a
T2	15.00 a	8.30 b	1.93 a	230.33 a	38.00 a	6.30 b	76.00 c
T3	12.66 a	8.46 b	2.13 a	208.66 a	32.00 b	6.10 b	62.00 d
C.	13.83 a	8.16 b	2.03 a	221.33 a	33.00 b	5.50 c	80.00 b

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after sowing date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)

Table 50: Physical characteristics of the fourth flower head of globe artichoke grown by direct seeding during 1999-2000 season

Treat-ments	Head length cm.	Head diameter cm.	Head stem diameter cm.	Head fresh weight g.	No. of removed bracts	Edible part diameter cm.	Edible part fresh weight g.
T1	13.73 a	9.36 a	1.83 a	235.33 a	35.33 ab	6.91 a	112.50 a
T2	15.66 a	8.63 b	1.73 a	237.66 a	38.13 a	6.41 b	79.00 c
T3	12.93 a	8.76 b	2.23 a	215.33 a	32.66 b	6.43 b	65.00 d
C.	13.96 a	8.33 b	2.16 a	228.66 a	33.06 b	5.66 c	83.00 b

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after sowing date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)

The three GA3 treatments did not supply any significant differences for the fifth head parameters except for T2 where the edible part diameter appreciatively increased. The highest edible part fresh weight was obtained in T2 plants similar to control (tables 51 & 52).

The length, diameter, stem diameter and fresh weight of the sixth head remained unchanged by all the three GA3 treatments. But number of removed bracts and edible part diameter and fresh weight produced was highest in T1 plants (tables 53 & 54).

Table 51: Physical characteristics of the fifth flower head of globe artichoke grown by direct seeding during 1998-1999 season

Treat-ments	Head length cm.	Head diameter cm.	Head stem diameter cm.	Head fresh weight g.	No. of removed bracts	Edible part diameter cm.	Edible part fresh weight g.
T1	13.33 a	8.33 a	1.46 a	204.33 a	35.00 a	6.00 c	79.00 b
T2	12.50 a	8.50 a	1.43 a	222.66 a	35.00 a	6.40 a	89.00 a
T3	12.83 a	8.83 a	1.36 a	225.66 a	35.00 a	6.20 b	75.00 c
C.	12.50 a	9.00 a	1.53 a	235.33 a	35.00 a	6.20 b	90.00 a

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after sowing date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)

Table 52: Physical characteristics of the fifth flower head of globe artichoke grown by direct seeding during 1999-2000 season

Treat-ments	Head length cm.	Head diameter cm.	Head stem diameter cm.	Head fresh weight g.	No. of removed bracts	Edible part diameter cm.	Edible part fresh weight g.
T1	13.43 a	8.43 a	1.56 a	213.33 a	34.00 a	6.20 c	81.00 b
T2	12.63 a	8.60 a	1.53 a	231.33 a	34.33 a	6.60 a	91.00 a
T3	12.96 a	8.93 a	1.46 a	234.66 a	34.00 a	6.40 b	77.00 c
C.	12.66 a	9.13 a	1.63 a	244.33 a	34.00 a	6.40 b	92.00 a

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after sowing date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)

Table 53: Physical characteristics of the sixth flower head of globe artichoke grown by direct seeding during 1998-1999 season

Treat-ments	Head length cm.	Head diameter cm.	Head stem diameter cm.	Head fresh weight g.	No. of removed bracts	Edible part diameter cm.	Edible part fresh weight g.
T1	12.00 a	8.63 a	1.40 a	193.33 a	40.00 a	7.60 a	100.00 a
T2	12.83 a	8.33 a	1.36 a	183.33 a	35.00 b	6.40 b	87.00 b
T3	13.00 a	8.36 a	1.40 a	187.33 a	35.00 b	6.60 b	81.00 c
C.	13.16 a	8.96 a	1.60 a	237.66 a	35.00 b	6.10 c	85.00 b

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after sowing date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)

Table 54: Physical characteristics of the sixth flower head of globe artichoke grown by direct seeding during 1999-2000 season

Treat-ments	Head length cm.	Head diameter cm.	Head stem diameter cm.	Head fresh weight g.	No. of removed bracts	Edible part diameter cm.	Edible part fresh weight g.
T1	12.33 a	8.66 a	1.50 a	201.33 a	40.33 a	7.70 a	102.33 a
T2	12.93 a	8.63 a	1.46 a	192.66 a	35.00 b	6.52 b	89.00 b
T3	13.66 a	8.33 a	1.50 a	194.66 a	35.03 b	6.71 b	83.00 c
C.	13.36 a	8.86 a	1.70 a	244.33 a	35.33 b	6.20 c	85.63 b

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after sowing date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)

4.2.4 Yield

T2 and T3 of the three GA3 treatments had a significant effect on number of early heads per plant (table 55 and Fig. 17).

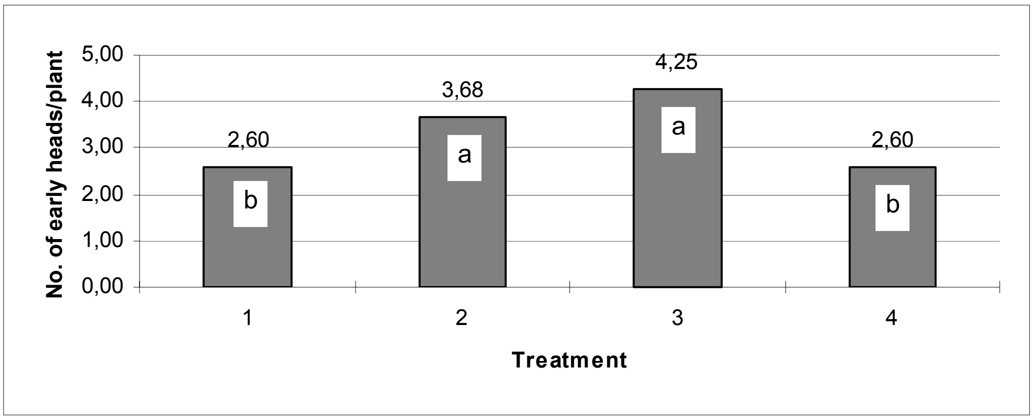
No significant increase was found in number of heads per plant and average number of heads per hectare of the three treatments in both tested seasons and were similar to control (tables 55+56).

The three GA3 applications had a significant increase in early yield per plant and average early yield per hectare in both T2 & T3. Control plants produced the lowest total yield per plant and also average total yield per hectare in the two successive seasons (tables 55+56 and Fig. 18).

Table 55: Early and total yield of globe artichoke grown by direct seeding during 1998-1999 season

Treat-ments	No. of early heads/ plant	No. of heads/ plant	Average no. of heads/ha	Early yield Kg/plant	Average early yield ton/ha	Total yield Kg/plant	Average total yield ton/ha
T1	2.50 b	19.08 a	152 640 a	0.53 b	4.24 b	1.16 ab	9.28 ab
T2	3.58 a	21.50 a	172 000 a	0.78 a	6.24 a	1.42 a	11.36 a
T3	4.15 a	20.13 a	161 040 a	0.73 a	5.84 a	1.36 ab	10.88 ab
C.	2.50 b	22.58 a	180 640 a	0.42 b	3.36 b	1.12 b	8.96 b

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after sowing date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)



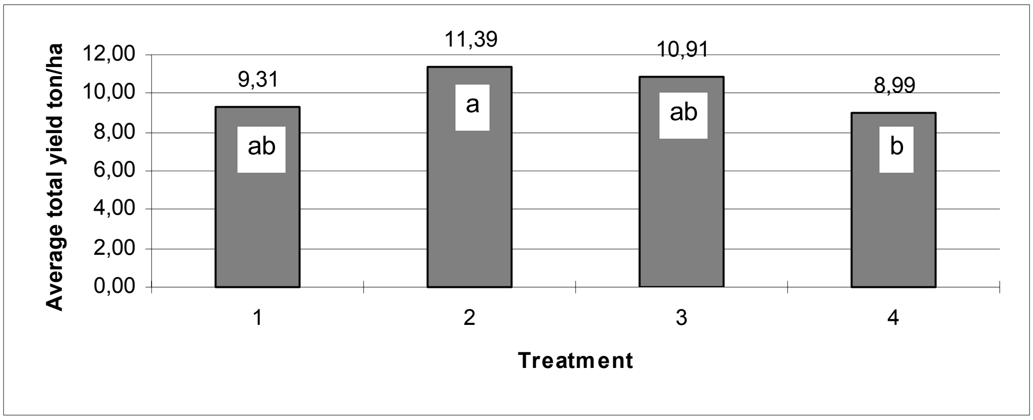
T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after sowing date, T4 = control
(means with the same letter are not significantly different)

Figure 17: Number of early heads per plant of globe artichoke grown by direct seeding during 1999-2000 season

Table 56: Early and total yield of globe artichoke grown by direct seeding during 1999-2000 season

Treat-ments	No. of heads/ plant	Average no. of heads/ha	Early yield Kg/plant	Average early yield ton/ha	Total yield Kg/plant
T1	19.18 a	152 657 a	0.63 b	4.37 b	1.26 ab
T2	21.60 a	172 019 a	0.88 a	6.36 a	1.52 a
T3	20.23 a	161 057 a	0.83 a	5.97 a	1.46 ab
C.	22.68 a	180 646 a	0.52 b	3.49 b	1.23 b

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after sowing date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)



T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after sowing date, T4 = control
(means with the same letter are not significantly different)

Figure 18: Average total yield of globe artichoke grown by direct seeding during 1999-2000 season

4.2.5 Chemical constituent of leaves

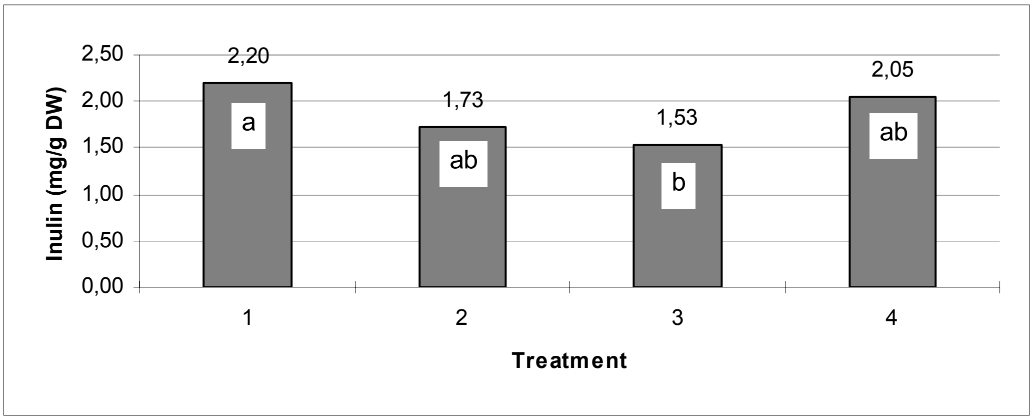
There were significant differences among the three treatments in total sugar content in leaves of globe artichoke. In this respect, the highest value was obtained in control plants and the lowest in T2 plants in both tested seasons. Reducing sugar content was highest in control and lowest in T1 plants. On the other hand, T3 recorded the lowest inulin content (tables 57+58 and Fig. 19).

Total protein was highest in T3 and similar to control. There was no significant effect on chlorogenic acid and cynarin content compared to the untreated control (tables 57+58 and Fig. 20).

Table 57: Chemical content in leaves of globe artichoke grown by direct seeding during 1998-1999 season

Treat-ments	Total Sugar %	Reducing Sugar %	Inulin (mg/g DW)	Total protein %	Chlorogenic acid %	Cynarin %
T1	10.92 b	4.24 d	2.13 a	18.57 b	0.424 a	0.188 a
T2	9.16 d	7.71 b	1.66 ab	18.37 b	0.518 a	0.232 a
T3	9.20 c	5.87 c	1.46 b	21.96 a	0.460 a	0.235 a
C.	14.26 a	9.57 a	1.98 ab	21.94 a	0.450 a	0.198 a

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after sowing date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)



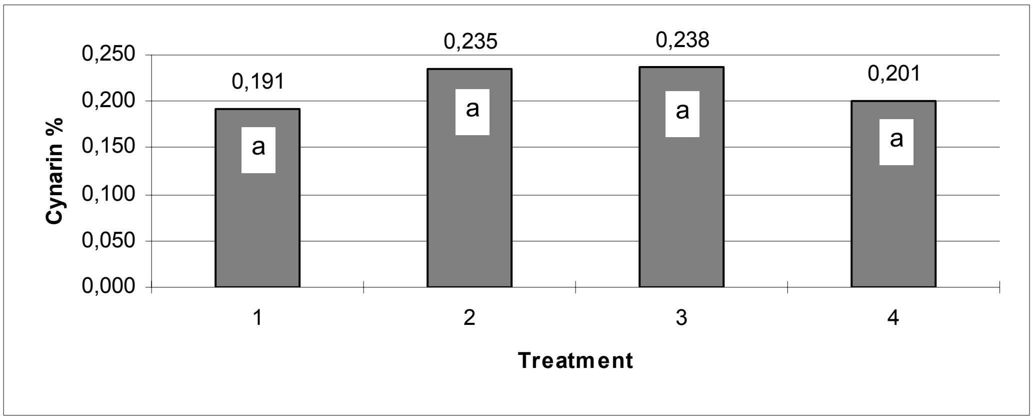
T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after sowing date, T4 = control
(means with the same letter are not significantly different)

Figure 19: Inulin content in leaves of globe artichoke grown by direct seeding during 1999-2000 season

Table 58: Chemical content in leaves of globe artichoke grown by direct seeding during 1999-2000 season

Treat-ments	Total Sugar %	Reducing Sugar %	Total protein %	Chlorogenic acid %
T1	10.99 b	4.31 d	18.66 b	0.427 a
T2	9.23 d	7.78 b	18.46 b	0.521 a
T3	9.27 c	5.94 c	22.05 a	0.463 a
C.	14.33 a	9.64 a	22.03 a	0.453 a

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after sowing date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)



T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after sowing date, T4 = control
(means with the same letter are not significantly different)

Figure 20: Cynarin content in leaves of globe artichoke grown by direct seeding during 1999-2000 season

4.2.6 Chemical constituent of the edible part

For nutritional value of globe artichoke it is important to evaluate the chemical constituent of the edible part, not only of the main head but also of the following orders.

Tables 59 and 60 have only data of T2 and T3 plants because only these ones produced early main heads with chemical constituent of total and reducing sugars as well as inulin & protein and also other substances important for medicinal usage such as chlorogenic acid and cynarin. Only minor differences appeared in the collected data within the two seasons of 1998/1999 and 1999/2000.

Table 59: Chemical content in the edible part of the main flower head of globe artichoke grown by direct seeding during 1998-1999 season

Treat-ments	Total Sugar %	Reducing Sugar %	Inulin (mg/g DW)	Total protein %	Chlorogenic acid %	Cynarin %
T2	10.87	6.36	1.97	21.02	0.019	0.027
T3	11.76	6.98	1.56	24.96	0.023	0.030

T2 and T3 = GA3 treatments 6 and 8 weeks after sowing date. These values are means

Table 60: Chemical content in the edible part of the main flower head of globe artichoke grown by direct seeding during 1999-2000 season

Treat-ments	Total Sugar %	Reducing Sugar %	Inulin (mg/g DW)	Total protein %	Chlorogenic acid %	Cynarin %
T2	10.92	6.41	2.00	21.09	0.021	0.029
T3	11.81	7.03	1.59	25.03	0.025	0.032

T2 and T3 = GA3 treatments 6 and 8 weeks after sowing date. These values are means

The following tables 61 to 70 and Figs. 21 to 30 depict the chemical constituent of artichoke heads (edible part) from the second to the sixth category in both seasons under evaluation.

Total sugar content in edible part of second head decreased significantly in T1 in the two successive seasons owing to treating plants with GA3 (tables 61+62).

For the reducing sugar content in the edible part, the highest value was obtained in control and the lowest in T3 plants (tables 61+62).

The inulin content was highest in T3 plants, followed by T1, then control and the lowest inulin content was in T2 (table 61 and Fig. 21).

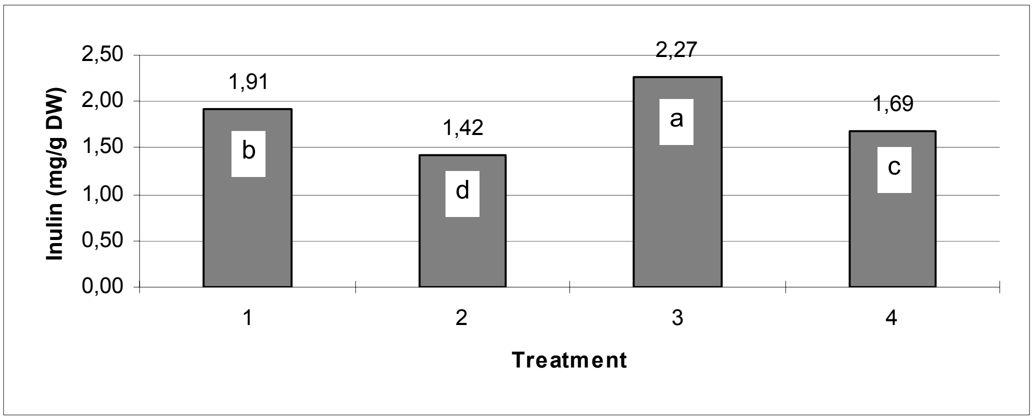
Total protein content was highest in control and the lowest value was recorded in T1 plants (tables 61+62).

GA3 applications had a significant decrease in chlorogenic acid of the edible part, with the lowest value in T2 plants in the two seasons of 1998/1999 and 1999/2000. The highest value was in the control plants (tables 61+62). T3 & control plants recorded the highest content of cynarin (table 61 and Fig. 22)

Table 61: Chemical content in the edible part of the second flower head of globe artichoke grown by direct seeding during 1998-1999 season

Treat-ments	Total Sugar %	Reducing Sugar %	Inulin (mg/g DW)	Total protein %	Chlorogenic acid %	Cynarin %
T1	9.86 d	6.96 b	1.87 b	19.78 d	0.023 c	0.022 b
T2	14.98 c	6.86 c	1.38 d	22.37 c	0.011 d	0.011 c
T3	15.82 b	6.31 d	2.23 a	24.78 b	0.030 b	0.030 a
C.	17.89 a	7.02 a	1.65 c	27.92 a	0.037 a	0.034 a

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after sowing date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)



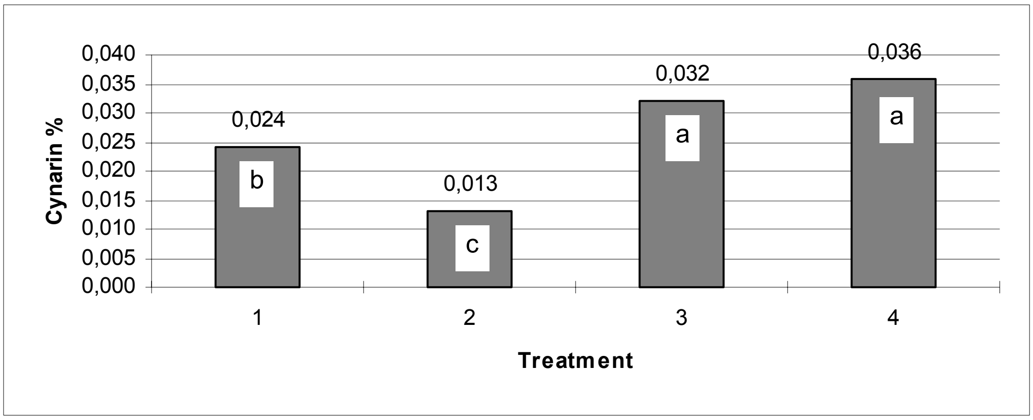
T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after sowing date, T4 = control
(means with the same letter are not significantly different)

Figure 21: Inulin content in the edible part of the second flower head of globe artichoke grown by direct seeding during 1999-2000 season

Table 62: Chemical content in the edible part of the second flower head of globe artichoke grown by direct seeding during 1999-2000 season

Treat-ments	Total Sugar %	Reducing Sugar %	Total protein %	Chlorogenic acid %
T1	9.91 d	7.01 b	19.84 d	0.025 c
T2	14.03 c	6.91 c	22.43 c	0.013 d
T3	15.87 b	6.36 d	24.84 b	0.032 b
C.	17.94 a	7.07 a	27.98 a	0.039 a

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after sowing date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)



T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after sowing date, T4 = control
(means with the same letter are not significantly different)

Figure 22: Cynarin content in the edible part of the second flower head of globe artichoke grown by direct seeding during 1999-2000 season

For the third head total sugar in edible part of globe artichoke increased significantly in T2 in the two tested seasons.

But reducing sugar content of the edible part had the highest value in control and the lowest value in T2 plants (tables 63+64).

The highest inulin was in T2 plants, followed by control, then T1 and the lowest inulin content was in T3 plants (table 63 and Fig. 23).

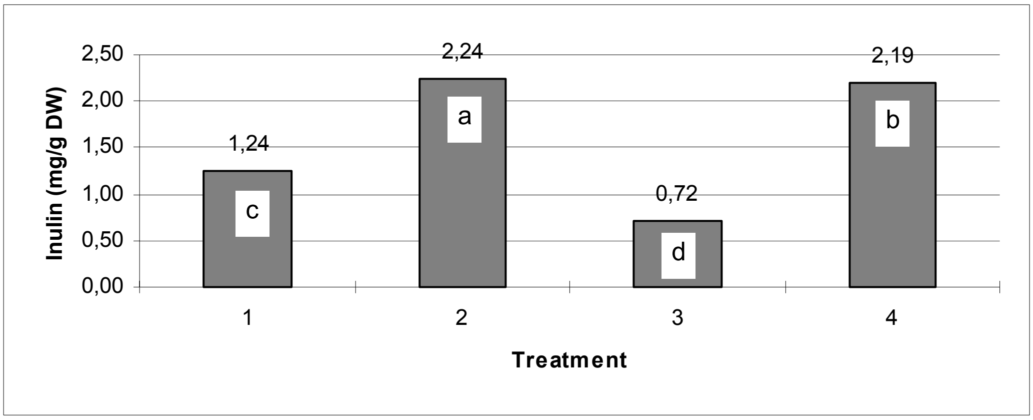
Total protein content decreased significantly in all GA3 treatments, with the highest value in control plants due to GA3 application and the lowest in T1 (tables 63+64).

The three GA3 applications had significant effect on chlorogenic acid and cynarin content in the edible part with the lowest in both T1 & T3 plants for chlorogenic acid and in T3 plants for cynarin content. The highest value of both was obtained in T2 plants (tables 63+64 and Fig. 24).

Table 63: Chemical content in the edible part of the third flower head of globe artichoke grown by direct seeding during 1998-1999 season

Treat-ments	Total Sugar %	Reducing Sugar %	Inulin (mg/g DW)	Total protein %	Chlorogenic acid %	Cynarin %
T1	11.45 d	6.33 c	1.21 c	21.22 d	0.024 c	0.028 c
T2	16.91 a	5.72 d	2.21 a	23.79 c	0.046 a	0.045 a
T3	11.63 c	7.04 b	0.69 d	24.83 b	0.022 c	0.023 d
C.	14.78 b	10.17 a	2.16 b	27.08 a	0.032 b	0.037 b

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after sowing date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)



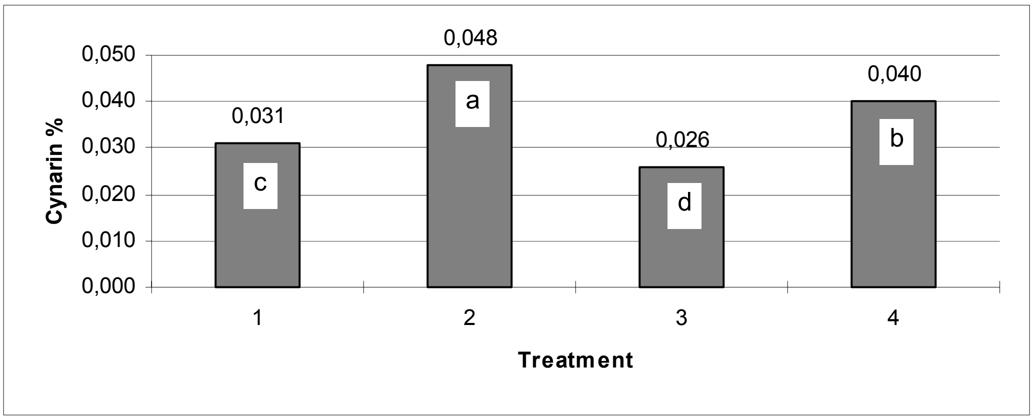
T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after sowing date, T4 = control
(means with the same letter are not significantly different)

Figure 23: Inulin content in the edible part of the third flower head of globe artichoke grown by direct seeding during 1999-2000 season

Table 64: Chemical content in the edible part of the third flower head of globe artichoke grown by direct seeding during 1999-2000 season

Treat-ments	Total Sugar %	Reducing Sugar %	Total protein %	Chlorogenic acid %
T1	11.53 d	6.41 c	21.29 d	0.027 c
T2	16.99 a	5.80 d	23.86 c	0.049 a
T3	11.71 c	7.12 b	24.90 b	0.025 c
C.	14.86 b	10.25 a	27.15 a	0.035 b

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after sowing date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)



T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after sowing date, T4 = control
(means with the same letter are not significantly different)

Figure 24: Cynarin content in the edible part of the third flower head of globe artichoke grown by direct seeding during 1999-2000 season

Total sugar in edible part of the fourth head increased significantly in T2 in both tested seasons.

Reducing sugar in the edible part was highest in control plants and the lowest in T2 (tables 65+66).

Inulin was highest in T2 plants, followed by T1, then T3 plants and the lowest content of inulin was obtained in control plants (table 65 and Fig. 25).

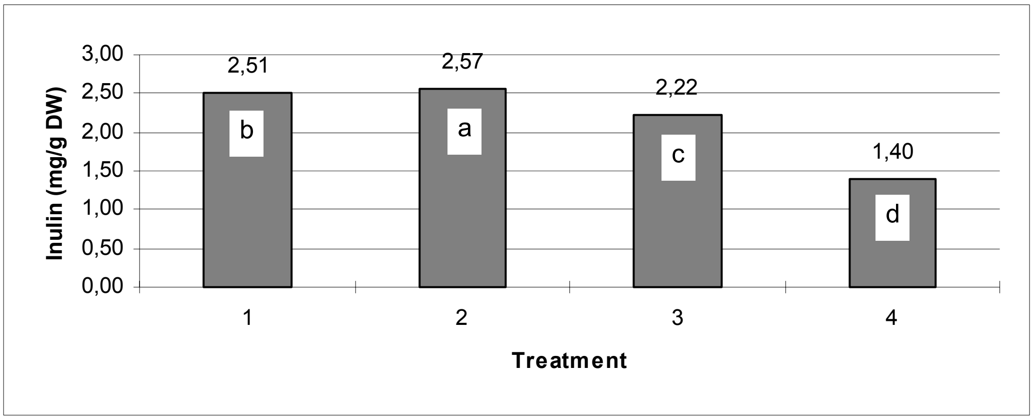
Total protein increased significantly in T3 plants due to GA3 application and the lowest value was recorded in T2 plants (tables 65+66).

The chlorogenic acid content was highest in T2 plants. Cynarin in the edible part was highest in T1 plants, followed by T2, then control plants and the lowest content was in T3 (tables 65+66 and Fig. 26).

Table 65: Chemical content in the edible part of the fourth flower head of globe artichoke grown by direct seeding during 1998-1999 season

Treat-ments	Total Sugar %	Reducing Sugar %	Inulin (mg/g DW)	Total protein %	Chlorogenic acid %	Cynarin %
T1	9.07 d	7.76 b	2.47 b	20.51 b	0.027 b	0.049 a
T2	12.78 a	6.32 d	2.53 a	16.28 d	0.061 a	0.030 b
T3	9.24 c	7.42 c	2.18 c	21.90 a	0.017 c	0.013 d
C.	11.77 b	9.24 a	1.36 d	16.68 c	0.015 c	0.026 c

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after sowing date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)



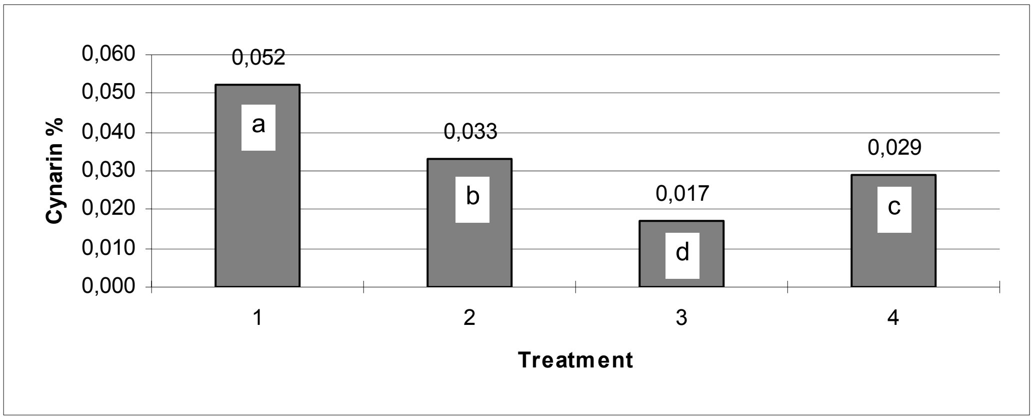
T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after sowing date, T4 = control
(means with the same letter are not significantly different)

Figure 25: Inulin content in the edible part of the fourth flower head of globe artichoke grown by direct seeding during 1999-2000 season

Table 66: Chemical content in the edible part of the fourth flower head of globe artichoke grown by direct seeding during 1999-2000 season

Treat-ments	Total Sugar %	Reducing Sugar %	Total protein %	Chlorogenic acid %
T1	9.12 d	7.81 b	20.58 b	0.030 b
T2	12.83 a	6.37 d	16.35 d	0.064 a
T3	9.29 c	7.47 c	21.97 a	0.020 c
C.	11.82 b	9.29 a	16.75 c	0.018 c

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after sowing date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)



T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after sowing date, T4 = control
(means with the same letter are not significantly different)

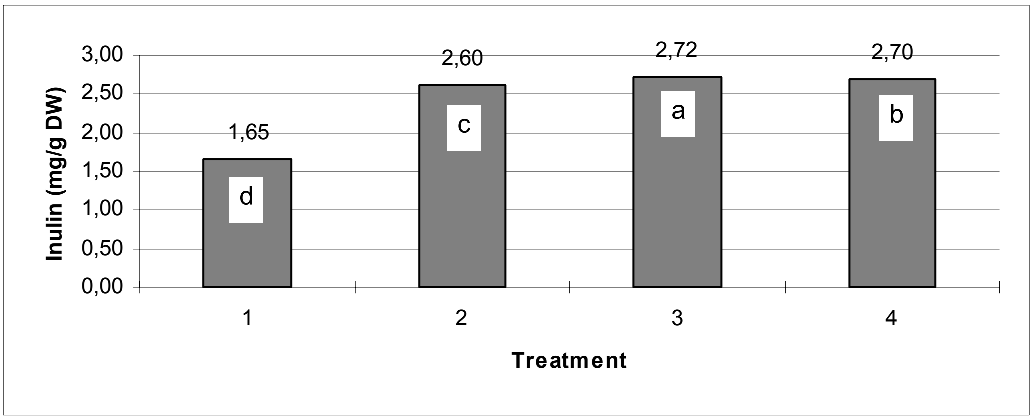
Figure 26: Cynarin content in the edible part of the fourth flower head of globe artichoke grown by direct seeding during 1999-2000 season

For the fifth head the highest content of total sugar, reducing sugar, inulin, total protein, chlorogenic acid and cynarin was obtained in plants of T3, followed by T2, T3, T2, T3 and T3 plants, respectively (tables 67+68 and Figs. 27+28).

Table 67: Chemical content in the edible part of the fifth flower head of globe artichoke grown by direct seeding during 1998-1999 season

Treat-ments	Total Sugar %	Reducing Sugar %	Inulin (mg/g DW)	Total protein %	Chlorogenic acid %	Cynarin %
T1	9.55 d	7.22 b	1.62 d	18.59 c	0.017 bc	0.013 b
T2	11.07 c	7.93 a	2.57 c	20.64 a	0.020 b	0.007 c
T3	15.31 a	6.31 d	2.69 a	19.54 b	0.041 a	0.029 a
C.	14.18 b	6.73 c	2.67 b	15.50 d	0.014 c	0.005 d

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after sowing date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)



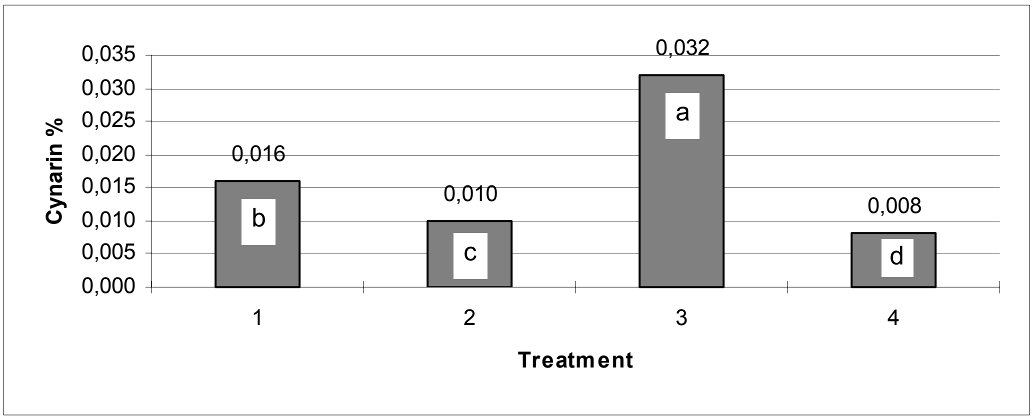
T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after sowing date, T4 = control
(means with the same letter are not significantly different)

Figure 27: Inulin content in the edible part of the fifth flower head of globe artichoke grown by direct seeding during 1999-2000 season

Table 68: Chemical content in the edible part of the fifth flower head of globe artichoke grown by direct seeding during 1999-2000 season

Treat-ments	Total Sugar %	Reducing Sugar %	Total protein %	Chlorogenic acid %
T1	9.61 d	7.28 b	18.64 c	0.020 bc
T2	11.13 c	7.99 a	20.69 a	0.023 b
T3	15.37 a	6.37 d	19.59 b	0.044 a
C.	14.22 b	6.79 c	15.55 d	0.017 c

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after sowing date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)



T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after sowing date, T4 = control
(means with the same letter are not significantly different)

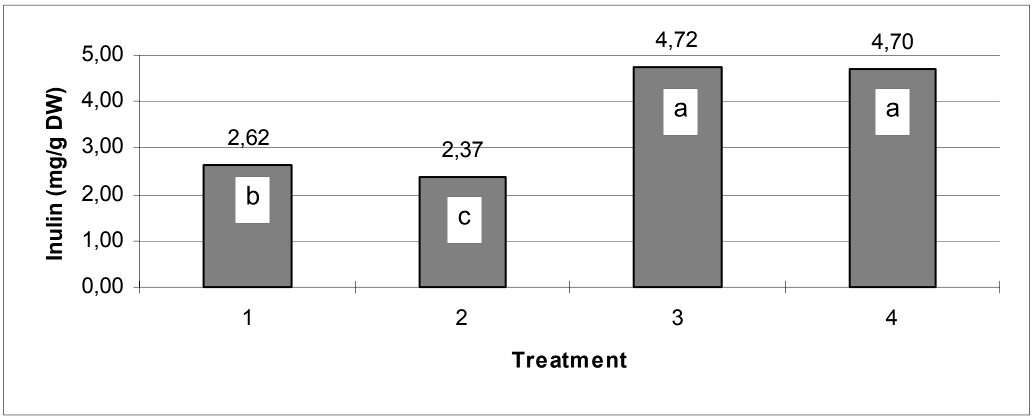
Figure 28: Cynarin content in the edible part of the fifth flower head of globe artichoke grown by direct seeding during 1999-2000 season

The untreated control plants recorded the highest content of total sugar and reducing sugar for the sixth head. The highest inulin and cynarin were obtained in T3 plants and was similar to control. GA3 applications positively influenced the total protein content with the highest value in T1 plants, followed by T2, then T3 and the lowest in the untreated control. Chlorogenic acid content was highest in T3 plants and was similar to T2 (tables 69+70 and Figs. 29+30).

Table 69: Chemical content in the edible part of the sixth flower head of globe artichoke grown by direct seeding during 1998-1999 season

Treat-ments	Total Sugar %	Reducing Sugar %	Inulin (mg/g DW)	Total protein %	Chlorogenic acid %	Cynarin %
T1	14.35 c	7.90 d	2.59 b	17.25 a	0.023 b	0.021 b
T2	17.22 b	10.87 b	2.34 c	16.38 b	0.031 a	0.019 b
T3	14.11 d	8.71 c	4.69 a	15.63 c	0.032 a	0.033 a
C.	24.40 a	14.07 a	4.67 a	12.72 d	0.022 b	0.029 a

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after sowing date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)



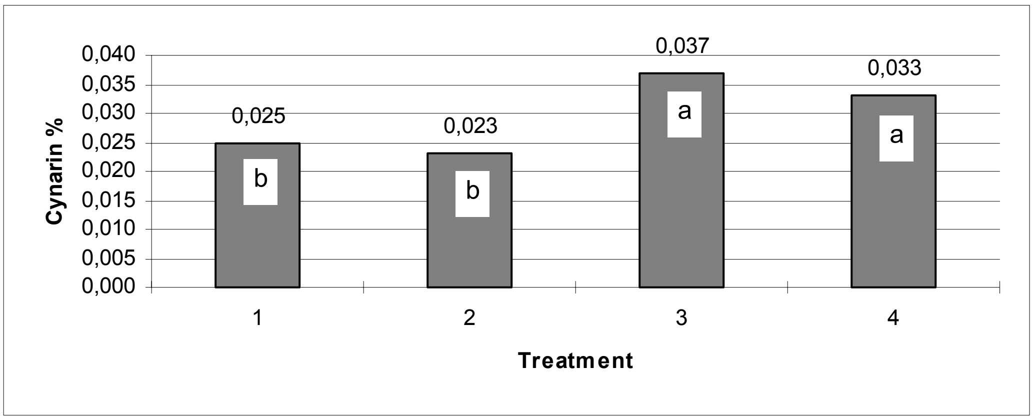
T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after sowing date, T4 = control
(means with the same letter are not significantly different)

Figure 29: Inulin content in the edible part of the sixth flower head of globe artichoke grown by direct seeding during 1999-2000 season

Table 70: Chemical content in the edible part of the sixth flower head of globe artichoke grown by direct seeding during 1999-2000 season

Treat-ments	Total Sugar %	Reducing Sugar %	Total protein %	Chlorogenic acid %
T1	14.42 c	7.97 d	17.34 a	0.027 b
T2	17.29 b	10.94 b	16.47 b	0.035 a
T3	14.18 d	8.78 c	15.72 c	0.036 a
C.	24.47 a	14.14 a	12.81 d	0.026 b

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after sowing date
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)



T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after sowing date, T4 = control
(means with the same letter are not significantly different)

Figure 30: Cynarin content in the edible part of the sixth flower head of globe artichoke grown by direct seeding during 1999-2000 season

4.2.7 Anthocyanin content of the bracts

Table 71 has only data for T2 & T3 due to T2 and T3 plants producing only early main heads with anthocyanin content in the bracts of the main head and also for all treatments of the second head.

Significant differences were recorded among the three treatments in anthocyanin content in the bracts of the second head with highest value in T3 plants and the lowest value was obtained in T2 plants in the two tested seasons (table 71).

Table 71: Anthocyanin content (mg/100 g DW) in the bracts of the main and second flower head of globe artichoke grown by direct seeding

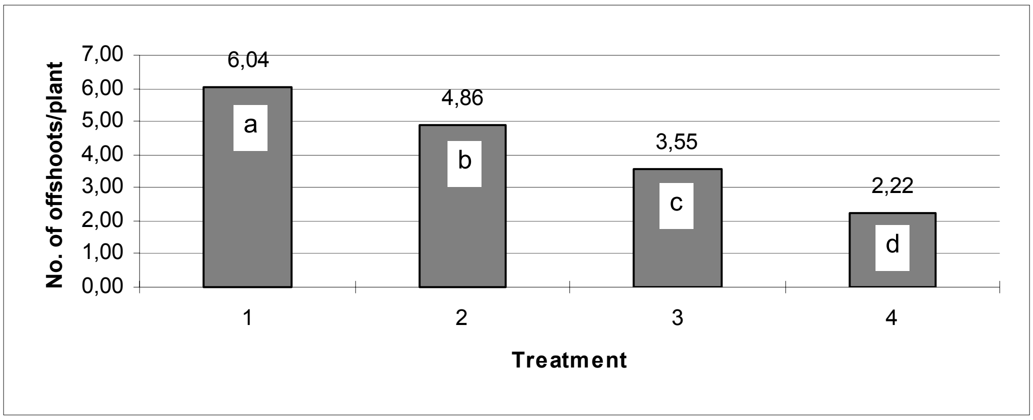
Treatments	1998-1999 season		1999-2000 season	
	Main head	Second head	Main head	Second head
T1	-	9.642 c	-	10.155 c
T2	9.606 *	9.410 d	10.119 *	9.923 d
T3	9.302 *	11.181 a	9.815 *	11.694 a
C.	-	10.465 b	-	10.978 b

T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after sowing date. * This value is mean
Any means within column followed by the same letter are not statistically different at 5 % level (Duncan's multiple test)

4.3 Third experiment

4.3.1 Number of offshoots

One week after the three apex removal treatments (pinching), the number of offshoots was highest in P1 plants, followed by P2, then P3 plants and the lowest value in the untreated control (Fig. 31).



P1 : Cutting back the plant completely near the soil surface

P2 : Removing the shoot-tip and keeping one true leaf on the plant

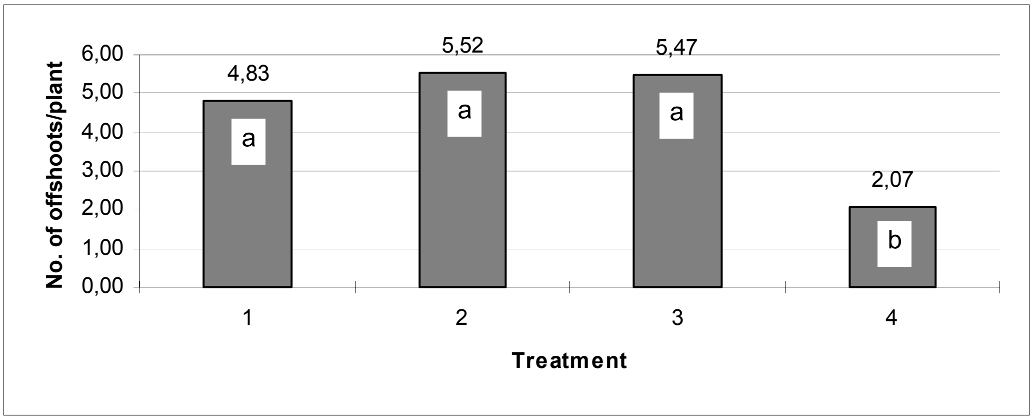
P3 : Removing the shoot-tip and keeping three true leaves on the plant

C. : Check (control without pinching)

(means with the same letter are not significantly different)

Figure 31: Number of offshoots per plant one week after treatments

There were no significant differences among the three treatments against control in number of offshoots four and ten weeks after the three treatments. But the lowest number of offshoots was in plants of the untreated also four and ten weeks after treatments (Fig. 32 & 33).



P1 : Cutting back the plant completely near the soil surface

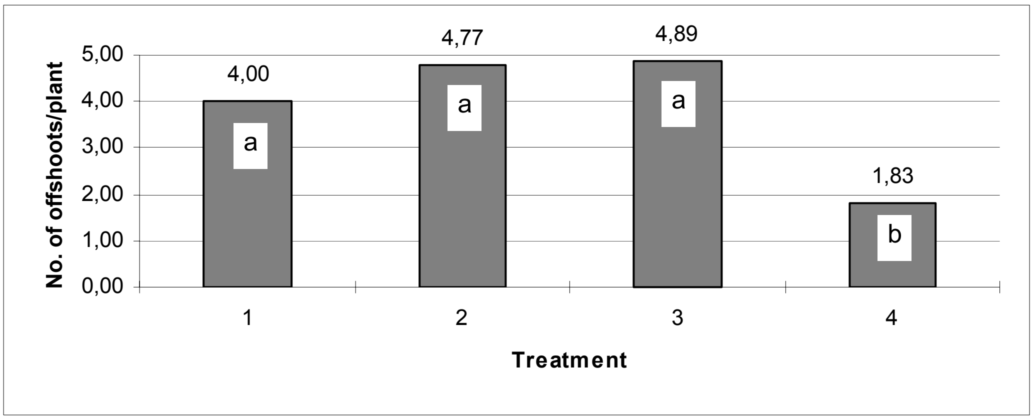
P2 : Removing the shoot-tip and keeping one true leaf on the plant

P3 : Removing the shoot-tip and keeping three true leaves on the plant

C. : Check (control without pinching)

(means with the same letter are not significantly different)

Figure 32: Number of offshoots per plant four weeks after treatments



P1 : Cutting back the plant completely near the soil surface

P2 : Removing the shoot-tip and keeping one true leaf on the plant

P3 : Removing the shoot-tip and keeping three true leaves on the plant

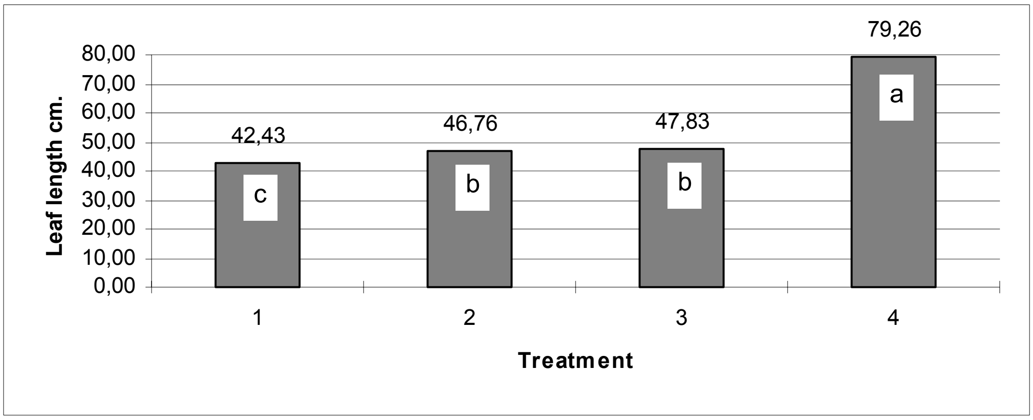
C. : Check (control without pinching)

(means with the same letter are not significantly different)

Figure 33: Number of offshoots per plant ten weeks after treatments

4.3.2 Leaf length

Untreated control was superior to the three treatments in leaf length four weeks after treatments followed by P2+P3 and the lowest value in P1 plants (Fig. 34). But ten weeks after treatments there were no significant differences anymore in leaf length compared to control plants (Fig. 35).



P1 : Cutting back the plant completely near the soil surface

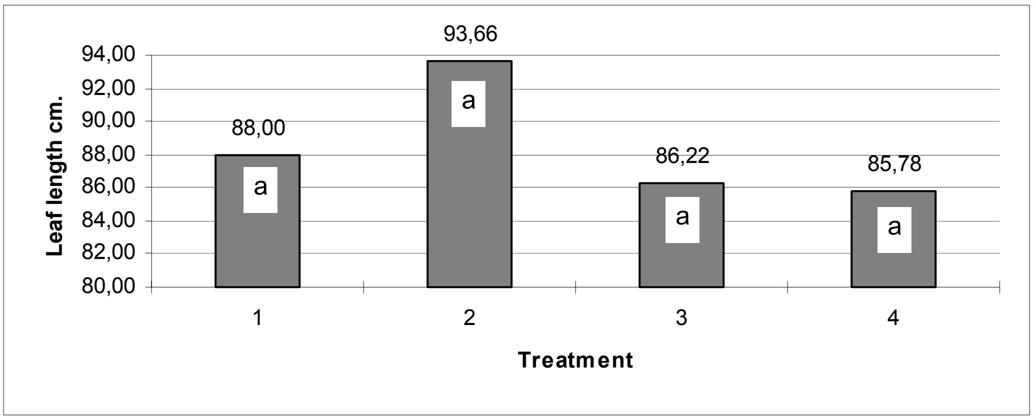
P2 : Removing the shoot-tip and keeping one true leaf on the plant

P3 : Removing the shoot-tip and keeping three true leaves on the plant

C. : Check (control without pinching)

(means with the same letter are not significantly different)

Figure 34: Leaf length of offshoots four weeks after treatments



P1 : Cutting back the plant completely near the soil surface

P2 : Removing the shoot-tip and keeping one true leaf on the plant

P3 : Removing the shoot-tip and keeping three true leaves on the plant

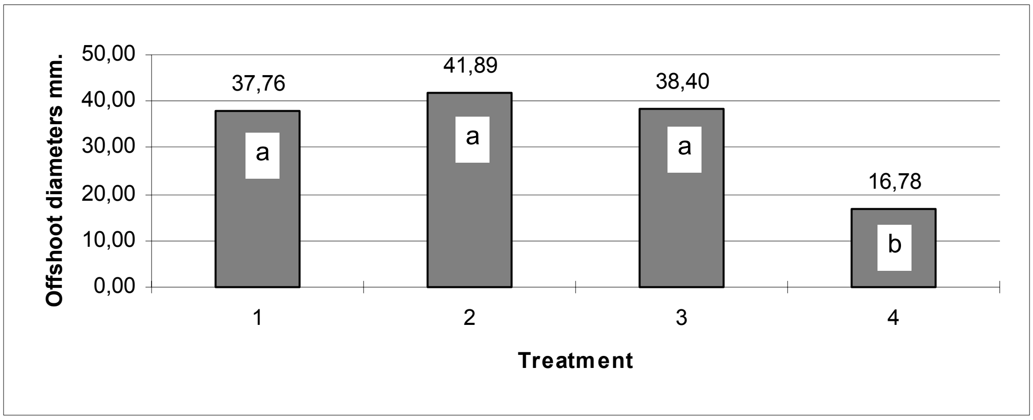
C. : Check (control without pinching)

(means with the same letter are not significantly different)

Figure 35: Leaf length of offshoots ten weeks after treatments

4.3.3 Offshoot diameters

The three treatments after ten weeks resulted in significant increase in diameters of the offshoots for all treatments compared to untreated control plants with no significant differences among the three treatments with lowest value in control (Fig. 36).



P1 : Cutting back the plant completely near the soil surface

P2 : Removing the shoot-tip and keeping one true leaf on the plant

P3 : Removing the shoot-tip and keeping three true leaves on the plant

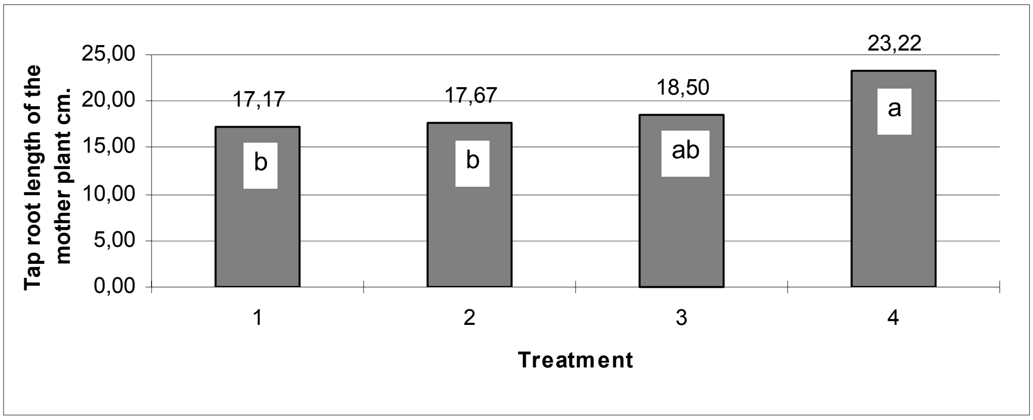
C. : Check (control without pinching)

(means with the same letter are not significantly different)

Figure 36: Offshoot diameters ten weeks after treatments

4.3.4 The average tap root length of the mother plants

Tap root lengths of the mother plants ten weeks after treatments was highest in untreated control and lowest in P1+P2 plants. P3 was similar to control and P1 & P2 plants (Fig. 37).

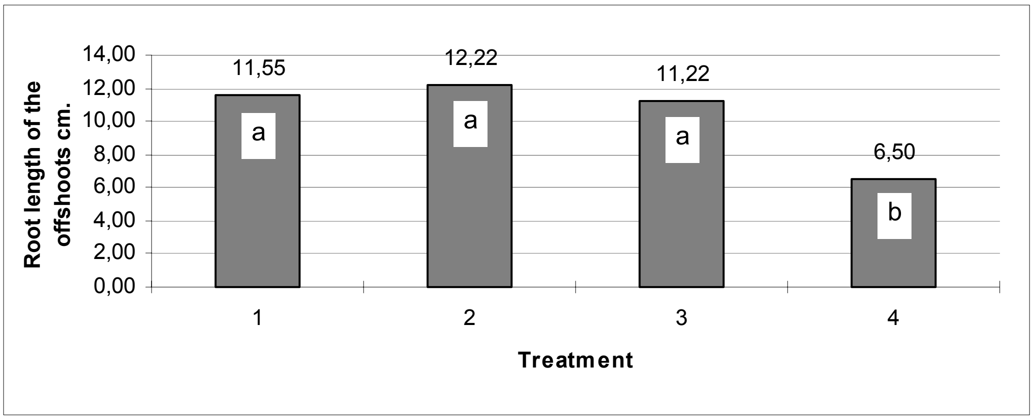


P1 : Cutting back the plant completely near the soil surface
P2 : Removing the shoot-tip and keeping one true leaf on the plant
P3 : Removing the shoot-tip and keeping three true leaves on the plant
C. : Check (control without pinching)
(means with the same letter are not significantly different)

Figure 37: Average length of tap roots of the mother plants ten weeks after treatments

4.3.5 Root length of the offshoots

Ten weeks after the three treatments, the average root lengths of the offshoot was significantly increased in all treatments with no significant differences among the three treatments and lowest value in untreated control (Fig. 38).



P1 : Cutting back the plant completely near the soil surface
P2 : Removing the shoot-tip and keeping one true leaf on the plant
P3 : Removing the shoot-tip and keeping three true leaves on the plant
C. : Check (control without pinching)
(means with the same letter are not significantly different)

Figure 38: Root length of the offshoots ten weeks after treatments

5. Discussion

5.1 Cultivation of globe artichoke in Egypt by new field technology

In Egypt, globe artichoke is mainly propagate by stump cuttings (crown pieces). Thus, growers leave after last harvest about 6-8 kerat (1 kerat = 175 m^2) of old mother plants to replant one feddan (1 hectare = 2.38 feddan, 1 feddan [**4200 m^2**] = 24 kerat) and this area is being occupied for about 3-4 months (May-August) till the new planting season to start normally at first week of September. At the end of the season (April/May) most growers leave the plants as they are without any especial treatments, even stopping the irrigation. Few growers cut back the globe artichoke plants by slashing (cutting the artichoke to 20-30 cm above ground) or stumping after last harvesting and when the dormant period starts. This technique of stumping involves cuttings the artichoke plants to 5-7.5 cm below ground level. Some growers prefer to prepare a nursery for the stump cuttings 3-4 weeks before transplanting in the field.

All mentioned above can be considered in term of vegetative propagation of globe artichoke which has some advantages and also some disadvantages. The most interesting advantage for the growers is that, they can select mother plants which they will keep for next growing season according to plant vigour, earliness, productivity and head quality. With this vegetative propagation is a guaranteed method to get new plants exactly as the mother plant (true to type).

On the other hand, there are some disadvantages such as the relatively low percentage of plant survival (only around 60-70 %) especially when the stump cuttings are transplanted directly into the field. As well, in case of making a nursery for the stump cuttings 3-4 weeks before transplanting, there may occur big differences in the physiological age between the detached offshoots and the stump cuttings (crown pieces) which lead to differences in head initiation and harvesting time.

For overcoming these problems, the seedlings propagation was developed as it lets the growers to avoid occupying the field for 3-4 months without any income, but they have a possibility to plant any summer crop such as corn. This also will improve the soil properties through soil preparation, irrigation, fertilization, in addition of generating income by selling the crop.

Furthermore, some growers can get early yield by transplanting the seedlings early in August in inter-cropping with maize plants. The shading by the taller corn plants will help the plant survival of the globe artichoke seedlings and avoid the negative effect of the high temperature during August. This will finally lead to accelerate early yield. In addition, seedling propagation saves the cost of making nursery for stump cuttings. The growers will get high survival percentage by using healthy seedlings with well developed and strong roots. Moreover, all the seedlings have the same physiological age of 6-8 weeks from sowing date, thus the head initiation and harvesting time will be the same over all the field.

Previously, lack of bud uniformity has been a limiting factor for commercially available seeded artichoke cultivars due to the high percentage of unmarketable (off-type, spiny, or small) buds (Baggett et al., 1982). But nowadays, some new seeded globe artichoke cultivars were developed for globe artichoke propagation. ‘Imperial Star’ (Sun Seed Company, California, USA) was developed to fill the need for a cultivar that is uniform and commercially acceptable when produced from seed in an annual-cropping system (Schrader and Mayberry, 1992).

Most globe artichoke growers prefer to apply GA3 to accelerate head initiation (early yield) and obtain increased benefits from higher prices. In Egypt the highest market prices are obtained from December to February. Furthermore, the floral induction requires about 250 h at temperatures $\leq$ 7 °C. Previous studies have demonstrated that, in the new seed-grown varieties, gibberellic acid treatments can replace cold requirements (Mauromicale et al., 2000a).

This presented research work (first experiment; **exp. 1)** is discussing seedlings propagation method together with the effect of GA3 application through the following parameters, such as plant height & number of leaves after GA3 treatments, vegetative growth characteristics, the morphological-physical traits of the globe artichoke heads and some chemical constituent of both, leaves and edible part.

Nowadays, commercially available seeded artichoke (*Cynara scolymus* L.) cultivars provide new and interesting perspectives for the cultivation of this crop (Basnizky and Zohary, 1987). The traditional propagation methods using vegetative parts of the plant such as offshoots, ovoli, crown pieces or stumps, gives rise to a number of problems: heterogeneitry of plants, intensification of phytopathological problems, the need for a larger labour force, especially for transplanting operation and offshoots removal. Seeds can be sown mechanically; artichoke can also be cultivated on an annual basis thus contributing to the flexibility of crop farm rotation. The use of seeds also ensure greater plant homogeneity (especially with F1 hybrids) with high productivity and contemporary harvests (Elia et al., 1994).

Cultivation of globe artichoke in Egypt by direct seeding in the field is a new propagation method which saves the cost of establishing a nursery (6-8 weeks) for providing globe artichoke seedlings. The second experiment **(exp. 2)** was conducted to evaluate this new method of propagation and the effect of GA3 application to accelerate the head initiation (earliness). The following parameters are discussing this method of propagation (direct seeding in the field) and the effect of GA3 application.

5.1.1 Plant height and number of leaves recorded after GA3 treatments

In the present study, all GA3 treatments had a significant increase in plant height compared to the untreated control plants. Two weeks after GA3 treatment the number of leaves significantly decreased in T1 (GA3 was sprayed 4 weeks after transplanting date) plants compared to untreated control (sprayed with water only). But six weeks after GA3 application the number of leaves increased in T1 plants compared to control. The stimulating effect of GA3 on plant height is due to its effect on cell elongation. Similar results of GA3 effect were obtained by Foury (1977) and Bekhit et al. (1985). Results in exp. 2 were similar except for the number of leaves were not affected by GA3 applications in all treatments in all stages.

5.1.2 Vegetative growth characteristics

On the same day of the first harvest of flower bud (picking), GA3 treatments significantly increased the plant height of the latest treatment (T3 = GA3 was sprayed 8 weeks after transplanting date) and was similar to T2 (GA3 was sprayed 6 weeks after transplanting date) plants, but there were no significant differences in plant height of T1 and the untreated control plants. These results are in agreement with those of Sims et al. (1977) and Bekhit et al. (1985).

On the other hand, GA3 application had no significant differences in number of leaves and the length & width of the 5th leaf among the three treatments and were similar to untreated control plants. The length of the 5th leaf can be an indicator for plant spacing of this cultivar (IS).

Based on the results obtained two weeks after GA3-T3, the highest number of leaves was in T1 plants (increase in the photosynthetic area) which lead to significant increase in the number of offshoots with the best effect in T1 plants. On the same day of the first picking, the number of offshoots increased significantly in all GA3 treatments compared to untreated control. The highest number of offshoots per plant in early growth stages can be taken for an indicator of lowest yield. This is also confirmed by the results discussed under **(5.1.5)**. It also can be an explanation why offshoots are removed 2-3 times during the growing season as most Italian artichoke growers do. The three GA3 treatments of exp. 2 were not produced any significant effect on the vegetative growth characteristics of globe artichoke plants.

5.1.3 Head parameters

The results of the presented experiments show that only T2 plants produced early main heads according to GA3 treatments and it was 15-17 days ahead of other treatments, similar to untreated control. In exp. 2, only T2 & T3 plants were produced early main head due to GA3 treatments and it was 16-18 days ahead of untreated control, similar to T1. Early main heads of exp. 1 were 15-17 days ahead of exp. 2, that may be due to the differences of the physiological age, since these plants of exp. 2 were 8 weeks younger than those of exp. 1 (seedling propagation).

Head length, head diameter, head stem diameter and number of removed bracts were not affected by GA3 treatments in the second and third picking. These results are in line with those of Snyder et al. (1971) and Bekhit et al. (1985) who found that GA3 applications had no significant effect on head diameter. Head stem diameter can help in increasing head size. Moreover, head stem can be eaten in early season.

In the second head, edible part diameter and fresh weight was highest in T2 plants. GA3 application increased head fresh weight in all GA3 treatments in the second head compared to the untreated control plants and the other head parameters remained unchanged. Head and edible part fresh weight of the third head was highest in T1 plants and the other head parameters remained unchanged. These good quality characteristics of the head and edible part fresh weight which is a main prerequisite for exportation can help in increasing the income of the artichoke growers. If they are interest in early yield, it is recommended to apply GA3 six weeks after transplanting (T2) as the earliest main head is obtained in GA3-T2 treated plants. All the previous head parameters are very important for promoting globe artichoke exportation of this promising new seed-grown cultivar (IS).

The three GA3 treatments had a negative effect on head stem diameter and number of removed bracts with highest value in the untreated control plants of the fourth head. All other head parameters remained unchanged by GA3 treatments. All head parameters of the fifth head were unchanged by GA3 treatments except the head fresh weight was highest in T3 plants.

The edible part diameter and fresh weight of the sixth head were significantly affected by GA3 treatments with highest increase in T3 plants and lowest value in T2. The other head parameters were not affected by GA3 applications.

No significant differences were found among the three treatments against the untreated control plants in head length, number of removed bracts and edible part fresh weight of the seventh head. Head diameter and head stem diameter were lowest in T3 plants. Head fresh weight was highest in T2 plants and was similar to the untreated control plants. Edible part diameter was lowest in T1 plants and similar to untreated control plants.

The variations in head characteristics during the long harvest period may probably be related to seasonal changes of gibberellin in the plant, since modification in head length and diameter have been obtained in some trials carried out in Sicily by Mangano and Signorelli (1981) as a result of gibberellic acid application to the plants.

5.1.4 Yield

Gibberellic acid treatments, if misapplied, can negatively affect plant vigour, cause elongation of early buds and lead to brittle leaves that break easily. These negative impacts are especially apparent when gibberellic acid treatments are applied too early in the season at very high rates, or when excessive heat is experienced during or immediately after application (Hoffmann, 2001).

Time of GA3 application is significantly affecting the number of early heads per plant with highest value in T2 plants. The other two treatments remained unchanged and were similar to untreated control. But all three GA3 applications had no significant effect on number of heads per plant and average number of heads per hectare and were similar to control plants.

Similar results of GA3 application on globe artichoke were obtained by many investigators. Lin et al. (1991) reported that GA3 application can be used to compensate for the insufficient chilling conditions. As well, GA3 application replaced the cold requirement (Mauromicale and Ierna, 1995). In this respect, also Mauromicale et al. (1996) found that GA3 treatment resulted in earlier maturity and higher yields.

Schrader et al. (1992) reported that growers occasionally use transplants to obtain earlier production. But GA3 treatments provide the good possibility to enlarge production of seed-grown artichoke (Calabrese and Bianco, 2000). This high number of heads of globe artichoke plants treated with GA3 can increase the quantities needed for exportation and local consumption.

GA3-T2 plants were highest for early yield (Kg/plant), average early yield (ton/ha) and total yield (Kg/plant & ton/ha), followed by T1 plants, with lowest for T3, similar to untreated control.

In exp. 2, due to GA3 treatments, T1 & T2 plants were produced the highest number of early heads per plant, early yield per plant and average early yield per hectare, lowest were obtained in untreated control, similar to T1. Number of heads per plant and average number of heads per hectare were remained unchanged by GA3 treatments. Untreated control plants were produced the lowest total yield per plant and average total yield per hectare.

Also De Malach et al. (1976); Foury (1977); Zaki et al. (1991); Miguel et al. (1997); Garica et al. (1998) and Kocer & Eser (1999) reported advancement of harvest with GA3 treatments. In this respect, Schrader (1994) found that application of 20 ppm GA3, three times at 2 weeks interval significantly increased early, total and large bud yields, with application beginning 4 weeks after transplanting being the most effective. As well, application of GA3 generated an increase in gross revenue (Garica et al., 1999). It seems that the significant increase in early yield by GA3 application was due to the increase in head number rather than its increase in other head characters (weight, length and diameter).

GA3 applications did not increase the number of early heads in T1 plants but it increased the weight of early yield compared to the untreated control plants. This is in agreement with Pandita et al. (1988); Elia et al. (1994b) and Garica et al. (1994).

On the other hand, these results did not agree with those of El-Baz et al. (1979) who reported that, GA3 treatment at 50 and 75 ppm increased the early yield in ‘Selected French’ but had no effect in the total yield. Also Eser et al. (1985) revealed that early yield was improved by double GA3 (30 ppm) application but total yield and bud size were unaffected. This high total yield is very important as it can increase globe artichoke grower’s income and also indirectly can increase the cultivation area of globe artichoke in Egypt. The GA3 application showed promising results for commercial production. The suitable application time was 6 weeks after transplanting. Further studies should be carried out on more concentrations and application times at other locations in Egypt with different environmental conditions to rectify presented results.

5.1.5 Chemical constituents of leaves

Both, traditional and more recent literature make reference to the fact that artichoke leaf extracts alleviate abdominal pain and have choleretic, lipid-lowering and hepatoprotective effects. However, it was only in the last few years that the underlying mechanisms of action were evaluated. Experimental and clinical results for artichoke leaf extract complement each other, a rare phenomenon in phytotherapy (Kraft, 1997). Artichoke leaf extract is suitable for treating chronic gastrointestinal, metabolic, and cardiovascular diseases. Additionally, carminative, spasmolytic and antiemetic effects have been verified through recent investigations, confirming that the dyspeptic syndrome is a traditional indication for artichoke leaf extract (Monography: Cynarae folium 1988 [corr. 1990]).

The history of the artichoke as a medicinal plant has been dealt within reviews by Mayr and Fröhlich (1965) and by Ernst (1995). The extract is from the leaves (Cynarae folium). The 10th edition of the French Pharmacopoeia includes a monograph of the drug. The essential ingredients of artichoke extract are caffeic acid, chlorogenic acid, cynarin (1,5-di-caffeoylquinic acid), luteolin and the glycosides scolymoside and cynaroside. Modern extracts are produced using highly standardised procedures (Wagenbreth et al., 1996).

The results of the present study show significant differences among the three GA3 treatments for the chemical constituent of the leaves against the untreated control plants. On the same day of the first harvest of a flower bud, GA3 applications had significant effect on total sugar content in the leaves of globe artichoke plants with highest value in T3 plants, similar to T2. But T1 and the untreated control plants remained unchanged. Reducing sugar content was highest in T2 plants, followed by the untreated control, then T3 plants and the lowest value was in T1 plants. Inulin content was highest in T1 plants.

These results are in agreement with those of Pandita et al. (1988) and Khan et al. (1999). In this respect, Unisse (1994) reported that all varieties of artichoke contain inulin which helps those suffering from diabetes, liver problems, high blood pressure and other bowel disorders. As well, globe artichoke is used in the Western diet because of the presence of inulin and oligofructose (Loo et al., 1995).

Total protein content was lowest in T2 plants and was similar to T3 plants. The highest value was in the untreated control plants and was similar to T1. These results are in line with those of Moharram et al. (1981); Pandita et al. (1988) and Ruiperez et al. (1992).

The highest chlorogenic acid content was obtained in T1 plants and the lowest in T2 & T3 plants, was similar to the untreated control. Cynarin content was lowest in T2 & T3 plants and was the highest value in T1, similar to the untreated control. Adzet et al. (1987) in Spain reported that globe artichoke is used in folk medicine to treat liver complaints. And artichoke leaf extract has a marked antioxidative and protective potential (Gebhardt, 1997).

In exp. 2, on the same day of the first harvest of flower bud, GA3 treatments had a negative effect on total and reducing sugar of leaves, since the highest value was obtained in untreated control. T3 plants recorded the lowest content of inulin. Total protein was highest in T3, similar to untreated control. Chlorogenic acid and cynarin were remained unchanged by GA3 treatments. This variation may be due to timing of GA3 application and also a complex metabolic process occurring during the growth and development of the plant.

5.1.6 Chemical constituent of the edible part

Attention has focused on the protective effects of naturally occurring antioxidants on the cells of organisms. Chlorogenic acid, one of those compounds, is widely found in various agricultural products such as coffee beans, potatoes, apples, artemisia leaves and tobacco leaves. This substance may be present in substantial quantities, e.g. 3.4-14 mg/100 g FW in several varieties of potatoes, 12-31 mg/100 ml of apple juice, 89 mg/100 g of fresh mature apples and 559-674 mg/100 g of dry tea shoots. Catechol derivatives, such as chlorogenic acid and caffeic acid, are also present at about 250 mg per cup of coffee. Thus, the influence of chlorogenic acid and caffeic acid on human health is important in view of their widespread occurrence in food products and their huge daily consumption per head.

Depending upon the conditions, chlorogenic acid can be either detrimental or beneficial to biological processes. Investigators have reported an inhibitory effect of chlorogenic acid on lipoxygenase activity in prostaglandin metabolism, inhibition of oxidation of vitamin A, protection against oxidation of epinephrine, inhibition of retinoic acid 5,6-epoxidation, and antiviral activity, while others showed that chlorogenic acid is a potent cocarcinogenic agent and an inducer of DNA damage (Ohnishi et al., 1994).

The chemical constituent of the edible part of the early main head was determined only in T2 plants, since only T2 plants produced the main early flower bud (head). Application of GA3 had a negative effect on inulin, chlorogenic acid and cynarin content of the second head, while the highest value was in the untreated control plants. Highest content of total sugar was obtained in T2 plants. Reducing sugar and total protein content were highest by T3 and lowest in the untreated control plants.
But in exp. 2, inulin was highest in second head of T3 plants. GA3 applications had a negative effect on total & reducing sugar, total protein and chlorogenic acid. Cynarin content was highest in untreated control, similar to T3.

In the third head, GA3 application had a significant effect in total and reducing sugar content with highest value in T1 plants and lowest value for T3. Inulin and total protein were highest in T2 & T3, respectively. The three GA3 treatments had a negative decrease in chlorogenic acid and cynarin content with highest value in the untreated control. In exp. 2, all the chemical constituents were highest in the edible part of T2 plants of the third head, except reducing sugar and total protein were highest in untreated control.

The content of (reducing sugar & total protein), total sugar, inulin and (chlorogenic acid & cynarin) of the fourth head were highest in T1, T2, T3 and the untreated control plants, respectively. In the fourth head of exp. 2, the content of total sugar, inulin and chlorogenic acid were highest in T2 plants. The untreated control, T3 and T1 plants recorded the highest content of reducing sugar, total protein and cynarin, respectively.

The untreated control plants recorded the highest content of inulin, chlorogenic acid and cynarin of the fifth head. Reducing sugar and total protein were highest in T1 plants. T3 plants showed the highest value of total sugar. In exp. 2, reducing sugar and total protein were highest in the edible part of T2 plants of the fifth head, but the other chemical constituents were highest in T3.

Highest total sugar content was in T1 plants of the sixth head. T2 plants recorded the highest value of reducing sugar, inulin and total protein. Highest chlorogenic acid content was in the untreated control plants. Cynarin content was highest in the untreated control plants and was similar to T2 plants. T1, T2, and T3 plants were recorded the highest content of (reducing sugar & chlorogenic acid), (total sugar & inulin) and (total protein & cynarin) of the seventh head, respectively.

In the sixth head of exp. 2, inulin and cynarin were highest in T3, similar to untreated control. The untreated control plants recorded the highest content of total and reducing sugar. Total protein was highest in T1 and lowest in the untreated control. T2 & T3 recorded the highest content of chlorogenic acid.

In general the results of the present experiment show that the content of total and reducing sugar was higher in edible part than in the leaves. On the contrary, the content of chlorogenic acid and cynarin was higher in leaves than in the edible part. Inulin content was higher in leaves than in the edible part. Except in fifth, sixth and seventh head, it was higher in edible part than in the leaves. As well, protein content was higher in edible part than in the leaves, except in sixth and seventh head, where it was higher in leaves than in the edible part.

As mentioned above, some chemical constituents were higher in the leaves and the others were higher in the edible part to a points that there may be some turnover or redistribution of chemical constituents within the plant. For example, total and reducing sugar were higher in edible part than in the leaves. The explanation may be that total and reducing sugar were synthesised in the vegetative tissues (leaves) and later transported to the generative tissue flower bud (head). These results suggest that individual chemical constituent vary independently. This variation may be due to timing of GA3 application and also a complex metabolic process occurring during the growth and development of the plant and its flowers.

5.1.7 Anthocyanin content of the bracts

Anthocyanin pigment is responsible to the violet (purple) colour of some globe artichoke cultivars, which is favourable in European market especially in southern of both Italy and France. The anthocyanin content of globe artichoke bracts as affected by GA3 treatments had the highest value in T1 plants of the second head but the lowest in third head of this treatment. The untreated control plants recorded the highest anthocyanin content in the bracts of the third head. In the second head of exp. 2, the highest anthocyanin was in T3, followed by untreated control, then T1 and the lowest value was in T2.

5.2 Rapid increase of offshoots for globe artichoke propagation in Egypt

During the last decade many Egyptian globe artichoke growers started to cultivate new seed-grown cultivars such as Imperial Star (IS), Green Globe (GG) and Large Green (LG) all supplied by Sun Seed Company, California, USA. The most promising new cultivar under environmental conditions of Egypt is Imperial Star (Abd-El-Salam, 1996 and Okasha et al.,1997). Globe artichoke seed production is fairly costly because it is a cross pollinator. The high cash price of seeds, therefore, prevent growers to accept cultivating these new seed-grown cultivars, because they think it will increase production cost with decreasing their revenue.

Thus, it is important to allow farmers the choice of economical and healthy, vegetatively propagated plant material with even growth development. This experiment laid the foundation for a rapid increase of offshoots with high percentage of plant survival in the field (rooted offshoots) and at the same time minimising the production costs. Establishment of a new artichoke field with rooted offshoots is one of possible (traditional) methods (Eser et al., 2000).

In experiment 3 the growing point of the artichoke plants was removed. The growing shoot apex is known to regulate a wide range of developmental processes in plants including axillary bud growth, the orientation of laterals, the growth of rhizomes and stolons, leaf abscission, and others (Cline, 1991; Hillman, 1984; Hutchings & de Kroon, 1994 and Phillips, 1975). These effects are expressions of correlative control, through which the shoot apex exerts a central co-ordinating influence on plant development. Plant response is affected by environmental variables such as light, soil nutrients and various forms of stress. The correlative signal pathway may involve nutrients and other factors, but plant hormones have a pre-eminent role. In recent years, the understanding of correlative phenomena in plants has broadened, and thus the developing flowers and fruit is now regarded as a potential source of correlative effects which regulate growth in other fruit and in axillary buds (Tamas, 1995).

Among the correlative effects of the growing shoot apex, the inhibition of axillary bud growth has received most attention, and therefore has become most closely associated with the concept of apical dominance. Axillary buds of developing shoots are generally kept in a state of partial or total inhibition, or ‘quiescence’. The primary source of the bud-inhibition effect is the growing shoot apex, and the relative strength of the repressive signal is related to the vigour of the apex. Therefore, the axillary buds of rapidly growing shoots are often fully repressed, while those on less vigorous shoots may escape inhibition and develop into lateral branches. The degree of bud growth repression is under genetic control, which explains the predictable extent of branching exhibited by individual plant species. The quiescent axillary buds may be regarded as ‘replacement apices’ many of which remain inhibited under unfavourable conditions such as nutrient poor soil, drought or shading. However, the bud may be induced to develop into lateral branches in case the plant is exposed to favourable conditions, or the shoot apex is lost (Cline, 1991; Hillman, 1984 and Phillips, 1975), like it was done in this experiment with globe artichoke plants.

The discovery and early characterisation of auxin were closely linked to the idea that growing tips of shoots and coleoptiles produce auxin, which may be released to regulate the development of other structures elsewhere in the plant. In their pioneering work on apical dominance, Thimann and Skoog (1934) demonstrated that axillary buds were under the correlative control of the growing shoot apex. They found that decapitation of *Vicia* plants caused the outgrowth of the axillary buds, but the treatment of the cut surface with auxin prevent bud growth. These results have since been confirmed in numerous plant species (Hillman, 1984). The active substance responsible for the inhibition of axillary buds has been isolated from *Phaseolus* shoot tips (particularly from the young, developing leaves) and identified as indoleacetic acid (IAA) by gas chromatography-mass spectrometry (Hillman, 1984).

The development of the axillary bud originates in the growing shoot apex. A small group of cells in the axial of the leaf primordium is detached from the apical meristem and becomes organised into the apex of the axillary bud (Garrison, 1955). Continuing growth produces a visible bud. Events in the developing bud are under the control of the shoot apex. In the axillary buds of intact *Pisum* plants mitosis is arrested, but it becomes activated within hours after the shoot is decapitated (Stafstrom et al., 1993).

When the shoot apex on the artichoke plants is detached, mitotic activity and growth resume in the lateral buds after some delay. Variation in the length of the lag period may depend on the stage of the cell division cycle at which the inhibited cells are held. In the axillary buds e.g. of chickpea (*Cicer arietinum* L.), mitosis can be observed within an hour after decapitation, followed by the resumption of bud growth and DNA synthesis in that order (Hillman, 1984). Presumably, the cells have already completed the duplication of DNA at the time of release (i.e., they are at the G_2 stage) and thus are able to undergo mitosis with little delay. On the other hand, *Tradescantia* requires over four days for the resumption of bud growth following shoot decapitation (Naylor, 1958). The cells of inhibited *Tradescantia* buds are held at the G_1 stage, and DNA needs to be synthesised before mitosis can occur.

There is strong similarity also in the pattern of expression between the dormant buds of *Pisum sativum* and the ones undergoing transition from the growing to dormant state. This transition is observed in small, subordinate buds that start growing after the shoot is decapitated, but become inhibited two to three days later under the influence of fast growing larger buds. The excision of the larger bud after five days enables the small bud to resume growth (Stafstrom, 1993 and Stafstrom & Sussex, 1992).

Therefore, IAA-regulated mass promoter activity can be monitored by measuring the amount of light emitted from the luciferase-catalyzed reaction. *Lux* expression is stimulated by applied IAA and other auxins. Video image analysis of luciferase activity reveals enhanced *lux* gene expression in and around the axillary buds within 12 hours after decapitation, suggesting that decapitation causes an increase in the auxin content of the buds (Langridge, 1989).

The basic mechanism of apical dominance remains unresolved even though extensive information is available on specific hormonal effects. Although, the correlative signal has not been conclusively identified, IAA is, by all indications, the prospective candidate. All the major classes of growth substances have at least some effect on axillary bud growth, but their interaction is largely undefined. There is strong evidence that cytokinin is a key factor in promoting bud growth. In general, a hormonal regime that enhances the vigour of the apical bud enhances apical dominance, while, when the apical bud is less vigorous, lateral growth may ensue under the influence of growth promotive hormones in the axillary bud. To understand the mechanism of hormonal control, it will be necessary to explore the fundamental cellular events involved in axillary bud growth inhibition and release. Important progress has been made in recent years regarding the mechanism of auxin transport and its role in tissue polarity. It can be now inferred that auxin-dependent cell polarity is involved in the control of axillary bud growth. How auxin controls polar cellular responses needs to be resolved before the mechanism of apical dominance can be elucidated (Tamas, 1995).

The results of the presented experiment show that, due to breaking the apical dominance through the apex removal **(P**inching; decapitation**)**, the lateral vegetative buds will develop shortly afterwards and grow to produce new offshoots with high growth rate, particularly in P1 plants (cutting back the plant completely near the soil surface with apex removed) because of the absent of any vegetative tissue on the P1 plants, followed with lower rate (number of offshoots) in P2 (removing the apex and keeping one true leaf on the plant) then P3 (removing the apex and keeping three true leaves on the plant). The number of offshoots one week after apex removal (pinching) treatments was highest in P1 plants, followed by P2, then P3 and the lowest value was in the untreated control plants (without pinching).

But four and ten weeks after the pinching treatments there were no significant differences in the number of offshoots among the three treatments but were higher than in untreated control plants. These insignificant differences among the three treatments can be due to the fact that all the plants have the same physiological age and the same size of roots. But leaving one leaf (P2) or three leaves (P3) on the plant with the consideration that such remain green tissues will support photosynthesis did not help in producing new offshoots but it reduced the bud growth rate within the first week after the treatment.

In Turkey, the effect of decapitation (apex removal) of globe artichoke offshoots before planting was tested in order to improve the yield. For this purpose, offshoots, 2.0-2.5 cm in stem diameter were taken and planted in a nursery at the end of March (Eser et al., 2000). In the here presented study, the offshoot diameter ten weeks after the apex removal increased significantly in all the three treatments compared to the untreated control plants, because the offshoots of the three treatments developed ahead of those of the untreated control plants which improved the offshoot diameter.

Results of this experiment lead to the recommendation that cutting back the globe artichoke plants completely near the soil surface (already at an age of three months and before the plants turn vegetatively) is the best and most practical method to produce many offshoots for multiplication. These results are in agreement with those of Eser et al. (2000), who found that the number of offshoots on plants increased with decapitation (apex removal).

6. Summary

Field research work was carried out at National Research Centre (NRC) Experimental Station, Al-Gizah Governorate in Egypt during two successive seasons in 1998-1999 and 1999-2000. The seeds of Imperial Star (IS) globe artichoke cultivar were supplied by Sun Seed Company, California, USA. Two experiments were conducted to examine the effect of gibberellic acid (GA3) for the early yield of globe artichoke plants propagated from seedlings and direct seeding under the environmental conditions of Egypt. Data were recorded on vegetative growth characteristics, head parameters, early and total yield, some chemical components, i.e., cynarin and inulin contents. All the chemical analyses were conducted in the laboratories of the Chair of Vegetable Science, Department for Plant Sciences, Technische Universität München in Freising-Weihenstephan, Germany.

The third experiment was conducted during 2001 in Germany at the Research Station in Dürnast in field Glaslaker 1, Chair of Vegetable Science, Technische Universität München to rapidly increase the offshoots production for globe artichoke propagation of Green Globe (GG) cultivar. Seeds were supplied by Juliwa, Heidelberg, Germany.

Results can be summarised as follows:

1. First and second experiment

- All GA3 (60 ppm) treatments (T1, T2 and T3 = GA3 treatments 4, 6 and 8 weeks after planting date, C. = control) had a significant increase in plant height compared to control plants. GA3 applications significantly decreased the number of leaves compared to control plants. Results in the second experiment were similar except for number of leaves were not affected by GA3 treatments.

- On the same day of the first harvest of main heads, GA3 treatments significantly increase the plant height in the latest treatment (T3) compared to the other treatments, but there were no significant differences in plant height in T1 & control plants.

- The applications of GA3 significantly increased the number of offshoots per globe artichoke plants, especially in T1 plants. In the second experiment GA3 treatments had no significant differences in plant height, number of leaves and number of offshoots among the three treatments and was similar to control.

- The treatments of GA3 had no significant effect on width and length of the 5^{th} leaf compared to control plants.

- GA3 treatments in general increased fresh weight of the edible part compared to the control plants. But in the second experiment it was decreased.

- Head length, head diameter, head stem diameter and number of removed bracts were not affected by GA3 treatments in the first three harvests (early yield).

- Number of early heads per plant was affected by GA3 applications with highest value obtained in T2 plants. On the other hand, the applications of GA3 had no significant effect on number of heads per plant and average number of heads per hectare. Results in the second experiment were similar except for the number of early heads per plant was highest in T2 & T3 plants.

- The applications of GA3 significantly increased the early yield per plant and the average early yield per hectare with highest values obtained in T2 plants. In the second experiment the highest values obtained in both T2 & T3 plants.

- GA3 applications significantly increased the total yield per plant and the average total yield per hectare, highest values obtained in T2 plants.

- Total and reducing sugar content in leaves of globe artichoke increased significantly by treating plants with GA3 with highest values obtained in T3 & T2 plants, respectively. Concerning inulin content of leaves, the highest value was recorded in T1 plants. Results in the second experiment were similar except for total and reducing sugar content was decreased by GA3 treatments.

- Total protein content in leaves of globe artichoke decreased significantly by treating plants with GA3 with highest value obtained in control plants and the lowest value was recorded in T2 plants. In the second experiment total protein content was highest in both control and T3 plants.

- The applications of GA3 significantly increased the content of chlorogenic acid & cynarin in leaves of globe artichoke. Highest value was obtained in T1 plants. In the second experiment they were not affected by GA3 treatments.

- The applications of GA3 had a significant effect on total and reducing sugar content in artichoke heads. Highest values of total sugar were obtained in T2, T1, T2, T3, T1 and T2 plants in the second, third, fourth, fifth, sixth and seventh head, respectively. On the other hand, the highest values of reducing sugar were recorded in T3, T1, T1, T1, T2 and T1 plants in the second, third, fourth, fifth, sixth and seventh head, respectively.

- Inulin content in edible part of globe artichoke increased significantly by treating plants with GA3. The highest values were obtained in T2, T3, T2 and T2 plants in the third, fourth, sixth and seventh head, respectively.

- GA3 treatments had a significant effect on total protein content with highest values obtained in T3, T3, T1, T1, T2 and T3 plants in the second, third, fourth, fifth, sixth and seventh head, respectively.

- The applications of GA3 had a significant decrease in content of chlorogenic acid and cynarin percent in the edible part of globe artichoke. Highest values were obtained in control plants. In the second experiment the content of chlorogenic acid and cynarin was varied within the different harvests.

- The three of GA3 treatments had a significant effect on anthocyanin content in the bracts of globe artichoke heads. Highest values were recorded in T1 in the second head and in control plants in third head.

2. Third experiment

- Earthing up or removing the apex **(P**inching**)** produced significant differences among the three treatments (P1: Cutting back the plant completely near the soil surface, P2: Removing the shoot-tip and keeping one true leaf on the plant, P3: Removing the shoot-tip and keeping three true leaves on the plant, C.: Control without pinching) in offshoots number. One week after the treatments the highest number of offshoots was obtained in P1 plants. Four and ten weeks after the treatments the highest number of offshoots were recorded in P1, P2 and P3 plants but there were no significant differences among them and the lowest number of offshoots was with control plants.

- Pinching treatments decreased significantly the leave length in globe artichoke plants. Four weeks after the treatments the highest value was obtained in control plants. On the other hand, ten weeks after the treatments there were no more significant differences among the three treatments in leave length.

- Concerning the offshoot diameters it increased significantly in ten weeks after the treatments due to pinching, highest values recorded in all the three treatments P1, P2 and P3 plants.

- Pinching treatments decreased significantly the root length of the mother plant of globe artichoke. Ten weeks after the treatments the longest tap root was in the control plants.

- Concerning the root length of the offshoots, it increased significantly in ten weeks after the treatments due to pinching with longest root recorded in all the three treatments.

7. Zusammenfassung

Die Feldversuche wurden während zweier aufeinander folgender Jahre 1998-1999 und 1999-2000 am National Research Centre (NRC) Experimental Station, Al-Gizah Governorate in Ägyten durchgeführt. Die Samen der Artischokensorte Imperial Star (IS) wurden von Sun Seed Company, Californien, USA zur Verfügung gestellt. In zwei Versuchen wurde der Einfluß von Gibberellinsäure auf den frühen Ertrag von Artischokenpflanzen, die sowohl aus Jungpflanzen als auch aus direkter Feldaussaat unter den Umweltbedingungen in Ägypten stammen, untersucht. Es wurden Daten über die vegetative Wachstumscharakteristik, Blütenparameter, frühen und gesamten Ertrag und über chemische Inhaltsstoffe wie zum Beispiel Cynarin und Inulin bewertet. Alle chemischen Analysen wurden in den Labors des Lehrstuhls für Gemüsebau, Department für Pflanzenwissenschaften, Technische Universität München in Freising-Weihenstephan durchgeführt.

Ein dritter Versuch wurde während des Jahres 2001 in Deutschland an der Versuchsstation Dürnast im Feld Glaslacker 1, Lehrstuhl für Gemüsebau, Technische Universität München, zur schnellen vegetativen Vermehrung von Schößlingen für die Vermehrung von Artischoken der Sorte Green Globe durchgeführt. Die Samen wurden von Juliwa, Heidelberg, Deutschland, zur Verfügung gestellt.

Die Ergebnisse können wie folgt zusammengefaßt werden:

1. Erstes und zweites Experiment

- Alle GA3 (60 ppm) Behandlungen (T1, T2 und T3 = GA3 Behandlung 4, 6 und 8 Wochen nach Pflanzdatum, C. = Kontrolle) zeigten eine deutliche Zunahme in der Höhe der Pflanzen im Vergleich zu Kontrollpflanzen. Bei der Behandlung mit GA3 war die Anzahl der Blätter deutlich geringer als bei Kontrollpflanzen. Im zweiten Experiment zeigten sich ähnliche Ergebnisse, außer daß die Anzahl der Blätter nicht durch GA3-Behandlung beeinflußt wurde.

- Am Tag der ersten Ernte der Hauptköpfe zeigte sich, daß bei der spätesten Behandlung mit GA3 (T3) die Pflanzenhöhe im Vergleich zu den anderen Behandlungen am meisten zunahm. Es war jedoch kein deutlicher Unterschied in der Pflanzenhöhe zwischen T1 und den Kontrollpflanzen zu erkennen.

- Bei Behandlung mit GA3 stieg die Anzahl der Schößlinge je Artischokenpflanze deutlich an, besonders bei den T1-Pflanzen. Im zweiten Experiment zeigten sich bei den drei Behandlungen mit GA3 keine bedeutenden Unterschiede in der Pflanzenhöhe, in der Anzahl der Blätter und in der Anzahl der Schößlinge und war insgesamt ähnlich mit den Kontrollpflanzen.

- Die Behandlung mit GA3 hatte keinen Einfluß auf die Breite und Länge des fünften Blattes im Vergleich zu den Kontrollpflanzen.

- Grundsätzlich nahm bei Behandlung mit GA3 das Frischgewicht des eßbaren Teils im Vergleich zu den Kontrollpflanzen zu. Im zweiten Experiment nahm es je-doch ab.

- Die Länge und der Durchmesser des Blütenkopfes, sowie der Durchmesser des Blütenstammes und die Anzahl der Deckblätter wurden bei den ersten drei Ernten (früher Ertrag) durch die Behandlung mit GA3 nicht beeinflußt.

- Die Anzahl der frühen Blütenköpfe je Pflanze wurde durch die Behandlung mit GA3 beeinflußt und bei den T2-Pflanzen die höchste Anzahl erhalten. Andererseits hatte die Behandlung mit GA3 keinen nennenswerten Einfluß auf die Anzahl der Blütenköpfe je Pflanze und die durchschnittliche Anzahl von Blütenköpfen je Hektar. Im zweiten Experiment wurden ähnliche Ergebnisse erhalten, außer daß die Anzahl der frühen Blütenköpfe je Pflanze bei den T2- und T3-Pflanzen am höchsten war.

- Durch die Behandlung mit GA3 wurde der frühe Ertrag je Pflanze und der durchschnittliche frühe Ertrag je Hektar deutlich erhöht, wobei die höchsten Werte bei den T2-Pflanzen erhalten wurden. Im zweiten Experiment wurden die höchsten Werte sowohl bei den T2-, als auch bei den T3-Pflanzen erhalten.

- Durch die Behandlung mit GA3 wurde der Gesamtertrag je Pflanze und der durchschnittliche Gesamtertrag je Hektar gesteigert. Die höchsten Werte wurden bei den T2-Pflanzen erhalten.

- Der Gesamtzuckergehalt sowie der reduzierte Zuckergehalt in den Blättern von Artischoken nahm bei den GA3-Behandlungen deutlich zu, mit den höchsten Werten bei den T2- und T3-Pflanzen. Beim Inulingehalt der Blätter wurde der höchste Wert bei den T1-Pflanzen nachgewiesen. Die Ergebnisse waren im zweiten Experiment ähnlich, jedoch nahm der Gesamtzuckergehalt und der reduzierte Zuckergehalt bei den GA3-Behandlungen ab.

- Der Gesamtproteingehalt in den Blättern von Artischoken nahm bei Behandlung der Pflanzen mit GA3 deutlich ab, wobei der höchste Wert in den Kontrollpflanzen und der niedrigste Wert in den T2-Pflanzen gemessen wurde. Im zweiten Experiment war der Gesamtproteingehalt sowohl in den Kontrollpflanzen, als auch in den T3-Pflanzen am höchsten.

- Durch die Behandlung mit GA3 stieg der Gehalt von Chlorogensäure und Cynarin in den Blättern von Artischoken deutlich an. Der höchste Wert wurde in den T1-Pflanzen nachgewiesen. Im zweiten Experiment wurde der Gehalt von Chlorogensäure und Cynarin durch die GA3-Behandlung nicht beeinflußt.

- Die Behandlung mit GA3 hatte einen deutlichen Einfluß auf den gesamten und reduzierten Zuckergehalt im Blütenkopf. Die höchsten Werte für den Gesamtzuckergehalt wurden bei den T2, T1, T2, T3, T1 und T2-Pflanzen im zweiten, dritten, vierten, fünften, sechsten und siebten Blütenkopf erhalten. Andererseits wurden die höchsten Werte für den reduzierten Zuckergehalt bei den T3, T1, T1, T1, T2 und T1 Pflanzen im zweiten, dritten, vierten, fünften, sechsten und siebten Blütenkopf nachgewiesen.

- Der Inulingehalt im eßbaren Teil der Artischokenpflanze stieg bei der Behandlung mit GA3 deutlich an. Die höchsten Werte wurden bei den T2, T3, T2 und T2 Pflanzen im dritten, vierten, sechsten und siebten Blütenkopf gemessen.

- Die Behandlung mit GA3 zeigte einen deutlichen Einfluß auf den Gesamtproteingehalt, wobei die höchsten Werte bei den T3, T3, T1, T1, T2 und T3 Pflanzen im zweiten, dritten, vierten, fünften, sechsten und siebten Blütenkopf auftraten.

- Die Behandlung mit GA3 führte zu einer deutlichen Abnahme des Gehalts an Chlorogensäure und Cynarin im eßbaren Teil der Artischoke. Der höchste Wert wurde bei den Kontrollpflanzen gemessen. Beim zweiten Experiment war der Gehalt an Chlorogensäure und Cynarin bei den einzelnen Ernten unterschiedlich.

- Die Behandlung mit GA3 hatte einen deutlichen einfluß auf den Anthocyangehalt in den Deckblätten der Blütenköpfe. Die höchsten Werte traten bei den T1-Pflanzen im zweiten Blütenkopf und bei den Kontrollpflanzen im dritten Blütenkopf auf.

2. Drittes Experiment

- Die Entfernung der Apex führte zun deutlichen Unterschieden zwischen den drei Behandlungen (P1: Rückschnitt der gesamten Pflanze knapp über der Erdoberfläche, P2: Entfernung der Sproßspitze und Zurücklassen eines echten Blattes an der Pflanze, P3: Entfernung der Sproßspitze und Zurücklassen dreier echter Blätter an der Pflanze, C.: Kontrolle ohne Rückschnitt) in der Anzahl der Schößlinge. Eine Woche nach den Rückschnitten wurde die höchste Anzahl an Schößlingen bei den P1-Pflanzen erhalten. Vier und zehn Wochen nach den Rückschnitten lag die höchste Anzahl bei den P1, P2, und P3 Pflanzen, wobei keine nennens-werten Unterschiede auftraten. Die niedrigste Anzahl hatten die Kontrollpflanzen.

- Bei Entfernung der Sproßspitze nahm die Blattlänge bei den Artischokenpflanzen deutlich ab. Vier Wochen nach der Entfernung wurde der höchste Wert bei den Kontrollpflanzen gemessen. Allerdings zeigten sich zehn Wochen nach der Entfernung keine nennenswerten Unterschiede in der Blattlänge bei den drei Behandlungen mehr.

- Der Durchmesser der Schößlinge nahm in zehn Wochen nach der Entfernung der Sproßspitze deutlich zu, die höchsten Werte wurden bei allen drei Behandlungen P1, P2 und P3 gemessen.

- Durch das Entfernen der Sproßspitze nahm die Länge der Hauptwurzeln an der Mutterpflanze deutlich ab. Zehn Wochen nach der Entfernung hatten die Kontrollpflanzen die längsten Hauptwurzeln.

- Die Länge der Zentralwurzeln bei den Schößlingen nahm in zehn Wochen nach der Entfernung der Sproßspitze bei allen drei Behandlungen deutlich zu.

8. References

Abdalla, M.M.A., M.H. Aboul-Nasr (1995): Studies on globe artichoke (*Cynara scolymus* L.) under Assiut conditions. I. Effect of method of propagation and farm age. Assiut Journal of Agricultural Sciences 26 (1): 39-49

Abd-El-Salam, M.A (1996): Comparative Studies on Growth, Flowering and Yield of Some Globe Artichoke Cultivars (*Cynara scolymus* L.). M.Sc. thesis, Ain Shams University, Cairo, Egypt

Abou-Hadid A.F, A.S. El-Beltagy, S.Z. Abdel-Rahman, S.A.Gaafer (1995): Effect of shading and GA3 on Flowerhead artichoke storage. II. Egyptian Journal of Horticulture 22 (1): 41-48

Aboul-Nasr, M.H. (1995): Effect of method of propagation and planting date on globe artichoke (*Cynara scolymus* L.) under Assiut conditions. Assiut Journal of Agricultural Sciences 26 (2): 37-47

Adzet, T., M. Puigmacia (1985): High performance liquid chromatography of caffeoylquinic acid derivatives of *Cynara scolymus* L. leaves. Journal of Chromatography 348: 447-453

Adzet, T., J. Camarasa, J.C. Laguna (1987): Hepatoprotective activity of polyphenolic compounds from *Cynara scolymus* against CCL4 toxicity in isolated rat hepatocytes. Journal of Natural Products 50 (4): 612-617

Agwah, E.M.R., K.A. EL-Fadaly, E.A.A. EL-Hassan (1990): Effect of some fungicides on earliness, yield and quality of globe artichoke (*Cynara scolymus* L.). Bulletin of Faculty of Agriculture, University of Cairo 41 (3): 767-775

A.O.A.C. (1975): Official methods of analysis of the association of official analytical chemist.10th ed. Washington, D.C.

A.O.A.C. (1984): Official methods of analysis of the Association of official analytical chemist. 14th ed. Washington, D.C.

Atherinos, A.E., I.EL-S. EL-Kholy, G. Soliman (1962): Chemical investigation of *Cynara scolymus* L. part 1. The steroids of the receptacles and leaves. Jchem. Soc., Lond., May: 1700-1704

Aubert, S., C. Foury (1981): Globe artichoke colour and anthocyanin pigmentation. Industria Grafica Laterza: 57-76

Baggett, J.R., H.J. Mack, D. Kean (1982): Annual culture of globe artichoke from seed. HortScience 17(5): 766-768

Bartoshuk, L.M., C.H. Lee, R. Scarpellino (1972): Sweet taste of water induced by artichoke (*Cynara scolymus*). Science, USA 178 (4064): 988-990

Basnizki, Y., E. Goldschmit, Y. Luria, M. Itach, Z. Berg (1986): Effect of acidified GA3 spray on yield of globe artichoke. Hassadeh 9: 1814-1817 (C.F. Hort. Abstr. 56: 7728, 1986)

Basnitzki, Y., D. Zohary (1987): A seed-planted cultivar of globe artichoke. HortScience 22 (4): 678-679

Behr, Hans-Christoph (2001): ZMP-Marktbelanz, Gemüse 2001, Deutschland Europäsche Union Weltmarkt. ZMP Zentrale Markt- und Preisberichtstelle GmbH, Bonn. P. 233

Bekhit, R.S., K.A. El-Fadaly, E.A. Abou-El-Hassan (1985): Effect of gibberellic acid and some nutritional treatments on growth, yield and quality of globe artichoke (*Cynara scolymus* L.). J. Agric. Sci., Mansoura Univ. 11 (2): 745-751

Bell, D.J. (1955): Mono-and oligosaccharides and acidic monosaccharides derivatives, Modern methods of plant analysis 11: 2-4, Editor, Peach, K. and Tracey, M.V. Springer, Verlag. Co., Berlin

Ben, H.G, Y. Basnizki, D. Zohary, A.M. Mayer (1992): Cynarin and chlorogenic acid content in germinating seeds of globe artichoke (*Cynara scolymus* L.). Journal of Genetics & Breeding 46 (1): 63-68

Bernhard, H. (1982): Quantitative determination of the bitter sesquterpenes from *Cynara scolymus* (globe artichoke) and *Cynara cardunculus* (cardoon). Pharmaceutical Acta Helevetiae 57 (7): 179-180

Bianco, V.V., V. Dellacecca (1982): Influence of field temperature on growth and quality of artichoke (*Cynara scolymus* L.). XXIst International Horticultural Congress. Abstracts Vol.1

Bonomi, A., B.M. Bonomi, A. Quarantelli (1998): Use of dried artichoke leaf meal (*Cynara scolymus* L.) in broiler feeding. Rivista di Avicoltura 67 (12): 28-32

Bonomi, A. (1999): The use of dehydrated artichoke leaves meal (*Cynara scolymus* L.) in the feeding of meat rabbits. Rivista di Coniglicoltura 36 (4-5): 53-58

Bonomi, A., B.M. Bonomi, A. Sabbioni, P. Superchi (1999a): Use of dried globe artichoke leaf meal (*Cynara scolymus* L.) for feeding calves during the weaning period. Rivista di Scienza dell'Alimentazione 28 (1): 53-61

Bonomi, A., B.M. Bonomi, A. Quarantelli (1999b): The use of dehydrated artichoke leaf meal (*Cynara scolymus* L.) in duck feeding. Rivista di Avicoltura 68 (7-8): 38-43

Bucan, L., S. Goreta (1998): Introduction of artichoke cultivars to Dalmatia. Agronomski Glasnik 60 (3): 137-146

Calabrese, N., A. Elia, G. Sarli (1994): Yield and quality of new artichoke cultivars propagated by seed. Acta Horticulturae 371: 189-193

Calabrese, N., V.V. Bianco (2000): Effect of gibberellic acid on yield and quality of seed grown artichoke (*Cynara cardunculus* L. var. *scolymus* (L.) Fiori). Acta Horticulturae 514: 25-32

Choudhary, D.K., B.L. Kaul (1992): Globe artichoke (*Cynara scolymus* L.) oil a potential new source of essential polyunsaturated fatty acids. Research and Industry, India 37 (1): 29-30

Cirnu, I. (1988): Globe and Jerusalem artichoke as valuable sources of nectar and pollen. Apicultura Roman 63 (7): 7-8

Cline, M.J. (1991): Apical dominance. Bot. Rev. 57: 318-358

Constantinescu, D.G., F. Platon, M. Pavel (1967): Die Pharmazie 22 (3): 176

Cosentino S, G. Mauromicale (1990): Transpiration and plant water status of globe artichoke (*Cynara scolymus* L.) grown from seed and from vegetative organs with two water regimes. Acta Horticulturae 278: 261-270

Debenedetti, S.L., P.S. Palacios, E.G. Wilson, J.D. Coussio (1993): HPLC analysis of caffeoylquinic acids content in Argentine medicinal plants. Acta Horticulturae 333: 191-199

Deidda, M. (1968): Acontribution to the genetical improvement of globe artichokes. Studi sassar., Sez. I I I,16: 278-98

Dellacecca, V. , V. Marzi, L. Mancini (1987): Three year of trials on the forcing of Roman-type globe artichokes. Colture Protette 16 (1): 83-88

De Malach, J.G., M. Sachs, R. Rotem (1976): Timing and optimal concentration of gibberellic acid treatments for forcing yield of globe artichoke (*Cynara scolymus* L.). Edizioni Minerva Medica, Turin, Italy 633-642

De Vos, N.E. (1992): Artichoke production in California. HortTechnology 2 (4): 438-444

Dranik, L.I., L.G. Dolganenko, J. Slapke, H. Thoma (1996): Chemical composition and medical usage of *Cynara scolymus* L. Rastitel'Nye Resursy 32 (4): 98-104

Du, C.T. and F.J. Francis (1973): Anthocyanins of Roselle (*Hibiscus sabdariffa* L.). J. Food Sci. 38: 810-812

Dubois, M., K.A. Gilles, J.K. Hamilton, P.A. Rebers, F. Smith (1956): Colorimetric method of determination of Sugars and related substances. Anal. chem. 28 (3): 350-352

El-Baz, El-S., S.A. Foda, S.M. Moustapha (1979): Some studies on globe artichoke "*Cynara scolymus*, L.". Agricultural Research Review, Horticulture 57 (3): 109-117

Elia, A , F. Paolicelli, V.V. Bianco (1991): Effect of sowing date, plant density and nitrogen fertilizer on artichoke (*Cynara scolymus* L.): preliminary results. Advances in Horticultural Science 5 (3): 119-122

Elia, A., N. Calabrese, G. Sarli, F. Losavio (1994a): Plant spatial arrangement and production of new cultivars of 'seed' propagated artichoke. Acta Horticulturae 371: 195-199

Elia, A., N. Calabrese, V.V. Bianco (1994b): Sowing time, gibberellic acid treatments and cultivars of 'seed' propagated artichoke. Acta Horticulturae 371: 347-354

Elia, A., V. Miccolis (1996): Relationships among 104 artichoke (*Cynara scolymus* L.) accessions using cluster analysis. Advances in Horticultural Science 10 (3): 158-162

Elia, A., N. Calabrese, V.V. Bianco (1998): Cultural practices and cultivars of seed-propagated artichokes for fresh consumption and freezing. Annali della Facolta di Agraria, Universita di Bari 35: 137-146

El-Negoumy, S.I., N.H. El-Sayed, N.A.M. Saleh (1987): Flavonoid glycosides of *Cynara scolymus*. Fitoterapia 58 (3): 178- 180

Ernst, E. (1995): Die Artischocke - eine Heilpflanze mit Geschichte und Zukunftsperspektive. Naturamed 10 (1)

Eser, B, E. Ozzambak, H. Vural (1985): A study on the effect of Various factors on the early yield of globe artichoke. Ege Universitesi Ziraat Fakultesi Dergisi 22 (1): 21-34

Eser, B., J.A. Mohammad, þ. Özen (2000): Effects of apex removal of rooted offshoots at the artichoke production. IV International Congress on Artichoke, October 17-21, Valenzano-Bari, Italy

Fintelmann, V. (1999): Globe artichoke extract and a complex of digestive symptoms: method and results of monitoring after a treatment. Zeitschrift für Phytotherapie 20 (2): 93-95

Foti, S., G. Mauromicale (1994): Improvement in the production calendar of globe artichoke and in crop quality characters by the introduction of new varieties. Sementi Elette 40 (2): 19-29

Foti, S., G. Mauromicale, S.A. Raccuia, B. Fallico, F. Fanella, E. Maccarone (1999): Possible alternative utilization of Cynara spp. I. Biomass, grain yield and chemical composition of grain. Industrial Crops and Products 10 (3): 219-228

Foury, C. (1969): A study of the floral biology of the globe artichoke; its application to selection. Part II. A study of the progeny obtained by controlled fertilization. Ann Amel. Plantes 19: 23-52

Foury, C. (1977): Trials on gibberellic acid application to a spring crop of globe artichoke (*Cynara scolymus*) cv. Blanc Hyerois. Annales de L'Amelioration des Plantes 27 (4): 411-426

Foury, C. (1989a): Genetic resources and diversification of the artichoke (*Cynara scolymus* L.). Acta Horticulturae 242: 155-166

Foury, C. (1989b): Some characteristics of globe artichoke (*Cynara scolymus* L.) seeds. Acta Horticulturae 253: 45-54

Galvano, G., V. Scerra (1983): The use of bracts of artichoke (*Cynara scolymus* L.) in the feeding of cattle. World Review of Animal Production 19 (3): 41-46

Garcia, S.M., M.S. Panelo, F. Nakayama (1994): Effect of gibberellic acid (GA3) application on artichoke (*Cynara scolymus* L.). Horticultura Argentina 13 (33): 77-82

Garcia, S.M., I.T. Firpo, F.S. Lopez-Anido, E.L. Cointry (1998): Influence of cultural techniques on the profitability of globe artichoke (*Cynara scolymus* L.) in Argentina. Avances en Horticultura 3 (1): 43-48

Garcia, S.M., I.T. Firpo, F.S.L. Anido, E.L. Cointry (1999): Application of gibberellic acid in globe artichoke. Pesquisa Agropecuaria Brasileira 34 (5): 789-793

Garrison, R. (1955): Studies in the development of axillary buds. Am. J. Bot. 42: 257-266

Gebhardt, R. (1995): Artichoke extracts in-vitro evidence of an inhibitory effect on cholesterol biosynthesis. Medizinische Welt 46 (6): 348-350

Gebhardt, R. (1997): Antioxidative and protective properties of extracts from leaves of the artichoke (*Cynara scolymus* L.) against hydroperoxide-induced oxidative stress in cultured rat hepatocytes. Toxicol Appl Pharmacol 144 (2): 279-286

Gebhardt, R., M. Fausel (1997): Antioxidant and hepatoprotective effects of artichoke extracts and constituents in cultured rat hepatocytes. Toxicology in Vitro 11 (5): 669-672

Gebhardt, R. (1998): Inhibition of cholesterol biosynthesis in primary cultured rat hepatocytes by artichoke (*Cynara scolymus* L.) extracts. The Journal of Pharmacology and Experimental Therapeutics 286 (3): 1122-1128

Gil-Ortega, R., F. Villa, P. Arce, J.I. Macua (1995): Varieties of globe artichokes. Hf - Hortoinformacion 6 (9): 58-60

Gil-Ortega, R., F. Villa, P. Arce, J.I. Macua (1998): Comparison of vegetatively propagated and seed-grown globe artichoke cultivars. ITEA Produccion Vegetal 94 (1): 13-18

Hamdi, S. (1953): Effect of time planting and method of propagation on the yield of artichoke. Annals of Agric. Science, Fac. of Agric, Ain Shams Univ., Cairo, 3 (2): 75-79

Hammouda, F.M., M.M.S. El-Nasr, S.I. Ismail, A.A. Shahat (1993a): Quantitative determination of the active constituents in Egyptian cultivated *Cynara scolymus*. International Journal of Pharmacognosy 31 (4): 299-304

Hammouda, F.M., M.M. Seif El-Nasr, A.A. Shahat (1993b): Flavonoids of *Cynara scolymus* L. cultivated in Egypt. Plant Foods for Human Nutrition 44 (2): 163-169

Heckers, H., K. Dittmar, F.W. Schmahl, K. Huth (1977): Inefficiency of cynarin as therapeutic regimen in familial type II hyperlipoproteinaemia. Atherosclerosis 26 (2): 249-53

Hill, D.E. (1993): Annual culture of globe artichokes, mulching and planting date trials 1989-1992. Bulletin Connecticut Agricultural Experiment Station 911: 1-8

Hillman, J.R. (1984): Apical dominance. *In*: Advanced plant physiology, pp. 127-148, Wilkins, M.B., ed. Pitman, London

Hoffmann, H. (2001): New methods of globe artichoke production in the Warren district in south-west Australia. Farmnote 21/2001

Hutchings, M.J., H. de Kroon (1994): Foraging in plants: the role of morphological plasticity in resource acquisition. Adv. Ecol. Res. 25: 159-238

Ibrahim, A.M. (1980): Comparative morphology and anatomy of different artichoke cultivars and seed grown plants. HortScience 15 (3): 51

Ibrahim, A.M., E.J. Ryder, V.E. Rubatzky (1981): Offshoots VS. stumps as planting materials for globe artichokes. J. Amer. Soc. Hort. Sci.106 (6): 728-731

Iglesias, J., M. Puigmacia, J.M. Quiles (1985): Influence of the method of extraction on polyphenol content of *Cynara scolymus* L. extracts. Plantes Medicinales et Phytotherapie 19 (3): 202-210

Kalra, Y.P. (1998): Handbook of references methods for plant analysis. CRC press, Boca Raton. P. 75-83

Khan, I.A., G.S. Verma, H.K. Pandey (1999): Exploitation of globe artichoke (*Cynara scolymus* L.) a temperate exotic vegetable in mid hill conditions of Uttarakhand. Agricultural Science Digest Karnal 19 (1): 55-58

Kocer, G., B. Eser (1999): Assessment of the effects of rooted offshoot properties and GA3 applications on the yield of the globe artichoke. Turkish Journal of Agriculture and Forestry 23 (2): 325-332

Kraft, K. (1997): Artichoke leaf extract - recent findings reflecting effects on lipid metabolism, liver and gastrointestinal tracts. Phytomedicine 4 (4): 369-378

Kuliev, A.A., E.I. Gigienova, N.M. Ismailov, A.Sh. Ibragimov (1985): Fatty acid composition of *Cynara scolymus* L. seeds grown in the Nakhichevan ASSR. Rastitel'Nye Resursy 21 (3): 346-349

Langridge, W.H.R., K.J. Fitzgerald, C. Koncz, J. Schell, A.A. Szalay (1989): Dual promoter of *Agrobacterium tumefaciens* mannopine synthase genes is regulated by plant growth hormones. Proc. Natl. Acad. Sci., USA 86: 3219-3223

Lanteri, S., I. di Leo, L. Ledda, MG. Mameli, E. Portis (2001): RAPD variation within and among populations of globe artichoke cultivar 'Spinoso sardo'. PLANT BREEDING

Lattanzio, V. (1977): Determination of the polyphenolic active principles of artichoke (*Cynara scolymus* L.) by gel chromatography on Sephadex LH-20. Industria Conserve 52 (4): 316-320

Lattanzio, V, V. Linsalata, S. Palmieri, C.F. Sumere (1989): The beneficial effect of citric and ascorbic acid on the phenolic browning reaction in stored artichoke (*Cynara scolymus* L.) heads. Food Chemistry 33 (2): 93-106

Leoni, O., S. Palmieri, V Lattanzio, C.F. Sumere (1990): Polyphenol oxidase from artichoke (*Cynara scolymus* L.). Food chemistry 38 (1): 27-39

Lin, T.C., S.H. Chuan, S.T. Hong (1991): Effect of chemicals on the enhancement of bolting in artichoke (*Cynara scolymus* L.). Bulletin of Taichung District Agricultural Improvement Station 32: 11-15

Loo, J., P. Coussement, L. Leenheer, H. Hoebregs, G. Smits (1995): On the presence of inulin and oligofructose as natural ingredients in the Western diet. Critical Reviews in Food Science and Nutrition 35 (6): 525-552

Mangano, G., P. Signorelli (1981): Azione di trattamenti con acido gibberellico in fasi diverse dell'accrescimento della pianta, sulla produzione del carciofo. In:Atti 2° congr. Int. Carciofo, Bari, Laterza, Bari, Italy: 565-579

Mansour, S.A. (1983): Effect of some growth regulators on some physiological characters and the yield of globe artichoke. M.Sc. Agric. Sci., Fac. Agric., Cairo Univ.

Mauri, P., P. Pietta, M.G. Quaglia (2000): Electrospray characterization of selected medicinal plant extracts. Journal of Pharmaceutical and Biomedical Analysis 23 (1): 61-68

Mauromicale, G., V. Copani (1990): Techniques for regulating the production of reproductive organs in *Cynara scolymus* L. Tecnica Agricola 42 (1): 45-54

Mauromicale, G., A. Ierna (1995): Effects of gibberellic acid and sowing date on harvest time and yields of seed-grown globe artichoke (*Cynara scolymus* L). Agronomie 15: 527-538

Mauromicale, G., A. Ierna, G. Donzella, M. Assenza (1996): effects of planting date and gibberellic acid on yields of globe artichoke raised from seed and irrigated with brackish water. Sementi Elette 42 (6): 43-50

Mauromicale, G., A. Ierna (2000): Characteristics of heads of seed-grown globe artichoke [*Cynara cardunculus* L. var. *scolymus* (L.) Fiori] as affected by harvest period, sowing date and gibberellic acid. Agronomie 20 (2): 197-204

Mauromicale, G., S.A. Raccuia (2000): Influence of maturation time on some head characteristics of globe artichoke (*Cynara solymus* L.). Acta Horticulturae 533: 483-488

Mauromicale, G., A. Ierna, V. Cavallaro (2000a): Effects of vernalization and gibberellic acid on floral induction and harvest time of seed-grown artichoke. IV International Congress on Artichoke, October 17-21, Valenzano-Bari, Italy

Mauromicale, G., S.A. Raccuia, V. Cavallaro (2000b): Head characteristics of globe artichoke (*Cynara solymus* L.) as related to growth stage. Acta Horticulturae 533: 557-566

Maynard, D. N., T. K. Howe (1986): Evaluation of speciality vegetable crops for production in west central Florida. Proceedings of the Florida State Horticultural Society 99: 293-300

Mayr, A., E. Fröhlich (1965): Zwei Jahrtausende Artischocke, Cynara scolymus. Österr. Apoth. Ztg. 19: 468

Megias, M.D., J.H. Cherney, D.J.R. Cherney (1997): Effects of phenolic compounds in cell walls of orange and artichoke by-product silages on in vitro digestibility. Journal of Applied Animal Research 12 (2): 127-136

Miccolis, V., V.V. Bianco, P. Perrino, A. Elia, N. Volpe (1989): Evaluation of the European collection of globe artichokes raised in the Valle dell Ofanto (First note). Informatore Agrario 45 (23): 35-45

Miccolis, V., A. Elia, V.V. Bianco (1990): Timing field production in a germplasm collection of artichoke (*Cynara scolymus* L.). Acta Horticulturae 267:153-161

Miceli, A., P. Leo (1996): Extraction, characterization and utilization of artichoke-seed oil. Bioresource Technology 57 (3): 301-302

Miguel, A., J.V. Maroto, B. Iranzo, S. Loez-Galarza (1997): Gibberellic acid in artichoke. Horticultura, Revista de Hortalizas, Flores y Plantas Ornamentales 120: 111-113

Moharram, Y.G., M.K. Khalil, M.M. Mostafa (1981): Artichoke bracts (*Cynara scolymus*) as a source of protein. Monoufeia Journal of Agricultural Research 4: 273-283

Monography (1988): Cynarae folium (artichoke leaves); [corr. 01.09.1990]. BAnz. No. 122

Morison, N., BE. Vaissiere, F. Martin, P. Pecaut, G. Cambon, (2000): Pollination of globe artichoke (*Cynara scolymus* L.) by honey bees (Apis mellifera L.) to produce hybrid seed under enclosure. APIDOLOGIE

Mossi, A.J., S. Echeverrigaray, C. Acevedo (1999): Identification and characterization of antimicrobial components in leaf extracts of globe artichoke (*Cynara scolymus* L.). Acta Horticulturae 501: 111-114

Naylor, J.M. (1958): Control of nuclear processes by auxin in axillary buds of *Tradescantia paludosa*. Can. J. Bot. 36: 221-232

Ohnishi, M., H. Morishita, H. Iwahashi, S. Toda, Y. Shirataki, M. Kimura, R. Kido (1994): Inhibitory effects of chlorogenic acids on linoleic acid peroxidation and haemolysis. Phytochemistry 36 (3): 579-583

Okasha, KH.A., M.E. Ragab, H. El-Sayed Wahba, A.M. Razin, M.A. Abd-El-Salam (1997): Yield, head quality and some medicinal compounds of some new imported artichoke cultivars (*Cynara scolymus* L.). Zagazig Journal of Agricultural Research 24 (1): 101-115

Onisei, T., E.T. Toth, D. Amariei (1988): Callus induction and plant regeneration of *Cynara scolymus* L. Revue Roumaine de Biologie, Biologie Vegetale 33 (2): 115-119

Pandita, P.N., R.K. Ogra, Archana Kaul (1988): Evaluation of exotic cultivars for yield and chemical characters of globe artichoke (*Cynara scolymus*) in Kashmir Valley. Indian Journal of Agricultural Sciences 58 (9): 724-726

Papalini, P., A. Cinquanta, R. Ercolani (1997): Etrusco and Moro di Corneto, two new globe artichoke cultivars. L'Informatore Agrario 53 (27): 59-61

Paun, E., M. Verzea, A. Dumitrescu, C. Barbu (1996): Breeding research on medicinal and aromatic plants - a survey of the Romanian experience. Proceedings. International symposium. Breeding research on medicinal and aromatic plants, Quedlinburg, Germany. 30 June-4 July 2 (1): 136-141

Pecaut, P. (1992): Genetic improvement of vegetable crops. Edited by Kalloo, G. and Bergh, O.B. Pergamon Press

Phillips, I.D.J. (1975): Apical dominance. Ann. Rev. Plant Physiol. 26: 341-367

Pifferi, G., A. Vaccari (1978): Studies on natural pigments. X. Anthocyanins of artichokes (*Cynara scolymus* L.). Industria Conserve 53 (2): 107-110

Pittler, M.H., E. Ernst (1998): Artichoke leaf extract for serum cholesterol reduction. Perfusion 11 (8): 338-340

Reshetnik, L.A., K.S. Ladodo, O.V. Prokop'eva, N.K. Kochnev (1998): Jerusalem artichoke the possibility of using it in diet treatment of children. Voprosy Pitaniya 1: 18-20

Rodrigo, M., J. Safon, P. Lorenzo, A. Navarro, J.L. Vaya (1979): Agronomic and Processing characteristics of globe artichoke cultivars. Influence of harvesting conditions on yield and quality. Revistade Agroquimica Y Tecnologia de Alimentos 19 (4): 498-512

Rottenberg, A., D. Zohary (1996): The wild ancestry of the cultivated artichoke. Genetic Resources & Crop Evolution.43 (1): 53-58

Rottenberg, A., D. Zohary, E. Nevo (1996): Isozyme relationships between cultivated artichoke and the wild relatives. Genetic Resources & Crop Evolution 43 (1): 59-62

Ruiperez, F.H., M.A. Pulgar Gutierrez, J.M. Cid Diaz, R. Moreno Rios, E. Ocio Trueba (1992): Nutritive value of residues of the artichoke (*Cynara scolymus*) crop: sun dried leaves and whole plant silage. Archivos de Zootecnia 41 (153): 257-264

Ruppelt, B.M., E.F. Pereira, L.C. Goncalves, N.A. Pereira (1991): Pharmacological screening of plants recommended by folk medicine as anti-snake venom-I. Analgesic and anti-inflammatory activities. Mem Inst Oswaldo Cruz 86 (2): 203-5

Ryder, E.J., N.E. De Vos, M.A. Bari (1983): The globe artichoke (Cynara scolymus L.). HortScience 18 (5): 646-653

Schrader, W.L., K.S. Mayberry (1992): Imperial Star artichoke. HortScience 27 (4): 375-376

Schrader, W.L., K.S. Mayberry, D.W. Cudney (1992): Paving the way to a better artichoke. California Agriculture 46 (4): 28-29

Schrader, W.L. (1994): Growth regulator gives earlier harvest in artichokes. California Agriculture 48 (3): 29-32

Sims, W.L., V.E. Rubatzky, R.H. Sciaroni, W.H. Lange (1977): Growing globe artichokes in California. Division of Agricultural Sciences, University of California. Revised February, leaflet, 2675

Snedecor, G.W., W.G. Cochran (1967): Statistical method, 6th Ed. Iowa State Univ., Press, Iowa, USA

Snyder, M.J., N.C. Welch, V.E. Rubatzky (1971): Influence of gibberellin on time of bud development in globe artichoke. HortScience 6: 484-485

Stafstrom, J.P. (1993): Axillary bud development in pea: apical dominance, growth cycles, hormonal regulation and plant architecture. *In*: Cellular communication in plants, pp. 75-86, Amasino, R.M., ed. Plenum Press, New York

Stafstrom, J.P., M. Altschuler, D.H. Anderson (1993): Molecular cloning and expression of a MAP kinase homologue from pea. Plant Mol. Biol. 22: 83-90

Stafstrom, J.P., I.M. Sussex (1992): Expression of a ribosomal protein gene in axillary buds of pea seedlings. Plant Physiol. 100: 1494-1502

Stoev, S. (1998): Some metric, antidote and pathomorphological investigations in experimental intoxication with ochratoxin A and penicillic acid in chicks. Bulgarian Journal of Agricultural Science 4 (4): 551-563

Stoev, S., G. Angelov, D. Pavlov (1998): Some para-clinical investigations in experimental intoxication with ochratoxin A and penicillic acid in chicks. Bulgarian Journal of Agricultural Science 4 (4): 565-573

Tamas, I.A. (1995): Hormonal regulation of apical dominance. *In*: Plant hormones, pp. 572-597, Davies, P.J., ed. Kluwer Academic Publishers, Netherlands

Teeuwen, H., M. Thone, J. Vandrope (1992): Inulin: Aersatilefibere ingredient. Ancient Food Ingredient Rediscovered (5): 10-14

Tesi, R. (1994): Tema 2000, a new variety of perpetually flowering globe artichoke. L'Informatore Agrario 50 (30): 49-51

Thimann, K.V., F. Skoog (1934): On the inhibition of bud development and other functions of growth substance in *Vicia faba*. Proc. Roy. Soc. B 114: 317-339

Unisse, I (1994): The artichoke food for thought. Agrotica (2): 54

USA, Regents of the University of California (1994): Variety: 'Imperial Star'. Application no. 93/221. Plant Varieties Journal 7 (3): 39-40

Wagenbreth, D. (1995): Content of phenolic constituents in *Cynara scolymus* L., leaves: Influence of drying conditions, gradients within the plant and diurnal variations 43rd Annual Congress on Medicinal Plant Research. September 3-7: 73-74

Wagenbreth, D. (1996): Evaluation of artichoke cultivars for growing and pharmaceutical use. Beitrage zur Zuchtungsforschung - Bundesanstalt fur Zuchtungsforschung an Kulturpflanzen 2 (1): 400-403

Wagenbreth, D., M. Grün, A.N. Wagenbreth, T. Wegener (1996): Artischocke - Qualitätsdroge aus Arzneipflanzenanbau. Dtsch. Apoth. Ztg. 136: 3818-3826

Walker, A. (1996): Use of plant foods as medicines. BNF Nutrition Bulletin 21 (77): 26-34

Welbaum, G.E., S.C. Warfield (1992): Growing globe artichokes from seed. Second international symposium on speciality and exotic vegetable crops, Miami, Florida, USA, 15-19 Mar., 1992. Acta Horticulturae 318: 111-115

Welbaum,G.E. (1994): Annual culture of globe artichoke from seed in Virginia. HortTechnology 4 (2): 147-150

Wiklund, A. (1992): The genus Cynara L. (Asteraceae-Cardueae). Botanical Journal of the Linnean Society 109 (1): 75-123

Winton, A.L., K.B. Winton (1958): The analysis of foods. John Wiley and Sons, Inc. London, PP: 857

Yasukawa, K., T. Akihisa, H. Oinuma, T. Kaminaga, H. Kanno, Y. Kasahara, T. Tamura, K. Kumaki, S. Yamanouchi, M. Takido (1996): Inhibitory effect of taraxastane-type triterpenes on tumor promotion by 12-O-tetradecanoylphorbol-13-acetate in two-stage carcinogenesis in mouse skin. Oncology 53 (4): 341-344

Zaki, E.M., T.A. Abed, M.R. Gabal, M.M. El-Abagy (1991): Effect of some growth regulators on growth, yield and chemical constituents of artichoke plants *Cynara scolymus* L. Annals of Agricultural Science, Moshtohor 26(3): 1939-1957

Zapesochnaya, G.G., V.A. Kurkin, T.V. Kudryavtseva, B.S. Karasartov, K.S. Cholponbaev, N.A. Tyukavkina, V.E. Ruchkin (1992): Dicaffeoylquinic acids from Helichrysum italicum. Chemistry of Natural Compounds 28 (1): 40-44

CURRICULUM VITAE

Name	**Mahmoud** Abd-Elmoneim Abd-Elsalam **SHARAF-ELDIN**
Address	12, Hassan Mahmoud Str., Heliopolis, Cairo, Egypt
Date of birth	19.09.1969
Place of Birth	Heliopolis, Cairo, Egypt
Nationality	Egyptian
Marital Status	Single
Education	
1975 - 1981	Primary school, Salah-Eldin Elaubiy School, Cairo, Egypt
1981 - 1984	Preparatory school, Amar Ibn Yasser School, Cairo, Egypt
1984 - 1987	Secondary school, Tabbary Elhegaze School, Cairo, Egypt
1987 - 1991	B.Sc. in Agriculture, Horticulture Dept., Ain Shams Univ., Cairo, Egypt
1992 - 1996	M.Sc., Horticulture Dept., Ain Shams Univ., Cairo, Egypt
Working experience	
Since 01.2000	Ph.D. student, Chair of Vegetable Science, Technische Universität München, Freising-Weihenstephan, Germany
1997 - 2000	Ph.D. student, Horticulture Dept., Ain Shams Univ., Cairo, Egypt
Since 10.1996	Associate researcher, National Research Centre, Cairo, Egypt
1993 - 1996	Research assistant, National Research Centre, Cairo, Egypt
1992 - 1993	M.Sc. student, Ain Shams Univ., Cairo, Egypt
Membership	The Egyptian Horticultural Society