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Effect of Vermicompost and Calcium silicate to reduce the Soil Salinity on Growth and Oil determinations of Marjoram plant

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Abstract: This study was carried out during the two successive growing seasons of 2012/2013 and 2013/2014 at the farm of Soils, Water and Environ. Res. Inst., Agric., Res. Center in Sahl El-Hossynia Agric. Res. Station Farm in EL-Sharkia Governorate; Egypt, to investigate effects of vermicompost at 0,6,8 and 10 m^3/fed. on growth, essential oil %, essential oil components and chemical compotition of marjoram (Majorana hortensis L.) at four levels of calcium silicate at (0,10,15and 20 kg/fed).

Gradual and significant increases in plant height, number of branches, fresh & dry weights per plant, essential oil percentage, and essential oil yield per plant were recorded with vermicompost at 8 m^3/fed. Also, 8 m^3/fed. vermicompost produced the highest percentages of main components of the essential oil(Linalool, Terpinen-4-ol,β-Phyllandrene and Limonene).While the highest percentages of Sabinene and α-Phyllandrene resulted under the effect of 10m^3/fed vermicompost. Also, vermicompost treatments increased total carbohydrates%, nitrogenase and dehydrogenase activities and nutrient contents of N, P, K and Ca. While reduced the Na and proline content compared to the control.

As for calcium silicate ($CaSiO_3$**)** enhanced the above mentioned traits of growth and essential oil. The highest percentages of Linalool, Terpinen-4-ol, β-Phyllandrene and Limonene were recorded in essential oil extracted from plants treated with $CaSiO_3$ at 15 kg/fed. While the highest percentages of Sabinene and α-Phyllandrene resulted under the effect of 20 kg/fed $CaSiO_3$ comparing to control. On the other hand, the lowest percentages of Linalool, Terpinen-4-ol and β-Phyllandrene resulted under the treatment with 15 kg/fed $CaSiO_3$. In addition that, the treatment of $CaSiO_3$ at 15kg/fed. increased total carbohydrates%, nitrogenase and dehydrogenase activities and nutrient contents of N, P, K and Ca but decreased Na content and proline content compared to the control.

Interaction treatments of vermicompost at the rate of 8 m^3/fed., combined with 15 kg/fed. $CaSiO_3$ increased significantly in the above mentioned traits (plant growth, essential oil determinations). Also, the same treatment gave the highest values of the Terpinen-4-ol and Limonene. While the combination between 8 m^3/fed vermicompost and $CaSiO_3$ 20 kg/fed showed the highest values of the β-Phyllandrene content. Also, the highest values of the Linalool was obtained in the plants which treated by 10 m^3/fed vermicompost and $CaSiO_3$ at 15 kg/fed. In addition that, the highest total carbohydrates%, nitrogenase and dehydrogenase activities and nutrient contents of N, P, K and Ca were recorded with 8 m^3/fed. of vermicompost and $CaSiO_3$ at 15 kg/fed. On the opposite, the all tested treatments gave the lowest proline and Na content compared to the control.

Key words : *Majorana hortensis L.*, vermicompost, calcium silicate, Terpinen-4-ol, β-Phyllandrene chemical composition and essential oil components.

Introduction

Soil salinity is one of the most significant abiotic stresses among the adverse environmental factors on agricultural land sector[1]**.** It can be described as high ion concentration in the soil solution, a condition that restricts plant growth, due to high osmotic potential of the solution that inhibits plant water uptake. Under this scenario, water availability is reduced and there will be a need for resource optimization through the adoption of strategies that counteract for increasing demand of food production, shrinking of agriculture land, lack of water resources and global climate changes. High salt content also affects the physiology of plants, both at the cellular as well as whole plant levels[2]**.**

High salt levels in soil result in hyper-osmolarity, ion disequilibrium, nutrient imbalance, and production of reactive oxygen species (ROS), leading to plant growth retardation through molecular damage[3]**.** Much salinity resulted from NaCl cause osmotic pressure of external solution become more than osmotic pressure of plant cells which is require to regulating osmotic pressure to preventing dehydration by plant cells. Uptake and transform of nutrition ions such as potassium and calcium, by excess sodium would make problems. High Na^+ and Cl^- rates would cause to direct toxic effects on enzymatic and membranous systems[4]**.**

Marjoram (*Majorana hortensis* L.), Family Lamiaceae (labiatae) is indigenous to Mediterranean countries and was known to the ancient Egyptians, *Majorana hortensis* is cultivated as culinary herbs and garden plants as well, it is valued as a medicinal plant for improving antiseptic, antispasmodic, carminative, stimulant, and expectorant and nerve tonic rheumatic habits, stimulates moreover the blood circulation, nerve habits, muscle pain, muscle rheumatism, arthritis, flu, cold, bronchitis, stucked cough, asthma, hiccups, slow digestion, bad appetite, menstruation problems, low blood pressure, worm infections, cramps, mould infections[5]. In addition it is used in many industries. The major components of Marjoram oil are α- Pinene, β-Pinene, limonene, 1.8 cineole, linalool, terpinene-4-ol, α-Terpinene and eugenol. Some of these components are used for scenting cosmetics and others are used for flavoring pharmaceuticals such as D-limonene and Linalool [6].

Vermicompost is an ideal organic manure for better growth and yield of many plants. It can increase the production of crops and prevent them from harmful pests without polluting the environment. Application of vermicompost increased seed germination, stem height, number of leaves, leaf area, leaf dry weight, root length, root number, total yield, number of fruits/plant, chlorophyll content, pH of juice, TSS of juice, micro and macro nutrients, carbohydrate (%) and protein (%) content and improved the quality of the fruits and seeds[7]. Vermicompost is not only valuable compost and a biocontrol agent but also an effective way of solid waste management. In terms of improving soil health, vermicomposting is better than other ways of managing solid wastes like traditional composting and land filling. Land filling is expensive and may lead to leaching of toxic compounds[8]**.**

The vermicompost is the product of composting using various worms, usually red wigglers, white worms, and other earthworms to create a heterogeneous mixture of decomposing vegetable or food waste, bedding materials, and vermicast. The vermicompost is a management practice that may contribute to sustainable agroecosystems by making them less dependent on inorganic fertilizers[9]**.** Vermicompost is rich in humus, phosphorus, potassium and in micronutrients (Zn, Cu, Fe, Mn), exchangeable calcium and has high microbiological potential[10] **.**

Silicon (Si) is one of the most abundant elements found in the earth's crust, but is mostly inert and only slightly soluble. Although Si has not been classified as an essential element for higher plants, it has been shown to be beneficial for plant growth[11]**.** Si has a key role in improving crops' abilities to withstand biotic and abiotic stresses, such as disease and pest resistance, alleviation of heavy metal (Al, Mn, and Fe) toxicities, salinity resistance, resistance to drought stress, and alleviation of freezing stress[12]**.** The addition of Si can increase water use efficiency by reducing leaf transpiration and water flow rate in the xylem vessel[13]. Si benefits in maize have been related to its effect on the improving of population quality, effective leaf area, and photosynthetic efficiency as well as the delay of leaf senescence[14]**.**

Silicon fertilization impacts also the development of secondary and tertiary cells of the endodermis, thus allowing better root resistance in dry soils and a faster growth of roots. In addition,[15] observed that Si enhanced the uptake of major essential elements by various grasses exposed to a water deficit. The effects of Si in plants exposed to drought have also been observed at the physiological or metabolic level[16] observed that Si increased antioxidant defenses and therefore maintained physiological processes such as photosynthesis. In the case of saline soils, Si increased the activity of antioxidant enzymes, decreased plasma membrane permeability, and increased root activity, which allowed for a better absorption of nutrients[17].

Bacteria *(Bacillus circulans)* of the genus *Bacillus* are common soil microorganisms that play an important role in silicate biodegradation during the process of rock disintegration by producing solubilizing material such as, organic acids which stimulated plant growth and minerals uptake such as N, P and K [18]. Plant growth promoting rhizobacteria (PGPR) can play an essential role for helping plants to establish and grow under nutrient different conditions. Plant growth promotion by PGPR is due to root hair proliferation, root hair deformation and branching, increase in seedling emergence, increase leaf surface area, vigor, biomass, increasing indigenous, plant hormones levels, mineral and water uptake, promoted accumulation of carbohydrates and yield in various plant species [19]. Symbiotic nitrogen-fixing bacteria include Cyanobacteria have been shown to attach to the root and efficiently colonize root surfaces[20].

Considering that salinity is a major problem in the Egypt, the objective of this study was to evaluate the potential for mitigation of salt stress in marjoram plant by application of vermicompost and calcium silicate.

Materials and Methods

Two Field experiments were conducted in clay soil at Sahl El-Hossynia Agric. Res. Station Farm in EL-Sharkia Governorate; Egypt to study the effect of vermicompost and calcium silicate treatments on marjoram cultivated in saline soil. Some physical and chemical characteristics of the studied soil and irrigation water are presented in Table (A&B) respectively, according to[21].

Table (A) The main physical and chemical properties analyses of experimental soil

Course sand (%)	**Fine sand (%)**	**Silt(%)**	**Clay(%)**		**Soil Texture**		**OM(%)**		**CaCO$_3$(%)**
2.85	38.37	12.14	46.64		Clay		0.59		10.33
pH (1:2.5)	EC*(dSm^{-1})	Cations (meq/l)					Anions (meq/l)		
		Ca^{++}	Mg^{++}	Na^{+}	K^{+}		HCO$^{-}_{3}$	Cl^{-}	SO$^{--}_{4}$
8.34	15.38	10.85	14.63	175	1.30		10.29	172	22.33
Available Macronutrients (mg/kg)			Available Micronutrients (mg/kg)						
N	P	K	Fe	Mn	Zn	Cu			
30	3.55	196	1.73	2.33	0.72	0.080			

Table (B). Chemical analysis of irrigation water.

pH (1:2.5)	**EC (dSm^{-1})**	**Sodium Adsorption Ratio(SAR)**				
6.25	2.21	4.55				
Macro-micronutrients (mg/L)						
NO$_3$ -N	NH$_4$ -N	P	K	Fe	Mn	Zn
20.04	10.52	2.88	6.83	1.90	2.20	0.77

The experiments were carried out during two successive seasons 2012/2013 and 2013/2014, on marjoram (*Majorana hortensis* L.). The marjoram seeds that used in this study were obtained from Medicinal and Aromatic Plants Research Department, Dokki, Giza. They were sown on November 15th of the two seasons in a peat moss medium in the nursery beds. On 15th March, 2012 and 2013 in the first and second seasons, respectively, when the seedlings were 8-10 cm in height, with 6-8 leaves, were transplanted in plots 2.0× 3 m with 3 rows/ plot in hills at 30 cm apart within the same row. Each plot contained 21 plants. The experimental design was a split plot design with three replicates. vermicompost was set at the main plots at 0, 6, 8 and 10 m^3/fed. and calcium silicate was set at the sub plots at 0, 10, 15 and 20 kg/fed. So, the experiment implicated 16 interaction treatments.

The vermicompost fertilizer (Vcom) was obtained from the Egyptian company for Waste Recycling. It was added in one dose; at rates were 0, 6, 8 and 10 m^3/fed. Which was incorporated into the soil to a depth of 5-10 cm, two weeks before planting date (on 1st March 2012 and 2013, in the first and second seasons, respectively). The consists of the vermicompost fertilizer are presented in Table (C), while the physical and chemical characteristics of the vermicompost fertilizer are presented in Table (D) described by [22].

Table (C): consists of the vermicompost fertilizer

Vermicompost earthworm	Names of bacteria	Beneficial traits
Eudrilus sp**.**	Free-living N2 fixers: *Azospirillum ipoferum* *Azotobacrer chroococcum* *Nitrosomonas* *Nitrobacter* *Bacillus circulans*	Plant growth promotion by nitrification and silicate Solubilization

Table (D): Physical and chemical characteristics of the used vermicompost fertilizer

The character	1st season	2ed season
Weight of 1 m^3 (kg)	350	375
Moisture content (%)	35	42
Organic Matter (%)	10.54	11.20
Organic Carbon (%)	15.47	12.75
Total N (%)	2.1	1.9
C:N ratio	20.4:1	18.6:1
Total P (%)	1.5	1.7
Total K (%)	1.26	1.18
Fe (ppm)	1231	1240
Mn (ppm)	110	104
Zn (ppm)	24.9	18.3
EC	2.55	3.01
pH	7.1	7.2

Calcium silicate ($CaSiO_3$**)** was contained: 24.45% Si_2 O, 20.56% Al_2O_3, 9.82% S, 1.31% CaO, 0.34% TiO_2, 0.18% MgO and 0.36% F_e2O_3.It was obtained from "El-Ahram Company", El Talbia, Faisal St. area, El-Giza Governorate. The ($CaSiO_3$**)** treatments were added in one dose, which was incorporated into the soil to a depth of 15-20 cm two weeks before transplanting seedlings, at the same time of vermicompost fertilizer.

Recorded Data:

Each season, two cuts were taken from the plants on 15th May and 20th July (2012and 2013). The plants were harvested by cutting the vegetative parts 10-15 cm above the soil surface. The following data were recorded for each cut:

Plant growth and herb yield:

Vegetative growth records were implicated plant height (cm), number of branches/plant, fresh and dry weights (g)/plant.

Essential oil determinations:

Essential oil was extracted from fresh herb samples of each treatment by distillation according to the method of [23], and oil percentages were recorded. Then, oil yield per plant was calculated. Also, Samples of the extracted essential oil of the second cut of the second season 2013 were subjected to gas-liquid chromatographically (GLC) analysis as described by [24] to determine percentages of the main components of the volatile oil.

Enzymatic activates

Nitrogenase activity (N_2-ase) in rhizosphere zone was measured as described by [25]**.** The dehydrogenase activity was also determined according to[26].

Leaves chemical analysis:

Determination of total carbohydrates and proline

Total carbohydrates percentage in dry leaves was determined using the method described by [27]**.** While proline content in fresh leaves was determined according to[28]**.**

Determination of minerals content

Determination of (P, K, Ca and Na) which were determined in dry leaves using Atomic Absorption Spectrophotometer (SP 1900) as described by [29]**.** Total nitrogen was determined in the same solution using microkjeldahl methods according to[30] **.**

Statistical Analysis

The collected data were subjected to statistical analysis according to[31]**.** Mean separation was done using least significant difference test at 5% level (LSD 0.05). In addition, the general mean of the main effect of 2 cuts for vermicompost and calcium silicate were mathematically calculated and presented in the results.

Results

Plant Vegetative growth characteristics:

1-Plant height

Significant differences were noticed respecting marjoram plant height due to vermicompost and calcium silicate treatments and their interactions over the two cuts during the two tested seasons (Table 1).

Application of vermicompost at all tested concentrations resulted in significant increases in plant height comparing to unstreated control plants. In general, plant height was increased as vermicompost level increased from 0 up to 10 m^3/fed. While, no more significant increases were recorded by increasing vermicompost level from 8 to 10 m^3/fed. Accordingly, the tallest plants (40.56 and 32.00 cm in the first and second cuts, respectively) were those supplemented with vermicompost (8 m^3/fed). A similar trend was detected in the second season, with the tallest plants (with mean heights of 43.92 and 33.55 cm in the first and second cuts, respectively) resulting from the same rate of vermicompost. This was confirmed during the two cuts of the two tested seasons and was reflected on the grand mean of the two cuts which represented vermicompost effects. In both seasons, the lowest grand mean plant height (18.88 and 20.28 cm in the first and second seasons, respectively) was recorded in plants receiving no vermicompost treatment, whereas the highest grand mean plant height (36.28 and 38.74 cm in the two seasons, respectively) was that of plants supplied with 8 m^3/fed of vermicompost. Similar results were previously reported by[32] on geranium,[33] on fennel and[34] on barley.

The data in Table (1) also show that the calcium silicate ($CaSiO_3$**)** treatments had a considerable effect on the height of marjoram plants. In both cuts of the first season, application of the different $CaSiO_3$ treatments gave significantly taller plants than the control (which had mean heights of 23.97and 19.58 cm in the first and second cuts, respectively). Moreover, raising the $CaSiO_3$ application rate caused a gradual increase in plant height, The rate of $CaSiO_3$ (15 kg/fed) gave the tallest plants in both cuts of the first season (42.57 and 33.02 cm in the first and second cuts, respectively). The data recorded in the second season Table (1) confirmed those of the first season; all $CaSiO_3$ treatments gave significantly taller plants (in two cuts) compared to the control, which gave mean values of 27.36 and 20.81 cm in the first and second cuts, respectively. As in the first season, plant height was increased steadily with increasing the $CaSiO_3$ application rate, and the tallest plants (with heights of 45.71 and 34.92 cm in the first and second cuts, respectively) were those supplied with (15 kg/fed). The grand mean values recorded for the effect of $CaSiO_3$ treatments on plants height in the two seasons showed a similar trend. In both seasons, the calculated grand mean values were increased steadily with raising the $CaSiO_3$ application rate. Accordingly, the highest grand mean values (37.80 and 40.32 cm in the first and second seasons, respectively) were obtained with the same $CaSiO_3$ application rate. These data are in agreement with the conclusions reached by [35] on barley.

Regarding the interaction between the effects of vermicompost and $CaSiO_3$ treatments on height of marjoram plants, it is clear from the data in the Table (1) that in two cuts of the first season, plants receiving most of the vermicompost and $CaSiO_3$ treatment combinations were significantly taller than untreated control plants. The tallest plants in two cuts of the first season were those supplied with vermicompost at the rate of 8 m^3/fed combined with $CaSiO_3$ at 15 kg/fed being 55.45 and 43.73 cm in the first and second cuts, respectively, followed by plants fertilized using a combination of vermicompost at the rate of 10 m^3/fed combined with $CaSiO_3$ at 15 kg/fed (giving values 53.14 and 40.45cm in the first and second cuts, respectively). On the other hand, the shortest plants were those receiving no vermicompost or $CaSiO_3$ treatments. The results recorded in the second season (Table 1) confirmed those obtained in the first season. Combining the rate of vermicompost 8 m^3/fed with $CaSiO_3$ at 15 kg/fed gave the tallest plants (with heights of 58.30 and 45.77 cm in the first and second cuts, respectively). The recorded values were generally decreased by reducing the application rates of vermicompost and/or $CaSiO_3$. Thus, the shortest plants in the two cuts being 19.60 and 15.22 cm in the first and second cuts, respectively, were those receiving no vermicompost or $CaSiO_3$ treatment.

2- Number of branches/plant

Data in Table 2 show positive response and significant differences in marjoram growth in term of number of branches/ plant due to vermicompost and calcium silicate treatments and their interactions over the two cuts of two seasons.

Significant increases in number of branches/plant were recorded in vermicompost treated plants comparing to control. The highest number of branches/plant during the two cuts of the two seasons were resulted in plants treated with 8 m^3/fed vermicompost (with mean 15.03 and 16.24 for the first season, 16.81 and 18.39 for the second season, in the first and second cuts, respectively). There were no significant differences in this respect between 8 or 10 m^3/fed vermicompost. This in turn exhibited in the general mean during the two seasons (with 15.64 and 17.60 in the first and second seasons, respectively). These results are in harmony with those reported by[32] on geranium.

As for calcium silicate ($CaSiO_3$**)**, data of Table 2 clear that $CaSiO_3$ application, generally, resulted significant increases in number of branches/plant during the two cuts of the two seasons comparing to control plants. The highest number of branches/plant was resulted in the plants whivh treated with $CaSiO_3$ at15 kg/fed (with values of 15.25 and 16.49 for the first season, 17.22 and 18.85 for the second season, in the first and second cuts, respectively). The increments in number of branches/plant over than control in general mean of the two cuts were 27.57 and 34.52% in the first and second seasons, respectively. These results are in harmony with those reported by[35] on barley.

Table (1): Effect of vermicompost and calcium silicate to reduce the soil salinity on the plant height (cm) of *Majorana hortensis* L. during 2012 and 2013 seasons.

Treatment Vermicompost (Vcom)	First - season												Second - season										
	Calcium silicate ($CaSiO_3$), kg/fed																						
	First cut					Second cut					Grand Mean of (Vcom)	First cut					Second cut					Grand Mean of (Vcom)
	0	10	15	20	Mean of Vcom	0	10	15	20	Mean of Vcom		0	10	15	20	Mean of Vcom	0	10	15	20	Mean of Vcom	
0 m^3/fed	17.43	20.66	21.40	23.52	**20.75**	14.73	16.50	17.35	19.44	**17.01**	**18.88**	19.60	21.52	23.48	25.64	**22.56**	15.22	17.46	19.25	20.08	**18.00**	**20.28**
6 m^3/fed	24.17	34.15	40.30	49.63	**37.06**	20.18	26.75	30.54	38.55	**29.01**	**33.04**	27.45	37.56	44.23	53.15	**40.60**	21.12	28.20	32.50	39.42	**30.31**	**35.46**
8 m^3/fed	25.83	37.72	55.45	43.25	**40.56**	21.07	28.48	43.73	34.73	**32.00**	**36.28**	30.16	40.17	58.30	47.06	**43.92**	22.36	30.64	45.77	35.44	**33.55**	**38.74**
10 m^3/fed	28.45	46.86	53.14	30.65	**39.78**	22.33	36.83	40.45	23.77	**30.85**	**35.32**	32.23	50.14	56.84	34.22	**43.36**	24.55	37.53	42.16	25.68	**32.48**	**37.92**
Mean($CaSiO_3$)	**23.97**	**34.85**	**42.57**	**36.76**		**19.58**	**27.14**	**33.02**	**29.12**			**27.36**	**37.35**	**45.71**	**40.02**		**20.81**	**28.46**	**34.92**	**30.16**		
<u>L.S.D (0.05)</u>																						
Vcomp	7.872					5.240						8302					6.776					
$CaSiO_3$	6.110					4.036					8.005	6.451					5.643					8.407
Vcomp x$CaSiO_3$	5.014					3.324						6.553					6.031					

Grand mean of Calcium silicate ($CaSiO_3$)

	First - season				Second - season			
	0	**10**	**15**	**20**	**0**	**10**	**15**	**20**
	21.78	31.00	37.80	32.94	24.09	32.91	40.32	35.09
<u>LSD(0.05)</u> $CaSiO_3$	7.150				7.753			

Table (2): Effect of vermicompost and calcium silicate to reduce the soil salinity on the number of branches/plant of *Majorana hortensis* L. during 2012 and 2013 seasons.

Treatment Vermicompost (Vcom)	First - season											Second - season										
	Calcium silicate ($CaSiO_3$), kg/fed																					
	First cut					Second cut					Grand Mean of (Vcom)	First cut					Second cut					Grand Mean of (Vcom)
	0	10	15	20	Mean of Vcom	0	10	15	20	Mean of Vcom		0	10	15	20	Mean of Vcom	0	10	15	20	Mean of Vcom	
0 m^3/fed	10.02	10.33	11.00	11.45	**10.70**	11.20	11.55	12.13	12.60	**11.87**	**11.29**	11.00	11.50	12.22	12.60	**11.83**	11.45	12.50	13.07	13.45	**12.62**	**12.23**
6 m^3/fed	12.11	13.46	15.19	16.44	**14.30**	13.17	15.00	16.07	17.82	**15.52**	**14.91**	13.10	15.13	16.40	19.10	**15.93**	14.20	17.00	18.00	20.42	**17.41**	**16.67**
8 m^3/fed	12.53	14.10	17.64	15.86	**15.03**	13.45	15.55	19.40	16.55	**16.24**	**15.64**	13.42	16.02	20.75	17.06	**16.81**	14.81	17.33	22.56	18.85	**18.39**	**17.60**
10 m^3/fed	13.02	16.11	17.15	13.16	**14.86**	14.00	17.25	18.35	14.35	**15.99**	**15.43**	14.00	18.63	19.50	14.25	**16.60**	15.30	19.30	21.77	16.50	**18.22**	**17.41**
Mean($CaSiO_3$)	**11.92**	**13.50**	**15.25**	**14.23**		**12.96**	**14.84**	**16.49**	**15.33**			**12.88**	**15.32**	**17.22**	**15.75**		**13.94**	**16.53**	**18.85**	**17.31**		
L.S.D (0.05)																						
Vcomp	2.435					2.415						2.542					4.021					
$CaSiO_3$	1.304					1.882					2.451	1.624					2.746					3.835
Vcomp x $CaSiO_3$	3.074					2.757						2.873					3.721					

Grand mean of Calcium silicate ($CaSiO_3$)

	First - season				Second - season			
	0	10	15	20	0	10	15	20
	12.44	14.17	15.87	14.78	13.41	15.93	18.04	16.53
LSD(0.05) $CaSiO_3$	1.617				2.441			

As for vermicompost and $CaSiO_3$ interaction treatments, data in Table 2 reflected that number of branches/plant followed similar trend as in plant height. Since, subjected plants to interaction treatments of vermicompost at the rate of 8 m^3/fed or 10 m^3/fed combined with $CaSiO_3$ at 15 kg/fed produced the highest number of branches/plant during the two cuts of the both seasons with no significant differences between the two interaction treatments in several cases. On the other hand, the lowest number of branches/plant in the two cuts (with 10.02 and 11.20 for the first season, 11.00 and 11.45 for the second season, in the first and second cuts, respectively) were those receiving no vermicompost or $CaSiO_3$ treatment.

3-Fresh and dry weights/plant:

The data on the (Table 3&4) indicated that in the first season, fresh and dry weights/plant increased by increasing the rate of vermicompost. Moreover, the vermicompost at 8 m3/fed was the most effective rate for increasing the fresh and dry weights/plant (48.40 and 34.64 g/plant for the fresh weight, 16.53 and 12.11 g/plant for the dry weight in the first and second cuts, respectively, with grand mean 41.52 and 14.32 g/plant for fresh and dry weights, respectively), while the unfertilized plants gave significantly lower fresh and dry weights/plant in two cuts (24.12 and 19.16 g/plant for the fresh weight, 8.29 and 6.76 g/plant for the dry weight in the first and second cuts, respectively, with grand mean 21.64 and 7.53 g/plant for fresh and dry weights, respectively). Also, the results in Table (3&4) show that in the second season, the data followed a similar trend to that obtained in the first season. These results are in harmony with that presented by[32] on geranium, [33] on fennel and[34] on barley.

Regarding the effect of calcium silicate ($CaSiO_3$**)** on the fresh and dry weights/plant, the data in Table (3&4) show that in two cuts of the first season, unfertilized plants gave significantly lower fresh and dry weights/plant (29.63 and 22.71 g/plant for the fresh weight, 10.17 and 7.97 g/plant for the dry weight in the first and second cuts, respectively, with grand mean 26.17 and 9.07 g/plant for fresh and dry weights, respectively), than the plants receiving any of the tested fertilization treatments. Raising the application rate of $CaSiO_3$ from 0 to 20 kg/fed caused a steady increase in the fresh and dry weights/plant. Accordingly, $CaSiO_3$ was most effective when it was applied at the rate of 15 kg/fed giving the highest fresh and dry weights in the two cuts (49.91 and 36.08 g/plant for the fresh weight, 17.08 and 12.55 g/plant for the dry weight in the first and second cuts, respectively, with grand mean 43.00 and 14.82 g/plant for fresh and dry weights, respectively), followed by the rate of 20 kg/fed. In the second season, a similar trend was detected. The recorded values (Table 3&4) showed a steady increase in fresh and dry weights/plant with raising the $CaSiO_3$ application rate from 0 to 20 kg/fed. Accordingly, $CaSiO_3$ was most effective when applied at the rate 15 kg/fed. These results are in harmony with that presented by[32] on geranium.

The results in Table (3&4) show that in the both seasons, a significant interaction was detected between the effects of the vermicompost and $CaSiO_3$ treatments on fresh and dry weights/plant. Plants receiving no vermicompost and $CaSiO_3$ treatments gave the lowest values of fresh and dry weights/plant (19.30 and 16.68 gm fresh weight/plant, 6.75 and 5.82 gm dry weight/plant for the first season, 21.38 and 17.73 gm fresh weight/plant, 7.24 and 6.57 gm dry weight/plant for the second season in the first and second cuts, respectively,). On the other hand, plants receiving vermicompost at 8 m^3/fed plus $CaSiO_3$ at 15 kg/fed gave the highest fresh weight (65.42 and 45.53 g/plant for the first season, 73.55 and 54.66 g/plant for the second season in the first and second cuts, respectively), while the highest dry weight (22.27 and 16.26 g/plant for the first season, 25.00 and 18.63 g/plant for the second season in the first and second cuts, respectively) followed by plants fertilized with vermicompost at 10 m^3/fed plus $CaSiO_3$ at 15 kg/fed. Among plants receiving both vermicompost and $CaSiO_3$ treatments, those supplied with vermicompost at 10 m^3/fed combined with $CaSiO_3$ at 20 kg/fed gave the lowest fresh weight (37.46 and 28.66 g/plant for the first season, 45.60 and 30.07 g/plant for the second season in the first and second cuts, respectively), while the dry weight (12.76 and 10.07 g/plant for the first season, 15.27 and 10.22 g/plant for the second season in the first and second cuts, respectively).

Table (3): Effect of vermicompost and calcium silicate to reduce the soil salinity on fresh weight/plant (g) of *Majorana hortensis* L. during 2012 and 2013 seasons.

Treatment Vermicompost (Vcom)	First - season											Second - season										
	Calcium silicate ($CaSiO_3$), kg/fed																					
	First cut					Second cut					Grand Mean of (Vcom)	First cut					Second cut					Grand Mean of (Vcom)
	0	10	15	20	Mean of Vcom	0	10	15	20	Mean of Vcom		0	10	15	20	Mean of Vcom	0	10	15	20	Mean of Vcom	
0 m^3/fed	19.30	23.43	25.58	28.17	**24.12**	16.68	18.12	20.50	21.32	**19.16**	**21.64**	21.38	25.12	30.70	33.25	**27.61**	17.73	20.56	21.48	23.52	**20.82**	**24.22**
6 m^3/fed	30.52	40.34	47.30	57.80	**43.99**	23.34	30.70	34.64	40.14	**32.21**	**38.10**	36.44	49.40	55.24	65.48	**51.64**	24.12	32.14	38.34	48.63	**35.81**	**43.73**
8 m^3/fed	33.41	44.50	65.42	50.25	**48.40**	24.18	32.43	45.53	36.40	**34.64**	**41.52**	40.25	52.16	73.55	59.15	**56.28**	26.33	35.58	54.66	41.62	**39.55**	**47.92**
10 m^3/fed	35.28	53.55	61.35	37.46	**46.91**	26.65	38.45	43.64	28.66	**34.35**	**40.63**	43.16	62.67	70.70	45.60	**55.53**	28.40	45.43	51.44	30.07	**38.84**	**47.19**
Mean($CaSiO_3$)	**29.63**	**40.46**	**49.91**	**43.42**		**22.71**	**29.93**	**36.08**	**31.63**			**35.31**	**47.34**	**57.55**	**50.87**		**24.15**	**33.43**	**41.48**	**35.96**		
L.S.D (0.05)																						
Vcomp	5.336					4.674						6.325					5.217					
$CaSiO_3$	6.172					5.537					7.214	6.875					6.101					7.854
Vcomp x$CaSiO_3$	8.042					6.754						7.621					7.006					

Grand mean of Calcium silicate ($CaSiO_3$)

	First - season				Second - season			
	0	**10**	**15**	**20**	**0**	**10**	**15**	**20**
	26.17	35.20	43.00	37.53	29.73	40.39	49.52	43.42
LSD(0.05) $CaSiO_3$	6.471				8.115			

Table (4): Effect of vermicompost and calcium silicate to reduce the soil salinity on dry weight/plant (g) of *Majorana hortensis* L. during 2012 and 2013 seasons.

Treatment Vermicompost (Vcom)	First - season											Second - season										
	Calcium silicate ($CaSiO_3$), kg/fed																					
	First cut					Second cut					Grand Mean of (Vcom)	First cut					Second cut					Grand Mean of (Vcom)
	0	10	15	20	Mean of Vcom	0	10	15	20	Mean of Vcom		0	10	15	20	Mean of Vcom	0	10	15	20	Mean of Vcom	
0 m^3/fed	6.75	8.10	8.77	9.55	**8.29**	5.82	6.47	7.18	7.56	**6.76**	**7.53**	7.24	8.60	10.39	11.47	**9.43**	6.57	7.07	7.24	8.14	**7.26**	**8.35**
6 m^3/fed	10.39	13.91	16.19	19.83	**15.08**	8.14	10.75	11.74	14.11	**11.19**	**13.14**	12.39	16.80	18.44	22.27	**17.48**	8.26	11.15	13.07	16.59	**12.27**	**14.88**
8 m^3/fed	11.47	15.27	22.27	17.09	**16.53**	8.66	11.15	16.26	12.38	**12.11**	**14.32**	13.91	17.74	25.00	20.10	**19.19**	8.94	12.07	18.63	14.15	**13.45**	**16.32**
10 m^3/fed	12.08	18.63	21.09	12.76	**16.14**	9.24	13.27	15.02	10.07	**11.90**	**14.02**	14.70	21.29	24.03	15.27	**18.82**	9.65	15.37	17.53	10.22	**13.19**	**16.01**
Mean($CaSiO_3$)	**10.17**	**13.98**	**17.08**	**14.81**		**7.97**	**10.41**	**12.55**	**11.03**			**12.06**	**16.11**	**19.47**	**17.28**		**8.36**	**11.42**	**14.12**	**12.28**		
L.S.D (0.05)																						
Vcomp	3.331					2.548						3.647					3.245					
$CaSiO_3$	4.112					3.843					5.004	4.571					4.203					5.572
Vcomp x$CaSiO_3$	4.751					4.024						5.107					4.524					

Grand mean of Calcium silicate ($CaSiO_3$)

	First - season				Second - season			
	0	**10**	**15**	**20**	**0**	**10**	**15**	**20**
	9.07	12.20	14.82	12.92	10.21	13.77	16.80	14.78
LSD(0.05) $CaSiO_3$	4.140				4.625			

Essential oil determinations:

Recorded data represented essential oil determinations are in Tables (5-7). Data in the second season obtained significantly increased in oil determination compared to the first season.

1 .Effect of vermicompost treatments:

Results in (Table 5) indicate that application of vermicompost at 8 or 10 m^3/fed significantly increased percentage of essential oil comparing to control plants during two seasons. No significant differences were noticed in this respect between the two vermicompost levels. The essential oil % grand mean was reached 0.577% and 0.573% comparing to 0.452% in control in the 1st season and 0.599% and 0.593% comparing to 0.460% in control plants in the 2nd season for 8 and 10 m^3/fed vermicompost, respectively. It could be noticed that from the previous discussed results of such research that vermicompost treatments which improved plant height, branches no/plant, fresh and dry weights/plant, also increased essential oil percentage. These results are in harmony with that presented by[32] on geranium,[33] on fennel and[34] on barley.

For essential oil yield/plant data of (Table 6) show that application of 8 or 10 m3/fed of vermicompost significantly increased the oil yield/plant compared to the control during two seasons. The vermicompost at (8 m^3/fed) gave the highest grand mean of oil yield/plant (0.244 and 0.293 ml/plant in the first and second season respectively), while control plants gave significantly lower grand mean oil yields (0.098 and 0.112 ml/plant in the first and second season respectively).

Main components of essential oil (Sabinene, α-Phyllandrene, β-Phyllandrene, Limonene, Linalool and Terpinen-4-ol) from marjoram plants are shown in (Table 7). Treatment amended with 8 m^3/fed resulted in the highest percentages of the main components of the essential oil compared with control and other treatments. However, resulted in essential oil under the effect of 8 m^3/fed vermicompost contained 31.46% Linalool, 24.52% Terpinen-4-ol, 8.67% β-Phyllandrene and 8.13% Limonene. While the highest percentages of Sabinene and α-Phyllandrene resulted under the effect of 10 m^3/fed vermicompost (6.48% and 5.45% , respectively). On the other hand, the plants which treated with8 m^3/fed vermicompost gave the lowest percentages of Sabinene and α-Phyllandrene (6.00% and 3.12%, respectively) compared to the other treatments.

2. Effect of calcium silicate ($CaSiO_3$) treatments:

All calcium silicate ($CaSiO_3$) tested application treatments had significant effects on essential oil % as compare to control during the both seasons (Table 5). However, the control plants had significantly lower grand mean oil contents in the fresh herb (0.485% and 0.499% in the first and second seasons, respectively), compared to plants receiving the different $CaSiO_3$ treatments. On the other hand, the highest grand mean oil contents were obtained from plants supplied with $CaSiO_3$ at 15 kg/fed (0.583% and 0.606% in the first and second seasons, respectively). Whereas the treatment which 10 kg/fed gave the least effective $CaSiO_3$ treatments (giving grand mean values of 0.539% and 0.549% in the first and second seasons, respectively). These results are in harmony with that presented by[32] on geranium.

As for essential oil yield per plant (Tables 6) as affected by $CaSiO_3$ inoculation, generally, had significantly effect on the resulted oil yield per plant comparing to untreated control during the two seasons.

Table (5): Effect of vermicompost and calcium silicate to reduce the soil salinity on the essential oil content (%) in fresh herb of *Majorana hortensis* L. during 2012 and 2013 seasons.

Treatment Vermicompost (Vcom)	First - season											Second - season										
	Calcium silicate ($CaSiO_3$), kg/fed																					
	First cut					Second cut					Grand Mean of (Vcom)	First cut					Second cut					Grand Mean of (Vcom)
	0	10	15	20	Mean of Vcom	0	10	15	20	Mean of Vcom		0	10	15	20	Mean of Vcom	0	10	15	20	Mean of Vcom	
0 m^3/fed	0.428	0.433	0.452	0.466	**0.445**	0.435	0.454	0.465	0.483	**0.459**	**0.452**	0.432	0.441	0.456	0.472	**0.450**	0.453	0.466	0.472	0.490	**0.470**	**0.460**
6 m^3/fed	0.477	0.544	0.562	0.604	**0.547**	0.509	0.553	0.582	0.637	**0.570**	**0.559**	0.506	0.544	0.566	0.613	**0.557**	0.504	0.562	0.603	0.676	**0.586**	**0.572**
8 m^3/fed	0.483	0.552	0.634	0.581	**0.563**	0.511	0.562	0.684	0.605	**0.591**	**0.577**	0.513	0.552	0.664	0.584	**0.578**	0.526	0.583	0.731	0.634	**0.619**	**0.599**
10 m^3/fed	0.515	0.590	0.626	0.522	**0.563**	0.522	0.617	0.655	0.534	**0.582**	**0.573**	0.524	0.592	0.645	0.536	**0.574**	0.531	0.654	0.707	0.553	**0.611**	**0.593**
Mean($CaSiO_3$)	**0.476**	**0.530**	**0.569**	**0.543**		**0.494**	**0.547**	**0.597**	**0.565**			**0.494**	**0.532**	**0.583**	**0.551**		**0.504**	**0.566**	**0.628**	**0.588**		
L.S.D (0.05)																						
Vcomp	0.024					0.085						0.047					0.142					
$CaSiO_3$	0.017					0.046					0.114	0.025					0.119					0.126
Vcomp x$CaSiO_3$	0.075					0.100						0.088					0.095					

Grand mean of Calcium silicate ($CaSiO_3$)

	First - season				Second - season			
	0	**10**	**15**	**20**	**0**	**10**	**15**	**20**
	0.485	0.539	0.583	0.554	0.499	0.549	0.606	0.570
LSD(0.05) $CaSiO_3$	0.044				0.106			

Table (6): Effect of vermicompost and calcium silicate to reduce the soil salinity on the essential oil yield/plant (ml) of *Majorana hortensis* L. during 2012 and 2013 seasons.

Treatment Vermicompost (Vcom)	First - season											Second - season										
	Calcium silicate ($CaSiO_3$), kg/fed																					
	First cut					Second cut					Grand Mean of (Vcom)	First cut					Second cut					Grand Mean of (Vcom)
	0	10	15	20	Mean of Vcom	0	10	15	20	Mean of Vcom		0	10	15	20	Mean of Vcom	0	10	15	20	Mean of Vcom	
0 m^3/fed	0.083	0.102	0.116	0.131	**0.108**	0.073	0.082	0.095	0.103	**0.088**	**0.098**	0.092	0.111	0.140	0.157	**0.125**	0.080	0.096	0.101	0.115	**0.098**	**0.112**
6 m^3/fed	0.146	0.219	0.266	0.349	**0.245**	0.119	0.170	0.202	0.256	**0.187**	**0.216**	0.184	0.269	0.313	0.401	**0.292**	0.122	0.181	0.231	0.329	**0.216**	**0.254**
8 m^3/fed	0.161	0.246	0.415	0.292	**0.279**	0.124	0.182	0.311	0.220	**0.209**	**0.244**	0.207	0.288	0.488	0.345	**0.332**	0.139	0.207	0.400	0.264	**0.253**	**0.293**
10 m^3/fed	0.182	0.316	0.384	0.196	**0.270**	0.139	0.237	0.286	0.153	**0.204**	**0.237**	0.226	0.371	0.455	0.244	**0.324**	0.151	0.297	0.364	0.166	**0.245**	**0.285**
Mean($CaSiO_3$)	**0.143**	**0.221**	**0.295**	**0.242**		**0.114**	**0.168**	**0.224**	**0.183**			**0.177**	**0.260**	**0.349**	**0.287**		**0.123**	**0.195**	**0.274**	**0.219**		
L.S.D (0.05)																						
Vcomp	0.066					0.042						0.114					0.127					
$CaSiO_3$	0.076					0.063					0.124	0.086					0.057					0.144
Vcomp x $CaSiO_3$	0.087					0.055						0.136					0.062					

Grand mean of Calcium silicate ($CaSiO_3$)

	First - season				Second - season			
	0	**10**	**15**	**20**	**0**	**10**	**15**	**20**
	0.129	0.195	0.260	0.213	0.150	0.228	0.312	0.253
LSD(0.05) $CaSiO_3$	0.070				0.093			

Table (7): Effect of vermicompost and calcium silicate to reduce the soil salinity on the components (%) of essential oil of *Majorana hortensis* L. in the second cut of the second season 2013.

Vermicompost (Vcomp), m^3/fad.	Calcium silicate ($CaSiO_3$), kg/fed				
	0	10	15	20	Mean of Vcom
			Sabinene		
0 m^3/fed	6.33	4.36	4.36	5.02	**5.02**
6 m^3/fed	4.62	5.66	7.14	6.72	**6.04**
8 m^3/fed	7.26	5.17	6.32	5.24	**6.00**
10 m^3/fed	5.26	7.45	5.13	8.09	**6.48**
Mean($CaSiO_3$)	**5.87**	**5.66**	**5.74**	**6.27**	
			α-Phyllandrene		
0 m^3/fed	4.69	2.31	2.72	2.41	**3.03**
6 m^3/fed	3.16	2.95	3.07	4.63	**3.45**
8 m^3/fed	2.48	4.11	2.50	3.40	**3.12**
10 m^3/fed	3.21	5.33	4.22	5.05	**4.45**
Mean($CaSiO_3$)	**3.39**	**3.68**	**3.13**	**3.87**	
			β-Phyllandrene		
0 m^3/fed	5.77	5.46	6.57	6.03	**5.96**
6 m^3/fed	8.59	8.16	9.13	7.41	**8.32**
8 m^3/fed	7.73	7.38	8.40	11.18	**8.67**
10 m^3/fed	6.22	7.60	10.32	9.20	**8.34**
Mean($CaSiO_3$)	**7.08**	**7.15**	**8.61**	**8.46**	
			Limonene		
0 m^3/fed	8.40	7.08	8.22	6.99	**7.67**
6 m^3/fed	7.66	9.16	7.21	8.34	**8.09**
8 m^3/fed	7.43	7.33	9.83	7.92	**8.13**
10 m^3/fed	6.72	8.14	8.57	7.11	**7.64**
Mean($CaSiO_3$)	**7.55**	**7.93**	**8.46**	**7.59**	
			Linalool		
0 m^3/fed	20.13	22.64	30.06	24.32	**24.29**
6 m^3/fed	23.50	28.44	26.45	31.10	**27.37**
8 m^3/fed	32.16	30.76	33.64	29.27	**31.46**
10 m^3/fed	27.35	25.62	35.87	34.25	**30.77**
Mean($CaSiO_3$)	**25.79**	**26.87**	**31.51**	**29.74**	
			Terpinen-4-ol		
0 m^3/fed	18.53	18.22	16.88	19.12	**18.19**
6 m^3/fed	20.13	17.07	19.59	18.50	**18.82**
8 m^3/fed	22.64	25.41	26.36	23.65	**24.52**
10 m^3/fed	17.08	20.19	23.70	21.41	**20.60**
Mean($CaSiO_3$)	**19.60**	**20.22**	**21.63**	**20.67**	

The treated plants with $CaSiO_3$ at 15 kg/fed resulted the highest significant grand mean values represented essential oil yield per plant (0.260 and 0.315 ml, in the first and second seasons, respectively) comparing to control. While the plants which treated by $CaSiO_3$ at 10 kg/fed resulted the lowest grand mean values (0.195 and 0.228ml, in the first and second seasons, respectively) compared to the other treatments.

Data showed that $CaSiO_3$ effects had significant effects on the essential oil components (Table 7) in marjoram plant, the highest percentages of Linalool, Terpinen-4-ol, β-Phyllandrene and Limonene (31.51%, 21.63%, 8.61% and 8.46% respectively) were recorded in essential oil extracted from plants treated with 15 kg/fed. While the highest percentages of Sabinene and α-Phyllandrene (6.27% and 3.87%) resulted under the effect of 20 kg/fed comparing to control. On the other hand, the lowest percentages of Sabinene, β-Phyllandrene, Linalool and Terpinen-4-ol resulted under the treatment with 10 kg/fed $CaSiO_3$ (5.66%, 7.15%, 26.87% and 20.22%).

3. Effect of Interaction treatments between vermicompost and $CaSiO_3$:

It is evident that the interaction between vermicompost and $CaSiO_3$ had significant effects on essential oil % in fresh herb of marjoram plant during two seasons (Table 5). Plants received 8 m^3/fed vermicompost combined with $CaSiO_3$ at 15 kg/fed had the highest essential oil percentages comparing to all other interaction treatments during two seasons. The mean in this respect recorded 0.634% and 0.684% in the first season while it recorded 0.664 % and 0.731% in the second season at the first and second cuts, respectively. Followed by plants treared with 10 m^3/fed vermicompost combined with $CaSiO_3$ at 15 kg/fed (giving values of 0.626% and 0.655% in the first season , 0.645% and 0.707% in the second season for the first and second cuts, respectively), whereas $CaSiO_3$ at 20 kg/fed recorded the least effective with 10 m^3/fed vermicompost.

The interaction between vermicompost and $CaSiO_3$ caused significant effect on essential oil yield/plant (Table 6), vermicompost at 8 m^3/fed plus $CaSiO_3$ at 15 kg/fed, recorded significant increases in essential oil/plant compared to control and other interaction treatments. The highest essential oil yield/plant were recorded in the first cut of the second season comparing to all other interaction treatments during two seasons, these values were (0.488 and 0.455 ml for $CaSiO_3$ at 15 kg/fed with 8 m^3/fed or 10 m^3/fed vermicompost, respectively).On the other hand, the lowest essential oil/plant (0.219 and 0.170ml in the first and second cuts of the first season, respectively) recorded in the plants which treated by vermicompost at 6 m^3/fed plus $CaSiO_3$ at 10 kg/fed.

Data in Table (7) stated that, the combined between vermicompost at 8 m^3/fed plus $CaSiO_3$ at 15 kg/fed gave the highest values of the Terpinen-4-ol and Limonene with value of 26.36% and 9.83% respectively. While the combined between 8 m^3/fed vermicompost and $CaSiO_3$ at 20 kg/fed showed the highest values of the β-Phyllandrene content (11.18%) compared to control. Also, the highest values of the Sabinene (8.09%) was obtained in the plants which treated by 10 m^3/fed vermicompost and $CaSiO_3$ at 20 kg/fed. On the other hand, the combined between 10 m^3/fed vermicompost and $CaSiO_3$ at 15 kg/fed gave the highest value of the Linalool with value of 35.87%. On the opposite, the lowest values of Linalool (25.62%) was obtained in the plants which treated by 10 m^3/fed vermicompost and $CaSiO_3$ at 10 kg/fed. While the lowest values of Terpinen-4-ol (17.07%) recorded in the plants that treated by 6 m^3/fed vermicompost with 10 kg/fed $CaSiO_3$.

Leaves chemical analysis:

Total carbohydrates contents (% of dry matter):

The results presented in Table (8) show that fertilization of marjoram plants with vermicompost and calcium silicate and their interaction increased the total carbohydrates contents in two cuts of the two seasons, compared to the control.

For the vermicompost This was evident in the first season, with unfertilized control plants giving the lowest values (14.87 and 14.33%, in the first and second cuts, respectively, with a grand mean of 14.60%). While the plants which fertilized by vermicompost at 8 m^3/fed giving the highest values of total carbohydrates contents (20.14 and 19.24 %, in the first and second cuts, respectively and a grand mean of 19.69%). Similarly, in the second season the rate of vermicompost (8 m^3/fed) gave the maximum values of total carbohydrates contents (23.63 and 22.53 %, in the first and second cuts, respectively and a grand mean of 23.08%) compared to the unfertilized (control) plants gave the lowest total carbohydrates contents (17.07 and 16.07 %, in the first and second cuts, respectively and a grand mean of 16.57%).

As for the main effect of calcium silicate ($CaSiO_3$) fertilization, The data recorded in Table (8) for first season also show that, the control plants gave the lowest total carbohydrates contents (15.93 and 15.55 %, in the first and second cuts, respectively and a grand mean of 15.74%). Generally, raising the application rate of $CaSiO_3$ from 0 to 20 kg/fed increased the total carbohydrates contents In fact, $CaSiO_3$ at 15 kg/fed gave higher values in two cuts (20.76 and 19.54 %, in the first and second cuts, respectively and a grand mean of 20.15%) than the values were obtained in plants receiving 20 kg/fed of $CaSiO_3$.

Table (8): Effect of vermicompost and calcium silicate to reduce the soil salinity on the total carbohydrates content (% of dry matter) in the herb of *Majorana hortensis* L. during 2012 and 2013 seasons.

Treatment Vermicompost (Vcom)	First - season											Second - season										
	Calcium silicate ($CaSiO_3$), kg/fed																					
	First cut					Second cut					Grand Mean of (Vcom)	First cut					Second cut					Grand Mean of (Vcom)
	0	10	15	20	Mean of Vcom	0	10	15	20	Mean of Vcom		0	10	15	20	Mean of Vcom	0	10	15	20	Mean of Vcom	
0 m^3/fed	14.05	14.63	15.21	15.57	**14.87**	13.67	14.07	14.33	15.25	**14.33**	**14.60**	16.20	16.65	17.26	18.18	**17.07**	15.13	15.77	16.36	**17.00**	**16.07**	**16.57**
6 m^3/fed	16.17	18.10	19.16	21.48	**18.73**	15.63	17.63	18.34	20.73	**18.08**	**18.41**	18.75	21.11	22.33	26.63	**22.21**	17.53	20.34	21.50	**24.16**	**20.88**	**21.55**
8 m^3/fed	16.48	18.77	25.53	19.78	**20.14**	16.15	18.07	23.66	19.07	**19.24**	**19.69**	19.34	21.70	30.30	23.16	**23.63**	18.45	21.04	28.46	**22.17**	**22.53**	**23.08**
10 m^3/fed	17.03	20.45	23.14	17.51	**19.53**	16.75	19.63	21.82	17.18	**18.85**	**19.19**	20.07	24.73	28.13	20.46	**23.35**	19.10	23.52	26.25	**19.63**	**22.13**	**22.74**
Mean($CaSiO_3$)	**15.93**	**17.99**	**20.76**	**18.59**		**15.55**	**17.35**	**19.54**	**18.06**			**18.59**	**21.05**	**24.51**	**22.11**		**17.55**	**20.17**	**23.14**	**20.74**		
L.S.D (0.05)																						
Vcomp	3.542					3.446						4.723					4.376					
$CaSiO_3$	2.014					2.007					3.550	2.436					2.226					4.573
Vcomp x$CaSiO_3$	3.172					3.118						3.541					3.285					

Grand mean of Calcium silicate ($CaSiO_3$)

	First - season				Second - season			
	0	**10**	**15**	**20**	**0**	**10**	**15**	**20**
	15.74	17.67	20.15	18.33	18.07	20.61	23.83	21.43
LSD(0.05) $CaSiO_3$	2.176				2.653			

As in the first season, the results recorded in the second season Table (8) also show that, $CaSiO_3$ at 15 kg/fed was the most effective treatment in this respect, giving the highest values of total carbohydrates contents (24.51 and 23.14 %, in the first and second cuts, respectively and a grand mean of 23.83%) compared to the other treatments. These values were followed by those obtained in plants which treated by 20 kg/fed of $CaSiO_3$. While the control plants gave the lowest total carbohydrates contents (18.59 and 17.55 %, in the first and second cuts, respectively and a grand mean of 18.07%).

Regarding the general effect of interaction treatments between the vermicompost and $CaSiO_3$ on total carbohydrates contents, The results in Table (8) indicated the increase in total carbohydrates contents during the two cuts, in the first season. The control plants gave the lowest total carbohydrates contents (14.05 and 13.67 %, in the first and second cuts, respectively). Moreover, the maximum values of total carbohydrates contents (25.53 and 23.66 %, in the first and second cuts, respectively) were obtained by using vermicompost at 8 m^3/fed plus $CaSiO_3$ at 15 kg/fed. Followed by the plants fertilized by vermicompost at 10 m^3/fed plus $CaSiO_3$ at 15 kg/fed. However, the plants treated by 10 m^3/fed of vermicompost combined with $CaSiO_3$ at 20 kg/fed gave the lowest values of total carbohydrates contents. Also, the results in Table (8) for the second season take a similar trend as that recorded in the first season. When using vermicompost at 8 m^3/fed combined with $CaSiO_3$ at 15 kg/fed gave the highest values of total carbohydrates contents (30.30 and 28.46 %, in the first and second cuts, respectively) compared to the control plants (giving values of 16.20 and 15.13 %, in the first and second cuts, respectively). The plants received vermicompost at 10 m^3/fed plus $CaSiO_3$ at 15 kg/fed gave higher values of total carbohydrates contents than the plants which fertilized by vermicompost at 10 m^3/fed plus $CaSiO_3$ at 20 kg/fed.

Enzymatic activates content:

The results presented in Table (9&10) show that fertilization of marjoram plants with vermicompost and calcium silicate and their interaction increased the enzymatic activates as nitrogenase (N_2-ase) and dehydrogenase contents in soil the during two cuts of the two seasons, compared to the control.

For the effect of vermicompost on nitrogenase (N_2-ase) activity. This was evident in the first season, with unfertilized control plants giving lower grand mean (6.31 and 8.00 µmole C_2H_4/g dry soil, in the first and second seasons, respectively) than plants fertilized with vermicompost at 15 m^3/fed giving the highest grand mean of N_2-ase content (10.30 and 12.20 µmole C_2H_4/g dry soil, in the first and second seasons, respectively). Similarly, for the dehydrogenase content the rate of vermicompost (8 m^3/fed) gave the maximum grand mean (34.62 and 37.68 mg/g dry soil, in the first and second seasons, respectively) compared to the unfertilized (control) plants gave the lowest dehydrogenase content (15.36 and 17.12 mg/g dry soil, in the first and second seasons).

As for the main effect of calcium silicate ($CaSiO_3$) fertilization, The data recorded in Table (9&10) for both seasons also show that, the control plants gave the lowest grand mean of N_2-ase content (7.15 and 9.14 µmole C_2H_4/g dry soil, in the first and second seasons, respectively). Generally, raising the application rate of $CaSiO_3$ from 0 to 20 kg/fed increased the N_2-ase content. In fact, $CaSiO_3$ at 15 kg/fed gave a higher grand mean (10.37 and 12.25 µmole C_2H_4/g dry soil, in the first and second seasons, respectively) than the values were obtained in plants which receiving 20 kg/fed of $CaSiO_3$. As N_2-ase content, the results were recorded of dehydrogenase content show that, $CaSiO_3$ at 15 kg/fed was the most effective treatment in this respect, giving the highest grand mean (34.65 and 37.52 mg/g dry soil, in the first and second seasons, respectively) compared to the other treatments. These values were followed by those obtained in plants which treated by 20 kg/fed of $CaSiO_3$. While the control plants gave the lowest grand mean of dehydrogenase content (20.14 and 22.44 mg/g dry soil, in the first and second seasons, respectively).

Table (9): Effect of vermicompost and calcium silicate to reduce the soil salinity on the nitrogenase (N_2-ase, mole C_2H_4/g dry soil) in the rhizosphere of *Majorana hortensis* L. during 2012 and 2013 seasons.

Treatment Vermicompost (Vcom)	First – season											Second – season										
	Calcium silicate ($CaSiO_3$), kg/fed																					
	First cut					Second cut					Grand Mean of (Vcom)	First cut					Second cut					Grand Mean of (Vcom)
	0	10	15	20	Mean of Vcom	0	10	15	20	Mean of Vcom		0	10	15	20	Mean of Vcom	0	10	15	20	Mean of Vcom	
0 m^3/fed	6.02	6.44	7.03	7.53	**6.76**	5.18	5.70	6.05	6.48	**5.85**	**6.31**	8.15	8.77	9.23	9.80	**8.99**	6.21	6.75	7.16	7.87	**7.00**	**8.00**
6 m^3/fed	8.14	9.77	10.90	12.42	**10.31**	7.20	8.68	9.44	10.72	**9.01**	**9.66**	10.28	12.21	13.02	14.41	**12.48**	8.26	10.27	11.14	12.63	**10.58**	**11.53**
8 m^3/fed	8.66	10.35	13.66	11.23	**10.98**	7.75	9.10	11.71	9.87	**9.61**	**10.30**	10.75	12.73	15.84	13.37	**13.17**	8.84	10.85	13.41	11.76	**11.22**	**12.20**
10 m^3/fed	9.00	11.74	13.02	9.36	**10.78**	8.07	10.15	11.14	8.22	**9.40**	**10.09**	11.33	13.86	15.11	11.84	**13.04**	9.25	12.04	13.08	9.76	**11.03**	**12.04**
Mean($CaSiO_3$)	**7.96**	**9.58**	**11.15**	**10.14**		**7.05**	**8.41**	**9.59**	**8.82**			**10.13**	**11.89**	**13.30**	**12.36**		**8.14**	**9.98**	**11.20**	**10.51**		
L.S.D (0.05)																						
Vcomp	3.145					2.651						3.354					3.241					
$CaSiO_3$	1.573					1.340					3.105	1.825					1.742					3.511
Vcomp x$CaSiO_3$	2.341					2.212						2.773					2.633					

Grand mean of Calcium silicate ($CaSiO_3$)

	First – season				Second – season			
	0	**10**	**15**	**20**	**0**	**10**	**15**	**20**
	7.51	9.00	10.37	9.48	9.14	10.94	12.25	11.44
LSD(0.05) $CaSiO_3$	1.212				1.832			

Table (10): Effect of vermicompost and calcium silicate to reduce the soil salinity on the Dehydrogenase (mg/g dry soil) in the rhizosphere of *Majorana hortensis* L. during 2012 and 2013 seasons.

Treatment Vermicompost (Vcom)	First – season											Second – season										
	Calcium silicate ($CaSiO_3$), kg/fed																					
	First cut					Second cut					Grand Mean of (Vcom)	First cut					Second cut					Grand Mean of (Vcom)
	0	10	15	20	Mean of Vcom	0	10	15	20	Mean of Vcom		0	10	15	20	Mean of Vcom	0	10	15	20	Mean of Vcom	
0 m^3/fed	12.14	15.46	17.63	19.71	**16.24**	10.11	13.31	16.30	18.14	**14.47**	**15.36**	15.61	18.46	19.14	21.72	**18.73**	13.13	15.31	18.17	20.24	**16.71**	**17.72**
6 m^3/fed	21.46	31.46	38.45	43.16	**33.63**	19.71	28.64	33.92	37.85	**30.03**	**31.83**	23.16	35.50	41.85	47.22	**36.93**	21.44	30.44	34.73	39.17	**31.45**	**34.19**
8 m^3/fed	24.57	35.36	47.64	40.67	**37.06**	21.43	30.72	40.81	35.76	**32.18**	**34.62**	26.46	38.24	52.72	44.63	**40.51**	24.62	32.61	44.63	37.55	**34.85**	**37.68**
10 m^3/fed	27.06	42.34	43.72	29.58	**35.68**	24.63	37.03	38.74	25.55	**31.48**	**33.58**	28.91	46.53	48.56	31.82	**38.96**	26.11	38.47	40.33	27.64	**33.14**	**36.05**
Mean($CaSiO_3$)	**21.31**	**31.16**	**36.86**	**33.28**		**18.97**	**27.43**	**32.44**	**29.33**			**23.54**	**34.68**	**40.57**	**36.35**		**21.33**	**29.21**	**34.47**	**31.15**		
L.S.D (0.05)																						
Vcomp	6.125					5.542						7.336					6.545					
$CaSiO_3$	5.362					4.462					7.215	6.347					3.346					8.347
Vcomp x$CaSiO_3$	4.841					4.610						5.224					5.017					

Grand mean of Calcium silicate ($CaSiO_3$)

	First - season				Second - season			
	0	**10**	**15**	**20**	**0**	**10**	**15**	**20**
	20.14	29.30	34.65	31.31	22.44	31.95	37.52	33.75
LSD(0.05) $CaSiO_3$	5.412				5.887			

Regarding the general effect of interaction treatments between the vermicompost and $CaSiO_3$ on N_2-ase content, The results in Table (9) indicate increase in N_2-ase content during the two seasons. The control plants gave the lowest N_2-ase content (6.02 and 5.18 µmole C_2H_4/g dry soil, for the first season and 8.15 and 6.21 µmole C_2H_4/g dry soil for the second seasons, in the first and second cuts, respectively). Moreover, the maximum values of N_2-ase content (13.66 and 11.71 µmole C_2H_4/g dry soil, for the first season and 15.84 and 13.41 µmole C_2H_4/g dry soil for the second seasons, in the first and second cuts, respectively) were obtained by using vermicompost at 8 m^3/fed plus $CaSiO_3$ at 15 kg/fed. Followed by the plants which amended with vermicompost at 10 m^3/fed plus $CaSiO_3$ at 15 kg/fed. While, the treatment amended with 10 m^3/fed of vermicompost combined with $CaSiO_3$ at 20 kg/fed gave the lowest values of N_2-ase content. Also, the results in Table (10) for the dehydrogenase content take a similar trend as that recorded for N_2-ase content. Vermicompost at 8 m^3/fed combined with $CaSiO_3$ at 15 kg/fed gave the highest values of dehydrogenase content (47.64 and 40.81 mg/g dry soil, for the first season and 52.72 and 44.63 mg/g dry soil for the second seasons, in the first and second cuts, respectively) compared to the control plants (12.14 and 10.11 mg/g dry soil, for the first season and 15.16 and 13.13 mg/g dry soil for the second seasons, in the first and second cuts, respectively). The plants received vermicompost at 10 m^3/fed plus $CaSiO_3$ at 15 kg/fed gave higher values of dehydrogenase content than the fertilized plants by vermicompost at 10 m^3/fed plus $CaSiO_3$ at 20 kg/fed.

Proline content (mg/g fresh weight):

The results presented in Table (11) show that fertilization of marjoram plants with vermicompost and calcium silicate and their interaction decreased the proline content in the two seasons, compared to the control.

For the vermicompost. This was evident in the both seasons, the plants fertilized with vermicompost at 8 m^3/fed giving the lowest values of proline content (4.99 and 4.48 mg/g fresh weight, in the first and second seasons, respectively) than unfertilized control plants giving the highest values (9.60 and 8.73 mg/g fresh weight, in the first and second seasons, respectively).

As for the main effect of calcium silicate ($CaSiO_3$) fertilization, The data recorded in Table (11) for the both seasons also show that, the control plants gave the highest values of proline content (8.34 and 7.74 mg/g fresh weight, in the first and second seasons, respectively). Generally, raising the application rate of $CaSiO_3$ from 0 to 20 kg/fed decreased the proline content. In fact, $CaSiO_3$ at 15 kg/fed gave a lower values in two seasons (4.85 and 4.27 mg/g fresh weight, in the first and second seasons, respectively) than the values were obtained in the plants which receiving 20 kg/fed of $CaSiO_3$.

Regarding the general effect of interaction treatments between the vermicompost and $CaSiO_3$ on proline content, The results in Table (11) indicate the decrease in proline content during the two seasons. The control plants gave the highest values of proline content (10.33 and 9.41 mg/g fresh weight, in the first and second seasons, respectively). Moreover, the lowest values of proline content (2.51 and 2.03 mg/g fresh weight, in the first and second seasons, respectively) were obtained by using vermicompost at 8 m^3/fed plus $CaSiO_3$ at 15 kg/fed. Followed by the plants fertilized by vermicompost at 10 m^3/fed plus $CaSiO_3$ at 15 kg/fed. However, the plants treated by 10 m^3/fed of vermicompost combined with $CaSiO_3$ at 20 kg/fed gave the highest values of proline content.

Table (11): Effect of vermicompost and calcium silicate to reduce the soil salinity on the proline content in the fresh herb of of *Majorana hortensis* L. during 2012 and 2013 seasons.

Treatment Vermicompost (Vcom)	First - season					Second - season				
	Calcium silicate ($CaSiO_3$), kg/fed									
	0	**10**	**15**	**20**	**Mean of Vcom**	**0**	**10**	**15**	**20**	**Mean of Vcom**
0 m^3/fed	10.33	9.89	9.24	8.92	**9.60**	9.41	9.05	8.46	8.00	**8.73**
6 m^3/fed	8.25	6.32	5.00	3.14	**5.68**	7.85	5.22	4.37	2.85	**5.07**
8 m^3/fed	7.63	5.67	2.51	4.14	**4.99**	7.07	4.92	2.03	3.89	**4.48**
10 m^3/fed	7.16	3.62	2.64	6.82	**5.06**	6.64	3.10	2.21	6.12	**4.52**
Mean($CaSiO_3$)	**8.34**	**6.38**	**4.85**	**5.76**		**7.74**	**5.57**	**4.27**	**5.22**	
L.S.D (0.05)										
Vcomp	2.325					2.245				
$CaSiO_3$	2.147					2.063				
Vcomp x $CaSiO_3$	3.334					3.077				

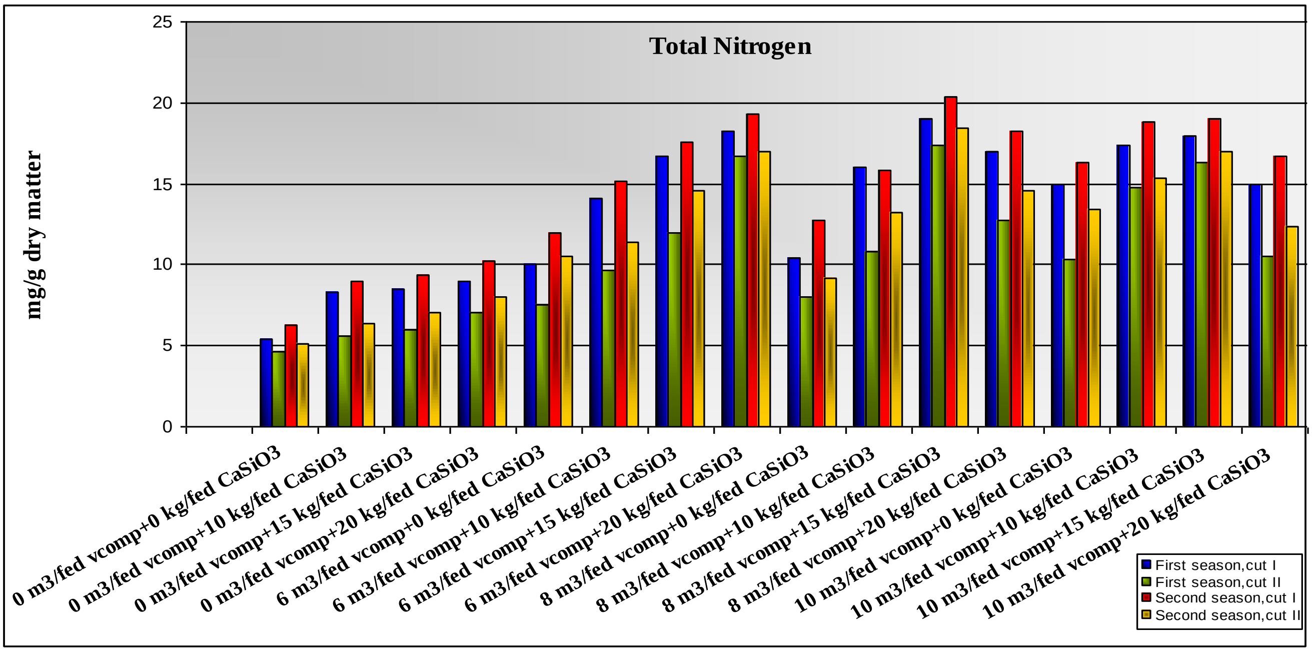
Mineral Contents:

Data showed in (fig 1-3) represent the effects of vermicompost and calcium silicate and their interaction during the two successive seasons on mineral contents as nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and sodium (Na) of marjoram plants

Results from (fig 1-3) indicated that the application of different vermicompost had considerable effects on the different mineral contents of marjoram especially N, P, K, Ca and Na. In the most cases, application of different vermicompost levels resulted in significant increases in the values of N, P, K and Ca but the amounts of sodium decreased compared to the control plants. Gradual increases in the above mentioned traits were noticed with the plants which received vermicompost (8 m^3/fed) followed by that the treatment by (10 m^3/fed).

All calcium silicate ($CaSiO_3$) tested application treatments had significant effects on different mineral contents of marjoram especially N, P, K, Ca and Na as compare to control during the both seasons (fig 1-3). However, the control plants had significantly lower N, P, K and Ca contents in the dry herb in the both seasons compared to plants receiving the different $CaSiO_3$ treatments. The highest N, P, K and Ca contents were obtained from plants supplied with 15 kg/fed of $CaSiO_3$. Whereas the treatment which 10 kg/fed gave the least effective $CaSiO_3$ treatments. On the other hand, the different $CaSiO_3$ treatments gave the lowest Na contents compared to control during the both seasons.

Concerning, the effect of the interaction treatments between vermicompost and $CaSiO_3$ on the mineral contents. The data in (fig 1-3) state that, the combined treatments show great effect during the two seasons compared to the control. The unfertilized plants gave lower values of the N, P, K and Ca contents.While, the highest values of the N, P, K and Ca contents obtained when using 8 m^3/fed of vermicompost combined with $CaSiO_3$ at 15 kg/fed. While, The Na accumulation was significantly lower compared to control plants. Followed by the treatment amended with vermicompost at 10 m^3/fed plus $CaSiO_3$ at 15 kg/fed. However, the plants treated by 10 m^3/fed of vermicompost combined with $CaSiO_3$ at 20 kg/fed gave the lowest values of N, P, K and Ca contents and highest values of Na contents.



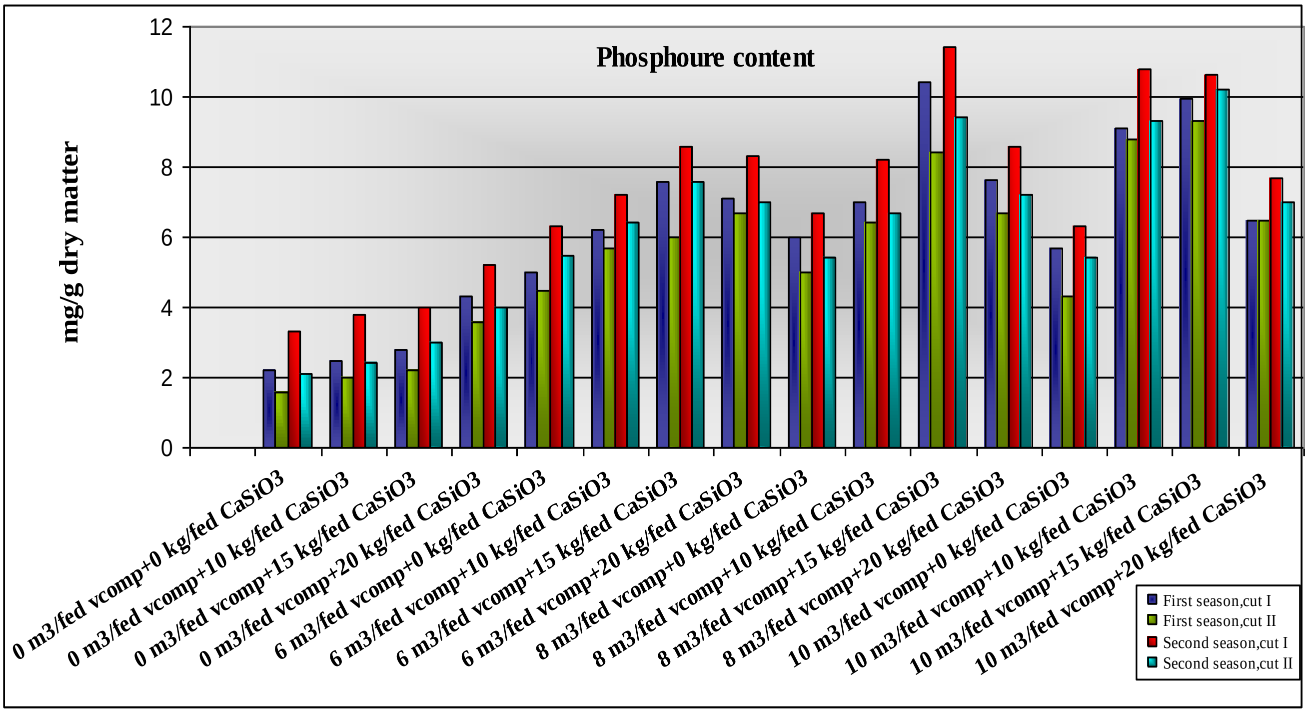
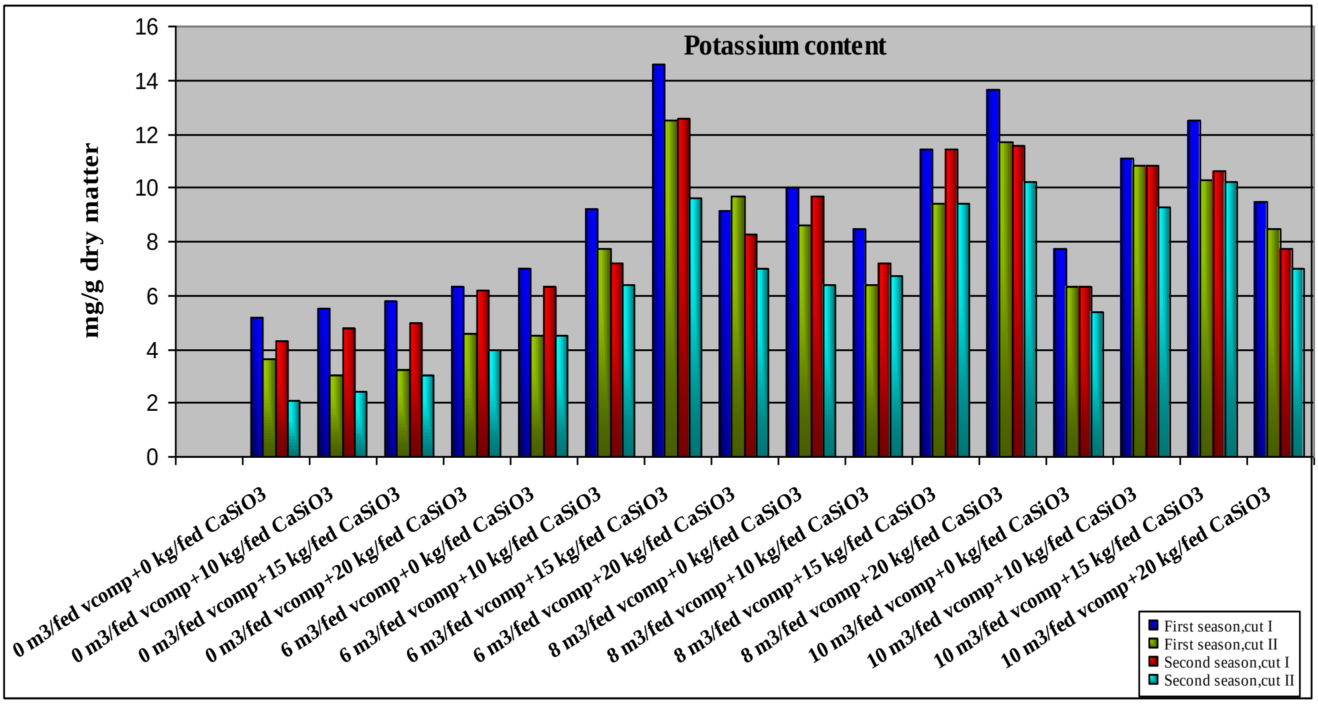


Fig (1): Effect of vermicompost and calcium silicate to reduce the soil salinity on the nitrogen and phosphoure contents in dry herb of *Majorana hortensis* L. during 2012 and 2013 seasons.



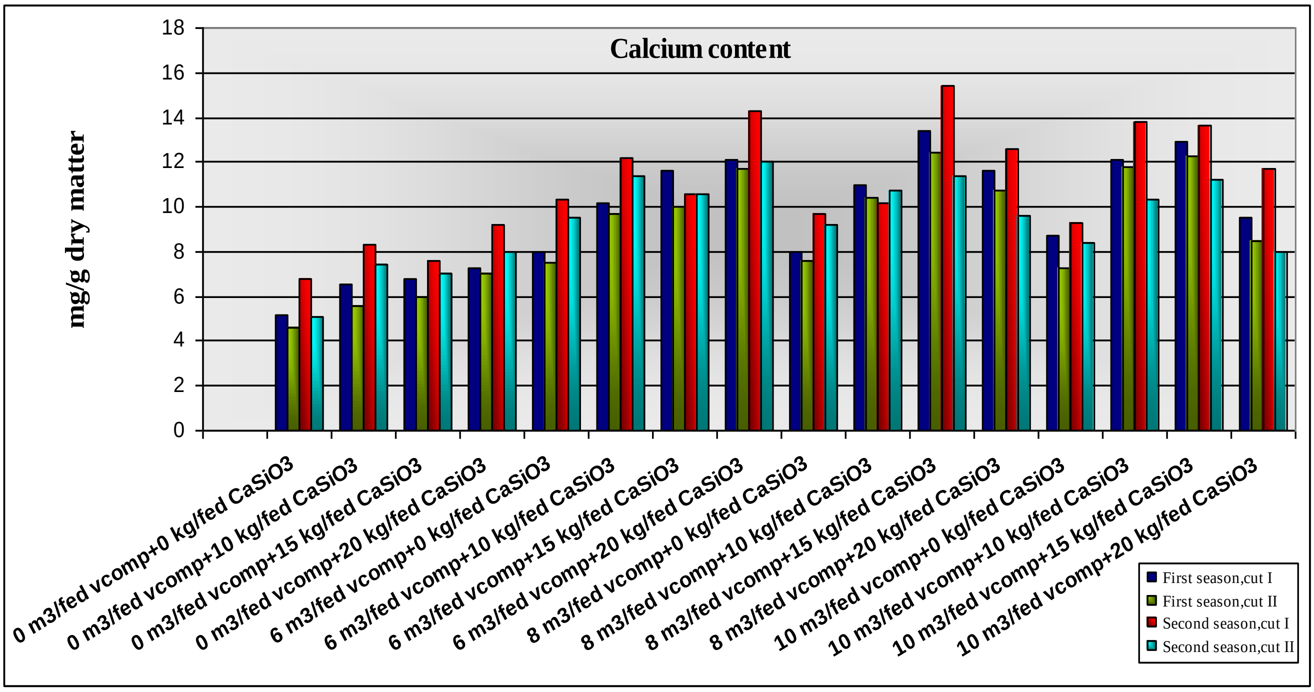


Fig (2): Effect of vermicompost and calcium silicate to reduce the soil salinity on the potassium and calcium contents in dry herb of *Majorana hortensis* L. during 2012 and 2013 seasons.

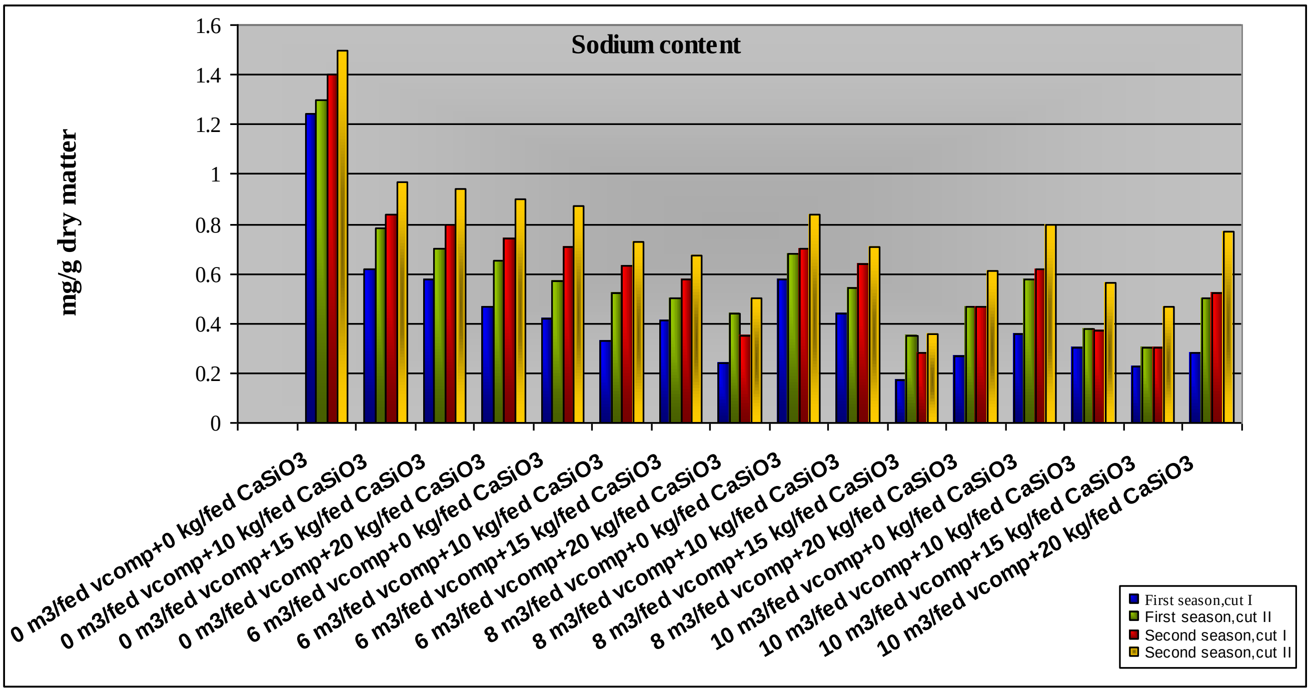


Fig (3): Effect of vermicompost and calcium silicate to reduce the soil salinity on the sodium contents in dry herb of *Majorana hortensis* L. during 2012 and 2013 seasons.

Discussion

Salinity is one of the major abiotic stresses that adversely affect modern agriculture and constitutes a problem everywhere in the world. More than 6% of the world's total land area is salt-affected; most of this salt-affected land has arisen from natural causes and the accumulation of salts over long periods of time in arid and semiarid zones[37]. Soils that have excessive amounts of salts (i.e., electrical conductivity (EC) > 4 dS/m) are classified as saline soils[38]. Soil salinity stresses plants in two ways: high concentrations of salts in the soil make it harder for roots to extract water and high concentrations of salts within the plant can be toxic. Salts on the outside of the roots have an immediate effect on cell growth and associated metabolism; toxic concentrations of salts take time to accumulate inside plants, before they affect plant function[39].

Vermicomposts are finely divided peat-like materials with high porosity, aeration, drainage, and water-holding capacity and usually contain most nutrients in the available forms such as nitrates, phosphates, exchangeable calcium and soluble potassium. Vermicompost increases the growth rate because of water and mineral uptake such as; nitrogen and phosphorus, which lead to the biological yield improvement[10]. Vermicompos leads to an increase in root biomass, root initiation and better growth and development of plants[40]. vermicompost leads to greater root expansion, which in turn leads to greater uptake of nutrients, water and rate of photosynthesis, ultimately leading to better flowering and heading[41]. Vermicompost significantly influenced flowering and umbel number per plant. On the other hand, vermicompost application through the improvement of biological activities of soil and mineral element absorption[42].

Silicon application may increase tolerance to salinity and drought in plants. its application may help reduce the need for irrigation, which in turn would reduce salinization of crop land[43]. Moreover, application of silicon can decreases both Na+ and Cl- levels but increases K+, with Na+ and K+ being more evenly distributed over the whole root[44]. Silicon-mediated decrease in lipid peroxidation helps maintain membrane integrity and decrease plasma membrane permeability under salt stress[45]. Silicon application also enhances plasma membrane H^+- ATPase activity [46], which may be related to the silicon-mediated decrease in oxidative damage to proteins under salt stress. [46] proposed that, silicon may affect membrane fluidity and enzyme activity indirectly or secondarily because addition of silicon does not affect membrane fluidity and H+-ATPase activity in vitro in plants not treated with salt. The fact that, silicon addition enhances antioxidant defense indicates that silicon may be involved in the physiological or metabolic activity in plant[35,36]**.** silicon reportedly increased chlorophyll content and photosynthetic activity of leaf cell organelles with or without salt stress[47]**.** In saline conditions, the silicon-mediated protective roles on the photosynthetic apparatus and increased photosynthetic activities may be partly attributed to a silicon-mediated decrease in Na^+ uptake and increase in K^+ uptake and enhanced antioxidant defense.

This general increase in the total carbohydrates content of fertilized plants (compared to the control) that was recorded in the first season can be easily explained, since the nitrogen supplied by fertilization is essential in the structure of prophyrines, which are found in the cytochrome enzymes essential in photosynthesis. This increase in the cytochrome enzymes results in an increase in the rate of photosynthesis, and a promotion in carbohydrate synthesis and accumulation. Moreover, the potassium added by fertilization acts as an activator for several enzymes involved in carbohydrate metabolism[48]**.**

Conclusion

Although all the applied treatments improved the growth parameters, essential oil determinations and Chemical analysis of marjoram (Majorana hortensis L.) under saline stress, the combination of vermicompost with calcium silicate $CaSiO_3$ especially 8 m^3/fed. of vermicompost combined with $CaSiO_3$ at 15 kg/fed . followed by vermicompost at 10 m^3/fed. plus $CaSiO_3$ at 15 kg/fed.

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