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Effect of chemical, organic fertilization and storage time on the yield and quality of the dragon head (*Dracocephalum moldavica* L.) plant

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Abstract
A field experiment was conducted in Egypt on the dragon's head plant (*Dracocephalum moldavica* L.), a highly valuable medicinal and aromatic plant. The study used a split-plot design to investigate how fertilization type, storage period, and their interaction affect the raw drug. The main plots involved two kinds of fertilizers: (1) a combination of chemical and organic fertilizers and (2) organic fertilizer, while the sub-plots had four storage periods for dry herb: 0, 3, 6, and 9 months at room temperature in sealed kraft paper bags. The findings indicated that using chemical and organic fertilization resulted in significantly better plant height, number of branches per plant, herb fresh and dry weights per plant, and fresh and dry yields per feddan. In contrast, plants that received only organic fertilizer showed maximum increments in essential oil percentage and essential oil yield per plant and feddan. The dry weight of herb and essential oil percentages significantly decreased as storage time increased, reaching their lowest values in the 9th month. The study advised against storing herbs at room temperature for more than 6 months to avoid potential impairment to their quality, regardless of fertilization type.

Keywords: Moldavian dragonhead, fertilization, storage, yield, essential oil

Introduction
Dragon head, dragonhead, dragon's head, Moldavian dragonhead, or Moldavian balm (*Dracocephalum moldavica* L.), other names include blue dragonhead, Turkish melissa, and Turkish dragonhead, is an attractive medicinal herb with a distinct flavor and fragrance. The plant is annual, belonging to the family Lamiaceae, originated in a temperate climate in central Asia, and has been grown across East and Central Europe, North Africa, and the United States. This plant has several stems (as many as six) and a 22-45 cm height. Its blue flowers are grouped in pseudo-whorls and develop in the leaf axils. The essential oil accumulates in external oil-containing cells on the leaves and the inflorescence. As a result, the whole herb has a citrusy flavor, similar to lemon balm and catnip. The primary ingredients of essential oil are citral and geranyl acetate (Tenenbaum, 2003; Allen, 2010; Acimovic *et al*., 2019) [1-3].

Dracocephalum moldavica L. is deeply rooted in tradition, finding its way into herbal teas, tea mixes, and iced teas and being a delightful food spice for desserts, salads, and fish dishes. Its essential oil is crucial in producing perfumes, soaps, and shampoos. The plant is very attractive to bees. In traditional medicine, dragonhead has been a trusted remedy for cardiovascular conditions, digestive and liver problems, headaches, fever, and asthma. Its extract, with its anticancer, antioxidant, and antimutagenic properties, offers hope for those seeking natural health solutions. Its classical uses include heart tonic, component, calming, diarrhea, vermifuge, irritable, snake bites and bee pains, nausea, diarrhea, and illnesses caused by bacteria or fungi. Studies have shown its potential in treating childhood pyelonephritis. Further work evaluated the collagen-boosting effects of a Moldavian dragonhead extract and proved that it is a safe and effective treatment option for aged skin, highlighting its significant health benefits (Sonboli *et al*., 2008; Heydari *et al*., 2019; Wandrey *et al*., 2021; Zhan *et al*., 2023) [4-7].

Bringing foreign medicinal and aromatic plants into the country due to their therapeutic relevance, global market demand, and diversity of flavor significantly promotes our herb and spice trade. Plants with medicinal and aromatic properties from the Lamiaceae family are seen as having great potential. The dragonhead plant was introduced to Egypt in the last two decades of the twentieth century. However, more information is needed about the effects of various agricultural practices and techniques in newly reclaimed lands, like the impacts of fertilization types on growth, yield, active ingredients, and post-harvest treatments, such as the influence of storage periods on herb quantity and quality (El-Gengaihi and Wahba, 1995; Nofal and Menesi, 2024) [8, 9].

Farmers carry out all traditional processes in conventional agriculture and use chemical fertilizers. Chemical fertilizers contain macro- and micronutrients manufactured by providing industrial compounds that increase growth and plant production. One advantage of chemical fertilizers is that they give quick results. We can see the desired improvements in the plants quickly. However, overuse of chemical fertilizers can cause environmental pollution and health concerns. On the other hand, organic farming refers to growing medicinal and aromatic plants without synthetic materials such as mineral fertilizers. Organic agriculture uses natural sources such as organic fertilizers like compost and animal manure to fertilize plants, maintain soil fertility by adding materials of organic origin, and, most importantly, maintain natural cycles of nutrients. Organic manures are rich in nutrients and advantageous to plant growth. This responsibility is integral to sustainable farming practices, as it limits non-renewable sources and protects the environment (Mengel and Kirkby, 2012; Somasundaram *et al*., 2021; Toaima *et al*., 2023) [10- 12].

Dry medicinal and aromatic plants are stored for sale or as raw substances for producing medicines, cosmetics, and spices. The excellence of stored herbs and spices depends on the efficiency of the storage conditions, which include storage time. Consequently, exploring the changes in the physical and chemical traits of stored herbs and spices is critical to limiting adverse impacts on human health affected by variations or declines in chemical active constituents during storage intervals. This ensures the safety and effectiveness of the final products and maximizes the financial profit from the storage process. Standardized raw herb and condiment storage will produce safe, effective, and high-excellence herbal goods, thereby enhancing the economic viability of the medicinal and aromatic plant industry (Sameet Masand *et al*., 2014; Salim *et al*., 2016; Abd El-Aleem and Hamed, 2018) [13-15].

There has been limited research on how the type of fertilization impacts the quantity and quality of herbal material in storage. The present study examines how chemical and organic fertilizers affect herbage and volatile oil production, how storage time affects herbage quantity and quality characteristics, and how the interaction of these factors influences the end product.

Materials and Methods

This study was conducted at the Botanical Garden of Heliopolis University in Belbeis, Sharqia Governorate, Egypt, during the 2020-2021 and 2021-2022 seasons. Table 1 provides the soil's physical properties in the experimental area, and Table 2 shows its chemical traits. Table 3 displays the chemical properties of irrigation water. Soil and water samples were tested in accordance with AOAC (2022) [16]. The seeds were obtained from the Botanical Garden of Heliopolis University. They were sown in the first half of October 2020 and 2021 for the first and second seasons, respectively. The cultivation was carried out using a drip irrigation system, with rows spaced 65 cm apart and 35 cm between plants. The plants were thinned to one per hill (18462 plants per feddan) (Figure 1).

A split-plot trial utilized eight treatments and had three replications. The main plots were to investigate the impact of using two different types of fertilization: a) combining chemical and organic fertilizers, and b) using only organic fertilizer. The subplots included four storage durations for the obtained dry herb: 0, 3, 6, and 9 months. The data was analyzed with an ANOVA, and variations were explored at a 5% significance level using Least Significant Difference (L.S.D.) according to Snedecor and Cochran (1982) [17].

Compost manure at 15 m^3 per feddan was added during soil preparation. Table 4 contains details about the chemical characteristics of the organic manure. The amounts of mineral fertilizers used were 300 kg of ammonium sulfate (20.5% N), 200 kg of calcium superphosphate (15.5% P_2O_5), and 100 kg of potassium sulfate (48% K_2O) per feddan (Mostafa, 2018) [18]. Calcium superphosphate was added to the soil before cultivation. Nitrogen and potassium fertilization were applied in two equal doses to plants. All other farming practices followed the guidance of the Egyptian Ministry of Agriculture and Land Reclamation. The herb was harvested manually at flowering in the last week of March and the first week of April for the first and second seasons, respectively.

The second-season harvested samples were selected to investigate the impact of storage duration on them. The foreign materials were eliminated from the fresh herb. The fresh herb was washed with clean running water after harvesting and dried in the open air under shade for three weeks before moving on to the next stage of the experiment. They were packed in brown kraft paper bags weighing 90 g and kept at a room temperature of 22-25ºC with a humidity level of 50-60%. Samples of dried herbs were collected for analysis before and at the end of each storage period. The sampling method guaranteed that it accurately represented the entire raw material (Figure 2).

The following measurements were taken in the field and after harvesting: plant height (cm), number of branches per plant, fresh weight of herb per plant (g), dry weight of herb per plant (g), fresh yield of herb per feddan (ton), dry yield of herb per feddan (ton), essential oil percentage in the air-dried herb was measured using hydrodistillation (British Pharmacopoeia, 1963) [19]. Essential oil yield per plant (ml) was calculated by multiplying the essential oil percentage by the weight of dry herb per plant, and essential oil yield per feddan was determined by multiplying the essential oil yield per individual plant by the total number of plants per area. The percentages of nitrogen, phosphorus, and potassium were estimated in the dried leaves using the procedure outlined in AOAC (2022) [16]. The percentage of total carbohydrates in the dried leaves was determined as outlined by Herbert *et al*. (1970) [20].

The subsequent data were obtained through the storage stage; weight loss was observed by measuring the weight of 100 g samples taken from each treatment during storage periods. The essential oil percentage in the samples was measured using hydrodistillation after each storage period. The extracted essential oils were analyzed after each storage time with a gas chromatography-mass spectrometer

(GC/MS). Thermo Scientific Corp.'s TRACE GC Ultra Gas Chromatographs were utilized alongside an ISQ Single Quadrupole Mass Spectrometer detector from Thermo. The GC-MS system utilized a TR-5MS column measuring 30 m in length, 0.32 mm in internal diameter, and with a film thickness of 0.25 m. The examinations were conducted using helium as the carrier gas at a flow rate of 1.3 ml/min, a split ratio of 1:10, and a temperature program starting at 80 °C for 1 minute, increasing at 4 °C/min to 300 °C, and then maintaining it for 1 minute. The injector and detector were maintained at 220 and 200 °C, respectively. Diluted (1:10 hexane, v/v) samples of µl mixtures were continuously injected. Electron ionization (EI) at 70 eV gave mass spectra ranging from m/z 40-450. Retention time comparisons with established standards, the mass spectral library, and commercial spectra were used to identify compounds consistent with Massada (1976) and Jennings and Shibamoto (1980) [21, 22].

Table 1: Physical properties of the soil

Very coarse sand (%)	Coarse sand (%)	Medium sand (%)	Fine sand (%)	Very fine Sand (%)	Silt and clay (%)	Soil texture
10.85	21.11	34.10	23.50	7.75	2.69	Fine sandy

Table 2: Chemical analyses of the soil

pH	EC ($dS\ m^{-1}$)	O. M. (%)	Cations ($mmolc\ L^{-1}$)				Anions ($mmolc\ L^{-1}$)			N (mg/l)	P (mg/l)	K (mg/l)
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3^{-}	SO_4^{--}	Cl^{-}			
7.5	0.94	1.85	3.21	0.95	4.42	0.82	2.51	3.31	3.58	65.2	4.88	57.65

Table 3: Analyses of the irrigation water

pH	EC ($dS\ m^{-1}$)	Soluble cations ($mmolc\ L^{-1}$)				Soluble anions ($mmolc\ L^{-1}$)			
		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	SO_4^{--}	Cl^{-}
7.11	0.40	1.62	1.11	0.91	0.36	0.23	1.43	1.35	0.99

Table 4: Compost chemical analyses

pH	EC ($dS\ m^{-1}$)	O.M. (%)	C/N ratio (%)	N (%)	P (%)	K (%)	Organic carbon (%)	Humidity (%)	Weight m^3 (kg)
7.85	2.75	50.00	17:1	1.60	0.70	1.25	29.00	27.50	625

Fig 1: Grown dragonhead plants

Fig 2: Prepared dry herb for storage

Results and Discussion

1. Influence of fertilization type

Results in Tables 5 and 6 showed the significant effect of fertilization type on growth characteristics. The combined use of organic and chemical fertilizers resulted in the maximum height of plants, the highest number of branches, the most fresh herb weight, and the most dry herb weight. These values in the first season were 85.83 cm, 49.08 branches, 479.25 g, and 93.76 g, and in the second season, they were 87.08 cm, 50.42 branches, 487.92 g, and 94.43 g, whereas plants that were only given organic fertilizer presented lower measurements.

Table 7 shows how the type of fertilization impacts the yield of herbs produced per feddan. The combination of chemical and organic fertilizers resulted in significantly higher fresh and dry herb yields. The first season's data were 8.85 and 1.73 tons, and the second season's records were 9.01 and 1.74 tons, while plants that received only organic fertilizer showed lesser fresh and dry herb yields per area.

Similar to the previous direction, plants provided with both organic and chemical fertilizers had the highest nitrogen, phosphorus, potassium, and total carbohydrate contents in their leaves. The first season's values were 2.06, 0.23, 2.26, and 19.54%, and the second season's values were 2.14, 0.24, 2.34%, and 20.13%. On the contrary, plants that were provided with organic manure without any mineral fertilizers had lower levels of nitrogen, phosphate, potassium, and total carbohydrates in their leaves.

Regarding aroma attributes, organic manure treatment resulted in the maximum increase in essential oil percentage, essential oil yield per plant, and essential oil yield per feddan. In the first season, the essential oil values were 0.29%, 0.23 ml, and 4.25 l, and in the second season, they were 0.30%, 0.26 ml, and 4.80 l. However, the application of mineral and organic fertilizers resulted in lower essential oil percentage, essential oil yield per plant, and essential oil yield per feddan.

The beneficial impact of using both chemical and organic fertilization on increasing herbage yield can be explained by multiple factors: regarding mineral fertilization, nitrogen is an essential macronutrient for plant growth and is a key building unit of amino acids. Amino acids are the basic building blocks of proteins and enzymes. Nitrogen is part of the chlorophyll molecule, allowing the plant to utilize the sun's energy for photosynthesis. Phosphorus is necessary for the production of ATP in plant cells. Potassium participates in activating enzymes in the plant and regulates the frequency of stomatal opening and closing. Organic fertilization improves the physical, chemical, and biological properties of soil to increase total soil fertility, resulting in increased plant growth and vegetative production (Jain, 2017) [23].

Organic manure played a role in increasing essential oil because organic fertilizer alone was enough to encourage plants to accumulate secondary metabolites, such as essential oil, in the oil hairs in steady steps. This was achieved by slower plant growth, which corresponded to the slower growth and development of the oil hairs since the other cells in leaves require more minerals for rapid growth. Also, organic fertilizer provides plants with nutrients that are released slowly. Thus, organic plants were under stress. Secondary metabolites are crucial in adaptation to the environment and in dealing with stress (Abd El-Wahab, 2002; Akula and Ravishankar, 2011) [24, 25].

These results coincided with the findings obtained by Hussein *et al*. (2006), Janmohammadi *et al*. (2014), Mady and Youssef (2014), Faridvand *et al*. (2021), and Nasiri (2021) [26-30], who indicated that the addition of organic and/or chemical fertilization boosted growth characteristics and yield parameters of dragonhead plants.

Table 5: Effect of fertilization types on plant height (cm) and number of branches per plant of *Dracocephalum moldavica* during the two successive seasons

Fertilization types	Plant height (cm)		Number of branches per plant	
	1st season	2nd season	1st season	2nd season
Mineral fertilization + organic fertilization	85.83 a	87.08 a	49.08 a	50.42 a
Organic fertilization	74.79 b	75.92 b	44.42 b	46.08 b

Means with the same letter are not significantly different at the 5% level of probability

Table 6: Effect of fertilization types on fresh weight of herb per plant (g) and dry weight of herb per plant (g) of *Dracocephalum moldavica* during the two successive seasons

Fertilization types	Fresh weight of herb per plant (g)		Dry weight of herb per plant (g)	
	1st season	2nd season	1st season	2nd season
Mineral fertilization + organic fertilization	479.25 a	487.92 a	93.76 a	94.43 a
Organic fertilization	431.67 b	443.5 b	80.82 b	86.75 b

Means with the same letter are not significantly different at the 5% level of probability

Table 7: Effect of fertilization types on fresh yield of herb per feddan (ton) and dry weight of herb per feddan (ton) of *Dracocephalum moldavica* during the two successive seasons

Fertilization types	Fresh yield of herb per feddan (ton)		Dry yield of herb per feddan (ton)	
	1st season	2nd season	1st season	2nd season
Mineral fertilization + organic fertilization	8.85 a	9.01 a	1.73 a	1.74 a
Organic fertilization	7.97 b	8.19 b	1.49 b	1.60 b

Means with the same letter are not significantly different at the 5% level of probability

Table 8: Effect of fertilization types on essential oil percentage, essential oil yield per plant (ml), and essential oil yield per feddan (l) of *Dracocephalum moldavica* during the two successive seasons

Fertilization types	Essential oil percentage		Essential oil yield per plant (ml)		Essential oil yield per feddan (l)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season
Mineral fertilization + organic fertilization	0.20 a	0.20 a	0.19 a	0.19 a	3.51 a	3.51 a
Organic fertilization	0.29 b	0.30 b	0.23 b	0.26 b	4.25 b	4.80 b

Means with the same letter are not significantly different at the 5% level of probability

Table 9: Effect of fertilization types on nitrogen, phosphorus, potassium, and total carbohydrates contents (%) of *Dracocephalum moldavica* during the two successive seasons

Fertilization types	N (%)		P (%)		K (%)		Total carbohydrates content (%)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Mineral fertilization + organic fertilization	2.06 a	2.14 a	0.23 a	0.24 a	2.26 a	2.34 a	19.54 a	20.13 a
Organic fertilization	1.49 b	1.65 b	0.16 b	0.25 b	1.79 b	1.96 b	15.30 b	16.99 b

Means with the same letter are not significantly different at the 5% level of probability

2. Influence of storage periods

In Table (10), the data presented indicated how storage periods negatively impacted the weight of dry herbs, highlighting the influence of storage time on drug quantity characters. A noticeable drop in herb weight occurred as storage periods increased from 0 to 6 months, but this drop was insignificant between 6 and 9 months. The values measured for 0, 3, 6, and 9 months were 100.00, 98.61, 97.72, and 97.47 g, respectively. These results aligned with the research presented by Badawy (2010) [31] on *Rosmarinus officinalis*, which showed that extending the duration of storage leads to a rise in weight loss of the herb.

Also, the data in Table 10 demonstrated the influence of storage durations on the percentage of essential oil in dried herbs, serving as a crucial quality measure. There was a notable decrease in essential oil percentage as storage time increased from 0 to 3 months. Subsequent storage periods of 3 and 6 months showed no significant changes among them, but the most significant decrease in essential oil percentage occurred at 9 months of storage. The data for periods 0, 3, 6, and 9 months were 0.25, 0.20, 0.20, and 0.12%, respectively. These results were in agreement with the studies on *Ocimum basilicum*, which showed that essential oil losses varied after storage for different periods, with decreases observed at 3, 6, and 7 months. Similar findings were reported by other researchers who noted decreases in essential oil content after storing dried leaves for 6 and 12 months (Baritaux *et al*., 1992; Abd El-Wahab and Salem, 2008) [32, 33]. Other research on spearmint and peppermint herbs was stored for 12 months and found that prolonging the storage time led to a decrease in the essential oil content of both herbs. Regarding *Mentha spicata* L. cv. Siwa, the longer storage periods led to a significant decrease in both the weight of leaves and the percentage of essential oil. Its dried leaves should be kept at room temperature for no longer than 4 months. The smell and taste of marjoram were highly sensitive to store ambient temperature (Pääkkönen *et al*., 1990; El-Moghazy, 2013; Abd El-Aleem and Hamed, 2018) [15, 34, 35].

Table 10: Effect of storage periods on the weight of 100 g of herb and the percentage of essential oil of *Dracocephalum moldavica* during the second season

Storage periods	Weight of 100 g of herb	Essential oil percentage
0 months	100.00 a	0.25 a
3 months	98.61 b	0.20 b
6 months	97.72 c	0.20 b
9 months	97.47 c	0.12 c

Means with the same letter are not significantly different at the 5% level of probability

3. Influence of interaction: Tables 11, 12, 13, and Figures 3 and 4 represent how different types of fertilizers added in the field interact with the attributes of herbs during storage.

Table 11 displays the effect of the interaction between treatments on the weight of the herb. The findings indicated that the herbs fertilized by chemical and/or organic nutrients were significantly influenced by the duration of storage, leading to a noticeable decrease in dry weight. The weight loss did not display any significant variations between the two types of fertilization at the same storage time.

Regarding plants treated with chemical and organic fertilizers, there was a significant decrease in herb weight at three and six months of storage, followed by no significant loss at 9 months. These weights were 100.00, 98.38, 97.47, and 97.40 g for 0, 3, 6, and 9 months. Also, regarding the plants that were given just organic manure, there was a notable reduction in herb weight at three and six months of storage, although there was no further significant decline afterward. The weights measured were 100.00, 98.83, 97.97, and 97.53 g at 0, 3, 6, and 9 months, respectively.

Table 12 presents the effect of interaction among treatments on the essential oil percentage. The results proved that the obtained herbs from plants fertilized by chemical and/or organic fertilizers were negatively affected by the duration of storage, leading to a decrease in essential oil percentage. In terms of treatment received mineral and organic fertilizers, there were no significant differences in the essential oil percentage before storage and up to 6 months, but there was a sudden decrease at 9 months. The essential oil values were 0.20, 0.20, 0.20, and 0.10% at 0, 3, 6, and 9 months, respectively. Plants that had only organic manure recorded a significant decrease in essential oil percentage at three months of storage, with levels remaining steady until 6 months before experiencing another significant drop at 9 months. For 0, 3, 6, and 9 months, the essential oil values were 0.30, 0.20, 0.20, and 0.13% in that order.

Table 11: Effect of interaction between fertilization types and storage periods on the weight of 100 g of herb of *Dracocephalum moldavica* during the second season

Fertilization type	Storage periods				Mean
	0 months	3 months	6 months	9 months	
Mineral fertilization + organic fertilization	100.00 a	98.38 bc	97.47 de	97.40 e	98.31f
Organic fertilization	100.00 a	98.83 b	97.97 cd	97.53 de	98.58 f
Mean	100.00 g	98.61 h	97.72 i	97.47 i	

Means with the same letter are not significantly different at the 5% level of probability

Table 12: Effect of interaction between fertilization types and storage periods on essential oil percentage of *Dracocephalum moldavica* during the second season

Fertilization type	Storage periods				Mean
	0 months	3 months	6 months	9 months	
Mineral fertilization + organic fertilization	0.20 b	0. 20 b	0.20 b	0.10 c	0.18 g
Organic fertilization	0.30 a	0.20 b	0.20 b	0.13 c	0.21 f
Mean	0.25 h	0.20 i	0.20 i	0.12 j	

Means with the same letter are not significantly different at the 5% level of probability

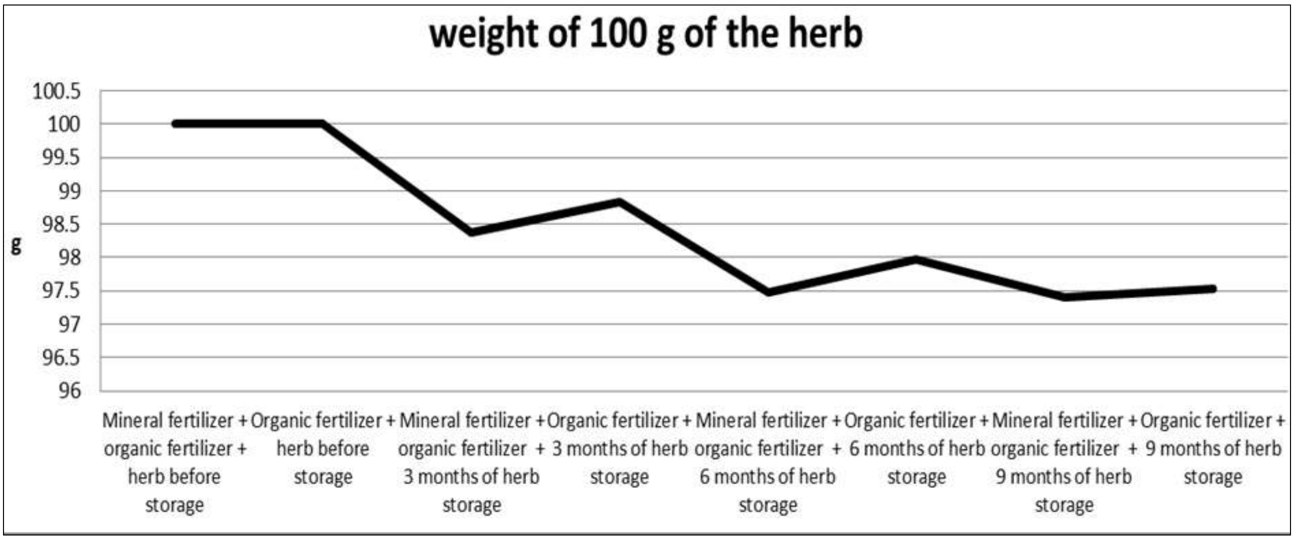

Fig 3: Effect of interaction between treatments on the weight of the herb

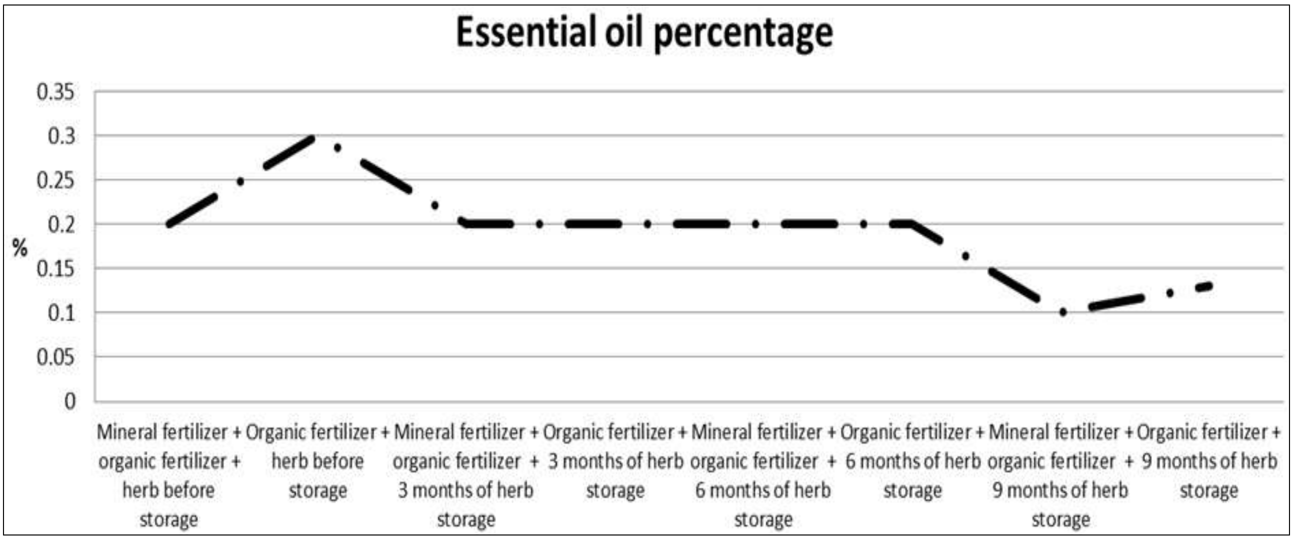

Fig 4: Effect of interaction between treatments on the essential oil percentage

The main components of the essential oil were Z-citral, E-citral, and geranyl acetate. The concentrations of these compounds in the treatment of organic fertilization were higher than in the treatment of organic and chemical fertilization. These percentages before storage were 28.93, 21.71, and 43.68% in organic oil. In contrast, the treatment fertilized using organic and chemical nutrients had lower concentrations of Z-citral, E-citral, and geranyl acetate, which were 20.37, 13.65, and 32.38%. The oil also contained other compounds in minor contents, such as nerol, which was the highest (3.92%) in the chemical and organic fertilization treatment, followed by neryl acetate, which was the maximum (3.06%) in the organic fertilization treatment. These compounds identified were consistent with the results of studies by Alaei and Mahna, 2013; Said-Al Ahl *et al*., 2015; Mostafa *et al*., 2019; and Zaji *et al*., 2019 [36-39].

In traditional fertilization via using chemical and organic fertilizers, the Z-citral percentage decreased to 19.07% at 3 months of storage. The concentration continued to decrease to 18.86% at 6 months but then increased to 22.88% at 9 months. While the percentage of E-citral increased after 3 and 6 months of storage to 18.62 and 18.43%, respectively, its concentration decreased to reach 14.77% when storage time increased to 9 months. Concerning geranyl acetate, it rose as the storage period extended, peaking at 46.15% by the 9th month. As the storage period increased, there was a steady reduction in the levels of nerol and neryl acetate compounds, reaching their lowest points of 0.30% and 1.80%, respectively, in the 9th month.

The changes in the essential oil components of plants treated with organic fertilizer were as follows: The Z-citral compound dropped to 14.24, 16.05, and 9.53 after 3, 6, and 9 months, respectively. The E-citral compound decreased to 14.42, 16.41, and 9.45% at 3, 6, and 9 months of storage, respectively. The percentage of geranyl acetate increased with increasing storage periods, reaching the highest value of 64.45% at the end of the storage time. There was a decrease in the content of neryl acetate at the end of the storage period to 2.70%, while there was an increase in the nerol at the end of the duration to reach 4.71%.

As well, plants that received a combination of chemical and organic fertilizers retained more essential oil and citral contents during storage periods compared to those only treated with organic manure.

The negative effect of storage on the quality of dragonhead was in agreement with several researchers who discovered that essential oils are sensitive to heat and easily affected by oxidation when exposed to air and light, as well as during storage. The usual outcome of these alterations is a negative impact on the taste quality since most flavoring substances are thermolabile or heat-sensitive to high temperatures. Reorganization, addition, or removal of other components can cause changes in essential oil composition during storage (Choi and Sawamura, 2002; Salim *et al*., 2016; Abd El-Aleem and Hamed, 2018; Li *et al*., 2018) [14, 15, 40, 41].

Table 13: Effect of interaction between treatments on essential oil constituents (%) of *Dracocephalum moldavica* during the second season

Compounds	Treatments							
	Mineral fertilizer + organic fertilizer + herb before storage	Organic fertilizer + herb before storage	Mineral fertilizer + organic fertilizer + 3 months of herb storage	Organic fertilizer + 3 months of herb storage	Mineral fertilizer + organic fertilizer + 6 months of herb storage	Organic fertilizer + 6 months of herb storage	Mineral fertilizer + organic fertilizer + 9 months of herb storage	Organic fertilizer + 9 months of herb storage
Z-citral	20.37	28.93	19.07	14.24	18.86	16.05	22.88	9.53
Nerol	3.92	1.68	0.43	0.88	0.34	0.75	0.30	4.71
E-citral	13.65	21.71	18.62	14.42	18.43	16.41	14.77	9.45
Neryl acetate	2.75	3.06	2.72	3.30	2.56	3.22	1.80	2.70
Geranyl acetate	32.38	43.68	45.36	57.48	42.94	50.29	46.15	64.45
Total citral content	34.02	50.64	37.69	28.66	37.29	32.46	37.65	18.98
Total identified compounds	73.07	99.06	86.2	90.32	83.13	86.72	85.9	90.84

Conclusion

Our investigation on dragonhead (*Dracocephalum moldavica* L.) prompted us to suggest using a mix of organic and chemical fertilizers to achieve the highest herbage yield. Nevertheless, for optimal production of essential oil, it is important for farmers to only utilize organic fertilizer. When storing the produced dry herbs at room temperature, it is advised to be stored for no more than six months in closed kraft paper bags to minimize negative impacts on their attributes.

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