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Effect of soil fertilizing methods on cholorogenic acid contents of Globe Artichoke (*Cynara scolymus* L.)

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ABSTRACT

An experiment was conducted to evaluate the effects of different soil fertilizing treatments on the cholorogenic acid content of globe artichoke. The experiment was done over the two growing seasons of 2007 and 2008 at Tehran University. sIt warandomized complete block design with four replicates including five levels of chemical fertilizer, four levels of manure, five levels of a mixture (in different ratios) of chemical fertilizer and manure (integrated fertilizer), and a control without any fertilizer. Results showed that the highest cholorogenic acid content was obtained from the treatment of 40 tones.ha^{-1} cattle manure. It was found that leaves had higher cholorogenic acid contents compared to bracts. The highest (430 mg/kg) and lowest (238 mg/kg) cholorogenic acid contents were obtained from applications of manure fertilizer treatments. It was also concluded that organic and integrated fertilizing systems produced the most cholorogenic acid content in leaves and bracts.

Key words: Artichoke (*Cynara scolymus* L.), integrated, chemical and organic fertilizer, cholorogenic acid contents.

Introduction

Globe artichoke (*Cynara cardunculus* L. var. *scolymus*) is an important vegetable crop belonging to the Composite family (*Asteraceae*). The immature flower bud is the edible part of the plant, it has a fleshy receptacle and a fleshy tender base of bract. Artichoke is a native Mediterranean crop (Ryder et al., 1983). Nearly 85% of artichokes cultivated globally are grown in countries bordering the Mediterranean basin; Italy being the largest producer as well as consumer of artichokes followed by Spain and then France (Bianco, 2000). The globe artichoke has important nutritional value attributed to its high content of phenolic compounds such as flavonoids, but it also contains inulin, fibers and minerals. The edible flower bud and other artichoke plant extracts are rich in polyphenols and have high levels of antioxidant activity (Llorach et al., 2002; Zapolska Downar et al., 2002; Alamanni and Cossu, 2003; Jiménez-Escrig et al., 2003; Lattanzio et al., 2004). Isorhoifolin (apigenin-7-O-rutinoside), narirutin, cynarin (1,5-dicaffeoylquinic acid and 1,3-dicaffeoylquinic acid), chlorogenic acid, caffeic acid and cynaroside are all present in various different parts of the plant (Alamanni and Cossu, 2003 and Wang *et al*., 2003). Dichloromethane and ethanol extract from the leaves have antibacterial properties. Dranik *et al*., (1996) reported that the globe artichoke, *Cynara scolymus*, possesses both food value and medicinal properties. Medicinal preparations from the leaves clearly induces choleretic and diuretic activity and decreases levels of cholesterol in the blood. Fresh leaves gathered in the first year after sowing provide the most suitable raw material for the formulation of medicinal preparations.

There are no published papers about effects of N, P and K fertilizers with and without manure on the medicinal properties (Cynarine and Cholorogenic acid) in artichoke leaves and bracts.

Pomares *et al*., (1993) mentioned that in each production cycle, Californian growers typically apply fertilizers in the ranges of 168 to 336 kg ha-1 of N, 56 to 112 kg ha^{-1} of P2O5 and 34- 112 kg.ha^{-1} of K_2O. All of the P and K and much of the N treatments are supplied at the first fertilizer application when the new-planted crop has become established or after regrowth from cut-back plants has started. Elia and Santamaria, (1994) have determined suitable levels of NPK fertilizers. A nutrient solution should contain at least 130 mg N l^{-1} and rates of 100 and 250 mg l^{-1} of P and K, respectively. These rates evidently produced the best plant height, leaf area and number, shoot fresh and dry weight as well as root dry weight with improvement to the root/shoot ratio. In another study, Elia *et al*., (1996) investigated 4 different ratios, 100:0, 70:30, 30:70 and 0:100 of ammonium to nitrate (NH4:NO_3) to determine the best ratio of nitrogen forms in a nutrient solution for artichoke growth. Results also indicated that NO_3 in the form of N was the most suitable application for artichoke. Nutrient solution containing 70-100% NO_3 resulted in the best vegetative growth with highest leaf area, root volume and

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dry weight. A higher application of NO_3-N increased water use efficiency. El-Abagy, (1993) investigated three NPK levels, low level (71 kg N, 57 kg P2O5 and 119 kg K2O ha-1), medium level (142 kg N, 114 kg P2O5 and 238 kg K2O ha-1) and high level (213 kg N, 171 kg P2O5 and 357 kg K2O ha-1) on globe artichokes cultivated in clay soil in Egypt. The author recommended supplying a medium level as the best results for plant height, number of leaves per plant and leaf fresh weight as well as leaf dry weight achieved from this treatment.

Pedreno *et al,. (*1996) reported that the reduction of nitrogen application from 500 to 300 kg N ha-1 resulted in a reduction of total biomass of artichoke. Salamah, (1997) investigated the response of artichoke (cv. Herious) to N-fertilization levels ranging from 95 to 380 kg ha^{-1} in Ismailia region, Egypt. The results indicated that all characteristics of plant growth such as number of leaves as well as leaf fresh weight and dry weight markedly increased when N-fertilization increased from 95 to 285 kg N ha^{-1} without further increases when N-level increased from 285 to 380 kg N ha^{-1}. Fotti *et al,. (*2000) noticed that responses of leaf transpiration and stomatal conductance to the nitrogen rates was not linear. The physiological measurements were high with 200 kg N ha^{-1} compared to non-application (control). Pomares *et al., (*1993) studied effects of three different levels of NPK fertilization on artichoke (cv. Blanca de Espana) productivity in Valencia, Spain. There was no significant response on the yield with a N dose higher than 200 kg ha-1, where only slight differences were obtained with the higher levels of 400 and 600 kg N ha^{-1}. Moreover, PK fertilizer did not increase bud yield. The results showed that levels of available P from 27-33 ppm and of available K from 250-282 ppm in the soil were adequate for the optimal growth of artichoke. Fotti *et al., (*2000) demonstrated that 200 kg N ha-1 as NH4NO3 in southern Italy was sufficient for the production of an economically viable yield (var. Orlando F1). The yield response to nitrogen rates was not linear. Bud yield with 0 kg N ha^{-1} was the lowest, followed by those fertilized crops with either 200 or 400 kg N ha-1. Earliness and total yield were better with 200 kg ha^{-1} of N. Eich *et al,. (*2000) investigated several levels of N ranging from 40 to 240 kg N ha^{-1}, half of the fertilizer was applied at the time of sowing and the rest 6 weeks later. The content of both caffeoylquinic acids and flavonoids reduced with increased nitrogen fertilizer rates.

Wang *et al*., (2003) compared the leaf phenolic compound HPLC profile of three artichoke varieties and the results showed differences between the varieties. Imperial Star artichoke leaves contained the highest antioxidant level with a total average of 7.2%, whereas the Violet variety contained an average of only 4.1%. The contents of cynarin (the most active antioxidant) were almost the same in the leaves of all three varieties. In contrast, the contents of Chlorogenic acid were different in each variety, with chlorogenic acid content in Imperial Star and Green Globe artichoke leaves nearly 3 times that of Violet. Imperial Star artichoke also contained the highest content of flavonoids (luteolin-7-glucopyranoside). This research investigation has been conducted as a response to the lack of information on effects of different soil fertilizing systems on Cholorogenic acid contents of artichoke. Its goal was to identify the effects of different soil fertilizing systems on Chlorogenic acid contents in artichoke.

Materials and Methods

Experimental design:

This study was conducted as a field experiment at the experimental station of Tehran University, Karaj, Iran (latitude: 35°26́ N; longitude: 71° 28́ E; elevation: 1321 m) during the growing seasons 2007–2008. The soil was a clay loam with the following basic properties: pH (7.4), organic matter (0.61%), total nitrogen (0.08%), P2O5 (22.8 ppm) and K2O (140 ppm). The treatments were arranged in randomized complete block design with four replications. The seeds were domestic ecotypes. Four levels of chemical fertilizers consisting of N, P and K (Chemical Fertilizing System), three levels of animal manure (Organic Fertilizing System), and four levels of integrated use of manure and chemical fertilizers (Integrated Fertilizing System) were used as treatments (Table 1). The sources of N, P, K and animal manure were Urea, super phosphate, potassium sulfate and dairy cow manure, respectively. The first half of the nitrogen fertilizer and total phosphorus and potassium fertilizers were applied before sowing and the rest at 9-10 leaf stage. Plot size was 9 x 3.75 m which included 5 rows of plants 75 cm apart. Each row was planted with plants were sown at 65 cm intervals. Each plot consisted of 60 plants. The seeds were sown in May 2007. Three or four seeds were sown per hole and thinning was done to one plant per hole after full establishment. Normal cultivation practice was applied uniformly on all experimental units.

Measurements:

The plots were hand weeded at different vegetative stages. Irrigation was applied at weekly intervals. Areas of $5m^2$ were hand harvested from each plot to estimate dry weight and bud and leaf acid cholorogenic contents in October 2006. To measure acid cholorogenic contents, 0.25 g of leaf powder was extracted with 100 ml boiling water for 2 h. Then the extract was cooled to room temperature and was 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 0.45µm membrane filter. The measurements were made in duplicates. The used HPLC equipment and conditions: Gradient pump: Maxi- Star K-1000, Column: Erospher 100 C-18, 250 x 4 mm (5 µm), Detection: Spectrophotometer K-2500, Wavelength: 325 nm, Flow rate: 1.0 ml/min, Column temperature: 25 °C, Injection volume: 20 µl, Analysis time: 20 min.

Table 1: Soil fertilizing treatments details.

Soil fertilizing systems	Treatment number	Chemical fertilizer (Kg/ha)			Manure fertilizer (Tone/ha)
		K_2O	P_2O_5	N	
Control	1	-	-	-	-
Chemical	2	48	40	40	-
	3	144	120	120	-
	4	192	160	160	-
	5	240	200	200	-
Integrated (Chemical + Organic)	6	48	40	40	25
	7	96	80	80	20
	8	144	120	120	15
	9	240	200	200	5
Organic	10	-	-	-	20
	11	-	-	-	30
	12	-	-	-	40

1:Control, 2 (N= 40, P=40, K=48 kg/ha), 3 (N= 120, P=120, K=144 kg/ha), 4 (N= 160, P=160, K=192 kg/ha), 5 (N= 200, P=200, K=240 kg/ha), 6 (N= 40, P=40, K=48 + animal manure =25000 kg/ha), 7 (N= 80, P=80, K=96 + animal manure =20000 kg/ha), 8 (N= 120, P=120, K=144 + animal manure =15000 kg/ha), 9 (N= 200, P=200, K=240 + animal manure =5000 kg/ha), 10 (OM =20000 kg/ha), 11 (OM =30000 kg/ha), 12 (OM =40000 kg/ha),

Statistical Analysis:

Experimental data were analyzed with the SAS 9.1 software. All data sets were tested for normal distribution and variance homogeneity of ($P < 0.05$). In case of homogeneous sample variances, means were compared by Duncan tests.

Results and Discussions

The highest (430 $mg.kg^{-1}$) and lowest (238 $mg.kg^{-1}$) cholorogenic acid contents were obtained from the application of manure fertilizer treatment T12 (Organic Matter (OM) = 40 $t.ha^{-1}$) and the control treatment, respectively (Table 3). An orthogonal comparison showed that all fertilizing methods (chemical, integrated and organic) caused a significant increase in leaf cholorogenic acid content compared to the control (Table 4). The increasing percentages of each treatment compared to the control were 24, 38.6 and 61.7% for the chemical, integrated and organic fertilizing systems, respectively. The organic fertilizing method was more effective on cholorogenic acid content than other methods. No other study on the effect of fertilizing systems on cholorogenic acid content of globe artichoke was found in any publication. Pouryosef *et al*., (2007) showed that among fertilizing systems, the chemical system had less effect on mucilage percentage and swelling factor of Isabagol (*Plantago ovate*). The study also showed that an integrated fertilizing system could increase seed and mucilage yields compared to an organic system. In chemical fertilizing systems, it has been demonstrated that increasing the amount of fertilizer application, leaf cholorogenic acid content linearly increased. The highest amount of cholorogenic acid (310 $mg.kg^{-1}$) was obtained from treatment T5 (N= 200, P=200, K=240 $kg.ha^{-1}$) and the lowest from treatments T2 (N= 40, P=40, K=48 $kg.ha^{-1}$) and T3 (N= 120, P=120, K=144 $kg.ha^{-1}$) producing 227 & 296 $mg.kg^{-1}$, respectively (Tables 3 & 4). Cserni and Sas, (1994) reported that 60 & 90 $kg.ha^{-1}$ nitrogen was more effective at increasing fennel essence yield than 120 $kg.ha^{-1}$ nitrogen. Bontain, (1994) showed that 20 tones of animal manure and its combination with 20 kg N and 10 kg P, increased the mucilage yield of Isabagol (*Plantago Ovata*). In organic fertilizing systems, with increased animal manure application there was an incremental increase to cholorogenic acid yield (Table 3).

Table 2: Mean squares of soil fertilizing system effects on leaves and bracts cholorogenic acid contentsof globe artichoke (*Cynara scolymus*).

SOV	df	Mean squares					
		Leaves cholorogenic acid content	Leaves cholorogenic acid yield	Bracts cholorogenic acid content	Bracts cholorogenic Acid yield	Total cholorogen ic acid content	Total cholorogenic acid yield
Replication	2	0. 001 *	0. 006 ns	0. 002ns	0. 01 ns	0. 001 ns	0. 015 ns
Soil fertilizing systems	11	0. 01 **	0. 086**	0. 003**	0. 04**	0. 19**	0. 16 *
Error	22	0. 0001	0. 001	0. 0004	0. 0004	0. 0006	0. 003

Table 3: Mean comparison of cholorogenic acid contents of leaves and bracts of artichoke (*Cynara scolymus*) as affected by soil fertilizing systems.

Soil fertilizing Systems	Treatment number	Leaves cholorogenic acid content (mg/kg)	Leaves cholorogenic acid yield (gr/ha)	Bracts cholorogenic acid content (mg/kg)	Bracts cholorogenic Acid yield (gr/ha)	Total cholorogenic acid content (mg/kg)	Total cholorogenic acid yield (gr/ha)
Control	1	238 e	284 d	170 e	508 e	408 g	792 f
Chemical	2	296 cd	361 cd	195 de	580 de	492 f	940 ef
	3	277 cd	302 cd	223 a-e	639 cde	500 f	941 ef
	4	298 c	377 c	218 b-e	607 cde	517 ef	984 e
	5	310 c	379 c	218 b-e	671 cde	528 def	1050 de
Integrated (Chemical + Organic)	6	360 b	530 b	210 cde	651 cde	569 cde	1182 cd
	7	424 a	736 a	240 a-d	681 cde	664 ab	1417 b
	8	276 cd	312 cd	272 ab	733 bcd	533 def	1015 de
	9	262 de	286 d	263 abc	927 a	539 def	1239 c
Organic	10	370 b	566 b	250 a-d	661 cde	589 cd	1177 cd
	11	354 b	515 b	235 a-d	758 bc	620 bc	bc 1323
	12	430 a	430 a	277 a	861 ab	707 a	1621 a

* Means of the same category followed by different letters are significantly different at 0. 05% level of probability using Duncan test.
1: Control, 2: (N = 40, P = 40, K= 48 kg/ha), 3 (N = 120, P = 120, K = 144 kg/ha), 4 (N = 160, P = 160, K = 192 kg/ha), 5 (N = 200, P = 200, K = 240 kg/ha), 6 (N= 40, P = 40, K= 48 + animal manure =25000 kg/ha), 7 (N= 80, P=80, K=96 + animal manure =20000 kg/ha), 8 (N= 120, P=120, K=144 + animal manure =15000 kg/ha), 9 (N= 200, P=200, K=240 + animal manure =5000 kg/ha), 10 (OM =20000 kg/ha), 11 (OM =30000 kg/ha), 12 (OM =40000 kg/ha).

In integrated fertilizing systems, the highest leaf cholorogenic acid content of 424 mg.kg^{-1} was for treatment T7 (N= 80, P=80, K=96 + animal manure =20000 kg.ha^{-1}) and the lowest amount of 264 mg.kg^{-1} was for treatment T9 (N= 200, P=200, K=240 + animal manure =5000 mg.kg^{-1}) (Table 3). It was observed that leaf cholorogenic acid content increased with elimination of chemical fertilizer substituded with animal manure (Organic system) (Tables 3 & 4).

Among the organic fertilizing treatments the lowest leaf cholorogenic acid of 370 mg.kg^{-1} obtained at treatment 10 (animal manure=20000 kg.ha^{-1}) and the highest level of 430 mg.kg^{-1} was produced at treatment 12 (animal manure =40000 kg.ha^{-1}) (Table 3). The benefit of animal manure is that it constitutes stabilized organic matter as well as nutritive elements and this has been emphasized as beneficial for agricultural production especially in organic farming systems (Ghosh *et al*., 2004 and Ewulo, 2005). There were positive significant correlations between leaf cholorogenic acid contents and soil electrical conductivity (EC), pH, organic matter, nitrogen, phosphorus and potassium contents as well as negative significant correlations with soil bulk density (Table 5). This could be attributed to the fact that animal manure can improve both the physical and chemical properties of soil (Blaise *et al*., 2005) that stimulate cholorogenic acid production in organic systems (Tables 3, 4 & 5). Sharifiashorabadi, (1998) showed significant over production obtained for three fertilizing systems (chemical, integrated and organic systems) compared to the control for fennel (*Foeniculum vulgare*) essence yield with mean values of 75, 147 and 89%, respectively. Sing *et al.,* (2003) reported that biological, seed and mucilage yield of Isabagol increased with applications of animal manure and chemical fertilizers in organic and integrated systems due to the effect of improvment to the physical and chemical properties of the soil.

In the chemical system, the lowest leaf cholorogenic acid yield was obtained in treatments T3 (N= 120, P=120, K=144 kg.ha^{-1}) and T2 (N= 40, P=40, K=48 kg.ha^{-1}) producing 302 and 361 g/ha respectively (Table 3). The highest leaf cholorogenic acid yield was obtained from treatments T5 (N= 200, P=200, K=240 kg.ha^{-1}) and T4 (N= 160, P=160, K=192 kg.ha^{-1}) by 379 and 377 g.ha^{-1} (Table 3). In the integrated fertilizing system, with levels of increasing chemical fertilizer and decreasing animal manure, leaf cholorogenic acid yield followed an increasing and then a decreasing trend.

Results for bract and leaf cholorogenic acid contents as affected by the fertilizing systems are shown in Table 3. The leaf cholorogenic acid content was significantly more than the bract content (Figure 1 & Table 3). Feratiani *et al*., (2007) showed that different artichoke varieties had different cholorogenic acid contents and reported that applications of all kinds of fertilizers significantly increased biomass of artichoke compared to controls. The overall production rates were 26%, 45% and 108% for chemical fertilizer, integrated system and organic systems, respectively. These results are supported by other research experiments by Eghbal *et al*., (2001), Adediran *et al.*, (2004) and Sharifiashorabadi (1998). There were no significant differences between the chemical treatments, but the highest bract artichoke cholorogenic acid content of 223 mg.kg^{-1} was obtained with treatment 3 (N= 120, P=120, K=144 kg.ha^{-1}) (Table 3). In the organic system, bract cholorogenic acid content increased with increasing animal manure application (Table 3). Treatment T12 (OM=40000 kg.ha^{-1}) with 277 mg.kg^{-1} produced the highest value (Table 3). The positive correlations between soil properties and bract cholorogenic acid contents support this assertion that integrated and organic fertilizing systems could be effective on secondary metabolite production in artichoke because of the effect of improvement to the physical and chemical properties of soil. These results are supported by other research by Eghbal, *et al,*. (2001) and Adediran *et al.*, (2004). It seems that organic fertilizing systems had less effect on biomass compared to the other fertilizing treatments. This was probably due to slower nutrient release from manure in the first year of application (transient period). In some of the integrated fertilizing systems which received higher amounts of manure than others, the same results could be expected. However, in some of the integrated fertilizing systems, biomass was increased only because there was no transient period (Acharya *et al*., 1998). It seems that manure or other organic fertilizing applications will only show an increasing effect on DM yield at the second or third year of application. Similarly, Francis *et al.,* (1990) and Fateh *et al*., (2008) reported that, an application of a mixture of chemical and manure fertilizer had a significant effect on bract DM yield. Wang *et al*., (2003) showed that the edible artichoke heads contained significantly lower amounts of phenols inside for dried mature heads at the range of 1.48-2.89% than for young dried buds at the range of 2.58-3.22%, this was however dependent on the variety.

Table 4: Orthogonal comparison of leaves and bracts cholorogenic acid contents of globe artichoke (*Cynara scolymus*).

Orthogonal Comparisons	Leaves cholorogenic acid content	Leaves cholorogenic acid yield	Bracts cholorogenic acid content	Bracts cholorogenic Acid yield	Total chologrogenic acid content	Total chologrogenic acid yield
Chemical vs control	$+^{**a}$	$+^{**}$	$+^{**}$	$+^{**}$	$+^{**}$	$+^{**}$
Organic vs control	$+^{**}$	$+^{**}$	$+^{**}$	$+^{**}$	$+^{**}$	$+^{**}$
combination vs control	$+^{**}$	$+^{**}$	$+^{**}$	$+^{**}$	$+^{**}$	$+^{**}$
Chemical vs organic	$-^{**b}$	$-^{**}$	$-^{**}$	$-^{**}$	$-^{**}$	$-^{**}$
Chemical vs combination	$-^{**}$	$-^{**}$	$-^{**}$	$-^{**}$	$-^{**}$	$-^{**}$
organic vs combination	$+^{**}$	$+^{**}$	$+^{ns}$	$+^{ns}$	$+^{**}$	$+^{**}$
High vs low manure level	$+^{**}$	$+^{**}$	$+^{ns}$	$+^{ns}$	$+^{**}$	$+^{**}$
High vs low chemical fertilizer level	$+^{**}$	$+^{**}$	$+^{ns}$	$+^{ns}$	$+^{**}$	$+^{**}$
20 tones manure in organic vs combination	$+^{**}$	$-^{**}$	$+^{ns}$	$+^{ns}$	$-^{*}$	$-^{ns}$

a: + means Chemical system has higher significant value than control.
b:- means organic system has higher significant value than chemical system.

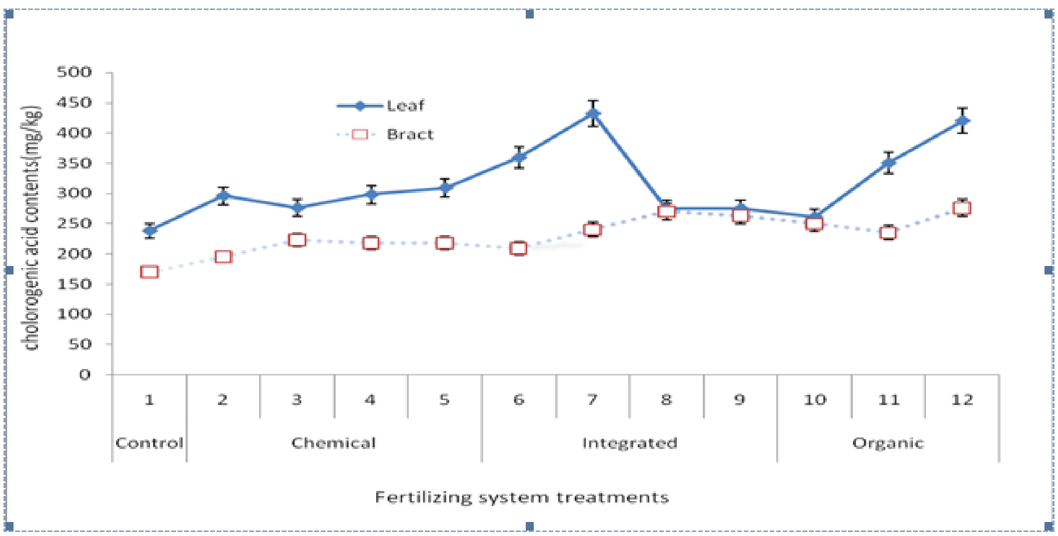

Fig. 1: Effect of fertilizing systems on leaf and bract cholorogenic acid contents of Artichoke (Cynara scolymus). Bar indicate means± SE.

The highest total (leaf+bract) cholorogenic acid content (707 $mg.kg^{-1}$) was observed in treatment 12 (OM=40000 $kg.ha^{-1}$) and the lowest content (408 $mg.kg^{-1}$) was obtained in the control (Table 3). In the integrated and organic fertilizing systems, the total cholorogenic acid contents increased as animal manure applications increased (Table 3). These results correspond to results reported by Sharifiashorabadi, (1998) for Anethol percentage in Fennel (*Foeniculum vulgare*). Also findings by Francis *et al*., (1990), Vogtman *et al*., (1986) and Alievi *et al*., (1993) support these results. The higher percentages of cholorogenic acid content along with higher biomass yield for artichoke in integrated fertilizing systems in this experiment highlights the superiority of this integrated treatment over other fertilizing treatments. This result supports the finding of Urashima *et al*., (2003) on spinach and Sahin *et al*., (2004) on sugar beet and barley and Poberejskaya and Egamberdiyeva, (2003) on cotton. In a similar experiment Gosh *et al*., (2004) obtained the highest values of DM yield from an integrated fertilizing system compared to organic and chemical fertilizing systems in soybean (*Glycin max*) and sorghum (*Sorghum bicolor*). Eghbal *et al*., (1999) and Adeddiran *et al.,* (2004) reported that an application of manure fertilizer based on a percentage of absorbable nitrogen, could produce the same yield as a chemical system. In contrast, Loecke *et al.,* (2004) showed that, only a decade old manure fertilizer could produce the same yield as a chemical system. Van lauw *et al.,* (2001) showed that an application of organic fertilizer alone could not fulfill the nitrogen requirement of a plant crop. Kramer *et al.,* (2002) reported that although total nitrogen absorption by plants in an organic system was less than in a chemical system, the continuous release of nitrogen from organic matter led to continuous and sustainable nitrogen absorption which resulted in better synchronization between absorption rate and availability of nitrogen which lead to higher yield.

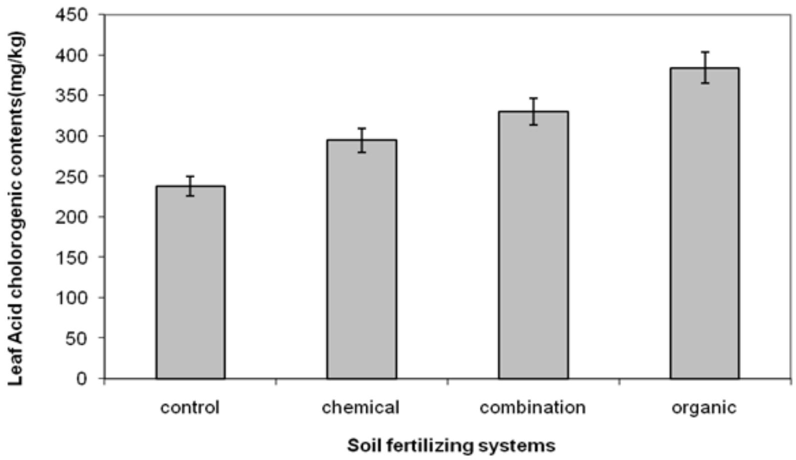

Fig. 2: Effect of fertilizing systems on leaf and bract cholorogenic acid contents of Artichoke (Cynara scolymus). Bar indicate means± SE.

Conclusions:

In this research, it was found that organic and an integrated fertilizing system produced the most cholorogenic acid content and yield and provided more benefits compared to the chemical fertilizer system. To prevent environmental pollution from extensive application of chemical fertilizers, biological fertilizers such as animal manure and other possible sources, are recommended to ensure more sustainable agricultural practice (Figures 2 & 3). Lack of quality forage, and limited arable land allocated to forage crops in Iran calls for the focus of more attention to high quality forage crops with their high potential for biomass production together with medicinal properties. With regard to the potential of artichoke to produce 40 and 50 tons of fresh and dry yield, respectively per hectare, with high cholorogenic acid contents in bracts and leaves, it is suggested that further complementary studies be conducted on this plant as a new medicinal crop and a source of forage in Iran.

Abbrevation:

RCBD- randomized complete block design; OM- organic matter; C/N – carbon/nitrogen.

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