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The Effects of Amino Acid and Organic Fertilizers on Some Growth Characteristics and Yield of Dragonhead (*Dracocephalum moldavica* L.)

Leila Pirahmadi[1], Yousef Nasiri[*1], Mohammad Reza Morshedloo[2], Farzad Rasouli[2]

[1]*Department of Plant Production and Genetics, Faculty of Agriculture, University of Maragheh, Maragheh, Iran*
[2]*Department of Horticultural Science, Faculty of Agriculture, University of Maragheh, Maragheh, Iran*

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ABSTRACT

The present experiment evaluated the influence of L-phenylalanine and different organic fertilizer resources on growth, yield, and essential oil production in Dragonhead. The field experiments were conducted in a factorial based on a Randomized Complete Block Design with three replicates at the University of Maragheh, East Azarbaijan Province, Iran during 2018-2019. The experimental treatments were arranged as the application of fertilizer resources at four levels of the chemical, poultry manure, municipal waste compost, and vermicompost as the first factor and the foliar application of L-phenylalanine at four levels of 0, 50, 100, and 150 mM as the second factor. Results showed that the growth characteristics in Dragonhead plants were significantly improved under foliar application of higher doses of L-phenylalanine (50 and 100 mM), which was revealed by a higher dry matter yield. The highest dry matter yield and essential oil yield were observed for the plants treated with municipal waste compost and vermicompost compared to the plants treated with chemical fertilizer and poultry manure. The application of 100/150 mM L-phenylalanine along with vermicompost in the first year produced the highest dry matter yield (481/531 $g.m^{-2}$). The highest percentage of essential oil was observed under 150 mM of phenylalanine + chemical fertilizer (0.58 %) and 50 mM of L-phenylalanine + vermicompost (0.55%) in the first year. As a result, fertilizing with organic manures and L-phenylalanine can increase the dry matter and essential oil production, and improve the yield of dragonhead.

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1. Introduction

Excessively favorable application of chemical fertilizers in agroecosystems has led to environmental problems in recent decades, as a result, the product's quality and quantity have been severely affected and sustainable production has been challenged (Niu *et al.*, 2021). Organic fertilizers are effective in increasing plant growth and productivity by improving soil organic matter, structure, and microbial activities, and hence these fertilizers can be a suitable alternative to chemical fertilizers in agricultural production systems (Verma *et al.*, 2020; Liu *et al.*, 2024). According to several studies, medicinal plants' production quantity and quality have improved under organic nutrition. It has been reported that dry matter and essential oil (EO) production and some compounds of basil essential oil were improved with the application of organic fertilizers (Singh *et al.*, 2014). According to Bajeli et al. (2016), EO production and menthol contents in Japanese mint (*Mentha arvensis* L.) were enhanced under livestock and poultry manure application.

Biostimulators as organic substances are used to stimulate plant growth, improve nutrient absorption, and increase plant resistance against environmental stresses (Ghatas *et al.*, 2021). Amino acids, which are known as biostimulators, are nitrogenous compounds that are involved in the structure of proteins, enzymes, and plant growth regulators (Shokunbi *et al.*, 2012). There are different roles for amino acids in plants such as improving nutrient availability, stimulating germination, chlorophyll and auxins synthesis, defense mechanisms, cell division, and hormone metabolism

[*] Corresponding author.
E-mail addresses: ysf_nasiri @maragheh.ac.ir; ysf_nasiri@yahoo.com

(Popko *et al.*, 2018; Trovato *et al.*, 2021). Nowadays, the external use of biostimulators based on amino acids has been identified as a new way to supply some nutrients and increase plant performance. Sowmya et al. (2023) found that the use of amino acids in coriander led to increases in chlorophyll, carotenoid, and linalool contents. It is reported that the application of some amino acids had positive impacts on EO in mint (Velička *et al.*, 2022) and basil (Reham *et al.*, 2016).

Dragonhead (*Dracocephalum moldavica* L.) belongs to the Lamiaceae family and its EO has many uses in the food, pharmaceutical, and health industries (Martinez-Vazquez *et al.*, 2012). This plant has antioxidant, antimicrobial, sedative, antidepressant, antinociceptive, neuroprotective, and cardioprotective properties (Zúñiga *et al.*, 2019; Nie *et al.*, 2021). Active substances (secondary metabolites) of medicinal plants are significantly influenced by their genetic characteristics, agronomic management, and climatic conditions where the plants grow (Emami Bistgani *et al.*, 2018; Nasiri, 2021; Tursun, 2022; Nasiri *et al.*, 2024).

Considering the global tendency to produce medicinal plants in a sustainable and low-input production system and the lack of sufficient information regarding the reaction of medicinal plants to other sources of fertilizers and biostimulants, this study aimed to investigate the effect of different sources of organic fertilizers and L-phenylalanine on some growth characteristics, yield, and essential oil production of dragonhead.

2. Materials and methods

2.1. Study area and experimental treatments

This experiment was carried out at the Research Farm of the University of Maragheh, Maragheh, East Azerbaijan province, Iran (37˚23′N, 46˚16′E and 1485 m. a. s. l.) in two crop years of 2018 and 2019. According to the Koppen-Geiger climate classification, Maragheh has moderate climate conditions with a dry summer. Some weather data during the performance of this experiment is presented in Fig. 1. The farm soil had a sandy-clay loam texture, and some of its chemical features (soil depth of 0-30 cm) are shown in Table 1. This research was conducted in a factorial experiment with three replications based on randomized complete blocks design (RCBD). The fertilizers of chemical (CF), poultry manure (PM), municipal waste compost (MWC), and vermicompost (V) were considered as the first factor, and the L-phenylalanine was arranged in four concentrations of 0, 50, 100, and 150 mM as the second factor.

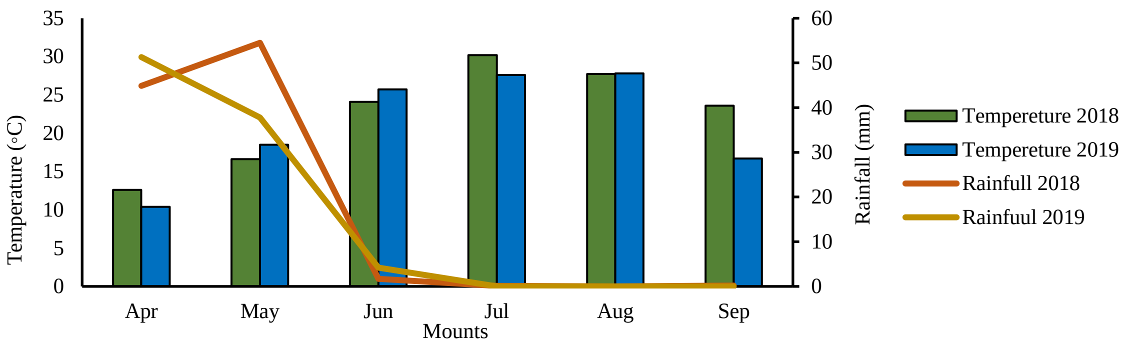

Figure 1. Monthly average temperature and precipitation during the months of the experiment in 2018 and 2019.

Table 1. Texture and some chemical properties of the soil at site of this experiment.

Texture	Total N (%)	Available P (mg kg^{-1})	Exchangeable K_2O (mg kg^{-1})	EC (dS m^{-1})	pH	OC (%)
sandy-clay loam	0.02	5.65	345	0.69	7.75	0.22

2.2. Experimental implementation

After initial preparation of the soil, 48 plots (each plot: 2.5 × 3 m^2) were prepared. Five rows (50 cm apart) were considered in each plot. A distance of 2 m between plots and a distance of 0.5 m between blocks were considered. According to the results of soil and organic fertilizers analyses (Tables 1 and 2), Urea (equivalent to 200 kg.ha^{-1} of pure nitrogen) and Triple Superphosphate (equivalent to 100 kg.ha^{-1} of pure phosphors) were used as chemical fertilizers. The consumption amounts of organic fertilizers (PM, MWC, and V) were 8, 10, and 15 t.ha^{-1}, respectively. Organic fertilizers were used one month before planting. The phosphorus was applied at the sowing time and nitrogen was applied during seedling emergence, stem elongation, and before flowering.

Table 2. Chemical properties of organic fertilizers used in this experiment.

Organic fertilizer	N	P	K	Ca	OC	Zn	Mn	Fe	Cu	pH	EC
	%					ppm					(dS m^{-1})
Vermicompost	1.3	0.89	0.63	2.15	14.6	535	671	1364	97	7.9	6.63
Poultry manure	2.5	1.62	3.2	3.2	27	550	1500	5900	90	7.56	9.78
Municipal waste compost	2.0	1.05	0.9	4.1	21.5	162	335	5800	31	7.2	7.73

N: Nitrogen, P: Phosphorus, K: Potassium, Zn: Zinc, Mn: Magnesium, Fe: Iron, Cu: Copper, OC: Organic Carbone, and EC: Electrical conductivity.

2.3. Plant material and evaluation of traits

Seeds of a local dragonhead (*Dracocephalum moldavica* L.) variety, were used for planting. The sowing operation was done on May 14-15 in both years. The distance between the plants was considered 10 cm. After planting, to facilitate seed germination and seedling emergence, sandy soil was manually spread on the surface of the plots. The drip irrigation method was used to irrigate the plots. Light irrigation was performed every other day until the seedlings emerged, and then once a week until harvest. Weeds were manually controlled as needed during the growing period. During the experiment, no pest or disease threatened the plants.

The L-phenylalanine was applied two times (the beginning of the stem elongation period and the beginning of flowering) as a foliar application method on dragonhead plants. Foliar spraying with distilled water was considered as the control. The characteristics of plant height (PH; cm), number of branches (NB), number of inflorescences (NI), number of leaves (NL) (per plant), inflorescence dry weight (IDW; g per plant), dry matter yield (DMY; gm^{-2}), EO content (EOC; %), and EO yields (EOY; gm^{-2}) were evaluated in this research. At the flowering stage, three middle rows of each plot were considered for sampling and harvesting of plants. A dry, shaded, and ventilated place was considered for drying the collected samples. The dried samples were weighed and their weight was recorded as dry matter yield. Extraction of essential oil was carried out using a Clevenger apparatus and steam distillation method. Fifty grams of dried plant samples were extracted for 2.5 hours in the Clevenger. The percentage of extracted EO (based on weight) was calculated and after multiplying the essential oil percentage and the dry matter yield, the essential oil yield was also obtained.

2.4. Statistical data analysis

A statistical analysis system (SAS) software package (version 9. 3) was applied to the analysis of variance (ANOVA). The least significant difference (LSD) was used to compare the means.

3. Results and discussion

3.1. Morphological and growth traits

According to ANOVA (Table 3), the plant height was significantly ($p<0.05$) affected by fertilization and amino acid. Means comparison (Table 4) showed that the plants treated with vermicompost showed a higher plant height than those treated with PM and CF. On the other hand, the plants were foliar applied with L-phenylalanine at concentrations of 100 and 150 mM. The values were 16% and 19.3% higher than those of the control plants, respectively. The number of branches (NB) was significantly ($p<0.05$) affected by amino acid and the interaction of year and fertilizer (Table 3). The application of L-phenylalanine (100 and 150 mM) significantly increased the NB by an average of 19.5% compared to the non-application of amino acids. Results also showed that the plants that were treated with vermicompost in the first year had the highest NB (Table 5).

The amino acid, interaction of fertilizer × amino acid, and the interaction of fertilizer × year significantly affected the number of inflorescences. The highest NI were obtained with the use of 50/150 mM of L-phenylalanine + V and with the use of 100 mM of L-phenylalanine + CF (Fig. 2). The lowest NI was obtained with the application of CF without amino acid foliar application. Results (Table 5) also disclosed that the highest NI was gained with V and MWC applications in the first year (2018). The amino acid and the interaction of year and fertilizer had significant effects on the number of leaves (Table 3). The comparison of the means (Table 4) discovered that the application of L-phenylalanine with concentrations of 100/150 mM significantly increased the NL by an average of 19.9% compared with the control. The highest NL (90.7 per plant) was also observed under vermicompost in the first year, with an increase of 22% compared to the other treatments (Table 5).

Table 3. Analysis variance for the traits of dragonhead under fertilizers and amino acid application.

SOV	df	Plant height	Number of branches	Number of inflorescences	Number of leaves	Inflorescence dry weight	Dry matter yield	Essential oil	Essential oil yield
Year	1	23.4^{ns}	2.69^{ns}	20.7^{ns}	18.8^{ns}	0.013	19408.6**	0.047*	0.094*
Error a	4	43.7	1.59	3.19	41.9	0.255	879.2	0.0056	0.115
Fertilizer (Fr)	3	51.5*	23.9^{ns}	42.2^{ns}	1274.1^{ns}	6.39^{ns}	27877*	0.0092^{ns}	0.783*
Amino acid (AA)	3	378.5*	14.8*	129.4*	1007.9**	3.57*	29628.3*	0.0707^{ns}	2.85*
Fr × AA	9	43.8^{ns}	0.505^{ns}	10.88*	20.99^{ns}	0.11^{ns}	705.5^{ns}	0.0028^{ns}	0.041^{ns}
Year × Fr	3	3.169^{ns}	16.4*	53.05**	487.5**	6.54**	2978**	0.0032**	0.077**
Year × AA	3	38.83^{ns}	1.516^{ns}	9.49^{ns}	27.68^{ns}	0.189^{ns}	3126**	0.0103**	0.117**
Year × Fr × AA	9	77.95^{ns}	0.328^{ns}	2.631^{ns}	41.65^{ns}	0.151^{ns}	1450**	0.0023**	0.034^{ns}
Error b	60	61.35	0.73	7.62	44.96	0.54	474.5	0.00045	0.017
CV (%)		14.91	9.13	9.01	8.83	12.78	5.35	4.93	7.45

* and ** indicate significance at the probability level of 5% (p<0.05) and 1% (p<0.01), respectively, and ^{ns} indicates non-significance. SOV refers to source of variance.

Table 4. Effect of fertilizers and amino acid application on traits of dragonhead.

Treatments	Plant height (cm)	Number of branches (per plant)	Number of inflorescences (per plant)	Number of leaves (per plant)	Inflorescence dry weight (g)	Dry matter yield (g.m^{-1})	Essential oil (%)	Essential oil yield (g.m^{-1})
Fertilizer								
Chemical fertilizer	51.6±1.9	10.4±0.2	32.1±0.9	70.1±1.9	5.3±0.21	378±8.9	0.44±0.02	1.7±0.07
Poultry manure	51.1±1.6	9.9±0.2	31.4±0.6	71.0±1.8	5.4±0.13	385±9.1	0.40±0.01	1.56±0.06
Municipal waste compost	53.1±1.7	8.9±0.3	29.6±0.8	77.4±1.8	6.0±0.15	419±8.2	0.43±0.02	1.77±0.08
Vermicompost	54.3±1.5	8.2±0.3	29.4±0.7	86.0±2.1	6.4±0.20	453±9.7	0.44±0.01	1.99±0.08
LSD (p<0.05)	1.6	3.7	6.69	20.29	2.35	50.13	0.052	0.256
Amino acid concentrations (mM)								
0	47.1±1.2	8.3±0.3	27.5±0.6	67.5±1.6	5.3±0.15	358±8.5	0.35±0.01	1.25±0.04
50	52.2±1.6	9.4±0.2	31.5±0.6	74.7±2.4	5.6±0.20	408±8.0	0.45±0.02	1.85±0.04
100	54.6±1.7	9.7±0.3	31.9±0.6	79.0±2.1	6.0±0.21	422±9.0	0.46±0.01	1.92±0.06
150	56.8±1.7	10.1±0.3	32.0±0.8	82.6±1.9	6.7±0.18	439±9.8	0.47±0.02	2.01±0.05
LSD (p<0.05)	5.725	1.131	2.83	4.833	0.3994	51.37	0.932	0.3141

Each value is mean of twenty-four replicates ± standard error.

Table 5. Effect of year and fertilizer sources on some traits of dragonhead.

Year	Fertilizer sources	Number of branches (per plant)	Number of inflorescences (per plant)	Number of leaves (per plant)	Inflorescence dry weight (g plant^{-1})
2018	Chemical fertilizer	7.3±0.3	27.9±1.0	64.6±1.7	4.64±0.1
	Poultry manure	9.0±0.37	30.0±0.7	70.3±2.1	5.33±0.2
	Municipal waste compost	10.5±0.27	32.6±0.6	79.9±2.3	6.14±0.1
	Vermicompost	11.4±0.25	34.0±0.8	90.7±2.4	7.00±0.2
2019	Chemical fertilizer	9.2±0.25	31.0±1.2	75.5±2.6	5.95±0.3
	Poultry manure	8.9±0.35	29.2±0.9	71.1±3.1	5.49±0.2
	Municipal waste compost	9.4±0.45	30.2±1.3	74.8±2.7	5.75±0.3
	Vermicompost	9.5±0.34	30.3±0.8	80.7±0.8	5.83±0.2
LSD (p<0.05)		0.699	2.254	5.475	0.602

Each value is mean of twelve replicates ± standard error.

3.2. Inflorescence dry weight and dry matter yield

The results showed that the inflorescence dry weight was significantly affected by the amino acid and the interaction of the year and fertilizer (Table 3). The application of 100/150 mM L-phenylalanine significantly increased the IDW by an average of 14% compared to the control. As seen in Table 4, the highest IDW was obtained with the application of V in the first year, followed by MWC in the first year. According to the ANOVA (Table 3), the tripartite effect of year, fertilizer, and AA on the dry matter yield (DMY) was significant (P<0.01). The highest DMYs (531 and 481 g.m^{-1}) were obtained with the application of V + 150/100 mM of L-phenylalanine in the first year (Fig. 3). In the second year, the application of all three concentrations of phenylalanine (50, 100, and 150 mM) + V as well as the foliar application of 150 mM phenylalanine + PM showed superiority over the other treatments.

Since organic fertilizers contain macro and micronutrients, their application can increase plant access to nutrients and consequently lead to improvements in plant photosynthetic activity, vegetative growth, and biomass. Organic fertilizers such as vermicompost are effective in sustaining soil resources and increasing plant growth by improving soil structure and biological activity (Pączka *et al.*, 2021; Voko *et al.*, 2022). It seems that after applying the vermicompost, poultry manure, and municipal waste compost, the plant's ability to absorb nutrients such as zinc, copper, iron, phosphorus, potassium, and nitrogen was increased, and subsequently, greater plant growth and an increase in the number of leaves were observed. (Liu *et al.*, 2021; 2024). On the other hand, it seems that the increase in the number of leaves under organic fertilizer application led to an enhancement in light absorption, an increase in the activity of the photosynthesis process, and an increase in the production of hydrocarbons in the leaves. As a result, the plant height, the number of branches, inflorescences, and leaves, the inflorescence dry weight, the dry matter yield, and the essential oil yield were also increased. Other researchers also indicated that the application of vermicompost led to an increase in the plant height, number of branches, and dry matter yield of hyssop (*Hyssopus officinalis* L.) (Aghaei *et al.*, 2019) and peppermint (Azizi Balabiglou *et al.*, 2022).

Amino acids as growth-promoting substances have different roles in plants. They are involved in stimulating seed germination, increasing plant's access to nutrients, chlorophyll synthesis, plant's defense mechanism against stress, cell division, hormone metabolism, biosynthesis of enzymes, vitamins, terpenoids, and alkaloids, etc. (Popko *et al.*, 2018; Sowmya *et al.*, 2023). They help the development of the plant's root system, increase the absorption of nutrients by the roots, and thus provide suitable conditions for plant growth (Nikiforova *et al.*, 2016). As a result, with greater plant access to nutrients, the activity of photosynthesis is increased, and the growth characteristic and dry weight of the plant will be improved. Consistent with our results, Elshorbagy et al. (2020) have indicated that the growth characteristics in lavender (*Lavandula officinalis* CHAIX) were increased under L-tryptophan and phenylalanine application.

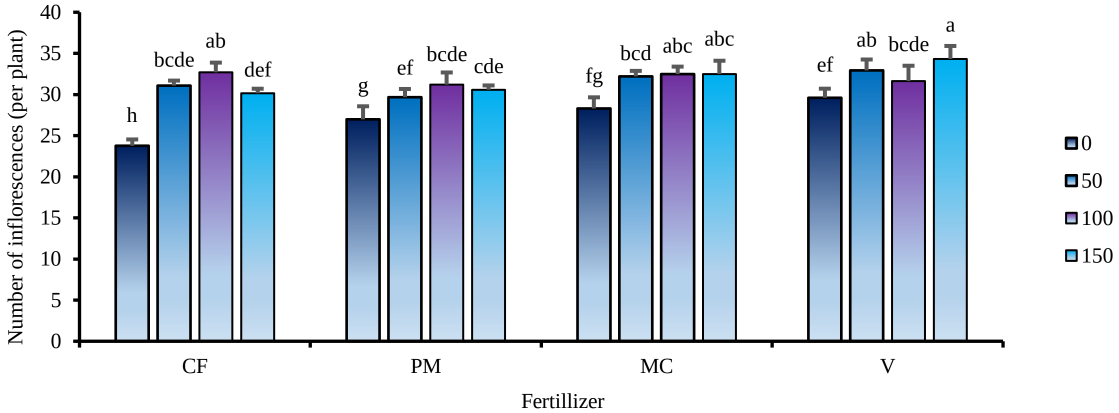

Figure 2. Response of number of flowering branches of dragonhead to fertilizer and amino acid (L-phenylalanine; 0, 50, 100, and 150 mM) application. CF: Chemical fertilizer, PM: Poultry manure, MC: Municipal waste compost, and V: Vermicompost. Different letters on each column indicate a significant difference between treatments according to the LSD test (p<0.05). Figures are expressed as mean ± standard error.

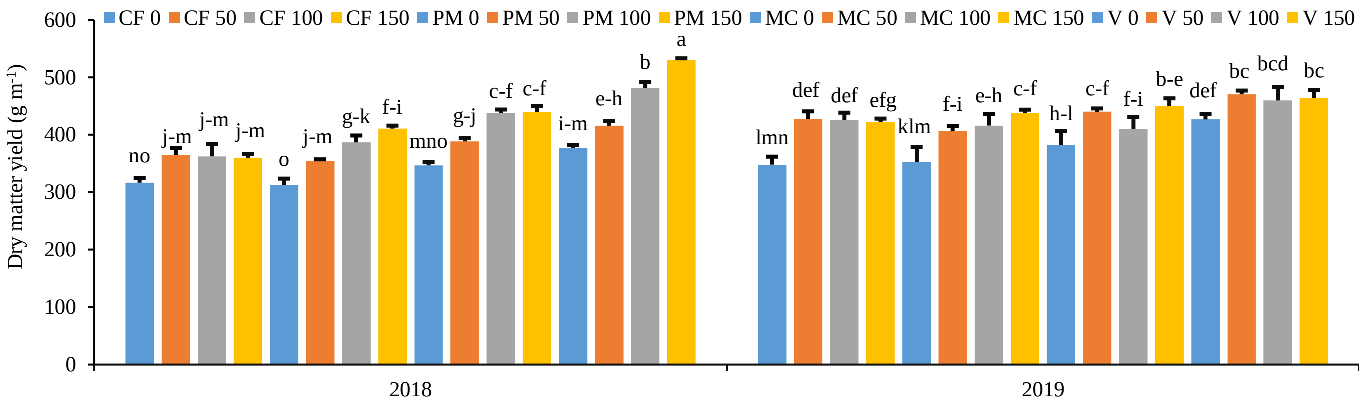

Figure 3. Effect of fertilizer and amino acid (L-phenylalanine; 0, 50, 100, and 150 mM) application on dry matter yield of dragonhead in two years. CF: Chemical fertilizer, PM: Poultry manure, MC: Municipal waste compost, and V: Vermicompost. Different letters on each column indicate a significant difference between treatments according to the LSD test (p<0.05). Figures are expressed as mean ± standard error.

3.3. Essential oil content

Dragonhead's EOC was significantly affected by the tripartite effect of year, fertilizer, and amino acid (Table 3). The compression of the means (Fig. 4) indicated that the application of 150 mM of phenylalanine + CF (0.58 %) and 50 mM of L-phenylalanine + MWC (0.55%) in the first year led to the production of the highest content of essential oil. In the second year, the application of 100 mM of L-phenylalanine + V significantly increased the EOC compared to the other treatments. In both years, the lowest EOC in all fertilizer treatments (CF, PM, MWC, and V) was observed under non-application of the amino acid (water distilled).

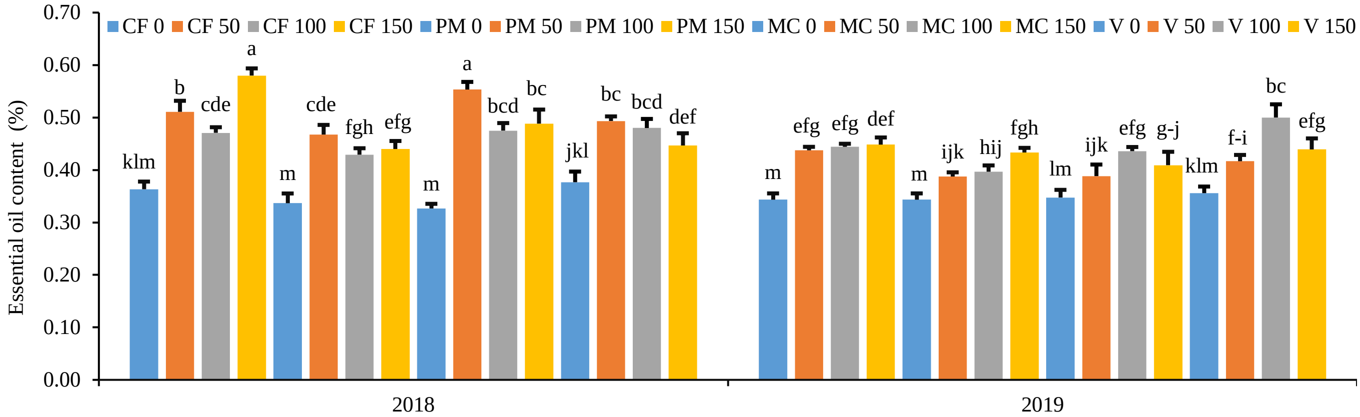

Figure 4. Effect of fertilizer and amino acid (L-phenylalanine; 0, 50, 100, and 150 mM) application on essential oil content of dragonhead in two years. CF: Chemical fertilizer, PM: Poultry manure, MC: Municipal waste compost, and V: Vermicompost. Different letters on each column indicate a significant difference between treatments according to the LSD test (p<0.05). Figures are expressed as mean ± standard error.

3.4. Essential oil yield

According to Table 3, the interaction of year and fertilizer and the interaction of year and amino acid on the EOY were significant. As shown in Fig. 5a, in both years, the highest EOY was recorded for V (2.04 and 1.95 gm^{-1} for the first and the second years, respectively). The recent treatment increased the EOY by 19.8, 32.4, and 8.5% in the first year (2018) and 14, 23.4, and 17.5% in the second year (2019) compared with the application of CF, PM, and MWC, respectively. Results also showed that the highest EOY (2.1 gm^{-1}) was obtained in the first year under 150 mM of phenylalanine (Fig. 5b). Overall, in both years, the application of L- phenylalanine significantly increased EOY compared to control.

Consistent with our results, Dashti et al. (2022) have stated that organic manures (compost and vermicompost) significantly increased essential oil production in salvia (*Salvia leriifolia* Benth). Khalesro et al. (2012) in anise (*Pimpinella anisum* L.) plants have reported similar results. Asadi et al. (2023) also showed that the EO production in peppermint was significantly enhanced by applying chemical fertilizer, vermicompost, and farmyard manure. Since the EOY value is affected by the percentage of EO and DMY, any increase in the values of these two parameters can cause an increase in EOY. Essential oils are terpenoid compounds, and ATP and NADPH are required to produce the precursors of these compounds. Given that the production of ATP and NADPH requires nitrogen, phosphorus, and other nutrients, the use of fertilizers (chemical and organic) and amino acids can provide additional nitrogen and phosphorus to the plant and help produce greater ATP and NADPH needed for essential oil production (Kapoor *et al.*, 2017; Nasiri, 2021). It is known that amino acids act as precursors of many secondary metabolites and have an essential role in catalyzing the biosynthesis of these compounds (Sowmya *et al.*, 2023; Barros *et al.*, 2016). In this regard, Velička et al. (2022) have reported that the EOC in mint was increased under spraying with phenylalanine compared to unsprayed plants. Aghaei et al. (2019) in hyssop have also found that the application of amino acids led to an increase in EOC. The results showed a notable difference between the values of some characteristics measured in two years. Overall, the difference in the values of some traits in 2018 and 2019 can be attributed to different humidity and temperature conditions during the growing seasons of the two years (Fig. 1).

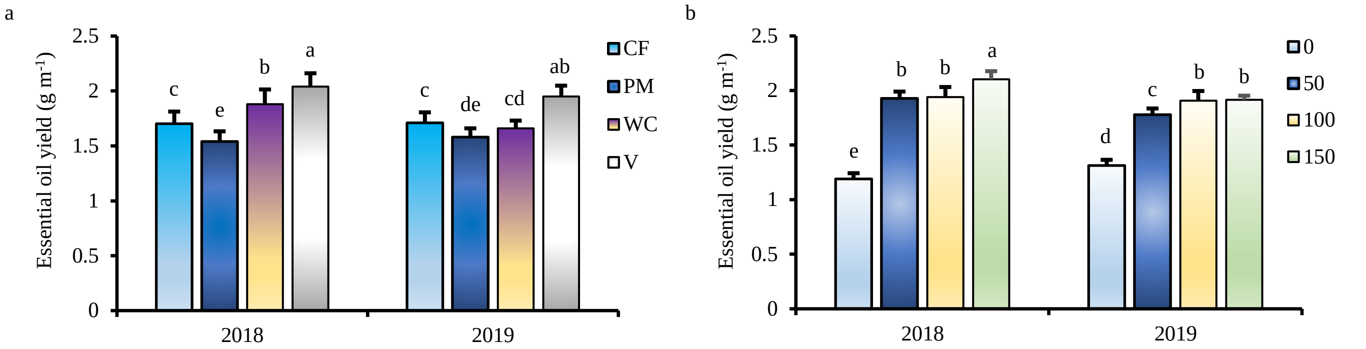

Figure 5. Effect of fertilizer (CF: Chemical fertilizer, PM: Poultry manure, MC: Municipal waste compost, and V: Vermicompost) application (a) and amino acid (L-phenylalanine; 0, 50, 100, and 150 mM) application (b) on essential oil yield of dragonhead in two years. Different letters on each column indicate a significant difference between treatments according to the LSD test (p<0.05). Figures are expressed as mean ± standard error.

4. Conclusion

Our results showed that foliar spraying of different concentrations of L-phenylalanine under the application of organic fertilizers had valuable effects on growth parameters, dry matter yield, and production of essential oil of dragonhead. Therefore, organic fertilizers such as vermicompost, poultry manure, and municipal waste compost can be used effectively instead of chemical fertilizers in the production of medicinal plants. Overall, the application of L-phenylalanine with a concentration of 50/100 mM in combination with an organic fertilizer such as vermicompost will be a suitable option to increase the quantity and quality of dragonhead production.

Abbreviation

AA: Amino acid, CF: Chemical fertilizer, PM: Poultry manure, MC: Municipal waste compost, V: Vermicompost, CF: Chemical fertilizer, PH: Plant height, NB: Number of branches, NI: Number of inflorescences, LN: Number of leaves, IDW: Inflorescence dry weight, DMY: Dry matter yield, EOC: Essential oil content, EOY: Essential oil yield.

Conflict of interests

All authors declare no conflict of interest.

Ethics approval and consent to participate

No humans or animals were used in the present research. The authors have adhered to ethical standards, including avoiding plagiarism, data fabrication, and double publication.

Consent for publications

All authors read and approved the final manuscript for publication.

Availability of data and material

All the data are embedded in the manuscript.

Authors' contributions

The first author [L. P.]: Performance of the research, data collection, and writing the initial draft. The second author [Y.N.]: Conceptualization, statistical analysis of the data, writing original draft, reviewing, and editing the manuscript. The third [M. R. M.] and the fifth [F. R.] authors: Advisors.

Informed consent

The authors declare not to use any patients in this research.

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References

Aghaei K., Pirbalouti A.G., Mousavi A., Badi H.N., Mehnatkesh A. 2019. Effects of foliar spraying of l-phenylalanine and application of bio-fertilizers on growth, yield, and essential oil of hyssop [*Hyssopus officinalis* L. subsp. Angustifolius (Bieb.)]. Biocatalysis and Agricultural Biotechnology 21: 101318. https://doi.org/10.1016/j.bcab.2019.101318

Asadi M., Nasiri Y., Maggi F., Rasouli F., Morshedloo M.R. 2023. Biomass yield and essential oil chemical composition of Mentha x piperita as affected by amino acids and different fertilizer resources. Journal of Soil Science and Plant Nutrition 23(1): 668-682. https://doi.org/10.1007/s42729-022-01073-7

Azizi Balabiglou S., Rahimi A., Heydarzadeh S., Holgoumi R., Ataei I. 2022. Effects of organic fertilizers on quantitative and qualitative traits of *Mentha piperita* L. under low water stress.

Iranian Journal of Medicinal and Aromatic Plants Research 38(4): 669-680. (In Farsi). https://doi.org/10.22092/ijmapr.2022.357546.3125

Bajeli J., Tripathi S., Kumar A., Tripathi A., Upadhyay R.K. 2016. Organic manures a convincing source for quality production of Japanese mint (*Mentha arvensis* L.). Industrial Crops and Products 83: 603-606. https://doi.org/10.1016/j.indcrop.2015.12.064

Barros J., Serrani-Yarce J.C., Chen F., Baxter D., Venables B.J., Dixon R.A. 2016. Role of bifunctional ammonia-lyase in grass cell wall biosynthesis. Nature Plants 2: 16050. https://doi.org/10.1038/nplants.2016.50

Dashti M., Kafi M., Mirza M. 2022. Chemical variation in the essential oil of Salvia leriifolia Benth. in response to organic and biological fertilizers. Journal of Medicinal plants and By-Products 11(1): 93-101. https://doi.org/10.22092/JMPB.2021.352430.1282

Elshorbagy A.I., Meawad A.A.A., Abdelkader M.A.I. 2020. Effect of some amino acids concentration on growth and yield of lavender (*Lavandula officinalis*, CHAIX) plant under different NPK fertilization levels. Zagazig Journal of Agricultural Research 47(4): 895-907. https://doi.org/10.21608/ZJAR.2020.110318

Emami Bistgani Z., Siadat S.A., Bakhshandeh A., Pirbalouti A.G., Hashemi M., Maggi F., Morshedloo M.R. 2018. Application of combined fertilizers improves biomass, essential oil yield, aroma profile, and antioxidant properties of *Thymus daenensis* Celak. Industrial Crops and Products 121: 434-440. https://doi.org/10.1016/j.indcrop.2018.05.048

Ghatas Y., Ali M., Elsadek M., Mohamed Y. 2021. Enhancing growth, productivity and artemisinin content of *Artemisia annua* L. plant using seaweed extract and micronutrients. Industrial Crops and Products 161: 113202. https://doi.org/10.1016/j.indcrop.2020.113202

Kapoor R., Anand G., Gupta P., Mandal S. 2017. Insight into the mechanisms of enhanced production of valuable terpenoids by arbuscular mycorrhiza. Phytochemistry Reviews 16: 677-692. https://doi.org/10.1007/s11101-016-9486-9

Khalesro S., Ghalavand A., Sefidkon F., Asgharzadeh A. 2012. The effect of biological and organic inputs on quantity and quality of essential oil and some elements content of anise (*Pimpinella anisum* L.). Iranian Journal of Medicinal and Aromatic Plants Research 27(4): 551-560. (In Farsi). https://doi.org/10.22092/ijmapr.2012.4504

Liu D., Ding Z., Ali E.F., Kheir A.M., Eissa M.A., Ibrahim O.H. 2021. Biochar and compost enhance soil quality and growth of roselle (*Hibiscus sabdariffa* L.) under saline conditions. Scientific Reports 11(22): 8739. https://doi.org/10.1038/s41598-021-88293-6

Liu Y., Lan X., Hou H., Ji J., Liu X., Lv Z. 2024. Multifaceted ability of organic fertilizers to improve crop productivity and abiotic stress tolerance: Review and perspectives. Agronomy 14(6): 1141. https://doi.org/10.3390/agronomy14061141

Martinez-Vazquez M., Estrada-Reyes R., Martinez-Laurrabaquio A., Lopez-Rubalcava C., Heinze G. 2012. Neuropharmacological study of *Dracocephalum moldavica* L. (Lamiaceae) in mice: Sedative effect and chemical analysis of an aqueous extract. Journal of Ethnopharmacology 141(3): 908-917. https://doi.org/10.1016/j.jep.2012.03.028

Nasiri Y. 2021. Crop productivity and chemical compositions of dragonhead (*Dracocephalum moldavica* L.) essential oil under different cropping patterns and fertilization. Industrial Crops and Products 171: 113920. https://doi.org/10.1016/j.indcrop.2021.113920

Nasiri Y., Asadi M., Zahedi S.M., Venditti A. 2024. Selenium nanoparticles improved biochemical and physiological properties and antioxidant systems of savoury under drought stress. Natural Product Research. https://doi.org/10.1080/14786419.2023.2299303

Nie L., Li R., Huang J., Wang L., Ma M., Huang C., Wu T., Yan R., Hu X. 2021. Abietane diterpenoids from *Dracocephalum moldavica* L. and their anti-inflammatory activities in vitro. Phytochemistry 184: 112680. https://doi.org/10.1016/j.phytochem.2021.112680

Nikiforova V.J., Bielecka M., Gakière B., Krueger S., Rinder J., Kempa S., Morcuende R., Scheible W.R., Hesse H., Hoefgen R. 2016. Effect of sulfur availability on the integrity of amino acid biosynthesis in plants. Amino Acids 30(2): 173-183. https://doi.org/10.1007/s00726-005-0251-4

Niu J.H., Liu C., Huang M.L., Liu K.Z., Yan D.Y. 2021. Effects of foliar fertilization: A review of current status and future perspectives. Journal of Soil Science and Plant Nutrition 21: 104-118. https://doi.org/10.1007/s42729-020-00346-3

Pączka G., Mazur-Pączka A., Garczyńska M., Hajduk E., Kostecka J., Bartkowska I., Butt K.R. 2021. Use of vermicompost from sugar beet pulp in cultivation of peas (*Pisum sativum* L.). Agriculture 11(10): 919. https://doi.org/10.3390/agriculture11100919

Popko M., Michalak I., Wilk R., Gramza M., Chojnacka K., Górecki H. 2018. Effect of the new plant growth biostimulants based on amino acids on yield and grain quality of winter wheat. Molecules 23(2): 470. https://doi.org/10.3390/molecules23020470

Reham M.S., Khattab M.E., Ahmed S.S., Kandil M.A.M. 2016. Influence of foliar spray with phenylalanine and nickel on growth, yield quality and chemical composition of genovese basil plant. African Journal of Agricultural Research 11(16): 1398-1410. https://doi.org/10.5897/AJAR2015.10699

Shokunbi O.S., Fayomi E.T., Sonuga O.S., Tayo G.O. 2012. Nutrient composition of five varieties of commonly consumed Nigerian groundnut (*Arachis hypogaea* L.). Grasas y Aceites 63(1): 14-18. https://doi.org/10.3989/gya.056611

Singh K., Chand S., Yaseen M. 2014. Integrated nutrient management in Indian basil (*Ocimum basilicum*). Industrial Crops and Products 55: 225-229. https://doi.org/10.1016/j.indcrop.2014.02.009

Sowmya R.S., Warke V.G., Mahajan G.B., Annapure U.S. 2023. Effect of amino acids on growth, elemental content, functional groups, and essential oils composition on hydroponically cultivated coriander under different conditions. Industrial Crops and Products 197: 116577. https://doi.org/10.1016/j.indcrop.2023.116577

Trovato M., Funck D., Forlani G., Okumoto S., Amir R. 2021. Amino acids in plants: Regulation and functions in development and stress defense. Frontiers in Plant Science 12: 772810. https://doi.org/10.3389/fpls.2021.772810

Tursun A.O. 2022. Effect of foliar application of seaweed (organic fertilizer) on yield, essential oil and chemical composition of coriander. Plos One 17(6): e0269067. https://doi.org/10.1371/journal.pone.0269067

Velička A., Tarasevičienė Ž., Hallmann E., Kieltyka-Dadasiewicz A. 2022. Impact of foliar application of amino acids on essential oil content, odor profile, and flavonoid content of different mint varieties in field conditions. Plants 11(21): 2938. https://doi.org/10.3390/plants11212938

Verma B.C., Pramanik P., Bhaduri D. 2020. Organic fertilizers for sustainable soil and environmental management. Nutrient dynamics for sustainable crop production (pp. 289-313), Springer, Singapore. https://doi.org/10.1007/978-981-13-8660-2_10

Voko M.P., Kulkarni M.G., Ngoroyemoto N., Gupta S., Finnie J.F., Van Staden J. 2022. Vermicompost leachate, seaweed extract and smoke-water alleviate drought stress in cowpea by influencing phytochemicals, compatible solutes and photosynthetic pigments. Plant Growth Regulation 97(2): 327-342. https://doi.org/10.1007/s10725-022-00815-y

Zúñiga M.I., Mariles A.J., Flores J.L., Herrera J.A., Sotelo M.G., Montes G.I. 2019. Antidepressant-like effects of *Dracocephalum moldavica* L. in mouse models of immobility tests. Pharmacognosy Journal 11(5): 976-983. https://doi.org/10.5530/pj.2019.11.154

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