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The Effect of Utilizing Different Types of Organic and Bio-Fertilizers on Growth, Elements Concentration, Seed Yield and Essential Oil of *Coriandrum sativum* L.

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ABSTRACT

Background: Bio-fertilizers may be used to maintain soil fertility and soil improvement.

Methods: In this study involving 12 treatments and 3 replications was conducted in Tehran, Iran. The experiment was conducted in 2018–2019 as a randomized complete block design. The treatments were 1- vermicompost (10 t/ha), 2- nitroxin, 3- bio-superphosphate, 4- biosulfur, 5- vermicompost + nitroxin, 6- vermicompost + bio-superphosphate, 7- vermicompost + biosulfur, 8- nitroxin + bio-superphosphate, 9- nitroxin + biosulfur, 10- bio-superphosphate + biosulfur, 11- chemical fertilizer and 12- control (without fertilizer).

Result: The results showed that the treatments had a significant impact on the characteristics examined such as the highest plant height (75.3 cm) in the treatment combining vermicompost and biological superphosphate and the highest number of shoots/plant. The highest concentration of N in seeds (2.92%) was obtained when plants were treated with nitroxin and biosulfur and the highest concentration of P in seeds (0.83%) when treated with biological superphosphate. In addition, the highest K content in seeds (4.06%) and grain yield (1297.5 kg.ha^{-1}) were found in the treatment of nitroxin and bio-superphosphate, as well as the content of essential oil (0.32%). and the yield of essential oils (2.89 kg.ha^{-1}) was obtained when treated with nitroxin. Consequently, Bio-organic fertilizers can be considered as an alternative to chemical fertilizers in organic coriander cultivation.

Key words: Biosulfur, Bio-superphosphate, Essential oil yield, Nitroxin, Vermicompost.

INTRODUCTION

Modern agriculture is based on the use of organic fertilizers, which play an important role to produce good quality and higher yield per unit area. Since the excessive consumption of chemical fertilizers in the long term has caused a decrease in the yield of crops and caused negative environmental consequences and increased production costs, therefore in the years recently, the use of organic and biological fertilizers has been considered (Kamayestani *et al*., 2015). Finding the alternative sources of nutrients should be cheap and environmentally friendly for farmers By maintaining good environmental conditions of the soil, farmers can reduce their fertilizer investments and thus practice ecologically sustainable agriculture (Dikr and Belete, 2017). Plant nutrients supplied through organic fertilizer sources have profound effect on growth and yield of crop as the biological decomposition processes of the organic sources supply nutrients to the plants in the available forms (Nouri *et al*., 2020).

Eliminate or greatly reduce the use of chemical additives and increase the stability of herb quantity, quality and yield using organic and biofertilizers such as vermicompost and the bacteria *Azotobacter, Azospirillum, Bacillus* and *Thiobacillus*. According to another study showed that the increased seed yield, essential oil content and yield on medicinal plants that the use of organic and biofertilizers in sustainable agricultural systems provides optimal conditions for the production of these plants and provides maximum qualitative and quantitative yields (Akbari and Gholami, 2016).

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Movaghatian *et al*. (2015) reported that using combined use of nitroxin and biosuprophosphate biofertilizers which have improved soil microbial activity and producing some plant growth regulators, due to the positive effect on plant vegetative and reproductive growth has finally led to increased seed yield and essential oil content. Khalesro *et al*., (2012) showed that the combined use of nitrogen-fixing and phosphate-solubilizing bacteria *(Azotobacter, Azospirillum* and *Pseudomonas*) increased the concentration of nitrogen of *Matricaria chamomilla* (Salehi *et al*., 2011) and the concentration of nitrogen of seeds in *Pimpinella anisum* (Darzi and Akhani, (2016) depicted that *Coriandrum sativum* and *Anethum graveolens* also showed that the use of nitroxin and biological fertilizers containing *Azotobacter* and *Azospirillum* increased the essential oil of these plants compared to the control, respectively.

Therefore, since medicinal plants are used for the production of medicine, food and cosmetics, it is better to use biological fertilizers instead of using chemical fertilizers which are harmful to humans and animals.

Regarding the importance of plant nutrition management in sustainable and organic agriculture, this study was conducted aimed to study the separate and combined effect of organic and biological fertilizers on the quantitative and qualitative properties of *Coriandrum* to eliminate the use of chemical fertilizers in order to determine the appropriate treatment to achieve the maximum content of essential oil and its yield.

MATERIALS AND METHODS

The study was conducted in 2018 and 2019 at the Green Space Research, Training and Consulting Center of Tehran Municipality which is located in the eastern part of Tehran, Iran. Firstly, a random composite sample (0-30 cm) was sampled from the field soil for analyzing some properties (Table 1).

This study was conducted based on a randomized complete block design with twelve treatments and three replications. The soil nitrogen was also selected as a criterion for determining the amount of vermicompost used. The treatments include 1) vermicompost (10 ton/ha), 2) nitroxin (2L/ha) (A solution containing nitrogen fixing 10^8 active bacteria called *Azotobacter chroococcum* and *Azospirillum lipoferum*) per milliliter, 3) biosuperphosphate (2L/ha)(contained phosphate-solubilizing bacteria (*Bacillus* sp) which contained about 10^8 active bacteria per milliliter), 4) biosulfur (5 kg/ha) (containing *Thiobacillus* sp (about 10^9 active bacteria per gram) was used with bentonitated organic sulfur (250 kg/ha)), 5) vermicompost + nitroxin, 6) vermicompost + biosuperphosphate, 7) vermicompost + biosulfur, 8) nitroxin + biosuperphosphate, 9) nitroxin + biosulfur, 10) biosuperphosphate + biosulfur, 11) chemical fertilizers (60 and 80 kg/ha of nitrogen and phosphorus, respectively) and 12) control (without fertilizer application). Therefore, according to the amount of nitrogen required by *Coriandrum sativum* and the amount of nitrogen in the soil and the source of vermicompost and considering the release of 50% of total nitrogen in the first year from organic fertilizer (Pimentel, 1993), the amount of vermicompost use is ten tons per ha. *Coriandrum sativum* seeds used in this study, which is an ecotype, were prepared by Isfahan Giah Gostar Agricultural Company.

In order to perform the test, the size of each plot was 3 × 2.1 m containing 6 rows of planting with a distance between rows of 35 cm and on a row of 10 cm was considered. The distance between plots was 70 cm and 2 m between replications. *Coriandrum sativum* seeds were planted and experimental treatments were applied on May 10 in spring. Ten days before planting, vermicompost was poured and mixed with the soil by a rake and then ridge and furrow were created. Seeds were inoculated with nitroxin and bio super phosphate for 10 min, then dried in the shade and exposed to air and planted at a depth of 2 cm in the soil.

In addition, the mentioned plots were sprayed with nitroxin and bio super phosphate at branching stage of *Coriandrum sativum*. Also, in the plots containing biosulfur biofertilizer, the required amount of biosulfur powder along with bentonitated organic sulfur was placed under the seeds during planting. Irrigation operations, as ridge and furrow, were first performed once every 2 days and after the plants were established, according to the climatic conditions of the region, about once every 5 days. The field weeds control operations were performed in six shifts mechanically and by hand. In the plots containing chemical fertilizer treatment, all phosphorus (triple superphosphate type) and half of the nitrogen (urea type) required during planting and the other half were used at branching stage.

In this study, the final harvest was performed to determine the seed yield at seed maturity in an area of one square meter in each experimental plot, taking into account the margin effect. In order to measure all desired elements in *Coriandrum sativum* seeds, this extract was used. The mean height of five plants per plot at full flowering stage (excluding the margin effect) was used. The mean number of flowers of five plants per plot at seed maturity was used. In order to determine the concentrations of nitrogen, phosphorus and potassium in *Coriandrum sativum* a 20 g sample of seeds from each plot was randomly prepared. Based on the methods of Emami (1996), the content of nitrogen was measured using the titration method the content of phosphorus was measured using the calorimetric method by spectrophotometer. The content of potassium was measured using the flame diffusion method by flame photometer. In order to determine the content of essential oil, a sample of 50 g of seeds was prepared from each experimental plot, which was ground and extracted for 4 h using water distillation by Clevenger (Sefidkon 2001). The content of essential oil was also calculated after dehydration of its water by dry sodium sulfate. The yield of essential oil was obtained from multiplying seed yield and essential oil content.

Table 1: Some physical and chemical properties of site soil and vermicompost.

	Soil texture	pH	EC	Organic matter	Total nitrogen	Phosphorus	Potassium
				%		$Mg.kg^{-1}$	
				$dS.m^{-1}$			
Soil	Loamy sand	8.24	1.10	1.4	0.14	22.1	300.3
Vermicompost	-	7.22	3.46	18.97	0.93	4800	2700

The difference between parameters was tested by combined analysis of variance followed by Duncan's test at the probability level of 5%. All statistical analyses were performed using SAS software (9.3) (SAS Institute, 1997), to examine associations between properties a multivariate Pearson correlation analysis based on Principal Components Analyses Ranking (PCA Ranking) was performed using R version 4.3.19.

RESULTS AND DISCUSSION

In this study, the effects of different single and combined analysis of year and treatments of fertilizers on the studied treatment are shown at Table 2 and 3. The effect of year on all treatments except for on the thousand grain weight, yield of fresh and dried vegetative growth were significant. Moreover, the effect of different fertilizers treatments on all parameters was significant. The combined effect of year and fertilizers showed significant effects on all treatments except for plant height, flowers per plant, thousand grain weight and grain yield.

The mean comparison of the treatments showed that plant height in the combined use treatment of vermicompost and bio super phosphate showed the highest significantly (75.3 cm) compared to chemical fertilizer (58.7 cm), bio super phosphate (55.8 cm) and control (54.4 cm) treatments and did not differ significantly from other treatments (Fig 1). Moreover, the mean comparison of number of flowers per plant and dry matter showed that all fertilizer treatments were significantly different from the control treatment .So the highest number of flowers per plant was obtained from chemical fertilizer treatments (23.6 flowers) and the combined use of vermicompost and bio super phosphate (22.4 flowers) (Fig 1).

In addition to chemical fertilizer treatments, organic and biological fertilizers treatments had significant superiority in terms of the number of flowers per plant compared to the control and among them, the highest number of flowers per plant was obtained from the combined treatment of vermicompost and bio super phosphate. The results of the present study are in close accordance with the findings of the studies carried out by Talaei and Amini Dehaghi (2015) indicated that the highest number of flowers per plant in *Cuminum cyminum* was obtained from the treatment of combined use of chemical (nitrogen + phosphorus) and biological (nitroxin + biophosphate fertilizer) fertilizers and inoculation of *Cuminum cyminum* with microorganisms in biophosphate fertilizer and nitroxin biofertilizer due to the production of growth-promoting hormones and biologically active matter increased vegetative growth and consequently the number of flowers per plant.

Also, the grain and biological yield and performance of fresh and dried vegetative growth mean comparison of the treatments showed a significant difference. The highest grain yield was obtained significantly from the treatment of combined use of nitroxin and bio super phosphate (1297.5 kg/ha) in comparison with most of the treatments except for

Table 2: Combained analysis of the effect of year and fertilizers on *Coriandrum sativum* studied traits.

	df	Plant height	Flowers no.	Thousand grain weight	Dry matter weight	Biological yield	Performance of fresh vegetative growth	Performance of dried vegetative growth	Grain yield
Year	1	576.3**	30**	1.5ns	26.2**	24166310.6**	481^{ns}	88438^{ns}	4188.2^{ns}
R	2	1.03^{ns}	0.08^{ns}	0.53^{ns}	4^{ns}	337884.3^{ns}	1286647^{ns}	39493.2^{ns}	9928^{ns}
R × Year	2	31.6	0.44	0.13	6.5	518894	196161.5	88703	18152.5
Treatment	11	156.5**	23**	2**	65.8**	4943165.5**	14129012.5**	700654.6**	152325**
Year × Treatment	11	34.4^{ns}	4^{ns}	0.61^{ns}	9^{ns}	896385.5*	13206.5**	468365.3**	21082.6^{ns}
Error	44	31.5	3.6	0.7	5	381380.8	443655.5	48609.3	11179
CV (%)	-	8.2	9	9.5	9.6	9.7	7	8.8	10

ns, * and **: insignificant and significant at 1 and 5% probability levels, respectively.

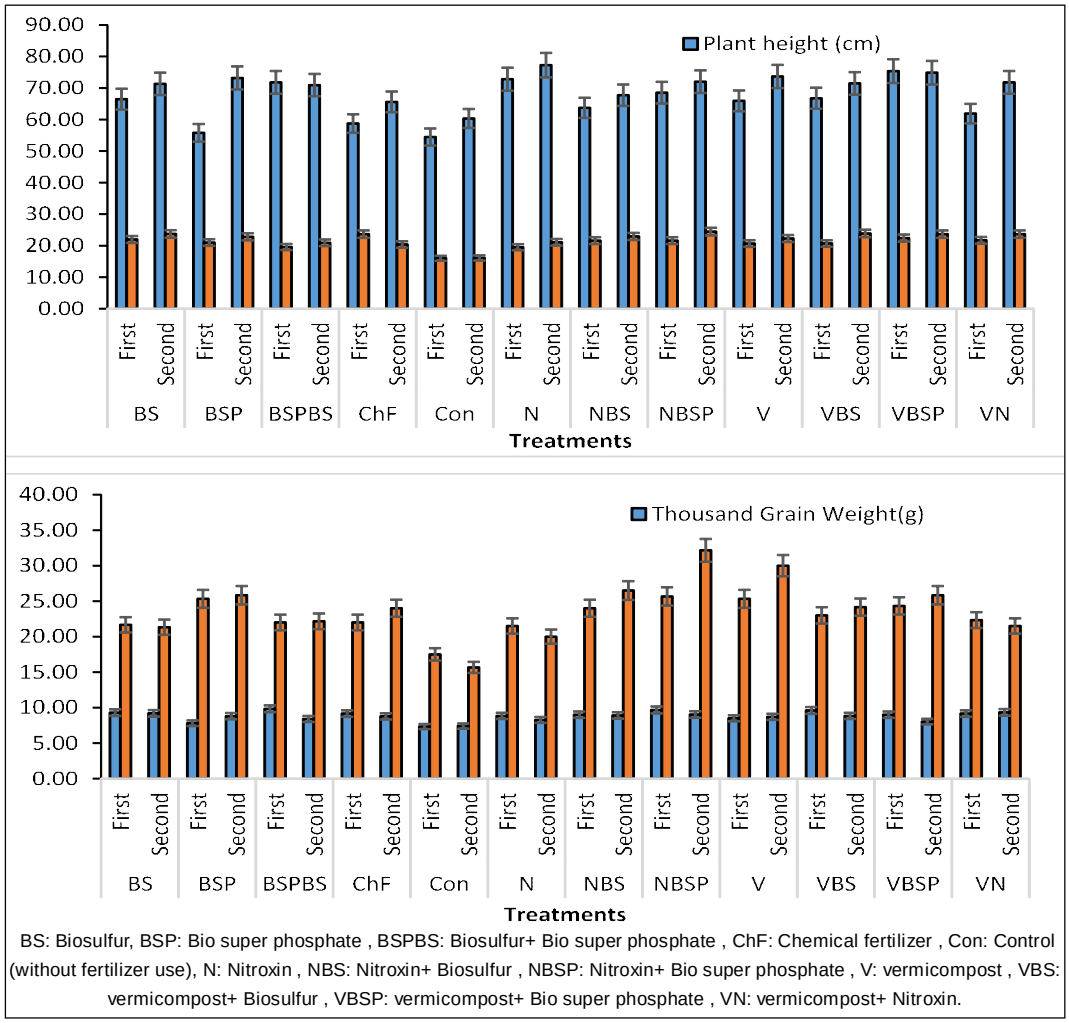
Table 3: Combained analysis of the effect of year and fertilizers on *Coriandrum sativum* L. studied nutritional traits.

	df	Essential oil vegetative growth	Essential oil yield of vegetative growth	Essential oil grain	Essential oil yield of grain	Nitrogenn concentratio in seeds	Phosphorus concentration in seeds	Potassium concentration in seeds
Year	1	1.6**	1084.6**	0.26**	32.2**	4.7**	0.36**	16.3**
R	2	0.009^{ns}	8^{ns}	0.001^{ns}	0.18^{ns}	0.003^{ns}	0.006^{ns}	0.03^{ns}
R × Year	2	0.006	6	0.002	0.02	0.0002	0.001	0.007
Treatment	11	0.03**	24**	0.02**	3**	0.92**	0.04**	0.68**
Year × Treatment	11	0.01*	12.3**	0.01**	1.4**	0.23**	0.02**	0.41**
Error	44	0.005	3	0.002	0.28	0.04	0.004	0.07
CV (%)	-	27.5	27.2	20.2	21.6	12.5	11.4	9.3

ns, * and **: insignificant and significant at 1 and 5% probability levels, respectively.

treatments of the combined use of nitroxin and biosulfur (1258.3 kg/ha), biosulfur (1208.3 kg/ha), combined use of vermicompost and nitroxin (0.1128 kg/ha) and chemical fertilizer (1191.6 kg/ha) (Fig 2).

The mean comparison of grain nutritional showed that the highest concentration of nitrogen in grains was obtained from the two treatments of combined use of nitroxin and biosulfur (2.92%) and biosulfur (85 (2.2%) and had significant superiority to other treatments, especially vermicompost (1.66%), chemical fertilizer (1.63%), combined use of vermicompost and bio super phosphate (1.28%) and control (1.04%) treatments (Fig 2). Therefore, the highest concentration of phosphorus in grains was obtained from the treatment of bio super phosphate (0.835%) which compared to vermicompost (0.648%), combined use of nitroxin and biosulfur (0.633%), combined use of vermicompost and nitroxin (0.627%), nitroxin (0.457%) and control (0.320%) treatments was about 29, 32, 33, 83 and 161% higher and showed no significant difference with other treatments (Fig 2). Moreover, combined use of nitroxin and bio super phosphate (4.06%) had significantly amount of potassium camper to nitroxin (2.91%), vermicompost (2.63%) and control (2.25%) treatments and (Fig 2). It seems that increasing seed yield in some biofertilizer treatments (such as biosulfur) and especially the combined use of nitroxin and bio super phosphate is due to the positive and obvious effect of bacteria in these biofertilizers on the optimal absorption of nitrogen, phosphorus and potassium and subsequent improvement in growth and functional properties such as the number of flowers per plant. In this regard and consistent with the present study, in a study on *Foeniculum vulgare*, it was observed that the combined use of biofertilizers nitroxin and bio super phosphate increased seed yield compared to the control (Movaghatian *et al*., 2015). It is reported that using biofertilizer, due to the availability of more bacterial volume by the plant, by affecting various aspects of development since application to the final yield, through synergy for growth promoters and antagonistic effect on reducing factors, increase growth and better yield (Nada *et al*., 2022). The results of a field study also showed that using biofertilizers containing *Azotobacter* and *Pseudomonas* bacteria and mycorrhizal fungus increased



BS: Biosulfur, BSP: Bio super phosphate , BSPBS: Biosulfur+ Bio super phosphate , ChF: Chemical fertilizer , Con: Control (without fertilizer use), N: Nitroxin , NBS: Nitroxin+ Biosulfur , NBSP: Nitroxin+ Bio super phosphate , V: vermicompost , VBS: vermicompost+ Biosulfur , VBSP: vermicompost+ Bio super phosphate , VN: vermicompost+ Nitroxin.

Fig 1: Mean comparison of some morphological traits under effects of different year and fertilizers on *Coriandrum sativum* L.

the yield of seeds of *Foeniculum vulgare* (Zamani *et al*., 2019). In two other crop tests on *Cuminum cyminum*, it was observed that in a test using *Azotobacter* and *Pseudomonas* bacteria and in the other using nitroxin and biophosphate biofertilizers increased seed yield (Saeidnejad and Rezvani Moghaddam, 2010; Karimzadeh Asl and Baghbani Arani, 2019). A study by Kamayestani *et al*. (2015) on *Pimpinella anisum* also confirmed that using biosulfur biofertilizer increased seed yield compared to other single and combined treatments of organic and biological fertilizers such as vermicompost treatments. According to the result, most of the single and combined treatments containing vermicompost did not have the expected seed yield, which seems that the proper condition of the organic matter in the tested soil has reduced the effect of vermicompost.

According to the increase in nitrogen concentration in the grain when treated using a combination of nitroxin and biosulfur, bacteria fix nitrogen and solubilize the phosphate

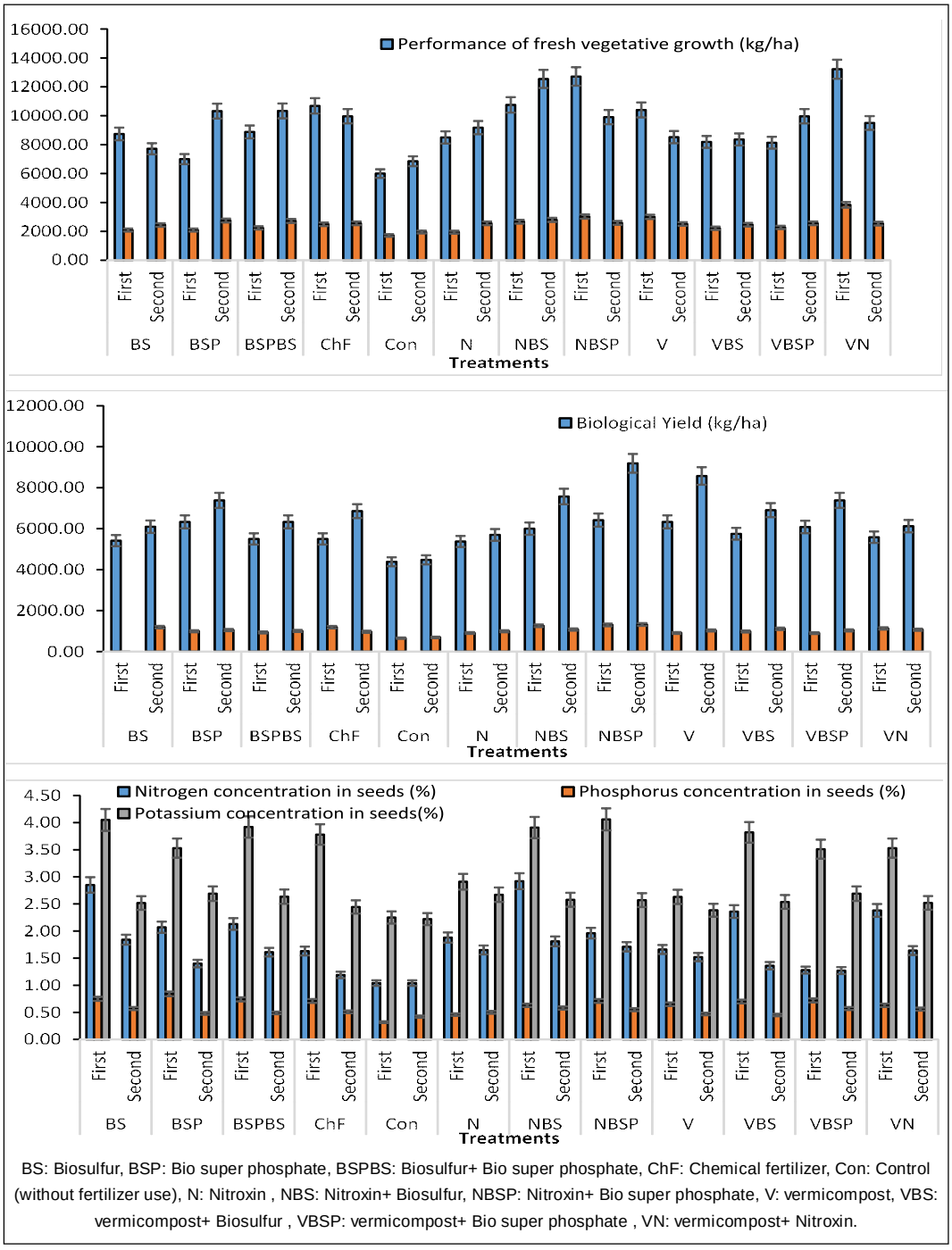


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Fig 2: Mean comparison of some phisiological traits under effects of different year and fertilizers on *Coriandrum sativum* L.

in the mentioned biofertilizer, improving nutrient availability absorbed by root growth and soil nutrient availability, together with the growth, development and biomass of *Coriandrum sativum*, significantly improved the nitrogen concentration in the seeds (Zamani *et al*., 2019). In this regard, the results of two field studies also showed that the combined use of nitrogen-fixing and phosphate-solubilizing bacteria (Azotobacter, Azospirillum and Pseudomonas) increased the concentration of nitrogen in *Matricaria chamomilla* L. and increased the concentration of nitrogen in *Pimpinella anisum* seed (Salehi *et al*., 2011; Khalesro *et al*., 2012) which is consistent with the results of the present study. The researchers acknowledged that in addition to nitrogen fixation, rhizosphere bacteria that promote plant growth release plant hormones such as gibberellic acid and auxin, which stimulate plant growth and increase photosynthesis and uptake of nutrients including nitrogen (Gahory *et al*., 2022, Nada *et al*., 2022). In a field study on *Satureja hortensis* it was found that using nitroxin biofertilizer increased the concentration of nitrogen in the plant compared to the control (Haj Seyed Hadi and Darzi, 2018).

The results demonstrated that the phosphorus concentration in the seeds was high both with the biosulfur treatment (0.751%) and the combined use of biosulfur and biosulfur (0.740%) and after the biosuperphosphate treatment. Karimzadeh and Baghbani Arani (2019) claim that the use of bio-fertilizers by increasing the ability of roots to absorb water and available elements by increasing root mass penetrates into the pores of the soil, preventing leaching nutrients, increasing the absorption and transport of phosphorus and potassium into the seeds.

The highest concentration of phosphorus in seeds was obtained from the treatment of bio super phosphate use and the highest concentration of potassium in seeds was obtained from the combined use treatment of nitroxin and bio super phosphate. In this regard, the results of a study on *Cuminum cyminum* revealed that the highest concentration of phosphorus in seeds was obtained from the use of biophosphorus biofertilizer and the highest concentration of potassium in seeds was obtained from the combined use of nitroxin and biophosphorus fertilizers (Karimzadeh Asl and Baghbani Arani, 2019) which is

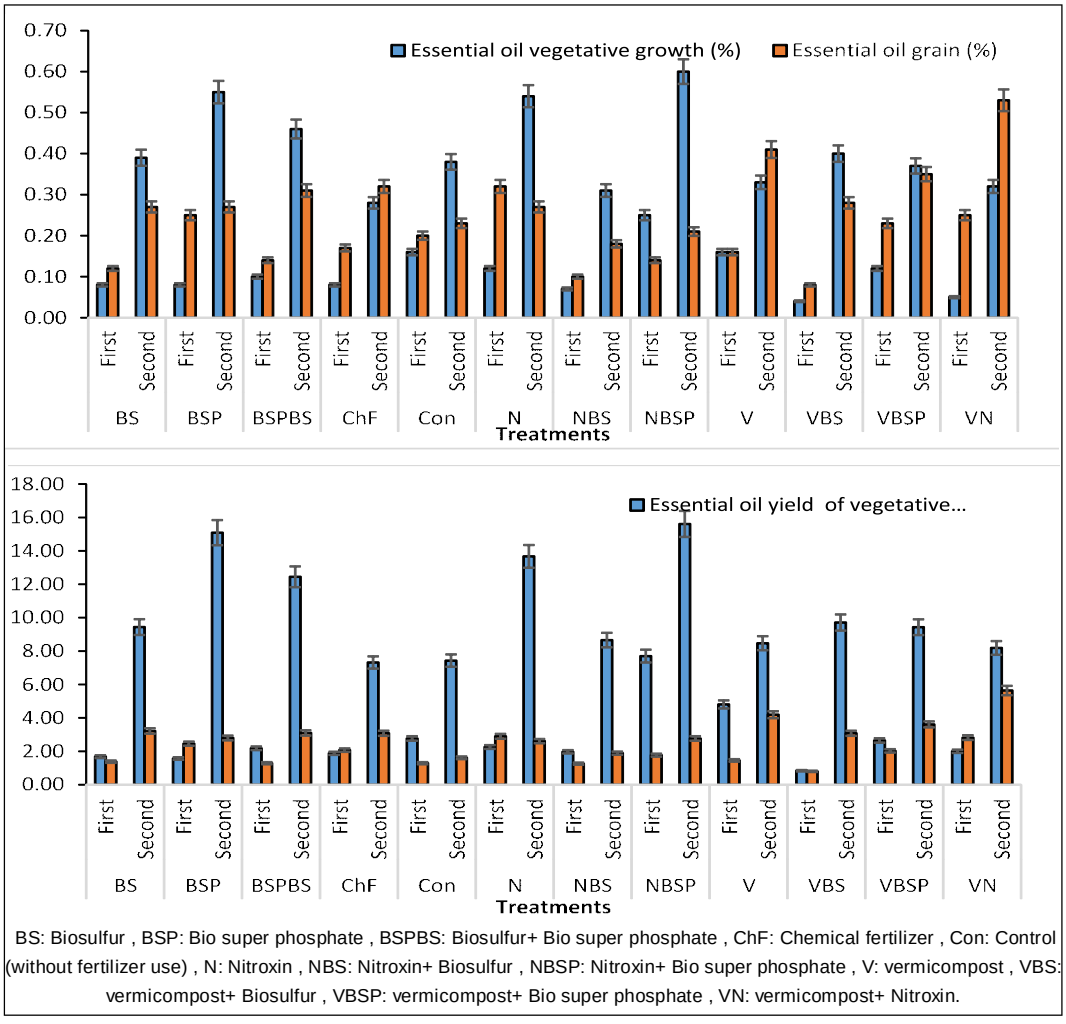

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Fig 3: Mean comparison of some essential oil traits under effects of different year and fertilizers on *Coriandrum sativum* L.

consistent with the results of the present study.Also, in a field study on *Foeniculum vulgare*, it was observed that the combined use of nitroxin and bio super phosphate biofertilizers increased the concentration of phosphorus in seeds (Movaghatian *et al*., 2015). In another study on *Foeniculum vulgare*, researchers attributed the increase in the concentration of potassium in seeds by the combined use of growth-promoting bacteria (*Azotobacter, Pseudomonas* and *Bacillus*) and mycorrhiza fungi to the ability of these bacteria to increase usable potassium in the soil and improve mycorrhizal symbiosis (Zamani *et al*., 2019). The researchers attributed the increase in phosphorus concentration to the spread of plant roots inoculated with the fungus and an increase in growth-promoting hormones (Rousta *et al*., 2023).

The mean comparison of fertilizers treatment showed significant difference on essential oil. The highest content of essential oil was obtained significantly from two treatments of combined use of vermicompost and nitroxin (0.550%), then use of vermicompost (0.320%) while the lowest content of essential oil was observed in the combined use of vermicompost and biosulfur (0.083%) (Fig 3). The mean

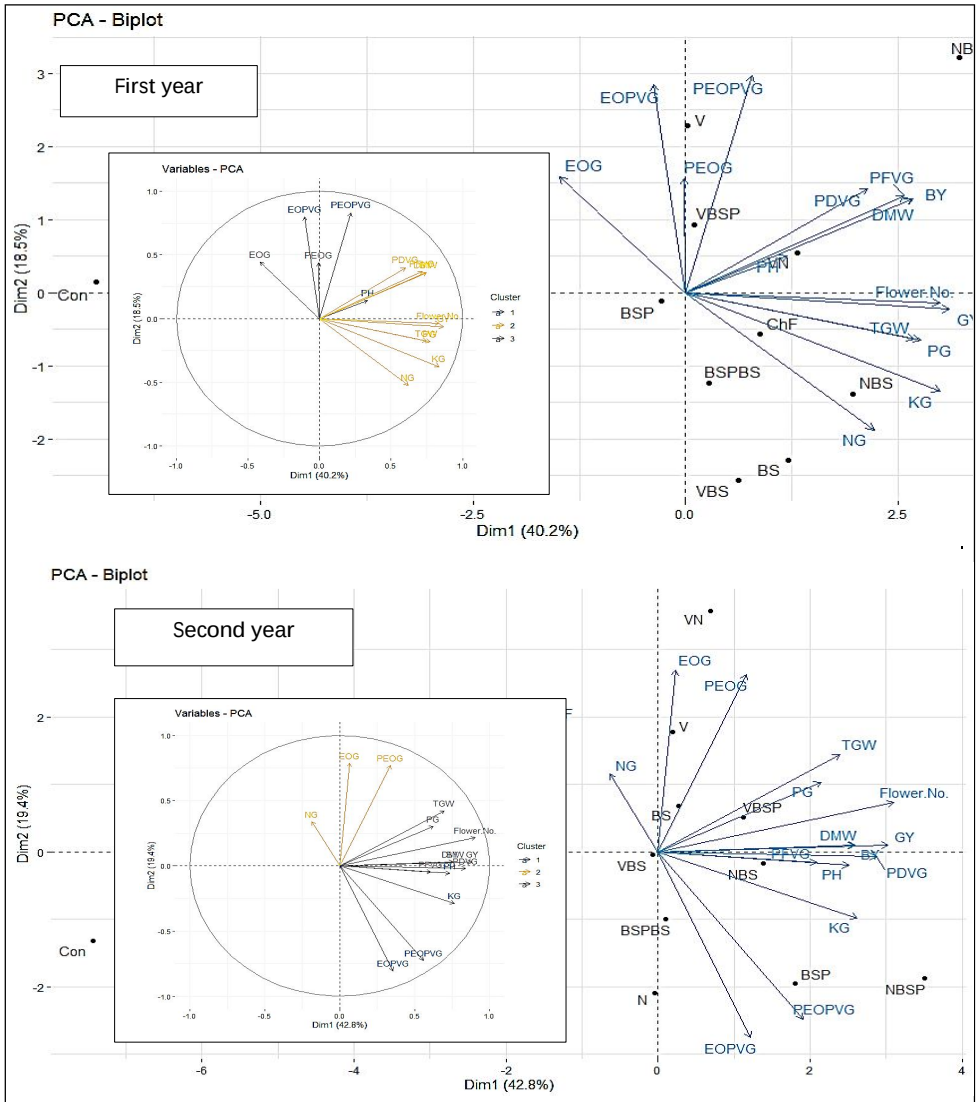

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Fig 4: Principal component analysis (PCA) of data for all characteristics of plants under different planting date.

comparison showed that the yield of essential oil in nitroxin use treatment (2.89 kg/ha) showed no significant difference with the two treatments of combined use of vermicompost and nitroxin (2.82 kg/ha) and use of bio super phosphate (2.46 kg/ha) but a significant difference compared to other treatments, especially compared to the two treatments of combined use of nitroxin and biosulfur (1.26) and vermicompost and biosulfur (0.80 kg/ha) had about 129 and 261% higher essential oil yield, respectively (Fig 3).

Consistent with the present study, in a study on *Thymus vulgaris* it was observed that using nitroxin caused a significant increase in the content of essential oil compared to the other two biofertilizers *i.e*. mycorrhiza and biophosphorus (Mohammadpour Vashvaei *et al*., 2015). The researchers stated that using these biofertilizers increased the content of essential oil through affecting the absorption of nitrogen and phosphorus, which are effective on the formation of essential oils (Nada *et al*., 2022; El-Beltagi *et al*., 2023). A study reported that single and combined use of nitrogen-fixing bacteria (*Azotobacter* and *Azospirillum*) and phosphate-solubilizing bacteria (Pseudomonas) increased essential oil of *Cuminum cyminum* compared to the control (no use), which is consistent with the results of the present expriment (Saeidnejad and Rezvani Moghaddam, 2010). The results of two studies on *Coriandrum sativum* and *Anethum graveolens* confirmed that using nitroxin and biofertilizer containing Azotobacter and Azospirillum increased the essential oil of these plants compared to the control, respectively (Darzi and Akhani, 2016).

Regarding significant superiority of essential oil in nitroxin use treatment compared to other treatments and its acceptable seed yield, it was not unexpected that the yield of essential oil in this treatment was higher than other treatments. Of course, the yield of essential oil in the two treatments of biospherphosphate and combined use of vermicompost and nitroxin was not statistically different from nitroxin treatment, but in terms of cost savings (vermicompost) and economic efficiency, the superiority of nitroxin treatment was justified. In this regard, studies on *Pimpinella anisum*, *Cuminum cyminum* and *Foeniculum vulgare* also showed that using nitrogen biofertilizer (*Azotobacter*), the combined use of nitroxin and biophosphate biofertilizers and the combined use of bacterial biofertilizer (*Azotobacter* and *Pseudomonas*) and mycorrhiza fungi, respectively significantly increased the yield of essential oil (Karimzadeh Asl and Baghbani, 2019; Zamani *et al*., 2019).

As the (Fig 4) shows, the first and second components represented about 40.2% and 18.5% for the first year and 42.8% and 19.4% for the second year , respectively. The cosine of the angle between two vectors estimates the correlation between them; therefore, clustered points are highly correlated with each other. There are three clusters of variables that are strongly correlated with each. The first cluster is highly correlated with VN, ChF, BSPBS in first year and with VBSP, NBS and BSP in second year. Running perpendicular to the first cluster, the second cluster of highly correlated variables includes V, VBSP and VN for two years. The control treatment in the tow years has no correlathin with all parameters for two years.

CONCLUSION

In general, the study results showed that nutritional management of medicinal herb *Coriandrum sativum* using organic and biological fertilizers had a significant effect on the studied properties, so that in all studied traits, separate and combined use of organic and biological fertilizers were superior to the control treatment (no fertilizer use) and superior or equal to the chemical fertilizer treatment. Also, among biological (nitroxin, bio super phosphate and biosulfur) and organic (vermicompost) fertilizers, separate and integration treatments containing biofertilizers had a significant superiority to separate and combined treatments containing organic vermicompost. As a result, in the present study, the highest seed yield was obtained from the treatment of combined use of nitroxin and bio super phosphate biofertilizers and the highest content and yield of essential oil was obtained from the treatment of single use of nitroxin biofertilizer. In general, use one type of nitroxin treatment, which is economically justifiable and cost-effective, was introduced as the superior treatment in the present test.

Conflict of interest

The authors declare that they have no conflict of interest or personal relationships.

Statements and declarations

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