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RESEARCH ARTICLE

Responses of salt-affected French basil plants grown in new reclamation lands to biofertilization and selenium

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Abstract

The current study aimed to investigate the effects of inoculate application with *arbuscular mycorrhizal* fungi (AMF), *Azospirillum brasilense* bacteria (AZSB) and *Azotobacter chrococcum* bacteria (AZBB) individually or in combination with selenium spraying at rates 0, 25, 50 and 100 ppm as well as their interaction on vegetative growth, herb yield, chemical composition of leaf and volatile oil productivity of French basil (*Ocimum basilicum* L.) plants grown in salinity affected soil in sandy new reclamation land. A field trial was conducted in two successive seasons (2021 and 2022) at a private farm located at Sanur Village, Biba Bistrict, Beni-Suef Governorate, Egypt. The obtained results indicated that inoculated basil plants with the three micro-organisms (AMF, AZSB, and AZBB) or/and spraying selenium at different concentrations significantly enhanced all vegetative growth parameters, herb yield, leaf main pigments and mineral composition, volatile oil content, and volatile oil yield. Also, the companies application of micro-organisms and selenium application was superior to using each one individually. The highest values of investigated parameters were found in plants that were inoculated with AMF and sprayed with selenium at 50 or 100 ppm. Whereas there were no significant variations between the two higher selenium concentrations. Consequently, we recommended that inoculating French basil plants with AMF and selenium spraying at 50 ppm in the form of sodium selenite could be an effective method of enhancing the growth, yield, and oil productivity of plants grown in similar conditions.

Keywords: French basil; Biofertilization; Selenium; Salinity affected soil.

1. Introduction

Sweet basil (*Ocimum basilicum* L.), is a member of Lamiaceae family. It originated in India and other Asian countries. Also, it is now grown throughout the world. Traditionally, basil has been used as a medicinal herb to treat a wide range of diseases, including kidney malfunction, warts, worms, constipation, diarrhea, and headaches (Kaurinovic et al. 2011). Basil is one of the most common aromatic plants that can be used as an alternative crop because of its importance in several fields including nutrition, economics, medicine, and industries (Simon et al. 1990; Carovic-Stanko et al. 2010; Alhasan et al. 2020). Dry leaves, flowers, and essential oils are the main products of this plant (Makri and Kintzios, 2007). The volatile oil of basil is highly valuable for food and pharmaceutical purposes. Basil essential oils have been shown in numerous studies to possess anti-inflammatory, antimicrobial, and antioxidant properties in addition to repellent, insecticidal, larvicidal, and nematicidal activities (Saggiorato et al. 2012;

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Avetisyan et al. 2017; Kavoosi and Amirghofran, 2017).

Salinity is one of the most significant issues with farming on newly reclaimed land. It's considered one of the most significant environmental stresses that negatively impacts plant growth and development and reduces yield and quality. However, numerous negative effects of salinity stress on plants include reduced productivity and changes in morphological, physiological, biochemical, molecular, and agronomic traits. Reduced nutrients, hormonal imbalances, an increase in reactive oxygen species (ROS), and the toxicity of ionic and osmotic stress all contribute to a reduction in plant growth under salinity stress (Kumar et al. 2020).

Recently, the trend toward using biofertilizers as important tools in sustainable agriculture has increased due to advancements in beneficial microorganisms. Biofertilizers are beneficial to plant growth in several ways. It can regulate soil texture and stimulate soil biology. Additionally, they are comparatively less costly than commercial chemical fertilizers. Also, do not contain harmful substances so can't harm the ecological system. Biofertilizers enhance phytohormone production and plant growth, which raises plant yield and quality. Moreover, the application of biofertilizers increases salinity tolerance thus it is widely preferred around the world (Dodd and Pérez-Alfocea, 2012).

Arbuscular mycorrhizal fungi (AMF) and a group of bacteria known as plant growth-promoting rhizobacteria (PGPR) are among the microorganisms that have been used as biofertilizers; they have been identified for potential applications in horticulture and agriculture (Lucy et al. 2004). In mycorrhizal relationships, plants provide the fungi with carbohydrates, and the fungi enhance plant nutrition by increasing nutrient absorption and translocation (Linderman, 1992). However, there are many different ways that PGPR promotes plant growth, and frequently a combination of mechanisms is responsible for the beneficial effect. The process of fixing nitrogen, phosphorus solubilization in the rhizosphere, and phytohormone synthesis all directly promote plant growth (Bashan et al. 2004).

Mineral plant nutrition is one of the most important variables affecting plant metabolism and the concentration of secondary metabolites. Selenium (Se) is a trace mineral that is necessary for plants, humans, and animals. It is a critical microelement that plays a role in plants' antioxidative system (Ekelund and Danilov, 2001). Also, selenium inhibits oxidative stress by preventing lipid peroxidation which leads to protecting plants from various abiotic stresses (Djanaguiraman et al. 2005). It can delay senescence, increase plant tolerance to oxidative stress, and improve the growth and development of plants, as well as increase the antioxidant capacity of stressed plants (Xue et al. 2001; Pennanen et al. 2002; Peng et al. 2002). Plant selenium accumulation varies based on species of plant and it can be influenced by many factors such as soil properties, soil selenium content, and chemical form (Zhu et al. 2009).

The purpose of this study is to investigate the effects of inoculation application with *arbuscular mycorrhizal* fungi (AMF), *Azospirillum brasilense* bacteria (AZSB), and *Azotobacter chrococcum* bacteria (AZBB), and selenium spraying treatments as well as their interaction on growth, herb yield, oil production of French basil (*Ocimum basilicum* L.) gown in salinity affected soil.

Materials and methods

This field experiment was conducted during the 2021 and 2022 seasons, on French sweet basil plants (*Ocimum basilicum*, L.) grown in salinity-affected soil in sandy new reclamation land located at Sanur Village, Biba District, Beni-Suef Governorate, Egypt. The data of some physic-chemical analyses of soil and water samples are shown in Table (1).

Table 1. Soil and irrigation water analysis

Soil sample analysis		Irrigation water analysis	
Contents	Values	Contents	Values
Sand %	90.1	E.C (dS/m)	1. 6
Silt %	7.8	Hardness	18.8
Clay %	2.1	pH	7.52
Texture	Sandy	Ca (mg/L)	42.8
EC (dS/m)	3.84	Mg (mg/L)	20.9
Organic matter %	0.37	K (mg/L)	3.19
pH (1 : 2.5 extract)	8.62	Na (mg/L)	70.2
Active lime ($CaCO_3$ %)	8.90	Sum of Cations (mg/L)	8.49
Total N %	0.09	Alkalinity (mg/L)	172
Available P (ppm)	1.89	Chlorides (mg/L)	123
Available Ca (meq/100g)	20.9	Nitrate (mg/L)	11.0
Available Mg (meq/100g)	2.13	Sulphates (mg/L)	43.9
Available K (meq/100g)	0.47	Sum of anions (mg/L)	8.62

Plant materials and experimental design

Seeds of French sweet basil plants, obtained from the Medicinal and Aromatic Plants Department, Sides Research Station, Beni-suef Governorate. The seeds were sown on 1st March, 2021 and 2022 in the first and second seasons, respectively in wooden boxes filled with a mixture of sand and plant compost (1:1). After 45 days from sowing the seedlings were transplanted in the experimental area on 15th April. In both seasons, plants were harvested on 1st July and 15th September for the first and second cut, respectively.

The current study was arranged in a randomized complete block design (RCBD), in the form of split plots design with three replicates (Snedecor and Cochran, 1990). The main plots were bio-fertilizers, whereas selenium spraying rates were the subplots. The field experiment is on one side of the row. The experimental plot was 3.60 × 3.0 meters, with 5 rows at a distance of 60 cm between rows. The planting distance was 30 cm between hills, two plants per hill (16 plants/ row, 80 plants/ plot and 30,000 plants /fed., feddan here equal 4050 m^2).

Microorganism strains

The *arbuscular mycorrhizal* fungi (AMF), *Azospirillum brasilense* bacteria (AZSB), *Azotobacter chrococcum* bacteria (AZBB) were used in this experiment. *Azospirillum*, *Azotobacter* bacteria, and *Mycorrhiza* fungi were isolated and propagated at the Laboratory of Microbiology, Minia University, Egypt. As stated by (Shehata et al. 2019) with slight modification. *Azospirillum* and *Azotobacter* bacteria were successively grown on a liquid medium at 30 °C and 120 rpm. The culture was inoculated to the soil, two times yearly at a rate of 20 ml per plant, each ml containing 108 cells of Azospirillum or *Azotobacter* bacteria. While *Arbuscular mycorrhiza* fungi spores were successively developed on onion plants roots. So, at the end of plant's growth cycle, the onion soil is added to the farm to 20 g/plant. Each gram contained 108 spores. The three examined bio-fertilizers were mixed with ½ kg of plant compost, and then, it was added to the plants as a soil application. The first dose was added to the soil during soil preparation for culture, and the second one at 15 days after transplanting the basil plant.

Treatments

The three biomicroorganisms (AMF, AZSB, and AZBB) were added as described previously. Selenium concentrations (0, 25, 50, and 100 ppm) were prepared from sodium selenite (Na_2SeO_3). The selenium treatments were sprayed on the herb three times, the first time two weeks after transplanting and the other two times at 15-day intervals in the two seasons. On the other hand, water spraying was applied to untreated plants and used as a control. The routine agricultural procedures were followed as advised.

Estimated data

Vegetative growth Characteristics and yield

Before cutting the basil herb (first and second cuts), during the two seasons, plant height (cm), and number of branches per plant were recorded. After the harvest, the weight of fresh herbs of each plant individually was recorded and the yield of herb fresh weight per feddan was calculated. The herbs were washed and air dried, so, it was dried in the oven at 70 °C until constant weight. Then, the dry weight of each herb was recorded and the yield of herb dry weight per feddan was calculated.

Leaf pigment content determination

The content of leaf pigments was determined in fresh adult leaf samples that were extracted with 80% acetone and measured colorimetrically (UV OPTIZEN POP, Korea) as per the method described by Metzner et al. (1965). In both seasons, the contents of chlorophylls and carotenoids were only measured in the second cut and expressed as mg/g fresh weight of leaves.

Leaf minerals content determination

As stated by A.O.A.C. (1990) and Martin-Préval et al. (1984), the chemical analysis was performed on dried leaf samples obtained from the various treatments to determine the percentage of nitrogen, phosphorus, potassium, and magnesium. The contents of leaf minerals were only determined in the second cut.

Volatile oil Determination

According to Erich (1982), dried herb samples were precisely weighed and then hydrodistilated for three hours with sterile water using a Clevenger- type apparatus. The percentage of oils calculated and then the oil content per plant and yield of volatile oil per feddan were calculated.

Statistical Analysis

The obtained data were statistically analyzed by using Statistic version 8.1 software (Analytical Software, 2005). The Least Significant Difference (L.S.D. at 0.05) test was used to determine differences among means.

Results

Vegetative Growth Characteristics

The impact of fertilizing with bio-fertilizers, spraying with selenium, and their interactions on some vegetative growth characteristics of sweet basil, including plant height, and branch number per plant for both cuts during the two seasons were shown in Table 2. In terms of the impact of biofertilizers, the results clearly showed that inoculated sweet basil with the three micro-organisms significantly enhanced all growth parameters, rather than control treatment. It is worth mentioning that the plants inoculated with AMF present higher growth parameters than those inoculated with AZSB or AZBB. However, there were no significant variations between the two AZSB and AZBB micro-organisms during the two experimental seasons.

Selenium spraying also had a benefit effect on all vegetative growth parameters, in this concern it is also clear that increasing the concentration used from selenium was accosted with significant improvement in all vegetative growth parameters as compared with untreated plants except the case of branches number per plant in two cuts during both seasons, whereas non-significant differences were observed between the lowest concentration 25 ppm and the control. Also, it was noticed that the two highest concentrations (50 and 100 ppm) were not statistically different for all vegetative growth parameters during the two seasons, except the case of plant height in the second season of first cut which was significant.

Table 2. Effect of bio-fertilizers inoculation and selenium spraying on plant height and branches a number of sweet basil plants during 2021 and 2022 seasons

Plant height (cm) first cut

	First season					Second season				
Treatments	without	AMF	AZSB	AZBB	Mean B	without	AMF	AZSB	AZBB	Mean B
0 ppm Se	34.34	43.11	40.32	39.80	39.39	35.91	46.22	43.12	40.52	41.44
25 ppm Se	37.12	48.23	43.81	42.32	42.87	39.34	49.11	45.21	43.24	44.23
50 ppm Se	42.89	54.31	48.22	46.13	47.89	45.32	56.20	51.40	48.29	50.30
100 ppm Se	44.11	56.00	50.11	46.35	49.14	46.21	58.93	53.87	49.91	52.23
Mean A	39.62	50.41	45.62	43.65		41.70	52.62	48.40	45.49	
LSD at 5%	A= 2.0 ; B= 1.7 ; AB= 3.4					A= 2.5 ; B= 1.9 ; AB= 3.8				

Plant height (cm) second cut

	First season					Second season				
Treatments	without	AMF	AZSB	AZBB	Mean B	without	AMF	AZSB	AZBB	Mean B
0 ppm Se	37.68	45.86	44.12	42.62	42.57	38.56	47.97	46.45	43.57	44.14
25 ppm Se	39.58	51.89	47.60	45.90	46.24	41.77	55.75	49.69	48.12	48.83
50 ppm Se	46.81	58.52	54.50	53.29	53.28	49.91	63.82	56.65	55.17	56.39
100 ppm Se	48.25	60.12	55.60	55.11	54.77	51.78	65.13	57.98	56.23	57.78
Mean A	43.08	54.10	50.46	49.23		45.51	58.17	52.69	50.77	
LSD at 5%	A= 1.7 ; B= 2.0 ; AB= 4.0					A= 2.1 ; B= 1.8 ; AB= 3.7				

Number of branches/ plant first cut

	First season					Second season				
Treatments	without	AMF	AZSB	AZBB	Mean B	without	AMF	AZSB	AZBB	Mean B
0 ppm Se	9.80	12.90	11.70	11.00	11.35	10.20	13.20	12.50	12.00	11.98
25 ppm Se	11.20	14.00	13.00	12.90	12.78	11.80	14.30	13.80	13.10	13.25
50 ppm Se	13.20	16.30	15.67	14.50	14.92	13.70	16.77	15.67	14.80	15.24
100 ppm Se	14.60	17.90	15.80	15.33	15.91	14.30	18.00	16.00	15.33	15.91
Mean A	12.20	15.28	14.04	13.43		12.50	15.57	14.49	13.81	
LSD at 5%	A= 1.1 ; B= 1.2 ; AB= 2.4					A= 0.9 ; B= 1.1 ; AB= 2.3				

Number of branches / plant second cut

	First season					Second season				
Treatments	without	AMF	AZSB	AZBB	Mean B	without	AMF	AZSB	AZBB	Mean B
0 ppm Se	11.67	14.80	13.90	13.70	13.52	13.20	15.33	14.70	14.50	14.43
25 ppm Se	13.60	16.33	15.00	14.90	14.96	14.40	17.00	16.50	16.00	15.98
50 ppm Se	14.50	19.70	17.67	16.50	17.09	14.90	19.85	17.80	17.20	17.44
100 ppm Se	14.90	20.33	18.00	17.60	17.71	15.20	20.66	18.50	18.00	18.09
Mean A	13.67	17.79	16.14	15.68		14.43	18.21	16.88	16.43	
LSD at 5%	A= 1.1 ; B= 1.0 ; AB= 2.0					A= 1.2 ; B= 0.9 ; AB= 1.9				

Se, selenium; AMF, *arbuscular mycorrhizal* fungi; AZSB, *Azospirillum brasilense* bacteria; AZBB, *Azotobacter chrococcum* bacteria

Table 3. Effect of bio-fertilizers inoculation and selenium spraying on herb fresh weight and herb dry weight (g) per plant of sweet basil plants during 2021 and 2022 seasons

Herb fresh weight (g)/ plant first cut

	First season					Second season				
Treatments	without	AMF	AZSB	AZBB	Mean B	without	AMF	AZSB	AZBB	Mean B
0 ppm Se	152.10	194.20	184.60	181.70	178.15	153.80	200.30	188.50	188.90	182.88
25 ppm Se	161.30	203.70	195.80	193.90	188.68	165.50	212.40	201.70	198.60	194.55
50 ppm Se	179.60	217.30	207.40	205.60	202.48	184.70	221.60	215.80	210.70	208.20
100ppm Se	183.37	220.10	209.70	208.90	205.52	189.90	224.40	218.10	212.80	211.30
Mean A	169.09	208.83	199.38	197.53		173.48	214.68	206.03	202.75	
LSD at 5%	A= 3.2 ; B= 3.6 ; AB= 7.2					A= 3.5 ; B= 3.4 ; AB= 6.8				

Herb fresh weight (g)/ plant second cut

	First season					Second season				
Treatments	without	AMF	AZSB	AZBB	Mean B	without	AMF	AZSB	AZBB	Mean B
0 ppm Se	167.71	225.50	210.42	204.78	202.10	171.82	228.53	219.80	215.90	
25 ppm Se	178.82	237.84	221.21	213.66	212.88	187.12	242.82	227.32	223.81	220.27
50 ppm Se	197.21	252.75	231.56	229.78	227.83	200.37	261.66	238.69	236.89	234.40
100ppm Se	201.42	255.63	233.11	232.18	230.59	205.56	262.11	241.32	238.67	236.92
Mean A	186.29	242.93	224.08	220.10		191.22	248.78	231.78	228.82	
LSD at 5%	A= 4.1 ; B= 2.9 ; AB= 5.9					A= 3.2 ; B= 2.7 ; AB= 5.5				

Herb dry weight (g)/ plant first cut

	First season					Second season				
Treatments	without	AMF	AZSB	AZBB	Mean B	without	AMF	AZSB	AZBB	Mean B
0 ppm Se	43.33	54.11	51.52	51.31	50.07	43.88	55.09	52.41	52.11	50.87
25 ppm Se	45.12	56.32	54.6	52.9	52.24	45.74	57.12	53.2	53.12	52.30
50 ppm Se	46.87	58.82	56.9	56.2	54.70	47.23	59.2	57.2	56.7	55.08
100ppm Se	47.89	59.1	57	56.9	55.22	48.54	59.72	57.61	57.13	55.75
Mean A	45.80	57.09	55.01	54.33		46.35	57.78	55.11	54.77	
LSD at 5%	A= 1.0 ; B= 1.1 ; AB= 2.4					A= 0.9 ; B= 1.0 ; AB= 2.1				

Herb dry weight (g)/ plant second cut

	First season					Second season				
Treatments	without	AMF	AZSB	AZBB	Mean B	without	AMF	AZSB	AZBB	Mean B
0 ppm Se	45.23	62.2	61.91	61.11	57.61	45.91	63.17	62.04	61.76	58.22
25 ppm Se	47.11	63.71	62.34	61.55	58.68	47.96	64.08	62.94	62.13	59.28
50 ppm Se	48.87	65.22	63.97	63	60.27	49.24	65.88	64.27	63.47	60.72
100ppm Se	49.04	65.67	64.35	64.2	60.82	49.67	65.97	65.19	64.12	61.24
Mean A	47.56	64.20	63.14	62.47		48.20	64.78	63.61	62.87	
LSD at 5%	A= 1.3 ; B= 0.8 ; AB= 1.6					A= 1.1 ; B= 0.9 ; AB= 1.9				

Se, selenium; AMF, arbuscular mycorrhizal fungi; AZSB, Azospirillum brasilense bacteria; AZBB, Azotobacter chrococcum bacteria

Table 4. Effect of bio-fertilizers inoculation and selenium spraying on yield of fresh and dry herb (ton per feddan) of sweet basil plants during 2021 and 2022 seasons

Herb fresh yield (ton/fed.) first cut

	First season					Second season				
Treatments	without	AMF	AZSB	AZBB	Mean B	without	AMF	AZSB	AZBB	Mean B
0 ppm Se	4.56	5.83	5.54	5.45	5.34	4.61	6.01	5.66	5.67	5.49
25 ppm Se	4.84	6.11	5.87	5.82	5.66	4.97	6.37	6.05	5.96	5.84
50 ppm Se	5.39	6.52	6.22	6.17	6.07	5.54	6.65	6.47	6.32	6.25
100 ppm Se	5.50	6.60	6.29	6.27	6.17	5.70	6.73	6.54	6.38	6.34
Mean A	5.07	6.26	5.98	5.93		5.20	6.44	6.18	6.08	
LSD at 5%	A= 0.26 ; B= 0.19 ; AB= 0.39					A= 0.25 ; B= 0.22 ; AB= 0.40				

Herb fresh yield (ton/fed.) second cut

	First season					Second season				
Treatments	without	AMF	AZSB	AZBB	Mean B	without	AMF	AZSB	AZBB	Mean B
0 ppm Se	5.03	6.77	6.37	6.02	6.05	5.15	6.86	6.59	6.48	6.27
25 ppm Se	5.36	7.14	6.66	6.35	6.38	5.61	7.28	6.82	6.68	6.60
50 ppm Se	5.86	7.57	7.22	6.89	6.89	6.01	7.85	7.49	7.14	7.12
100 ppm Se	6.04	7.67	7.32	6.97	7.00	6.32	7.95	7.51	7.30	7.27
Mean A	5.57	7.29	6.89	6.56		5.77	7.49	7.10	6.90	
LSD at 5%	A= 0.34 ; B= 0.31 ; AB= 0.62					A= 0.36 ; B= 0.32 ; AB= 0.64				

Herb dry yield (ton/fed.) first cut

	First season					Second season				
Treatments	without	AMF	AZSB	AZBB	Mean B	without	AMF	AZSB	AZBB	Mean B
0 ppm Se	1.30	1.62	1.55	1.54	1.50	1.32	1.65	1.57	1.56	1.53
25 ppm Se	1.35	1.69	1.64	1.59	1.57	1.37	1.71	1.60	1.59	1.57
50 ppm Se	1.41	1.76	1.71	1.69	1.64	1.42	1.78	1.72	1.70	1.65
100 ppm Se	1.44	1.77	1.71	1.71	1.66	1.46	1.79	1.73	1.71	1.67
Mean A	1.37	1.71	1.65	1.63		1.39	1.73	1.65	1.64	
LSD at 5%	A= 0.05 ; B= 0.06 ; AB= 0.12					A= 0.07 ; B= 0.04 ; AB= 0.08				

Herb dry yield (ton/fed.) second cut

	First season					Second season				
Treatments	without	AMF	AZSB	AZBB	Mean B	without	AMF	AZSB	AZBB	Mean B
0 ppm Se	1.36	1.87	1.86	1.83	1.73	1.38	1.90	1.86	1.85	1.75
25 ppm Se	1.41	1.91	1.87	1.85	1.76	1.44	1.92	1.89	1.86	1.78
50 ppm Se	1.47	1.96	1.92	1.89	1.81	1.48	1.98	1.93	1.90	1.82
100 ppm Se	1.47	1.97	1.93	1.93	1.82	1.49	1.98	1.96	1.92	1.84
Mean A	1.43	1.93	1.89	1.87		1.45	1.94	1.91	1.89	
LSD at 5%	A= 0.03 ; B= 0.04 ; AB= 0.07					A= 0.03 ; B= 0.04 ; AB= 0.09				

Se, selenium; AMF, *arbuscular mycorrhizal* fungi; AZSB, *Azospirillum brasilense* bacteria; AZBB, *Azotobacter chrococcum* bacteria

Table 5. Effect of bio-fertilizers inoculation and selenium spraying on Chlorophyll a, b, total Chlorophyll and total Carotenoids of sweet basil plants in second cut during 2021 and 2022 seasons

Chlorophyll a (mg/g F.W.)										
	First season					Second season				
Treatments	without	AMF	AZSB	AZBB	Mean B	without	AMF	AZSB	AZBB	Mean B
0 ppm Se	1.70	1.95	1.83	1.81	1.82	1.78	1.98	1.82	1.85	1.86
25 ppm Se	1.89	2.26	2.09	2.02	2.07	1.97	2.44	2.19	2.11	2.18
50 ppm Se	2.20	2.78	2.55	2.46	2.50	2.29	2.89	2.59	2.61	2.60
100 ppm Se	2.38	2.84	2.64	2.63	2.62	2.51	2.92	2.75	2.7	2.72
Mean A	2.04	2.46	2.28	2.23		2.14	2.56	2.34	2.32	
LSD at 5%	A= 0.18 ; B= 0.24 ; AB= 0.48					A= 0.17 ; B= 0.31 ; AB= 0.63				
Chlorophyll b (mg/g F.W.)										
	First season					Second season				
Treatments	without	AMF	AZSB	AZBB	Mean B	without	AMF	AZSB	AZBB	Mean B
0 ppm Se	0.40	0.55	0.50	0.49	0.485	0.45	0.57	0.52	0.51	0.513
25 ppm Se	0.55	0.69	0.57	0.56	0.593	0.58	0.73	0.60	0.60	0.628
50 ppm Se	0.68	0.87	0.79	0.78	0.780	0.70	0.94	0.84	0.83	0.828
100 ppm Se	0.70	0.91	0.83	0.80	0.810	0.73	0.96	0.86	0.85	0.850
Mean A	0.583	0.755	0.673	0.658		0.615	0.800	0.705	0.698	
LSD at 5%	A= 0.05 ; B= 0.10 ; AB= 0.29					A= 0.09 ; B= 0.13 ; AB= 0.26				
Total Chlorophyll (mg/g F.W.)										
	First season					Second season				
Treatments	without	AMF	AZSB	AZBB	Mean B	without	AMF	AZSB	AZBB	Mean B
0 ppm Se	2.10	2.50	2.33	2.30	2.31	2.23	2.55	2.34	2.36	2.37
25 ppm Se	2.44	2.95	2.66	2.58	2.66	2.55	3.17	2.79	2.71	2.81
50 ppm Se	2.88	3.65	3.34	3.24	3.28	2.99	3.83	3.43	3.44	3.42
100 ppm Se	3.08	3.75	3.47	3.43	3.43	3.24	3.88	3.61	3.55	3.57
Mean A	2.63	3.21	2.95	2.89		2.75	3.36	3.04	3.02	
LSD at 5%	A= 0.23 ; B= 0.34 ; AB= 0.68					A= 0.25 ; B= 0.41 ; AB=0.83				
Total Carotenoids (mg/g F.W.)										
	First season					Second season				
Treatments	without	AMF	AZSB	AZBB	Mean B	without	AMF	AZSB	AZBB	Mean B
0 ppm Se	0.701	0.769	0.762	0.751	0.746	0.718	0.804	0.799	0.793	0.779
25 ppm Se	0.721	0.802	0.796	0.792	0.778	0.744	0.823	0.801	0.794	0.791
50 ppm Se	0.774	0.869	0.841	0.836	0.830	0.783	0.89	0.86	0.853	0.847
100 ppm Se	0.799	0.874	0.852	0.843	0.842	0.8	0.903	0.878	0.871	0.863
Mean A	0.749	0.829	0.813	0.806		0.761	0.855	0.835	0.828	
LSD at 5%	A= 0.04 ; B= 0.05 ; AB= 0.11					A= 0.06 ; B= 0.03 ; AB= 0.07				

Se, selenium; AMF, *arbuscular mycorrhizal* fungi; AZSB, *Azospirillum brasilense* bacteria; AZBB, *Azotobacter chrococcum* bacteria

Also, the combined treatments (inoculation with micro-organisms and spraying selenium) show more effective in all vegetative growth rather than using each one alone. Furthermore, the interaction between the three micro-organisms and selenium concentrations was significant in both experimental seasons. The plants inoculated with AMF combined with selenium spraying at 100 ppm presented the greatest values of vegetative parameters in both cuts. In the first cut (56.00 and 58.93 cm) for plant height, (17.90 and 18.00 branches) for branches number per plant during the first and second seasons, respectively. In the second cut, the same pattern was noted, the greatest height of the plant (60.12 and 65.13 cm), and the maximum branches/plant (20.33 and 20.66 branches) were obtained when plants were inoculated with AMF combined with selenium spraying at 100 ppm for first and second season, respectively. Conversely, untreated plants exhibited the lowest values across all vegetative growth parameters.

Yield Characteristics

Data illustrated in Tables 3 and 4 showed the impact of biofertilizers, spraying with selenium as well as their interactions on herb fresh weight and herb dry weight (g) per plant and yield of fresh and dry herb (ton) per feddan during 2021 and 2022 seasons. Data shows that, fresh and dry herb yield per plant and per feddan taken the same line of other growth parameters. It’s clear from these tables that, micro-organisms inoculations and selenium spraying individually or in combination significantly enhanced both fresh and dry yield of herb. However, combined application of both materials was significantly higher than using each one individually. In among micro-organisms, the plants inoculated with AMF present superiority in yield of fresh and dry herb (per plant and per feddan) than those inoculated with AZSB or AZBB. Whilst, in both seasons non-significant differences were found between the two AZSB and AZBB micro-organisms.

Regarding the effect of selenium (Se) spraying on the yield of fresh and dry herbs of basil plants, a significant influence of selenium treatments on the investigated traits was observed in both seasons. The increasing of Se concentrations from 25 to 100 ppm was capable of enhancing the herb's fresh and dry yield. There were non-significant variations found between the two highest Se concentrations (50 and 100 ppm) in both two cuts during both experimental seasons. In the case of herb dry yield per feddan, it was noticed that increasing concentration of Se caused an increase in herb dry yield. However, there were no significant differences between the lowest concentrations of Se (25 ppm) and untreated plant in the second cut only during both seasons (Table 4).

The interaction between biofertilizers and selenium spraying revealed that treatments had a greater impact on fresh and dry herb yield than untreated plants. Treated basil plants with AMF and 100 ppm of Se were responsible for producing the greatest values of fresh and dry yield of herb per plant and per feddan in both cuts. In the first cut (220.10 and 224.40 g) for herb fresh weight per plant and (59.1 and 59.72 g) for herb dry weight per plant during the first and second seasons, respectively. In the second cut the same line was noted. the highest weight of fresh herb per plant (255.63 and 262.11 g), as well as the maximum weight of dry herb per plant (65.67 and 65.97 g), were obtained when plants were inoculated with AMF combined with selenium spraying at 100 ppm for first and second season, respectively. The maximum yield of fresh herb per feddan (6.60 and 7.67 ton/feddan) in the first and second cuts, respectively of the first season and (6.73 and 7.95 ton/feddan) in the first and second cuts, respectively of the second season were obtained from the same combined treatment. On the other hand, untreated plants produced the lowest yield of fresh herb (4.56 and 5.03 ton/feddan) in the first and second cuts respectively of the first season and (4.61 and 6.86 ton/feddan) in the first and second cuts, respectively of the second season. The greatest yield of dry herb per feddan (1.77 and 1.97 ton/feddan) in first and second cuts respectively of the first season and (1.79 and 1.98 ton/feddan) in first and second cuts, respectively of the second season. On the opposite side, the minimum dry herb yield (1.30 and 1.36 ton/feddan) in first and second cuts, respectively of the first season and (1.32 and 1.38 ton/feddan) in first and second cuts, respectively of the second season were obtained from untreated plants.

Leaves photosynthetic pigments

Data in Table (5) showed the effect of AMF, AZSB and AZBB inoculation as well as selenium spraying at 25, 50 and 100 ppm on leaves pigments (chlorophylls a, b, total chlorophyll and total carotenoids) of sweet basil. Data showed that inoculated sweet basil plants with the three examined micro-organisms and spraying selenium, individually or in combination, significantly improved leaves contents of chlorophylls (a, b and total chlorophylls) and carotenoids during two experimental seasons.

Concerning micro-organisms, inoculated sweet basil with the three micro-organisms significantly enhanced all examined pigments, rather than control treatment during both experimental seasons. Among three micro-organisms, plants inoculated with AMF present higher content of chlorophyll a, b, and total chlorophylls than those inoculated with AZSB or AZBB. Whilst, the two AZSB and AZBB microorganisms were not different significantly from each other. In the case of total carotenoids, no significant differences were observed between all three micro-organisms in both seasons. Regarding selenium treatments, increasing the concentration used from 0 to 100 ppm was accosted with gradual and significant promotion of chlorophyll a, b, and total chlorophylls. However, non-significant differences were found between the two higher concentrations (50 and 100 ppm). In the case of total carotenoids, it was noticed that increasing concentration of Se caused an increase in total carotenoid content. Whilst, were non-significant variations between the lowest concentrations of Se (25 ppm) and untreated plants.

Significant interactions occurred in both experimental seasons between microorganisms and selenium spraying. The plants inoculated with AMF and sprayed with selenium at 100 ppm gave the highest pigments in their leaves (2.84 and 2.92 mg/g F.W.) for chlorophyll “a”, (0.91 and 0.96 mg/g F.W.) for chlorophyll “b”, (3.75 and 3.88 mg/g F.W.) for total chlorophyll and (0.874 and 0.903 mg/g F.W.) for total carotenoids. On the opposite side, the un-inoculated plants sprayed with tap water (control) present the lowest values of pigments (1.70 and 1.78 mg/g F.W.) for chlorophyll “a”, (0.40 and 0.45 mg/g F.W.) “b”, (2.10 and 2.23 mg/g F.W.) for total chlorophyll and (0.701 and 0.718 mg/g F.W.) for total carotenoids during first and second seasons, respectively.

Leaves mineral contents

Data illustrated in Table (6) showed the influence of biofertilizers and spraying with selenium as well as their interactions on nitrogen, phosphorus, potassium, and magnesium contents in dry leaves of basil plants. The results showed that all selenium concentrations had a remarkable and significant impact on leaves mineral contents in both experimental seasons. While, the plants inoculated with AMF didn’t have any significant effect on N content during the first seasons, and those inoculated with AZSB and AZBB didn’t have any significant effect on leaves phosphors and magnesium during the first seasons. On the contrary, during the second season, inoculations with the three micro-organisms individually present higher and significant promotions on all leaf’s mineral contents. It is clear from the same table that all combined treatments (selenium + any micro-organism inoculation) showed superior effects rather than using each one individually. Moreover, the interaction between micro-organisms inoculation and selenium spraying was significant in all examined mineral elements, during the two experimental seasons. The plants inoculated with AMF and received selenium at 100 ppm present the highest mineral contents in their leaves (0.21 and 0.25% for phosphorus, (1.56 and 1.59%) for potassium and (0.78 and 0.83%) for magnesium contents. Those inoculated with AZBB and sprayed with 100 ppm selenium present the highest nitrogen contents in their leaves (1.9 and 2.1%), during the first and second seasons respectively. On the contrary, untreated plants present the lowest mineral contents in their leaves (1.4 and 1.4%) for nitrogen, (0.13 and 0.12%) for phosphorus, (1.21and 1.24%) for potassium and (0.545 and 0.55%) for magnesium contents, during first and second seasons, respectively.

Volatile Oil Content

Data presented in Table (7) showed the effect of AMF, AZSB, and AZBB inoculation or/and selenium spraying at 0.0, 25, 50, and 100 ppm on volatile oil percentage and volatile oil content per plant of sweet basil dry herb during 2021 and 2022 seasons. Data showed that the concentration of volatile oil (%) and volatile oil content per plant were higher in the second cut than those found in the first cut. Moreover, sweet basil volatile oil % and its contents per plant significantly increased as a result of inoculating the plants with the three micro-organisms, each one individually relative to the untreated plants. However, inoculated plants with AMF present superior volatile oil % and volatile oil content per plant, rather than control plants or those inoculated with ASZB or AZBB during the two experimental seasons. As well as no significant differences were found between the two AZSB and AZBB micro-organisms in both two seasons. Concerning selenium treatments, there was a remarkable and gradual increase in volatile oil % and oil per plant. These increases correlated with rising selenium concentrations. However, between the two highest concentrations of Se, there were no significant differences. All combined treatments between micro-organisms and selenium concentration were more effective in improving plant contents of volatile oil % and volatile oil per plant, rather than the individual treatments of each one alone. Concerning the connection between spraying selenium and inoculating microorganisms, increasing the concentration of selenium combined with inoculating the plants with the three micro-organisms significantly enhanced the volatile oil % and oil per plant during two experimental seasons. Furthermore, the plants inoculated with AMF and sprayed with selenium at 100 ppm present the highest volatile oil % (0.50 and 0.55%) in the first and second cuts respectively of the first season and (0.50 and 56%) in the first and second cuts respectively of the second season. On the Contrary, control plants present the minimum volatile oil percentage (0.29 and 0.32 %) in the first and second cuts respectively of the first season and (0.28 and 0.33 %) in the first and second cuts of the second season. As illustrated in Table (7), the same combination treatment (AMF and Se at 100 ppm) produced the maximum volatile oil per plant (0.30 and 0.36 ml/plant) in the first and second cuts respectively of the first season and (0.30 and 0.37 ml/plant) in first and second cuts respectively of the second season. On the opposite side, the lowest volatile oil per plant (0.13 and 0.14 ml/plant) in the first and second cuts of the first season and (0.12 and 0.15 ml/plant) in the first and second cuts respectively of the second season were obtained from untreated plants.

Yield of Volatile Oil

Data recorded in Table 8 shows the effect of biofertilizers, spraying with selenium as well as their interactions on volatile oil yield (liter per feddan) during 2021 and 2022 seasons. It was noticed that the volatile oil yield per feddan of basil plants followed the same trend that had been previously noted in the case of volatile oil per plant in response to micro-organisms inoculations and selenium spraying and their interactions.

Table 6. Effect of bio-fertilizers inoculation and spraying selenium on N%, P%, K% and Mg% in dry leaves of sweet basil plants in second cut during 2021 and 2022 seasons

N %

	First season					Second season				
Treatments	without	AMF	AZSB	AZBB	Mean B	without	AMF	AZSB	AZBB	Mean B
0 ppm	1.4	1.5	1.6	1.6	1.5	1.4	1.6	1.6	1.7	1.6
25 ppm	1.4	1.7	1.6	1.6	1.6	1.6	1.7	1.7	1.8	1.7
50 ppm	1.6	1.7	1.7	1.8	1.7	1.7	1.9	1.9	2.0	1.9
100 ppm	1.7	1.7	1.8	1.9	1.8	1.7	1.9	2.0	2.1	1.9
Mean A	1.5	1.6	1.7	1.7		1.6	1.8	1.8	1.9	
LSD at 5%	A=0.12 ; B= 0.15 ; AB= 0.3					A= 0.2 ; B= 0.2 ; AB= 0.4				

P %

	First season					Second season				
Treatments	without	AMF	AZSB	AZBB	Mean B	without	AMF	AZSB	AZBB	Mean B
0 ppm Se	0.13	0.16	0.15	0.14	0.15	0.12	0.19	0.18	0.17	0.17
25 ppm Se	0.16	0.18	0.17	0.17	0.17	0.15	0.21	0.20	0.20	0.19
50 ppm Se	0.17	0.20	0.19	0.19	0.19	0.18	0.24	0.21	0.22	0.21
100 ppm Se	0.18	0.21	0.18	0.19	0.19	0.19	0.25	0.22	0.22	0.22
Mean A	0.16	0.19	0.17	0.17		0.16	0.22	0.20	0.20	
LSD at 5%	A= 0.02 ; B= 0.02 ; AB= 0.03					A= 0.03 ; B= 0.02 ; AB= 0.04				

K %

	First season					Second season				
Treatments	without	AMF	AZSB	AZBB	Mean B	without	AMF	AZSB	AZBB	Mean B
0 ppm Se	1.21	1.31	1.28	1.29	1.27	1.24	1.39	1.24	1.25	1.28
25 ppm Se	1.29	1.43	1.33	1.39	1.36	1.33	1.48	1.37	1.39	1.39
50 ppm Se	1.32	1.49	1.39	1.40	1.40	1.40	1.55	1.46	1.47	1.47
100 ppm Se	1.35	1.56	1.41	1.42	1.43	1.41	1.59	1.46	1.47	1.48
Mean A	1.29	1.45	1.35	1.38		1.35	1.50	1.38	1.40	
LSD at 5%	A= 0.13 ; B= 0.12 ; AB= 0.18					A= 0.19 ; B= 0.20 ; AB= 0.30				

Mg %

	First season					Second season				
Treatments	without	AMF	AZSB	AZBB	Mean B	without	AMF	AZSB	AZBB	Mean B
0 ppm Se	0.54	0.68	0.59	0.58	0.59	0.55	0.66	0.58	0.58	0.59
25 ppm Se	0.57	0.71	0.62	0.60	0.63	0.59	0.79	0.66	0.66	0.68
50 ppm Se	0.61	0.77	0.71	0.68	0.69	0.62	0.81	0.72	0.70	0.71
100 ppm Se	0.63	0.78	0.71	0.69	0.70	0.65	0.83	0.74	0.73	0.74
Mean A	0.59	0.74	0.66	0.64		0.60	0.77	0.68	0.67	
LSD at 5%	A= 0.15 ; B= 0.18 ; AB= 0.26					A= 0.07 ; B= 0.11 ; AB= 0.16				

Se, selenium; AMF, *arbuscular mycorrhizal* fungi; AZSB, *Azospirillum brasilense* bacteria; AZBB, *Azotobacter chrococcum* bacteria

Table 7. Effect of bio-fertilizers inoculation and selenium spraying on volatile oil percentage and content (ml/plant) of sweet basil plants during 2021 and 2022 seasons

Volatile oil (%) First cut										
	First season					Second season				
Treatments	without	AMF	AZSB	AZBB	Mean B	without	AMF	AZSB	AZBB	Mean B
0 ppm Se	0.29	0.42	0.4	0.4	0.38	0.28	0.43	0.41	0.4	0.38
25 ppm Se	0.32	0.45	0.44	0.43	0.41	0.33	0.45	0.44	0.44	0.42
50 ppm Se	0.36	0.49	0.47	0.46	0.45	0.37	0.49	0.48	0.47	0.45
100 ppm Se	0.38	0.5	0.48	0.47	0.46	0.38	0.5	0.49	0.48	0.46
Mean A	0.34	0.47	0.45	0.44		0.34	0.47	0.46	0.45	
LSD at 5%	A= 0.021 ; B= 0.020 ; AB= 0.041					A= 0.01 ; B= 0.02 ; AB= 0.04				
Volatile oil (%) Second cut										
	First season					Second season				
Treatments	without	AMF	AZSB	AZBB	Mean B	without	AMF	AZSB	AZBB	Mean B
0 ppm Se	0.32	0.5	0.46	0.45	0.43	0.33	0.51	0.47	0.46	0.44
25 ppm Se	0.34	0.51	0.5	0.48	0.46	0.35	0.52	0.5	0.48	0.46
50 ppm Se	0.38	0.54	0.52	0.51	0.49	0.39	0.55	0.53	0.5	0.49
100 ppm Se	0.4	0.55	0.53	0.52	0.50	0.4	0.56	0.54	0.53	0.51
Mean A	0.36	0.53	0.50	0.49		0.37	0.54	0.51	0.49	
LSD at 5%	A= 0.019 ; B= 0.020 ; AB= 0.040					A= 0.015 ; B= 0.016 ; AB= 0.032				
Volatile oil content (ml/plant) First cut										
	First season					Second season				
Treatments	without	AMF	AZSB	AZBB	Mean B	without	AMF	AZSB	AZBB	Mean B
0 ppm Se	0.13	0.23	0.21	0.21	0.19	0.12	0.24	0.21	0.21	0.20
25 ppm Se	0.14	0.25	0.24	0.23	0.22	0.15	0.26	0.23	0.23	0.22
50 ppm Se	0.17	0.29	0.27	0.26	0.25	0.17	0.29	0.27	0.27	0.25
100 ppm Se	0.18	0.30	0.27	0.27	0.25	0.18	0.30	0.28	0.27	0.26
Mean A	0.16	0.27	0.25	0.24		0.16	0.27	0.25	0.25	
LSD at 5%	A= 0.02 ; B= 0.017 ; AB= 0.034					A= 0.13 ; B= 0.019 ; AB= 0.038				
Volatile oil content (ml/plant) Second cut										
	First season					Second season				
Treatments	without	AMF	AZSB	AZBB	Mean B	without	AMF	AZSB	AZBB	Mean B
0 ppm Se	0.14	0.31	0.28	0.27	0.25	0.15	0.32	0.29	0.28	0.26
25 ppm Se	0.16	0.32	0.31	0.30	0.27	0.17	0.33	0.31	0.30	0.28
50 ppm Se	0.19	0.35	0.33	0.32	0.30	0.19	0.36	0.34	0.32	0.30
100 ppm Se	0.20	0.36	0.34	0.33	0.31	0.20	0.37	0.35	0.34	0.31
Mean A	0.17	0.34	0.32	0.31		0.18	0.35	0.32	0.31	
LSD at 5%	A= 0.02 ; B= 0.02 ; AB= 0.041					A= 0.013 ; B= 0.019 ; AB= 0.038				

Se, selenium; AMF, *arbuscular mycorrhizal* fungi; AZSB, *Azospirillum brasilense* bacteria; AZBB, *Azotobacter chrococcum* bacteria

Table 8. Effect of bio-fertilizers inoculation and selenium spraying on volatile oil yield per feddan of sweet basil plants during 2021 and 2022 seasons.

Oil yield/feddan (liter) first cut										
	First season					Second season				
Treatments	without	AMF	AZSB	AZBB	Mean B	without	AMF	AZSB	AZBB	Mean B
0 ppm Se	3.77	6.82	6.18	6.16	5.73	3.69	7.11	6.45	6.25	5.87
25 ppm Se	4.33	7.60	7.21	6.82	6.49	4.53	7.71	7.02	7.01	6.57
50 ppm Se	5.06	8.65	8.02	7.76	7.37	5.24	8.70	8.24	7.99	7.54
100 ppm Se	5.46	8.87	8.21	8.02	7.64	5.53	8.96	8.47	8.23	7.80
Mean A	4.66	7.98	7.41	7.19		4.75c	8.12a	7.54b	7.37b	
LSD at 5%	A= 0.51 ; B= 0.42 ; AB= 0.85					A= 0.56 ; B= 0.49 ; AB= 0.98				
Oil yield/feddan (liter) second cut										
	First season					Second season				
Treatments	without	AMF	AZSB	AZBB	Mean B	without	AMF	AZSB	AZBB	Mean B
0 ppm Se	4.34	9.33	8.54	8.25	7.62	4.55	9.67	8.75	8.52	7.87
25 ppm Se	4.81	9.75	9.35	8.86	8.19	5.04	10.00	9.44	8.95	8.36
50 ppm Se	5.57	10.57	9.98	9.64	8.94	5.76	10.87	10.22	9.52	9.09
100 ppm Se	5.88	10.84	10.23	10.02	9.24	5.96	11.08	10.56	10.20	9.45
Mean A	5.15	10.12	9.53	9.19		5.33	10.40	9.74	9.30	
LSD at 5%	A= 0.49 ; B= 0.35 ; AB= 0.71					A= 0.76 ; B= 0.48 ; AB= 0.96				

Se, selenium; AMF, *arbuscular mycorrhizal* fungi; AZSB, *Azospirillum brasilense* bacteria; AZBB, *Azotobacter chrococcum* bacteria

Data clearly shows that the yield of volatile oil was higher in the second cut than in the of first cut. Concerning bio fertilizers treatments, the yield of volatile oil per feddan significantly increased as a result of inoculating the plants with the three micro-organisms, each one individually as relative to the control. The greatest yield of volatile oil was obtained from plants inoculated with AMF which present superior volatile oil yield rather than control plants or those inoculated with ASZB or AZBB during two seasons. Meanwhile, non-significant variations were recorded between the two AZSB and AZBB micro-organisms in both seasons.

Results, concerning the effect of selenium spraying on the volatile oil yield of basil plants, our finding noted a significant influence of selenium treatments on the yield of volatile oil in both seasons. Increasing Se concentrations from 25 to 100 ppm was capable of increasing volatile yield. However, non-significant variations were observed between the two highest concentrations of Se in both two cuts during both seasons.

The interaction between bio-fertilizers inoculation and selenium spraying revealed that treated plants had a significantly higher volatile oil yield/feddan than untreated plants. Yield of volatile oil increased with increasing the concentration of selenium combined with inoculation the plants with the three micro-organisms during two seasons. The highest yield of volatile oil was recorded in treated plants with AMF combined with selenium spraying at 100 ppm. It produced (8.87 and 10.84 liter/ feddan) in the first and second cuts of the first season and (8.96 and 11.08 liter/ feddan) in the first and second cuts of the second season.

Discussion

The obtained results demonstrated the favorable influence of biofertilizers and selenium treatments on basil plant grown in salinity-affected soil. Inoculated basil plants with the three micro-organisms (AMF, AZSB and AZBB) decreased the salt effect and enhanced all vegetative growth parameters as compared with untreated plants. Also mycorrhiza application had a greater effect than that of bacteria applications. This promotion may result from PGPR and fungal biofertilizers increasing the rate of photosynthesis. Mycorrhiza can assist plants by boosting photosynthesis, promoting growth-regulating substances, and enhancing osmotic adjustment to salinity and drought stress (Al-Karaki, 2006). PGPR and mycorrhizal fungi are known for their relatively common trait of cytokinin hormone productivity (Dodd et al. 2010), which decreases salt stress and can play a role in stomatal opening and photosynthesis.

Moreover, beneficial microorganisms involved in the biosynthetic pathway of plant metabolism have closely correlated with plant development. They have multiple secondary roles in plant growth and survival (Singh et al. 2021). Furthermore, the photosynthetic pigmentation of the leaves (carotenoids and chlorophyll), antioxidant potential, root volume, and increased nutrient uptake efficiency due to proper use of endophytic fungi and rhizobacteria are indicative in the physiology and biochemistry of inoculated crops in various ecosystems (Malik et al. 2021). These finding are consistent with those issued by (Abdel-Rahman et al. 2011; Khalediyan et al. 2021) on basil, and (Abdollahi-Arpanahi et al. 2020) on Thyme.

Regarding Chlorophyll concentration, biofertilizer treatments increased the chlorophyll content in the leaves of basil. This might be because of the mechanisms by which certain types of bacteria and fungi interact with plant biochemical pathways to produce large amounts of secondary metabolites during the elicitation process. This also improves the crop's quality in terms of growth, flavor, aroma, and color (Aguirre-Becerra et al. 2021). The advantageous effects of AMF when combined with PGPR because of the direct or indirect processes by which microbes create metabolites, antibiotics, phytohormones, and organic compounds that promote plant growth and nutrient uptake (Chiquito-Contreras et al. 2018; Anguiano-Cabello et al. 2019). Similarly, mycorrhizal fungi boost mineral uptake and protect plants from abiotic stresses that modify photosynthetic products (Emmanuel and Babalola, 2020; Suchitra et al. 2020). Our results were in harmony with Bordoloi and Shukla (2020), who found that the chlorophyll content in Piper plants differed considerably among isolates of arbuscular mycorrhizal fungi and there was a greater trend in mycorrhizal treatments than that of non-inoculated ones.

Treatment plants with AMF and PGPR enhance the contents of nutrient elements such as N, P, K and Mg in leaves as relative to untreated plants. According to Delgado-Ospina et al. (2012), macronutrients uptake can be affected by microorganisms. This result is in line with Bordoloi and Shukla (2020), who reported that microorganisms play a role in the availability and uptake of nutrients by plants.

Our experiment showed that inoculated basil plants with AMF and PGPR increased the quantity of in dry herbs. These results could be explained by increased P availability for inoculated plants and enhanced soil microbial activity (Sailo and Bagyaraj, 2005; Weisany et al. 2015), which is in agreement with the findings of this study. The contents of secondary metabolites may directly increase in response to P concentration (Abu-Zeyad et al. 1999). The availability of nutrients, particularly P and N, which are important for the synthesis of essential oils, may have an impact on the quality and quantity of the oil (Abdel Wahab et al. 2016). Furthermore, the inoculated plants' leaves exhibited an increase in the number of peltate glandular trichomes (primary sites for EO accumulation and synthesis). This increase in trichome count was attributed to modifications in phytohormones which caused by AMF (Copetta et al. 2006). In general, the improvement in plant growth, photosynthetic pigments, and general plant metabolism may be responsible for increasing productivity of volatile oil.

Treating basil with selenium as foliar application caused a positive effect on vegetative growth parameters. This promotion may result from the rise in accumulation of starch in chloroplasts, increasing in the permeability and activity of the cellular membrane, as well as enhancing tolerance and antioxidant capacity of plants (Xue et al. 2001; Djanaguiraman et al. 2005; Fernandez et al. 2013) which in turn enhances growth and development of plant.

The results obtained revealed that fresh and dry herb yield per plant was positively impacted by Se treatments that were applied, increasing fresh and dry herb yield per feddan. These improvements were probably due to enhance the capacity of the root system to absorb nutrients, which would then promote cell division and raise plant yield. Moreover, selenium applications might boost flowering stages and physiological growth indices, which would impact yield. (Teimouri et al. 2014). Moreover, selenium is able to increase the plant's antioxidant defense system (Hasanuzzaman and Fujita, 2011). In several horticultural species, it has been shown to retard fruit ripening and plant senescence (Hartikainen et al. 2000; Zhu et al. 2016; Zhu et al. 2017), this might reduce post-harvest loss. The same results were previously reported by (Hawrylak et al. 2010) on cucumber, (Hajiboland et al. 2015; Dawood et al. 2020) on wheat and (Tufail, et al. 2023) on lettuce.

Concerning chlorophyll contents, our finding results noted that Se spraying increased pigments contents in fresh leaves. The explanation for the increase in pigments is that selenium may benefit leaf pigments by raising antioxidant capability and delaying the aging process of leaf tissues (Germ et al. 2005). Moreover, the protective effect of selenium on chloroplast enzymes may contribute to the rise in chlorophyll contents of basil leaves. which result in a rise in photosynthetic pigment biosynthesis (Pennanen et al. 2002). As well as, this increase might be as a result of an increase in carotenoids, which protect chlorophyll from photooxidative degradation. (Singh, 1996). This conclusion agrees with the findings of Ibrahim et al. (2023) on basil, Dawood et al. (2020) on wheat and Tufail et al. (2023) on lettuce.

Regarding volatile oil, Se application increased the volatile oil content and oil productivity of basil plant. This might be connected to the increase in plant growth occurred by Se treatments. Selenium has a positive impact on oil production because it is an essential element for many metabolic pathways and acts as an antioxidant in the different redox reactions involved in the synthesis of primary and secondary plant biomolecules, including essential oils productivity (Khalid, 2011). Similar outcomes were observed by (Lee et al. 2001; Skrypnik et al. 2019; Ibrahim et al. 2023), they reported that Se successfully increased essential oils production of basil.

Conclusion

Findings indicated that inoculated basil plants with the three micro-organisms or/and spraying selenium at different concentrations significantly enhanced all vegetative growth parameters, herb fresh and dry yield, leaf photosynthetic pigments, mineral composition of leaf, essential oil percentage and yield. The companied application of micro-organisms and selenium application was superior than using each one individually. The highest values of the investigated parameters were found in plants that were inoculated with AMF and sprayed with selenium at 50 ppm or 100 ppm. Whereas there were not significant variations between the two higher selenium concentrations. In order to boost growth, yield of herb and essential oil production of French basil grown in salinity affected soil in sandy new reclamation land or resembling conditions, it is strongly recommended to inoculate the plants with AMF and spraying selenium at 50 ppm in form of sodium selenite.

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The authors disclosed no conflict of interest.

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