Yuzuncu Yil University
Journal of Agricultural Sciences
(Yüzüncü Yıl Üniversitesi Tarım Bilimleri Dergisi)
https://dergipark.org.tr/en/pub/yyutbd
ISSN: 1308-7576
e-ISSN: 1308-7584

Research Article

Effect of Winter Sowing and Different Fertilizer Sources on Physiological Parameters and Yield Components of Dragon's Head (*Lallemantia iberica* Fisch. & C.A.Mey.)

Shayesteh MADDAHI[1], Amir RAHIMI*[2], Murat TUNCTURK[3], Sina Siavash MOGHADDAM[4]
Ruveyde TUNCTURK[5], Latifeh POURAKBAR[6]

[1] M.Sc. Student of Ecological Agriculture, Department of Agronomy, Faculty of Agriculture, Urmia University, Urmia, Iran
[2]Assistant Professor, Department of Agronomy, Faculty of Agriculture, Urmia University, Urmia, Iran
[3] Professor, Department of Agronomy, Faculty of Agriculture, Van Yuzuncu Yil University, Van, Türkiye
[4]Assistant Professor, Department of Biology, Faculty of Science, Urmia University, Urmia, Iran

[1]https://orcid.org/0009-0001-8705-5391, [2]https://orcid.org/0000-0003-0443-6584, [3]https://orcid.org/0000-0002-7995-0599
[4]https://orcid.org/0000-0001-8643-8991, [5]https://orcid.org/0000-0002-3759-8232, [6]https://orcid.org/0000-0002-2623-7394

*Corresponding author e-mail: e.rahimi@urmia.ac.ir; emir10357@gmail.com

Article Info

Received: 13.02.2024
Accepted: 16.07.2024
Online published: 15.09.2024
DOI: 10.29133/yyutbd.1436260

Keywords

Dragon's head,
Humic acid,
Thiobacillus,
Vermicompost,
Winter sowing

Abstract: The effects of autumn sowing and chemical, organic, and biological fertilizer sources were explored on yield components and physiological traits of dragon's head (*Lallemantia iberica* Fisch. & C.A.Mey). The study was conducted as a factorial experiment based on a randomized complete block design with three replications in a field experiment in the 2017-2018 crop year. The fertilizer treatments included organic fertilizers (vermicompost, manure, and humic acid), biofertilizer (Thiobacillus mixed with sulfur), chemical fertilizer (macro NPK), and control (no fertilizer). The studied traits included seed yield per ha, harvest index, biological yield per ha, chlorophyll *a*, chlorophyll *b*, carotenoid, proline, and dissolved carbohydrate. The results of the comparison of the means revealed that the winter sowing outperformed the spring sowing evidently and increased traits like seed yield per ha, biological yield per ha, and harvest index significantly. The fertilization of the plants in both sowing seasons, especially in the winter sowing, increased seed yield per ha, biological yield per ha, and harvest index so that the vermicompost-fertilized winter-sown plants produced the highest seed yield per ha (0.91 g), whereas the application of manure was related to the highest harvest index in the winter sowing (27.9%). The highest biological yield (8797 kg ha^{-1}) was related to the treatment of Thiobacillus of the winter-sown plants. Proline content was higher in the spring sowing plants, and the control treatment in the spring sowing had the highest proline content (0.120 mg g^{-1}). Concerning dissolved carbohydrates, the spring sowing and the unfertilized plants had the highest content (20.3 mg g^{-1}). On the other hand, chlorophyll *a*, chlorophyll *b*, and carotenoid were higher in the treatments of Thiobacillus and vermicompost, which resulted in achieving higher yields due to the increase in photosynthesis rate. According to the results, the winter sowing of the dragon's head in the Azerbaijan region of Iran and the use of *Thiobacillus* and vermicompost could be recommended for obtaining plants with optimum quality parameters.

To Cite: Maddahi, S, Rahimi, A, Tuncturk, M, Moghaddam, S S, Tuncturk, R, Pourakbar L, 2024. Effect of Winter Sowing and Different Fertilizer Sources on Physiological Parameters and Yield Components of Dragon's Head (*Lallemantia iberica* Fisch. & C.A.Mey.). *Yuzuncu Yil University Journal of Agricultural Sciences*, 34(3): 515-526. DOI: https://doi.org/10.29133/yyutbd.1436260

1. Introduction

Medicinal plants have always been an effective treatment in history so research has revealed that plants have been a primary source of medicine for millennia. Presently, the World Health Organization reports that more than 80 percent of individuals continue to depend on traditional medicine, including the utilization of plants (Rahimi et al., 2019). The family Lamiaceae has major medicinal plant species used to treat various diseases. Some have essential oils and many are used in nutritional cases (in raw or cooked forms) or are planted for their beautiful and aromatic flowers (El-Sheshtawy et al., 2019). Dragon's head (*Lallemantia iberica* Fisch. & C.A.Mey.) is an invaluable species from this family as all of its parts have economic applications; for instance, it has curative effects as stimulator, diuretic, and expectorant and is good in the treatment of neural disorders, renal disorders, and hepatitis (Rezaei-Chiyaneh et al., 2020). The seeds of the dragon's head are dark and oval-shaped and contain oil, fiber, and protein that provide various medicinal and nutritional advantages (Amanzadeh et al., 2011; Razavi et al., 2012).

Various factors affect the medicinal plants' yield such as increasing rainfall use efficiency and proper sowing date (Talaat, 2019). Increasing plant yields were reported by Wang et al. (2019) in spring sowing, due to severe rainfalls in which case plant yields will be remarkably impaired because of adverse environmental conditions of summer such as moisture deficiency, higher temperatures, and hot winds. The results of Akhzari et al. (2018) show that yields can be considerably improved both qualitatively and quantitatively by using winter-winter sowing instead of spring sowing and taking more advantage of precipitation (Kumar et al., 2018).

A major pillar of sustainable farming involves the utilization of organic and biological fertilizers within agricultural environments to minimize or eliminate the use of chemical inputs (Rodnuch et al., 2019). Long-term studies have documented that excessive use of chemical fertilizers impairs crop yields arising from soil acidification, the decline of soil biological activities, the loss of soil physical properties, and the lack of micronutrients in macro-chemical fertilizers (Adediran et al., 2004). Organic fertilizers increase soil organic matter and improve its fertility by enhancing its chemical attributes like pH, cation exchange capacity, microorganism activity, and nutrient availability (Nejatzadeh-Barandozi and Pourmaleknejad, 2014; Wang et al., 2019). The results of Amooaghaie and Golmohammadi (2017) showed that the use of organic fertilizers, e.g. manure and vermicompost, in sustainable agriculture escalates the presence of vital nutrients like nitrogen (N), phosphorus (P), and potassium (K), in addition to increasing the population and activity of beneficial soil-borne microorganisms, and it consequently improves crop growth and yields (Abd El Ghafour et al., 2017). The results of Amooaghaie and Mardani Korrani (2018) showed that using organic fertilizers increased the phytochemical properties of medicinal plants. Similar results were found by different researchers (Amooaghaie and Golmohammadi, 2017; El Kinany et al., 2019).

In recent years, the use of biological fertilizers has drawn attention as a good alternative to chemical fertilizers in increasing soil fertility and has been interested by producers as a major nutritional approach for plants to achieve the goals of sustainable agriculture (Wang et al., 2019). The findings by Akhzari et al (2018) demonstrated that Biofertilizers are capable of converting key nutrients from unavailable to available forms in biological processes and improving root system development and seed germination, which caused to increase in medicinal and phytochemical properties of different medicinal plants (El Kinany et al., 2019). It is even known that the association of Plant Growth Promoting Rhizobacteria (PGPR) and AMF, which have the capacity to minimize the damage of abiotic stress factors especially in agricultural production, not only protects plants against stress factors but also supports growth and development (Nadeem et al., 2014; Selem et al., 2021).

Low crop efficiency and the contamination of pesticide and chemical fertilizer residues are among the major challenges of medicinal plant production, especially in Iran. The overuse of chemical fertilizers has harmful effects such as the toxicity arising from the overuse of fertilizers and the loss of crop quantity and quality. Although the application of chemical fertilizers has extensively been developed as it is the fastest way to offset soil nutrient deficiencies and improve crop yield, their application has entailed environmental pollution and ecological destructions in many cases and has pushed up production costs. Conversely, excessive utilization of N-containing fertilizers threatens human health. So, the present study aims to find the best sowing date for the dragon's head relying on an optimal organic and biological fertilization system for physiological traits and seed yield.

2. Material and Methods

The research was conducted at the research farm of the Department of Agriculture, Urmia University in Western Azerbaijan province, Iran (45°10' E., 37°44' N., 1338 m. from sea level) in the 2017-2018 crop year. Before sowing, combined soil samples were taken from five random points at a depth of 0-30 cm to analyze its Physicochemical properties and estimate the fertilizer requirements of the dragon's head. The findings of the soil examination are displayed in Table 1. Table 2, also, presents a summary of the physical and chemical characteristics of the organic fertilizers used in the study. The fertilizer requirement was estimated according to Tables 1 and 2 and was mixed into the soil before sowing.

Table 1. Some properties of soil in the study site

EC(dS m^{-1})	pH	Texture	Clay	Silt	Sand	$CaCO_3$	BC[1]
1.38	7.79	Clay loam	41%	36%	23%	15.71%	54%
N	**Organic carbon**	**Mn**	**B**	**Zn**	**Fe**	**K**	**P**
%		mg kg^{-1}					
0.03	1.16	11.2	0.28	1.1	8.11	282	9.02

(1) BS: base saturation.

Table 2. Some physical and chemical properties of the organic fertilizers applied in the experiment

	K (%)	P (%)	N (%)	OM[1] (%)	EC[2] (dSm^{-1})	pH
Cattle manure	1.07	1.12	1.01	61	8.87	7.49
Vermicompost	3.29	1.59	1.79	55	6.56	8.68

(1) OM = organic matter; (2) EC = electrical conductivity.

The research was designed as a factorial experiment following a randomized complete block design with three replications. The factors considered in the study were the sowing season and the type of fertilizer used. The sowing season was the primary factor with two levels: winter sowing and spring sowing. The second factor was the fertilizer source, which included manure (6.3 ton ha^{-1}), NPK fertilizer (Urea: 110 kg ha^{-1} + Triple superphosphate: 60 kg ha^{-1} + Potassium sulfate: 50 kg ha^{-1} + Micronutrients: 23 kg ha^{-1}), vermicompost (6.8 ton ha^{-1}), humic acid (400 kg ha^{-1}), and thiobacillus (2%) + granular sulfur (400 kg ha^{-1}). The experimental blocks were established on November 27, 2017, after the land was plowed and leveled in autumn. Sowing rows were then prepared, with each experimental plot covering an area of 6 m^2. Winter sowing took place on November 28, 2017, with row spacing set at 1 cm and inter-row spacing at 25 cm. Spring sowing, on the other hand, was conducted on February 27, 2018. Throughout the growing season, activities such as thinning, gap-filling, and weeding were carried out as needed. According to the sampling procedure, a total of 10 plants were selected at random from each plot to assess their morphological characteristics. To determine the yield, the two rows at the edges of the plots, as well as a 0.5 m section from both ends, were excluded to account for any potential marginal effects.

As per the sampling procedure, a total of 10 plants were selected at random from each plot to assess their morphological traits. To determine yield, the two rows at the edges of the plots, as well as a 0.5 m section from both ends, were excluded to account for any marginal effects. To find out seed yield per ha, the seeds were detached from the achene of the plants collected from an area of 1 m^2. Then, they were weighed with a digital scale and it was recorded as seed yield per m^2 and it was used to estimate seed yield per ha. To determine biological yield, three rows were harvested from an area of 1 m^2 within each plot after full maturity and the plants of different plots were placed in different packages. Then, they were oven-dried at a temperature of 39 °C for 48 hours, ensuring the complete elimination of any remaining moisture content. Following the drying procedure, they were weighed with a scale. The sum of the dry weight of aerial parts was recorded as the biological yield.

The harvest index was determined by dividing the seed yield by the biological yield. It was presented in percent.

To measure proline content, 1 mL of the alcoholic extract was mixed with 10 mL of distilled water and combined with 5 mL of ninhydrin reagent. Then, 5 mL of glacier acetic acid was introduced, followed by placing the mixture in a 100 °C water bath for 45 minutes with continuous agitation. After that, they were cooled down, added with 10 mL of benzene, and agitated so that proline could enter into the benzene phase. The samples were left undisturbed for 30 minutes Proline standards ranging from 0 to 0.1 mM/mL were prepared and finally, the absorption of the samples was measured at 515 nm with a spectrophotometer (PD-303, Japan) (Rodnuch et al., 2019). To measure dissolved carbohydrates, 0.1 mL of the alcoholic extract kept in a refrigerator was poured into a test tube with a micropipette and 3 mL of freshly prepared anthrone was introduced into the solution. The test tubes were positioned within a boiling water bath and left for 10 minutes as long as a colorful material was formed. After they were cooled down, the absorption of the samples was measured at 625 nm with the spectrophotometer. To prepare sugar standard, glucose solutions were prepared with concentrations of 0-120 ppm, and all experimental procedures were performed on them. Finally, their absorption was read at 625 nm (Abd El Ghafour et al., 2017). Also, to determine chlorophyll content, 0.25 g of fresh and fully developed leaves were harvested at the full flowering stage, crushed in a Chinese mortar, and ground with 5 mL of distilled water in a dim cool environment as long as it turned into a uniform bulk. The mixture was poured into a 25-mL volumetric flask and adjusted to the required volume. Subsequently, 0.5 mL of the solution was combined with 4.5 mL of acetone 80%, and centrifuged at 3000 rpm for 10 minutes. Afterward, the supernatant was taken and its absorption was read at 470, 646.8, and 663.2 nm with the spectrophotometer (PD-303, Japan). Chlorophyll *a*, chlorophyll *b*, total chlorophyll, and carotenoid content were determined using the equations provided by El-Sheshtawy et al. (2019).

$$\text{Chlorophyll a (mg/ml)} = 12.25\,(A_{663.2}) - 2.79\,(A_{646.8}) \tag{1}$$

$$\text{Chlorophyll b (mg/ml)} = 21.50\,(A_{646.2}) - 5.10\,(A_{663.2}) \tag{2}$$

$$\text{Carotenoid } (\mu\mu g/ml = \frac{1000(A_{470}) - 1.8(Chl_a) - 85.2(Chl_b)}{198} \tag{3}$$

3. Results and Discussion

3.1. Seed yield

The statistical analysis of variance (ANOVA) results for the measured characteristics can be found in Table 3 Both the individual effects of sowing date and fertilizer, as well as their combined effects, were significant ($p < 0.01$) on seed yield per ha. Means comparison revealed that winter sowing in all fertilization treatments well-outperformed spring sowing. The highest seed yield (0.91 g ha^{-1}) was related to the application of vermicompost to the winter-sown plants whereas the spring-sown plants that were not fertilized exhibited the lowest seed yield of 0.19 g ha^{-1} (Figure 1). Even the fertilized spring-sown plants failed to produce yields comparable to the control winter-sown plants. It seems that the winter-sown plants produced higher seed yield because they did not meet stressful conditions, so they outperformed the spring-sown plants in most yield-related traits, which resulted in their higher seed yield per ha. So, it can be recommended to opt for winter sowing for dragon head cultivation. Similarly, Semenov et al. (2020) and Dast Borhan (2017) reported that the best yield of dragon's head and winter wheat (*Triticum aestivum* L.) was obtained from timely winter sowing. They explained that winter sowing in these regions was performed in late autumn and winter in rain-fed farming systems. Nutrition and proper sowing dates are the most effective factors that increase plant yields (Brzozowska and Brzozowski, 2020). The sowing date is a major management factor in crop production because when the sowing date is changed, the meteorological parameters are changed and this influences plant growth and production (Mazurenko et al., 2020). Nutrition can also impact the absorption and efficiency of growth-affecting environmental factors. It appears that the dragon's head plants sown in winter yielded more seeds as a result of their improved establishment, ability to withstand cold temperatures, an earlier start of spring growth, and subsequently increased vegetative growth. Brzozowska and Brzozowski (2020) attributed the higher seed yield of anise and fennel in winter sowing to these factors, especially cold hardiness and vegetation growth.

Table 3. Analysis of variance for the yield-related traits

Sources of variations	**Degrees of freedom**	**Means of squares**		
		Seed yield (kg ha^{-1})	**Biological yield (kg ha^{-1})**	**Harvest index**
Block	2	12672.8^{ns}	1210109^{ns}	0.90^{ns}
Sowing season (A)	1	2000676**	16738414**	1826**
Fertilizer (B)	5	1008159**	23120645**	38.1**
A × B	5	116117**	1764668^{ns}	17.09^{ns}
Error	22	13808.4	896857.2	7.38
Coefficient of variations		6.48	14.28	10.82

ns, *, and ** show insignificance and significance at the $p < 0.05$ and $p < 0.01$ levels, respectively.

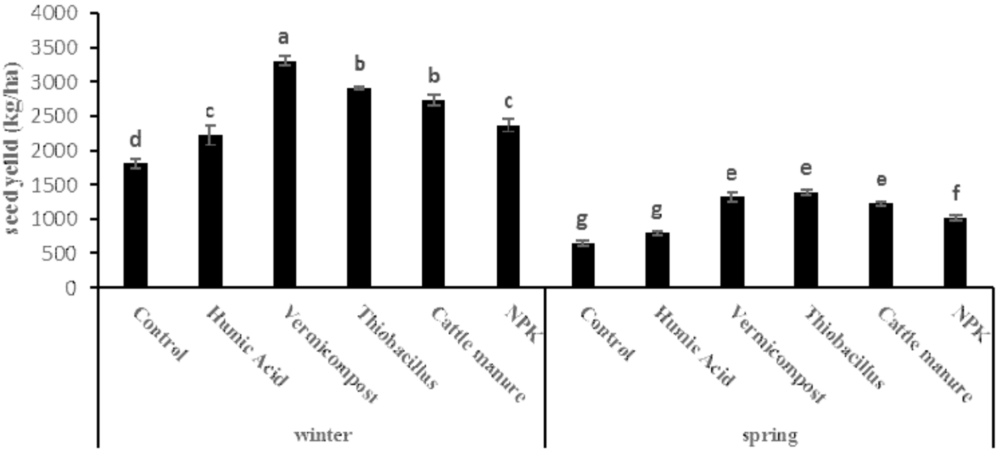

Figure 1. Means comparison of the interactive effect of sowing date × fertilizer on seed yield per ha.

3.2. Biological yield

The results of ANOVA for this trait are shown in Table 3. The sowing date × fertilizer interaction was not statistically significant for biological yield per ha, but this trait was significantly ($p < 0.01$) affected by their simple effects. According to the analysis of the simple effects of the treatments (Figure 2), it was found that the winter sowing resulted in a greater biological yield compared to the spring sowing. (7312 kg ha^{-1} versus 5948 kg ha^{-1}). Among fertilizer treatments, thiobacillus (8797 kg ha^{-1}) and vermicompost (8763 kg ha^{-1}) produced optimal biological yield, but the control no-fertilizer treatment produced a non-optimal yield (3673 kg ha^{-1}). The higher biological yields in these treatments were associated with higher root, stem, and leaf dry weight of the plants. The same result was found by Semenov et al. (2020). They reported that due to its short growth period, the plant has low nutrient requirements and does not need much N, P, and K for productivity. Haque et al. (2020) and Swathi et al., 2020 stated that the utilization of NPK at the rate of 25-50-25 kg ha^{-1} + vermicompost improved the biological yield of basils versus the control, which is in part consistent with our findings.

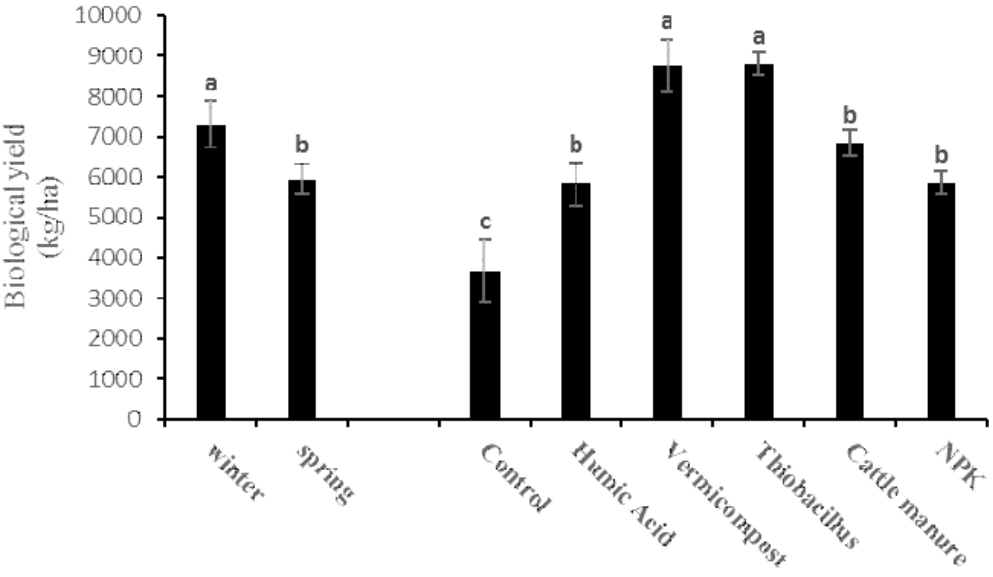

Figure 2. Means comparison of the simple effects of sowing date and fertilizer on biological yield per ha.

3.3. Harvest index

The effect of fertilizer type and sowing season was remarkable ($p < 0.01$) on the harvest index, however, the statistical insignificance of their interaction was apparent (Table 3). The insignificance of the interaction implies that different fertilization levels had a similar effect on the harvest index in both seasons. According to means comparison, the winter sowing (32.2%) had almost twice as great harvest index as the spring sowing (17.9%), and the application of manure (27.9%) and NPK (27.7%) resulted in the attainment of the greatest harvest index. and the lowest from the no-fertilization treatment (21.1%). Except for the Thiobacillus biofertilizer (24.4%), the other fertilizer treatments differed from the control significantly (Figure 3). The higher harvest index of the winter sowing may be associated with the environmental conditions of the plants during their vegetative growth period. The application of manure affects both biological and chemical processes, as well as soil P variability, thereby contributing to the better growth of the plants (Nayak et al., 2020; Haque et al., 2020).

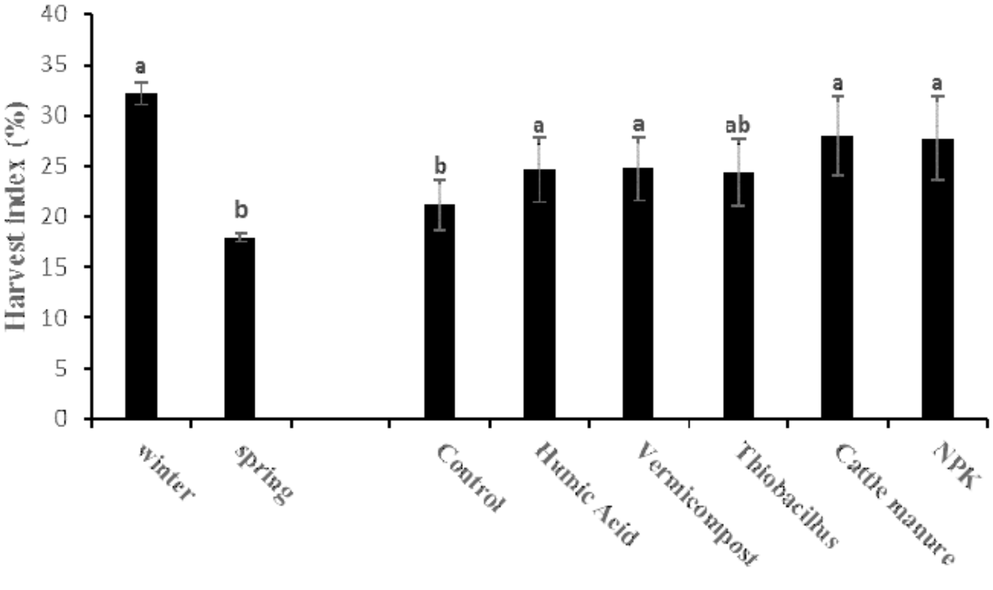

Figure 3. Means comparison of the simple effects of sowing date and fertilizer on the harvest index.

3.4. Physiological parameters

3.4.1. Chlorophyll a, chlorophyll b, and carotenoid

The results of ANOVA revealed the strongly significant effects of sowing season and fertilizer and the insignificant interactive effect of these two factors on chlorophyll *a*, chlorophyll *b*, and carotenoid (Table 4). Means comparison for the simple effects indicated higher chlorophyll *a* content of the winter sowing (0.186 mg g^{-1}) than the spring sowing (0.153 mg g^{-1}). Also, the highest chlorophyll *a* content was observed in the plants treated with Thiobacillus (0.228 mg g^{-1}) and vermicompost (0.222 mg g^{-1}) and the lowest in the control treatment (0.093 mg g^{-1}). Other fertilization treatments were ranked in the same statistical group and had a moderate content of chlorophyll *a*.

The results were similar for chlorophyll *b* and carotenoid so that, as is evident in Figure 5, the winter sowing resulted in elevated levels of chlorophyll *b* content in comparison to spring sowing (0.132 vs. 0.105 mg g^{-1}), and the plants treated with Thiobacillus and vermicompost demonstrated elevated levels of chlorophyll *b* content compared to the unfertilized plants (0.157, 0.151, and 0.079 mg g^{-1}, respectively). Brzozowska and Brzozowski (2020) reported that the winter sowing resulted in higher chlorophyll *b* content compared to the spring sowing. Furthermore, the winter sowing exhibited a higher carotenoid content (0.098 mg g^{-1}), whereas the spring sowing had a lower carotenoid content (0.070 mg g^{-1}). Among the fertilizer treatments, Thiobacillus (0.119 mg g^{-1}) and vermicompost (0.112 mg g^{-1}) produced the highest and the control treatment (0.059 mg g^{-1}) produced the lowest carotenoid contents (Figure 6). The results of Mazurenko et al. (2020) showed a higher carotenoid content in wheat with fertilizer treatments.

Vermicompost has a high water retention capacity and proper contents of available nutrients. Its microbial metabolism may, also, increase the number of chloroplasts per unit leaf area, chlorophyll density, photosynthesis rate, and finally, yield (Dao et al., 2020). In addition, the application of vermicompost contributes to maintaining soil nutrients, hindering N leaching, increasing microbial activity, and improving soil structure. Similar results have been reported (El Kinany et al., 2019; Nayak et al., 2020) so that the plants treated with vermicompost had higher total chlorophyll content than the untreated plants. By supplying the nutrient requirements of soil microorganisms, biofertilizers increase their population, thereby reducing soil pH and increasing the uptake of nutrients like Fe, Mg, and Mn that are involved in chlorophyll synthesis, so chlorophyll synthesis is enhanced (Dao et al., 2020).

Carotenoids are lipophilic compounds with low molecular weight in chloroplasts that protect plants against oxidative stresses. Carotenoids use the xanthophyll cycle to consume oxygen and protect chlorophyll against photo-oxidation. In addition to their structural role, carotenoids act as a light absorber and photosystem protectant against singlet oxygen radicals (Akhzari et al., 2018). A research study concluded that chlorophyll *a*, chlorophyll *b*, carotenoid, proline, and dissolved carbohydrate contents of dragon's head were affected by the foliar application of osmolytes and micronutrients (Swathi et al., 2020).

Table 4. Analysis of variance for the physiological parameters

S.V.	df	Means of squares				
		Chlorophyll *a*	Chlorophyll *b*	Carotenoid	Proline	Dissolved carbohydrates
Block	2	0.00097^{ns}	0.0001^{ns}	0.0001^{ns}	0.0002^{ns}	8.083*
Sowing season (A)	1	0.0098**	0.0063**	0.0032**	0.0024**	74.56**
Fertilizer (B)	5	0.154**	0.0056**	0.0032**	0.0007**	19.11**
A × B	5	0.0011^{ns}	0.00025^{ns}	0.0002^{ns}	0.00002^{ns}	0.72^{ns}
Error	22	0.00067	0.00017	0.00016	0.00007	2.15
Coefficient of variations		15.25	11.13	14.54	8.24	8.68

ns, *, and ** show insignificance and significance at the $p < 0.05$ and $p < 0.01$ levels, respectively.

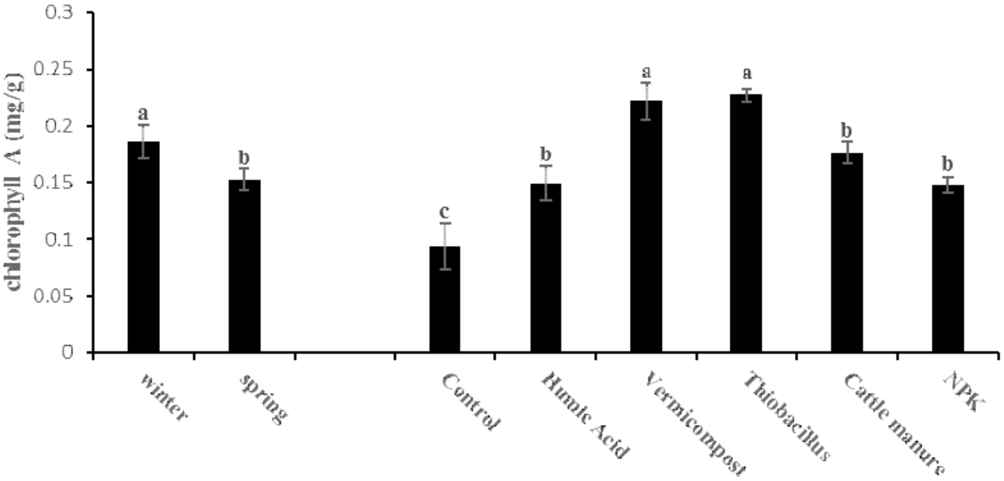

Figure 4. Means comparison of the simple effects of sowing date and fertilizer on chlorophyll *a* content.

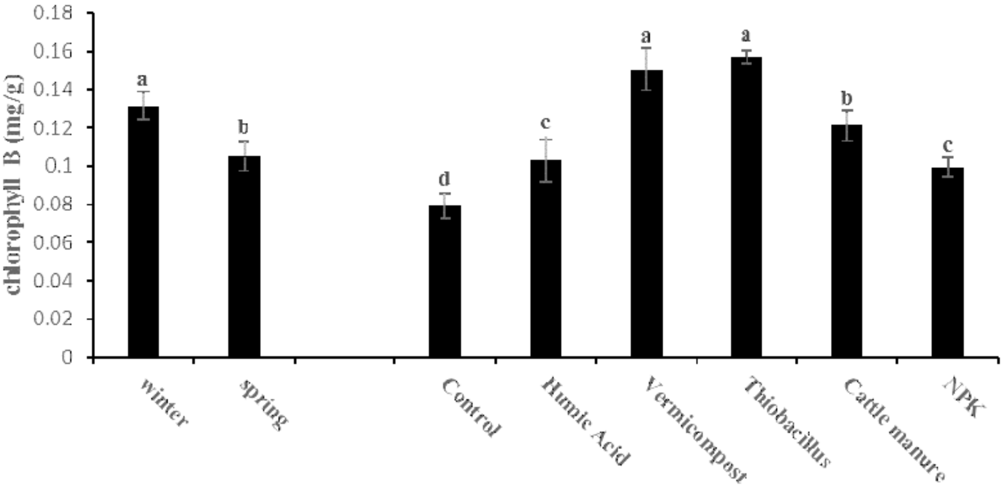

Figure 5. Means comparison of the simple effects of sowing date and fertilizer on chlorophyll *b* content.

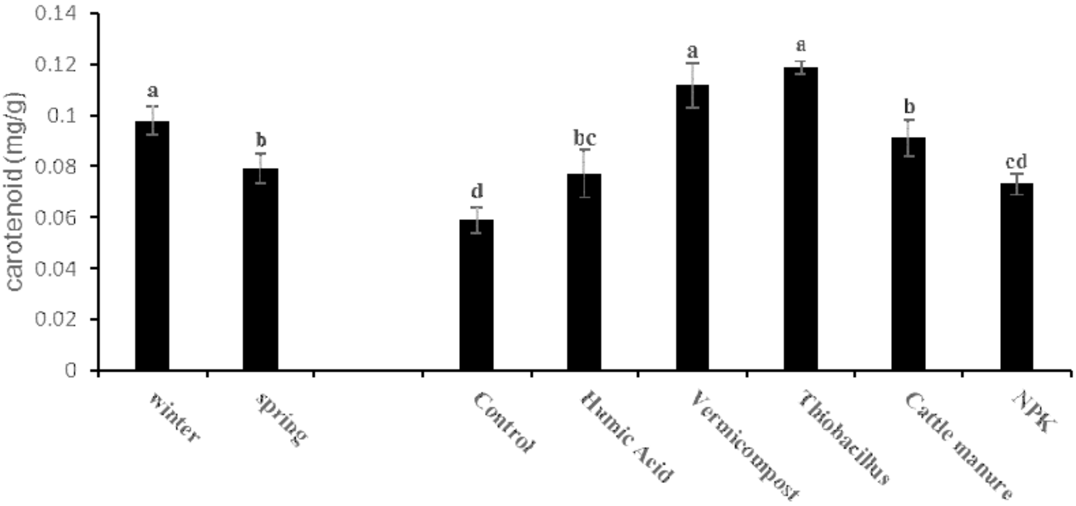

Figure 6. Means comparison of the simple effects of sowing date and fertilizer on carotenoid.

3.4.2. Proline and dissolved carbohydrates

ANOVA for proline content and dissolved carbohydrates revealed the significant effects of sowing season and fertilizer type at the $p < 0.01$ level and the insignificant interactive effect of these two factors on these two traits (Table 4). According to the findings of means comparison, the proline content of the spring-sown plants (0.108 mg g^{-1}) was higher than that of the winter-sown plants (0.091 mg g^{-1}). Also, the unfertilized plants produced the highest proline content (0.120 mg g^{-1}) followed by the NPK fertilizer (0.103 mg g^{-1}). The other fertilizers, especially vermicompost (0.090 mg g^{-1}), were related to the lowest proline content (Figure 7).

The dissolved carbohydrate content exhibited the same trend. It was higher in the spring sowing (18.3 mg g^{-1}) than in the winter sowing (13.5 mg g^{-1}). On the other hand, the unfertilized plants produced the highest dissolved carbohydrate content of 20.3 mg g^{-1}, and the different fertilization treatments, especially vermicompost (15.3 mg g^{-1}), resulted in the decline of dissolved carbohydrates in the dragon's head plants (Figure 8).

Higher plants often respond to stress by accumulating proline (Grace and Mbogue, 2020). The utilization of N-containing fertilizers has been documented to contribute to the synthesis of more proline in plants because proline is a protein compound with a nitrogenous structure (Temel and Yolcu, 2020). It has been concluded for chicory that biofertilizers have significant effects on chlorophyll *a*, chlorophyll *b*, total chlorophyll, carotenoid, dissolved carbohydrates, and proline. According to a study conducted by Nourzad et al. in 2015, it was found that the utilization of organic and inorganic fertilizers in stressed plants could effectively increase proline and carbohydrate contents. However, since the plants in the present study were not exposed to stress, the application of fertilizers failed to increase proline and dissolved carbohydrate contents. Nonetheless, the higher contents of these two traits were at a considerable level in the spring sowing.

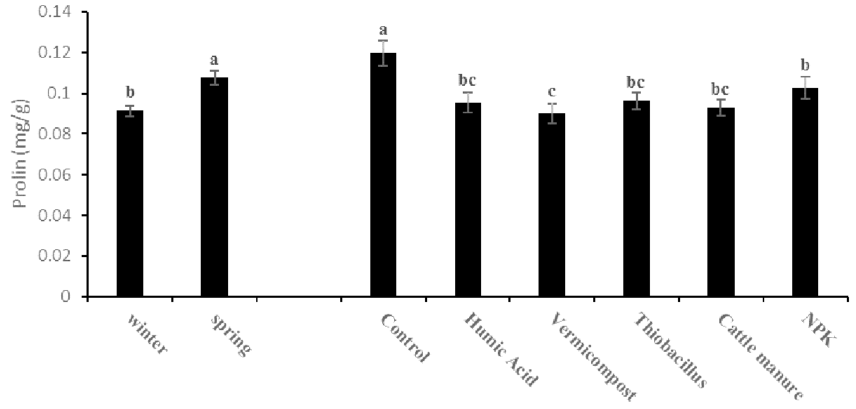

Figure 7. Means comparison of the simple effects of sowing date and fertilizer on proline content.

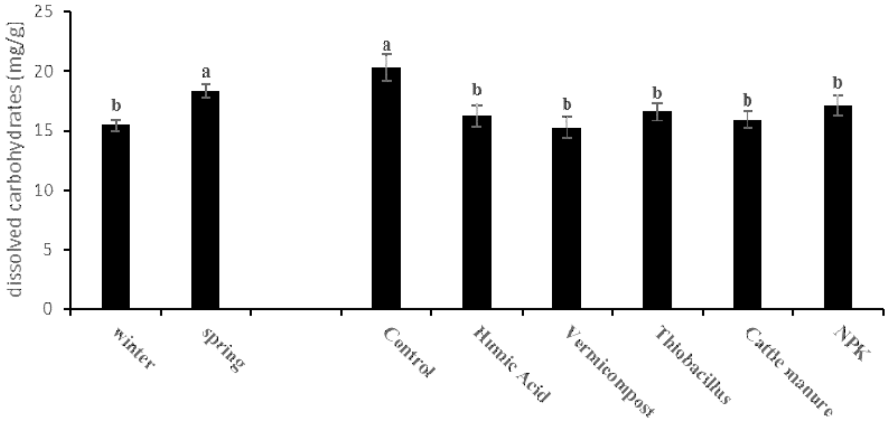

Figure 8. Means comparison of the simple effects of sowing date and fertilizer on dissolved carbohydrates.

Conclusion

The results of the present study revealed that the winter sowing of the dragon's head resulted in superior performance compared to spring sowing, leading to a significant enhancement in seed yield. Fertilization of the plants during both seasons, particularly in winter sowing, increased yield and yield components. Among the fertilizer treatments, vermicompost and Thiobacillus were found to be the most effective fertilizer treatments, while humic acid application, especially during spring sowing, was deemed the least effective in enhancing the characteristics. Unlike the other traits, proline and dissolved carbohydrates exhibited higher levels in spring sowing with no fertilizer treatment. On the other hand, chlorophyll *a*, chlorophyll *b,* and carotenoid contents were higher in the Thiobacillus and vermicompost treatments of the spring-sown plants, which could increase yield in these treatments by increasing the photosynthesis rate.

Ethical Statement

Ethical approval is not required.

Conflict of Interest

The authors declare that there are no conflicts of interest.

Funding Statement

No financial support was received.

Author Contributions

Authors contributed equally.

References

Adediran, J. A., Akande, M. O., Oluwatoyinbo, F. I., (2004). Effect of mucuna intercropped with maize on soil fertility and yield of maize. *Geomorphology*, *58*(1), 357-370.

Akbarinia, A., Khosravifard, M., Rezaee, M., Sharifi Ashoorabadi, E. (2005). Comparison of fall and spring cultivation on seed yield of some medicinal plant under irrigation and no-irrigation conditions. *Iranian Journal of Medicinal and Aromatic Plants*, *21*, 319-334. (In Persian with an English Abstract)

Akhzari, D., Kalantari, N., Mahdavi, S. (2018). Studying the effects of mycorrhiza and vermicompost fertilizers on the growth and physiological traits of Vetiver Grass (*Chrysopogon zizanioides* L.). *Desert, 23*(1), 57-62.

Amanzadeh, V., Khosravi, D., Haghi, N., Qorbani, A., Monsef Isfahani, H., Sa'adat Ibrahimi, S. (2011). Antioxidant activity of dragon's head essential oil at pre and post flowering stages. *Journal of Biological Science*, *6*,114-117. (In Persian)

Amooaghaie, R. & Mardani Korrani, F. (2018). *Bacillus subtilis* and Vermicompost Suppress Damping-off Diseasein Psyllium through Nitric Oxide-Dependent Signaling System. *Russian Journal of Plant Physiology, 65*(3), 435-445.

Amooaghaie, R. & Golmohammadi, S. H. (2017). Effect of vermicompost on growth, essential oil, and health of *Thymus vulgaris*. *Compost Science and Utilization, 25*(3), 166-171.

Anwar, M., Patra, D. D., Chand, S., Alpesh, K., Naqvi, A. A., Khanuja, S. P. S. (2005). Effect of organic manures and inorganic fertilizer on growth, herb and oil yield, nutrient accumulation, and oil quality of French basil. *Community Soil Science and Plant*, *36*, 1737-1746.

El Sayed, A. E. G., Darwish, M. A., Azoz, S. N., Abd-Alla, A. M., Elsayed, S. I. (2017). Effect of mineral, bio and organic fertilizers on productivity, essential oil composition and fruit anatomy of two dill cultivars (*Anethum graveolens* L.). *Sciences*, *7*(3), 532-550.

Brzozowska, I., Brzozowski, J. (2020). Content of macronutrients in winter wheat grain depending on the sowing date and level of NPK fertilization. *Journal of Elementology*, *25*: 226-234.

Dao, A., Guira, A., Alvar-Beltrán, J., Gnanda, A., Nebie, L., Sanou, J. (2020) Quinoa's response to different sowing periods in two agro-ecological zones of Burkina Faso. *Italian Journal of Agrometeorology, 1*: 63-72.

El-Sheshtawy, A.A., Hager, M.A., Shawer, S.S. (2019) Effect of bio-fertilizer, Phosphorus source and humic substances on yield, yield components and nutrients uptake by barley plant. *Journal of Biological Chemistry and Environmental Science*, 14: 279-300.

El Kinany, S., Achbani, E., Faggroud, M., Ouahmane, L., El Hilali, R., Haggoud, A., Bouamri, R. (2019) Effect of organic fertilizer and commercial arbuscular mycorrhizal fungi on the growth of micropropagated date palm cv. Feggouss. *Journal of the Saudi Society of Agricultural Sciences*, 18(4): 411-417.

Grace, A.M., Mbogue, C.N. (2020) Effects of sowing depth on seed germination and seedling growth of *Aframomum citratum* (Pereira) K. Schum. *African Journal of Plant Science*, *14*(7): 262-269.

Haque, M.A., Sarker, B.C., Karim, M.R., Rahman, M.Z., Hasan, M. (2020) Effect of sowing time and plant spacing on growth and yield of dwarf hyacinth bean. *Plant Archives, 20*(1): 2953-2958.

Kumar, N., Kumar, A., Shukla, A., Uthappa, A.R., Kumar, S. (2018) Effect of arbuscular mycorrhizal inoculations on growth and seedling quality of four Leucaena species. *Journal of Pharmacognosy and Phytochemistry*, *7*(4): 2089-2093.

Mazurenko, B., Honchar, L., Novytska, N., Kalenska, S. (2020) Grain yield response of facultative and winter triticale for late autumn sowing in different weather conditions. *EMU DSpace*, 13:225-236.

Nadeem, S. M., Ahmad, M., Zahir, Z. A., Javaid, A., & Ashraf, M. (2014). The role of mycorrhizae and plant growth promoting rhizobacteria (PGPR) in improving crop productivity under stressful environments. *Biotechnology Advances, 32*(2), 429-448. doi:10.1016/j.biotechadv.2013.12.005

Nayak, A., Mohanty, S.K., Khanda, C.M. (2020) Effect of Sowing Dates and Varieties on Growth, Yield and Yield Attributes of Soybean (*Glycine max* L.) in Odisha. *Journal of Plant Production Research 9*(2): 1121-1126.

Nejatzadeh-Barandozi, F., Pourmaleknejad, B. (2014) Effect of biological, organic and chemical fertilizers on vegetative growth, physiological characteristics and essential oils of (*Thymus vulgaris* L.). *Annual Research and Review in Biology*, *10*:1847-1853.

Nourzad, S., Ahmadian, A., Moghaddam, M. (2015) Proline, total chlorophyll, carbohydrate amount and nutrients uptake in coriander (*Coriandrum sativum* L.) under drought stress and fertilizer application. *Iranian Journal of Field Crops Research, 13*:131-139. (In Persian with an English Abstract)

Rahimi, A., Siavash Moghaddam, S., Ghiyasi, M., Heydarzadeh, S., Ghazizadeh, K., Popović-Djordjević, J. (2019) The Influence of chemical, organic and biological fertilizers on agrobiological and antioxidant properties of Syrian cephalaria (*Cephalaria Syriaca* L.). *Agriculture, 9*(6): 122-136.

Razavi, M., Moghaddam, T., Amini, M.A. (2012) Physical-mechanical properties and chemical composition of Balangu (*Lallemantia royleana* (Benth. in Walla.)) seed. *International Journal of Food Engineering*, 4: 115-123.

Rezaei-Chiyaneh, E., Amirnia, R., Machiani, M.A., Javanmard, A., Maggi, F., Morshedloo, M.R. (2020) Intercropping fennel (*Foeniculum vulgare* L.) with common bean (*Phaseolus vulgaris* L.) as affected by PGPR inoculation: A strategy for improving yield, essential oil and fatty acid composition. *Scientia Horticulturae,* 261: 108-119.

Rodnuch, N., Phongsri, S., Aninbon, C. (2019) Responses of Landrace Rice to Organic Fertilizer for Physiological Traits, Grain Yield and Total Phenolic Content. Current Applied *Science and Technology, 19*(3) : 297-305.

Selem, E., Nohutcu, L., Tuncturk, R., Tuncturk, M., (2021). The Effect of Plant Growth Promoting Rhizobacteria Applications on Some Growth Parameters and Physiological Properties of Marigold (Calendula officinalis L.) Plant Grown under Drought Stress Conditions. *Yuzuncu Yil University Journal of Agricultural Sciences, 31*(4), 886-897.

Semenov, A., Korotkova, I., Sakhno, T., Marenych, M. (2020) Effect of UV-C radiation on basic indices of growth process of winter wheat (*Triticum aestivum* L.) seeds in pre-sowing treatment. *Journal of Agronomy and Plant Breeding*, 12: 36-43.

Swathi, T., Padma, M., Rajkumar, M., Sivasankar, A. (2020) Effect of sowing time, seed rate and harvesting duration on germination of ashwagandha (*Withania somnifera). Journal of Pharmacognosy and Phytochemistry, 9*(3): 2087-2088.

Talaat, N.B. (2019) Effective microorganisms: An innovative tool for inducing common bean (*Phaseolus vulgaris* L.) salt-tolerance by regulating photosynthetic rate and endogenous phytohormones production. *Scientia Horticulturae*, 250: 254-265.

Temel, S., Yolcu, S. (2020) The effect of different sowing time and harvesting stages on the herbage yield and quality of quinoa (*Chenopodium quinoa* Willd.). *Turkish Journal of Field Crops*, *25*(1): 41-49.

Wang, J., Zhong, H., Zhu, L., Yuan, Y., Xu, L., Wang, G., Zhang, J. (2019) Arbuscular Mycorrhizal Fungi Effectively Enhances the Growth of Gleditsia sinensis Lam. Seedlings under Greenhouse Conditions. *Forests, 10*(7): 567-572.