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Original Article

Can vermicompost improve the yield and essential oil of chamomile (*Matricaria chamomilla* L.) more than N-chemical fertilizer?

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ABSTRACT

Intensive cultivation has led to a rapid decline in organic matter and nutrient levels besides affecting the physical properties of soil. The sustainability of production systems has become an important issue throughout the world. This study assessed the effects of nitrogen fertilizer and vermicompost on chamomile's qualitative and quantitative yield. The investigation was conducted at the Research Fields of Ran Company in Firouzkouh, Iran, in the spring of 2017. Treatments consisted of 1) Control, 2) 100% nitrogen from urea, 3) 100% nitrogen from ammonium nitrate, 4) 75% nitrogen from urea and 25% from vermicompost, 5) 75% nitrogen from ammonium nitrate and 25% from vermicompost, 6) 50% nitrogen from urea and 25% from vermicompost, 7) 50% nitrogen from ammonium nitrate and 25% from vermicompost, 8) 25% nitrogen from urea and 25% from vermicompost, 9) 25% nitrogen from ammonium nitrate and 25% from vermicompost and 10) 100% nitrogen from vermicompost. The results of this investigation showed that the maximum plant height (67.03 cm) and plant weight (93.21 g plant^{-1}) were obtained by 200 kg ha^{-1} urea. The application of 202.5 kg ha^{-1} ammonium nitrate + 1.5-ton ha^{-1} vermicompost, caused maximum flower diameter. The highest fresh flower yield (7539.45 kg ha^{-1}), dry flower yield (1715.93 kg ha^{-1}) and essential oil yield (6.95 kg ha^{-1}) were obtained in plots that received 135 kg ha^{-1} nitrate ammonium + 3-ton ha^{-1} vermicompost. It seems using vermicompost could enhance the quantitative and qualitative characteristics of chamomile.

1. Introduction

Chamomile (*Matricaria chamomilla* L.) is a plant from Asteraceae family (Mosleh et al., 2014; Dastgheibifard et al., 2014). Plant height ranges from 20 to 50 cm, according to the ecological conditions of the production region. Root system is short and widespread mainly in top 30 cm layer of soil (Sharafzadeh & Alizadeh, 2011). Because of medicinal properties, its production and consumption is of high interest in most countries (Baghalian, 200). The growth indices, flower yield and active substance of chamomile plants are affected by genetic background and environmental conditions. These attributes are strongly modified by many other factors and management skills such as using different kinds of fertilizers (Mosleh et al., 2014; Ghan et al., 2008).

In recent decades, production of agricultural crops has been mainly reliant on use of chemical inputs. This has resulted in environmental problems. One of the approaches to alleviate this problem is to use the strategies which are based on the principles of organic farming in agro-systems. In this system, synthetic inputs such as chemical fertilizers and pesticides are replaced with the use of crop rotation with pulse crops, plant debris, and different types of manures, organic and biological fertilizers. This results in control of weeds and pests and increase of biodiversity in the fields while conserving nutrients in the soil (Elsen, 2000).

Growth and qualitative characteristics of chamomile depend on management of nutrients (Emonger & Chweya, 1992; Heneka, 1993). Among the macro-elements, nitrogen has the most significant effect on growth characteristics of chamomile (Letchamo, 1992; Karami et al., 2008). Increasing concerns about the negative effects of chemical fertilizers have generated substantial interest in the use of other N sources (Pandey, 2005; Ashwini & Sridhar, 2006; Najm et al., 2012).

Despite the importance of nitrogen in production of field crops and medicinal plants, application of this nutrient element from chemical sources has resulted in environmental problems and pollution of the global ecosystem (Nikolova et al., 1999). One of the strategies to alleviate this problem is to use the methods which are based on the principles of organic farming in agro-systems (Elsen, 2000).

Sustainable agriculture aims at considerable reduction in application of chemical inputs by following the ecological principles and so it is regarded a proper solution to overcome the current agricultural problems (Darzi et al., 2012).

Conventional agriculture with focus on chemical fertilizers has caused rapid reduction in organic matter and fertility of soils. So, it is essential to apply proper production managements in order to improve physical, chemical and biological characteristics of soils (Liu et al., 2009).

Application of biofertilizers is among the approaches of crop fertilization to achieve the objectives of sustainable agriculture (Kapoor et al., 2004; Shaalan, 2005). Biofertilizers are the bacterial and fungal microorganisms and their metabolic compounds. Biofertilizers contain the conserving materials of high density derived from one or many helpful soil- borne microorganisms or their metabolites that form clones in root peripheral or plant internal sections and induce the host plant growth by numerous strategies (Omidi et al., 2009; Manaffee & Kloepper, 1994).

One of the most important biological fertilizers produced by earthworms (especially Eisenia foetida), is vermicompost. Vermicompost is rich in macro- and microelements that are in available forms for plants (Sadeghi et al., 2014). High microbial population and their diversity, containing plant growth regulators or hormones and large amounts of humic acids, are the advantages of vermicompost (Sadeghi et al., 2014; Heidarianpoor et al., 2014; Gutierez-Miceli et al., 2007). It has been reported that vermicompost could increase plant weight (Ali et al., 2007) and nutrient use efficiency (Chaoui et al., 2003). There are many reports on positive effects of vermicomost on field crops (Singh et al., 2008; Fernandez-Luqueno et al., 2010; Suthar, 2009; Najar & Khan, 2013).

Growth, yield and active substance of some medicinal plants such as basil (Anwar et al., 2005), garlic (Verma et al., 2013), fennel (Godara et al., 2014), chamomile (Dastgheibifard et al., 2014; Ansarifar et al., 2012) and roman chamomile (Sirousmehr et al., 2014) were increased by vermicompost application. This study was done to assess the effects of nitrogen fertilizer and vermicompost on qualitative and quantitative yield of chamomile.

2. Materials and Methods

2.1 Field experiment

The investigation was conducted at the Research Fields of Ran Company located in Firouzkouh (Latitude: 35° 45´ N; Longitude: 52° 45´E; Altitude: 1930m), Iran, in spring of 2017. Before seed sowing, soil of the experiment site was sampled randomly at top 0-30 cm layer of the field in crinkle method and analyzed at Khak Azmoon Pishahang laboratory located at Qom province (Table 1).

Table 1. Physical and chemical properties of the soil of experiment site

Soil Texture	ECe (dS/m)	pH	OC (%)	N (%)	P (ppm)	K (ppm)	ECe (dS/m)
Loamy-Clay	3.39	7. 6	0.65	0.055	10	300	3.39

The statistical design was a randomized complete block design (RCBD) with three replications. Treatments consisted of:

- Control
- 100% nitrogen from urea (200 kg ha-1)
- 100% nitrogen from ammonium nitrate (270 kg ha-1)
- 75% nitrogen from urea and 25% from vermicompost (150 kg ha-1 urea + 1.5 ton ha-1 vermicompost)
- 75% nitrogen from ammonium nitrate and 25% from vermicompost (202.5 kg ha-1 ammonium nitrate + 1.5 ton ha-1 vermicompost)
- 50% nitrogen from urea and 25% from vermicompost (100 kg ha-1 urea + 3 ton ha-1 vermicompost)
- 50% nitrogen from ammonium nitrate and 25% from vermicompost (135 kg ha-1 ammonium nitrate + 3 ton ha-1 vermicompost)
- 25% nitrogen from urea and 25% from vermicompost (50 kg ha-1 urea+4.5 ton ha-1 vermicompost)
- 25% nitrogen from ammonium nitrate and 25% from vermicompost (67.5 kg ha-1 ammonium nitrate + 4.5 ton ha-1 vermicompost)
- 100% nitrogen from vermicompost (6 ton ha-1 vermicompost)

The nitrogen requirement of chamomile is 90 kg ha^{-1} (Ghazi Manas et al., 2013). So, according to this value, treatments were calculated. Chemical analysis of vermicompost is presented in Table 2.

Table 2. Physical and chemical properties of the vermicompost applied in experiment

Acidity (pH)	Electrical Conductivity (dS/m)	Organic Carbon (%)	Organic Matter (%)	Total Nitrogen (%)	Phosphorous (%)	Potassium (%)
7	1.1	37.7	65	4.92	0.61	3.19

Vermicompost was applied to the top 5-10 cm layer of soil. Experimental plots were 3 × 2.25m. Seeds were obtained from Medicinal Plants Research Center, Isfahan, Iran. Seeds were sown on the rows with 30 cm spacing. 15-20 days after sowing, the plants were thinned to 10 cm distance between plants. Irrigation was done weekly.

2.2 Measurements

Measured traits included plant height (cm), flower head diameter (mm), plant weight (g $plant^{-1}$), flower yield (kg ha^{-1}) and essential oil percentage. Samplings were done on the middle rows in each plot.

Plant height was measured by a ruler at the flowering stage. Flower head diameter was measured using a vernier caliper. 1m2 of inner rows of each plot was harvested for calculating flower yield. Dry weight of flowers was measured after putting the plants at room temperature (25° C) for 72 h (Azizi et al., 2008).

Essential oil extraction was carried out at the IBB Laboratory, University of Tehran, using a Clevenger-type apparatus. Protocol of Letchamo and Marquard (2013) was used for measuring essential oil in the flowers. To determine the amount of essential oil, a sample of 100 g of flowers was mixed with 500 ml of tap water in a flask and the water was distilled for 3 h using a Clevenger-type apparatus. The oil content was measured by following the protocol of Letchamo and Marquard (1993), based on ml oil per 100 g dry matter of flower. Essential oil yield was obtained by multiplying essential oil percentage and dry flower yield.

SAS 9.1 software was used to analyze the data (SAS Inc., 2002). Means comparisons were carried out by Duncan's Multiple Range Test at 5% probability level. The results of analysis of variance showed that all the measured traits were significantly affected by the vermicompost and nitrogen fertilizer (Table 3).

4. Results

3.1. Plant Height

Chamomile plant height was significantly affected by various levels of treatments. The maximum height (67.03 cm) was obtained by using 200 kg ha^{-1} urea (Table 4).

3.2. Flower Head Diameter

Flower head diameter was significantly affected by treatments. Use of 198.75 kg ha^{-1} ammonium nitrate + 1.5 ton ha^{-1} vermicompost caused the maximum flower head diameter (Table 4).

3.3. Plant Weight

Fresh and dry weights of chamomile plants were significantly affected by treatments. The maximum fresh weight (93.207 g $plant^{-1}$) and dry weight (11.843 g $plant^{-1}$) were obtained when 200 kg ha^{-1} urea was used (Table 4).

Table 3. Analysis of variance for the measured traits of chamomile (*Matricaria chamomilla* L.).

S.O.V	df	Mean of squares: Plant Height	Plant Weight	Flower Head Diameter	Fresh Flower Yield	Dry Flower Yield	Essetial Oil Content	Essential Oil Yield
Rep.	2	148.80**	1610.01**	0.49	2130755.40	99558.29	0.0008933	0.20
Treat.	9	214.26**	819.26**	14.58*	6345953.11*	257575.20**	0.0209867**	7.48**
Error	18	15.99	49.08	5.71	1837899.01	59764.97	0.0004711	0.81
CV%		7.47	10.14	13.09	14.80	19.93	6.41	20.41

* and ** indicate significant differences at P-value<0.05 and P-value<0.01., respectively

Table 4. Mean comparison for treatment effects on measured traits of chamomile

Treatments	Plant Height (cm)	Plant Weight ($gPlant^{-1}$)	Flower Head Diameter (mm)	Fresh Flower Yield (kg ha^{-1})	Dry Flower Yield (kg ha^{-1})	Essetial Oil Content (%)	Essential Oil Yield (kg ha^{-1})
1	37.66 e	35.46 f	13.19 b	2346.11 c	661.60 d	0.21 f	1.38 e
2	67.03 a	93.21 a	18.52 a	5489.21 ab	1296.21 abc	0.33 c	4.23 cd
3	60.47 ab	77.14 bc	17.49 ab	5352.10 ab	1291.32 abc	0.30 cd	3.89 d
4	59.90 ab	70.69 bcd	16.78 ab	5564.72 ab	1320.11 abc	0.26 e	3.41 d
5	58.96 bc	70.38 cd	20.90 a	4706.84 b	1134.48 c	0.31 cd	3.49 d
6	58.73 bc	52.03 bc	20.19 a	6393.20 ab	1450.10 abc	0.28 de	4.05 cd
7	52.37 cd	83.65 ab	18.53 a	7539.45 a	1715.93 a	0.41 b	6.95 a
8	46.43 d	52.02 e	19.89 a	7243.96 ab	1614.18 ab	0.38 b	6.06 ab
9	47.16 d	66.87 cd	17.60 ab	5191.44 ab	1098.30 c	0.45 a	4.96 bcd
10	46.30 d	61.58 de	19.45 a	4812.27 b	1221.77 bc	0.46 a	5.64 bc

1) Control, 2) 100% nitrogen from urea (200 kg ha^{-1}), 3) 100% nitrogen from nitrate ammonium (265 kg ha^{-1}), 4) 75% nitrogen form urea and 25% from vermicompost (150 kg ha^{-1} urea + 1.5 ton ha^{-1} vermicompost), 5) 75% nitrogen form nitrate ammonium and 25% from vermicompost (198.75 kg ha^{-1} nitrate ammonium + 1.5 ton ha^{-1} vermicompost), 6) 50% nitrogen form urea and 25% from vermicompost (100 kg ha^{-1} urea + 3 ton ha^{-1} vermicompost), 7) 50% nitrogen form nitrate ammonium and 25% from vermicompost (132.5 kg ha^{-1} nitrate ammonium + 3 ton ha^{-1} vermicompost), 8) 25% nitrogen form urea and 25% from vermicompost (50 kg ha^{-1} urea + 4.5 ton ha^{-1} vermicompost), 9) 25% nitrogen form nitrate ammonium and 25% from vermicompost (66.25 kg ha^{-1} nitrate ammonium + 4.5 ton ha^{-1} vermicompost), 10) 100% nitrogen from vermicompost (6 ton ha^{-1} vermicompost).

3.4. Fresh and dry flower yield

Flower yields (7539.2 and 1715.9 kg ha^{-1} for fresh and dry yields, respectively) were maximum at 132.5 kg ha^{-1} ammonium nitrate + 3 ton ha^{-1} vermicompost (Table 4, Fig.1).

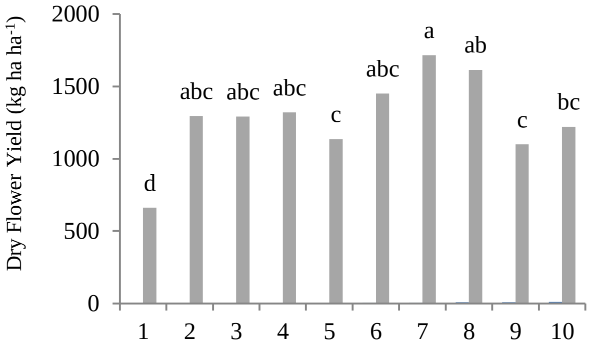

Fig. 1. Mean comparison for the effects of treatments on fresh flower yield.

3.5 Essential oil

Essential oil content was influenced by urea, ammonium nitrate and vermicompost application. The maximum essential oil yield (6.95 kg ha^{-1}) (Fig. 2) was obtained by using 6 ton ha^{-1} vermicompost.

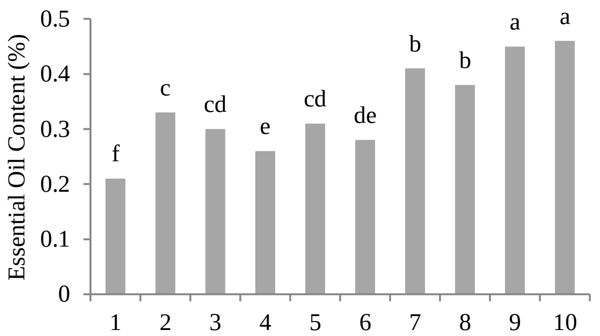

Fig. 2. Mean comparison for the effects of treatments on essential oil content in chamomile flowers.

4. Discussion

According to the results of this study, 200 kg ha^{-1} urea increased the plant height and plant weight. Organic amendments only release 30-35% of total nitrogen in the first growing season. It seems nitrogen uptake by plants from chemical sources is more than that from biofertilizers such as vermicompost (Ghazi Manas et al., 2013). Niknejad et al. (2013) found that nitrogen enhances vegetative growth and plant height of chamomile.

Results of research conducted by Zeinali et al. (2014) showed that nitrogen application had significant effect on the number of flowers per plant, number of auxiliary branches, and flower yield. Dadkhah et al. (2012) also found that nitrogen had a significant effect on plant height, number of flowers per plant, and dry flower yield of chamomile. The positive effect of nitrogen on root characteristics and essential oil content and chamazulene of chamomile has also been reported in other studies (Rahmati et al., 2009; Zeinali et al., 2008; Nikolova et al., 1999; Jadwiga Andrzejewska & Woropaj-Janczak, 2014). Application of biofertilizers such as vermicompost in a sustainable agriculture system improves the yield and quality of active ingredient in medicinal plants (Ratti et al., 2001; Sharma, 2002; Darzi et al., 2012; Kapoor et al., 2004). Azizi et al. (2008) studied the impact of different levels of vermicompost and irrigation on morphological traits and essential oil content of chamomile and found that increased level of vermicompost significantly improved the plant height, early flowering, flower yield and length and diameter of receptacle. Results of another research conducted on basil (*Ocimum basilicum* L.) revealed that application of vermicompost improved the yield and quality of essential oil content, essential oil yield and biological yield as compared with the control treatment (Anwar et al., 2005). Also, the results of research conducted on one of the species of Davana (*Artemisia pallens*) indicated that application of vermicompost significantly improved the essential oil yield as compared with the control treatment and this was due to the increase of dry matter content (Pandey, 2005). Arguello et al. (2006) also displayed the improved quality of garlic (*Allium sativum*) as a result of vermicompost application. Results of Chand et al. (2007) showed the increase of yield and quality of rose-scented geranium (*Pelargonium graveolens*) due to the application of vermicompost. Darzi et al. (2008) also indicated that application of 10 ton ha^{-1} vermicompost increased the essential oil contents in Fennel (*Foeniculum vulgare*). Similar results on the positive effects of vermicompost on garlic (Verma et al., 2013), coriander (Godara et al., 2014), chamomile (Ansarifar et al., 2012) and Roman chamomile (Sirousmehr et al., 2014) have been reported.

Using vermicompost and chemical nitrogen together resulted in maximum values which are in accordance with Fallahi et al. (2009). Vermicompost could increase plant growth and development by improving physical, chemical and microbial properties of soil (Fallahi et al., 2009).

Sanches Govin et al. (2005) reported that vermicompost is a main factor for increasing flower yield of chamomile and marigold. Findings of a research project on rose showed that integration of chemical nitrogen and vermicompost increases plant growth indices such as leaf area index, roots length and plant dry weight (Senthilkumar et al., 2004).

Essential oil is a terpenoid compound and its components (isoprenoids) such as Isopantyl pyrophosphate (IPP) and Dimethyl Alyl pyrophosphate (DMAPP) highly demand NADPH and ATP and the presence of elements such as nitrogen and phosphorous is necessary for formation of the latter compounds. Therefore, while interpreting the results of improved essential oil content caused by application of vermicompost, it could be stated that the increased vermicompost can increase the essential oil content of flower by increasing the absorption of nitrogen and phosphorous (Ghazi Manas et al., 2013).

Anwar et al. (2005) found that applying 5 ton ha^{-1} vermicompost along with 50, 25 and 25 kg ha^{-1} of N, P and K, respectively, increase essential oil percentage, essential oil yield and biological yield of basil. Other investigations have shown that vermicompost increases the essential oil of chamomile (Ansarifar et al., 2012; Haj Seyed Hadi et al., 2011).

5. Conclusion

Results of this investigation showed that the maximum plant height and plant weight were observed for using 200 kg ha^{-1}. Flower yield and essential oil yield of chamomile plants cultivated in soil amended with urea were minimum. The maximum values for these traits were recorded at plots which received 135 kg ha^{-1} ammonium nitrate + 3 ton ha^{-1} vermicompost. But, the maximum essential oil content obtained by applying 6 ton ha-1 vermicompost. The application of vermicompost had positive effect on essential oil and by increasing vermicompost, rate essential oil of flowers was increased.

It is obvious that in the case of chamomile (and of course all medicinal plants) the quality and thus the concentration of essential oil and its yield are much more relevant than the flower yield. As our results showed, essential oil content was maximum by applying 6 ton ha^{-1} vermicompost, while the maximum essential oil yield was related to 135 kg ha^{-1} ammonium nitrate + 3 ton ha^{-1} vermicompost.

Integration of vermicompost and ammonium nitrate fertilizer could increase growth, flower yield and essential oil of chamomile and have thus important roles for sustainable production of chamomile.

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