Influence of Bio- and Mineral Fertilization on Rosemary Plants Grown in Sandy and Calcareous Soils

Salem, Amal, G.[1], A. M. Awad[2] and T.A.T. Abd El-Latif[3]

[1,3] Aromatic and Medicinal plants Res. Department Hort. Res. Institute.

[2] Soil Fertility and Plant Nutrition Res. Department, Soils, Water and Environment Res. Inst., Nubaria Agric. Res. Station, ARC.

ABSTRACT

Two pots experiments were carried out in Sabahia Horticulture Research Station, Alexandria through the two successive seasons of 2004 and 2005 to study the effect of biofertilizer and different rates of mineral fertilization NP (nitrogen and phosphorous) on growth, yield, percentages of essential oil and its components as well as N,P and K uptake of rosemary plants grown in sandy and calcareous soils. These experiments were planned in split-split plot design. The main plots were occupied by the two types of soils (Sandy and Calcareous). Two rates of biofertilizer inoculations (with and without) were the sub-plots. Biofertilizer was added as Nitrobein and Phosphorein (1:1 ratio, w:w). Sub-sub plots contained of different four rates of mineral (NP) fertilization. N and P fertilizers were added at two rates include low rate (L) and high rate (H) equals to (50 and 67 kg N/fed), (15 and 20 kg P_2O_5/fed) respectively. The tested four mineral (NP) fertilization treatments can defined as LL, LH, HL and HH. Ammonium nitrate (33.5% N) and phosphoric acid (85% and 1.6 g/cm3 specific gravity) were used as sources of N and P nutrients respectively.

The results indicated that, generally, all vegetative growth parameters i.e. plant height, number of main branches, fresh and dry weight, also the oil yield per plant gave the highest values in plants grown in calcareous soil and received biofertilization with mineral (NP) fertilizer at the rate of HL (high nitrogen + low phosphorous) followed by HH (high nitrogen + high phosphorous). The lowest results in this respect almost were recorded on plants grown in sandy soil and fertilized by (NP) fertilization at rate LL (low nitrogen and low phosphorous) without biofertilization. By using Gas Chromatography-Mass Spectrum Technique (GC-MS), sixteen components were identified in rosemary essential oil. Camphor, borneol and verbenone are considered the main principle components besides other important components such as 1,8 cineol, linalool, alpha-Terpineol, bornyl acetate, beta-myrcene and camphene. The rest components were found in small amounts. Most of components were significantly affected by the interaction between the factors under study but every component responded to the applied treatments in a different manner. The highest content of camphor was obtained in plants fertilized with the treatment of LL + biofertilizer in Sandy soil. While the maximum percentage of borneol was recorded in plants fertilized with the treatment of HL + biofertilizer in calcareous soil. The best result of verbenone was in plants grown in sandy soil and fertilized with the treatment of HL combined with biofertilization. Also the result illustrated that-in general-the plant nutrients uptake (NPK) as well as the soil macronutrients (NPK) availability produced the maximum values in plants grown in Calcareous soil and fertilized with mineral (NP) at the rate of HH and / or HL plus biofertilizer inoculation.

INTRODUCTION

Rosmarinus officinalis L. (Fam. Lamiaceae or Labiatae) is one of the earliest and renowned of the medicinal herbs. It is indigenous to Southern Europe and the volatile oil is produced in the South of France, Yugoslavia, Spain and North Africa (Trease and Evans, 1985). Rosemary had many uses in the past. The ancient Egyptian carried the rosemary boughs at wedding and placed on coffins at funerals. Also, they placed the leaves under pillows to prevent nightmares. The ancient Greeks and Romans burned the leaves as incense (Philip, 1974).

Rosemary water was used as beatifying and cleaning facial wash. The herb was used as a condiment and medicinally to strengthen the memory and nerves and to prevent balding and condition hair. Rosemary oil is clear and has a warm sharp, Camphoraceous taste which has, surprisingly, very little bitterness. It contains borneol, resin, bitter principle and tannin (Mahran, 1967). Its Volatile oil helps to normalize a high cholesterol level in blood, hence its use in arteriosclerosis (Tisserand, 1987).

Nitrogen and Phosphorus play an essential role in the mineral nutrition of medicinal and aromatic plants. However, in the recent years many constraints have been raised due to their adverse impact on the public health, environmental and national income. To confront this problem, it was necessary to develop alternative methods of supplying nutrients to the growing plants as the biofertilizer utilization. Biofertilization is used in order to compensate a part of the mineral fertilizer doses, taking in consideration the complementary or synergetic effects of such combination between bio- and mineral fertilization. This could be of economic value from the applied point of view of minimizing the used rates of mineral fertilizers and consequently reduce agricultural costs as well as soil pollution. Biological fertilizers are generally, based on altering the rhizospher flora, by seed or soil inoculation with certain organisms, capable of inducing beneficial effect on a compatible host. Bio-fertilizers mainly comprise nitrogen fixer, phosphate dissolvers or Vesicular Arbuscular Mycorrhizae and silicate bacteria. These organisms may affect their host plant by one or more mechanisms such as nitrogen fixation, production of growth promoting substance or organic acids, enhancing nutrient uptake or protection against pathogens (Bashan *et al.* 1989).

Several studies have been carried out to investigate the effects of mineral fertilizers or bio-fertilizers solely on the medicinal and aromatic plants production, but there were lack of informations regarding such plants produced under the combination between the mineral and biofertilizer. However, Abd El- Latif *et al.* (2002) on chamomile plants found that, the best results of growth and oil yield were recorded with combination between ammonium sulphate at 200 kg/fed. and biogein at 2 and 4 kg/fed.

Recently, there is a tendency for expanding in cultivation of medicinal and aromatic plants in newly reclaimed lands as sandy and calcareous soils. So, the work reported here aimed to fulfill the information gape regarding the combined effects between the bio-fertilization and different rates of mineral nitrogen and phosphorus on growth, yield and chemical composition of rosemary plants grown in sandy and calcareous soils.

MATERIALS AND METHODS

The present experiments were carried out in Sabahia Horticulture Research station, Alexandria, through the two successive seasons of 2004 and 2005 to study the effect of biofertilization in combination with mineral nitrogen (N) and phosphorus (P) on growth, yield, essential oil components and N, P and K uptake in dried herb of rosemary plants grown in sandy and calcareous soils.

Terminal stems cuts of *Rosmarinus officinalis* (rosemary) plants were obtained from Medicinal and Aromatic Plants Research Department in Sabahia, Horticulture Research Station and planted in pots 20 cm diameter, on March 2^{nd} in seasons of 2003 and 2004. One terminal stem cut was planted in each pot. Plants were transferred to the final size of glazed pots of 40 cm diameter and 8 kg of soil capacity on September 4^{th} and 7^{th} in the first and second seasons of 2003 and 2004 respectively. Two types of soils were used, the first one was sandy soil collected from the Experimental Farm of South Tahrir Horticultur Research Station, Ali Mubarak Farm at El-Bostan area, and the second one was calcareous soil obtained from Nubaria Agricultural Research Station at North Tahrir area. Soil samples were analyzed for main chemical and physical properties according to the standard procedures (page, 1982 and Klute, 1986). Results of two soil samples analysis are presented in Table 1a. Also, soil samples were subjected to laboratory analysis at the end of the experiments.

During pot preparation for cultivation chicken manure was mixed by the two types of experimental soils with rate of 3g organic fertilizer /pot (10 m3/fed). Also samples of used organic manure during the two seasons were taken and subjected to laboratory analysis (Table 1b).

The used biological fertilizers (biofertilizers) in the experiment includes nitrogen fixing bacteria (NFB) and phosphate dissolving bacteria (PDB). Strains of NFB (*Azospirillum spp.*) under commercial name 'Nitrobein', whereas PDB (*Bacillus megaterium*) under commercial name 'phosphorein' were used (1:1 ratio, w:w). Biofertilizers were used at two rates, with and without biofertilizer. The biofertilizers were mixed immediately before sowing terminal stems cuts of rosemary plants and irrigated directly.

Table 1a. Some physical and chemical characteristics of the experimental sandy and calcareous soils.

Characteristics	Soil Type			
	Sandy		Calcareous	
	Sample 1	Sample 2	Sample 1	Sample 2
Sand; %	94.90	93.90	85.70	79.5
Soil texture class	Sand	Sand	LS	LS
FC; %	11.30	11.70	18.60	18.20
PWP; %	6.01	5.75	8.50	8.40
EC; dS m^{-1} (Soil paste)	0.39	0.36	0.40	0.62
pH (1:2.5)	9.05	9.02	7.80	7.90
OM; %	0.15	0.12	0.52	0.21
$CaCO_3$; %	5.21	5.40	23.50	21.5
NO_3+NH_4;mg kg^{-1}	40.35	49.15	80.2	48.8
$NaHCO_3$-P;mgkg^{-1}	10.52	12.42	21.8	17.5
Exch.-K; mg kg^{-1}	132.50	120.70	225	88.5

LS, loamy sand FC, field capacity PWP; permanent wilting point

Table 1b. Some chemical and nutritional characteristics of the used chicken manure.

Organic fertilizer	Growing season	pH	O.C	O.M	N	P	K	C/N ratio
			%					
Chicken	Sample1	8.21	14.10	24.01	1.16	0.18	0.85	12.16
	Sample2	8.19	14.69	25.02	1.22	0.17	0.93	12.04

Different four rates of mineral fertilization (NP fertilizers) were applied. N and P fertilizers were added at two rates include low rate (L) and high rate (H) equal to (50 and 67kg N/fed), (15 and 20kg P_2O_5/fed), respectively. The tested four mineral NP fertilization treatments can defined as LL, LH, HL, and HH. Ammonium nitrate (33.5%N) and phosphoric acid (85% and 1.6 g/cm^3 specific gravity) as sources of N and P nutrients respectively, were added as 1.2 and 1.6 g/pot Amm. nitrate and 0.12 and 0.16ml/pot phosphoric acid for L and H rates respectively. Phosphorus fertilizer was applied in one dose before transplanting. While the N fertilizer was added in three equal doses at 30 and 60 days after transplanting, whereas the third dose was applied 3 weeks after the first cut. Potassium sulfate (48% K_2O) was added to all treatments at rate of 100kg fertilizer /fed (0.8 gm/pot) in three equal doses at the same time of amm. nitrate applications.

The treatments were distributed in split split-plot in a randomized complete block design (RCBD) with three replications. The main plot was occupied by the two soils type (sandy and calcareous), the two rates of biofertilizers (without and with) were the sub plots within main plots. While the sub sub plots were consisted of the four rates of NP mineral fertilization (LL, LH, HL and HH). So there were 16 treatments in each replicate (2×2×4). Every treatment was consisted of three pots.

The rosemary plants were given all the recommended agronomic management. At full blooming the plants were harvested 2 times in every season. In the first season the first and second cuts were on March 30th and October 5th (2004), respectively. In the second season, the first and second cuts were on April 4th and October 7th (2005), respectively. The plants were harvested by cutting the vegetative part 10 cm above the soil surface.

The following data for every cut were recorded for each treatment; plant height (cm), number of the main branches per plant, fresh and dry weight per plant (g), percentages of essential oil and its constituents. Also the macronutrients (NPK) uptake in dry herb were determined.

The essential oil was extracted by water distillation according to the method described by British pharmacopia (1968) and oil constituents were determined by using the Gas Chromatography-Mass Spectrum (GC-MS) Technique with the conditions as follows:

Information	Condition
Instrument	GC 5890 Mass spectrophotometer 5989, Hewlett Packared (HP),
Column	HP/5 30m × 0.25 mm × 0.25μm film thickens,
Stationary phase	Polyphenyle methyl silioxane,
Flow rate	0.6 ml Helium min^{-1},
Column temp.	50-200 °C,
Rate temp.	6 °C min^{-1},
Injection temp.	200 °C,
Detector temp.	220 °C,
Recorder	HP

The oil constituent's percentage was estimated from the measured peak area of the chromatograms according to Gunther and Joseph (1978).

Macro- (N, P, K) nutrients were determined in rosemary dried herb. Samples were dried at 65 °C then ground and wet digested using H_2SO_4 and H_2O_2 (FAO, 1980). N, P and K concentrations were determined using Gerhard Vapodust 50 nitrogen distillation unit, spectrophotometer 21D and Jenway flame photometer, respectively, (Westerman, 1990).

Appropriate analyses of variance were performed using SAS software (SAS institute, 1985). Comparisons among means of the different treatments were carried out; using Duncan's multiple range tests as illustrated by Gomez and Gomez (1983).

RESULTS AND DISSECTION

Initial State of the Experimental Soil

Results of soil analysis in the two soil types of the study were presented in Table (1a). The analysis of the calcareous soil indicated low organic matter content. Mineral nitrogen (NO_3+NH_4), and exchangeable K were at moderate level whereas available P at adequate level. Soil not saline with high total $CaCO_3$%. The water holding capacity at moderate level and the available water about 10%.

However, sandy soil analysis showed very low organic matter content, mineral nitrogen (NO_3+NH_4), available P and exchangeable K, all nutrients were under the critical level of response to fertilization and were very low. Soil profile has light texture of sandy (>92%), and soil was not saline. Correspondingly, the soil under consideration was characterized by low fertility and low water holding capacity, and low available water (about 5%).

Organic Fertilizers

Some main fertilizer characteristics of chicken manure used in the experiment was presented in Table (1b). The results indicated that the manure was not rich in organic carbon (OC) and organic matter content. Total macronutrient content indicted that, chicken manure was relatively rich in N which had narrow C/N ratio, whereas P and K contents in chicken manure were not high reflecting low supplying capacity with P and K nutrients. Application of significant amount of organic manures to the soil has been a successful practice for improving the physical and chemical conditions as well as its productivity (Tate, 1989).

I. Growth and yield characteristics

Main Effects

Data of growth and yield characters in terms of plant height, number of main branches per plant (Table 2), both fresh and dry weight per plant (Table 3) indicated that, all growth characters of all cuts of the experimental seasons significantly increased for plants grown in calcareous soil than that of sandy soil. The only exception to this general trend was detected in the first cut of the first season with number of main branches per plant giving an insignificant difference between the effects of Sandy and calcareous soils. These results may due to the higher content of nutrients and organic matter in calcareous soil than in sandy soil as shown in (Table 1a). These results are in a good agreement with those of El-Kouny (2002) who found that, the fresh weights of tomato fruits grown in sandy and calcareous soils were (550, 710 gm per plant) and (650, 750 gm per plant) respectively when each soil was treated with saline waters of $6dSm^{-1}$ and $3dSm^{-1}$ orderly. But our results conflict with those obtained by Youssef *et al.* (1998) who stated that, the highest herbage yield of *Ocimum basilicum* plants were obtained from plants fertilized with 4gmN/pot and grown in clay soil followed by sandy soil then calcareous soil.

It could be observed from the previous data (Table 2 and 3) that in general when the biofertilizer inoculation was applied, positive responses in all growth characters in all cuts were recorded against control (unfertilized plants). The favorable effects of the biofertilizer may be explained on the basis of the beneficial effects of bacteria on the nutrient availability, vital enzymes, hormonal stimulating effects on plant growth or the increasing of photosynthetic activity (Bashan *et al.* 1989). Several researchers have investigated the effect of biofertilization on a number of lamiaceae (Labiatae) plants [Kandeel *et al.* (2002) on *Ocimum basilicum*, Eid and Ghawwas (2002) and El-Ghadban *et al.* (2002) on *Majorana hortensis*, and El-sayed (2004) on *Salvia officinalis*].

Also, results clearly indicated that, there were significant differences between the different rates of mineral (NP) fertilization. The treatment of HL (high nitrogen and low phosphorus rates) and/or HH (high nitrogen and high phosphorous rates) gave the best effect on growth and yield characters. Generally the least values were obtained in plants received the treatment of (LL) (Low nitrogen and low phosphorus rates). The significant positive effect on plant growth as a result of the fertilization by N and P can be explained by the important roles played by these elements in the different physiological processes within the plant, which in turn affect plant growth. Nitrogen is present in the structure of protein molecules. While phosphorus is an essential constituent of nucleic acids and phospholipids (Devlin, 1975). The effect of (NP) fertilization on growth and yield of most aromatic and medicinal plants was studied by numerous investigators [El-Sayed *et al.* (2003) on *Ocimum basilicum*, El-Ghawwas (2002) and Khater *et al.* (2003) on *Ambrosia martima*, Sadek (2002) on *Cymbopogon citratus* STAPF., Dasha *et al.* (2006) on *Mentha arvensis* L. and many others].

Table 2. Influence of bio-and mineral fertilization on plant height (cm) and number of branches of rosemary plants cultivated in sandy and calcareous soils during the two growing seasons of 2004 and 2005

Soil Type	Bio Inoc.	NP rates	Plant height				No of main branches			
			1st season		2nd season		1st season		2nd season	
			1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut
Sandy			41.49b	43.50b	41.11b	42.21b	10.00a	21.04b	9.25b	20.00b
Calcareous			42.93a	46.83a	44.20a	44.74a	10.67a	27.42a	11.00a	24.46a
	Without		41.39b	43.39b	40.58b	41.85b	9.75b	23.38b	8.96b	19.50b
	With		43.03a	46.94a	44.74a	45.10a	10.92a	25.08a	11.29a	24.96a
		LL	40.04b	39.13c	39.91b	39.28d	8.58c	13.17c	8.17c	12.25d
		LH	41.39b	43.83b	40.20b	42.93c	9.83b	21.92b	9.42b	18.42c
		HL	43.14a	48.41a	45.32a	46.59a	11.17a	31.08a	11.58a	30.50a
		HH	44.26a	49.28a	45.20a	45.11b	11.75a	30.75a	11.33a	27.75b
Sandy	Without	LL	40.50	37.67	38.33	38.33	7.00	11.33	6.66	10.33
		LH	35.43	33.00	36.67	40.00	10.33	14.67	8.33	11.67
		HL	41.10	45.33	42.93	41.70	10.00	25.33	10.67	24.67
		HH	45.57	49.00	40.13	43.27	10.66	29.67	8.67	19.00
	With	LL	41.67	38.87	38.67	36.23	8.00	10.33	7.33	11.33
		LH	43.67	48.33	41.33	44.80	10.00	20.00	9.67	19.00
		HL	41.23	49.10	45.80	47.90	12.33	31.67	11.00	31.67
		HH	42.43	46.67	48.00	45.47	11.67	25.33	11.67	32.33
Calcareous	Without	LL	39.33	41.67	41.53	40.10	8.00	17.33	8.00	12.00
		LH	41.67	44.67	38.57	40.27	9.33	24.67	7.67	19.33
		HL	44.23	46.00	43.97	46.97	10.67	28.33	10.33	29.67
		HH	42.97	49.80	45.4	44.13	12.00	35.67	11.33	29.33
	With	LL	38.67	38.33	44.10	42.43	11.33	13.67	10.67	15.33
		LH	44.80	49.33	44.23	46.67	9.67	28.33	12.00	23.67
		HL	46.00	53.20	48.57	49.77	11.67	39.00	14.33	36.00
		HH	45.77	51.67	47.20	47.57	12.67	32.33	13.67	30.33
LSD 0.05			4.66	4.65	3.76	4.30	3.09	3.31	2.84	3.34

Bio Inoc. = bio-fertilizer inoculation, NP rates = Nitrogen and Phosphorus fertilization rates, L = low, H =high
LL= low N and low P fertilization rate, LH= low N and high P fertilization rate
HL= high N and low P fertilization rate, HH= high N and high P fertilization rate

Table 3. Influence of bio-and mineral fertilization on fresh and dry weight per plant (gm) of rosemary plants cultivated in sandy and calcareous soils during the two growing seasons of 2004 and 2005

Soil Type	Bio Inoc.	NP rates	Fresh weight				Dry weight			
			1st season		2nd season		1st season		2nd season	
			1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut
Sandy			81.77b	94.53b	78.44b	90.16b	29.84b	34.76b	28.93b	32.82b
Calcareous			92.41a	111.15a	89.15a	103.70a	33.95a	42.22a	32.30a	37.71a
	Without		84.58b	94.14b	77.11b	89.81a	30.99a	36.20b	28.25b	32.46b
	With		89.60a	111.55a	90.48a	104.06a	32.80a	40.78a	32.98a	38.07a
		LL	74.37c	59.04c	73.08c	73.81d	27.34b	21.76c	26.63c	26.24d
		LH	82.46b	99.08b	77.53b	86.57c	29.91b	35.93b	28.27b	32.09c
		HL	94.72a	131.99a	93.11a	120.05a	34.57a	48.93a	33.77a	43.56a
		HH	96.81a	121.25a	91.45a	107.30b	35.76a	47.34a	33.80a	39.16b
Sandy	Without	LL	69.33	50.00	65.20	67.17	25.70	18.35	23.85	24.56
		LH	74.90	65.80	69.13	64.33	27.24	24.23	25.65	23.94
		HL	75.00	113.33	81.23	99.56	26.87	41.93	29.78	35.81
		HH	82.80	116.67	80.97	107.43	31.10	42.76	29.94	39.19
	With	LL	72.15	53.33	68.00	65.22	25.92	19.74	25.07	23.50
		LH	89.44	117.44	77.67	88.80	32.88	42.18	28.78	32.06
		HL	98.33	124.11	92.17	113.10	35.95	45.85	34.12	40.69
		HH	92.22	115.56	93.13	115.67	33.09	43.00	34.28	42.82
Calcareous	Without	LL	62.64	89.50	71.10	72.44	23.08	33.08	25.58	24.96
		LH	89.48	95.56	69.87	91.13	32.26	35.27	25.77	33.74
		HL	101.89	106.11	87.81	118.50	37.00	39.29	31.55	42.51
		HH	120.56	116.11	91.53	97.90	44.67	54.64	33.88	34.98
	With	LL	93.33	43.33	88.03	90.43	34.65	15.88	32.00	31.95
		LH	76.00	117.50	93.43	102.00	27.27	42.04	32.87	38.62
		HL	103.67	184.42	111.22	149.03	38.45	68.63	39.64	55.23
		HH	91.67	136.67	100.17	108.20	34.18	48.94	37.10	39.64
LSD 0.05			7.80	39.29	8.07	9.78	8.30	7.19	5.00	6.34

Bio Inoc. = bio-fertilizer inoculation, NP rates = Nitrogen and Phosphorus fertilization rates, L = low, H =high
LL= low N and low P fertilization rate, LH= low N and high P fertilization rate
HL= high N and low P fertilization rate, HH= high N and high P fertilization rate

Interaction effects

The interaction between the soil type, biofertilizer and different rates of (NP) fertilization had significant effect on most treatments of growth and yield characters. The maximum values of plant height, number of main branches, fresh and dry weight per plant were 53.20 cm, 39, 184.42 gm and 68.63 gm per plant, respectively. These results were obtained in plants fertilized by bioferilizer and received the mineral fertilization (NP) of treatment (HL) grown in calcareous soil in the second cut of the first season. The superiority of biofertilizer + HL may be attributed to the high solubility of these nutrient (N and P) besides the microbiological processes can change the unavailable forms of nutrients into available ones that can be easily assimilated by plants (Dawa *et al.* 2000). These results are in agreement with those obtained by Menesy *et al.* (2002) on dill, coriander and parsley, Abd El-Latif and Salem (2002) on *Tagetes minuta*, L and Maheshwari *et al.* (1998) on palmarosa (*Cymbopogon martini var. motia*) who found that the highest dry-matter yield were recorded by applying *Azotobacter spp.* At 2kg/ha together with 20kg N + 20kg p/ha.

II. Herb chemical composition

- Essential oil percentage
- Essential oil yield per plant.

Main effects

Data tabulated in Table (4) cleared that, the rosemary essential oil percentages were not affected by the soil type either sandy or calcareous in all cuts of the two seasons. While the oil yield per plant was higher with calcareous soil than with sandy soil. These results may be due to increasing the corresponding herb yield in calcareous soil over sandy soil as shown in Table (3). In contrast Youssef *et al.* (1998) reported that basil plants grown in sandy soil and received 4 gm N/pot recorded higher values of oil content and oil yield per plant than those grown in calcareous soil.

Data in Table (4) revealed that, generally application of biofertilizer inoculation stand favorable and responsible for the statistically increments in oil percentage and yield per plant during growing seasons compared with control treatment (without biofertilization). This stimulated effect of biofertilizer application on rosemary oil content and yield may be attributed to its role on the physiological and biochemical processes in plants. In this respect similar results were obtained by Kandeel *et al.* (2002) on *Ocimum basilicum*, El-Sayed (2004) on *Salvia officinalis* and Shaalan (2005) on *Nigella sativa*.

Also, it could be observed from data in the same Table (4) that, the oil percentages and yield per plant were affected by the different rates of (NP) fertilization with variable degrees of significance in the experimental seasons. In general, the highest mean values of oil percentages and yield were found with the treatment of rate (HL) followed by (HH). The important role of nitrogen and phosphorous on oil content and yield of most aromatic and medicinal plants was studied by many researchers [Sadek (2002) on

Cymbopogon citratus STAPF., El-Sayed *et al.* (2003) on *Ocimum basilicum*, Dasha *et al.* (2006) on *Mentha arvensis L.* and others].

Interaction effects

The presented data (Table 4), also showed that, there were promotive effects for the combination between biofertilizer and different rates of mineral fertilization (NP) on oil percentages and oil yield per plant of rosemary plants cultivated in-sandy and calcareous soils. These results might be attributed to their enhancing effect on vegetative growth, in terms of the fresh yield and increasing the uptake of nutrient by roots of plant especially phosphorous element. However, the most important compound in which phosphate groups one linked by pyrophosphate bonds is adenosine triphosphate (ATP). The energy absorbed during photosynthesis or released during respiration is utilized in the synthesis of the pyrophosphate bonds in adenosine triphosphate (ATP). In this form, the energy can be conveyed to various undergoing processes such as activation uptake and the synthesis of various organic compounds such as volatile oils (El-Ghadbar *et al.* 2002). The maximum mean values of oil percentages (0.74%) was obtained when the biofertilizer were applied with the treatment of (LL) in second cut of the second season in calcareous soil. While the best results of oil yield per plant was (0.411 ml per plant). It was recorded as a result of the combination between biofertilization and the mineral (NP) fertilization at the treatment of (HL) in second cut of the first season, also in the calcareous soil. These results agreed with those obtained by Abdel-Latif and Salem (2002) on *Tagetes minuta, L*, Maheshwari *et al.* (1998) on palmarosa (*Cymbopogon martinii var. motia*). They found that applying of *Azotobacter spp.* at 2kg/h together with 20kg N/h + 20kg p/ha were produced the maximum oil yield per plant.

Essential oil components

Data on percentage means of rosemary essential oil components are given in Table (5) and shown in Fig (1a and 1b). Sixteen components were identified in rosemary essential oil by using Gas Chromatography Mass Spectrum Technique (GC-MS). Three components of them are considered main principle components such as; camphor, borneol and verbenone. There are some other important components; i.e. 1,8-cineol, linalool, alpha-Terpineol, bornyl acetate, beta-myrcene and camphene. The rest components were found in small amounts.

Table 4. Influence of bio-and mineral fertilization on oil percentage and oil yield per plant of rosemary plants cultivated in sandy and calcareous soils during the two growing seasons of 2004 and 2005

Soil Type	Bio Inoc.	NP rates	Oil %				Oil yield / plant, ml			
			1st season		2ed season		1st season		2ed season	
			1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut
Sandy			0.600a	0.576a	0.628a	0.648a	0.180b	0.202b	0.182b	0.210b
Calcareous			0.608a	0.588a	0.638a	0.628a	0.206a	0.250a	0.206a	0.232a
	Without		0.579b	0.569a	0.626a	0.614b	0.180b	0.209b	0.180b	0.200b
	With		0.629a	0.595a	0.639a	0.661a	0.207a	0.244a	0.208a	0.242a
		LL	0.608b	0.565b	0.643ab	0.653ab	0.167b	0.120c	0.172c	0.168d
		LH	0.568c	0.568b	0.610b	0.618b	0.170b	0.208b	0.171c	0.196c
		HL	0.638a	0.610a	0.615b	0.678a	0.220a	0.298a	0.208b	0.285a
		HH	0.603b	0.585ab	0.663a	0.603bc	0.216a	0.278a	0.225a	0.236b
Sandy	Without	LL	0.520	0.610	0.700	0.560	0.133	0.112	0.167	0.138
		LH	0.580	0.480	0.640	0.640	0.158	0.117	0.164	0.153
		HL	0.640	0.560	0.620	0.720	0.172	0.235	0.185	0.258
		HH	0.550	0.600	0.570	0.590	0.172	0.257	0.170	0.231
	With	LL	0.640	0.570	0.580	0.720	0.166	0.113	0.145	0.147
		LH	0.600	0.630	0.550	0.610	0.197	0.265	0.158	0.195
		HL	0.680	0.610	0.670	0.690	0.244	0.280	0.229	0.280
		HH	0.590	0.550	0.690	0.650	0.195	0.237	0.236	0.278
Calcareous	Without	LL	0.610	0.490	0.600	0.590	0.141	0.162	0.153	0.147
		LH	0.520	0.530	0.690	0.570	0.167	0.186	0.178	0.192
		HL	0.630	0.670	0.580	0.640	0.233	0.264	0.182	0.271
		HH	0.580	0.610	0.710	0.600	0.259	0.333	0.240	0.210
	With	LL	0.660	0.590	0.690	0.740	0.228	0.093	0.220	0.237
		LH	0.570	0.630	0.560	0.650	0.155	0.264	0.184	0.242
		HL	0.600	0.600	0.590	0.660	0.231	0.411	0.234	0.331
		HH	0.690	0.580	0.680	0.570	0.236	0.284	0.252	0.226
LSD 0.05			**0.07**	**0.12**	**0.11**	**0.12**	**0.06**	**0.08**	**0.05**	**0.07**

Bio Inoc. = bio-fertilizer inoculation, NP rates = Nitrogen and Phosphorus fertilization rates, L = low, H =high
LL= low N and low P fertilization rate, LH= low N and high P fertilization rate
HL= high N and low P fertilization rate, HH= high N and high P fertilization rate

Main effects

Data in Table (5) and Fig (1a and 1b) cleared that, in most cases, the oil components percentages were positively and/or significantly higher in plants cultivated in calcareous than in sandy soil. In this respect Youssef *et al.* (1998) reported that, volatile oil of *Ocimum basilicum L.* plants grown in calcareous soil contained the most hydrocarbon terpenes. While those in sandy soil produced that most oxygenated compounds.

Also, the previous data, almost, demonstrated that, the percentages of oil components were insignificantly affected by biofertilizer application. On the contrary, Eid and Ghawws (2002) on marjoram plants, mentioned that the highest values of α-pinene, β-pinene, Ocimene, borneol, linalyl acetate and geranyl acetate were obtained as a result of applying microbein (4gm/plot).

From the above mentioned results, it was noticed that, there were different levels of significance between the different rates of (NP) fertilization in most oil components. The response of components to different rates of (NP) fertilization differ from component to another.

Interaction effects

Data on the interaction effects among the three tested factors cleared that, the interaction had significant effect on most oil components. Data in the same Table (5) and Fig. (1a and 1b) showed that the highest content of camphor was (21.40%) and obtained in plants fertilized with the treatment of (LL) combined with biofertilizer and grown in sandy soil. While the maximum percentage of borneol was (22.69%) and recorded in plants received the treatment of (HL) combined with biofertilizer and cultivated in calcareous soil. Meanwhile the treatment of (HL) combined with biofertilizer inocultation was the most effective one in increasing the verbenone component in oil plants grown in sandy soil. The highest value of percentage of 1,8 cineol was (11.81%) and produced in plants oil grown in sandy soil and fertilized with the combination of LH and biofertilizer. The highest percentage (8.44%) of Linalool was recorded in plants fertilized with the rate of (LL) combined with biofertilizer and grown in calcareous soil. The maximum percentage of alpha-Terpineol, bornyl acetate, beta-myrcene and camphene were 6.32, 5.99, 4.11 and 4.60%, respectively and found in fertilized plants oil with biofertilizer combined with (NP) at the rate of HL and cultivated in calcareous soil. Our results coincide with those obtained by Graven *et al.* (1991) and Abd El-Latif and Salem (2002) on *Tagetes minuta L.* who reported that, the percentages of dihydrotageton and cis-tagetone increased due to the combination between mineral fertilizer (NPK) and biofertilizer (1:1 Nitrobien and Phosphorien, w:w), but the percentages of limonene and B-ocimene were reduced.

Table 5. Influence of bio-and mineral fertilization on essential oil constituents of rosemary plants cultivated in sandy and calcareous soils during the second cut of the second growing season of 2004 and 2005

Soil Type	Bio Inoc.	NP rates	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
			Essential Oil Constituents															
Sandy			0.52a	5.58a	7.59a	2.22a	19.56a	2.26a	16.50b	2.08a	4.63b	3.64b	16.88b	2.68b	3.05b	1.56a	1.47a	1.37b
Calcareous			0.39b	2.33b	7.57a	1.66b	16.66b	2.03b	19.06a	2.18a	5.17a	4.33a	17.44a	3.05a	3.47a	1.65a	1.38b	1.74a
	Without		0.46a	4.32a	7.58a	1.88a	18.65a	2.19a	17.55a	2.13a	4.83a	3.93a	17.23a	2.80a	3.17a	1.59a	1.40a	1.50a
	With		0.44a	3.59b	7.57a	2.00a	17.57b	2.10a	18.01a	2.13a	4.96a	4.04a	17.09a	2.94a	3.35a	1.62a	1.44a	1.60a
		LL	0.56a	5.44a	7.83a	2.26a	19.98a	2.35a	16.41b	2.08ab	4.78a	3.71b	17.02b	2.68b	2.99c	1.56b	1.47a	1.16c
		LH	0.49a	5.49a	7.54a	2.10a	18.18b	2.07b	16.86b	2.05b	4.78a	3.93b	16.88b	2.78b	3.11bc	1.84a	1.43a	1.49b
		HL	0.37b	2.35b	7.27a	1.63b	15.62c	1.82b	19.05a	2.15ab	5.16a	4.42a	18.53a	3.10a	3.65a	1.63ab	1.27b	1.80a
		HH	0.40b	2.55b	7.68a	1.79b	18.65b	2.35a	18.80a	2.23a	4.87a	3.89b	16.21c	2.91ab	3.29	1.60ab	1.52a	1.76a
Sandy	Without	LL	0.51	4.92	7.45	2.68	20.10	2.33	18.21	2.13	4.77	3.76	17.32	2.82	3.16	1.65	1.10	1.38
		LH	0.67	11.81	7.47	2.19	21.20	2.11	11.25	1.81	3.96	3.10	14.57	2.22	2.44	2.10	2.11	0.92
		HL	0.44	2.43	7.47	1.79	17.95	2.08	17.28	2.10	4.97	4.05	18.83	2.98	3.41	1.52	1.47	1.52
		HH	0.39	3.60	8.05	2.43	19.54	2.62	18.89	2.22	4.87	3.87	14.90	2.87	3.15	1.44	1.38	1.87
	With	LL	0.66	10.30	7.60	2.12	21.40	2.17	12.51	1.90	4.21	3.18	16.38	2.31	2.60	1.09	1.33	0.86
		LH	0.67	7.91	7.59	2.45	20.26	2.17	15.19	1.90	4.39	3.22	16.40	2.38	2.73	1.40	1.56	1.08
		HL	0.45	1.83	7.61	1.95	18.52	2.31	19.12	2.16	5.05	3.73	20.35	2.89	3.44	1.51	1.07	1.53
		HH	0.36	1.83	7.45	2.17	17.47	2.28	19.53	2.35	4.81	4.22	16.26	2.99	3.44	1.75	1.70	1.78
Calcareous	Without	LL	0.52	3.85	7.83	1.99	18.94	2.28	16.66	2.12	5.07	4.02	17.29	2.72	3.04	1.30	1.84	1.15
		LH	0.29	0.25	7.95	1.54	13.36	1.76	21.39	2.27	5.75	4.70	19.57	3.43	3.75	1.86	1.19	2.10
		HL	0.47	5.12	7.12	2.10	18.92	2.11	17.13	2.20	4.31	3.92	16.90	2.41	2.97	1.11	1.32	1.40
		HH	0.42	2.57	7.31	0.33	19.16	2.20	19.61	2.19	4.97	3.99	18.44	2.92	3.46	1.74	0.81	1.66
	With	LL	0.53	2.68	8.44	2.24	19.47	2.60	18.6	2.18	5.05	3.89	17.09	2.85	3.19	1.39	1.60	1.26
		LH	0.33	1.98	7.13	2.20	17.91	2.22	19.60	2.14	5.03	4.68	16.97	3.09	3.52	2.01	0.86	1.84
		HL	0.13	0.00	6.88	0.69	7.07	0.77	22.69	2.15	6.32	5.99	18.02	4.11	4.60	2.37	1.23	2.74
		HH	0.41	2.21	7.89	2.21	18.43	2.31	17.18	2.17	4.85	3.46	15.24	2.87	3.09	1.45	2.18	1.73
LSD0.05			0.11	1.66	1.82	0.71	3.00	0.81	2.34	0.52	1.24	1.19	1.62	0.82	0.82	1.17	0.33	1.56

Bio Inoc. = bio-fertilizer inoculation , NP rates = Nitrogen and Phosphorus fertilization rates, L = low, H =high, LL= low N and low P fertilization rate, LH= low N and high P fertilization rate, HL= high N and low P fertilization rate, HH= high N and high P fertilization rate

Essential oil constituents :

1. Alpha pinene 2. 1,8 Cineol 3. Linalool 4. O-Ethylphenol 5. Camphor 6. Beta-pinene 7. Borneol 8. 4-Terpineol 9. alpha-Terpineol 10. Bornyl acetate 11. Verbenone 12. Beta-Myrcene 13. Camphene 14. Piperitenone 15. Beta-Caryophllene 16.Farnesene

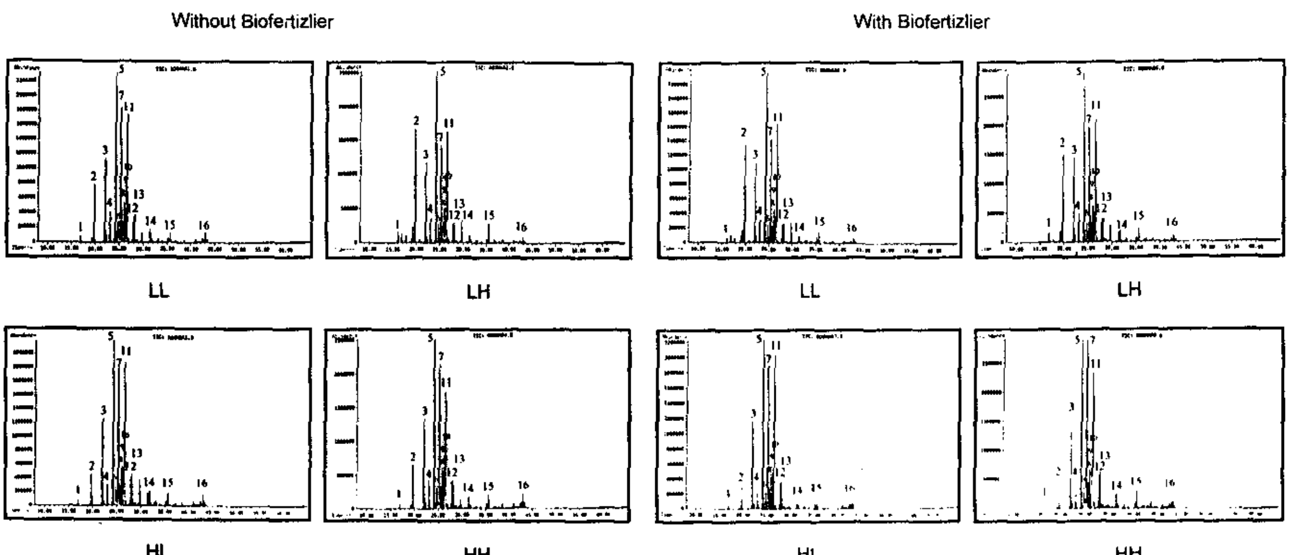

Fig. (1a): Chromatogram of rosemary essential oil components grown in sandy soil as affected by bio and mineral fertilization in the second cut of the second season.
LL = low N and low P fertilization rate, LH = low N and high P fertilization rate, HL = high N and low P fertilization rate and HH = high N and high P fertilization rate.

1- Alpha pinene	5- Camphor	9- alpha-Terpineol	13- Camphene
2- 1,8-Cineol	6- Beta-pinene	10- Bornylacetate	14- Piperitenone
3- Linalool	7- Borneol	11- Verbenone	15- Beta-caryophyllene
4- O-Ethylphenol	8- 4-Terpineol	12- Beta-Myrcene	16- Farnesene

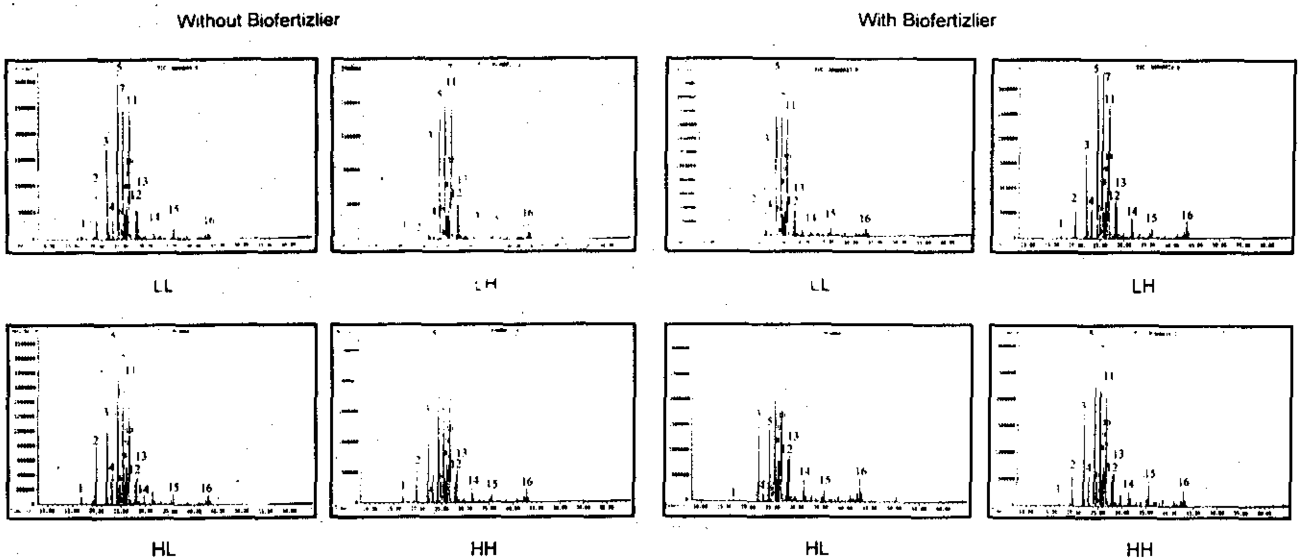

Fig. (1b): Chromatogram of rosemary essential oil components grown in Calcareous soils as affected by bio-and mineral fertilization in the second cut of the second season.
LL = low N and low P fertilization rate, LH = low N and high P fertilization rate, HL = high N and low P fertilization rate and HH = high N and high P fertilization rate.

1- Alpha pinene	5- Camphor	9- alpha-Terpineol	13- Camphene
2- 1,8-Cineol	6- Beta-pinene	10- Bornylacetate	14- Piperitenone
3- Linalool	7- Borneol	11- Verbenone	15- Beta-caryophyllene
4- O-Ethylphenol	8- 4-Terpineol	12- Beta-Myrcene	16- Farnesene

Macronutrients Uptake

Main effects

The main effects of the tested parameters (soil type, inoculation treatments and mineral fertilization rate) on rosemary plants NPK uptake were presented in Table (6), for first and second cuts during the two growing seasons.

The results show that about all evaluated parameters of rosemary plants was affected significantly to the accomplished treatments. The results indicated that nutrients uptake were higher in second cut than in the first one. Soil type were affected significantly NP uptake in the two cuts during the two growing seasons, whereas in the first season K uptake affected insignificantly by soil type. The result indicated that the nutrients uptake was higher under calcareous soil than sandy soil; it may due to higher content of nutrients and organic matter (Table 1a). Inoculation with microorganisms (nitrogen fixing bacteria (NFB) and phosphate dissolving bacteria (PDB)) increased NPK uptake of rosemary over the two growing seasons in the two cuts more than the un-inoculated treatments, Carter *et al.* (1999) concluded that in regard to the function of soil as a medium for plant growth, soil microbial biomass (SMB) controlains a store of labile plant nutrients (e.g., N and P) and that microbially mediated N mineralization can meet a significant portion of plant N requirements. Mineral fertilization were significantly affect NPK uptake in the two growing seasons through the two cuts. Mostly the highest values for nutrients uptake were found in treatments of high rate of (HH) of NP fertilization except some cases of higher uptake in treatment of (HL) high rate of N and low rate of P fertilization.

Interaction effects

The results of interaction effect between the tested parameters indicated that significant differences were obtained for N, P in the first growing season only whereas K uptake showed significant differences during the two growing seasons. Inoculation using NFB and PDB under sandy and calcareous soils resulted in higher NP and K uptake than the other un-inoculated treatments (without) under different mineral fertilization rates. The uptake of N, P and K in rosemary plants was increased positively and/or significantly when N applied with high rate under the two rates of P fertilization; indicate the importance of N fertilization either with or without inoculation by biofertilizers. The results showed higher response to P fertilization under sandy soil than under calcareous soil, especially under inoculated treatments; it may due to low available P in sandy soil than calcareous soil (Table 1a) which indicated that P level for sandy soil was under critical level for response to P fertilization (Amer, 1995).

Table 6. Influence of bio-and mineral fertilization on N, P and K uptake (g per pot) for rosemary plants cultivated in sandy and calcareous soils during the two growing seasons of 2004 and 2005

Soil Type	Bio Inoc.	NP Rates	N uptake				P uptake				K uptake			
			1st season		2nd season		1st season		2nd season		1st season		2nd season	
			1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut
Sandy			0.264 b	0.439 b	0.330 b	0.432 b	0.227 b	0.486 b	0.273 b	0.500 b	0.411 a	0.496 a	0.296 b	0.356 b
Calcareous			0.345 a	0.559 a	0.395 a	0.522 a	0.462 a	0.654 a	0.433 a	0.619 a	0.432 a	0.533 a	0.408 a	0.477 a
	Without		0.273 b	0.444 a	0.311 b	0.435 b	0.323 b	0.501 b	0.305 b	0.472 b	0.424 a	0.471 b	0.308 b	0.357 b
	With		0.336 a	0.553 a	0.416 a	0.521 a	0.367 a	0.639 a	0.402 a	0.64 a	0.420 a	0.558 a	0.396 a	0.477 a
		LL	0.229 d	0.284 c	0.294 c	0.331 c	0.272 c	0.297 d	0.278 d	0.390 c	0.371 c	0.277 c	0.278 b	0.273 d
		LH	0.267 c	0.447 b	0.311 c	0.412 b	0.326 b	0.531 c	0.324 c	0.517 b	0.392 c	0.468 b	0.315 b	0.363 c
		HL	0.345 b	0.666 a	0.413 b	0.590 a	0.345 b	0.676 b	0.384 b	0.669 a	0.436 b	0.648 a	0.394 a	0.485 b
		HH	0.378 a	0.598 a	0.437 a	0.577 a	0.436 a	0.775 a	0.426 a	0.663 a	0.487 a	0.666 a	0.422a	0.547 a
Sandy	Without	LL	0.187	0.210	0.219	0.278	0.150	0.206	0.181	0.345	0.355	0.261	0.200	0.206
		LH	0.228	0.278	0.255	0.306	0.207	0.339	0.231	0.373	0.425	0.378	0.247	0.230
		HL	0.238	0.541	0.304	0.480	0.174	0.455	0.210	0.466	0.354	0.551	0.288	0.346
		HH	0.306	0.564	0.336	0.545	0.255	0.633	0.321	0.646	0.480	0.660	0.275	0.361
	With	LL	0.230	0.245	0.291	0.298	0.197	0.332	0.212	0.343	0.347	0.265	0.217	0.204
		LH	0.297	0.515	0.347	0.410	0.276	0.759	0.288	0.495	0.441	0.518	0.296	0.330
		HL	0.316	0.601	0.444	0.562	0.246	0.679	0.368	0.618	0.442	0.624	0.471	0.562
		HH	0.303	0.581	0.470	0.608	0.331	0.721	0.487	0.719	0.450	0.727	0.494	0.617
Calcareous	Without	LL	0.177	0.443	0.292	0.323	0.286	0.397	0.3212	0.325	0.390	0.384	0.303	0.296
		LH	0.246	0.455	0.272	0.446	0.417	0.536	0.340	0.475	0.336	0.458	0.320	0.419
		HL	0.363	0.548	0.388	0.582	0.444	0.534	0.391	0.595	0.500	0.491	0.412	0.555
		HH	0.456	0.781	0.437	0.489	0.643	0.907	0.461	0.553	0.558	0.601	0.430	0.444
	With	LL	0.331	0.240	0.372	0.399	0.471	0.253	0.410	0.550	0.381	0.214	0.396	0.395
		LH	0.301	0.568	0.374	0.514	0.404	0.726	0.440	0.726	0.368	0.517	0.401	0.471
		HL	0.463	0.975	0.523	0.831	0.523	1.043	0.574	0.999	0.473	0.927	0.521	0.726
		HH	0.446	0.729	0.508	0.594	0.506	0.842	0.546	0.734	0.461	0.675	0.487	0.521
LSD 0.05			0.07	0.08	ns	ns	0.06	0.08	ns	ns	0.05	0.06	0.05	0.05

Bio Inoc. = bio-fertilizer inoculation, NP rates = Nitrogen and Phosphorus fertilization rates, L = low, H =high
LL= low N and low P fertilization rate, LH= low N and high P fertilization rate
HL= high N and low P fertilization rate, HH= high N and high P fertilization rate

Nitrogen fertilization is generally needed because of its mobility in soils and the large amounts needed by plants. The response of rosemary plant to the NPK supply is an important determinant for accurate NPK fertilizer recommendations. Development of recommendations according to dry matter production and nutrients uptake rates during each crop growth stage has the potential of increasing the final yield. Both efficiency and production may be optimized by N fertilization practices that maximize plant growth rates early and during the growing season, while sustaining an adequate plant canopy (Westermann and Kleinkopf, 1985).

The K uptake data illustrate significant increase with inoculation by biofertilizers and high rats of NP fertilization under the two types of soils, reflecting the importance of application of K fertilizers under the role of balanced fertilization.

III. Soil Macronutrient Availability

Main effect:

Soil macronutrients (NPK) availability as affected by mineral fertilization and biological inoculation (combined analysis for two seasons) were presented in Table (7). The data indicated that availability of nutrient related to soil type, inoculation treatment and fertilization type and rate. The results showed higher levels of N, P and K in calcareous soil than sandy soil as a result of initial state analysis (Table 1a), whereas inoculation with microorganisms [nitrogen fixing bacteria (NFB) and phosphate dissolving bacteria (PDB)] generally increased level of nutrients availability comparing with uninoculated treatments. This may due to increase soil microbial biomass (SMB) as this parameter reflects a soil's ability to store and cycle nutrients and organic matter, and has a high turnover rate relative to the total soil organic matter (Gregorich *et al.* 1994 & 1997). Also type and rate of mineral fertilization affect on N and P availability levels at the end of the two growing seasons, the results indicated that increasing level of fertilization increased residual nutrients in the soil.

Interaction effects:

The interaction of tested soil type, inoculation and fertilization indicating the importance of managing all parameters at the same time to insure fertility build up and sustainability. The results showed that under sandy and calcareous soils inoculation with microorganisms increased availability of N, P and K nutrient under all alternatives of NP rates comparing with the control treatment (uninoculated).

Table 7. The concentrations of N, P and K in soil samples as affected by mineral fertilization and biological inoculation (combined analysis for two seasons of 2004 and 2005)

Soil Type	Bio Inoc.	NP Rates	N, mg kg^{-1}	P, mg kg^{-1}	K, mg kg^{-1}
Sandy			39.02 b	19.46 b	115.70 b
Calcareous			44.90 a	24.80 a	234.50 a
	Without		38.03 b	17.91 b	164.32 b
	With		45.60 a	26.35 a	197.23 a
		LL	38.10 b	18.32 d	177.92 a
		LH	38.43 b	23.89 b	169.56 c
		HL	45.50 a	20.37 c	177.85 b
		HH	45.81 a	25.95 a	175.13 a
Sandy	Without	LL	31.50	12.80	114.3
		LH	28.62	13.12	108.6
		HL	43.50	13.84	110.9
		HH	40.25	16.60	112.5
	With	LL	36.80	20.46	121.40
		LH	37.50	31.08	122.50
		HL	46.50	18.25	118.50
		HH	47.60	29.50	116.80
Calcareous	Without	LL	38.50	16.59	192.60
		LH	39.80	22.65	188.85
		HL	41.50	22.48	200.50
		HH	42.80	25.20	195.60
	With	LL	45.60	23.42	283.30
		LH	47.80	28.70	258.30
		HL	50.50	26.90	281.50
		HH	52.60	32.50	275.60
LSD 0.05			4.25	3.17	5.33

Bio Inoc. = bio-fertilizer inoculation, NP rates = Nitrogen and Phosphorus fertilization rates,
L = low, H =high
LL= low N and low P fertilization rate, LH= low N and high P fertilization rate
HL= high N and low P fertilization rate, HH= high N and high P fertilization rate

Awad and Hegazi (2002) on potato, Awad *et al.* (2004) on alfalfa and wheat, Abd El-Latif *et al.* (2002) on chamomile plants and other researchers indicated that, NP fertilization under inoculation with biofertilizers produced higher production and decreased nitrate content. From the commercial viewpoint the produce was good and had the value-added factor of the low nitrate. The latter is an extremely remarkable factor because the European Union is drafting a directive on the allowable NO_3 content in vegetables and other medicinal plants, which increase the chance of Egyptian growers to export additional amounts to EU countries and safe environment from NO_3^- leaching.

CONCLUSION

It could be concluded that, the growth and yield of rosemary plants i.e. (plant height, number of main branches, fresh and dry weight per plant) as well as oil yield per plant were higher in plants given biofertilization plus mineral fertilization (NP) at the rate of HL [(high nitrogen + low phosphorous) equals to (67kg N/fed. + 15kg P_2O_5/fed)] and grown in calcareous soil than of those in sandy soil.

The responses of different essential oil components to the interaction effects between the three tested factors were in different trends, but there were significant differences between most treatments.

Also, generally, N, P and K plant uptake as well as soil macronutrients (NPK) availability increased in plants grown in calcareous soil with biofertilization and (NP) fertilization at the rate of HH equals to [(67kg N/fed + 20kg P_2O_5/fed) and / or HL equals to (67kg N/fed + 15kg P_2O_5/fed)], respectively.

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الملخص العربى

تأثير التسميد الحيوى والمعدنى على نباتات حصى البان النامية فى الأراضى الرملية والجيرية

أمل جابر سالم[1] ــ أحمد محمد عوض[2] ــ طه أحمد طه عبد اللطيف[3]

١، ٣ قسم بحوث النباتات الطبية والعطرية ــ معهد بحوث البساتين ــ مركز البحوث الزراعية

٢ قسم بحوث خصوبة الأراضى وتغذية النبات ــ معهد بحوث الأراضى والمياه والبيئة ــ محطة البحوث الزراعية بالنوبارية ــ مركز البحوث الزراعية

أجريت تجربتان أصص فى محطة بحوث بساتين الصبحية بالإسكندرية خلال موسمى ٢٠٠٤ و٢٠٠٥ لدراسة تأثير السماد الحيوى مع معدلات مختلفة من الأسمدة المعدنية نيتروجين وفوسفور على

النمو والإنتاجية والنسب المئوية للزيت الطيار ومكوناته بالإضافة إلى تقدير مدى امتصاص النبات للعناصر الكبرى (النيتروجين والفوسفور والبوتاسيوم) وذلك فى نباتات حصى البان النامية فى نوعين من الأراضى (الرملية والجيرية). وقد صممت هذه التجربة بالتصميم الإحصائى بنظام القطع المنشقة مرتين. شُغلت القطع الرئيسية بنوعين من التربة (التربة الرملية والتربة الجيرية) وفى القطع تحت الرئيسية معدلين من السماد الحيوى (نباتات مسمدة ونباتات غير مسمدة) وأُضيف السماد الحيوى (نيتروبين وفوسفورين) بنسبة (١ : ١، وزن:وزن). والقطع تحت تحت الرئيسية اشتملت على أربعة معدلات مختلفة من الأسمدة المعدنية [(نيتروجينى وفوسفورى (NP)] وأُضيفت الأسمدة المعدنية بمعدلين معدل منخفض (L) ومعدل مرتفع (H) [تعادل ٥٠ و٦٧ كجم (N) للفدان]، [١٥ و ٢٠ كجم (P_2O_5) للفدان] على الترتيب. وقد عرفت الأربعة معدلات من التسميد (NP) كالآتى: LL, LH, HL, HH. وأشارت النتائج بصفة عامة إلى أن جميع صفات النمو الخضرى بمعنى طول النبات وعدد الفروع الرئيسية والوزن الطازج والجاف للنبات بالإضافة إلى إنتاج الزيت للنبات قد أعطى أعلى النتائج فى النباتات النامية فى التربة الجيرية وسُمدت بالسماد الحيوى مع السماد المعدنى NP عند المعدل HL (نيتروجين مرتفع + فوسفور منخفض) وتبع بالمعدل HH (نيتروجين مرتفع + فوسفور مرتفع). وسُجلت أقل النتائج فى هذا الخصوص على النباتات النامية فى الأرض الرملية واستقبلت المعدل LL (نيتروجين منخفض + فوسفور منخفض) وبدون تسميد حيوى. باستخدام التحليل الكروماتوجرافى (GC-MS) أمكن التعرف على ١٦ مكون فى الزيت الطيار لحصى البان (الكامفور والبورينول والفيربينون تعتبر الثلاث مكونات الأساسية والرئيسية فى الزيت الطيار). وهناك مكونات أخرى هامة مثل ١,٨ سينيول ولينالول والفاـــتربينيول واسيتات البرونايل وبيتاميرسين وكامفين. وباقى المكونات وجدت بكميات صغيرة. معظم المكونات تأثرت إحصائياً بمعاملات التداخل بين الثلاث عوامل تحت الدراسة وأن كان كل مكون قد استجاب للمعاملات المطبقة بطريقة مختلفة. فقد كان أعلى محتوى من الكامفور تم الحصول عليه فى النباتات المسمدة بالتسميد الحيوى + معاملة LL فى التربة الرملية. بينما أعلى نسبة مئوية للبرينيول سجلت فى النباتات المنزرعة فى التربة الجيرية والمسمدة بالسماد الحيوى + المعاملة (HL). وأفضل النتائج بالنسبة لمكون فيربينون كانت فى النباتات المنزرعة فى التربة الرملية ومسمدة بالسماد الحيوى + المعامل (HL). وبصفة عامة قد أوضحت النتائج أن امتصاص النباتات من NPK وأيضاً العناصر الكبرى الميسرة (المتاحة) بالتربة (NPK) قد تحسنت فى النباتات النامية فى التربة الجيرية والمسمدة بالتسميد الحيوى + تسميد معدنى عند المعدل (HH) و / أو (HL).