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Research Article

Effects of biological fertilizers on some morphological and nutritional properties of globe artichoke

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ABSTRACT- Cultivation of globe artichoke (*Cynara cardunculus* var. *scolymus* L.), as a multipurpose species of vegetable, medicine and green forage, along with using biological fertilizers and reduced rates of chemical fertilizers is arranged within sustainable cropping systems. In order to study the effects of chemical and biological fertilizers and integrated plant nutrient systems on some traits of globe artichoke, a factorial experiment was conducted on the basis of randomized complete block design with three replications in Isfahan, Iran in 2014. Factors included chemical fertilizers at the levels of control (no fertilizer), 100 and 50 % of the recommended amounts, and bio-fertilizers at levels of control (no bio-fertilizer), Nitroxin (*Azotobacter, Azospirillium* and *Pseudomonas*), Barvar 2 (*Pseudomonas putida*-p13 and *Pantoea agglomerans*-p5) and Nitroxin+Barvar 2. Morphological traits, chemical composition, metabolizable energy and net energy for lactation were determined at the vegetative rosette stage. Results indicated that using bio-fertilizer and chemical fertilizer significantly improved effective parameters in increasing forage quality. Inoculation with two bio-fertilizers increased more forage quality than those of single application of them. However, Nitroxin had more positive effects than Barvar 2. In general, it was concluded that integrated plant nutrient treatments are more beneficial effects on the growth and quality of globe artichoke forage.

INTRODUCTION

Globe artichoke (*Cynara cardunculus* var. *scolymus* L.) from the Asteraceae family is a perennial plant native to the Mediterranean Basin (Sonnante et al., 2007). This plant is cultivated as a vegetable (Ceccarelli et al., 2010; Pistón et al., 2014), medicine (Pandino et al., 2011; Rondanelli et al., 2011; Aksu and Altinterim, 2013) and green forage for ruminant feeding (Meneses et al., 2007; Sallam et al., 2008). Globe Artichoke can be nourished fresh or ensilaged for livestock feeding (Meneses et al., 2007). Italy was the main world producer of globe artichoke in 2018, with a production of 389813 tons, followed by Egypt, Spain and Argentina (FAO, 2018).

Although applying chemical fertilizers help to overcome nutrient deficiency and enhancing crop yield, indiscriminate use of them has many disadvantages. These fertilizers are not only costly but may also bring environmental pollutions to the soil, water and air. Chemical residues in food resources negatively influence the health of humans and livestock (Savci, 2012).

With the continuous growth of the world's population and the demand for high-quality forage for livestock feed, there is a need to increase agricultural production. One of the ways to approach this goal is to investigate the effect of various environmental factors on plants. The nutritional requirements of the plants are the most important factors among various factors that affect plant growth (Singh et al., 1989). Nitrogen and phosphorus are the two major essential plant nutrients and key inputs to increase the yield of plant products, including globe artichoke. The deficiency of these nutrient elements could be supplied using integrated plant nutrition management (IPNM). IPNM maintains or emends soil fertility and the optimum supply of nutrients to sustain the plant productivity through the optimization of the benefits from all possible sources of crop nutrients in an integrated manner (FAO, 1995). It comprises an appropriate combination of mineral fertilizers, bio-fertilizers, organic manures, etc.

Bio-fertilizers are different microbial populations. They convert the unavailable form of nutrition elements to available form in biological ways (Rajendran and Devaraj, 2004). Phosphate solubilizing bacteria (PSB) and nitrogen-fixing bacteria which are provided in the form of bio-fertilizer have an important role in the nutrient supply of plants. Bacteria that work as a solver of phosphate include microorganisms belonging to *Pseudomonas* and *Bacillus* (Tilak et al., 2005). *Azotobacter* and *Azospirillum* make and leak different materials such as vitamin B, nicotinic acid, pentoterik acid, biotin, auxins, gibberellins, etc in the root's environment, so they have an important role in increasing root absorbance (Kader et al., 2002). In a glasshouse experiment, Fateh et al. (2012) who studied the effect of organic and chemical fertilizers on yield, quality and some growth characteristics of globe artichoke plants, stated that the positive effect of *Pseudomonas fluorescens* on most traits was significant and that such bacteria could be used as a complementary fertilizer with manure and chemical fertilizer in sustainable agricultural practices. Van Oosterom et al. (2010) reported that the application of bio-fertilizers such as *Azotobacter* and *Azospirillum* bacteria significantly improved sorghum yield. Yadav et al. (2011) found that all the PSB treatments were considerably effective in increasing seed wheat yield, compared to control. The integrated nutrition system not only improved forage quality in annual medics but also declined chemical fertilizer application (Shabani et al., 2011). In other studies, integrated fertilizers applications remarkably enhanced leaf area index, plant height, grain production, biomass, oil yield, and protein content in sunflower (Shoghi-Kalkhoran et al., 2013). Ahilandeswari and Maheswari (2016) suggested that the co-inoculation of *Azospirillum lipoferum* and phosphate solubilizing microorganisms could improve some growth indices of rice (*Oryza sativa* L.) in terms of root and shoot length. Thus the fundamental aims of the current research were to evaluate the effects of bio-fertilizer and chemical fertilizers on some important traits of globe artichoke, to analyze the integrated plant nutrient systems for minimizing chemicals application, and to study synergic effects between nitrogen (Nitroxin) and phosphorus (Barvar 2) bio-fertilizers.

MATERIALS AND METHODS

This research was conducted at the Research Station of Agricultural and Natural Resources of Isfahan (32° 37' N, 51° 28′E and an altitude of 1612 m), Iran in 2014. The experimental site had a semi-arid climate. The mean of annual precipitation and temperature were 140 mm and 16 °C, respectively (Yaghmaei et al., 2009). At first, farm soil was analyzed to determine the physical and chemical properties (Table 1). Samples of soils were collected from agricultural soils. Sampling depth was 0-30 cm from the surface. The soils were air-dried and put through a 2-mm sieve. The particle-size distribution was assessed by the hydrometry method. Soil electrical conductivity was obtained by the extraction method. The **soil pH meter** PCE-228S was used to measure the **soil pH** value. Organic carbon was evaluated by the Walkley-Black procedure. Total nitrogen of soil was measured by the semi-micro Kjeldahl method. Available phosphorus was assessed by a spectrophotometer according to Olsen method. Available potassium was determined by atomic absorption spectrometry (Ali Ehyaei and Behbahanizadeh, 1993).

A factorial set of treatments (3 chemical fertilizers ×4 bio-fertilizers) was arranged within Randomized Complete Block Design (RCBD) with three replications. The experiment consisted of two factors: chemical fertilizers at levels of 100 % recommended rates of chemical fertilizers (200 kg N ha^{-1} and 100 kg P_2O_5 ha^{-1}), 50 % chemical fertilizers (100 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1}) and control (no chemical fertilizers), and bio-fertilizers at levels of 1 L ha^{-1} Nitroxin (including *Azotobacter*, *Azospirillium* and *Pseudomonas*), 100 g ha^{-1} Barvar 2 (including *Pseudomonas putida*-p13 and *Pantoea agglomerans*-p5), 1 L ha^{-1} Nitroxin+100 g ha^{-1} Barvar 2 and control (no bio-fertilizers). Sources of nitrogen and phosphorus chemical fertilizer were urea (46 % pure nitrogen) and triple superphosphate (46 % phosphorus as P_2O_5), respectively. Before sowing (26 April 2014), globe artichoke seeds were immediately inoculated with bio-fertilizer (Nitroxin and Barvar 2) according to the manufacturer's instructions. Phosphorus and half of the urea fertilizers were added to soil at sowing time and the rest was used at the 7-8 leaf stage. Each plot size was 5 m (length) ×3.5 m (width). Plant density was 4 plants/ m^2. Seeds were planted in 5 rows in 60 cm apart and with 30 cm spacing intra rows. Then, all plots were immediately irrigated. Weed control was carried out by hand during the growing season. Some properties of each plant sample, such as the leaf number per plant and leaf length were determined at harvesting time. At the vegetative rosette stage (November 2014), plants were harvested and samples were dried at room temperature. Then 100 g of each was transferred to the laboratory.

Samples were then ground to pass through a 2 mm sieve and then were used for chemical analysis and *in vitro* gas production technique. Crude fat (CF), crude protein (CP) and total ash were determined by procedures of AOAC (2005). Neutral detergent fiber (NDF) was measured using the methods of Van Soest et al. (1991).

Table 1. Some physical and chemical characteristics of the experimental soil

Texture	Sand (%)	Silt (%)	Clay (%)	K (mg/kg)	P (mg/kg)	TN (%)	OC (%)	pH	ECse ($dS.m^{-1}$)
Clay loam	45	24	31	250	12	0.04	0.065	7.7	2.8

Non-fiber carbohydrates (NFC) was calculated according to the following equation described by Van Soest et al. (1991):

$$NFC=100-(CP+CF+NDF+ASH) \quad (1)$$

where CP, CF, NDF, and ASH are crude protein, crude fat, neutral detergent fiber and crude ash, respectively. The amount of *in vitro* gas production from the fermentation of feed was measured using a water displacement technique for each incubation time (2, 4, 6, 8, 12, 24, 36, 48, 72 and 96 h) (Fedorak and Hrudey, 1983). According to this method, rumen liquor was obtained from the 3 adult male sheep. Three replicate 50 mL serum vials were prepared for each of 12 treatments and blank (only contains rumen liquor and buffer solution). Samples loaded (200 mg) into serum vials and buffered rumen liquor solution (2:1, buffer: liquor) was added (20 mL) to each vial. All vials were purged with oxygen-free CO_2 and then placed on a rotary incubator-shaker at 39°C. The obtained data from gas production at 24 h of incubation were used according to the following equations adapted from Menke and Steingass (1988) to estimate metabolizable energy (ME) and net energy for lactation (NE_L).

$$ME\ (MJ/kg\ DM) = 1.06+0.1570\ GP + 0.0084\ CP+ 0.0220\ CF - 0.0081\ CA\ (n = 200, r^2 = 0.94) \quad (2)$$

$$NE_L\ (MJ/kg\ DM) = -0.36 + 0.1149\ GP + 0.0054\ CP + 0.0139\ CF - 0.0054\ CA\ (n=200, r^2 = 0.93) \quad (3)$$

GP: gas production at 24 h after incubation (mL), CP: crude protein, CF: crude fat and CA: crude ash

The ANOVA test was done by using SAS (Ver 9.1). The means of treatments were compared by Duncan's Multiple Range Test.

RESULTS and DISCUSSION

Number of Leaves Per Plant

The presented results in Table 2 have demonstrated that only the main effects of chemical and biological fertilizers on the number of leaves per plant were significant. Compared with control, different levels of chemical and biological fertilizers significantly increased the number of leaves per plant.

Regarding chemical fertilizers, the maximum number of leaves per plant (44.91) was observed in the treatment of 100 % chemical fertilizers (Table 3). For bio-fertilizers, the highest number of leaves per plant (39, 38.77) was obtained in co-inoculation with Nitroxin + Barvar 2 and Nitroxin treatments, respectively (Table 4).

However, plants treated with chemical fertilizers had the higher number of leaves per plant than that of plants treated with bio-fertilizers. The importance of nitrogen in leaf production is well known in plants (Hopkins, 1999) and it can improve the vegetative growth of plants (Sharma et al., 2002). Some researchers showed that the use of fertilizers containing elements such as nitrogen (Longnecker and Robson, 1994) and phosphorus (Peaslee, 1978), increased the number of leaves per plant due to an increase in leaf appearance rate. Bio-fertilizers can improve the vegetative parameters of plants (Rahimi et al., 2013).

The maximum number of leaves per plant in marigold (*Tagetes erecta* L.) was obtained under inoculation of seeds and roots with bio-fertilizer and 400 mg L^{-1} chemical phosphorus (Hashemabadi et al., 2012). Rahimi et al. (2013) reported that the highest leaves number of basil (*Ocimum bacilicum* L.) was recorded in treatment with Nitroxin and aminoflorte. Makvandi et al. (2013) showed that the highest number of leaves per plant in silage corn (*Zea Mays* L.) was related to the treatment with 100 % urea and 100 % Nitroxin. Abbas et al. (2013) found that the maximum number of leaves in maize was obtained in plants in which seeds were co-inoculated with plant growth-promoting rhizobacteria (PGPR), PSB and reduced doses of nitrogen and phosphorous along with recommended K.

Table 2. Analysis of variance for qualitative traits of globe artichoke

SOV	df	Mean squares (MS)								
		Number of leaf per plant	Leaf length	CP	CF	Ash	NDF	NFC	ME	NE_L
Replication	2	30.77**	290.79**	3.0**	0.28**	0.79 ns	2.11 ns	18.49**	0.87**	0.46**
Chemical fertilizer	2	875.19**	2063.85**	22.82**	3.24**	38.30**	38.28**	12.88**	4.02**	2.16**
Bio-fertilizer	3	16.398**	32.53**	4.78**	0.13**	1.22*	54.53**	8.20**	4.23**	2.20**
Chemical fertilizer* Bio-fertilizer	6	3.12 ns	0.82 ns	0.24 ns	0.01 ns	0.66 ns	40.67**	8.16**	1.22**	0.65**
Error	22	0.17	3.23	0.24	0.02	0.29	1.66	0.40	0.05	0.02

CP: Crude protein, CF: Crude fat, NDF: Neutral detergent fiber, NFC: Non-fiber carbohydrates, ME: Metabolizable energy, NE_L: Net energy for lactation. ns: non-significant. * and ** significant at $P \leq 0.05$ and $P \leq 0.01$, respectively

Table 3. Means comparison of qualitative traits of globe artichoke in three levels of chemical fertilizer

Chemical fertilizer	Number of leaf per plant	Leaf length (cm)	CP (%)	CF (%)	Ash (%)
Control	28.33 c	78.58 c	13.8 c	2.80 a	12.57 c
50 %	40.16 b	97.33 b	15.49 b	2.16 b	14.16 b
100 %	44.91 a	103.84 a	16.53 a	1.76 c	16.13 a

CP: Crude protein, CF: Crude fat. Means followed by a various letter (s) are significantly different at 5 % probability level, using Duncan's Multiple Range Test ($P \leq 0.05$)

Table 4. Means comparison of qualitative traits of globe artichoke in four levels of bio-fertilizer

Bio-fertilizer	Number of leaf per plant	Leaf length (cm)	CP (%)	CF (%)	Ash (%)
Control	36.11 c	90.83 c	14.61 b	2.40 a	13.97 b
Nitroxin	38.77 a	94.49 a	15.70 a	2.19 b	14.30 ab
Barvar 2	37.33 b	92.66 b	14.70 b	2.26 ab	14.07 b
Nitroxin+ Barvar 2	39 a	95.01 a	16.08 a	2.11 b	14.80 a

CP: Crude protein, CF: Crude fat. Means followed by a various letter (s) are significantly different at 5 % probability level, using Duncan's Multiple Range Test ($P \leq 0.05$)

Leaf Length

Results showed that both chemical and biological fertilizers significantly affected the leaf length of plants (Table 2). As regards chemical fertilizer levels, maximum (103.84 cm) and minimum (78.58 cm) leaf length were observed in 100 % chemical fertilizer and control, respectively (Table 3). Among bio-fertilizer levels, seed inoculation with Nitroxin+ Barvar 2 had the longest leaf length (95.01 cm), and control (no fertilizer) had the lowest leaf length (90.83 cm). Similar to the number of leaves per plant, Nitroxin effect was more effective in enhancing leaf length than that of Barvar 2 (Table 4).

The beneficial effects of bio-fertilizer on leaf length may have been due to an increase in the supply of available N and P. These effects are mostly due to N, because Bavar 2 only carries microorganisms related to phosphorus. Some researchers stated that the inoculated plants by bio-fertilizer absorb nutrients at faster rates than non-inoculated plants which led to the accumulation of more nitrogen, phosphorus and potassium in plant tissues (Castagno et al., 2011; Saharan and Nehra, 2011). Growth stimulating bacteria such as *Azospirillum*, *Azotobacter*, and *Pseudomonas* have the ability to biological fixation of nitrogen and solubilizing the soil phosphate. Also, they notably influence plant growth regulators (auxin, gibberellin and cytokinin) and cause an improvement in plant growth and performance (Subba Rao, 1979). Hejazi et al. (2013) reported that the maximum length of leaf in globe artichoke plants was obtained by the use of 250 kg urea per hectare among different levels of nitrogen manure. Also, using 14 tons of organic manure had the highest leaf length. Pourhadi et al. (2012) reported that the longest leaf length of peppermint (*Mentha piperita* L.) was obtained in the combined use of Nitroxin (8 Kg ha^{-1}) and urea fertilizer (100 Kg ha^{-1}). Omidi et al. (2009) showed that the application of chemical and biological fertilizers significantly increased the leaf length of saffron (*Crocus sativus* L.).

Crude Protein (CP)

Crude protein percentage was significantly improved as chemical fertilizers application increased, with the maximum value of 16.53 % (100 % chemical fertilizer, Table 3). Among bio-fertilizer levels, co-inoculation with Nitroxin and Barvar resulted in maximum CP % with the value of 16.08 %. Nitroxin bio-fertilizer increased CP as same as 50 % chemical fertilizer and more than Barvar 2 (Table 4). Increasing of CP % under mineral fertilization or inoculation with bio-fertilizers may be attributed to the improvement of available nitrogen in the soil. The increase of urea fertilizer has enhanced the percentage of nitrogen because it contains nitrogen which is an important element in the structure of proteins and nucleic acids (Makvandi et al., 2013). It was reported that application of PGPRs increased both N and P uptakes in plants through stimulation of root growth (Galal et al., 2000; Panwar and Singh, 2000). Inoculation with PGPR improved the crude protein content of maize and wheat (Singh et al., 2010). Chaichi et al. (2015) showed that the highest crude protein content of berseem clover (*Trifolium alexandrinum*) was obtained from the integrated use of biological fertilizer (nitrogen-fixing bacteria + phosphorus solubilizing bacteria treatment).

Crude Fat (CF)

The results presented in Table 2 revealed that chemical and biological fertilizers had significant effects on CF % ($P \leq 0.01$). An increase in chemical fertilizer rate decreased the crude fat content of globe artichoke forage (Table 3). For biological fertilizers, the highest

CF % (2.4) was achieved in the control treatment. In accordance with results, Nitroxin and Nitroxin + Barvar2 could replace chemical fertilizer application (Tables 4). Bakhoum et al. (2016) found that the treatment of bio+organic +mineral fertilization (chicken manure + nitrobine and phosphorine+ ammonium sulfate) in clover berseem (*Trifolium alexandrinum*) resulted in the highest CF %. Alexander et al. (1963) studied the effect of two fertilizer rates including 62.76-53.79-53.79 and 125.52-107.58-107.58 kg of N-P-K/ha on corn silage. They noted that an increase in fertilizer rate showed little effect on the crude fat of corn silage. Archibald (1930) reported that the crude fat of grass in plots without N fertilization was higher than that of the completely fertilized plots because of the formation of less nitrogenous. Thalooth et al. (2015) found that the combination of bio, organic and mineral fertilization produced higher CF content in the mixture of Egyptian clover with ryegrass. Hasan et al. (2010) reported that the different levels of nitrogen fertilizer had no significant effect on the amount of crude fat in cowpea forage.

Ash

The results of this study showed that bio-fertilizers and chemical fertilizers had significant effects ($P \leq 0.01$) on plant ash content. Ash percentage was accelerated as the chemical fertilizers rate increased. 100 % urea + triple superphosphate treatment had the highest (16.13 %) ash content (Table 3). This is probably due to the rapid uptake of chemical fertilizers by plants. Application of Nitroxin + Barvar 2 and Nitroxin resulted in improving ash plant content compared to control and Barvar 2 treatments (Table 4). Application of bio-fertilizers can provide favorable conditions to uptake more nitrogen, phosphorus and other elements due to more nutrients uptake by these kinds of fertilizers. Ehteshami et al. (2012) reported that barley seed inoculation with *P. fluorescens* + 75 % triple superphosphate fertilizer resulted in the highest percentage of total plant ash content, whereas the minimum percentage of total plant ash content was observed in the control treatment (no fertilizer). In a study conducted by Bakhoum et al. (2016), it was shown that the highest ash content of clover berseem (*Trifolium alexandrinum*) was obtained at bio-organic + mineral fertilization treatment (chicken manure + nitrobine and phosphorene + ammonium sulfate).

Neutral Detergent Fiber (NDF)

The main effects of chemical and biological fertilizers and also interaction effects of them were significant on neutral detergent fiber content (Table 2). The highest NDF content (33.13 %) was obtained from control treatment followed by Barvar 2 and Nitroxin. The application of both kinds of fertilizers significantly diminished NDF %. The sole application of Nitroxin and Barvar 2 decreased NDF %, but co-inoculation of seeds by these bio-fertilizers resulted in more reduction in NDF % (Table 5).

It appears that co-application of bacterial strains could provide more suitable conditions for decreasing NDF percentage and increasing the quality of globe artichoke forage. This phenomenon indicates the synergic effects of these bacteria. Rhizosphere bacteria produce plant growth-promoting compounds and uptake nutrients from the soil. They can directly or indirectly affect plant growth. For example, direct competitive effects and the production of antimicrobial agents by bacteria protect root surfaces from colonization by pathogenic microbes (Mantelin and Touraine, 2004).

Table 5. Interaction effect of chemical fertilizers × biological fertilizers on qualitative traits of globe artichoke

Chemical fertilizer	Bio-fertilizer	NDF %	NFC %	ME (MJ/kg DM)	NE_L (MJ/kg DM)
Control	Control	33.13 a	34.01 e	3.83 e	1.65 e
	Nitroxin	25.70 bc	39.19 bcd	6.58 b	3.67 b
	Barvar 2	26.50 b	40.20 abc	5.88 cd	3.16 cd
	Nitroxin+Barvar 2	25.40 c	38.99 cd	7.05 a	4.02 a
50 % Chemical fertilizer	Control	22.83 d	40.35 ab	5.72 d	3.04 d
	Nitroxin	22.43 de	39.98 abc	6.33 b	3.48 b
	Barvar 2	22.43 de	40.50 a	6.19 bc	3.38 bc
	Nitroxin+Barvar 2	22.03 def	39.75 abcd	6.42 b	3.55 b
100 % Chemical fertilizer	Control	21.80 efg	39.55 abcd	6.52 b	3.62 b
	Nitroxin	21.03 gh	39.13 bcd	7.05 a	4.01 a
	Barvar 2	21.13 fgh	40.14 abc	6.97 a	3.95 a
	Nitroxin+Barvar 2	20.43 h	38.74 d	7.31 a	4.21 a
	Nitroxin	21.03 gh	39.13 bcd	7.05 a	4.01 a

NDF: Neutral detergent fiber, NFC: Non-fiber carbohydrates, ME: Metabolizable energy, NE_L: Net energy for lactation. Means followed by a various letter (s) are significantly different at 5 % probability level, using Duncan's Multiple Range Test ($P \leq 0.05$)

Almodares et al. (2009) stated that increasing N levels resulted in the reduction of raw fiber value in the forage of corn and sweet sorghum. Chaichi et al. (2015) indicated that different fertilizer types had significant effects on NDF % in berseem clover as the highest NDF was observed in nitrogen-fixing bacteria + triple superphosphate treatment. In another study, the application of *Pseudomonas* bacteria decreased NDF up to 50.4 % in barley (Mehrvarz and Chaichi, 2008).

Non-fiber Carbohydrates (NFC)

Non-fiber carbohydrates (NFC) are made up of starch, simple sugars, and soluble fiber (NRC, 1985). Analysis of forage quality in this study indicated that NFC % was statistically affected by the main and interaction effects of chemical and biological fertilizers ($P \leq 0.01$) (Table 2). For the integrated system, the highest NFC values belonged to Barvar 2 + 50 % chemical fertilizers, Barvar 2 + 100 % chemical fertilizers, Nitroxin +50 % chemical fertilizers, and 50 % chemical fertilizers+ Nitroxin + Barvar 2, respectively (Table 5).

It was excellent to confirm that Nitroxin bio-fertilizer could be substituted for NFC %, instead of whole chemical fertilizers. Forage carbohydrates can vary widely due to the interaction of plants and environment (Buxton and Fales, 1994). Environmental factors such as the availability of nutrients affect carbohydrate content of forage during plant growth. Digestibility and nutritional value of forage increase with an enhancement in non-fiber carbohydrates content of forage. Campos et al. (2013) studied the effects of N fertilization doses (0, 150, 300, or 450 kg N ha^{-1}) on the chemical composition of Milenio grass (*Panicum maximum*). They mentioned that the N application led to an increase in CP content, which occurred concomitantly with a reduction in the NFC amounts. The NFC concentrations were decreased, mainly due to the synthesis of a cell wall, which drained the cytoplasmic nutrients. There was an inverse relationship between N rates and NFC content. It was reported that the NFC reserves are mostly consumed for fiber synthesis under intense growth (Schmidt and Blaser 1969; Trenholm et al., 1998).

Metabolizable Energy (ME) and Net Energy for Lactation (NE_L)

The energy in forage that is not lost in feces, urine, or rumen gases is called metabolizable energy (Robinson et al., 1998). Net energy for lactation is defined as an estimate of the energy value of forage used for maintenance plus milk production for maintenance plus the last two months of gestation for pregnant cows (Van Alfen, 2014). In the integrated system of the current study, the highest ME and NE_L have obtained at Nitroxin+ Barvar 2 + 100 % chemical fertilizers, Nitroxin+ 100 % chemical fertilizers, Nitroxin+ Barvar 2, and Barvar 2 + 100 % chemical fertilizers, respectively (Table 5). It has been noted that is a positive correlation between metabolizable energy and protein content (Makkar et al., 1995). It has been however noted that NDF and metabolizable energy have a negative correlation (Kamalak et al., 2005). So, the main reason for increasing the metabolizable energy in plants by applying fertilizers probably is a reduction in NDF percentage and enhancing crude protein content. Khan et al. (1992), Sultana (2003) and Hasan et al. (2010) found no significant effect of nitrogen fertilizer application on ME content of cowpea forage (*Vigna unguiculata*). Tarcău et al. (2012) indicated that net energy for lactation of *Nardus stricta* L. was significantly increased with the application of organic and mineral input variants.

CONCLUSIONS

In accordance with the results of this research, increasing chemical fertilizer application from 0 to 100 % significantly enhanced the number of leaves per plant, leaf length, CP and ash content of globe artichoke. Both seed inoculation with bio-fertilizer and usage of chemical fertilizers diminished crude fat content compared to control. Co-inoculation with two fertilizers resulted in more values of most traits in comparison with single bio-fertilizers use. It can be attributed to the synergic effects of bio-fertilizers Nitroxin and Barvar 2. The maximum number of leaves per plant, leaf length, CP and ash content were obtained by application of Nitroxin + Barvar 2 and sole Nitroxin followed by Barvar 2. The lowest NDF and the highest NFC, ME and NE_L were recorded in the integrated plant nutrition system. According to the findings of this study, biological fertilizers along with chemical fertilizers led to increasing some of the important qualitative and quantitative traits of globe artichoke. By using bio-fertilizer such as Nitroxin and Barvar 2, the utilization of chemical fertilizers can be reduced, which is an efficient step in achieving the objectives of kindly environmental agricultural systems.

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اثرات کودهای زیستی بر برخی خصوصیات مورفولوژیکی و تغذیه‌ای کنگر فرنگی

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انرژی ویژه شیردهی

چکیده- کشت کنگر فرنگی به عنوان گیاهی چند منظوره (سبزی، دارو و علوفه) با استفاده از کودهای زیستی و کاهش میزان مصرف کودهای شیمیایی در سیستم‌های کشاورزی پایدار قرار می‌گیرد. برای ارزیابی اثرات کود شیمیایی، کود زیستی و سیستم‌های تلفیقی تغذیه گیاهی بر برخی صفات کنگر فرنگی، آزمایش مزرعه‌ای با استفاده از طرح فاکتوریل بر پایه بلوک‌های کامل تصادفی با سه تکرار در اصفهان در سال ۱۳۹۳ انجام شد. فاکتورها شامل کودهای شیمیایی در سطوح شاهد (بدون کود شیمیایی)، ۱۰۰ و ۵۰ درصد از مقدار توصیه شده و کودهای زیستی در سطوح شاهد (بدون کودهای زیستی)، نیتروکسین (ازتوباکتر، آزوسپیریلیوم و سودوموناس)، بارور ۲ (سودوموواس پوتیدا و پانتوا آگلومرانس) و بارور۲+ نیتروکسین بودند. صفات مورفولوژیکی، ترکیب شیمیایی، انرژی قابل متابولیسم و انرژی ویژه شیردهی در مرحله رشد رویشی (روزت) تعیین شدند. نتایج نشان داد که با استفاده از کودهای زیستی و شیمیایی پارامترهای موثر در افزایش کیفیت علوفه به صورت قابل توجهی بهبود یافتند. تلقیح همزمان با دو کود زیستی در مقایسه با کاربرد منفرد آنها تاثیر بیشتری در افزایش کیفیت علوفه داشت. با وجود این، نیتروکسین اثرات مثبت بیشتری نسبت به بارور ۲ داشت. به طور کلی نتیجه گیری شد که تیمارهای تغذیه تلفیقی گیاه برای رشد و کیفیت علوفه کنگر فرنگی سودمندتر هستند.