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Original article

Effect of mycorrhiza, vermicompost and nanofertilizer on quantitative and qualitative characteristics of *Cucurbita pepo* L.

S.A. Razzaghifard[1], A. Gholipouri[1], A. Tobeh[1] and S. Reza mousavi meshkini[2]

[1] Department of Agronomy and Plant Breeding, Faculty of Agriculture, University of Mohaghegh Ardabili, Ardebil, Iran
[2] Department of Environment, Ardebil, Iran

Summary

The aim of this study was to investigate the effect of mycorrhiza, vermicompost, and nanofertilizer on the quantitative and qualitative traits of *Cucurbita pepo* L. For this, a split plot-factorial experiment was conducted in a randomized complete block design with three repetitions at a research farm in Miane Islamic Azad University in 2014 and 2015. Vermicompost was used in the main plots in three levels (V0: 0, V1: 10 t ha^{-1} and V2: 20 t ha^{-1}), and mycorrhiza and micro chelated nanofertilizer were used in the subplots, in two levels (M0: without mycorrhiza and M1: with mycorrhiza) and three levels (N0: 0, N1: 2 and N2: 4 per thousand concentration), respectively. The combined analysis of variance showed that vermicompost had significant effects on fruit weight, total dry weight, weight of seeds per fruit, number of seeds per fruit, seed yield, oil yield, fruit yield, and fruit diameter. The effects of nanofertilizer and vermicompost-mycorrhiza-nanofertilizer interaction on fruit weight, fruit diameter, and fruit yield were significant. Maximum grain yield (576.25 kg ha^{-1}) and oil yield (190.16 kg ha^{-1}) were obtained using V2N1 (20 t ha^{-1} vermicompost and foliar spray of 2 per thousand nanofertilizer concentration). The maximum fruit yield (24,551.60 kg ha^{-1}) was obtained using V2N2 (20 t ha^{-1} vermicompost and foliar spray of 4 per thousand nanofertilizer concentration). The minimum grain yield (150.89 kg ha^{-1}) and oil yield (37.72 kg ha^{-1}) were obtained using V0N0 (control). The minimum fruit yield (5,888.43 kg ha^{-1}) was obtained using V0M0N0 (control). Thereby, it is recommended to use 20 tons vermicompost ha^{-1} and foliar spray of nanofertilizer in order to achieve an acceptable yield in *Cucurbita pepo* L.

Keywords
Cucurbita pepo L., yield, mycorrhiza, nanofertilizer, vermicompost, micro chelated nanofertilizer

Significance of this study

What is already known on this subject?

- The importance of medicinal plants has been discovered by millions of people worldwide who are active in the fields of planting, harvesting, processing and other aspects of medicinal herbs. Therefore, medicinal plants, such as *Cucurbita pepo* L., are of great economic importance as they can also serve as a food source and can be considered in land use planning. Vermicompost significantly affects biological yield and grain yield.

What are the new findings?

- The present study aimed to investigate the effect of vermicompost, mycorrhiza, and nanofertilizer on the yield of *Cucurbita pepo* L. The combination of vermicompost and nanofertilizer maximally increased most of the traits such as seed weight per fruit, seed yield, oil yield, fruit weight, fruit yield and fruit diameter in *Cucurbita pepo* L.

What is the expected impact on horticulture?

- Understanding the relationship between fertilizer and minerals helps in implementing optimum fertilization practice in an economical manner. The combined use of vermicompost and nanofertilizer supplies better nutritional systems and increased yield with no adverse environmental impacts arising from the use of chemical fertilizers, which supports sustainable agriculture.

Introduction

The importance of medicinal plants has been discovered by millions of people worldwide who are active in the fields of planting, harvesting, processing and other aspects of medicinal herbs. Therefore, medicinal plants, such as *Cucurbita pepo* L., are of great economic importance as they can also serve as a food source and can be considered in land use planning.

Cucurbita pepo L. is a herbaceous perennial plant, of the *Cucurbitaceae* family. Academics believe that this plant was generated through an accidental mutation (Omidbaigi, 2008). The skinless seeds are the most important feature of this plant (Murkovic et al., 2004), as they produce and store beta sitosterol and vitamin E. These micronutrients help in the treatment of gastritis and arteriosclerosis, reduce unwanted fats and blood clots in the veins, prevent irregular contraction of the heart, reduce the risk of formation of bladder and kidney stones, and treat prostate cancer and urinary tract irritation (Huang et al., 2004; Hosseinzadeh and Amjadi, 2012; Yadav et al., 2010). In addition, the active ingredients in this plant are currently used in pharmaceutical industry to produce peponene, gronfing, and prostaliquid (Murkovic et al., 1996; Siegmund and Murkovic, 2004). The oil content of this plant is also used to produce edible oils in a variety of sauces and salads as well as in the cosmetic industry.

Crop management techniques, such as the use of fertilizers, affect the qualitative and quantitative yield of *Cucurbita pepo* L. Since the current fertilization system is focused on providing a limited number of macronutrients, it has been scientifically proven that every plant requires 13 minerals

in the soil. As a result, mineral fertilizers cause imbalances in the chemical composition of plants (Atiyeh et al., 2000). Hence, the prevailing soil deficiencies necessitate the use of various agronomic measures, such as nanofertilizers containing micronutrients and organic and biofertilizers like vermicompost and mycorrhiza, for improving plant growth, to overcome rivalry between vegetative and reproductive organs of the plant and increasing the yield potential. Unlike conventional fertilizers, limited studies have been conducted on the effects of nanofertilizers and biofertilizers like vermicompost and mycorrhiza, on the quantitative and qualitative yield of pharmaceutical plants, such as *Cucurbita pepo* L. However, various studies have suggested that organic fertilizers have different effects on the quantitative and qualitative characteristics of the medicinal plants. Even some reports have indicated inefficacy or adverse effects of organic fertilizers on plants (Chauhan et al., 2000). Daneshian et al. (2010) showed that mycorrhiza had no significant effect on fruit yield in medicinal zucchini. In addition, Jahan et al. (2013) also showed that vermicompost had no effect on fruit yield in *Cucurbita pepo* L. On the other hand, Moslemi et al. (2012) investigated the effects of various levels of vermicompost on the yield of coriander. They showed that vermicompost significantly affected biological yield and grain yield. A study by Farahani and Abadi (2010) showed that maximum shoot yield, root yield, and thousand grain weight (TGW) in coriander were obtained using mycorrhiza. Given the application of nanofertilizers, the biological and organic fertilizers have effectively been used in sustainable agriculture. Hence, the present study aimed to investigate the effect of vermicompost, mycorrhiza, and nanofertilizer on the yield of *Cucurbita pepo* L.

Materials and methods

Study settings and experimental design

This experiment was conducted on a research farm in Miane Islamic Azad University (located at 47.42°N, 37.24°E and 1,100 m a.s.l.) in 2014 and 2015. Soil specimens were collected from this region in order to determine the soil properties. The soil properties at 0–0.3 m depth are given in Table 1. The pH of soil saturated paste, EC of saturated extract, and total soil N were measured as described by Thomas (1996), Rhoades (1996), and Boltz and Howell (1978), respectively. The organic carbon content of soil was determined by Walkly and Black method (Nelson and Sommers, 1996), available P in 0.5 M sodium bicarbonate extract using ascorbic acid colorimetric method (Kuo, 1996), available K in 1 M ammonium acetate extract by flame photometer (Jones, 2001), and soil texture through hydrometry (Gee and Bauder, 1989). Available Fe, Mg, Zn, and Cu were detected in AB-DTPA extract through atomic absorption spectroscopy. Also available B were detected in AB-DTPA extract through atomic absorption spectrophotometry (Jones, 2001). Miane has an arid and semiarid ecosystem with relatively warm and dry summers and relatively cold and wet winters. The meteorological parameters relevant to this region throughout the experiment are shown in Table 1.

A split plot-factorial experiment in a randomized complete block design with three repetition was conducted. Vermicompost was used in three levels (V0: 0, V1: 10 and V2: 20 t ha^{-1}) in the main plots. Mycorrhiza and micro chelated nanofertilizers were used in the subplots in two levels (M0: without mycorrhiza and M1: with mycorrhiza) and three levels (N0: 0, N1: 2 and N2: 4 per thousand concentration) (nanofertilizer levels refer to ratios of nanofertilizers dissolved in water), respectively. Each experimental unit had five rows at a distance of 140 cm and a length of 4 m. The distance between adjacent plots in a block was 280 cm, and the distance between adjacent blocks was 3 m. The field size was 3,465 m^2 containing 9 main plots and each main plot containing 6 sub plots. The subplot size was 28 m^2 (7 m × 4 m) containing five rows and number of seeds planted per sub plot was 50 that 80% to 100% of them germinated and grew. Ridge and furrow planting methods were used. The seeds were planted as clusters at a distance of 40 cm from each other at a depth of 2 cm in water tail area. Three seeds were included in each cluster. The thinning procedure was conducted after the four-leaf stage, and the strongest seedling was maintained.

Fertilizer treatments

Different levels of vermicompost were distributed at the surface of the plots and mixed with the soil at a depth of 10 to 15 cm before the plantation. 2% and 4% nanofertilizer treatments were obtained from dissolving 2 and 4 mL nano-

Table 1. Soil properties and meteorological parameters of the studied region.

Soil properties of the studied region														
Soil profile	pH	EC (dS m^{-1})	Clay (%)	Silt (%)	Sand (%)	Organic carbon (%)	N (%)	P (ppm)	K (ppm)	Br (ppm)	Zn (ppm)	Mg (ppm)	Fe (ppm)	Cu (ppm)
Silt loam	7.9	0.55	44	51	5	0.98	0.095	8.4	35	1.92	0.68	4.72	7.99	2.46

Meteorological parameters of the studied region						
Parameters	Year	May	June	July	August	September
Sunny hours	2014	281.9	329	344.8	351.5	327.2
	2015	313.5	323	439.8	271.2	301.9
Mean monthly temperature (°C)	2014	12.3	24	28.2	28.9	26.8
	2015	19	25.2	29.1	29.6	23.8
Rainfall (mm)	2014	27.3	28.4	14.3	0	0
	2015	22.2	2.8	3.9	0	27.9
Relative humidity (%)	2014	49	38	41	31	35
	2015	41	34	34	27	50

EC: Electrical Conductivity; N: Nitrogen.

fertilizer in water, respectively. Each nanofertilizer treatment was divided into three equal parts. Each section was used at green leaves, stem elongation, and flowering stages. A total of 140 mL from each nanofertilizer treatment used for each plant. Again,15 g mycorrhiza fertilizer (*Glomus mosseae*) was also used in each cluster during the planting of seeds. Therefore, mycorrhiza fertilizer concentration was 26.7 g m^{-2}. Weed control was done manually and continuously at different developmental stages. Furrow irrigation was performed at all plots on an average of eight days interval. The following steps were taken in order to measure the yield and yield characteristics. Three plants were collected from the middle lines in each plot when the fruits were orange-yellowish in color. The stems, leaves and fruits were removed. The fruits were weighed with a digital scale. Then, the seeds were removed from the fruits and counted. The seeds belonging to each treatment were separately dried in a dry room with proper ventilation for a week, and then weighed. The stems and leaves were kept in an electric oven at 75°C for 72 h and weighed. Harvest index was calculated using the following equation (HI = seed weight / total dry weight × 100). The dimensions of the seeds were measured as follows. Ten seeds were selected from each treatment and measured using a caliper to calculate the average dimension. For extraction seed oil, 20 g seed was conducted in a soxhlet extractor using n-hexane (boiling point of 40–60°C) for 5 hours. The lipid was obtained after the solvent was removed in oven at 40°C to remove excess solvent used in the oil. Extracted seed oil was stored in freezer at -2°C for fatty acids analysis. Fatty acid composition of oil samples containing palmitic acid, stearic acid, oleic acid and linoleic acid was determined by gas-liquid chromatography and was reported based on the relative percentage levels. For this purpose, 0.3 g of oil from each sample was mixed with 7 mL of hexane. The solution was mixed with 7 mL of methanol-containing potassium hydroxide at 50°C for 15 min to obtain fatty acid esters belonging to each treatment. The fatty acid esters were also determined by HP-5890 chromatograph (Hewlett-Packard, SC, USA) equipped with a BPX 70 silica glass capillary column (60 m long, 0.22 mm internal diameter, 0.2 µm inner layer thickness) and a flame ionization detector. Helium carrier gas flow rate was 0.7 mL per minute. The temperatures in the oven, injection, and detector were 198°C, 280°C, and 250°C, respectively. The main and interactional effects of the treatments were determined by analysis of variance (ANOVA) using the GLM procedure generated by SAS software. Statistical analysis was performed using SAS software (SAS Institute Inc., Cary, N.C.). The mean comparison was also performed using Duncan's multiple range test at 5% level by MSTAT-C software. The combined analysis of variance was performed to evaluate the effect of year and the interaction between year and treatments after uniformity testing for the errors by Bartlett's test.

Table 2. Analysis of combined effect of vermicompost, nanofertilizer and mycorrhiza on yield components of *Cucurbita pepo* L.

	Mean square						
Source of variation	Degree of freedom	Number of male flowers per plant	Number of female flowers per plant	Fruit weight (g)	Total dry weight (kg)	Seed weight per fruit (g)	Number of seeds per fruit
Year	1	0.41ns	7.03ns	0.17ns	125.25ns	0.68ns	25034.31ns
Repetition (year)	4	0.06	0.2	0.23	361.68	0.42	33906.47
Vermicompost	2	0.06ns	0.6ns	0.05**	109.43*	0.26*	7108.14*
Year × vermicompost	2	0.04ns	0.2ns	0.08ns	244.11ns	0.25ns	24422.06ns
Main error	8	0.05	0.31	0.2	311.22	0.26	26145.59
Mycorrhiza	1	0.008ns	0.01ns	0.000001ns	27.09ns	0.05ns	12257.44ns
Year × mycorrhiza	1	0.01ns	0.28ns	0.002ns	102.60ns	0.008ns	875.34ns
Vermicompost × mycorrhiza	2	0.01ns	0.29ns	0.01ns	25.16ns	0.01ns	2874ns
Year × vermicompost × mycorrhiza	2	0.01ns	0.61ns	0.03ns	63.43ns	0.1ns	273.51ns
Nanofertilizer	2	0.009ns	0.89ns	0.02*	10.61ns	0.01ns	905.86ns
Year × nanofertilizer	2	0.07ns	0.19ns	0.03ns	7.81ns	0.01ns	734.83ns
Vermicompost × nanofertilizer	4	0.03ns	0.39ns	0.24**	199.13ns	0.17*	7477.15ns
Year × vermicompost × nanofertilizer	4	0.05ns	0.1ns	0.03ns	112.53*	0.14ns	10540.69*
Mycorrhiza × nanofertilizer	2	0.04ns	0.13ns	0.002ns	39.45ns	0.01ns	1557.08ns
Year × mycorrhiza × nanofertilizer	2	0.02ns	0.07ns	0.1ns	161.79ns	0.12ns	7006.25ns
Vermicompost × mycorrhiza × nanofertilizer	4	0.009ns	0.91ns	0.09*	203.37ns	0.09ns	11593.22ns
Year × vermicompost × mycorrhiza × nanofertilizer	4	0.03ns	0.24ns	0.07ns	172.62**	0.22ns	6187.72ns
Sub error	60	0.01	0.08	0.02	26.43	0.04	2016.94
CV (%)		8.60	19.71	5.06	0.02	17.07	22.37

ns, * and ** respectively represent no significance, significant at 5% and 1%.

Results and discussion

Fruit weight

The combined analysis of variance within two years showed that the effects of vermicompost and nanofertilizer, vermicompost-nanofertilizer interaction, and vermicompost-nanofertilizer-mycorrhiza interaction on fruit weight were significant. However, the effects of year, and year-treatments interaction on this trait were not significant (Table 2). This shows that fruit weight is mostly affected by crop management techniques. The comparison of the data obtained from different levels of vermicompost, nanofertilizer, combination of vermicompost-nanofertilizer, and combination of vermicompost-mycorrhiza-nanofertilizer showed that the minimum fruit weight (331.13 g) was observed in V0M0N0 (control) and maximum fruit weight (1,374.89 g) was observed in V2N2 (using 20 t ha^{-1} vermicompost and four per thousand foliar spray of nanofertilizer). It can be justified that there is a synergy between vermicompost and nanofertilizer, which has increased the fruit weight in comparison with the singular use of nanofertilizer and vermicompost. Vermicompost increases the water and nutrient holding capacity of the soil, which facilitates absorption of nutrients by plants, leads to the proper development of shoot organs, increases efficient use of sunlight, and increases the photosynthetic capacity of the plant. On the other hand, the nanofertilizer is more quickly absorbed by the plant, which supplies more photosynthetic material and consequently increases fruit weight.

Number of flowers

The combined analysis of variance (ANOVA) showed that vermicompost, mycorrhiza and nanofertilizer and their interaction had no significant effects on the number of male and female flowers (Tables 2 and 3). The gender and number of flowers in cucurbits, such *as Cucurbita pepo* L., is influenced by genetic, hormonal and environmental factors, such as light, temperature and photoperiod (long days and high temperatures lead to the formation of male flowers while short days and low temperature lead to the formation of female flowers) (Robinson and Decker-Walters, 1997). Therefore, fertilizers have no significant effect on the number

Table 3. Analysis of combined effect of vermicompost, mycorrhiza and nanofertilizer on different yield components of *Cucurbita pepo* L.

		Mean squares								
Source of variation	Degree of freedom	Seed harvest index	Seed yield (kg ha^{-1})	Fruit yield (kg ha^{-1})	Fruit diameter (cm)	Seed length (mm)	Seed width (mm)	Seed thickness (mm)	Oil content (%)	Oil yield (kg ha^{-1})
Year	1	1.01ns	0.68ns	0.17ns	30.33ns	4.94ns	3.42ns	0.007ns	0.005ns	0.81ns
Repetition (year)	4	0.06	0.42	0.23	24.82	1.95	0.37	0.005	0.01	0.49
Vermicompost	2	0.06ns	0.26*	0.05**	3.83*	1.15ns	0.36ns	0.01ns	0.004ns	0.29*
Year × vermicompost	2	0.07ns	0.24ns	0.07ns	10.42ns	1ns	0.27ns	0.01ns	0.01ns	0.21ns
Main error	8	0.04	0.26	0.2	33.12	1.52	0.26	0.008	0.009	0.19
Mycorrhiza	1	0.04ns	0.05ns	0.00001ns	7.87ns	2.43ns	1.18ns	0.001ns	0.05ns	0.00009ns
Year × mycorrhiza	1	0.04ns	0.008ns	0.002ns	0.71ns	0.95ns	0.33ns	0.007ns	0.006ns	0.0006ns
Vermicompost × mycorrhiza	2	0.01ns	0.01ns	0.01ns	1.23ns	2.16ns	0.34ns	0.0006ns	0.003ns	0.01ns
Year × vermicompost × mycorrhiza	2	0.02ns	0.1ns	0.03ns	8.15ns	0.43ns	0.48ns	0.001ns	0.0004ns	0.11ns
Nanofertilizer	2	0.01ns	0.01ns	0.02*	1.86*	0.64ns	0.44ns	0.0001ns	0.009ns	0.02ns
Year × nanofertilizer	2	0.04ns	0.01ns	0.03ns	0.52ns	1.06ns	0.45ns	0.0002ns	0.002ns	0.03ns
Vermicompost × nanofertilizer	4	0.01ns	0.16*	0.24**	20.69**	1.56ns	0.73ns	0.006ns	0.04ns	0.27*
Year × vermicompost × nanofertilizer	4	0.04ns	0.14ns	0.04ns	5.69ns	1.56ns	0.14ns	0.003ns	0.01ns	0.2ns
Mycorrhiza × nanofertilizer	2	0.000002ns	0.01ns	0.002ns	0.08ns	0.13ns	0.55ns	0.005ns	0.01ns	0.0002ns
Year × mycorrhiza × nanofertilizer	2	0.01ns	0.12ns	0.1ns	7.13ns	1.16ns	0.35ns	0.001ns	0.03ns	0.08ns
Vermicompost × mycorrhiza × nanofertilizer	4	0.01ns	0.09ns	0.09*	14.02**	0.52ns	0.34ns	0.005ns	0.01ns	0.05ns
Year × vermicompost × mycorrhiza × nanofertilizer	4	0.07ns	0.22ns	0.07ns	10.22*	1.60ns	0.15ns	0.001ns	0.009ns	0.3ns
Sub error	60	0.01	0.04	0.02	2.41	0.64	0.22	0.001	0.009	0.04
CV (%)		20.83	8.46	3.56	11.19	5.52	6.05	15.78	6.82	10.47

ns, * and ** respectively represent no significance, significant at 5% and 1%.

and gender of flowers per plant. Ghazi Manas et al. (2013) showed that vermicompost had no significant effect on the number and gender of flowers.

Total dry weight

A combined ANOVA showed that vermicompost and year-vermicompost-nanofertilizer interaction and year-vermicompost-nanofertilizer-mycorrhiza interaction had significant effects on total dry weight (Table 2). The mean comparison results showed that the maximum total dry weight (906.34 g) was associated with 20 t ha^{-1} vermicompost, and the minimum total dry weight (324.05 g) was associated with the control (Table 4). These results are consistent with the results obtained by Darzi et al. (2010) for *Pimpinella anisum* L. and Moslemi et al. (2012) for coriander, which showed that biological yield increased with the use of vermicompost. Vermicompost consists of several nutrients, which improve the soil structure, increase the absorption of water and nutrients by plants, and consequently, increase the rate of photosynthesis and dry weight. The significant interaction between year, vermicompost and nanofertilizer and the significant interaction between year – vermicompost – nanofertilizer – mycorrhiza indicated that the total dry weight varies and is not stable in terms of climatic changes. The results showed that the total dry weight was mostly higher in the first year compared to the second year, due to better climatic conditions in the first year.

Seed weight per fruit

ANOVA results showed that the effects of vermicompost and vermicompost-nanofertilizer interaction on seed weight per fruit were significant ($P \leq 0.05$) (Table 2). The mean comparison relevant to seed weight per fruit within two years at different levels of vermicompost showed that the seed weight per fruit (maximum weight = 31.17 g) significantly increased by increasing vermicompost application up to 20 t ha^{-1} (V2) (Table 4). Increased seed weight caused by using vermicompost may be due to the increased plant growth, higher production of photosynthetic materials, and consequently, more access to photosynthetic materials during seed filling. In the combination of vermicompost and nanofertilizer, the maximum seed weight per fruit (32.27 g) belonged to V2N1 treatment (using 20 t ha^{-1} vermicompost with a foliar spray of 2 per thousand nanofertilizer concentration) and minimum seed weight per fruit (8.45 g) belonged to control (V0N0) (Table 5). The study of the changes in seed weight during the simultaneous use of vermicompost and nanofertilizer showed that seed weight depended on the ratio of vermicompost. It was shown that seed weight per fruit was significantly increased when using 20 t ha^{-1} vermicompost, either singularly or simultaneously with nanofertilizer. Therefore, it can be stated that the second level, is the most effective level, whether singularly or in combination with nanofertilizer. Seed weight per fruit was higher in V2N2 than V2. Therefore, V2N2 (vermicompost and nanofertilizer) had a complementary effect on seed weight. The seed weight was found to be higher in the simultaneous use of vermicompost and nanofertilizer than the singular use of vermicompost.

Number of seeds per fruit

The combined analysis of variance within two years showed that the effect of vermicompost and year-vermicompost-nanofertilizer interaction on the number of seeds per fruit was significant ($P \leq 0.05$) (Table 2). The mean comparison in all treatments showed that the greatest number of seeds per fruit (on average 285.60) was obtained using 20 t ha^{-1} vermicompost and the least seeds per fruit (on average 96.21) belonged to the control (not using vermicompost) (Table 4). Since all other factors were assumed to be similar, increased seed number per fruit is dependent on the climatic conditions and the presence of pollinators prior to the pollination stage. As a result, the number of seeds per fruit increased due to greater access to fertilizers, which in turn increased the rate of photosynthesis in the pre-flowering stage. There was a significant interaction between year, vermicompost and nanofertilizer, which indicated that the number of seeds per fruit is influenced by climate change. It was shown that the number of seeds per fruit was greater in the second year than in the first year in all treatments due to better climatic conditions in the second year.

Harvest index

Based on the results of combined ANOVA showed that vermicompost, mycorrhiza, nanofertilizer and different combinations of these treatments had no significant effects on harvest index in the seeds (Table 3). It can be interpreted

Table 4. Effect of vermicompost and nanofertilizer on yield components of *Cucurbita pepo* L.

Treatment	Fruit weight (g)	Total dry weight (g)	Seed weight per fruit (g)	Number of seeds per fruit	Seed yield (kg ha^{-1})	Fruit yield (kg ha^{-1})	Fruit diameter (cm)	Oil yield (kg ha^{-1})
Year								
2014	831.76a	730.09a	13.80a	183.23a	245.47a	14791.08a	13.27a	64.56a
2015	977.23a	603.56a	19.95a	213.85a	354.81a	17378a	14.28a	97.72a
Vermicompost								
0	533.42b	324.05b	15.91b	96.21b	284.10b	9525.35b	11.59b	71.02b
10 t ha^{-1}	941.25ab	614.14ab	20.14b	161.91b	359.64b	16808.03ab	13.49ab	107.89b
20 t ha^{-1}	1316.29a	906.34a	31.17a	285.60a	556.60a	23505.17a	15.08a	183.67a
Nanofertilizer								
0	564.96b	401.55a	15.84a	199.50a	281.83a	10088.57b	10.88b	74.13a
2 per thousand concentration	909.23ab	565.50a	17.37a	201.34a	309.02a	16236.25ab	12.86ab	89.12a
4 per thousand concentration	1301.25a	658.12a	17.31a	201.48a	316.22a	23236.60a	14.80a	81.28a

Mean of each column with common letters had no significant difference based on Duncan's test at 5% level.

Table 5. Effect of vermicompost and nanofertilizer interaction on yield components of *Cucurbita pepo* L.

Treatment	Fruit weight (g)	Seed weight per fruit (g)	Seed yield (kg ha^{-1})	Fruit yield (kg ha^{-1})	Fruit diameter (cm)	Oil yield (kg ha^{-1})
Nanofertilizer × vermicompost						
V0N0	416.86d	8.45c	150.89c	7585.77d	11.33e	37.72c
V0N1	691.83bc	10.47c	186.96c	12302.68bc	12.38bde	44.87c
V0N2	831.76ab	13.48bc	240.71bc	14791.08ab	13.96abcd	52.95c
V1N0	870.96ab	15.48bc	276.42bc	15848.93ab	13.22abcde	80.16bc
V1N1	1000ab	16.59bc	296.25bc	18197ab	14.23abc	74.06bc
V1N2	758.57ab	15.84bc	282.85bc	13489.62ab	12.48bde	82.02bc
V2N0	1023.29ab	22.37ab	399.46ab	18197ab	14.70a	87.88bc
V2N1	1296.47a	32.27a	576.25a	23151.25a	15.24a	190.16a
V2N2	1374.89a	29.17a	520.89a	24551.60a	14.44ab	166.68a

Mean of each column with common letters had no significant difference based on Duncan's test at 5% level. V0: 0, V1: 10 t ha^{-1} vermicompost, V2: 20 t ha^{-1} vermicompost, N0: 0, N1: 2 per thousand nanofertilizer concentration; N2: 4 per thousand nanofertilizer concentration.

that economic yield (seed yield) was increased to a certain ratio by increasing the biological yield. Therefore, fertilizers had no significant effect on harvest index. Ramroudi et al. (2011) showed that harvest index was not affected by foliar spray of micronutrients in fleawort medicinal herb. Gholami et al. (2015) showed that the interaction of vermicompost and mycorrhiza was not significant on harvest index in fennel.

Seed dimension

The contents of Table 3 show that length, width, and thickness of seeds were not influenced by vermicompost, mycorrhiza, nanofertilizer and their interaction. This is because seed dimension is dependent on the genetic factors and less affected by agronomic factors, such as fertilizers.

Seed yield

On the basis of the ANOVA findings showed that the effects of vermicompost and interaction of vermicompost and nanofertilizer were significant on seed yield at 5% level (Table 3). These results were consistent with the results obtained by other scholars like Darzi et al. (2010), Aroyi et al. (2006), and Moslemi et al. (2012). Moslemi et al. (2012) investigated the effects of various levels of vermicompost on the yield of coriander. They showed that vermicompost significantly affected grain yield. The number of fruits per unit area is the most effective barrier to seed yield in *Cucurbita pepo* L. (Nerson, 2005). The seed yield increases by using fertilizer due to increased number of fruits per hectare (Jahan et al., 2007). The seed yield per unit area is calculated by multiplying the number of fruits per plant and seed weight per fruit in the case of *Cucurbita pepo* L. It should be noted that the number of fruits per plant was constant and equal to one in all treatments. Thereby, the seed yield is equal to seed weight per fruit. The maximum seed weight per fruit belonged to V2N1 and minimum seed weight per fruit belonged to V0N0, the highest seed yield (576.25 kg ha^{-1}) and the lowest seed yield (150.89 kg ha^{-1}) also belonged to these treatments (Table 5; Figure 1a). The highest seed yield in this experiment, was almost same as the conventional commercial production (657 kg ha^{-1}). It should be noted that the main barrier to the production of this medicinal plant was low seed yield. Thereby, seed yield did not increase more than what was reported due to the relatively high vegetative growth and unlimited growth of *Cucurbita pepo* L. and the significant effect of the number of fruit in improving yield in

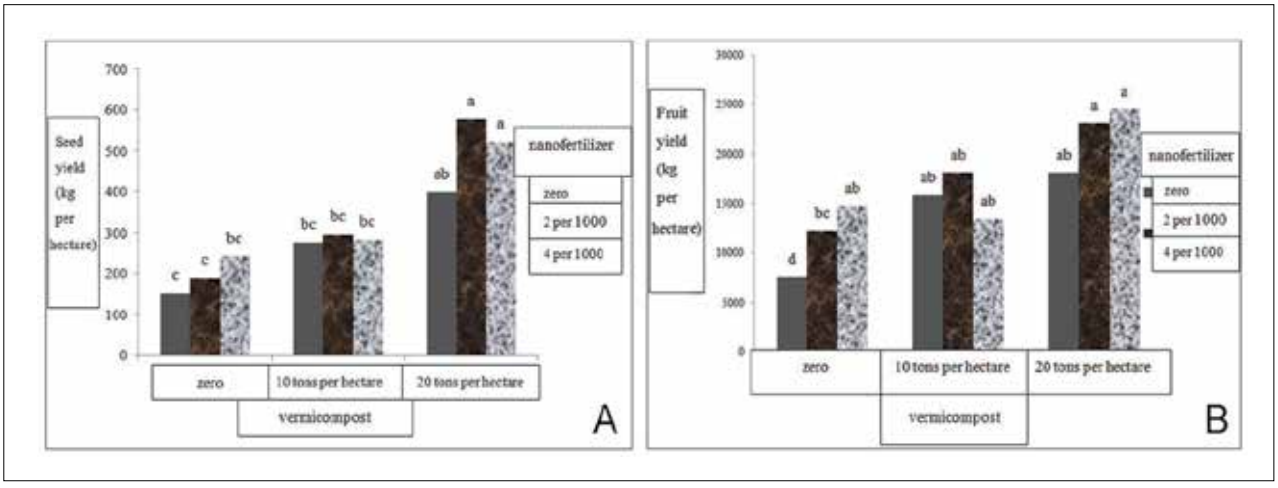


Figure 1. Effect of vermicompost and nanofertilizer on seed yield (A) and fruit yield (B) in *Cucurbita pepo* L. in combined analysis of variance. (Columns with the same letters had no significant difference based on Duncan's test at 5% level).

Table 6. Effect of interaction of mycorrhiza, vermicompost and nanofertilizer on yield components of *Cucurbita pepo* L.

Treatment	Fruit weight (g)	Fruit yield (kg ha^{-1})	Fruit diameter (cm)
Nanofertilizer × mycorrhiza × vermicompost			
V0M0N0	331.13h	5888.43i	10.29f
V0M0N1	537.03cegh	9549.92fhi	10.69f
V0M0N2	549.54bcefgh	10000bdfghi	11.98ef
V0M1N0	602.55bcefgh	10715.19bdfghi	12.44b-f
V0M1N1	707.94a-g	12589.25a-h	12.16cef
V0M1N2	969.13a-e	17378a-f	13.72a-e
V1M0N0	794.32a-g	14454.39a-h	12.80a-f
V1M0N1	851.13a-g	15135.61a-h	13.55a-e
V1M0N2	977.23a-f	17378a-g	12.66a-f
V1M1N0	714.24a-g	12882.49a-h	15.10a-c
V1M1N1	1023.29a-e	18197a-f	14.34a-e
V1M1N2	1050.02a-d	19054.60a-e	14.48a-e
V2M0N0	1047.12abc	18620.87a-f	14.54a-e
V2M0N1	1318.25a	23442.28a	15.68a
V2M0N2	1096.47ab	19498.44a-d	14a-e
V2M1N0	1148.15a	20417.37abc	15.26ab
V2M1N1	1202.26a	21877.61ab	15.37ab
V2M1N2	1071.51abc	19054.60a-f	14.91a-d

Mean of each column with common letters had no significant difference based on Duncan's test at 5% level. V0: 0, V1: 10 t ha^{-1} vermicompost, V2: 20 t ha^{-1} vermicompost, N0: 0, N1: 2 per thousand nanofertilizer concentration; N2: 4 per thousand nanofertilizer concentration.

this medicinal plant (Ghanbari et al., 2007) because of low number of fruits per plant (which was equal to one fruit per plant). As a result, the highest seed yield was obtained when a combination of vermicompost and nanofertilizer was used, which was the best possible result with regard to the above limitations in *Cucurbita pepo* L.

Fruit yield

According to the combined analysis of variance showed that the effects of vermicompost, nanofertilizer, vermicompost – nanofertilizer interaction and vermicompost – mycorrhiza – nanofertilizer interaction were significant on fruit yield (Table 3). The mean comparison results relevant to the fruit yield in different levels of vermicompost, nanofertilizer, combination of vermicompost and nanofertilizer, and combination of vermicompost, mycorrhiza and nanofertilizer showed that minimum fruit yield (5.8 t ha^{-1}) belonged to V0M0N0 (control). The maximum fruit yield (24.5 t ha^{-1}) belonged to V2N2 (use of 20 t ha^{-1} vermicompost with a foliar spray of 4% nanofertilizer) (Tables 5 and 6; Figure 1b). In *Cucurbita pepo* L., the fruit yield per unit area is calculated by multiplying the number of fruits per plant and fruit weight. Since the number of fruits per plant in all treatments was constant, the fruit yield was found to be equal to fruit weight.

Fruit diameter

The fruit diameter represents the size and volume of the fruit and is directly associated with the fruit weight. The effects of vermicompost, nanofertilizer, vermicompost-nanofertilizer interaction, vermicompost-mycorrhiza-nanofertilizer interaction, and year-vermicompost-mycorrhiza-nanofertilizer interaction were significant on this trait (Table 3). The highest fruit diameter (15.68 cm) belonged to V2M0N2 (using 20 t ha^{-1} vermicompost with a foliar spray of 2% nanofertilizer without mycorrhiza), and the least fruit diameter (10.29 cm) belonged to the control (V0M0N0) (Table 6). Increased fruit diameter using nanofertilizer and vermicompost can be attributed to favorable plant growth, and consequently, the production of more photosynthetic materials, and more cellular division in the fruit. Studying the changes in fruit diameter in double and triple interactions showed that the fruit diameter was significantly increased when more vermicompost (20 t ha^{-1}) was used. This represents more contribution of vermicompost than nanofertilizer in increasing fruit diameter. On the other hand, the fruit diameter was more significantly increased in the simultaneous use of vermicompost and nanofertilizer (V2M0N1) than the separate use of vermicompost and nanofertilizer. It can be concluded that *Cucurbita pepo* L. better reacted to the simultaneous use of vermicompost and nanofertilizer. The significant interaction of year, vermicompost, mycorrhiza and nanofertilizer on fruit diameter showed that fruit diameter was not stable during climatic changes within the two studied years. It was reported that fruit diameter was higher in the second year compared to the first year due to better climatic conditions.

Oil content

The combined analysis of variance showed that this trait was not affected by any treatment (Table 3). Aghaee and Ehsanzadeh (2012) attributed the significant effect of various treatments on this trait to high heritability and less effect of environmental factors.

Oil yield

On the basis of the combined analysis of variance (Table 4) showed the significant effect of vermicompost and interaction of vermicompost and nanofertilizer on oil yield ($P \leq 0.05$). Maximum oil yield (190.16 kg ha^{-1}) belonged to V2N1 and minimum oil yield (37.72 kg ha^{-1}) belonged to

Table 7. Analysis of combined effect of mycorrhiza, vermicompost and nanofertilizer on fatty acid percent in *Cucurbita pepo* L.

Source of variation	Degree of freedom	Mean squares			
		Linoleic acid (%)	Oleic acid (%)	Stearic acid (%)	Palmitic acid (%)
Year	1	0.27ns	5.99ns	2.92ns	0.39ns
Repetition (year)	4	9.95	2.31	7.83	11.91
Vermicompost	2	110.72**	170.72**	4.57ns	16.81ns
Year × vermicompost	2	2.75ns	7.45ns	0.03ns	1.48ns
Main error	8	7.09	3.98	4.35	10.76
Mycorrhiza	1	4.65ns	17.01ns	1.55ns	5.53ns
Year × mycorrhiza	1	0.17ns	0.02ns	0.55ns	0.09ns
Vermicompost × mycorrhiza	2	6.89ns	16.11ns	3.75ns	1.94ns
Year × vermicompost × mycorrhiza	2	0.32ns	1.78ns	0.14ns	1.74ns
Nanofertilizer	2	4.31ns	2.36ns	3.29ns	0.84ns
Year × nanofertilizer	2	0.74ns	1.49ns	0.87ns	0.20ns
Vermicompost × nanofertilizer	4	6.23ns	3.66ns	2.65ns	2.56ns
Year × vermicompost × nanofertilizer	4	0.38ns	0.86ns	0.24ns	0.53ns
Mycorrhiza × nanofertilizer	2	0.17ns	1.63ns	3.23ns	4.80ns
Year × mycorrhiza × nanofertilizer	2	1ns	0.88ns	0.15ns	0.21ns
Vermicompost × mycorrhiza × nanofertilizer	4	1.81ns	7.97ns	1.59ns	0.24ns
Year × vermicompost × mycorrhiza × nanofertilizer	4	0.94ns	0.80ns	0.06ns	0.57ns
Sub error	60	1.77	4.22	1.52	1.16
CV (%)		2.98	8.04	9.81	17.98

ns, * and ** represents no significance, significant at 5% and 1% respectively.

V0N0 (Table 5). The highest oil yield in this experiment was almost same as the conventional commercial production (202 kg ha^{-1}). Oil yield is calculated by multiplying oil content and seed yield (Aroyi et al., 2006). On the other hand, the oil content was not significantly different among the treatments. The highest oil yield belonged to the treatment with the highest seed yield when using vermicompost.

Active oil ingredients

The most important fatty acids composing 90% of oil content are linoleic acid, oleic acid, and palmitic acid among which 50% of fatty acids are linoleic acid (Fruhwirth and Hermetter, 2008). The combined analysis of variance within two years showed that vermicompost had a significant effect on the content of linoleic acid and oleic acid among all treatments ($P \leq 0.05$). However, vermicompost had no significant effect on stearic acid and palmitic acid content (Table 7). In addition, Shour Gashti et al. (2014) showed that vermicompost had a significant effect on determining the linoleic acid content at 1% level in *Cucurbita pepo* L. The mean comparison showed that the percentage of linoleic acid increased from 42.08% to 46.96% by increasing vermicompost appli-

Table 8. Effect of mycorrhiza, vermicompost and nanofertilizer on fatty acid content in *Cucurbita pepo* L.

Treatment	Mean squares			
	Linoleic acid (%)	Oleic acid (%)	Stearic acid (%)	Palmitic acid (%)
Year				
2014	44.36a	25.13a	12.36a	5.61a
2015	44.68a	25.75a	12.66a	6.20a
Vermicompost				
0	42.08c	23.16b	12.36a	5.80a
10 t ha^{-1}	44.35b	24.35b	12.38a	5.49a
20 t ha^{-1}	46.96a	28.82a	12.85a	6.02a
Nanofertilizer				
0	44.16a	25.40a	12.80a	5.90a
2 per thousand concentration	44.75a	26.07a	12.29a	6.18a
4 per thousand concentration	44.25a	25a	12.48a	5.77a
Mycorrhiza				
Using	44.76a	25.64a	12.48a	6.23a
Not using	44.35a	26.04a	12.57a	5.71a

Mean of each column with common letters had no significant difference based on Duncan's test at 5% level.

cation from zero to 20 t ha^{-1}. The same trend was observed in the case of oleic acid (an increase from 23.16% to 28.82% by increasing vermicompost application) (Table 8). An adequate amount of vermicompost increases fatty acids like linoleic acid and oleic acid due to the following reasons: fatty acids compose most part of oil content in *Cucurbita pepo* L., and vermicompost effectively increases the leaf area and photosynthesis rate, which leads to accumulation of more carbon in leaves. However, palmitic acid and stearic acid are saturated fatty acids with less fluidity compared to unsaturated fatty acids and are less affected by climatic conditions and nutrients such as vermicompost (Murkovich et al., 1999).

Conclusions

The results of this study indicated that the combination of vermicompost and nanofertilizer maximally increased most of the traits such as seed weight per fruit, seed yield, oil yield, fruit weight, fruit yield and fruit diameter in *Cucurbita pepo* L. In addition, these traits were significantly increased by increasing vermicompost up to 20 t ha^{-1}. It can be stated that the combined use of vermicompost and nanofertilizer supply better nutritional system and increased yield with no adverse environmental impacts arising from the use of chemical fertilizer. This issue contributes to sustainable agriculture. Therefore, it is recommended to use 20 t ha^{-1} vermicompost and foliar spray of nanofertilizer to increase the yield to an acceptable level in *Cucurbita pepo* L.

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Addresses of authors:
Seyyed Ali Razzaghifard[1,*], Abdolghayoum Gholipouri[2], Ahmad Tobeh[2] and Seyyed Reza mousavi meshkini[3]

[1] Ph.D. student in ecology crops, Department of Agronomy and Plant Breeding, Faculty of Agriculture, University of Mohaghegh Ardabili, Ardebil, Iran

[2] Associate Professor, Department of Agronomy and Plant Breeding, Faculty of Agriculture, University of Mohaghegh Ardabili, Ardebil, Iran

[3] Director manager Environment, Department of Environment, Ardebil, Iran

* Corresponding author; E-mail: razzaghifard@aftermail.ir Department of Agronomy and Plant Breeding, Faculty of Agriculture, University of Mohaghegh Ardabili, Ardebil, Iran, Tel.: 09141241618