Morphological Traits and Nutrient Uptake of Dragon’s Head (Lallemantia Iberica Fish.): Effects of Sowing Seasons and Different Fertilizer Sources

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Abstract

The effects of sowing seasons and chemical, organic and biological fertilizer sources were explored on morphological traits of dragon's head (*Lallemantia iberica* Fish.) in a field experiment based on a randomized complete block design in three replications and six treatments. The fertilization treatments included organic fertilizers (vermicompost, manure, and humic acid), biological fertilizer (Thiobacillus mixed with sulfur), chemical fertilizer (macro NPK), and control (no-fertilization). The recorded traits included leaf area index, plant height, number of flower cycles per plant, number of achenes per plant, number of seeds per plant, 1000-seed weight, number of auxiliary branches, plant diameter, and the uptake of nitrogen, potassium, phosphorus, calcium, and sodium. The results showed that the winter sowing outperformed the spring sowing by a wide margin and results obtained for morphological traits were significantly higher than those of the spring sowing. The fertilization of the plants in both sowing seasons, especially in the winter sowing, improved yield and yield components. The uptake of N and K was not influenced by the sowing season and fertilizer type, whereas the uptake of P, Ca, and Na was influenced by these factors but with a slight difference. It can, so, be inferred that the uptake of nutrients in dragon's heads is less influenced by the environment. Overall results indicated that the improvement of morphological traits in the ecological conditions of Azerbaijan region (Iran) was most notable for winter sowing of dragon's heads with the use of Thiobacillus and vermicompost fertilizers.

Introduction

The safety of crops produced by different agronomic systems in the world in terms of the residues of pesticides and agrochemicals and their harmful effects on the health of humans and the environment has drawn attention to production methods and inputs used in crop production. Following the recent crises of environmental pollution, extensive attempts have been made to find solutions to improve the safety of soil and crop quality, remove pollutants, and protect the sustainability of natural ecosystems[1]. Organic fertilizers constitute a major pillar of soil fertility as they have beneficial impacts on the physical, chemical and biological properties and the fertility of soils. These fertilizers increase soil organic matter and improve its fertility in the light of their impact on improving the chemical characteristics of soils including acidity, cation exchange capacity, the activity of microorganisms, and nutrient availability[2]. Biological fertilizers, which are sometimes used as an alternative to chemical fertilizers and the other times as their supplement, can guarantee the sustainability of agricultural systems[3]. The global approach in medicinal plant production is now towards improving the quantity, quality, and health of the active substances. So, the feeding of these plants with organic and biological fertilizers seems to be best suited with the goals of their production and can improve their quantitative and qualitative yields[4,5].

The history of using medicinal and aromatic plants to treat humans is as long as the history of mankind. Although the application of chemical and synthetic drugs has been expanded enormously in the last half-century, its harmful impacts on human life have revived interests in medicinal plants[6].

The plant species of the family Lamiaceae have traditionally been used as medicinal plants[7]. The medicinal and aromatic plants of this family are regarded as a rich genetic reserve because of their ecological resilience and extensive distribution in diverse climates. They have also extensive applications in the cosmetic and health industries due to their various aromatic compounds[8]. Dragon's head (*Lallemantia iberica* Fish.) is a plant species from this family that has a lot of applications. All parts of this plant species, including its leaves and seeds, can be consumed economically. Some applications of dragon's head include the extraction of oil from the seeds, the production of mucilage from the seeds, the extraction of essential oil from the vegetative parts, the application of seed meal (after oil extraction) as food and feed, the use of leaves and green twigs before flowering as edible vegetable, and its application as green fertilizer. Due to their mucilage compounds, the seeds of dragon's heads are good for cough[9]. These seeds are also used to treat neural, hepatic, and renal disorders and have traditionally been consumed as laxative, fortifier, sexual arouser, diuretic, and expectorant[10, 11].

Dragon's head is still grown in different parts of Iran sparsely, including provinces of Alborz, Guilan, Qazvin, Azerbaijan, Kurdistan, Kermanshah, Hamedan, Lorestan, Isfahan, Chaharmahal and Bakhtiari, Fars, Semnan, and Tehran[12]. A few studies have dealt with this plant species in the world in general, and in Iran in particular, but there are indications that it should be planted by the conventional patterns without the excessive use of chemical fertilizers[13]. The most recent research revealed that the appropriate combination of nano fertilizers enhanced the quality of yield components and antioxidant properties of dragon's head[14].

Continuing our interest for the improvement of qualitative and quantitative traits of dragon's head, the present study aimed to explore the effect of the sowing seasons and to explore the best fertilization system for the improvement of morphological traits and nutrient uptake of this medicinal plant with an emphasis on its organic production.

Materials And Methods

2.1 Experiments design

The study was carried out in the research farm of Faculty of Agriculture, Urmia University in Western Azerbaijan Province, Iran (longitude 45°10' east, latitude 37°44' north, and elevation 1338 meters from sea level) in the 2017-2018 growing season. The properties of the soil were as presented in our previous work[14]. The physicochemical properties of the applied organic fertilizers are shown in Table 1. The fertilizer requirement was calculated according to the results of soil analysis, fertilizer recommendations, and the N content of the applied organic fertilizer. Then, they were incorporated with the soil before sowing.

The study was a factorial experiment laid upon a randomized complete block design with three replications. The factors included sowing season and fertilizer source. The sowing season was assigned to the first factor including two levels of winter sowing and spring sowing. The fertilizer source was assigned to the second factor at five levels of manure, chemical NPK fertilizer, vermicompost, humic acid, and Thiobacillus + sulfur. The seeds were collected from a local landrace in the south of Western Azerbaijan Province. The blocks were developed on the farm on November 27, 2017. After an autumn plowing and land leveling, the sowing rows were created. The experimental plots were set at 6 m^2. The first experiment was set at the winter, and sowing was performed on November 28, 2017 by the row sowing technique. On-row spacing was set at 1 cm and between-row spacing at 25 cm. The second experiment was set at spring, and sowing was conducted on February 27, 2018. The thinning, gap-filling and weeding operations were performed conventionally during the growing season. To determine the morphological traits at the harvest time, 10 plants were randomly harvested from each plot to assess the traits. To estimate the yield, two side rows and 0.5 m from both ends of the plots were eliminated as the marginal effect. To measure the leaf area, three plants were randomly harvested from the second and third rows after eliminating 1 m from their ends. The leaf area of the three plants was first determined by the copying technique and the leaf area index was finally yield for different treatments.

2.2. Determination of morphological traits and nutrients

To measure the plant height, 10 plants were randomly taken from an area of 1 m^2 at each plot. Then, their height was recorded with a ruler in cm and it was averaged over each plot to yield the plant height. To measure the plant diameter, 10 randomly selected plants were harvested. After their roots were detached, the end part of the plants was measured with a caliper to find out plant diameter and its average was recorded for each plot. The auxiliary branches of 10 random plants in each plot were counted and averaged to find out the number of auxiliary branches. The number of achenes was counted on 10 plants and its average was recorded as the number of achenes per plant. The number of seeds was also determined for 10 plants and was averaged to yield this trait. The number of flowers was counted on 10 plants and was averaged to yield the number of flowers per plant. To determine the 1000-seed weight, 500 seeds were counted and their weight was doubled, and this was repeated three times to yield the 1000-seed weight.

Nutrients such as nitrogen (N), potassium (K), phosphorus (P), calcium (Ca), and sodium (Na) were determined as follows: Nitrogen content was measured by sulfuric acid and the Kjeldahl system. Phosphorus content was estimated by the method of dry combustion with HCl. Then, the samples were read by spectrophotometer. To measure potassium content, the samples were placed in a furnace and they were then undergone dry combustion with HCl. Then, a flamephotometer (the model Clinical pfp7) was used to read potassium standards first and then the main samples. To find out calcium and sodium content of foliage and shoot, 1 g of foliage was ground and screened and was placed in a furnace at 550°C for 24 hours. The samples were adjusted to 100 mL after digestion with dry combustion method (with HCl). Then, a flame photometer (model Clinical pfp7) was used to read the standards first and then the main samples.

Data were analyzed on the basis of the expected value of the base design and using the SAS 9.2 software package. Means comparison for the traits was carried out by multiple-range test at the $P < 0.05$

level. The graphs were drawn by the MS-Excel software package.

Results And Discussion

3.1. Morphological traits

Leaf area index - Leaf area index (LAI) is a major variable in climatic, ecological and agricultural research. Means comparison revealed that the maximum LAI (5.02) was obtained from the vermicompost-fertilized winter sowing treatment and the minimum (1.89) from the unfertilized spring sowing treatment (Figure 1). The highest LAI (4.08) among the spring-sown plants was related to those fertilized with Thiobacillus. The application of biosulfur (containing Thiobacillus), especially to spring-sown plants, seems to be a strategy to increase P availability in soils via oxidizing sulfur and influencing soil pH, which can improve plant growth[15]. The leaves of dragon's heads are another economic part of this medicinal plant. The leaves and green twigs of the pre-flowering plants are consumed as fresh vegetables or as green manure. The expansion of leaf area is important in the sense that it develops plant area and allows the interception of more radiation, and subsequently, this process increases photosynthesis and assimilation, resulting in higher growth rate. The fertilizers used here provided the plants with various amounts of nutrients, which was responsible for the difference among the treatments in LAI.

lant height - According to the results of means comparison, the winter sowing increased the plant height when compared to the spring sowing (76.6 cm versus 70.7 cm). The highest plant heights were related to the treatments of vermicompost (78.2 cm), Thiobacillus (77.9 cm), and manure (77.9 cm), respectively and the lowest (61.9 cm) was related to the control (Figure 2). Since nutrient deficiency is a key factor in dictating plant height, it seems that no-fertilizer treatment exhibited lower growth because of nutrient deficiency whereas all fertilization treatments had a positive effect on the vegetative growth of the plants.

Number of flower cycles per plant - The highest flower cycles per plant (79.8 cycles) were observed in the treatment of vermicompost and the second and third highest were related to the application of Thiobacillus (71 cycles) and manure (65.9 cycles) to the winter-sown plants. On the other hand, the lowest number of flower cycles per plant was related the no-fertilizer treatment (15.4 cycles) and the application of humic acid (19.7 cycles) to the spring-sown plants. Among the fertilizer treatments of the spring-sown plants, the highest number of flower cycles per plant were observed in those fertilized with Thiobacillus (34 cycles), vermicompost (32 cycles), and manure (29 cycles) (Figure 3). It has been reported that the application of organic compounds to soil improves yield, growth, and chemical compounds of peppermint[16,] , rosemary[17] and Sinderitis Montana[18].

Number of achenes per plant - The number of achenes per plant and the number of seeds per flower cycle are the determinants of the yield of dragon's heads[19]. The highest number of achenes per plant was obtained from the winter-sown plants fertilized with vermicompost (268 achenes), Thiobacillus (233 achenes), and manure (215 achenes), which were different to one another significantly. The lowest number of achenes was observed in the spring-sown plants under no fertilization treatment (51 achenes) and humic acid treatment (65 achenes). However, the spring-sown plants fertilized with Thiobacillus (109 achenes) and vermicompost (104 achenes) exhibited more achenes than their control counterparts, but even these higher number of achenes could not compete with that of the unfertilized winter-sown plants, which produced 143 achenes (Figure 4). In a study on the effect of high-input (urea and triple superphosphate) and low-input (Nitroxin, Barvar-2 phosphate, and biosulfate) fertilization system along with the effect of irrigation frequency on the morphological traits of dragon's heads, it was reported that these factors affected the number of achenes significantly and the high-input system produced more achenes[20,21] (34 achenes), also, reported that in the monocropping system of dragon's heads, the biofertilizer-treated plants produced more achenes per plant than the unfertilized plants. An effective way to enhance rainfall use efficiency is to make spring rainfalls coincide with the initiation of vegetative and reproductive growth by selecting a proper sowing date[22] .

Number of seeds per plant - The simple and interactive effect of the fertilizer source and sowing season was significant ($p < 0.01$) on the number of seeds per plant (Table 4). According to means comparison (Figure 5), the fertilizer treatments did not differ to one another significantly in the spring sowing, and their seed number per plant (85 seeds) was the lowest. But, these treatments in the winter sowing differed significantly. The highest number of seeds per plant in the winter sowing was obtained from the NPK fertilizer (181 seeds) and manure (175 seeds). The next ranks were related to the application of vermicompost (162 seeds) and Thiobacillus (152 seeds) followed by humic acid (131 seeds) and no-fertilization treatment (126 seeds). To explain the increase in the seed number per plant[19], argue that in a treatment in which soil moisture is appropriate, chlorophyll growth and then the number of achenes per plant will increase and this, in turn, will enhance the number of seeds per plant. Consequently, a severe competition will initiate between the filling grains that are strong sinks for photosynthate absorption and thereby smaller light-weight seeds will be produced.

*Thousand-seed weigh*t - It is evident that the highest 1000-seed weights were related to the application of Thiobacillus or vermicompost to the winter-sown plants (5.68 and 5.66 g, respectively) and the lowest was 2.31 g observed in the unfertilized spring-sown plants (Figure 6). Also, the application of Thiobacillus to the spring-sown plants exhibited a 1000-seed weight of as high as 4.48 g. In the winter sowing, the treatment of NPK fertilizer (3.85 g) had lower 1000-seed weight than the control (4.21 g), but their difference was insignificant. This is related to the fact that the application of NPK fertilizer produced the highest number of seeds per plant and it is obvious that when the number of seeds increases, their weight decreases due to competition. Based on the results, the higher seed yield was probably due to the positive effect of vermicompost and winter sowing on 1000-seed weight. The application of biofertilizers in the study of[21] enhanced the yield and yield components (e.g. 1000-seed weight, the number of pods per plant, the number of seeds per pod, the number of auxiliary branches, and plant height) of dragon's heads and peas so that they recommended the application of biofertilizers in the intercropping system of this plant. A sowing date that has recently been considered is winter sowing in which the sowing date is of crucial importance because the seeds should be sown when the air and soil are cold enough to prevent germination. Winter sowing aims at maximizing the use of rainfall, especially in regions where no land preparation is possible in springs due to rainfalls[23].

Number of auxiliary branches - As depicted in Figure 7, the winter-sown plants showed the highest number of auxiliary branches when they were fertilized with vermicompost (6.9 branches) or Thiobacillus (6.4 branches). In contrast, the spring-sown plants exhibited the lowest number of auxiliary branches when they were not fertilized (2.4 branches) or were fertilized with humic acid (2.9 branches). The highest number of auxiliary branches in the spring-sown plants was related to those treated with Thiobacillus (5.6 branches). The significant difference of the fertilization treatments with the control in both seasons implies that the application of fertilizer facilitates nutrient access for plants and help them establish better. In a study on the effect of time on some traits of dragon's heads[24], concluded that the number of auxiliary branches was significantly higher in the early sowing than in the late sowing. Our results about the effect of fertilization on the number of auxiliary branches of the dragon's heads are consistent with the results of[25,26,] for Silybum marianum L., for fennel, and[27] for lentil, who have all expressed the significant effect of biofertilizers on the number of main and auxiliary branches of the studied plant species.

Plant diameter - The highest plant diameter was 9.0 cm observed in the winter-sown plants that were treated with vermicompost. The next highest plant diameters were related the NPK-fertilized winter-sown plants (8.05 cm), manure-fertilized winter-sown plants (7.89 cm), and Thiobacillus-treated winter-sown plants (7.88 cm), which were all ranked in the same statistical group. The application of humic acid and no-fertilizer to the winter sowing resulted in the lowest plant diameters of 6.79 and 6.28 cm, respectively. All fertilization treatments in the spring sowing showed the minimum stem diameter and were ranked in the same statistical group (Figure 8). Since stems are a sink of assimilates, the improvement of nutritional conditions by consuming fertilizers increased assimilates, resulting in the enhancement of stem diameter. The failure of humic matter in improving plant growth has been reported in several research works. For example, a study on oregano reported that the plants treated with humic matter produced a stem diameter even lower than the control[28]. In their investigation of the effect of biofertilizers on the quantitative yield and morphological traits of dragon's heads exposed to severe water stress[29], recommended the application of Barvar-2 phosphate biofertilizer under optimal irrigation conditions to achieve the highest number of pods per plant, seeds per plant, seed yield, biological yield, and stem diameter.

3.2. Nutrient uptake

Despite the insignificant effect of the fertilizer on N content, means comparison by Duncan's multiple range test grouped the treatments as depicted in Figure 9. Among the studied six fertilization treatments, the application of manure and vermicompost produced the highest and no-fertilization treatment produced the lowest N contents (2.67%, 2.53%, and 2.12%, respectively). The remaining treatments were in between these two extremes and did not influence N content considerably. In terms of phosphorus (P) content, the simple effect of the sowing season and fertilizer type was significant ($p < 0.01$), but their interaction was insignificant (Table 5). Based on the results of means comparison for this nutrient, the winter sowing increased P content versus the spring sowing (0.73% versus 0.60%). Also, among the fertilization treatments, Thiobacillus was related to the highest P content of 0.76% and the other fertilizers did not differ from no-fertilizer application (0.60%) significantly, so they were all placed in the same statistical group. Therefore, in spite of the significant impact, there was not a remarkable difference between the fertilization treatments (Figure 10).

Means comparison for the simple effects (Figure 11) showed higher Ca content in the winter sowing (7.12%) than in the spring sowing (6.54%). Also, the treatment of humic acid (7.95%) and manure (7.04%) were related to the highest and the no-fertilizer treatment (6.03%) was related to the lowest Ca content. The winter sowing had a slightly but significantly higher Na content than the spring sowing (4.74% versus 4.33%). Furthermore, the application of manure was related to the highest Na content (7.06%), but the lowest was related to the no-fertilizer treatment (4.01%). The other fertilizers had almost as high Na content as the control (Figure 12).

It was observed that the application of manure increased the uptake of nutrients. Manure increases soil cation exchange capacity, soil nutrient contents, nutrient availability to plants, nitrogen balance, soil organic matter and humus content, and soil granulation, thereby increasing its porosity and improving its structure[30]. For these reasons, the growth and expansion of root systems are increased in soils treated with organic fertilizers where plants can grow and absorb nutrients well under the appropriate physical and chemical conditions created by the organic fertilizers[31]. Likewise[32], reported for coriander that the application of different fertilizers including manure enhanced the uptake of N, P, K, and Na significantly as compared to the no-fertilizer treatment. Although the phenotypic representation of traits is influenced by genetics, environment, and their interaction[33], these influences may vary with plant and trait.

3.3. The analysis of variance of morphological and yield traits

The results of the analysis of variance (ANOVA) indicated that the effects of fertilization and sowing date were significant on leaf area index (LAI) and plant height ($P < 0.01$), whereas the interactive effect of these factors was significant ($P < 0.01$) on LAI but insignificant for the plant height of the dragon's heads (Table 2).

The interactive effects of the sowing season and fertilizer were significant ($P < 0.01$) on the number of flower cycles per plant, number of achenes per plant, number of seeds per plant, 1000-seed weight, number of auxiliary branches and the plant diameter (Table 3). The results of ANOVA for the number of flower cycles per plant, the number of achenes per plant, number of seeds per plant, 1000-seed weight, and plant diameter indicated that the effects of the sowing season and fertilizer were significant

($P < 0.01$). Additionally, the interaction of studied effects was significant on the number of auxiliary branches at $P < 0.05$ (Table 3).

According to the results of ANOVA it is evident that the effects of the sowing season and fertilizer and their interaction were statistically insignificant for the uptake of N and K, whereas both factors were significant to phosphorus uptake ($P < 0.01$), unlike their interaction (Table 4). The data on Ca content revealed that this trait was influenced by the sowing season at the $P < 0.05$ level and by the fertilizer type at the $P < 0.01$ level, but their interaction was insignificant for this trait. The two sowing seasons and six fertilizer treatments differed significantly ($P < 0.05$) in Na content. Like the other studied elements, the interaction of sowing season × fertilizer was insignificant for this trait. The insignificant effect of sowing season and fertilizer on the uptake of some elements means that these traits were not influenced by sowing season and fertilizer type and there was not a specific trend in the variations of this trait. Even in elements in which the impacts were significant, the differences were not considerable among the treatments. It can, thus, be concluded that the uptake of nutrients is affected by sowing season and fertilizer to a lesser extent.

Conclusion

The obtained results revealed that the winter sowing of dragon's heads outperformed the spring sowing by a wide margin. The fertilization of this plant species in both sowing seasons, especially in winter sowing, improved its morphological traits. Among the different fertilizers, vermicompost and Thiobacillus proved to be more effective whereas the application of humic acid, especially to the spring-sown plants, was the least effective in improving the traits.

The uptake of some elements was not influenced by the sowing season or fertilizer type. Even the elements that were influenced by these factors did not exhibit large differences between the treatments. Nonetheless, the highest rate of nutrient uptake was observed in the treatments of manure, humic acid, and Thiobacillus with slight differences. Thus, it can be inferred that the trait of nutrient uptake, especially N and K, is influenced by the environment and fertilizer to a lesser extent.

Declarations

Conflict of interest

The authors declare no conflicts of interest.

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Tables

Table 1. Some physical and chemical properties of the organic fertilizers used 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

Table 2. The results of the analysis of variance of leaf area index and plant height

Sources of variations	Degrees of freedom	Means of squares	
		Leaf area index	Plant height
Block	2	0.015^{ns}	3.64^{ns}
Growing season (A)	1	163.8^{**}	319.8^{**}
Fertilizer (B)	5	115.7^{**}	229.9^{**}
A × B	5	5.29^{**}	19.7^{ns}
Error	22	0.037	9.64
Coefficient of variations		5.75	4.22

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

Table 3. The results of the analysis of variance of morphological and yield traits

S.O.V.	df	Means of squares					
		Flower cycles/plant	Achene No./plant	Seed No./plant	1000-seed weight	Auxiliary branch no.	Plant diameter
Block	2	7.29^{ns}	62.7^{ns}	72.9^{ns}	0.042^{ns}	0.20^{ns}	0.097^{ns}
Growing season (A)	1	1181.8^{**}	128145^{**}	41544^{**}	12.94^{**}	21.93^{**}	45.92^{**}
Fertilizer (B)	5	62.1^{**}	6636.7^{**}	1073^{**}	4.15^{**}	6.53^{**}	1.91^{**}
A × B	5	7.03^{**}	893.5^{**}	551.8^{**}	0.64^{**}	0.64^{*}	1.01^{**}
Error	22	9.79	84.62	107	0.054	0.237	0.155
Coefficient of variations		7.16	6.39	8.58	5.54	10.12	6.04

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

Table 4. The results of the analysis of variance of nutrient uptake status

S.O.V.	df	Means of squares				
		N	K	P	Ca	Na
Block	2	0.059^{ns}	0.85^{ns}	0.0047^{ns}	0.403^{ns}	0.033^{ns}
Growing season (A)	1	0.183^{ns}	0.73^{ns}	0.155^{**}	3.10^{*}	1.504^{*}
Fertilizer (B)	5	0.203^{ns}	0.80^{ns}	0.019^{**}	2.56^{*}	0.676^{*}
A × B	5	0.002^{ns}	0.13^{ns}	0.0008^{ns}	0.033^{ns}	0.129^{ns}
Error	22	0.098	0.52	0.0042	0.518	0.218
Coefficient of variations		12.87	19.97	9.73	10.54	10.28

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

Table 5. The results of the analysis of variance of nutrient uptake status

S.O.V.	df	Means of squares				
		N	K	P	Ca	Na
Block	2	0.059^{ns}	0.85^{ns}	0.0047^{ns}	0.403^{ns}	0.033^{ns}
Growing season (A)	1	0.183^{ns}	0.73^{ns}	0.155**	3.10*	1.504*
Fertilizer (B)	5	0.203^{ns}	0.80^{ns}	0.019**	2.56*	0.676*
A × B	5	0.002^{ns}	0.13^{ns}	0.0008^{ns}	0.033^{ns}	0.129^{ns}
Error	22	0.098	0.52	0.0042	0.518	0.218
Coefficient of variations		12.87	19.97	9.73	10.54	10.28

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

Figures

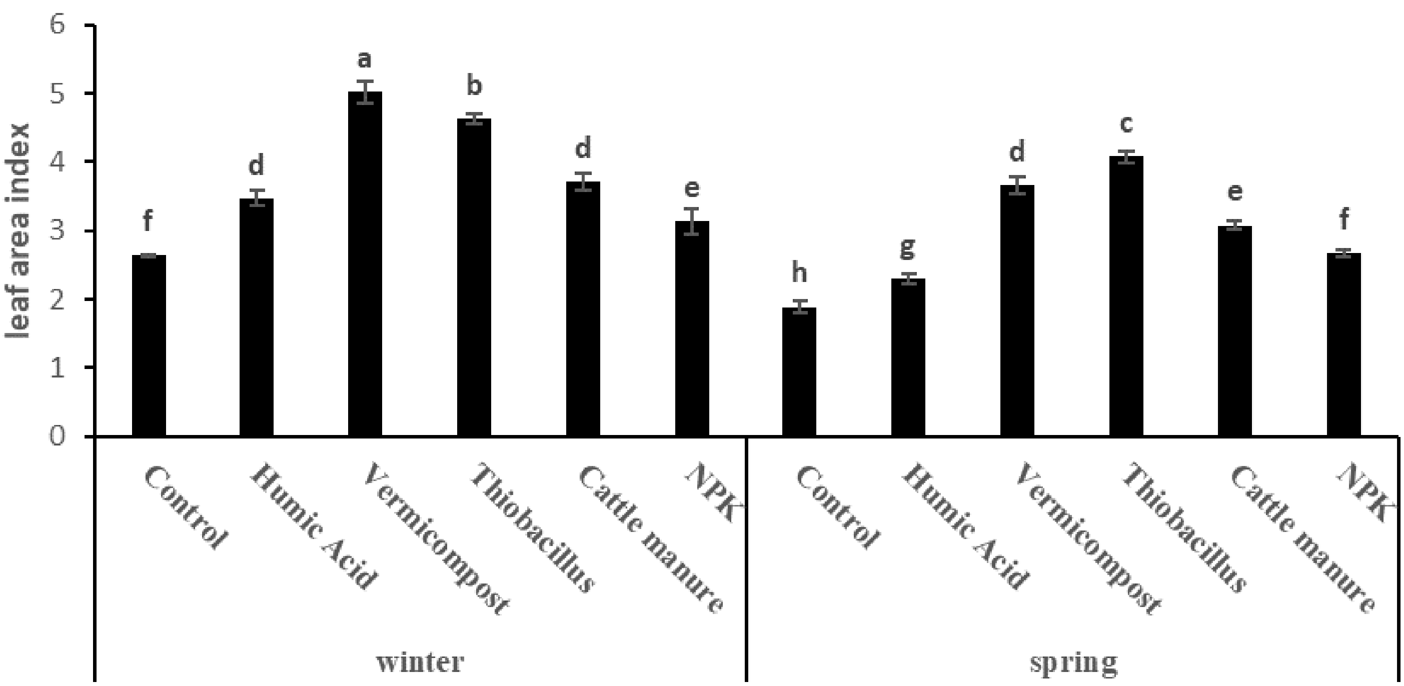

Figure 1

Means comparison for the interactive effect of sowing season and fertilizer source on leaf area index

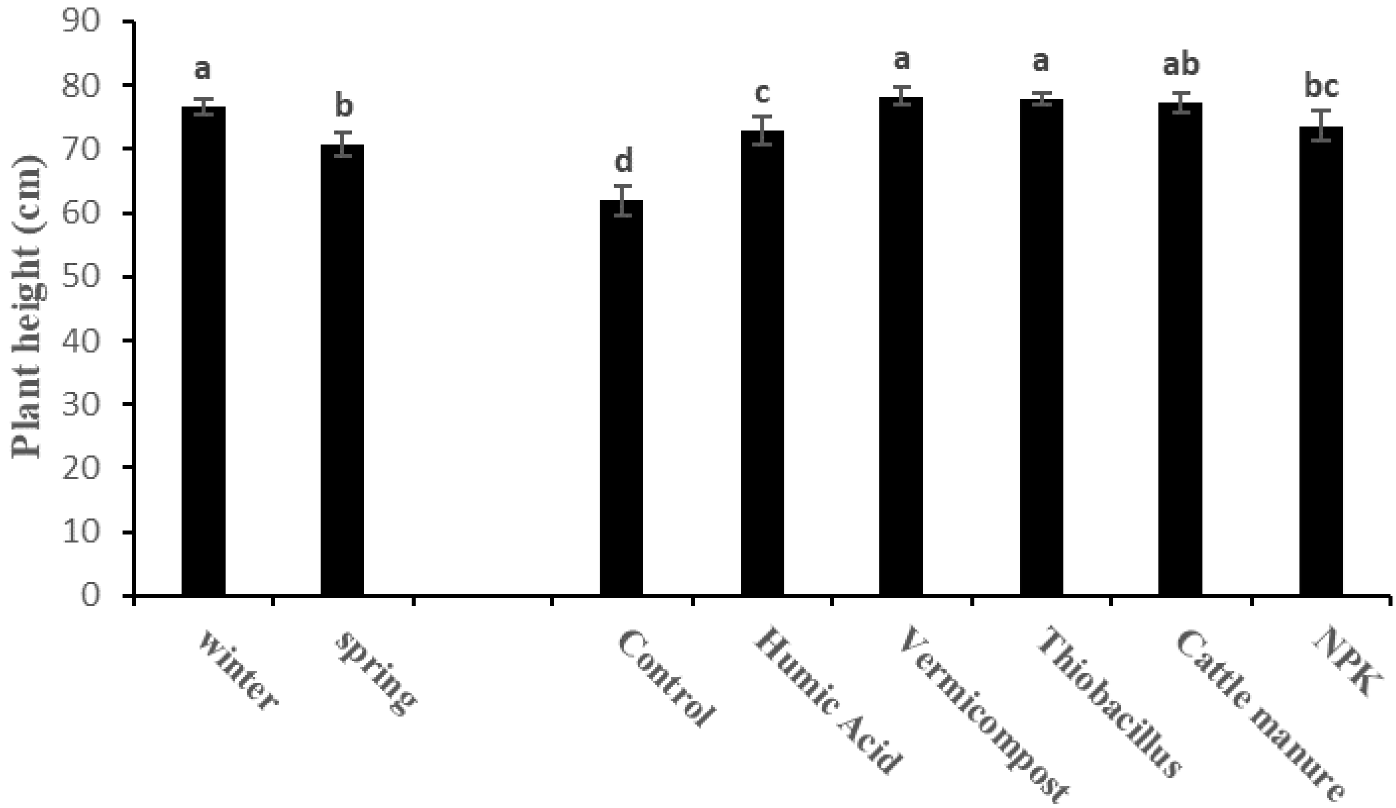

Figure 2

Means comparison for the simple effect of sowing season and fertilizer source on plant height

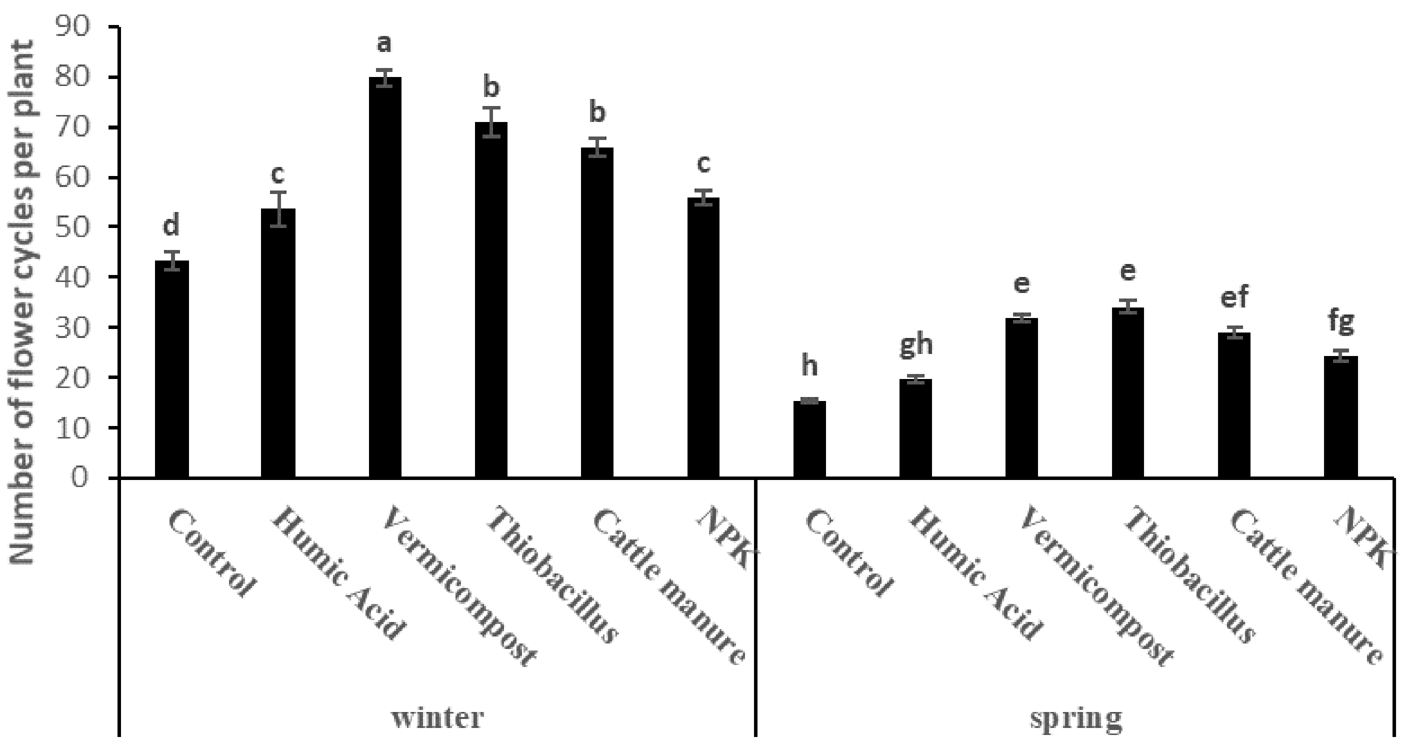

Figure 3

Means comparison for the interactive effect of sowing season and fertilizer source on the number of flower cycles per plant

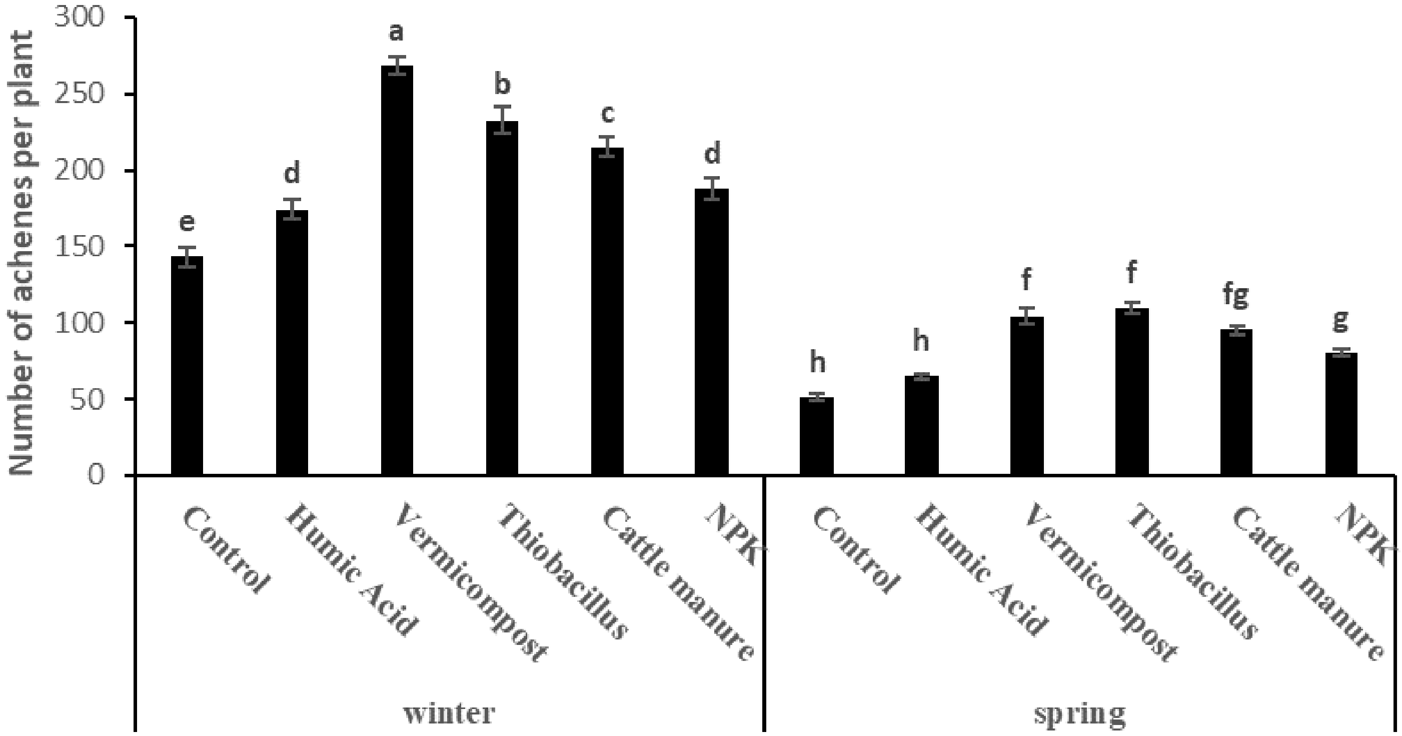

Figure 4

Means comparison for the interactive effect of sowing season and fertilizer source on the number of achenes per plant

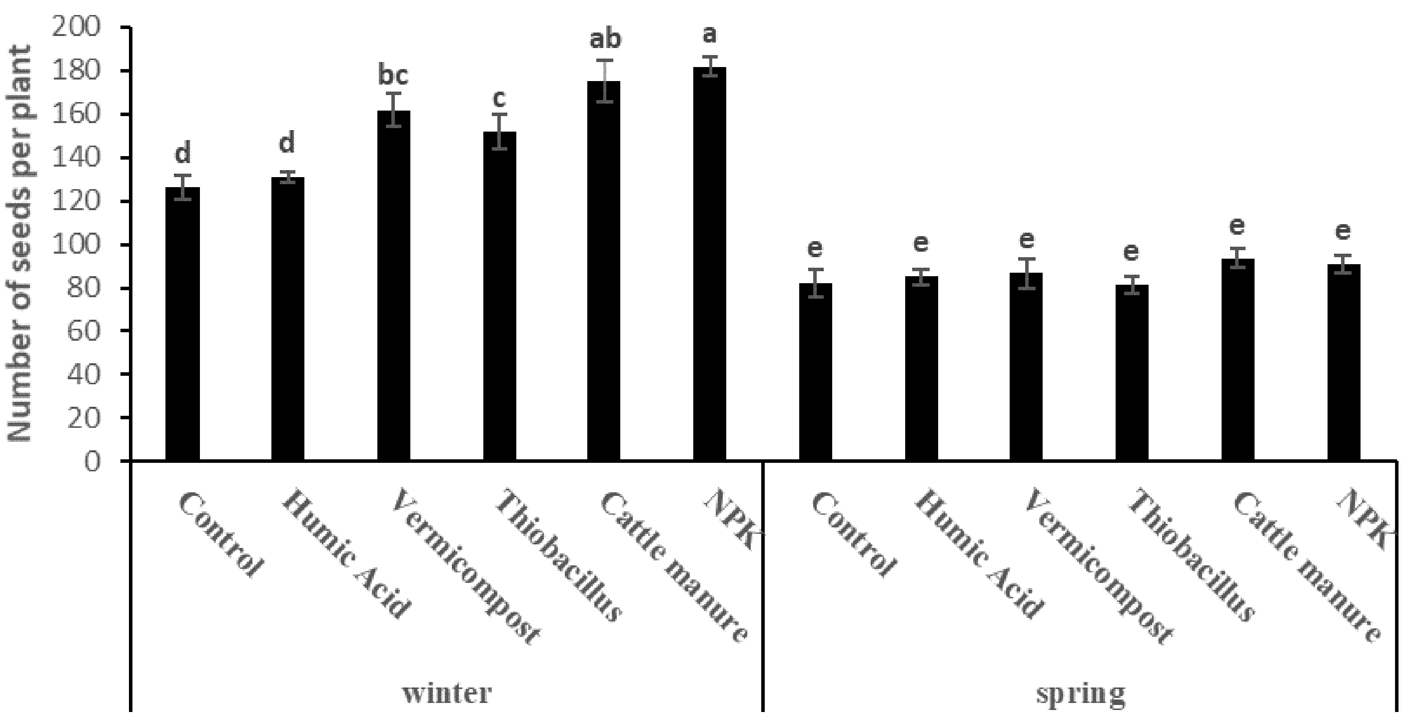

Figure 5

Means comparison for the interactive effect of sowing season and fertilizer source on the number of seeds per plant

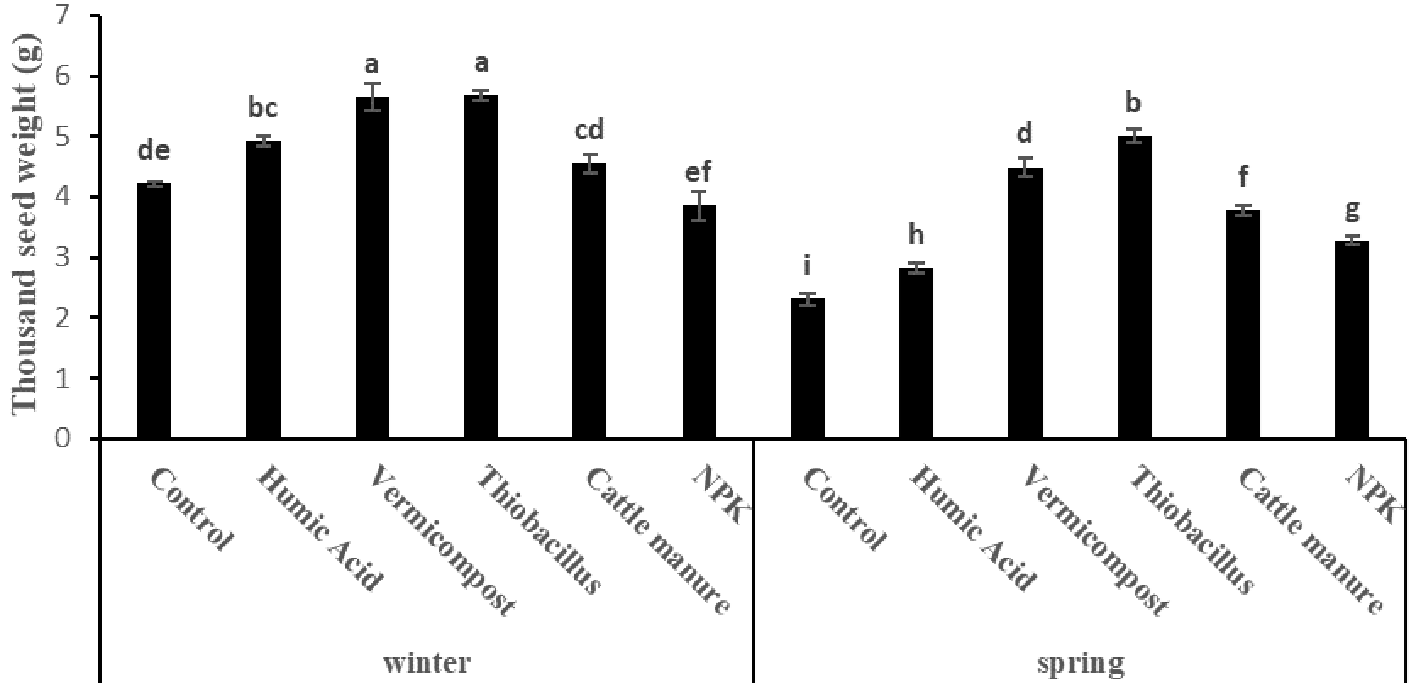

Figure 6

Means comparison for the interactive effect of sowing season and fertilizer source on thousand-seed weight

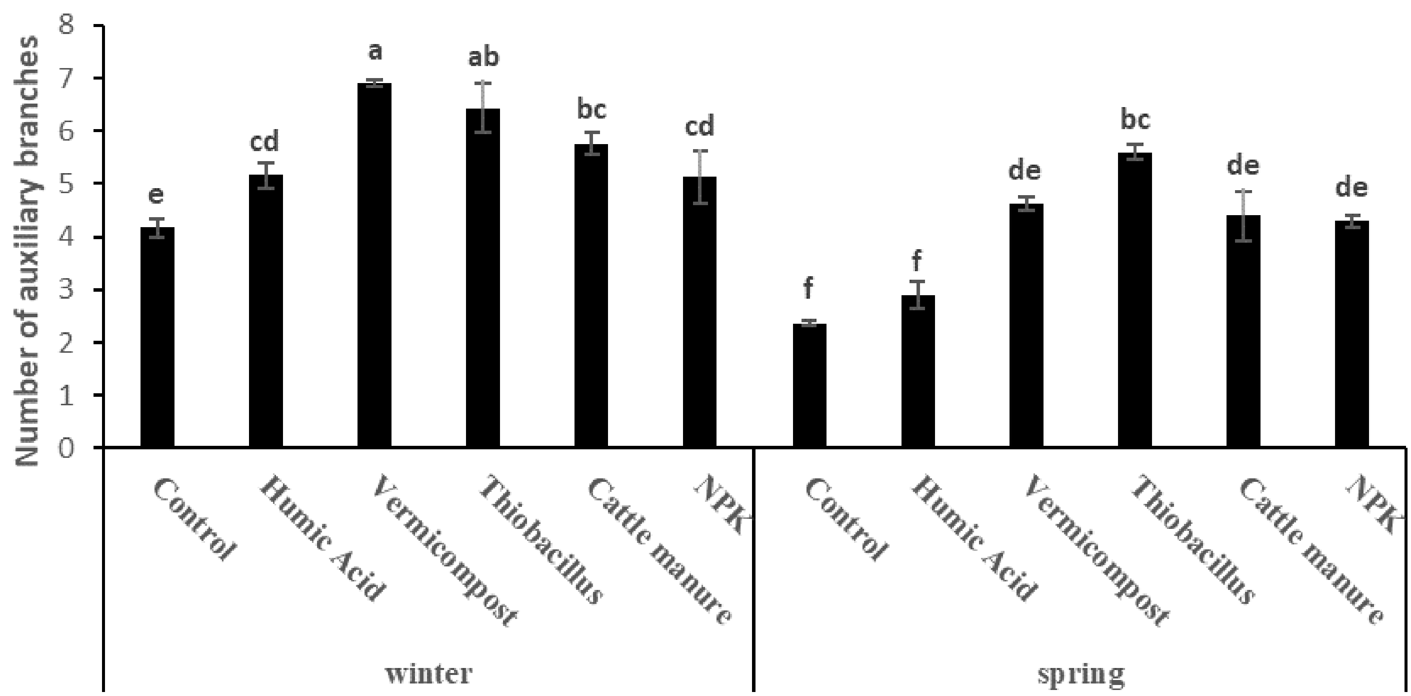

Figure 7

Means comparison for the interactive effect of sowing season and fertilizer source on the number of auxiliary branches

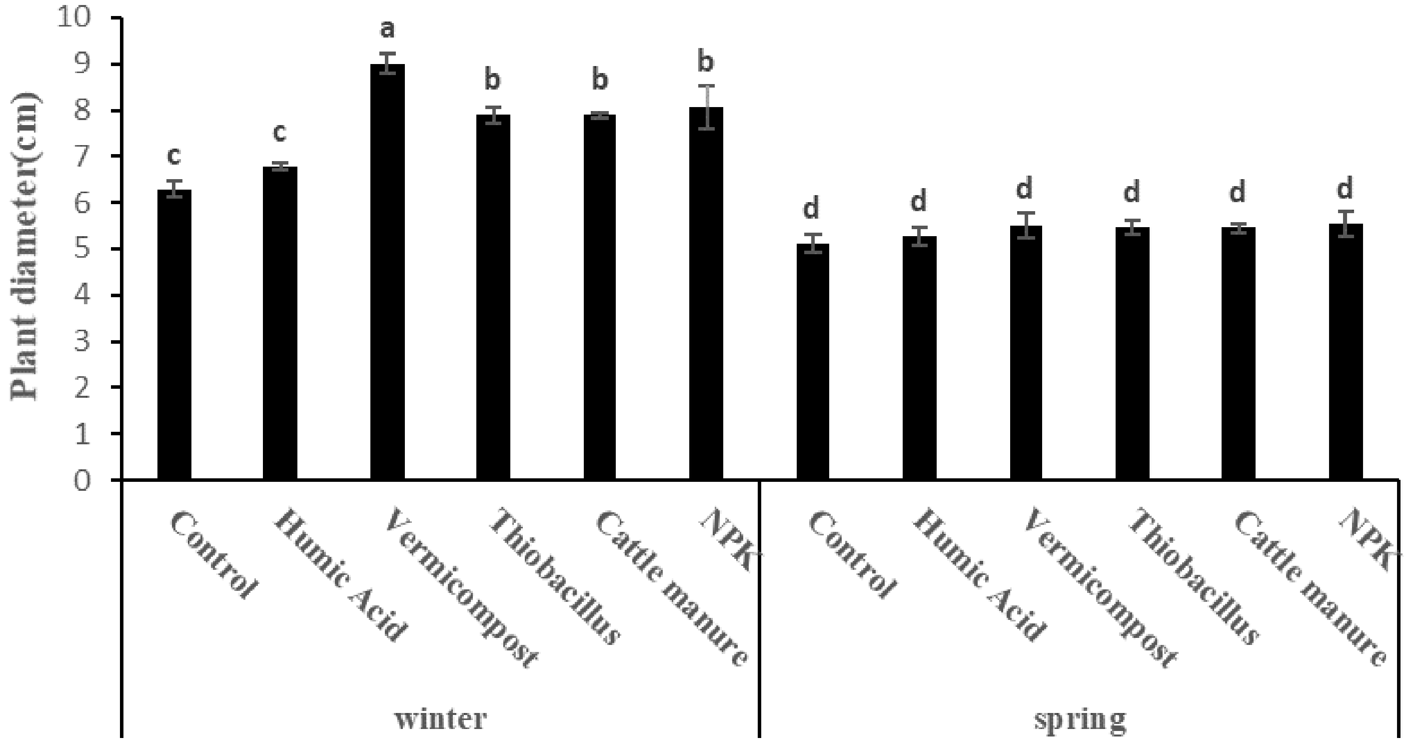

Figure 8

Means comparison for the interactive effect of sowing season and fertilizer source on plant diameter

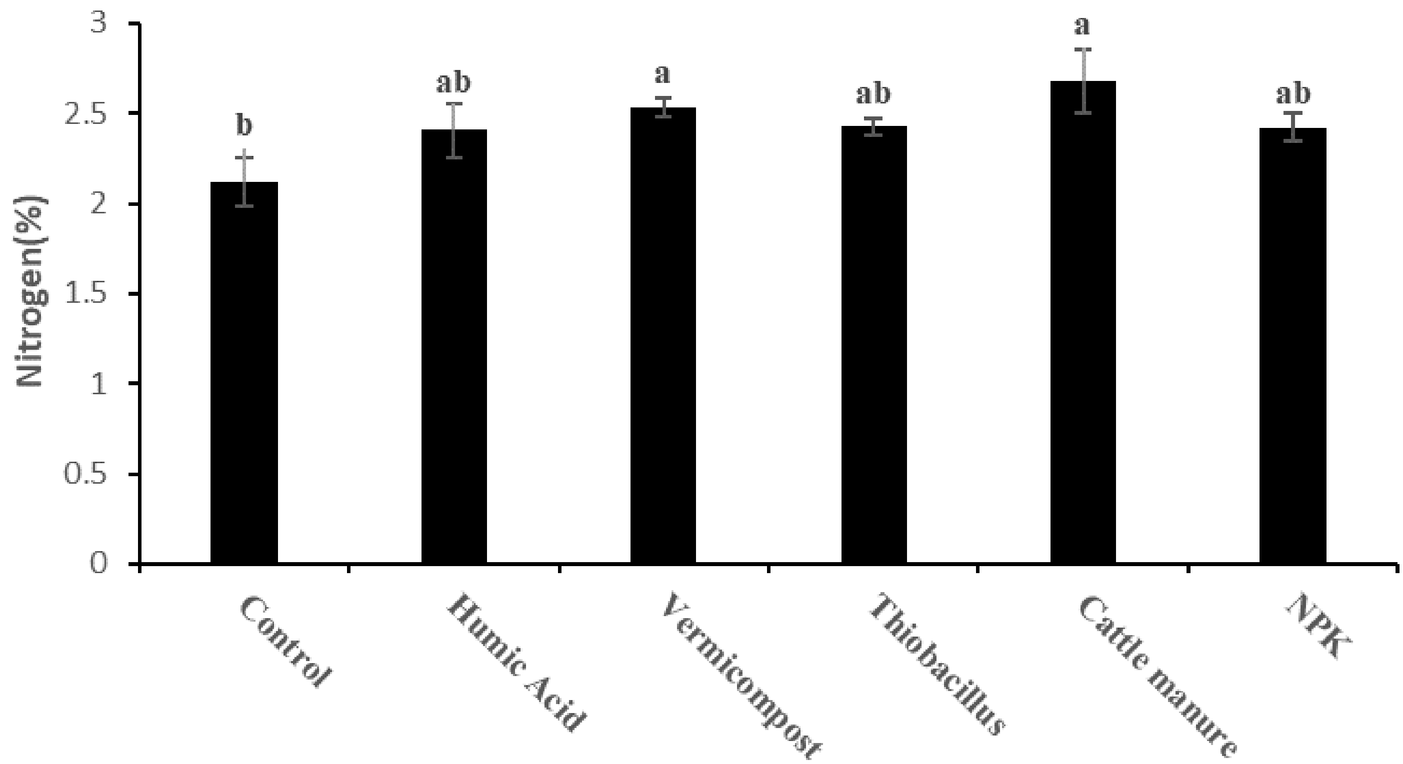

Figure 9

Means comparison for the effect of fertilizer source on nitrogen content

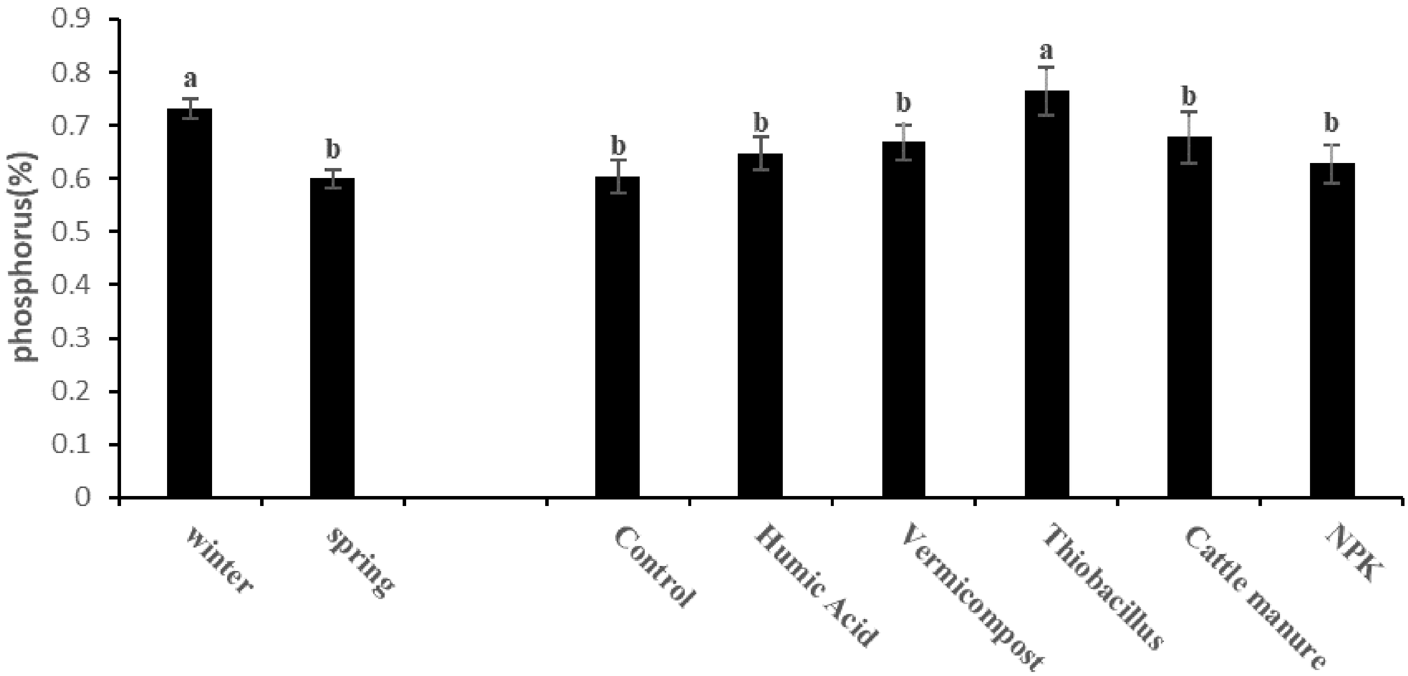

Figure 10

Means comparison for the effects of sowing season and fertilizer source on phosphorus content

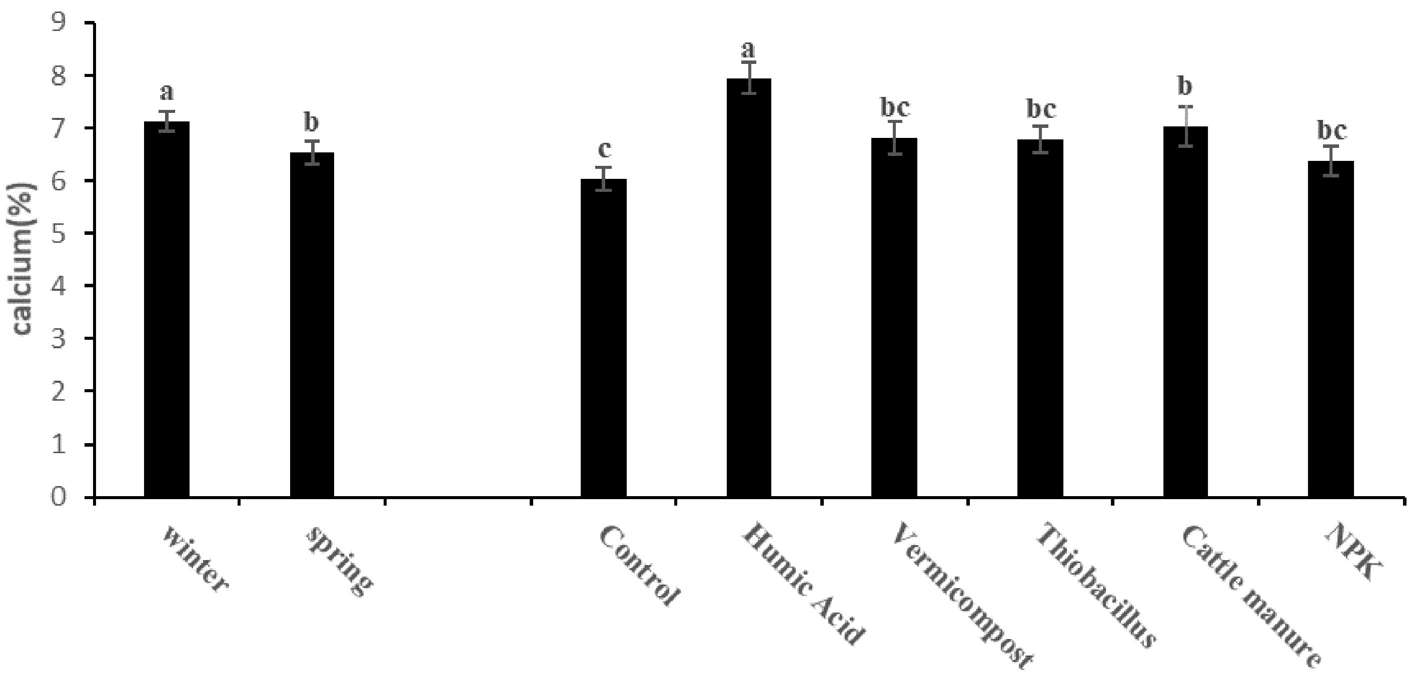

Figure 11

Means comparison for the effect of sowing season and fertilizer source on calcium content

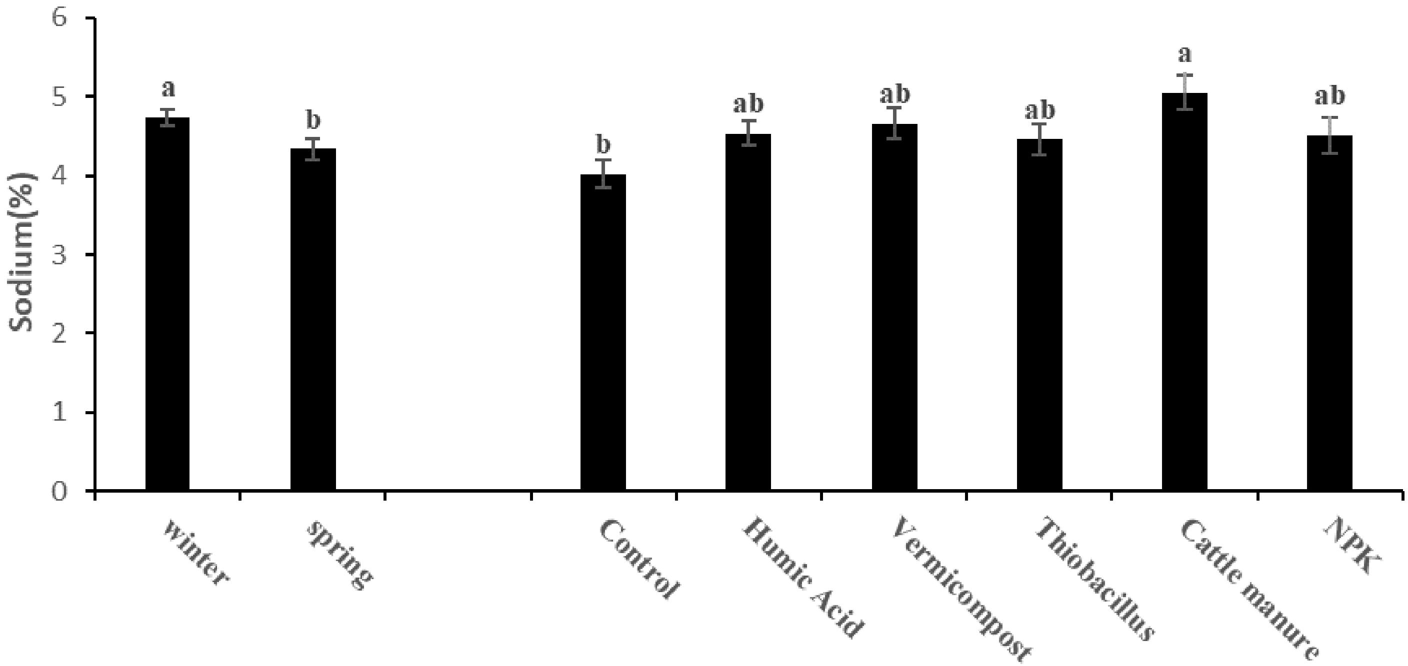

Figure 12

Means comparison for the effect of sowing season and fertilizer source on sodium content