Influence of foliar fertilization on the growth and yield of chia (*Salvia hispanica*) plant

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Background

Salvia hispanica plant is a new introduced crop to the Egyptian cultivation system to enrich it with new species or varieties of medicinal and aromatic plants. *S. hispanica* commonly known as chia is an annual herbaceous plant belongs to the mint family (Lamiaceae) and is native to southern Mexico and Northern Guatemala. Chia seeds are a promising source of antioxidants owing to their content of omega-3 and the presence of polyphenols, chlorogenic acid, caffeic acids, myricetin, quercetin, and kaempferol. This study was carried out to evaluate the effect of different doses and portions of NPK and/or mixture of biofertilizer (*Azotobacter chroococcum*+*Bacillus megaterium*+*Bacillus subtilis*) on the growth and yield of chia (*S. hispanica*) plant.

Materials and methods

This investigation was carried out in the Hawareya location, Beheira Governorate, Egypt (North West of the Nile Delta), during the two successive seasons 2016/2017 and 2017/2018. The experimental layout was randomly distributed in a split-plot design with three replicates. The 10 treatments of NPK (1.5, 3, and 4.5 g/l in 1, 2, or three portions and control) were randomly distributed in the main plots, whereas the two foliar applications, namely, control and biofertilizers, were randomly distributed in the subplots to study the influence of foliar application treatments, Nitrophoska foliar fertilizer (1.5, 3, and 4.5 g/l) in 1, 2, or three portions (as control) and a mixture of *A. chroococcum* 10 g/l+*B. megaterium* 10 g/l+*B. subtilis* 10 g/l on the growth and yield of chia plant. Data were recorded for the plant height (cm), number of branches/plant, number of inflorescence/plant, herb fresh weight (g/plant and ton/fed), herb dry weight (g/plant and ton/fed), and seeds weight (g/plant and kg/fed).

Results

The results showed that different doses and portions of NPK and/or mixture of biofertilizer significantly increased the vegetative growth and yield of chia plant. The results of the 2 years indicated that the highest values of plant height (199.33 cm/plant), number of branches (22.56 branches/plant), number of inflorescence (58.89 inflorescence/plant), fresh herb weight (1053.33 g/plant and 24.58 ton/fed), dry herb weight (352 g/plant and 8.22 ton/fed), seeds weight (24.22 g/plant), and seeds yield (565 kg/fed) of *S. hispanica* were recorded with NPK 3 g/l (two portions)+biofertilizer.

Conclusion

From these results, we may conclude that the recommended treatment to obtain the best growth characteristics and yield of *S. hispanica* are the application of NPK 3 g/l (two portions)+biofertilizer.

Keywords:
biofertilizer, chia (*Salvia hispanica*), foliar fertilization, NPK

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Introduction

Salvia hispanica plant is a new introduced crop to the Egyptian cultivation system to enrich it with new species or varieties of medicinal and aromatic plants. *S. hispanica*, commonly known as chia, is an annual herbaceous plant that belongs to the mint family (Lamiaceae) and is native to southern Mexico and Northern Guatemala [1–3]. It grows up to 1-m tall and has opposite arranged leaves. Chia flowers are purple or white, produced in numerous clusters in a spike at the end of each stem; moreover, they have small flowers (3–4 mm) with small corollas and fused flower parts that contribute to a high self-pollination rate. The seed color varies from black, grey and black spotted to white, and the shape is oval with size ranging from 1 to 2 mm [1,2,4–6]. *S. hispanica* grows naturally in tropical and subtropical environments; it is optimally established from 400 to 2500 m and considered to be a short-day plant with a threshold of 12–14 h [7]. Chia seedlings emerged after 3 days and had slow initial growth, which was also verified by Waisle [8].

Its minimum and maximum growth temperatures are 11 and 36°C, respectively, with an optimum range of 16–26°C [9]. Chia requires less water than cereals or other oil seeds to grow, so it is also investigated as future crop for more diversity in Argentina and the USA [10–13]. Owing to the fact that it can grow in arid environments, it has been highly recommended as an alternative crop for the field crop industry [14]. The duration of the crop cycle in most cases ranges from 140 to 180 days [11,15], *S. hispanica* L. seeds were harvested mechanically. In low-input conditions, the average yield is ~600 kg/ha, but can be up to 1200 kg/ha, whereas in high-input conditions with irrigation and fertilization, yields as high as 2500 kg/ha have been shown in some experimental trials in Argentina [16]. Chia is also an interesting forage crop in Greek [17] and the Mediterranean and desert climates of Chile [7,18]. Chia seeds were traditionally one of the four basic elements in the diet and also a source of energy in Aztec civilization of Central American and southern civilizations in the pre-Columbian era [1,7,19]. Chia is currently commercially cultivated for its seeds in Australia, Bolivia, Colombia, Guatemala, Mexico, Peru, Ecuador, and Argentina [20]. Mexico is the largest production center of chia and currently exports seeds to Japan, USA, and Europe [7]. Heavy metal analysis showed that chia seed contains heavy metals at safe levels, not exceeding the maximum metal levels for food safety, and the seed is also free from mycotoxins [21]. Chia has potential roles in reducing the risk of chronic degenerative diseases [22]. The lipid content in chia seeds varies from 25 to 40%, with 60% of the total lipids made up of ALA (n=3) and 20% composed of linoleic acid (n=6) [21]. When the oil is extracted from the chia seed, what remains is a significant concentration of dietary fiber (33.9/100 g) and protein (17/100 g) [23,24]. Nitrogen, phosphorus, and potassium are macronutrients that were involved in many plant processes. Nitrogen is the main yield-limiting mineral nutrient. Nitrogen takes part in many physiological and biochemical plant processes and is a structural component of amino acids, nucleic acids, enzymes and proteins, chlorophyll, and cell wall. Phosphorus is also a highly required macronutrient, playing vital roles in energy transfer, cell membranes, nucleic acids phospholipids, and co-enzymes, and potassium increases plant resistance to diseases and prevents excessive water loss and other key compounds. N, P and K fertilizers provide plants with macro-elements necessary for growth and yield [25–27].

Application of P and K fertilizers at different growth stages on the root growth and bioactive compounds were shown to vary greatly on *Salvia miltiorrhiza* production [28].

A mixture of biofertilizers (*Azotobacter chroococcum*, *Azospirillum lipoferum*, and *Bacillus megaterium*) with chemical fertilizer increased the measured traits in comparison with biofertilizer or chemical fertilizer alone on fennel plant [29]. In addition, *Majorana hortensis* L. plant recorded the maximum values of herb fresh and dry yield by using biofertilizers (Nitraboein and Halex-2 at a rate of 988 g/ha of each) as well [30].

Therefore, this study aimed to investigate the influence of some foliar fertilization treatments on the growth and yield on chia (*S. hispanica*) plant to increase the quantity of the yield.

Materials and methods

This study was carried out in the Hawareya location, Beheira Governorate, Egypt, during two successive seasons (2016/2017 and 2017/2018(.The soil was carefully prepared, and initial soil samples from a depth of 0 to 30 cm were analyzed. The physical and chemical properties were presented in Table 1, which

Table 1 Physical and chemical properties of soil in the two seasons (2016/2017 and 2017/2018)

(A) Physical properties	Fist season	Second season
Clay (%)	48.30	48.10
Silt (%)	29.20	29.50
Sand (%)	21.80	21.34
Soil texture	Clay loam	Clay loam
Organic matter	1.88	1.94
(B) Chemical properties		
pH (1 soil: 2.5 water suspension)	7.77	7.80
EC (dS/m^3 at 25°C)	1.80	1.82
Soluble ions (meq/l)		
Ca^{2+}	9.40	11.20
Mg^{2+}	5.20	7.10
Na^+	10.10	10.30
K^+	0.91	1.15
HCO_3^-	5.46	7.93
Cl^-	8.51	9.14
Available macronutrients (ppm)		
N	145	155
P	46	40
K	310	290
Available micronutrients (ppm)		
Fe	18.30	18.20
Zn	1.10	1.12
Mn	7.56	7.52
Cu	13.55	13.18

Table 2 Chemical composition of water used for irrigation

pH	EC (mmhos/cm)	Soluble ions (meq/l)							SAR
		Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^{-}	Cl^{-}	SO_4^{-}	
6.9	0.81	3	2.1	2.74	0.23	1.6	1.8	4.7	2

SAR, sodium adsorption ratio.

Table 3 The NPK treatments

N	Treatment
1	1.5 g/l (1 portions)
2	1.5 g/l (2 portions)
3	1.5 g/l (3 portions)
4	3 g/l (1 portions)
5	3 g/l (2 portions)
6	3 g/l (3 portions)
7	4 g/l (1 portions)
8	4 g/l (2 portions)
9	4 g/l (3 portions)
10	Control

indicated that the soil texture was clay soil. Chemical analysis of water irrigation is shown in Table 2.

The 10 NPK treatments were randomly distributed in the main plots and are presented in Table 3, whereas the two foliar applications, namely, control and *A. chroococcum*10 g/l+*B. megaterium* 10 g/l+*Bacillus subtilis* 10 g/l were randomly distributed in the subplots to study the influence of foliar application treatments (NPK and/or bio) on the growth and yield of chia plant.

The seeds of chia (*S. hispanica*) were imported from Original Hanoju Deutschland UG Company (Zum Rennplatz 6, 49401 Damme, Germany). All treatments received 15 m^3/fed of manure+300 kg/fed superphosphate during preparing and hoeing the soil. Moreover, 200 kg/fed of ammonium nitrate was added after 21 days from sowing. Chia seeds were directly sown in hills at distance of 30 cm between hills and intro-row spacing of 60 cm on 15 October in both seasons (2016–2017 and 2017–2018). After 5 weeks of planting, some plots were sprayed with Nitrophoska foliar fertilizer from Shoura Chemical Company (Egypt), with different levels added at different portions at different dates of application for the same level of fertilizer. Three different amounts of foliar fertilizer (1.5, 3, and 4.5 g/l) were used. Each dose of foliar fertilizer was applied either once (at 50 days from sowing) or was divided into two equal portions (added at 35 and 50 days after sown) or was divided into three equal portions (added at 35, 50, and 65 days after sown). The chemical composition of the used foliar fertilizer is presented in Table 4. After 45 days from sowing, some plots were sprayed with a mixture of biofertilizers from National Research Center, Egypt, consisting of *A. chroococcum*10 g/l+*B. megaterium* 10 g/l+*B. subtilis* 10 g/l on two portions, and the second portions was applied after 75 days from sowing date. Mixed cultures of bacterial species containing 1×10^6 colony forming units/ml were used for plant inoculation. The herb fresh weight was measured after reaching 60–70% of flowering; finally, plants were harvested by hand cutting after 160 days from sowing date in first season, and after 175 days in second season.

The data of the different parameters were measured during both seasons

Plant height (cm) was measured as the main plant stem at the date of harvest. Number of branches/plant (the main lateral branches were counted). Herb fresh and dry weights (g/plant and ton/fed), number of inflorescences/plant, and seeds weight (g/plant and kg/fed) were also assessed.

The yield per feddan was obtained according to the equation:

(The mean value of the treatment×number of plants/fed).

Number of plants/fed=(100×100×4200)/(30×60)=23 333 plant/fed.

All the obtained results were statistically analyzed according the design using CoStat program (version 6.4; CoHort Company, Birmingham, UK, 1998–2008). Least significant difference test was applied at 0.05 probability level to compare means of different treatments as illustrated by Williams and Abdi [31].

Results and discussion

Plant height (cm)

Effect of interaction between NPK and biofertilizer

Plant height responded significantly to interaction between NPK and biofertilizer in both seasons, as shown in Table 5.

Application of NPK 3 g/l (two portions)+biofertilizer resulted in the tallest plants (181.79 cm/plant for first

Table 4 The chemical composition of the used foliar fertilizer (Nitrophoska)

Macronutrients			Micronutrients							
N	P	K	Mg	S	Mn	Fe	Cu	Zn	B	Mo
20%	19%	19%	0.5%	0.3%	1000 ppm	1000 ppm	400 ppm	380 ppm	130 ppm	30 ppm

Table 5 Effect of foliar fertilization and/or biofertilizer on some growth parameters of *Salvia hispanica* plant in two seasons (2016/2017 and 2017/2018)

Dose NPK	Number of portions	Biofertilizer	Plant height (cm)		Number of branches		Number of inflorescences	
			First season	Second season	First season	Second season	First season	Second season
1.5 g/l	One	0	147.74^{g}	162.00^{f,g}	19.11^{f}	21.00^{b-d}	21.89^{d-g}	23.44^{d,e}
		Added	159.00^{e-g}	170.00^{d-f}	20.33^{d}	22.33^{a}	30.99^{b-e}	34.00^{b-d}
	Two	0	162.58^{c-e}	166.89^{d-g}	18.00^{g}	21.67^{a-c}	22.44^{d-g}	22.89^{d,e}
		Added	167.89^{b-d}	170.11^{d-f}	20.22^{d}	20.11^{a}	28.44^{b-g}	29.56^{c-e}
	Three	0	151.83^{e-g}	160.67^{f,g}	20.33^{d}	21.89^{a,b}	25.10^{c-g}	26.44^{c-e}
		Added	166.95^{c,d}	176.67^{c,d}	20.55^{b-d}	22.11^{a}	26.55^{c-g}	28.22^{c-e}
3 g/l	One	0	155.67^{e-g}	175.22^{c,d}	20.11^{d}	21.00^{b-d}	29.22^{b-g}	31.56^{b-e}
		Added	172.95^{a-c}	185.12^{b,c}	21.30^{a,b}	21.66^{a-c}	35.10^{b,c}	39.11^{b,c}
	Two	0	167.2^{c,d}	183.33^{b,c}	21.33^{a,b}	22.11^{a}	20.77^{e-g}	22.89^{d,e}
		Added	181.79^{a}	199.33^{a}	21.77^{a}	22.56^{a}	52.66^{a}	58.89^{a}
	Three	0	168.81^{b-d}	173.33^{c-e}	19.99^{d,e}	22.11^{a}	33.77^{b,c}	34.56^{b-d}
		Added	173.27^{a-c}	175.56^{c,d}	20.44^{c,d}	22.11^{a}	34.44^{b,c}	35.00^{b,c}
4.5 g/l	One	0	152.98^{e-g}	161.89^{f,g}	18.44^{f,g}	19.89^{e}	23.77^{c-g}	25.33^{c-e}
		Added	168.00^{b,d}	177.78^{c,d}	18.77^{f,g}	20.11^{d,e}	24.88^{c-g}	26.78^{c-e}
	Two	0	161.01^{d-f}	174.44^{c-e}	18.66^{f,g}	20.33^{d,e}	18.99^{f,g}	20.56^{e}
		Added	178.95^{a,b}	193.89^{a,b}	19.22^{e,f}	20.56^{d,e}	39.22^{b}	41.44^{b}
	Three	0	161.22^{d-f}	176.78^{c,d}	18.10^{g}	20.11^{d,e}	18.67^{f,g}	19.88^{e}
		Added	178.34^{a}	195.56^{a}	20.22^{d}	22.33^{a}	25.87^{c-g}	27.56^{c-e}
Control	0		145.11^{g}	157.22^{g}	16.11^{h}	17.89^{f}	18.44^{g}	19.89^{e}
		Added	162.55^{c-e}	176.11^{c,d}	20.33^{d}	22.33^{a}	24.21^{c-g}	26.56^{c-e}

Means with the same letters in each column indicate no significant difference between treatments at the 5% level of probability.

season and 199.33 cm/plant for second one), whereas the untreated plants gave the lowest plant height (145.11 and 157.22 cm/plant for first and second seasons, respectively) compared with other treatments. So, the increment in plant height as a result of NPK 3 g/l (two portions)+biofertilizer treatment reached to 25.28% than the control for first season and 26.78% for second one. These results were consistent with Azzaz and Hassan [32] on fennel plants, who revealed that applications of different mineral and organic fertilizers augmented the vegetative growth parameters. Abdelraouf *et al.* [33] on *Nigella sativa* L. plants and Larimi *et al.* [34] on sweet basil (*Ocimum basilicum* L.) revealed that the enhancement of plant height may be owing to the beneficial effect of NPK, compost, bacteria, and mycorrhiza on the soil properties, in addition to the role of increasing nitrogen in the initiation of new cells. The beneficial effect of N_2-fixers and P-dissolving bacteria on the plants development can be attributed not only to the N_2-fixation and dissolving phosphate process but also to the production of growth-promoting substances. Rademacher [35] reported that several soil microorganisms possess the capability to synthesize gibberellins.

Effect of NPK fertilizer

All foliar NPK treatments significantly increased plant height in both seasons compared with control (sprayed with water) plants as shown in Table 6.

Dividing the first dose (1.5 g/l) of NPK into two or three portions did not show any significant differences from its application once on the plant height compared with control. The same was true with the third dose (4.5 g/l). However, dividing the second dose (3 g/l) into two portions significantly increased plant height in both seasons. Dividing the dose of 3 g/l into two portions was more effective than the other treatments and resulted in the highest plant growth in both seasons. Foliar application of NPK at 3 g/l and divided into two portions showed the tallest plants for first season at 174.49 cm/plant and for second one at 191.33 cm/plant. It is clear from the data in Table 6 that control

Table 6 Mean values of plant height, number of branches, and inflorescences as affected by foliar fertilization doses and number of applied portions on *Salvia hispanica* in two seasons (2016/2017 and 2017/2018)

Dose NPK	Number of portions	Plant height (cm)		Number of branches		Number of inflorescences	
		First season	Second season	First season	Second season	First season	Second season
1.5 g/l	**1**	153.37^{c}	166.00^{d}	$19.72^{c,d}$	$21.67^{a–c}$	$26.44^{c,d}$	$28.72^{b–d}$
	2	$165.24^{a–c}$	$168.50^{c,d}$	$19.11^{d,e}$	$2089^{d,e}$	$25.44^{c,d}$	26.22^{d}
	3	$159.39^{b,c}$	$168.67^{c,d}$	$20.44^{b,c}$	$22.00^{a,b}$	$25.82^{c,d}$	$27.33^{c,d}$
3 g/l	**1**	$164.31^{a–c}$	$180.17^{a,b}$	20.72^{b}	$21.33^{b–d}$	$32.16^{a–c}$	$35.33^{a,b}$
	2	174.49^{a}	191.33^{a}	21.55^{a}	22.33^{a}	36.72^{a}	40.89^{a}
	3	$171.04^{a,b}$	$174.44^{b–d}$	$20.21^{b,c}$	22.11^{a}	$34.10^{a,b}$	$34.77^{a–c}$
4.5 g/l	**1**	$160.49^{b,c}$	$169.83^{c,d}$	$18.60^{e,f}$	20.00^{f}	24.33^{d}	26.05^{d}
	2	$169.98^{a,b}$	$184.17^{a,b}$	$18.94^{e,f}$	$20.44^{e,f}$	$29.10^{b–d}$	$31.00^{b–d}$
	3	$169.78^{a,b}$	$186.16^{a,b}$	$19.16^{d,e}$	$21.22^{c,d}$	22.27^{d}	23.72^{d}
Control		153.83^{c}	166.67^{d}	18.22^{f}	20.11^{f}	21.31^{d}	23.22^{d}
Mean of doses							
1.5 g/l		$159.28^{A,B}$	$167.72^{A,B}$	$19.76^{A,B}$	$21.52^{A,B}$	25.90^{B}	27.42^{B}
3 g/l		169.95^{A}	181.98^{A}	20.83^{A}	21.92^{A}	34.33^{A}	37.00^{A}
4.5 g/l		166.75^{A}	180.05^{A}	18.90^{B}	20.55^{B}	25.23^{B}	26.92^{B}
Control		153.83^{B}	166.67^{B}	18.22^{B}	20.11^{B}	21.31^{C}	23.22^{C}
Mean of portions							
1		157.88^{A}	170.66^{A}	18.91^{A}	20.66^{A}	27.48^{A}	29.90^{A}
2		165.88^{A}	177.66^{A}	19.52^{A}	21.05^{A}	29.56^{A}	31.90^{A}
3		163.51^{A}	173.98^{A}	19.84^{A}	21.36^{A}	27.29^{A}	27.29^{A}
Mean of biofertilization							
0		157.41^{b}	169.17^{b}	19.01^{b}	20.71^{b}	23.30^{b}	24.74^{b}
Added		170.96^{a}	182.01^{a}	20.31^{a}	21.71^{a}	32.23^{a}	34.71^{a}

Means with the same letters in each column indicate no significant difference between treatments at the 5% level of probability.

plants gave the mean value of 153.83 cm/plant for first season and 166.67 cm/plant for second one. So, the increment of plant height as a result of NPK 3 g/l (two portions) treatment reached to 13.43% than the control for first season and 14.80% for second season. The mean value of doses showed the best dose was 169.95 cm/plant for first season and 181.98 cm/plant for second season from the dose 3 g/l and did not show any significant differences between portions in both seasons as shown in Table 6. These results are in accordance with those of Yeboah *et al.* [2] and Capitani *et al.* [36] on *S. hispanica* who reported that the plant height ranged from 60 to 180 cm. Moreover, Lu *et al.* [28] on *S. miltiorrhiza*, Sonmez and Bayram [37] on sage plant, and finally Ramara and Garofalo [38] on *S. hispanica* found the plants cultivated without phosphorus application had the lowest values of plant height (17.63 and 37.33 cm/plant at 30 and 60 days after sowing, respectively) and number of leaves (7.67/plant).

Effect of biofertilizer

Biofertilizer application significantly increased plant height in both seasons, as shown in Table 6. The mean increment values in plant height were 8.61 and 7.59% for first season and second season, respectively, compared with the control plants. These results are in consistent with Mahfouz and Sharaf-Eldin [29] on fennel plants and Gharib *et al.* [39] on *M. hortensis* by using *Azospirillun brasiliense*, *Azotobacter chroocccum* and *Bacillus polymyxa*, and *Bacillus circulans*, and Maleki *et al.* [40] stated that it is possible that the favorable effect of microorganisms on growth characteristics will be owing to their ability to enhance the physical chemical and biological properties of the soil.

Number of branches and number of inflorescence/plant

Effect of interaction between NPK and biofertilizer

Number of branches responded significantly to interaction between NPK and biofertilizer in both seasons as shown in Table 5. NPK 3 g/l (two portions)+biofertilizer treatment gave the best or highest mean value (21.77 and 22.56/plant for first and second, respectively), whereas the lowest number of branches (16.11 and 17.89/plant for first and second seasons, respectively) were obtained from untreated plants comparing with treated plants.

The increment in number of branches as a result of NPK 3 g/l (two portions)+biofertilizer treatment reached to 35.13 and 26.10% than the control for first season and second seasons, respectively.

On the contrary, the number of inflorescence responded significantly to interaction between NPK and biofertilizer in both seasons as shown in Table 5, where NPK 3 g/l (two portions)+biofertilizer caused the highest mean values of 52.66 and 58.89/plant for first and second seasons, respectively, against the control plants, which resulted in the lowest inflorescence number (18.44 and 19.89/plant for first and second seasons, respectively) compared with other treatments. The increment in number of inflorescence as a result of NPK 3 g/l (two portions)+bio fertilizer treatment reached to 185.57 and 196.08% than the control for first and second seasons, respectively.

These results are in accordance with those of Wange and Patil [41] on tuberose who found that, applying nitrogen at the rate of 100 kg/ha alone or inoculating with *Azotobacter* plus *Azospirillum* mixtures significantly increased number of flowers/stalk and number of flowering stems. El-Kashlan [42] on roselle recorded significant increases in plant height and number of branches/plant. There was an increase in the number of fruits and fresh and dry weights of sepals as a result of using three commercial biofertilizers (Biogene, Netrobene, and Phosphorene). Farouk *et al.* [43] on fennel plants found that combining phosphorein with low NPK rate was effective than the high NPK alone in producing better growth and yield of fruits per plant/fed. The obvious results are in the same line with Matter [44] on *Hibiscus sabdariffa* plant who reported that the treatment of 75% NPK in combination with biofertilizer was given the best results of a number of flowers, quality and the dry weight of yield sepals/fed. Jafari *et al.* [45] studied the effect of chemical and biological fertilizers on sage (*Salvia officinalis* L.) and replacing biofertilizers instead of high doses of chemical fertilizers.

Effect of NPK fertilizer

Dividing the first dose (1.5 g/l) of NPK into two or three portions had no significant effect on the number of branches and inflorescence compared with the application once. The same was true with the third dose (4.5 g/l). However, dividing the second dose (3 g/l) into two portions significantly increased the number of branches and inflorescences in both seasons. Dividing the dose of 3 g/l into two portions was more effective than the other treatments and resulted in the maximum number of branches and inflorescences/plant in both seasons. Foliar application of NPK at 3 g/l and divided into two portions showed the maximum number of branches/plant (21.55 and 22.33/plant season and for first and second seasons, respectively) and number of inflorescence in both season (36.72 and 40.89/plant for first and second seasons, respectively). The mean value of doses showed the best dose of number of branches was 20.83/plant for first season and 21.92/plant for second season, whereas the best dose of number of inflorescences was 34.33/plant for first season and 37.00/plant for second season from the dose 3 g/l and did not show any significant difference between portions in both seasons as shown in Table 6. The promotive effect of NPK on number of branches/plant was reported by many investigators such as Jacoub [46] who fertilized *O. basilicum* L. and *Thymus vulgaris* L. plants with NPK at the rates of 400, 800, and 1200 kg/fed/season. NPK fertilization increased number of branches for both plants. Yebouh *et al.* [2] reported the mean value of branches number ranged from 18.3 to 21.2 branches/plant. Mary *et al.* [47] on chia (*S. hispanica* L.) found that the level of 90 : 60 : 75 kg NPK/ha produced significantly highest yield (18.42 branches/plant).

Moreover, these results were in harmony with those reported by Ramara and Garofalo [38] on *S. hispanica*, who found fertilization with 125 : 100 : 40 kg/ha of N : P : K. was the best results for parameters of biomass growth.

Effect of biofertilizer

Biofertilizer application resulted in significant increment in number of branches and number of inflorescence in both seasons as shown in Table 6. The mean increment values in number of branches recorded 6.84 and 4.83% for first and second seasons, respectively, compared with the untreated plants, whereas the mean increment values in number of inflorescence/plant were 38.33 and 40.30% for first and second season, respectively, compared with the untreated plants. These results are consistent with Shaalan [48] on *Nigella sativa* L. and El-Sherbeny *et al.* [49] on *Ruta graveolens* who reported that number of inflorescence and branches/plant showed significant affect, whereas Omran *et al.* [50] on *S. officinalis* found that the maximum number of child branches (53/19) in combining bacteria and manure.

Herb fresh and dry weight (g/plant) and (ton/fed)

Effect of interaction between NPK and biofertilizer

Herb fresh and dry weights of plant responded significantly to interaction between NPK and biofertilizer in both seasons as shown in Tables 7 and 8.

In the first season, herb fresh and dry weight responded significantly to interaction between NPK and biofertilizer in the first season (2016/2017), as shown in Table 7. NPK at 3 g/l (two portions)

Table 7 Effect of foliar fertilization and/or biofertilizer on herb fresh weight of *Salvia hispanica* plant in the first season (2016/2017)

Dose NPK	Number of portions	Biofertilizer	Fresh weight		Dry weight	
			g/plant	ton/fed	g/plant	ton/fed
1.5 g/l	One	0	495.38^{d,e}	11.56^{d,e}	116.13^{g,h}	2.71^{g,h}
		Added	612.68^{b}	14.30$^{b–d}$	190.67$^{b–e}$	4.45$^{b–e}$
	Two	0	578.81$^{b–d}$	13.51$^{b–d}$	170.27$^{d–g}$	3.97$^{d–g}$
		Added	597.06$^{b–d}$	13.93$^{b–d}$	183.38$^{d–f}$	4.28$^{d–f}$
	Three	0	382.12^{e,f}	8.92^{e,f}	126.15^{g,h}	2.94^{g,h}
		Added	626.25$^{b–d}$	14.61$^{b–d}$	200.7$^{b–e}$	4.68$^{b–e}$
3 g/l	One	0	621.71$^{b–d}$	14.51$^{b–d}$	183.65$^{d–f}$	4.29$^{d–f}$
		Added	711.57^{b,c}	16.60^{b,c}	271.41^{b,c}	6.33^{b,c}
	Two	0	561.50^{c,d}	13.10^{c,d}	140.89^{f,g}	3.29^{f,g}
		Added	951.64^{a}	22.20^{a}	318.23^{a}	7.43^{a}
	Three	0	592.14$^{b–d}$	13.82$^{b–d}$	205.37$^{b–d}$	4.79$^{b–d}$
		Added	613.35$^{b–d}$	14.31$^{b–d}$	234.72^{b,c}	5.48^{b,c}
4.5 g/l	One	0	578.47^{c,d}	13.50^{c,d}	156.07$^{e–g}$	3.64$^{e–g}$
		Added	583.2$^{b–d}$	13.61$^{b–d}$	195.45$^{c–e}$	4.56$^{c–e}$
	Two	0	500.70^{d,e}	11.68$^{c–e}$	125.19^{g,h}	2.92^{g,h}
		Added	527.36$^{c–e}$	12.30$^{c–e}$	160.06$^{d–g}$	3.73$^{d–g}$
	Three	0	532.62$^{c–e}$	12.43$^{c–e}$	141.4^{f,g}	3.30^{f,g}
		Added	671.9^{b,c}	15.68^{b,c}	205.74$^{b–d}$	4.80$^{b–d}$
Control	0		283.79^{f}	6.62^{f}	85.18^{h}	1.99^{h}
	Added		596.07$^{b–d}$	13.91$^{b–d}$	140.17^{f,g}	3.27^{f,g}

Means with the same letters in each column indicate no significant difference between treatments at the 5% level of probability.

+biofertilizer gave the highest mean values of herb fresh weight (951.64 g/plant and 22.20 ton/fed) and herb dry weight (318.23 g/plant and 7.43 ton/fed), whereas the untreated plants resulted in the lowest mean value of herb fresh weight (283.79 g/plant and 6.62 ton/fed) and herb dry weight (85.18 g/plant and 1.99 ton/fed). The increment in herb fresh weight as a result of NPK 3 g/l (two portions)+biofertilizer treatment reached to 235.35 and 273.37% for herb dry weight than the untreated plants.

Data of second season (2017/2018) gave the same trend of the first season as shown in Table 8, where NPK 3 g/l (two portions)+biofertilizer gave the highest mean values of herb fresh weight (1053.33 g/plant and 24.58 ton/fed) and herb dry weight (352.22 g/plant and 8.22 ton/fed), whereas the untreated plants gave the lowest mean value of herb fresh weight (317.22 g/plant and 7.40 ton/fed) and herb dry weight (95.56 g/plant and 2.23 ton/fed). The increment in herb fresh weight as a result of NPK 3 g/l (two portions)+bio fertilizer treatment reached to 232.16% than the control plants and 268.59% for herb dry weight.

These results are in harmony with those reported by some studies [51–55]. They reported that the vegetative growth (plant height, number of leaves or branches as well as fresh and dry weight of plant organs) increased by using organic fertilizer application. Improving the vegetative growth of plants is in turn on increasing yield and improving yield quality. These results were in accordance with those reported by some studies [53,56–58]. Increasing the vegetative growth of plants with biofertilizers application may be owing to the role of biofertilizer on increasing soil fertility and increasing the availability and uptake of many nutrients element such as N, P, K and S to plant absorption, which led to improving the vegetative growth of plants. Some application of bio-fertilizer (*Azospirillum* and *Azotobacter*) increased plant height and dry weight of shoots of the plant *S. hispanica* in China [59].

Effect of NPK fertilizer

Herb fresh and dry weights (g/plant and ton/fed) responded significantly to NPK fertilizer in both seasons compared with control (sprayed with water), as shown in Tables 9 and 10.

Dividing the first dose (1.5 g/l) of NPK into two or three portions did not show any significant effect on the fresh weight of herb compared with its application once. The same was true with the third dose (4.5 g/l). However, dividing the second dose (3 g/l) into two portions significantly increased fresh weight of herb in both seasons. Dividing the dose of 3 g/l into two portions was more effective than the other treatments and resulted in the best mean value in both seasons. Foliar application of NPK at 3 g/l and divided into two portions showed the maximum mean values of the herb weight of plants (756.57 g/plant and 17.65 ton/fed) for the first season and (839.44 g/plant

Table 8 Effect of foliar fertilization and/or biofertilizer on herb dry weight of *Salvia hispanica* plant in the second season (2017/2018)

Dose NPK	Number of portions	Biofertilizer	Fresh weight		Dry weight	
			g/plant	ton/fed	g/plant	ton/fed
1.5 g/l	One	0	538.67^{d,e}	12.56^{d,e}	149.52^{g-i}	3.49^{g-i}
		Added	681.67^{b-d}	15.91^{b-d}	189.36^{c-h}	4.42^{c-h}
	Two	0	595.56^{c,d}	13.90^{c,d}	175.56^{e-i}	4.10^{e-i}
		Added	622.22^{c,d}	14.52^{c,d}	191.11^{c-h}	4.46^{c-h}
	Three	0	413.89^{e,f}	9.66^{e,f}	136.67^{i,j}	3.19^{i,j}
		Added	672.22^{b-d}	15.68^{b-d}	215.56^{c-f}	5.03^{c-f}
3 g/l	One	0	683.33^{b-d}	15.94^{b-d}	202.22^{c-g}	4.72^{c-g}
		Added	798.33^{b,c}	18.63^{b,c}	303.34^{b,c}	7.08^{b,c}
	Two	0	625.56^{c,d}	14.60^{c,d}	157.78^{g-i}	3.68^{g-i}
		Added	1053.33^{a}	24.58^{a}	352.22^{a}	8.22^{a}
	Three	0	617.22^{c,d}	14.40^{c,d}	211.11^{c-g}	4.93^{c-g}
		Added	630.56^{b-d}	14.71^{b-d}	244.44^{b,c}	5.70^{b,c}
4.5 g/l	One	0	621.67^{c,d}	14.51^{c,d}	168.33^{f-i}	3.93^{f-i}
		Added	626.67^{c,d}	14.62^{c,d}	210.00^{c-g}	4.90^{c-g}
	Two	0	552.22^{d,e}	12.88^{d,e}	138.89^{h-j}	3.24^{h-j}
		Added	581.11^{d}	13.56^{d}	176.67^{d-i}	4.12^{d-i}
	Three	0	593.89^{c,d}	13.86^{c,d}	158.33^{g-i}	3.69^{g-i}
		Added	746.67^{b,c}	17.42^{b,c}	228.89^{b-e}	5.34^{b-e}
Control	0		317.22^{f}	7.40^{f}	95.56^{j}	2.23^{j}
	Added		655.56^{b-d}	15.30^{b-d}	163.89^{f-i}	3.82^{f-i}

Means with the same letters in each column indicate no significant difference between treatments at the 5% level of probability.

Table 9 Mean values of fresh weight of herb as affected by foliar fertilization doses and number of applied portions in two seasons

Dose NPK	Number of portions	Fresh weight (g/plant)		Fresh weight (ton/fed)	
		First season	Second season	First season	Second season
1.5 g/l	**1**	554.03^{b-d}	610.00^{b-d}	12.93^{b-d}	14.23^{b-d}
	2	587.94^{b,c}	608.89^{b-d}	13.72^{b,c}	14.21^{b-d}
	3	504.19^{c,d}	543.06^{c,d}	11.76^{c,d}	12.67^{c,d}
3 g/l	**1**	666.64^{a,b}	740.83^{a,b}	15.55^{a,b}	17.29^{a,b}
	2	756.57^{a}	839.44^{a}	17.65^{a}	19.59^{a}
	3	602.75^{b,c}	623.88^{b,c}	14.06^{b,c}	14.56^{b,c}
4.5 g/l	**1**	580.84^{b,c}	624.17^{b,c}	13.55^{b,c}	14.56^{b,c}
	2	514.03^{c,d}	566.67^{c,d}	11.99^{c,d}	13.22^{c,d}
	3	602.29^{b,c}	670.28^{b,c}	14.05^{b,c}	15.64^{b,c}
Control		439.93^{d}	486.39^{d}	10.26^{d}	11.35^{d}
Mean of doses					
1.5 g/l		548.72^{A,B}	587.32^{A,B}	12.80^{A,B}	13.70^{A,B}
3 g/l		675.32^{A}	734.72^{A}	15.75^{A}	17.15^{A}
4.5 g/l		565.72^{A,B}	620.37^{A,B}	13.20^{A,B}	14.47^{A,B}
Control		439.93^{B}	486.39^{B}	10.26^{B}	11.35^{B}
Mean of portions					
1		560.36^{A}	615.34^{A}	13.07^{A}	14.35^{A}
2		571.31^{A}	621.69^{A}	13.32^{A}	14.50^{A}
3		540.58^{A}	584.55^{A}	12.60^{A}	13.64^{A}
Mean of biofertilization					
0		512.72^{b}	555.88^{b}	11.96^{b}	12.97^{b}
Added		649.10^{a}	706.83^{a}	15.14^{a}	16.49^{a}

Means with the same letters in each column indicate no significant difference between treatments at the 5% level of probability.

and 19.59 ton/fed) for the second one. It is clear from the data in Table 9 that untreated plants gave the mean value of 439.93 g/plant and 10.26 ton/fed for first season and 486.39 g/plant and 11.35 ton/fed for second season. Concerning the effect of doses, Table 9 showed that the greatest mean values of herb weight were 575.32 g/plant and 15.75 ton/fed for first season and 734.72 g/plant and 17.15 ton/fed

Table 10 Mean values of the dry weight of herb as affected by foliar fertilization doses and number of applied portions in two seasons

Dose NPK	Number of portions	Dry weight (g/plant)		Dry weight (ton/fed)	
		First season	Second season	First season	Second season
1.5 g/l	**1**	153.40^{d,e}	169.44^{c,d}	3.58^{d,e}	3.95^{c,d}
	2	176.83$^{b–d}$	183.33$^{b–d}$	4.13$^{b–d}$	4.28$^{b–d}$
	3	163.42^{d,e}	176.11$^{b–d}$	3.81^{d,e}	4.11$^{b–d}$
3 g/l	**1**	227.53^{a,b}	252.78^{a}	5.31^{a,b}	5.90^{a}
	2	229.56^{a}	255.00^{a}	5.36^{a}	5.95^{a}
	3	220.05$^{a–c}$	227.70^{a,b}	5.13^{a,b,c}	5.31^{a,b}
4.5 g/l	**1**	175.76$^{b–d}$	189.16^{b,c}	4.10$^{b–d}$	4.41^{b,c}
	2	142.63^{d,e}	157.77^{c,d}	3.33^{d,e}	3.68^{c,d}
	3	173.57^{c,d}	193.61^{b,c}	4.05^{c,d}	4.52^{b,c}
Control		112.68^{e}	129.72^{d}	2.63^{e}	3.03^{d}
Mean of doses					
1.5 g/l		164.55^{B}	176.29^{B}	3.84^{B}	4.11^{B}
3 g/l		225.71^{A}	245.14^{A}	5.27^{A}	5.72^{A}
4.5 g/l		163.99^{B}	180.18^{B}	3.83^{B}	4.20^{B}
Control		112.68^{C}	129.72^{C}	2.63^{C}	3.03^{C}
Mean of portions					
1		168.83^{A}	183.63^{A}	3.93^{A}	4.28^{A}
2		165.93^{A}	183.40^{A}	3.87^{A}	4.23^{A}
3		165.42^{A}	181.45^{A}	3.86^{A}	4.23^{A}
Mean of biofertilization					
0		145.03^{b}	159.39^{b}	3.38^{b}	3.71^{b}
Added		210.05^{a}	227.54^{a}	4.90^{a}	5.30^{a}

Means with the same letters in each column indicate no significant difference between treatments at the 5% level of probability.

for second one from the dose (3 g/l) and did not show any significant differences between portions in both seasons. For the dry weight of herb, dividing the first dose (1.5 g/l) of NPK into two or three portions did not show any significant differences from its application once on the fresh weight of herb. The same was true with the third dose (4.5 g/l). However, dividing the second dose (3 g/l) into two portions significantly increased fresh weight of herb in both seasons. Dividing the dose of 3 g/l into two portions was more effective than the other treatments and resulted in the better mean value in both seasons. Foliar application of NPK at 3 g/l and divided into two portions showed the better weight of plants (229.56 g/plant and 5.36 ton/fed) for first season and (255 g/plant and 5.95 ton/fed) for second season. It is clear from data in Table 10 that untreated plants gave the mean value of 112.68 g/plant and 2.63 ton/fed for first season and 129.72 g/plant and 3.03 ton/fed for second season. The mean value of doses showed the best dose of weight of plants was 225.71 g/plant and 5.27 ton/fed for first season and 245.14 g/plant and 5.72 ton/fed for second season from the dose 3 g/l and did not show any significant between portions in both seasons, as shown in Table 10.

These results were in accordance with Sakr [60], who studied the effect of NPK fertilization at rates of 300, 600, and 900 kg/fed on growth and yield on *Mentha arvensis*. He found that all NPK doses caused significant increases on plant growth and total yield over control in both cuts of the two seasons. Application of 900 kg NPK/fed/season was the most efficient treatment. Increasing NPK levels correspondingly increased the dry weight of herb. Mahmoud [61] found that, Grindelia plants that received high doses of NPK achieved the maximum fresh and dry weight of mass production. Moreover, these results were in harmony with those reported by Yeboah *et al.* [2] who found the mean value of fresh biomass yield ranged from 1700 to 2100 kg/ha and Ramara and Garofalo [38] on *S. hispanica*, who found fertilization with 125 : 100 : 40 kg/ha of N : P : K. was the best results for parameters biomass growth. Mary *et al.* [47] reported that fertilization with 90 : 60 : 75 kg NPK/ha gave the best result of total dry matter accumulation (g/plant).

Effect of biofertilizer

Biofertilizer application resulted in a significant increment in fresh and dry weight of herb in both seasons as shown in Tables 9 and 10. The mean increment values in fresh weight (g/plant and ton/fed) were 26.60 and 27.16% for first season and second season, respectively, compared with the control plants, whereas the mean increment values in dry weight (g/plant and ton/fed) were 44.83 and 42.76% for first and second season, respectively, compared with the control plants. Biofertilizers are increasingly used in modern agriculture owing to the extensive knowledge in rhizosphere biology and the discovery of the promoter function of special groups of microorganisms such as *Azotobacter* known as plant growth-promoting rhizobacteria. They appear to be frequent colonizers of important medicinal crops [62]. Meanwhile, Subba Rao [63] stated that the favourable effect of biofertilizers on growth parameters might be ascribed to its important role in fixing atmospheric N as well as increasing the secretion of natural hormones, namely, IAA, GA3, and cytokinins, antibiotic, and possibly raising the availability of various nutrients. These results were in harmony with those reported by some other studies [63–65]. Moreover, Khater [66] reported that inoculation of phosphorein produced taller plants and heavier fresh and dry weights of *Coriandrum sativum* L. herb than the control plant.

Seeds weight (g/plant and kg/fed)

Effect of interaction between NPK and biofertilizer

Seed weight/plant responded significantly to interaction between NPK and biofertilizer in both seasons as shown in Table 11.

NPK 3 g/l (two portions)+biofertilizer gave the maximum mean values (12.88 g/plant and 300.53 kg/fed for first season and 24.22 g/plant and 565.13 kg/fed for second season). The increment in seeds weight as a result of NPK 3 g/l (two portions)+biofertilizer treatment reached to 122.73% for first season and 303.67% for second season than the control plants. Aly *et al.* [67] studied the effect of mineral and biofertilizer and found the medium rate of different mineral fertilizers with amixture of *Azospirillum lipoferium*+*A. chroococcum*+*B. polymyxa* increased number and fresh weight of fruits/plant, sepals fresh and dry weight per/plant, and seed yield per plant and per fed. Abdeiraouf *et al.* [33] revealed that fertilization with mineral NPK exhibited the best vegetative growth parameters on *Nigella sativa* L, and the highest number of capsule/plant, seed yield/plant and/fed. Moreover, Gharib *et al.* [39] found that the use of combined treatment of biofertilizers (compost+mixture of N fixers) (*A. brasiliense*, *A. chroocccum* and *B. polymyxa* and *B. circulans*) on *M. nahortensis* gave the best results for all growth parameters than those obtained from N fixers or *B. circulans* alone. Jafari *et al.* [45] found significant effect of chemical fertilizer on all measured traits studied in *S. officinalis* except for the number of tillers. Biofertilizer application had also significant effect on all measured traits except for essential oil percentage. The interaction of the two factors had only a significant effect on leaf area and leaf yield. Moreover, these results were in harmony with those reported by Coates [16] that *S. hispanica* L. in low-input conditions had average seed yield of around 600 kg/ha, but can be up to 1200 kg/ha, whereas in

Table 11 Effect of foliar fertilization and/or biofertilizer on seed production of *Salvia hispanica* plant in two seasons (2016/2017 and 2017/2018)

Dose NPK	Number of portions	Biofertilizer	Seeds weight (g/plant)		Seeds weight (kg/fed)	
			First season	Second season	First season	Second season
1.5 g/l	One	0	7.77^{e,f}	8.11$^{e–g}$	181.30^{e,f}	189.23$^{e–g}$
		Added	10.01^{b,c}	10.77^{a,b}	233.56^{b,c}	251.30^{a,b}
	Two	0	7.36^{e,f}	6.83^{g,h}	171.73^{e,f}	159.36^{g,h}
		Added	8.25^{d,e}	8.33$^{d–f}$	192.50^{d,e}	194.36$^{d–f}$
	Three	0	8.07^{d,e}	5.83^{h}	188.30^{d,e}	136.03^{h}
		Added	9.69^{b,c}	10.00^{c}	226.10^{b,c}	233.33^{c}
3 g/l	One	0	8.08^{d,e}	9.44$^{c–e}$	188.53^{d,e}	220.26$^{c–e}$
		Added	11.33^{a,b}	10.91^{a,b}	226.56^{a,b}	254.56^{a,b}
	Two	0	10.33^{b,c}	8.22$^{d–f}$	182.23^{b,c}	191.80$^{d–f}$
		Added	12.88^{a}	24.22^{a}	300.53^{a}	565.13^{a}
	Three	0	7.96^{e,f}	9.44$^{c–e}$	185.73^{e,f}	220.26$^{c–e}$
		Added	12.74^{a}	13.54^{b}	297.26^{a}	315.93^{b}
4.5 g/l	One	0	8.47$^{c–e}$	8.89$^{c–f}$	197.63$^{c–e}$	207.43$^{c–f}$
		Added	9.20$^{b–d}$	9.50^{c,d}	214.66$^{b–d}$	221.66^{c,d}
	Two	0	7.46^{e,f}	5.50^{h}	174.06^{e,f}	128.33^{h}
		Added	9.92^{b}	10.22^{c}	231.46^{b}	238.46^{c}
	Three	0	7.43^{e,f}	6.78^{g,h}	173.36^{e,f}	158.20^{g,h}
		Added	8.62$^{b–e}$	7.72^{f,g}	201.13$^{b–e}$	180.13^{f,g}
0 g/l		0	5.72^{g}	6.00^{h}	133.46^{g}	140.00^{h}
		Added	6.61^{f,g}	9.00$^{c–f}$	154.23^{f,g}	210.00$^{c–f}$

Means with the same letters in each column indicate no significant difference between treatments at the 5% level of probability.

high-input conditions with irrigation and fertilization, yields as high as 2500 kg/ha have been shown in some experimental trials in Argentina and Mary *et al.* [47] on chia (*S. hispanica* L.), where they found the treatment combination of 60×45 cm spacing and fertilizer level of 90 : 60 : 75 kg NPK/ha produced significantly higher yield (676.58 kg/ha).

Effect of NPK fertilizer

NPK foliar fertilizer application resulted in significant increase in seeds weight in both seasons as shown in Table 12.

Dividing the first dose (1.5 g/l) of NPK into two or three portions did not show any significant difference from its application once on the fresh weight of herb. The same was true with the third dose (4.5 g/l). However, dividing the second dose (3 g/l) into two portions significantly increased seeds weight in both seasons. Dividing the dose of 3 g/l into two portions was more effective than the other treatments and resulted in the better mean value in both seasons. Foliar application of NPK at 3 g/l and divided into two portions showed the better weight of plants (11.37 g/plant and 265.30 ton/fed for first season and 16.22 g/plant and 378.46 ton/fed for second season). It is clear from data in Table 12 that control plants gave the mean value of 6.16 g/plant and 143.73 ton/fed for first season and 7.50 g/plant and 174.99 ton/fed for second season. The increment in seeds weight (g/plant) and seeds weight (kg/fed) as a result of NPK 3 g/l (two portions) treatment reached to 116.27% than the control for second season whereas first season was reached to 84.58%. The values of doses showed the best mean values of seeds weight recorded were 10.47 g/plant and 244.30 kg/fed for first season and 12.63 g/plant and 294.62 kg/fed for second season from the dose 3 g/l and did not show any significant between portions in both seasons as shown in Table 12.

These results are in harmony with those reported by Yeboah *et al.* [2] who found the mean value of seed yield ranged from 1927 to 2790 kg/ha and Mary *et al.* [47] who found fertilization with 90:60:75 kg NPK/ha gave the best result of seed yield (623.60 kg/ha) and reported the variation in yield was associated with variation in plant population and number of spikes produced as well as difference in the amount of nutrients available in the rhizosphere of plant system.

Effect of biofertilizer

Biofertilizer application resulted in a significant increase in seeds weight in both seasons as shown in Table 12. The mean increment values in seeds weight (g/plant and ton/plant) were 25.25% for first season and 52.27% second season compared with the control plants. These results were in harmony with those reported by Yadav and Khurana [68] on fennel,

Table 12 Mean values of seed production as affected by foliar fertilization doses and number of applied portions in two seasons

Dose NPK	Number of portions	Seeds weight (g/plant)		Seeds weight (kg/fed)	
		First season	Second season	First season	Second season
1.5 g/l	**1**	8.89^{c}	$9.44^{c,d}$	207.43^{c}	$220.26^{c,d}$
	2	7.80^{e}	7.58^{e}	182.00^{e}	176.86^{e}
	3	8.88^{c}	7.92^{e}	207.20^{c}	184.80^{e}
3 g/l	**1**	9.69^{b}	10.17^{c}	226.10^{c}	237.30^{c}
	2	11.37^{a}	16.22^{a}	265.30^{a}	378.46^{a}
	3	10.35^{b}	11.49^{b}	241.50^{b}	268.10^{b}
4.5 g/l	**1**	8.84^{c}	9.19^{d}	206.26^{c}	214.43^{d}
	2	$8.69^{c,d}$	7.86^{e}	$202.76^{c,d}$	183.40^{e}
	3	$8.02^{d,e}$	7.25^{e}	$187.13^{d,e}$	169.16^{e}
Control		6.16^{f}	7.50^{e}	143.73^{f}	174.99^{e}
Mean of doses					
1.5 g/l		8.52^{B}	8.31^{B}	198.88^{B}	193.97^{B}
3 g/l		10.47^{A}	12.63^{A}	244.30^{A}	294.62^{A}
4.5 g/l		8.52^{B}	8.10^{B}	198.72^{B}	189.00^{B}
Control		6.16^{C}	7.50^{C}	143.73^{C}	174.99^{C}
Mean of portions					
1		8.39^{A}	9.07^{A}	195.88^{A}	211.74^{A}
2		8.45^{A}	9.73^{A}	197.36^{A}	227.74^{A}
3		8.39^{A}	8.59^{A}	195.96^{A}	200.57^{A}
Mean of biofertilization					
0		7.96^{b}	7.50^{b}	177.63^{b}	175.09^{b}
Added		9.97^{a}	11.42^{a}	227.79^{a}	266.48^{a}

Means with the same letters in each column indicate no significant difference between treatments at the 5% level of probability.

which reported that seed treatment with *Azotobacter* improved umbels/plant, seeds/umbel, and total seed yield. Gad [69] found a significant increase in plant height, number of leaves, fresh and dry weight of vegetative growth, number of branches, number of umbels, and fruit weight/plant as a result of using biofertilizers on *Foeniculum vulgare* and *Anethum graveolens*. Khandeel *et al.* [70] recorded a significant increase in plant height, number of leaves, fresh and dry weights of vegetative growth, number of branches, number of umbels, and fruits weight/plant as a result of using biofertilizers (Biogene, Netrobene and Serialene) on *A. graveolens* and *F. vulgare*. Also, El-Gendy *et al.* [71] studied the effect of different levels of cattle manure and biofertilizers (phosphorein and/or nitrobein) as well as their interactions and treatments on the growth, sepals, and seed yields on roselle plants and found the interactions and treatments between cattle manure (30 m^3/fed) combined with biofertilizers alone or mixture gave the highest values of sepals yield.

Results of our experiment showed significant effect of chemical fertilizers on the measured traits. Nitrogen, phosphorus and potassium are macronutrients that are involved in many plant processes. Nitrogen is the main yield-limiting mineral nutrient. Nitrogen takes part in many physiological and biochemical plant processes and is a structural component of amino acids, nucleic acids, enzymes and proteins, chlorophyll, and cell wall. Phosphorus is also a highly required macronutrient; playing vital roles in energy transfer, cell membranes, nucleic acids, and other key compounds. Potassium has been reported to be involved in rapid cell division [25–27,72,73].

Conclusion

From the mentioned and discussed results, we may recommend fertilization of chia plant with NPK 3 g/l (two portions)+biofertilizer for the best growth and yield of *S. hispanica* under the mentioned soil conditions.

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Conflicts of interest

There are no conflicts of interest.

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