Journal of Medicinal Plants Studies
www.PlantsJournal.com

ISSN (E): 2320-3862
ISSN (P): 2394-0530
www.plantsjournal.com
JMPS 2024; 12(4): 244-247

Received: 02-04-2024
Accepted: 03-05-2024

Mahan Amani
Bachelor, Department of Microbiology. Islamic Azad University, Arak, Iran

Mahdi Boshagh
Bachelor, Department of Microbiology Islamic Azad University, Arak, Iran

Gholamreza Naderi
Department of Agricultural Thia b Natural Resources, Islamic Aza d University. Arak, Iran

Corresponding Author:
Mahan Amani
Bachelor, Department of Microbiology Islamic Azad University, Arak, Iran

Effects of biofertilizers on growth, yield and essential oils percentage of *Satureja hortensis*

Mahan Amani, Mahdi Boshagh and Gholamreza Naderi

DOI: https://doi.org/10.22271/plants.2024.v12.i4c.1712

Abstract
Summer savory It is an annual herbaceous plant belonging to the Lamiaceae family. The aerial parts of some Satureja plants are widely used in herbal teas and food products, as well as in folk and traditional medicine to treat a variety of ailments including cramps, muscle pain, pressure, digestion, diarrhea and infectious diseases. This study was conducted for evaluation purposes cultivation of summer savory as A medicinal and aromatic plant from Iran to find out. The effect of biofertilizers on biological plants and essential oil yield. This study is done randomly block (CRB) with 4 We treat and reproduce. The bio-fertilizers (Nitroxen, Barvar2 & mixture of them) were compared with the control treatment. complex Variance analysis different traits showed, the effect of different treatments of fertilizers on Root length, plant height, number of branches, leaf dry weight per plant, shoot dry and wet weight ratio, shoot dry weight per plant, essential oil percent and biomass yield, essential oil yield, seed yield per hectare and leaf area index were significant at 1% level. The use of Barvar2, Nitroxen, and the mixture of them increased essential oil yield up to 26.1, 21.1 and (30.1^9g/m^2) respectively compared to control (16.9 g/m^2).

Keywords: *Satureja hortensis* L., bio-fertilizers, yield and essence

Introduction
Satureja hortensis L. is an aromatic and herbaceous perennial plant of the Lamiaceae family. Known as a summer delicacy, this dessert is native to Southern Europe and has been naturalized in North America (Sefidkon *et al.*, 2006) [11]. This plant has been traditionally used in Iran as a carminative, digestive aid, antispasmodic and cough suppressant (Zargari, 1990) [16]. The upper parts of some Satureja plants are widely used in folk and traditional medicine, as well as in herbal medicine and food products, to treat various ailments such as stomach ache, myalgia, nausea, indigestion, diarrhea and infectious diseases (Gulluce *et al.*, 2003) [5]. Zargari, 1990) [16]. When the literature is examined, it is seen that the essential oil of the parsley plant is rich in phenolic compounds such as carvacrol. γ- Although there are terpinene, thymol, paracimene, linalool and other terpenoid compounds, the chemical composition and content of orange plant oil are different. (Baher *et al.*, 2002; Baser *et al.*, 2004) [3, 4]. Essential oils are secondary plant metabolites known for their aroma and sweetness. They contain a complex mixture of monoterpenes and sesquiterpenes, phenylpropanoids and oxygenated compounds. Essential oils can be found in different plants and materials, and their storage is associated with specific processes (Novak *et al.*, 2006; Sefidkon *et al.*, 2006; Svoboda *et al.*, 2006) [7, 11, 14]. Nutrition systems are important treatments It can be used to increase production. Also the balance and source of fertilizers which are used in fields make an importance nutrition factor for *Satureja hortensis* L. production. Currently biofertilizers are more popular in the New World. Biological fertilizers consist of organic matter (animal manure) and microbial fertilizers. Nitrogen fixation, phosphorus fixation-solubilizing Microorganisms are two important microbial fertilizers that can be used to increase crop yields. Nitrogen-fixing bacteria and nitrogen-fixing green pigments are used to fix nitrogen. Generally, no phosphorus is absorbed into the soil and converted into insoluble phosphates.

Materials and Methods
do an experiment during 2009-2011 on field of Azad university research Station with 34°30´N,48°57´E in central province of Iran. The treatments included: control: without fertilizer.

Nitroxen: Nitrogen fixation microorganism,
Barvar 2: Phosphate-solubilizing microorganism
Nitroxen+ Barvar2: mixture of both

Measure growth and fat production green pepper. plants. The soil of farm was sandy loam. bergamot rookie L. were assembled from population of plant that was cultivated in post year in field of Azad university of Arak. Seeds had 95% germination. Seeds were sowed in field, cotyledons appeared within 3 days, and full emergence was achieved after 12 day. The experimental design was a randomized complete block design (CRB) with three replicates. with 40 cm of plant spacing and 50 cm of row spacing with seed depth of 1-2 cm. The total number of plants in a plot is 40. Furrow There is irrigation. Phosphate-solubilizing microorganism Nitrogen fixation microorganism and mixture of both Watering is done when the plants reach the two true leaf stage. Powder Barvar2 contained *Pantoea agglomerans* + *Pseudomanas putida* inoculants. And Nitroxen bio fertilizers consist *Azotobacter* and *Azospirillum* sp. (10^6 CFU g^{-1}).
The cultural practices consisted of weeds and pest control and water frequently to maintain soil moisture. Harvest individual plants during flowering. The data taking were fresh shoot weight (gr/plant), dry shoot weight) gr/plant), (gr/plant), and plant height (cm). Sixteen plants were selected from each plot to evaluate the factors. Essential oil percentage of 30 gram from each plot was measured by Clevenger.

Table 1: Physical and chemical properties top soil sample research station

Year	Ph	Available P (ppm)	Exchangeable K (ppm)	Total N *(%)*	Lime (%)	Organic matter (%)	Soil texture
2009	7.37	13.5	185	0.19	9.48	1.53	Loam
2010	7.45	12.8	168	0.18	9.38	1.16	Loam
2011	7.41	13.1	189	0.19	9.21	1.45	Loam

Results and Discussion

The effect of different biofertilizers caused significant increase on The most studied characteristics of the tree such as root length, height, number of branches, canopy cover, weight of fresh root, weight of dry root, weight of fresh leaf, weight of dry leaf, weight of fresh shoot, weight of dry shoot, percent of essence, root length and plant height ratio, yield of dry shoot, yield of essence, yield of seed, weight of 1000 seeds, leaf area per plant and leaf area index compare to control in *Satureja hortensis* L.
Application of Phosphate-solubilizing microorganism (Barvar2) increased root length (12.2 cm), plant height (52.4 cm), number of branches (66.7), canopy cover (536.3 cm2), weight of fresh root (1.68 gr), weight of dry root (0.97 gr), weight of fresh leaf (36.4 gr), weight of dry leaf (9.1 gr), weight of fresh shoot (65 gr), weight of dry shoot (26.3 gr), percent of essence (1.97%), root length and plant height ratio (0.24), yield of dry shoot (1316 kg ha^{-1}), yield of essence (26.1 kg ha^{-1}), yield of seed (111.4 kg ha^{-1}), weight of 1000 seeds (0.58 gr), leaf area per plant (251.7 cm^2) and leaf area index (0.47) compare to control. Treatment (Barvar2) had better results than the other three treatments for plant height and Weight of fresh shoot. Use of Nitrogen fixation microorganism (Nitroxen) augmented root length (11.8 cm), plant height (49.8 cm), number of branches (76.6), canopy cover (515.9 cm^2), weight of fresh root (1.76 gr), weight of dry root (1.24 gr), weight of fresh leaf (31.9 gr), weight of dry leaf (8.6 gr), weight of fresh shoot (52 gr), weight of dry shoot (23.6 gr), root length and plant height ratio (0.24), yield of dry shoot (1181 kg ha^{-1}), yield of essence (21.1 kg ha^{-1}), yield of seed (116.6 kg ha^{-1}), weight of 1000 seeds (0.54 gr), leaf area per plant (235.6 cm^2) and leaf area index (0.45) compare to control. Treatment (Nitroxen) had better results than the other three treatments for Yield of seed.

Table 2: Complex analyze variance of *Satureja hortensis* under effect of fertilizers (2009-11)

SOV	df	Root Length	Plant Height	Number branches	Canopy Cover	Weight fresh root	Weight dry root
Year	2	10.134 *	601.6 **	2565.4 **	12971.5 *	0.2640 ^{ns}	0.081767 ^{ns}
Error a	6	3.0566	18.269	33.256	3951.50	0.1129	0.050500
Treatment	3	15.883 **	168.0 **	1558.7 **	60957.5 **	0.7578 **	0.61095 **
T×Y	6	3.7655 *	6.4378 ^{ns}	135.86 ^{ns}	14818.3 ^{ns}	0.0585 ^{ns}	0.074211 *
Error b	18	1.3203	31.610	59.296	6052.34	0.05488	0.026586
CV%		9.74	11.44	11.26	14.77	14.12	15.25
SOV		Weight of fresh leaf	Weight dry leaf	Weight of fresh shoot	Weight of dry shoot	Percent of Essence	Root length Plant Ratio
Year	2	55.0832 ^{ns}	2.3316 ^{ns}	48.8909 ^{ns}	109.389 **	0.02409 ^{ns}	0.003006 ^{ns}
Error a	6	19.7710	1.4551	31.1321	8.31501	0.08464	0.001214
Treatment	3	1781.7 **	117.6 **	2903.03 **	513.928 **	0.09287 **	0.001465 ^{ns}
T×Y	6	103.74 **	10.509 *	288.171 **	71.3151**	0.01995 ^{ns}	0.001298 ^{ns}
Error b	18	24.3255	3.3832	51.0828	6.70888	0.017266	0.000948
CV%		13.60	19.50	11.85	10.08	6.75	12.70
SOV		Yield of dry shoot	Yield of essence	Yield of seed	weight of 1000 seeds	Leaf Area per plant	Leaf Area Index
Year	2	273474.2 **	152.4 **	890.822 ^{ns}	0.006062 ^{ns}	538068 *	0.00243 ^{ns}
Error a	6	20787.513	28.106	1107.74	0.004723	110307	0.00834
Treatment	3	1284820 **	641.1**	1551.90 *	0.007909 *	9069864**	0.11602 **
T×Y	6	178287.6 **	66.774 **	146.613 ^{ns}	0.008534 **	852275 *	0.01162 ^{ns}
Error b	18	16772.2	10.415	374.004	0.001682	268268	0.00705
CV%		10.08	12.84	18.05	7.35	19.88	17.33

**: Significance at 1% level. *: Significance at 5% level. note: it doesn't matter.

Biofertilizers consumption combined (Nitroxen+ Barvar2) increased root length (13.2 cm), plant height (51.5 cm),

number of branches (79.7), canopy cover (627.5 cm^2), weight of fresh root (1.94 gr), weight of dry root (1.32 gr), weight of fresh leaf (45.2 gr), weight of dry leaf (11.4 gr), weight of fresh shoot (64.9 gr), weight of dry shoot (29.5 gr), percent of essence (2.04%), root length and plant height ratio (0.26), yield of dry shoot (1475 kg ha^{-1}), yield of essence (30.1 kg ha^{-1}), yield of seed (112.8 kg ha^{-1}), weight of 1000 seeds (0.59 g), leaf area per plant (297.6 cm^2) and leaf area index (0.56) compare to control.

Treatment (Nitroxen+Barvar2) had better results than the other three treatments for increased root length, Number of Branches, canopy cover, Weight of Dry root, Weight of Fresh leaf, Weight of Dry leaf, Weight of Dry Shoot, percent of essence, root length and plant height ratio, yield of dry shoot, yield of essence, weight of 1000 seeds, leaf area per plant and leaf area index.

Table 3: The Mean characteristic of *Satureja hortensis* under effect of fertilizers (2009-11)

Treatment	Root Length (cm)	Plant Height (cm)	Number of branches	Canopy Cover (cm^2)	Weight of fresh root (g)	Weight of dry root (g)
Control	10.01 c	42.88 b	50.49 c	426.91 c	1.25 c	0.75 c
Barvar2	12.17 ab	52.42 a	66.71 b	536.25 b	1.68 b	0.97 b
Nitroxen	11.80 b	49.76 a	76.59 a	515.93 b	1.76 ab	1.24 a
Nitroxen+Brvar2	13.20 a	51.53 a	79.74 a	627.47 a	1.94 a	1.32 a
Treatment	Weight of fresh leaf (gr)	Weight of dry leaf (gr)	Weight of fresh shoot (gr)	Weight of dry shoot (gr)	Percent of Essence (%)	Root length And Plant height Ratio
Control	21.53 c	5.69 c	41.17 d	17.29 d	1.96 a	0.23 a
Barvar2	36.44 b	9.12 b	65.01 b	26.33 b	1.97 a	0.24 a
Nitroxen	31.88 b	8.55 b	51.99 c	23.61 c	1.80 b	0.24 a
Nitroxen+Brvar2	45.17 a	11.4 a	74.89 a	29.49 a	2.04 a	0.26 a
Treatment	Yield of dry shoot (g m^2)	Yield of essence (g m^2)	Yield of seed (g m^2)	weight of 1000 seeds (gr)	Leaf Area per plant (cm^2)	Leaf Area Index
Control	864.67 d	16.87 d	87.72 b	0.53 b	156.8 c	0.37 c
Barvar2	1316.4 b	26.05 b	111.4 a	0.58 a	251.7 b	0.47 b
Nitroxen	1180.5 c	21.12 c	116.6 a	0.54 b	235.6 b	0.45 bc
Nitroxen+ Brvar2	1474.6 a	30.13 a	112.8 a	0.59 a	297.6 a	0.56 a

Using the Duncan test, means in the same column followed by the same letter do not differ ($p< 0.05$)

This study may provide important information for the development of sweet pepper L. cultivation. Free inorganic phosphate is released from organophosphorus compounds through enzymatic processes (Rossolini *et al.*, 1998) [9], and the production of organic acids (e.g., gluconic acid) by soil microorganisms is the main mechanism of mps (Rodriguez and Fraga, 1999) [8]. Our results showed the same result of Shalby and Razin in *Thymus vulgaris* (1992) [12]. Also Sanches Govin *et al.* (2005) [10] in Chamomile and Calendula, Badran thiab Safwat (2004) [2] in Fennel Plant, Ajimoddin *et al.* (2005) [1] in *Ocimum basilicum*, Shaalan (2005) [13] in *Nigella sativa*, in Stevia plants, Yadegari *et al.* (2012) [15] in *Thymus vulgaris* found similar results.

Conclusion

The application of different biofertilizers significantly enhanced the growth characteristics and yield of *Satureja hortensis* L. compared to the control. Specifically, the combined use of Nitroxen and Barvar2 resulted in the most notable improvements in root length, number of branches, canopy cover, and various yield metrics. Treatment with Phosphate-solubilizing microorganism (Barvar2) significantly increased plant height and fresh shoot weight, while Nitrogen-fixing microorganism (Nitroxen) enhanced seed yield. Overall, biofertilizers demonstrated a substantial positive impact on the studied parameters, providing valuable insights for optimizing *Satureja hortensis* L. cultivation.

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