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ORIGINAL PAPER

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THE RESPONSE OF DIFFERENT FERTILIZER APPLICATIONS ON CHAMOMILE PRODUCTION AND THEIR QUALITY CHARACTERISTICS

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ABSTRACT

Chamomile is one of the well-known herbs in the world, with numerous medicinal, cosmetic and health benefits. In this study, a factorial experiment was conducted in a randomized complete block design technique to evaluate the three different dosses of nitrogen (N1 = 0, N2 = 50 and N3 = 100 kg·ha^{-1}) from urea 46%, and three different vermicompost dosses (V1 = 0, V2 = 4 and V3 = 8 t·ha^{-1}) and three different zeolite superabsorbent levels (S1 = 0, S2 = 50 and S3 = 100 kg·ha^{-1}) on flower yield and essential oil of chamomile in Kazeroon, Fars province in 2017. The results showed that increasing the amount of nitrogen and vermicompost increased the plant height, flower diameter, number of flowers, flower yield, essential oil content, biological yield and essential elements content of the Chamomile. In the interaction of N × V, the highest and lowest dry flower yields were observed in N3V3 (456 kg·ha^{-1}) and N1V1 (316.9 kg·ha^{-1}) treatments, respectively. The interaction showed that the highest and the lowest of essential oil content were observed in N3V3 (2.82 kg·ha^{-1}) and N1V1 (1.56 kg·ha^{-1}), respectively. The highest content of chamazulene compound were obtained in N2V3S3 treatments with 6.40% and the highest content of α-bisabolol oxide A related to N2V3 treatments with 53.50%. Based on the interaction results of N × V × S, the highest biological yield was observed in N3V2S3 with 2012 kg·ha^{-1}. The reason for the results can be due to the high moisture storage capacity of the superabsorbent and vermicompost, which can increase the availability of water consumption. In general, it seems that with increasing nitrogen and vermicompost ratios of soil, not only the nutritional availability of the plant (especially nitrogen, phosphorus and potassium) increased, but also the physical structure and vital processes of the soil by creating a suitable substrate for root growth – increased the production of chamomile flower yields.

Key words: superabsorbent, vermicompost, nitrogen, *Matricaria chamomilla*, essential oil yield

INTRODUCTION

At present, about 1/3 of the drugs used in human communities are medicinal plant origin. Therefore, pharmaceutical industries and affiliated research groups in many countries focus on the cultivation and production of medicinal plants [Kleinwächter et al. 2014]. Chamomile (*Matricaria chamomilla* syn. *M. recutita*) is one of the oldest and one of the well-known herbal medicines [Ghanavatifard et al. 2018]. This plant is one of the most expensive herbs in Europe, which is mainly cultivated in order to use its essential oil [Formisano et al. 2015]. Chamomile used to treat insomnia, gout, sciatica, indigestion and diarrhea and has a special place in the treatment of childhood diseases such as bloating, dental pain and childhood seizures [Park et al. 2017].

Improvements in production of medicinal and aromatic plant products are needed to meet increased

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market demands [Duc et al. 2015]. In order to achieve desired level of metabolites, correct nutrition of medicinal and aromatic herbs through organic methods as well as the combined method has a significant role in the essential oils of this group of plants [Moore et al. 2014]. Managing the essential nutritional elements of plants can be effective in the production of quality medicinal and aromatic herbs [Gopalakrishnan et al. 2016].

The use of organic or chemical fertilizers is necessary in order to achieve high yield in pharmaceutical products [Lim et al. 2015]. Correct and proper application of nutrients and elements during planting, growing and harvesting of medicinal plants, not only plays a major role in enhancing yield but also improves the quality and quantity of the active ingredients [Naguib et al. 2011]. Inappropriate use of chemical fertilizers has caused pollution of surface and underground water in many parts of the world [Qin et al. 2015]. The optimum application of nitrogen in medicinal plants is very important [Ranjbar et al. 2017]. Research has shown that 85 kg of potassium oxide, 53 kg of nitrogen and 21 kg of phosphorus oxide are absorbed from soil to produce 1,000 kilograms of flowers and 3,000 kilograms of vegetative organs [Hornok 1992]. Kariminejad and Pazoki [2015] showed that the highest performance of chamomile essential oil was obtained using 65 kg of pure nitrogen per hectare.

Today, organic fertilizers have been proposed as an alternative to chemical fertilizers in order to increase soil fertility in the production of the plant products in sustainable agriculture [Joshi et al. 2015]. Organic materials increase soil quality through improving soil structure, maintaining nutrition and biological activity [Lehmann and Kleber 2015, Paul 2016]. Given the emphasis of sustainable agriculture on improving the quality and sustainability of yield, in medicinal herbs that are quality products, vermicompost is a good option for this system and in such a condition, it seems to improve growth and yield.

The use of natural reformer compounds, such as super-absorbents in agricultural fields, has been used as a new way in order to increase the efficiency and preventing the loss of chemical fertilizers [Eroglu et al. 2017]. The structure of the superabsorbent, such as zeolite, is sufficiently open and it can accommodate water molecules similar to cations [Teotia et al. 2016]. Water molecules, as well as cations, can easily move inside the network, without changing the network structure. Because of its unique structure and features such as inert and non-toxicity, it is possible to use natural zeolites as Slow-down transporter for the release of chemical fertilizer elements [Ozbahce et al. 2015]. The use of natural materials such as zeolite improves the physical and chemical structure of the soil, increases water holding capacity in the soil for a long time reduces the use of chemical fertilizers and prevents environmental pollution [Lim et al. 2015]. Therefore, this research was carried out to investigate the effect of balanced nitrogen and vermicompost consumption with superabsorbent application on growth, yield and nutrients absorption in chamomile herb in Fars, Iran.

MATERIALS AND METHODS

This study was carried out in the Agricultural Research and Education Center of Kazeroon, Iran (29.6271°N, 51.6518°E) a factorial experiment based on randomized complete block design (RCBD) with 3 replications in 2017. The climatic traits and soil properties of the studied site were shown in Table 1 and 2.

Seed bed was prepared using plow and disk in late February, then the experimental plots were established. Each plot consists of six rows with 0.3 m distance between the rows. Each experimental unit was 3 m long and consisted of six rows spaced 0.3 m apart. Two m gaps were considered between blocks, and 1 m alley was established between each plot. The plant density of 33 plants per square meter was achieved by sowing seeds on the rows 10 cm.

The treatments included pure nitrogen at three levels (N1 = 0, N2 = 50 and N3 = 100 $kg \cdot ha^{-1}$) from urea 46% source, vermicompost at three levels (V1 = 0, V2 = 4 and V3 = 8 $t.ha^{-1}$) and zeolite superabsorbent at three levels (S1 = 0, S2 = 50 and S3 = 100 $kg \cdot ha^{-1}$). Chamomile seed (*Matricaria chamomilla* cv. Bodegold) used in this experiment was purchased from Pakan bazr Company in Isfahan, Iran. Vermicompost was provided from Zist Salem Kimia Company, (Tehran, Iran). The vermicompost characteristics were composed as the following: pH (7.70), EC (4.37 dSm^{-1}) and total organic carbon (1.82%). The natural superabsorbent used in this research was obtained from the

Table 1. Average temperature and precipitation of the studied site

Month	Minimum	Maximum	Mean	Total precipitation (mm)
April	13.2	30.9	22.1	101.2
May	6.8	20.4	13.6	23
June	5.8	17.3	11.6	145.3
July	5	17.5	11.3	29.4
August	10.3	24	17.2	10.1
September	11.5	24.9	18.2	35.8

Table 2. Physico-chemical properties of the soil in experimental region

Soil texture	SP (%)	pH	EC (dS/m)	Zn (mg/g)	Fe (mg/g)	P (mg/g)	K (mg/g)	N (%)	Oraganic carbon (%)
loam	52	7.50	0.63	0.78	4.2	15	345	0.08	1.02

Petrochemical Institute of Iran (Tehran). The superabsorbent and vermicompost were applied before sowing by hand and incorporated into the top 10 cm of the soil. Chemical N fertilizer (in chemical treatment, 125 and 225 kg ha^{-1} N as urea) was divided into two equal amounts and applied at two stages, sowing and at the four-leaf stage. The seeds were blended with the sand and cultivated during February. Irrigation operations performed once a day until the plant emergency. Weed control was carried out during the chamomile growth in three stages (20, 40 and 60 days after planting) mechanically. At 50% flowering stage (120 days after sowing), the fresh chamomile flowers were collected. At this stage, harvesting was performed from 2 m^2 of each plot weekly. Flowers were manually picked over 2–3 weeks period. Flower yield for each treatment was registered and final flower yield (sum of 3 harvesting) was calculated.

Plant height, flower head diameter, flower number, flower yield, biological yield, essential oil content and its yield, nitrogen, phosphorus, and potassium contents were measured at the full flowering stage (50% of flowers open).

Essential oil content and yield. To determine essential oil content, flowers were dried under shade and powdered using electric blender, then, samples (50 g, three replicates) were subjected to hydro-distillation for 3 h using an all glass Clevenger-type apparatus. The obtained aqueous essential oil was dehydrated by sodium sulfate (98%), followed by storage in airtight glass vials covered with aluminum foil at 4°C before the next analyses. Essential oil yield was result of multiplying percentage of essential oil in yield of flower.

Nutrient content. The last harvest (at the full flowering stage) was used to take samples for N, P, and K determination. 20 g of sample was taken from each plot. The plant samples were oven-dried at 75°C for 48 h and then powdered by an electric mill. Then, the total nitrogen was determined by the Kjeldahl method [Novozamsky et al. 1974]. Phosphorus was measured using the molybdate and vanadate, P content was determined using a 6505 JenWay spectrophotometer following colorimetrically method [Chapman et al. 1962], and total potassium (K^+) was measured via the Flame Photometric method (JENWAY PFP 7 Flame Photometer). This method is fully described in Hajiboland et al. [2010].

Gas chromatography–mass spectrometry analysis. Gas chromatography–mass spectrometry analysis was performed using an Agilent Technologies-5975C-MS, 7890A-GC system that fitted with a fused silica HP-5MS (30 m × 0.25 mm (ID) × film

Table 3. Analysis of variance (mean square) for different traits in chamomile medicinal herb

SOV	DF	Plant height	Flower diameter	flowers per plant	Flower yield	Biological Yield
Block (B)	21	3.636^{ns}	8.178*	0.481^{ns}	236.043^{ns}	184.975^{ns}
Nitrogen (N)	2	840.084**	87.529**	2042.019**	118155.354**	1440726.000**
Vermicompost (V)	2	133.142**	80.067**	857.352**	29005.381**	428580.690**
Superabsorbent (S)	2	4.105^{ns}	37.764**	43.556**	1141.129**	28508.910**
N × V	4	54.016**	0.524^{ns}	24.093*	3026.231**	28659.380**
N × S	4	16.032*	1.360^{ns}	4.352^{ns}	88.053^{ns}	10665.940*
V × S	4	6.857^{ns}	5.251*	21.546*	212.407^{ns}	34806.200**
N × V × S	8	6.739^{ns}	6.114**	7.079^{ns}	262.964*	6350.150^{ns}
Error	52	5.070	2.076	7.624	116.866	4357.350
CV (%)	–	5.061	7.250	4.471	2.692	4.716

ns, * and **: are non-significant and significant at 5 and 1% probability levels, respectively

Continue: Analysis of variance (mean square) for different traits in chamomile medicinal herb

SOV	DF	Essential oil content	Essential oil yield	Nitrogen	Phosphorus	Potassium	α-bisabolol oxide A	Chamazulene
Block (B)	2	0.006^{ns}	0.008^{ns}	0.193*	0.115**	0.002^{ns}	2.62^{ns}	0.73^{ns}
Nitrogen (N)	2	0.054**	7.917**	2.149**	0.188*	7.690**	39.76**	6.37**
Vermicompost (V)	2	0.056**	3.563**	0.586**	0.196*	5.672**	71.42**	0.94*
Superabsorbent (S)	2	0.002^{ns}	0.120^{ns}	0.034^{ns}	0.090^{ns}	0.187^{ns}	0.73^{ns}	1.88**
N × V	4	0.003^{ns}	0.160*	0.078*	0.041^{ns}	0.287*	31.38**	2.47**
N × S	4	0.009^{ns}	0.144^{ns}	0.050^{ns}	0.055^{ns}	0.132^{ns}	2.57^{ns}	0.49^{ns}
V × S	4	0.001^{ns}	0.026^{ns}	0.082*	0.046^{ns}	0.010^{ns}	5.84^{ns}	0.39^{ns}
N × V × S	8	0.004^{ns}	0.075^{ns}	0.013^{ns}	0.053^{ns}	0.125^{ns}	2.09^{ns}	0.75*
Error	52	0.003	0.064	0.025	0.049	0.086	2.78	0.27
CV (%)	–	10.992	11.150	14.516	19.282	13.208	3.24	9.98

ns, * and **: are non-significant and significant at 5 and 1% probability levels, respectively.

thickness 0.25 µm. The oven temperature was programmed as follows: from 60 (held isothermally for 2 min) to 210°C with ramp: 3°C/min then increased to 240°C with ramp 20°C/min and the final temperature kept for 8.5 min. Run time: 60 min. The election ionization energy was 70eV in the electronic ionization (EI) mode, ion-source: 230°C, detector: 290°C MS, interface line temperature: 280°C, injector: 280°C, split ratio: 1 : 50, He as the carrier gas (flow rate, 1 mL/min), mass range: 50–480 m/z. Gas chromatography–mass spectrometry (GC-MS) enables fast analysis, good separation and reliable quantitative and qualitative data [Rubiolo et al. 2008].

The data were analyzed using SAS software and the means were compared by LSD test at 5% probability level.

RESULTS

Plant height and flower diameter. The results showed that increasing the amount of nitrogen and vermicompost increased the plant height (Table 3 and 4) but the superabsorbent had no significant effect on plant height (Tab. 4).

The results also showed that increasing the amount of nitrogen, superabsorbent and vermicompost increased the flower diameter (Tab. 4). The highest diameter of flowers was observed in N1V3S3 and N3V3S2 treatments with 26.00 mm and the lowest in N1V1S1 and N2V1S2 treatments were 18.96 and 18.33 mm, respectively (Fig. 1 A).

Flower number and yield. Among all the quantitative traits studied in chamomile, flower yield is most important. The main effects of nitrogen, vermicompost and superabsorbent affected the number of flowers and the flower yield per plant. The results showed that increasing the amount of nitrogen, vermicompost and superabsorbent increased them (Tab. 4). In the interaction of N × V, the highest and lowest flower yields were observed in N3V3 (456 kg·ha^{-1}) and N1V1 (316.9 kg·ha^{-1}) treatments, respectively (Tab. 5).

Biological yield. Based on the interaction results of N × V × S, the highest biological yield was observed in N3V3S3, N3V3S1, N3V3S2 and N3V2S3 with 2012, 2065, 2097 and 2048 kg·ha^{-1}, respectively (Fig. 1 B). In contrast, the lowest biological activity was observed in N1V1S1 (control) with 1417 kg·ha^{-1}.

Essential oil yield, content and compositions

The results of mean comparison showed that with the increase of nitrogen and vermicompost, essential oil content increased. However, the main effect of superabsorbent had no significant effect on increasing the essential oil content (Tab. 4). In addition, the interaction of N × V showed that the highest and lowest of essential oil content were observed in N3V3 treatment (2.82 kg·ha^{-1}) and N1V1 (1.56 kg·ha^{-1}), respectively (Tab. 5). The major constituents of essential oil were α-bisabolol oxide A and chamazulen. The results of interaction effects showed that with increasing nitrogen and vermicompost content, α-bisabolol oxide A and chamazulen content were increased. Regarding the interaction effect of N × V × S had significant effect on chamazulen, and the interaction of N × V had significant effect on α-bisabolol oxide A (Tab. 3).

Table 4. Comparison of main effect of plant height, flower diameter, number of flowers per plant, flower yield and biological yield traits in chamomile medicinal herb

	Levels	Plant height (cm)	Flower diameter (mm)	Number of flowers per plant	Flower yield (kg·ha^{-1})	Biological yield (kg·ha^{-1})	Essential oil content (%)	Essential oil yield (kg·ha^{-1})	Nitrogen (%)	Phosphorus (%)	Potassium (%)
Nitrogen (kg·ha^{-1})	0	41.098 ^{c}	19.054 ^{b}	55.185 ^{c}	352.448 ^{c}	1257.930 ^{c}	0.534 ^{b}	1.906 ^{c}	0.922 ^{c}	0.131 ^{b}	1.881 ^{c}
	50	43.547 ^{b}	19.228 ^{b}	62.722 ^{b}	406.620 ^{b}	1362.590 ^{b}	0.555 ^{b}	2.271 ^{b}	1.078 ^{b}	0.177 ^{ab}	2.169 ^{b}
	100	48.817 ^{a}	21.341 ^{a}	67.370 ^{a}	445.589 ^{a}	1578.260 ^{a}	0.596 ^{a}	2.671 ^{a}	1.318 ^{a}	0.249 ^{a}	2.630 ^{a}
Vermicompost (t·ha^{-1})	0	43.085 ^{c}	18.707 ^{c}	58.185 ^{c}	377.798 ^{c}	1317.430 ^{c}	0.530 ^{c}	2.025 ^{c}	1.034 ^{b}	0.141 ^{b}	1.939 ^{c}
	4	44.193 ^{b}	19.778 ^{b}	61.037 ^{b}	402.756 ^{b}	1387.070 ^{b}	0.561 ^{b}	2.285 ^{b}	1.059 ^{b}	0.162 ^{b}	2.164 ^{b}
	8	46.184 ^{a}	21.137 ^{a}	66.056 ^{a}	424.104 ^{a}	1494.280 ^{a}	0.595 ^{a}	2.538 ^{a}	1.225 ^{a}	0.254 ^{a}	2.578 ^{a}
Superabsorbent (kg·ha^{-1})	0	44.325 ^{a}	19.357 ^{b}	61.611 ^{b}	396.326 ^{b}	1373.200 ^{b}	0.554 ^{a}	2.228 ^{a}	1.077 ^{a}	0.162 ^{a}	2.206 ^{a}
	50	44.332 ^{a}	19.426 ^{b}	60.944 ^{b}	403.363 ^{a}	1410.410 ^{a}	0.565 ^{a}	2.306 ^{a}	1.123 ^{a}	0.162 ^{a}	2.181 ^{a}
	100	44.806 ^{a}	20.839 ^{a}	62.722 ^{a}	404.969 ^{a}	1415.170 ^{a}	0.566 ^{a}	2.314 ^{a}	1.118 ^{a}	0.233 ^{a}	2.293 ^{a}

At α = 5% based on LSD, means with similar letter in each column are not significantly different

The results of current study showed that increasing application of vermicompost and nitrogen tended to result in increased α-bisabolol oxide A and chamazulene concentration, the highest content of chamazulene compound were obtained in N2V3S3 treatments with 6.40% and the highest content of α-bisabolol oxide A related compound to N2V3 treatments were 53.50% (Fig 2 A and B6).

Nitrogen, phosphorus and potassium. The results of main effects showed that with increasing nitrogen and vermicompost content, nitrogen, potassium and phosphorus content were increased. Regarding the interaction effect of N × V, the highest nitrogen content was observed in N3V1, N3V2 and N3V3 treatments with 1.32, 1.26 and 1.36% respectively and the highest rates of potassium related to N3V3 treatments were 2.8% (Tab. 5). Regarding the interaction of S × V (Tab. 6), the highest nitrogen content was related to S3V3 treatments with 1.3%.

DISCUSSION

In the present study, increasing the amount of nitrogen, superabsorbant and vermicompost increased the flower diameter with 0.37 compare to control. Many researchers showed that using nitrogen, superabsorbent and vermicompost increased the flower diameter that was consistent with the results of this experiment [Bichsel et al. 2008, Hadi et al. 2011, Hoover et al. 2012, Salehi et al. 2018, Gholami et al. 2018, Kisić et al. 2019, Giannoulis et al. 2020]. The results showed that the interaction of nitrogen and vermicompost increased the amount of plant height, number of flowers per plant, flower yield, essential oil yield, nitrogen and potassium by 31, 38, 43, 80, 73 and 92%, respectively, compared to the control.

Under the same environmental conditions, providing nutrients for the plant by different fertilizers can increase plant growth and subsequently increase plant height [Adesemoye et al. 2009]. Rahmati et al. [2011] in a study on chamomile plant said that the increase in nitrogen levels increases the flower yield, which is consistent with the results of this study. Different researchers have reported that that the effect of nitrogen fertilizer on the yield was increased with increasing the amount of photosynthesis and carbohydrate storage [Tamagno et al. 2018, Chen et al. 2019]. The results of the present experiment showed that the interaction of superabsorbent and vermicompost increased the amount of plant height, number of flowers per plant, nitrogen and flower yield by 7, 13, 26 and 15%, respectively, compared to the control.

Regarding the interaction of superabsorbent with vermicompost on flower yield (Tab. 6), it can be said that application of vermicompost with superabsorbent, by improving the physicochemical structure of soil such as increasing water absorption and nutrients, especially nitrogen and potassium, can increase the flower yield. In addition, adding superabsorbent to vermicompost seems to prevent nitrogen loss during mineralization process and these nutrients are gradually released and used at the right time and during the plant growth period [Lim et al. 2015, Nigussie et al. 2016, Sharma et al. 2017, Zheng et al. 2018].

It was also observed that with increasing nitrogen, vermicompost and superabsorbent, the biological yield increased, by 32% compared to control. The reason for this result can be due to the high moisture storage capacity of the superabsorbent, which can increase the quality and quantity of available water to the plant [Wu et al. 2016, Hazrati et al. 2017, Zheng et al. 2018]. It can be stated that superabsorbent polymer, by preserving water and preventing stress, increase the performance of the vegetative organs in chamomile. On the other hand, organic fertilizers, by supplying microelements and macroelements, improvement of physical, chemical and biological properties of soil, increasing water-holding capacity in soil, proper development of root system of the plant by improving soil structure and increasing soil porosity, enhancement and absorption and transfer of minerals, cause more plant growth [Jannoura et al. 2014, Glaser et al. 2015, Lim et al. 2015, Kammann et al. 2015].

The results of this study showed that increase in vermicompost application (0 to 10 $t \cdot ha^{-1}$) and nitrogen (0 to 100 $kg \cdot ha^{-1}$) significantly enhanced the essential oil yield of the chamomile by 44% compared to control. Increase in flower and branches increase the yield of essential oil [Chrysargyris et al. 2016, Stefanaki et al. 2016]. The presence of sufficient water due to the presence of the superabsorbent polymer also increases vegetative growth, followed by an increase in the essential oil content and yield. The results of this study are consistent with the results of

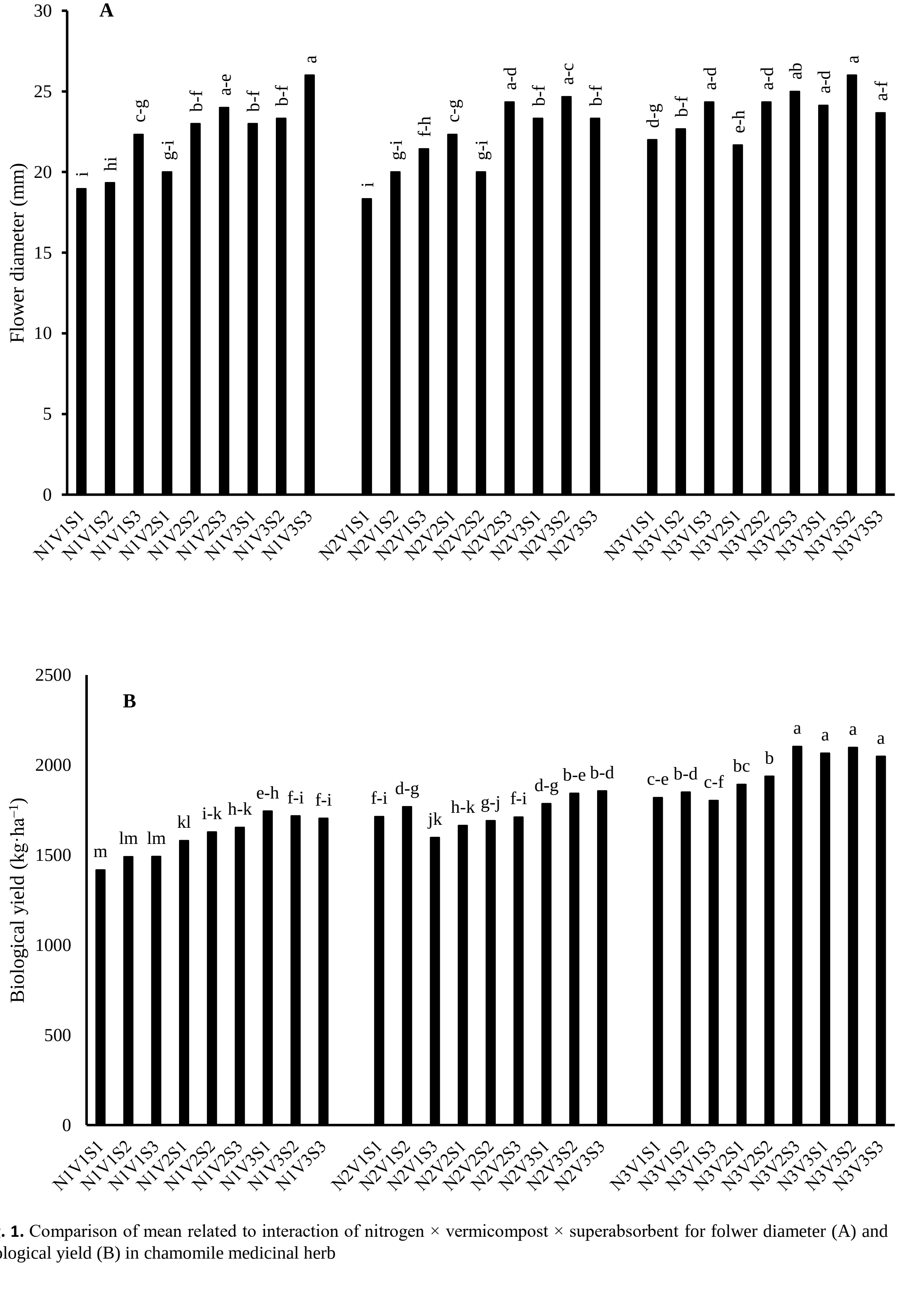

Fig. 1. Comparison of mean related to interaction of nitrogen × vermicompost × superabsorbent for folwer diameter (A) and biological yield (B) in chamomile medicinal herb

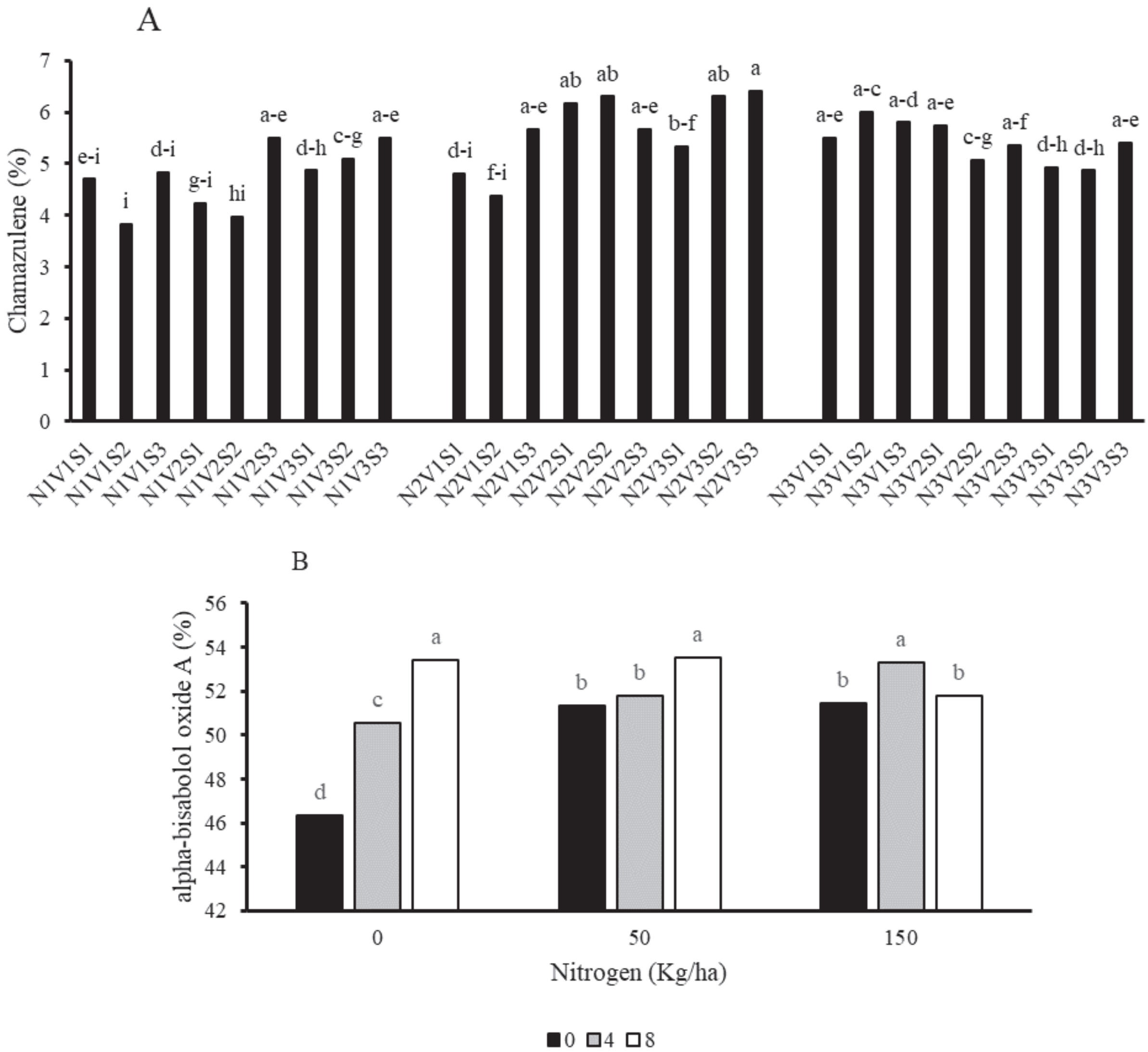

Fig. 2. Comparison of mean related to interaction of nitrogen × vermicompost × superabsorbent for chamazulene (A) and interaction of nitrogen × vermicompost for α-bisabolol oxide A (B) in chamomile medicinal herb

other studies and show that water scarcity reduced essential oil yield in these plants [Govahi et al. 2015, Salehi et al. 2018]. In addition, a study by Rahmati et al. [2011] showed that increasing the application of nitrogen fertilizer increased the amount of essential oil content in this plant.

Emongor et al. [1990] stated that the essential oil of chamomile increases with increasing nitrogen or phosphorus fertilizers. Nitrogen plays an important role in the development and division of new cells containing essential oil and biosynthesis of essential oils and active ingredients of medicinal plants. Therefore, it can be stated that the use of nitrogen fertilizer and the use of condensed matter. Such as superadsorbents that absorb nutrients and gradually are available to the plant, as well as the use of vermicompost by providing photosynthesis and producing these compounds, increased the essential oil in the plant than the control

Table 5. Comparison of mean related to interaction of vermicompost × nitrogen for plant height, flower yield, number of flowers per plant, essential oil yield, nitrogen and potassium in chamomile medicinal herb

Nitrogen ($kg\cdot ha^{-1}$)	Vermicompost ($t\cdot ha^{-1}$)	Plant height (cm)	Number of flowers per plant	Flower yield ($kg\cdot ha^{-1}$)	Essential oil yield ($kg\cdot ha^{-1}$)	Nitrogen (%)	Potassium (%)
0	0	37.710 d	51.167 g	316.928 f	1.561 f	0.793 e	1.472 d
	4	40.820 c	54.500 f	354.128 e	1.903 e	0.896 de	1.850 c
	8	44.750 b	59.889 de	386.289 d	2.252 cd	1.078bc	2.322 b
50	0	42.910bc	58.111 e	379.444 d	2.002 de	0.987 cd	1.894 c
	4	43.580bc	62.500 cd	410.394 c	2.275 cd	1.016 cd	2.041 c
	8	44.140 b	67.556 b	430.022 b	2.536bc	1.230 ab	2.572 ab
100	0	48.620 a	65.278bc	437.022 b	2.511bc	1.322 a	2.450 b
	4	48.170 a	66.111 b	443.744 ab	2.676 ab	1.265 a	2.600 ab
	8	49.650 a	70.722 a	456.000 a	2.827 a	1.368 a	2.839 a

At α = 5% based on LSD, means with similar letters in each column are not significantly different

Table 6. Comparison of mean related to interaction of vermicompost × superabsorbent for plant height, number of flower per plant and nitrogen in chamomile medicinal herb

Vermicompost ($t\cdot ha^{-1}$)	Superabsorbent ($kg\cdot ha^{-1}$)	Plant height (cm)	Number of flowers per plant	Nitrogen (%)	Flower yield ($kg\cdot ha^{-1}$)
0	0	43.028 b	59.333bc	1.032 c	372.844 e
	50	43.006 b	56.278 d	1.019 c	382.922 de
	100	43.222 b	58.944 cd	1.050 c	377.628 e
4	0	43.283 b	59.944bc	1.071bc	398.811 cd
	50	44.378 ab	61.111bc	1.106bc	401.050 cd
	100	44.917 ab	62.056bc	1.000 c	408.406bc
8	0	46.663 ab	65.556 a	1.129 a–c	417.322 a–c
	50	45.611 ab	65.444 a	1.244 ab	426.117 ab
	100	46.278 a	67.167 a	1.303 a	428.872 a

At α = 5% based on LSD, means with similar letters in each column are not significantly differe nt

[Sangwan et al. 2001, Bakkali et al. 2008, Amiri et al. 2017, El Gendy et al. 2017].

Results showed that with using of vermicompost and nitrogen, the content of nitrogen and potassium increased by 42 and 45%, compared to control, respectively. P uptake is highly affected by vermicompost and nitrogen, the application of 10 $t\cdot ha^{-1}$ vaemicompost and 100 kg^{-1} N increased by 44 and 45% in compared to control, respectively. Organic fertilizers will balance the soil in a long time, by having the required macro-elements and the smaller amount of microelements [Ravindran et al. 2016, Alinian et al. 2016, Joshi et al. 2016]. Moreover, it seems that adding vermicompost to the soil not only increases nutrients availability directly, but also operates as a slow-release fertilizer to provide N, P and K to the chamomile steadily [Salehi et al. 2016], Studies have shown that consumption of superabsorbent polymers, nitrogen and vermicompost, by maintaining water, increase the essential oil yield of the salvia herb [Govahi et al. 2015]. The results showed that nitrogen and vermicompost increased, the synthesis of chamazulen and α-bisabolol oxide A increased by 13.5 and 41%, compared to control, respectively. Chamazulene and α-bisabolol oxide A are terpenoids with anti-inflammatory properties. According to Ghavimi et al. [2012] report, chamazulene is an anti-oxidant-type inhibitor which strongly suppresses the formation of leukotriene B4 in intact cells.

Irrespective of management and environmental factors effects on essential oils quantity and quality, several reports have indicated that environmental conditions had no, or only slight, effect on chamazulene contents. According to reports, chamazulen and α-bisabolol oxide A are the most important secondary metabolite [Mohammad and Hamid et al. 2010, Salehi and Hazrati 2017]. The essential oil is terpenoid compounds that need N and P for their biosynthesis. The role of N in terpenoids biosynthesis is well documented as N increases photosynthesis rate then affect terpenoid compounds biosynthesis by supplying required C through photosynthesis [Niinemets et al. 2002, Salehi et al. 2018]. Also, the presence of vermicompost increases the amount of water in the environment around the roots and the water is gradually provided to the roots during the growth period of the plant. On the other hand, photosynthesis plays an important role in the production of primary metabolites, which are essential for the production of secondary metabolites. Therefore, with the presence of vermicompost and due to maintaining better conditions for photosynthesis, the amount of α-bisabolol oxide A and chamazulen metabolites increased. A number of researchers have pointed to the role of vermicompost in increasing photosynthetic capacity as well as the synthesis of secondary metabolites [Salehi et al. 2018].

CONCLUSION

Application of suitable amounts of superabsorbent, vermicompost and nitrogen improved biological activity of soil and fertility and optimum absorption of nutrients by the plant, by improving the components of yield. Increasing vermicompost levels affect the absorption capacity, maintaining high levels of moisture and nutrients such as nitrogen, phosphorus and potassium on increasing plant components such as height, number of flowers per plant, flower diameter and biological yield and therefore improve flower performance. The highest content of essential oil content related to N3V3 (2.8 $kg \cdot ha^{-1}$) treatment. In addition, the highest biological yield was obtained in N3V3 and all three superabsorbent levels. Regarding the increase in flower yield, with increasing the levels of vermicompost, it seems that with increasing vermicompost to soil, not only the nutritional availability of the plant (especially nitrogen, phosphorus and potassium) increased, but also vermicompost, with improving the physical structure and vital processes of the soil, by creating a suitable substrate for root growth, increased the production of flower yields. Also, the results of this experiment showed that the use of vermicompost and nitrogen played a very important role in increasing the amount of α-bisabolol oxide A and chamazulene secondary metabolites.

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CONFLICT OF INTEREST

All authors declare that they have no conflicts of interest.

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