



## Effects of foliar application of boric acid and nano-chelated boron on characteristics of the dragon's head (*Lallemantia iberica* (MB) Fischer & Meyer)

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### ABSTRACT

The seeds of the medicinal plant dragon's head are an excellent source of fiber, oil, and protein, and are used to treat a variety of conditions, including certain nervous disorders, liver diseases, and kidney diseases. This study aimed to determine the effects of foliar application of various nano-chelate and chemical boron fertilizers on morphological indices of the dragon's head (*Lallemantia iberica*). This study employed a completely randomized design with nano-chelate (500, 1000, and 1500 mg/l) and boric acid (1000, 2000, and 3000 mg/l) treatments, in addition to a control group. The results demonstrated that the investigated treatments had a significant effect on the majority of dragon's head indices. The highest inflorescence length (43.66 cm) and number of cycles in the main branch (28.56) were observed in the boric acid treatment with 3000 mg/l of boric acid. The highest number of lateral branches, flower cycle per plant, and seed weight per plant, 1000-seed weight, and seed yields were obtained at 3000 mg/l of boric acid and 1500 mg/l of nano-chelated treatments, respectively. The highest number of seed per plant, plant dry weight, and biological yield were obtained in the treatments of 2000 and 3000 mg/l of boric acid and 1500 mg/l of nano-chelated boron fertilizers, respectively. Application of boron fertilizers significantly increased the nitrogen, phosphorus, potassium, and boron concentrations in the treated plants. In general, foliar application of boron micronutrient increased the yield and improved the indices of dragon's head. Consequently, the application of nano-fertilizers yielded promising results due to their higher absorption efficiencies at lower concentrations than conventional fertilizers.

### Highlights

- Dragon's head seeds are high in fiber, oil, and protein and are used to treat nervous disorders, liver, and kidney diseases.
- This study examined the effects of nano-chelate and chemical boron fertilizers on dragon's head morphology.
- 3000 mg/l of boric acid produced the longest inflorescence (43.66 cm) and most main branch cycles (28.56).
- 3000 mg/l boric acid and 1500 mg/l nano-chelated treatments produced the most lateral branches, flower cycles, seed weight per plant, 1000-seed weight, and seed yields.

### 1. Introduction

*Lallemantia* sp. is one of the medicinal plants belong to the Lamiaceae family, that has 5 species (*L. peltata*, *L. oyleana*, *L. canescens*, *L. baldshuanica*, and *L. iberica*). Dragon's head (*L. iberica*) is an annual, herbaceous, and drought-resistant plant that has various usage (Rechinger,

1982). Their seeds are a very good source of fiber (29.66%), oil (20-28%), and protein (18%). Seeds extracted oil widely applicate to traditional medicine, foods industry, and dyeing. Moreover, the seeds of the dragon's head are a rich source of mucilage that is used for the treatment of different disorders, including nervous, liver, and kidney

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diseases (Amanzadeh et al., 2011). In the food industry, the gum and mucilage of dragon's head usage as ice cream stabilizers, as well as in sweets, dairy, beverages, sauces, edible desserts, and meat products (Sheykhi Sanandaji and Pirzad, 2019).

Plant nutrition is an important factor that affects agricultural products. Nutrition imbalance of plants lead to poor growth and yield reduction (Malakouti and Homaei, 2006). Plants need to low amount of micronutrient elements, but the roles of these elements are very important and efficient. Among the micronutrients, boron has a significant role in plant performance (Alihosinpour et al., 2011). Moreover, Boron has an important role in plant metabolism, the formation of cell wall pectin, cell division, carbohydrate transport, germination, and pollen tube growth (Wojcik and Wojik, 2003).

Foliar application of boron caused to increase in protein contents and oleic fatty acid in Soybean (Bellaloui, 2010), as well as plant yield and seed quality (Dordas, 2006) in alfalfa (*Medicago sativa* L.). Foliar application of boron during the active growth of rapeseed (*Brassica napus* L.) has been shown to enhance its seed yield (Bowyzys and Krauz, 2000). In another study, sesame oil content and seed yield has shown to be elevated with boron foliar application (Pratima et al., 1999).

Considering the low efficiency of chemical fertilizers and the environmental problems caused by their high consumption, the use of nano-fertilizers in agriculture is necessary. They are completely absorbed by plants and obviate the shortage of plant nutrients. The advantages of nano-fertilizers include high effectiveness, high solubility in water, a reasonable price, and greater controllability (Mahajan et al., 2011).

In an investigation, applications of complete nano-fertilizers at a concentration of 1:1,000 have ameliorated the quantitative and qualitative performance of dragon's head (Mafakheri et al., 2016). In research on the quantity and quality of the essential oil of the medicinal plant dragon's head with the use of conventional chemical fertilizers and nano-fertilizers in rainfed conditions, the results have revealed that the use of macro-nano-fertilizers with 50% chemical fertilizers has increased the amount of the studied traits (Javanmard et al., 2020). Applications of nano-chelated iron and zinc fertilizers in *Lallemantia royleana* Benth. have been seen to enhance the examined traits compared to the control treatment (Moghadam Barati et al., 2017).

In a study on the impacts of different concentrations of micronutrient elements, including chelated and nano-chelated iron fertilizers on basil plant, the results have demonstrated that the use of nano-chelated iron fertilizer has enhanced its growth characteristics and replacement of iron fertilizer prepared with nanotechnology in an appropriate concentration or a concentration of less than that of conventional iron fertilizer has been able to raise its quantitative and qualitative growths (Peyvandi et al., 2011).

The purpose of this research was to investigate and compare the effects of boric acid and nano-chelated boron fertilizers on the quantitative and qualitative characteristics

of the dragon's head (*L. iberica*) medicinal plant under greenhouse conditions.

## 2. Materials and methods

This study was conducted in a completely randomized design with 7 treatments and 3 replications in a greenhouse in the Pakdasht Region of Varamin with the geographical coordinates of 51° and 8' north longitude and 35° and 34' east latitude and an altitude of 1190 m above sea level. The treatments used in this experiment included spraying with boric acid fertilizer at the concentrations of 1000, 2000, and 3000 mg/l, nano-chelated boron at the concentrations of 500, 1000, and 1500 mg/l, and the control treatment (spraying with distilled water).

Dragon's head seeds were procured from Pakan Seed Co., Isfahan, Iran, and cultivated in the plugs. Then seedlings were transplanted in the greenhouse at the 4-leaf stage; the distance of the cultivation row was 25 cm, and the distance between plants in each row was 10 cm. Nano-chelated boron fertilizer used in this experiment was prepared from Sepehr Parmis Company. Foliar application of desired fertilizers was done three times: first when the plant had six leaves, second when the plant stem height reached about 22–25 cm, and third before the plant flowered.

After completing the experiment, the parameters of plant height, flowering branch height, inflorescence length, number of reproductive branches, number of cycles in the main branch, number of flowering cycles per plant, number of nutlets per flowering cycle, number of nutlets per plant, number of seeds per plant, seed weight per plant, and 1000-seed weight were measured.

At the end of the growing season and after fully ripening when the seeds were almost half-brown, the total dry weight of the aerial parts was first measured as a biological yield by using a digital scale and the seed yield was measured after separating the seeds with a sieve. The harvest index was calculated by dividing the seed yield by the biological yield (Goldani and Rezvani, 2006).

The Kjeldahl, spectrophotometric, flame photometer, and atomic absorption methods were employed to determine the amounts of nitrogen, phosphorus, potassium, and boron (Walinga et al., 1989).

The analysis of the obtained data was done using SAS software, version 9.1, and the means were compared by using Tukey HSD test at the 5% probability level.

## 3. Results and Discussion

The results presented in the data variance analysis table showed that foliar application with boron fertilizers had a significant effect on the traits of inflorescence length, number of lateral branches, number of cycles in the main branch, number of flowering cycles per plant, number of nutlets per plant, number of seeds per plant, seed weight per plant, 1000-seed weight, seed yield, plant dry weight, and biological yield at the probability level of 1%, while it had no significant impact on the traits of plant height, number of nutlets in the flowering cycle, and harvest index (Tables 2).

**Table 1. Soil physical and chemical characteristics of experimental location**

pH	EC (ds/m)	Organic matter(%)	Clay (%)	Silt (%)	Sand (%)	Nitrogen (%)	Phosphorus (mg/kg)	Potassium (mg/kg)	Boron (mg/kg)
7.5	1.15	0.92	21.37	42.75	35.88	0.39	31.5	295	4.12

**Table 2. Analysis of variance for the effect of foliar application of chemical and nano-chelate boron fertilizers on the characteristics of dragon's head**

S.O.V.	df	Mean of squares					
		Plant Height	Inflorescence length	Number of lateral branches	Number of cycles in the main branch	Number of flowering cycles per plant	Number of nutlets in the flowering cycle
Foliar application	6	0.56ns	13.95**	8.09**	47.82**	113.77**	0.21ns
Error	14	0.30	0.09	0.62	0.43	1.143	0.28
CV (%)	-	1.32	1.51	6.46	2.85	2.19	11.82

**Table 2. Continued**

S.O.V.	df	Mean of squares					
		Number of nutlets per plant	Number of seeds per plant	Seed weight per plant	1000-seed weight	Seed yield	Plant dry weight
Foliar application	6	2777.94**	5811.73**	0.23**	0.14**	378.64**	2.24**
Error	14	732.95	30.73	0.009	0.018	14.73	0.16
CV (%)	-	12.42	1.76	3.68	3.77	3.72	3.59

**Table 2. Continued**

S.O.V.	df	Mean of squares					
		Biological yield	Harvest index	N	P	K	B
Foliar application	6	3580.99**	3.07ns	0.89**	0.036**	0.15**	14.85**
Error	14	261.36	2.13	0.139	0.0006	0.014	0.672
CV (%)	-	3.63	6.31	12.35	3.15	8.83	4.86

ns, \*, and \*\* is no significant, significant at 5 and 1% probability level, respectively

Based on the comparison results of the data means, boric acid and nano-chelated boron fertilizer increased the inflorescence length. The highest (23 cm) and lowest (16.8 cm) lengths of inflorescences were related to the boric acid treatment with a concentration of 3000 mg/l and the control treatment, respectively. The results indicated that foliar spraying of boric acid and nano-chelated boron fertilizer at concentrations of 3000 and 1500 mg/l led to 33.72 and 25.77% enhancements in inflorescence length compared to that of the control treatment, respectively (Table 3). If the plant has enough boron, the cell division process will be successful, resulting in increased vegetative growth and plant and flowering stem heights (Marshner, 2012).

Based on the comparison results of the means in this study, foliar applications of boric acid and nano-chelated boron fertilizer had positive effects on the number of lateral branches of each plant. Nevertheless, the nano-chelated boron treatment with a concentration of 500 mg/l had no statistically significant difference from the control treatment in this regard (Table 3). The highest number of lateral branches was observed in the treatment of nano-chelated boron fertilizer at a concentration of 1500 mg/l (14.33 numbers) and boric acid at a concentration of 3000 mg/l (14 numbers), which led to enhancements of 38.72 and 35.52% compared to that of the control treatment, respectively. Our findings revealed no significant differences in the number of lateral branches between the two nano-chelated boron treatments (1000 and 1500 mg/l) and the two boric acid treatments (2000 and 3000 mg/l) on number of lateral branches (respectively). The results of research carried out on olives by Taherian and Bostani (2017) revealed that the applications of nano-chelated boron fertilizer and boric acid caused an increase in lateral

branches compared to the control treatment. This finding is consistent with that of this research. In an investigation on the effects of potassium nano-fertilizer treatment on wheat plants (N8019 variety) at concentrations of 1.5, 0.3, and 0.6%, it was reported that the growth of aerial parts and the emergence of lateral branches increased at the concentration of 1.5%. The potassium nano-fertilizer treatment showed a significant increase in the number of reproductive branches and yield compared to those of the control treatment (Tavan et al., 2014).

Based on the comparison results of the means in this research, boric acid and nano-chelated boron fertilizer had positive impacts on the number of cycles in the main branch of dragon's head. The highest (28.66) and lowest (17.66) numbers of cycles in the main branch were related to the treatments of boric acid at a concentration of 3000 mg/l and the control treatment, respectively (Table 3). Applications of boric acid and nano-chelated boron fertilizer at concentrations of 3000 and 1500 mg/l showed 62.28 and 50.96% enhancements in the number of cycles in the main branch compared to that of the control treatment, respectively.

Boric acid and nano-chelated boron fertilizer had positive effects on the number of flowering cycles per plant. Boric acid and boron nano-chelated treatments with concentrations of 3000 mg/l (55.66) and 1500 mg/l (54.66) led to the highest numbers of flowering cycles per plant, respectively, while the control treatment had the lowest number of flowering cycles per plant (41.33) (Table 3). The results indicated that the effects of boric acid and nano-chelated boron fertilizer at concentrations of 3000 and 1500 mg/l led to enhancements of 34.67 and 32.25% compared to the control treatment, respectively. The application of

1000 and 1500 mg/l boron nanochelated had no significant difference in the number of flowering cycles per plant compared with the 2000 and 3000 mg/l treatments of boric acid.

The results of the research conducted by Khiavi et al. (2010) on rapeseed revealed that the highest numbers of silique per plant and seeds were related to the boron+zinc+sulfur treatment. The results of this research were congruent with those of Yang et al. (2010) and Azizi et al. (2011), who reported that boron foliar application led to an increase in the number of pods per plant, the number of seeds per pod, and the weight of 1000 seeds per plant.

The numbers of clusters, branches, and flowers could be attributed to the role of boron in the transfer of sugar to the active growing parts and formations of young leaves and flowers, which determine the vegetative ratio in plants. If the boron required by the plant is supplied, a larger number of flowers and florets will be produced, and the transfer of sugar to the active growing parts of the plant, including young leaves, will enhance fruit production in the plant (Marschner, 2012). Foliar spraying with boric acid at a probability level of 1% was reported by Mashayekhi et al. (2016) to lead to an increase in the number of clusters in tomato plants (Supra variety).

Foliar spraying of boric acid and nano-chelated boron fertilizer increased the number of nutlets in dragon's head. A nano-chelated boron treatment with a concentration of 1500 mg/l led to the highest number of nutlets per plant (25.33), which showed a 42.64% increase compared to that of the control treatment. There are no significant differences between two treatments of nano-chelated boron (1000 and 1500 mg/l) and two treatments of boric acid (2000 and 3000 mg/l) on the number of nutlets (respectively) (Table 3).

There are no significant differences between two treatments of nano-chelated boron (1000 and 1500 mg/l) and two treatments of boric acid (2000 and 3000 mg/l) on the number of nutlets (respectively).

Boric acid had a positive and significant effect on 1000-seed weight, number of seeds per silique, and number of pods per plant in rapeseed (Pazoki et al., 2013).

Foliar spraying of boric acid and nano-chelated boron fertilizer had positive impacts on the number of seeds in dragon's head. The nano-chelated boron treatment with the concentration of 1500 mg/l (757.66) and the boric acid treatment with the concentrations of 3000 (755) and 2000 mg/l (750) resulted in the highest number of seeds per plant (Table 3).

In their study on the effects of iron and potassium nanochelates on the number of seeds in *Plantago ovata*, Aghazadeh Khalkhali et al. (2015) showed that they significantly raised this trait at the probability level of 5%. The application of boric acid and nano-chelated boron fertilizer resulted in a balance between reproductive and vegetative growth. This could be in part due to the role of boron in regulating growth traits via its contribution to cell division and elongation, nitrogen and carbohydrate metabolism, sugar transport, and the synthesis of indole acetic acid (Shireen et al., 2018).

Boric acid and nano-chelated boron fertilizer had positive effects on the seed weight per plant and seed yield per m<sup>2</sup> in dragon's head. The nano-chelated boron and boric acid treatments with the concentrations of 1500 mg/l (2.95 g) and 3000 mg/l (2.82 g) led to the highest seed weights per plant, which resulted in the enhancements of 47.47 and 34.28% compared to that of the control treatment, respectively (Table 3). Also, they provided the highest seed yields per m<sup>2</sup> at concentrations of 1500 mg/l (118.37 g) and 3000 mg/l (112.82 g), respectively. Our results show that there are no significant differences between two treatments of nano-chelated boron (1000 and 1500 mg/l) and two treatments of boric acid (2000 and 3000 mg/l) on seed weight per plant and seed yield per m<sup>2</sup> (respectively).

Boron foliar application increased the weight of 1000 seeds in dragon's head. The nano-chelated boron and boric acid treatments with concentrations of 1500 mg/l (3.9 g) and 3000 mg/l (3.76 g) led to the highest 1000-seed weights, which resulted in enhancements of 17.47 and 13.25% compared to that of the control treatment, respectively (Table 4).

**Table 3. Mean comparison for the effect of foliar application of chemical and nano-chelate boron fertilizers on some characteristics of dragon's head**

Foliar application	Inflorescence length (cm)	Number of lateral branches	Number of cycles in the main branch	Number of flowering cycles per plant	Number of nutlets per plant	Number of seeds per plant	Seed weight per plant (g)
Control	17.20d	10.33d	17.66f	41.33d	179c	632.66e	2.1e
Boric acid (1000 mg/l)	19.7c	11.33cd	22d	44c	205.66bc	719.66c	2.496d
Boric acid (2000 mg/l)	19.06c	12bc	25.33c	51.66b	222.66abc	750a	2.56cd
Boric acid (3000 mg/l)	23a	14a	28.66a	55.66a	241ab	755a	2.82ab
nano-chelated boron (500mg/l)	17.50d	10.33d	19.33e	41.66d	180.66c	706.66d	2.4d
nano-chelated boron (1000mg/l)	21.13b	13ab	21.66d	51.66b	241.33ab	738.33b	2.67bc
nano-chelated boron (1500mg/l)	21.66b	14.33a	26.66b	54.66a	255.33a	757.66a	2.95a

Same letters in each column are not significant at the 5% level based on the Tukey HSD test.

**Table 4. Mean comparison for the effect of foliar application of chemical and nano-chelate boron fertilizers on some characteristics of dragon's head**

Foliar application	1000-seed weight (g)	Seed yield (g/m <sup>2</sup> )	Plant dry weight (g)	Biological yield (g/m <sup>2</sup> )	N (%)	P (%)	K (%)	B (ppm)
Control	3.32d	84.21e	9.75e	390.13e	1.99c	0.65c	0.91d	12.17c
Boric acid (1000 mg/l)	3.47cd	99.94d	10.92de	436.8de	2.76b	0.68c	1.25c	16.04b
Boric acid (2000 mg/l)	3.39cd	102.67cd	11.65ab	466.13ab	3.05b	0.86a	1.29c	17.42ab
Boric acid (3000 mg/l)	3.76ab	112.82ab	11.64ab	465.34ab	3.31ab	0.89a	1.54ab	18.19a
nano-chelated boron (500mg/l)	3.38cd	96.09d	10.27de	410.93de	3.09b	0.66c	1.36bc	17.48ab
nano-chelated boron (1000mg/l)	3.61bc	106.76bc	11.44bc	457.6bc	3.12b	0.79b	1.44abc	18.10a
nano-chelated boron (1500mg/l)	3.9a	118.37a	12.2a	488.26a	3.77a	0.88a	1.57a	18.59a

Same letters in each column are not significant at the 5% level based on the Tukey HSD test.

Micro-elements play an important role in elevating the activities of some enzymes, amount of photosynthesis, durability of leaf surface, and cell division of meristem tissues besides storing more nutrients and consequently augmenting the 1000-seed weight of plants by affecting absorption of macronutrients, such as nitrogen, phosphorus, and potassium (Pazoki et al., 2013).

Plant yield is mainly related to basic processes, such as the initiation of flower-bud formation, differentiation, growth, and final fruit formation. The increase in yield achieved by applying boron at the stage of bud swelling and before flowering can be explained by its constructive effect on pollen viability and pollen tube elongation. In addition, the increase in yield may be attributed to the positive impact of boron on the improvement of plant nutritional status and assimilate production (Shireen et al., 2018).

This finding is consistent with those of the previous studies, which have shown that nano-fertilizers can be absorbed by plants more efficiently and quickly to meet nutritional needs (Naderi et al., 2011). Davarpanah et al. (2016) gave a similar report, in which the positive effect of nano-boron foliar application on fruit yield was mentioned in the pomegranate tree.

The role of boron in the synthesis of auxin hormone, which is involved in cell division, cell wall strength, and differentiation, has already been documented (Shireen et al., 2018). Boron plays an effective role in source-to-sink transports of sugar and growth regulators (Shireen et al., 2018). Compared to boric acid, the use of lower concentrations of boron in the form of nano-chelate had similar and sometimes more positive effects on the examined traits.

Boron deficiency in plants causes tissues to grow in an abnormal and unusual way, as a result of which vegetative growth decreases. The reduced vegetative growth leads to the reduction of internode length, which will result in a decrease in plant height, flowering branch height, and consequently lowered seed yield in plants (Marschner, 2012). Valenciano et al. (2011) discovered that boron foliar application increased the yield of chickpea plants.

Boric acid and nano-chelated boron foliar applications had positive effects on the dry weight of dragon's head. Nano-chelated boron treatment with a concentration of

1500 mg/l (12.2 g) and boric acid treatment with concentrations of 2000 mg/l (11.65 g) and 3000 mg/l (11.64 g) produced the highest plant dry weight (Table 4).

Fertilization with nano-chelated boron and boric acid increased the biological yield in dragon's head. Nano-chelated boron treatment with the concentration of 1500 mg/l (488.26 g) and boric acid treatment with the concentrations of 2000 mg/l (466.13 g) and 3000 mg/l (465.34 g) provided the highest biological yields (Table 4). In a report on *Plantago ovato*, the results revealed that foliar application of micronutrient elements significantly enhanced biological yield compared to the control treatment (Ramroudi et al., 2011). Foliar application of nano-fertilizers and common boron fertilizer in olive plants resulted in enhancements of 16.97% and 11.55% in yield compared to the control treatment, respectively (Taherian and Bostani, 2017).

Boric acid and nano-chelated boron fertilizer increased the amounts of nitrogen, phosphorus, potassium, and boron elements compared to the control treatment. The highest amounts of nitrogen elements were observed in the nano-chelated boron and boric acid treatments, with concentrations of 1500 mg/l (3.77%) and 3000 mg/l (3.31%), respectively. The highest amounts of phosphorus were obtained in the nano-chelated boron treatment with a concentration of 1500 mg/l (0.88%) and the boric acid treatment with concentrations of 2000 mg/l (0.86%) and 3000 mg/l (0.89%). The most potassium element was found in the nano-chelated boron treatment at concentrations of 1500 and 1000 mg/l, as well as in the boric acid treatment at 3000 mg/l. Boron element levels increased in all foliar spraying treatments when compared to the control treatment, but there was no significant difference between the treatments of 2000 and 3000 mg/l boric acid and the nano-chelated boron treatments. The application of 1000 and 1500 mg/l boron nano-chelated had no significant difference in amounts of nitrogen, potassium, and boron elements, respectively, compared with the 2000 and 3000 mg/l treatments of boric acid (Table 4).

The contents of minerals in leaves are measured to identify the nutritional status of plants and are used for fertilizer recommendations (Fernández-Escobar et al., 2009). Boron has been reported to affect the uptake of other

plant nutrients, causing an apparent increase in P, N, K, Zn, Fe, and Cu translocations in leaves, buds, and seeds. In the cotton plant, these elements were observed to increase after boron foliar application (Ahmed et al., 2011). In addition, an increase in boron concentration in leaves following boron consumption was reported in olive trees (Perica et al., 2001). Furthermore, foliar application of boron nano-fertilizer improved nutrient status in pomegranate trees (Davarpناه et al., 2016).

In their investigation of the effects of different amounts of boron on the concentrations of micro-elements in radish plants, the results showed that the concentrations of zinc, boron, iron, and copper elements in the leaves underwent a significant increase with the increase in boron amount from 0 to 5 mg/l. Leaf boron concentration was significant at the level of 1% (Tariq et al., 2006).

In comparison with boric acid, the application of lower concentrations of nano-chelated boron has the same positive effects on the mentioned traits. Several properties of nano-fertilizers may be the cause of such results. The specific properties of nanoparticles include their slow release, a large specific surface area, and the provision of a greater reactivity of catalysts that make them better candidates for selective reactivity compared to the equivalent bulk materials (Agrawal and Rathore, 2014).

#### 4. Conclusion

The results of this research indicated that foliar application of boron fertilizer improved the studied traits except plant height, number of nutlets in the flowering cycle, and harvest index. The maximum inflorescence length and number of cycles in the main branch were obtained in the treatment of 3000 mg/l of boric acid. The treatments with 3000 mg/l of boric acid and 1500 mg/l of nano-chelated boron fertilizer had the highest effects on most of the studied traits, including number of lateral branches, number of flowering cycles per plant, number of nutlets per plant, number of seeds per plant, weight of seeds per plant, 1000-seed weight, seed yield, plant dry weight, and biological yield, and these two treatments had no significant differences despite the use of a lower concentration of nano-chelated boron. In general, it could be concluded that foliar application of the micronutrient element of boron ameliorated the characteristics of dragon's head and elevated its yield. Overall, applications of nanofertilizers can achieve promising results due to their better efficiency at lower concentrations compared to conventional fertilizers. Foliar application of plants with boron nano-fertilizer can reduce production costs, lower fertilizer consumption, help maintain environmental health, and pave the way towards sustainable agriculture.

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