

# Enhancing Productivity of Sweet Marjoram in Substrate Culture

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**ABSTRACT---** Sweet Marjoram is considered as one of the important herbal plants, grown in many countries for medical and nutritional purposes and is an abundant source of valuable biologically active substances and mineral components. An experiment has been carried out on sweet marjoram at the experimental site of Central Laboratory for Agricultural Climate (CLAC), Agriculture Research Center, Ministry of Agriculture and land reclamation, Egypt under a net double span house, during seasons of 2019 and 2020. The experiment was carried out to study the effect of different nutrient solution sources and vermicompost rates on production of Sweet Marjoram grown in sand culture. In this experiment, Three sources of nutrient solution were under investigation (chemical nutrient solution "CN. S." as a control treatment, vermi-liquid "V. L." and mixture of chemical nutrient solution and vermi-liquid (50%:50%) "CN.S.+V.L."), also, five rates of vermicompost have been added to sand culture (zero% of vermicompost "V.C. 0%" as a control treatment, 10% Vermicompost "V.C. 10%", 20% Vermicompost "V.C. 20%", 30% Vermicompost "V.C. 30%" and 40% Vermicompost "V.C. 40%"). Regarding the effect of nutrient solution source; results illustrated that chemical nutrient solution recorded the highest values for vegetative growth, yield and chemical measurements. also data clarified that the mixture of chemical nutrient solution and vermi-liquid (50%:50%) "CN.S.+V.L." recorded a promising results very close to the chemical nutrient solution and more healthier; because the amount of chemicals used in this nutrient solution have been reduced into the half amount only comparison with chemical nutrient solution. For that, the mixture of chemical nutrient solution and vermi-liquid (50%:50%) could be considered as the most suitable nutrient solution for sweet marjoram. Concerning the effect of different vermicompost rates, results showed that adding vermicompost rate by 30% to sand culture recorded the highest values for plant height, number of branches /plant, Fresh and dry weights of the aerial parts /plant, yields of the fresh and dry herb/ m<sup>2</sup>, yield of aromatic oil/ m<sup>2</sup> (V.C. 40% recorded higher values for yield of the aromatic oil/m<sup>2</sup> than V.C. 30% but the difference between both of them was not significant), and N,P,K% in leaves.

**Keywords---** Sweet Marjoram, sand culture, chemical nutrient solution, vermicompost, vermi-liquid

## 1. INTRODUCTION

Soilless culture is defined as any method for growing plants without the use of soil as a rooting medium, in which the nutrients absorbed by the roots are supplied via the irrigation water. The fertilizers containing the nutrients to be supplied to the crop are dissolved in the appropriate concentration in the irrigation water and the resultant solution is referred to as "nutrient solution". Substrate culture in solid medium (organic and inorganic substrates) is one of soilless culture methods Savvas *et al.*, (2013). Soilless culture offers an ideal alternative production system for traditional cultivation in soil when there is no soil available at all or there is water shortage problem or any other problem made the traditional crop production process in soil are unavailable Olympios, (2011). Stable and high quality production is the main advantage of soilless substrate culture, which has already been proved by many studies in many different crops (Yashuba *et al.*, 1995 and Veys, 1997). Moreover, Grillas *et al.*, (2001) reported that soilless culture systems guarantee flexibility, intensification and provide high crop yield and high quality products, even in areas with adverse growing conditions. Furthermore, soilless cultivation represented a breakthrough and permitting to achieve high standardized production (Burrage, 1992).

The term growing medium (substrate) is used to describe the materials used to grow plants in containers and that surrounding the root system (Blok and Verhagen, 2009; Schroeder and Sell, 2009). Sand is the oldest hydroponic media, it is heavy when wet and tends to dry out quickly. It provides excellent support, gas exchange but has insufficient water and nutrient supplying capacity. The coarse particles of sand have little surface area per unit of volume compared to the finer particles of soil or peat moss. Since water is held on the surfaces of particles, sand has a small water holding capacity. Plants grown in sand would need to be watered three or more times per day especially in the summer. Since most nutrients in a sand medium are held in the water films, there is likewise little nutrient reserve. (Abul-soud, 2005).

The increased of health awareness led to increase the demand of safe agriculture products free of harmful chemicals (Metwally, 2015), this was one of the reasons led to increase the needs for optimizing soilless culture technology

inputs and maximize the production with concerns on the environmental impacts which led to the development of the ecology soilless culture system via alternating the peat moss by vermicompost and replace the chemical nutrient solution by organic sources of nutrient solution (Abul-Soud, *et al.*, 2015a).

Vermicomposting (Worm composting) is defined as a process in which earthworms play a major role with microorganism in the conversion of organic solid waste into more stabilized dark, earth-smelling soil conditioner and nutrient-rich compost that is rich in macro and micronutrients. During vermicomposting, organic matter is stabilized by the enhanced decomposition (humification) in the presence of earthworms, but by a non-thermophilic process (Atiyeh *et al.*, 2001 and Elvira *et al.*, 1998).

Vermicompost is a nutrient-rich, microbiologically-active organic amendment that results from the interactions between earthworms and microorganisms during the breakdown of wastes. The use of vermicompost in sustainable agriculture organic matter. It is a stabilized, finely divided peat-like material with a low C: N ratio, high porosity and high water-holding capacity, in which most nutrients are present in forms that are readily taken up by plants (Domínguez, 2004). Moreover, Abul-Soud *et al.*, (2014), Abul-Soud *et al.*, (2015 a and b) mentioned that the use of vermicompost as a substrate amendments had a significant encouragement impacts on the growth and yield of various vegetable crops such as sweet paper, snap bean, lettuce, strawberry, celery and others. Vermicompost contained essential nutrients for supporting the plant nutrient requirements beside the high organic matter and assist in improving the physical and chemical properties of the substrates.

Extract from vermicompost is known as vermicompost extract. The preparations of these vermicomposting derived liquids are different. Vermicomposting derived liquids contain valuable nutrients that promote plant growth. Substrates that have been used in these liquids production are mainly animal and agricultural waste. Different terms are used in describing these liquids as there are some differences in preparation (Pant *et al.*, 2009). Leachate known as (vermi-liquid) is generated along with vermicomposting process commonly referred to as vermicomposting leachate or worm-bed leachate (Ismail, 1997 and Gutiérrez-Miceli *et al.*, 2011)

Sweet marjoram (*Majorana hortensis* L.) is cultivated in Egypt as biennial plant for the leaves and essential oil that are used in the food and pharmaceutical industries (Omer *et al.*, 1994). Sweet marjoram is used worldwide as a spice and a medicinal source in the form of the essential oil in aromatherapy due to its stimulant and antispasmodic properties (Gharib *et al.*, 2008). Furthermore, Marjoram cultivation has economic impact due to its ability to produce and store essential oil used in perfumes and cosmetics industries. (Edris *et al.*, 2003).

For that this work aimed to investigate the effect of using different nutrient solution sources and different vermicompost rates on growth and production of Sweet Marjoram grown in sand culture.

## 2. MATERIALS AND METHODS

The experiment have been conducted at the experimental site of the Central Laboratory for Agricultural Climate (CLAC), Agriculture Research Center (ARC), Dokki, Giza, Egypt, during seasons of 2019 and 2020 under a net double span plastic house (18 x 60 x 4.5m).

Sweet Marjoram (*Majorana hortensis* L.) seedlings (10-12cm height) were transplanted to the plastic pots under study in the first week of April during the two seasons. Plant density were 8 plants/m<sup>2</sup>.

### Treatments

Two factors have been tested in this experiment in relation to growth and production of Sweet Marjoram (herb – oil). The tested factors were as follow:

Factor (A): Source of the nutrient solution

1. Chemical nutrient solution “CN. S.” as control treatment.
2. Vermi-liquid “ V. L.”
3. Chemical nutrient solution : Vermi-liquid (50%:50%) “CN.S. + V.L.”

Factor (B): Different vermicompost rates.

1. zero% of vermicompost "V.C. 0%" (100% Sand without vermicompost) as a control treatment.
2. 10% of vermicompost "V.C. 10%".
3. 20% of vermicompost "V.C. 20%".
4. 30% of vermicompost "V.C. 30%".
5. 40% of vermicompost "V.C. 40%".

### Chemical nutrient solution

The chemical nutrient solution used in this experiment was the nutrient solution described by El- Behairy, (1994). The composition of chemical nutrient solution was illustrated in Table (1).

**Table (1): Composition of chemical nutrient solution**

Macro nutrients (ppm)					Micro nutrients (ppm)							
N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B	Pb	Cd	
200	45	350	180	50	3.0	1.00	0.06	0.10	0.25	0.16	0.01	

### Vermicompost and vermi-liquid

Vermicompost and vermi-liquid had been produced through vermicomposting process. Epepic earthworms (*Lumbriscus rubellus* (Red Worm), *Eisenia fetida* (Tiger Worm), *Perionyx excavatus* (Indian Blue) and *Eudrilus eugeniae* (African Night Crawler)) were used to decomposed animal manure and agriculture wastes according to Ernst *et al.*, (2008) and Abul-Soud *et al.*, (2009 and 2015b). The physical and chemical properties of vermicompost were illustrated in Table (2).

**Table (2): Physical and chemical properties of vermicompost**

Physical properties			
B.D (Kg/m <sup>3</sup> )	O. M (%)		C/N ratio
721	33.9		1:13
Chemical properties			
pH	8.21	K (%) 0.61	
EC (dS/m)	6.8	Fe (ppm) 795	
N (%)	1.61	Mn (ppm) 139	
N-NH <sub>4</sub> (ppm)	68	Zn (ppm) 35.5	
N-NO <sub>3</sub> (ppm)	84	Cu (ppm) 14.8	
P (%)	1.20	Pb (ppm) 8.1	

Bulk density (**B.D**), Organic matter (**O.M**)

The vermi-liquid was collected through vermicomposting process. The vermi-liquid filtered by using nets to remove any residues or dust that could cause blocking of drippers before diluted to the desire EC. The compositions of Vermi-liquid was illustrated in Table (3).

**Table (3): Chemical composition of vermi-liquid.**

Macro nutrients (ppm)					Micro nutrients (ppm)							
N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B	Pb	Cd	
131	96	228	114	47.7	0.30	0.05	0.01	0.05	0.20	0.03	n.d	

### System description

The pots system was used in this experiment. the pot system consisted of 8 plastic pots per m<sup>2</sup>. pots were put on a black polyethylene sheet on cement beds (0.75m width and 7.5m length) prepared with slope about 1%. Each bed had one tank, the tank equipped with one submersible pump and drip irrigation set to deliver water and nutrient solutions to plants. Each pot was filled with 8 liters from different sand and vermicompost mixtures. the excess water and nutrient solutions were allowed to run to waste (open system). The EC of the different nutrient solutions were adjusted by using EC meter to the required level (1.5 mmhos<sup>-1</sup>).

### Harvesting

The experiment was extended from the beginning of April to the end of November in both seasons (2019 and 2020). The fresh herb of sweet marjoram have been cut and collected 5 times during the experimental time each season.

### Measurements

Different measurements have been recorded during the experimental time as follow:

#### Plant growth measurements

- Plant height (cm).
- Number of branches /plant.
- Fresh weight of the aerial parts /plant (g/plant).
- Dry weight of the aerial parts /plant (g/plant).

At full blooming stage, the plant herbage was harvested by cutting 5 cm above the substrate surface to recorded plant growth measurements; as plant height, number of branches per plant, fresh weight of aerial parts. For measured dry weight, Plant samples were dried in an electric oven with drift fan at 70°C till constant dry weight.

#### **Yield measurements**

- Yield of the fresh herb/ m<sup>2</sup> (kg/m<sup>2</sup>).
- Yield of the dried herb /m<sup>2</sup> (kg/m<sup>2</sup>).
- Yield of aromatic oil/ m<sup>2</sup> (ml / m<sup>2</sup>).
- Percentage of the aromatic oil (%).

#### **Chemical measurements**

- Percentages of main components in the aromatic oil (average of two seasons).
- Nitrogen percentage in leaves (%).
- Phosphorus percentage in leaves (%).
- Potassium percentage in leaves (%).

Aromatic oil from the first cut were separated and analyzed qualitatively by GC/MS in National Research Center, Dokki, Cairo, Egypt. The GC analysis was carried out using Varian 3400 GC, equipped with a DB-5 fused silica capillary column. Mass spectrometer was a Varian– Finnigan SSQ 7000.

Nitrogen, Phosphorus and Potassium % in leaves were measured using methods described by A.O.A.C., (1990).

Percentage of the aromatic oil of Sweet Marjoram obtained from each treatment was achieved by hydro-distillation using a Clevenger type apparatus (Clevenger, 1928) according to Italian Pharmacopoeia,(2008) during both seasons. Distillation of 100 g fresh herb was continued for 2.5-3.0 h after water boiling till no further increase in the oil was observed. The oil was permitted to stand undisturbed and the amount of oil obtained from plant material was calculated as:  
Oil (%) = observed volume of oil (mL)/weight of sample (g) × 100.

Total aromatic oil yield per plant was calculated by multiplying the average fresh weight of plant by the average oil percentage.

#### **Experimental Design and Statistical analysis**

The experiment was arranged in split plot design with three replicates. The sources of the nutrient solutions were arranged in the main plots, while vermicompost rates were arranged in sub plots. Data were statistically analyzed using the analysis of variance method one way ANOVA with SAS package software version 6 (SAS Institute, 1990). The Dunkun's test was used to compare among means.

### **3. RESULTS**

#### **Plant height**

Data in table (4) illustrate the effect of different sources of nutrient solution and different rates of vermicompost on plant height of sweet marjoram grown in sand culture. Regarding the effect of nutrient solution source, data collected from both seasons indicated that using chemical nutrient solution recorded the highest plant height values followed by mixture of chemical nutrient solution and vermi-liquid (CN.S.+V.L.)without significant difference between both of them. On contrary, plants grown using vermi-liquid only recorded the lowest plant height values.

Regarding the effect of vermicompost rate, data from first season indicated that V.C. 30% recorded the highest plant height values followed by V.C. 20% , V.C. 10% , V.C. 40% and V.C. 0% respectively. Similar trend were observed in the next season except there was no significant difference between V.C. 10% and V.C. 40%.

Regarding the effect of interaction between nutrient solution sources and vermicompost rates, in both seasons, the highest plant height was recorded by interaction between chemical nutrient solution and V.C. 30% while the lowest values were recorded by interaction between vermi-liquied and V.C. 0%

**Table (4): Effect of different nutrient solution sources and vermicompost rates on plant height (cm) of sweet marjoram grown in sand culture**

Source of the nutrient solution	Vermicompost rates in sand culture					Mean
	V.C. 0%(control )	V.C. 10%	V.C. 20%	V.C. 30%	V.C. 40%	
<b>First season (2019)</b>						
CN.S.(control)	28.3 ef	35.2 bc	34.2 c	40.2 a	30.9 d	33.8 A
V.L.	23.0 g	27.1 f	30.5 d	27.1 f	28.7 e	27.3 B
CN.S. +V.L.	31.4 d	34.0 c	34.1 c	35.7 b	33.1 c	33.6 A
Mean	27.6 E	32.1 C	32.9 B	34.3 A	30.9 D	
<b>Second season (2020)</b>						
CN.S.(control)	26.7 de	34.4 b	33.8 b	40.8 a	29.5 cd	33.1 A
V.L.	21.8 f	25.6 e	30.0 cd	27.8 d	28.0 d	26.6 B
CN.S. +V.L.	30.8 c	32.7 bc	34.6 b	34.8 b	31.5 c	32.9 A
Mean	26.4 D	30.9 C	32.8 B	34.4 A	29.7 C	

#### Number of branches /plant.

Data in table (5) illustrate the effect of different sources of nutrient solution and different rates of vermicompost on number of branches of sweet marjoram grown in sand culture. Regarding the effect of nutrient solution source, data collected from both seasons clarified that even using chemical nutrient solution recorded higher no. of branches than mixture of chemical nutrient solution and vermi-liquied but the difference between both of them was not significant. On the other hand, using vermi-liquied only led to having the lowest no. of branches.

Regarding the effect of vermicompost rate, data from first season illustrated that V.C. 30% recorded the highest no. of braches then V.C. 20% , V.C. 10%, V.C. 40% and V.C. 0% respectively. Moreover, there were significant differences among treatments except between V.C. 10% and V.C. 40%. On the other hand, data from second season indicated that the highest no. of branches recorded by V.C. 30% followed by V.C. 10%, V.C. 20%, V.C. 40% and V.C. 0% respectively. But there was no significant difference between V.C. 30% and V.C. 20%, also, there were no significant differences among V.C. 10%, V.C. 20% and V.C. 40%.

Regarding the effect of interaction, in both seasons, both (V.C. 30% with CN.S.) and (V.C. 30% with CN.S. +V.L.) recorded the highest no. of branches while (V.C. 0%withV.L.) recorded the lowest no. of branches.

#### Fresh weight of the aerial parts /plant.

Data in table (6) illustrate the effect of different sources of nutrient solution and different rates of vermicompost on aerial parts fresh weight/plant of sweet marjoram grown in sand culture. Regarding the effect of nutrient solution source, data recorded that in the first season CN.S. recorded higher fresh weight values than CN.S. +V.L. without significant difference between both of them, the opposite was recorded in the second season but the difference still not significant. On the other hand, V.L. recorded the lowest values in both seasons.

Regarding the effect of vermicompost rate, data from first season showed that V.C. 30% recorded the highest values followed by V.C. 20%, V.C. 10%, V.C. 40% and V.C. 0% respectively. Moreover, there were significant differences among treatments except between V.C. 10% and V.C. 40% the difference was not significant. Similar trends were observed in the second season except that there was no significant difference between V.C. 30% and V.C. 20% , also between V.C. 20% and V.C. 10%

Regarding the effect of interaction, in both seasons, both (V.C. 30% with CN.S.) and (V.C. 30% with CN.S. +V.L.) recorded the highest fresh weight values while (V.C. 0% with V.L.) recorded the lowest values.

**Table (5): Effect of different nutrient solution sources and vermicompost rates on number of branches /plant of sweet marjoram grown in sand culture**

Source of the nutrient solution	Vermicompost rates in sand culture					Mean
	V.C. 0%(control)	V.C. 10%	V.C. 20%	V.C. 30%	V.C. 40%	
<b>First season (2019)</b>						
CN.S.(control)	31.0 g	50.7 b	51.1 b	56.0 a	43.3 d	46.4 A
V.L.	22.1 h	24.0 h	34.5 f	30.7 g	33.8 fg	29.0 B
CN.S. +V.L.	38.1e	44.9 cd	46.5 c	54.2 a	42.3 d	45.2 A
Mean	30.4 D	39.9 C	44.0 B	47.0 A	39.8 C	
<b>Second season (2020)</b>						
CN.S.(control)	27.9 c	42.6 ab	42.0 ab	47.6 a	39.1 b	39.8 A
V.L.	18.7 d	20.9 d	31.0 c	26.6 cd	28.8 c	25.2 B
CN.S. +V.L.	32.3 c	37.5 bc	38.9 b	45.2 a	36.4 bc	38.1 A
Mean	26.3 C	33.7 B	37.3 AB	39.8 A	34.8 B	

**Table (6): Effect of different nutrient solution sources and vermicompost rates on aerial parts fresh weight (g/plant) of sweet marjoram grown in sand culture**

Source of the nutrient solution	Vermicompost rates in sand culture					Mean
	V.C. 0%(control)	V.C. 10%	V.C. 20%	V.C. 30%	V.C. 40%	
<b>First season (2019)</b>						
CN.S.(control)	437.2 e	765.2 b	763.2 b	854.8 a	672.8 c	698.6 A
V.L.	260.8 g	344.4 f	478.0 de	418.4 e	443.2 de	389.0 B
CN.S. +V.L.	491.2 d	722.0 bc	719.6 bc	805.6 ab	682.4 c	684.2 A
Mean	369.4 D	610.5 C	653.6 B	692.9 A	599.5 C	
<b>Second season (2020)</b>						
CN.S.(control)	407.5 e	724.7 b	699.1 b	792.0 a	621.1 c	648.8 A
V.L.	240.2 g	330.5 f	473.4 d	403.6 e	428.1 de	375.2 B
CN.S. +V.L.	467.2 d	718.8 b	698.5 b	749.4 ab	624.1 c	651.6 A
Mean	371.6 D	591.3 B	623.6 AB	648.3 A	557.7 C	

#### Dry weight of the aerial parts /plant.

Data in table (7) illustrate the effect of different sources of nutrient solution and different rates of vermicompost on aerial parts dry weight/plant of sweet marjoram grown in sand culture. Regarding the effect of nutrient solution source, in both seasons, the highest dry weight values obtained from CN.S. followed by CN.S. +V.L. then V.L. Moreover, differences among treatments were significant.

Regarding the effect of vermicompost rate, data from first season illustrated that V.C. 30% recorded the highest dry weight values then V.C. 20%, V.C. 40%, V.C. 10% and V.C. 0% respectively. Moreover, there were significant differences among treatments. Similar trends were observed in the second season except that the difference between V.C. 10% and V.C. 40% was not significant.

Regarding the effect of interaction, in both seasons, the highest dry weight values were obtained from (V.C. 30% with CN.S.) while the lowest values were obtained from (V.C. 0% with V.L.).

**Table (7): Effect of different nutrient solution sources and vermicompost rates on aerial parts dry weight (g /plant) of sweet marjoram grown in sand culture**

Source of the nutrient solution	Vermicompost rates in sand culture					Mean
	V.C. 0%(control)	V.C. 10%	V.C. 20%	V.C. 30%	V.C. 40%	
<b>First season (2019)</b>						
CN.S.(control)	165.4 f	240.6 c	242.4 c	275.4 a	243.4 c	233.4 A
V.L.	96.4 i	129.0 h	172.8 e	150.8 g	157.0 g	141.2 C
CN.S. +V.L.	162.4 fg	231.4 d	229.0 d	255.4 b	226.8 d	221.0 B
Mean	141.4 E	200.3 D	214.7 B	227.2 A	209.1 C	
<b>Second season (2020)</b>						
CN.S.(control)	158.8 g	236.0 c	230.0 cd	266.8 a	233.2 c	224.9 A
V.L.	89.6 j	125.0 i	173.2 f	147.0 h	153.0 gh	137.6 C
CN.S. +V.L.	154.2 gh	232.4 c	222.0 d	247.6 b	208.4 e	212.9 B
Mean	134.2 D	197.8 C	208.4 B	220.5 A	198.2 C	

**Yield of the fresh herb per m<sup>2</sup>.**

Data in table (8) illustrate the effect of different sources of nutrient solution and different rates of vermicompost on yield of fresh herb of sweet marjoram grown in sand culture. Regarding the effect of nutrient solution source, data collected from the first season showed that the highest yield was collected from CN.S. followed by CN.S. +V.L. without significant difference between both of them. While V.L. recorded the lowest yield. Similar trend was observed in the second season except that CN.S. +V.L. recorded higher yield than CN.S. but the difference still not significant.

Regarding the effect of vermicompost rate, data from first season showed that the highest yield was obtained from V.C. 30%, while the lowest yield was obtained from V.C. 0%. Moreover, data clarified that there were significant differences among treatments. Similar trends were recorded in the second season except that there was no significant difference between V.C. 20% and both (V.C. 10% & V.C. 30%).

Regarding the effect of interaction, in both seasons, (V.C. 30% with CN.S.) recorded the highest yield values, while the lowest values were obtained from (V.C. 0% with V.L.).

**Table (8): Effect of different nutrient solution sources and vermicompost rates on yield of the fresh herb (kg/m<sup>2</sup>) of sweet marjoram grown in sand culture**

Source of the nutrient solution	Vermicompost rates in sand culture					Mean
	V.C. 0%(control)	V.C. 10%	V.C. 20%	V.C. 30%	V.C. 40%	
<b>First season (2019)</b>						
CN.S.(control)	3.49 e	6.12 b	6.11 b	6.84 a	5.39 c	5.59 A
V.L.	2.09 g	2.76 f	3.82 de	3.35 e	3.55 de	3.11 B
CN.S. +V.L.	3.93 d	5.78 b	5.76 b	6.44 ab	5.46 c	5.48 A
Mean	2.95 D	4.88 C	5.23 B	5.55 A	4.80 C	
<b>Second season (2020)</b>						
CN.S.(control)	3.26 e	5.80 b	5.59 b	6.34 a	4.97 c	5.19 A
V.L.	1.92 g	2.64 f	3.79 d	3.23 e	3.42 de	3.00 B
CN.S. +V.L.	3.73 d	5.75 b	5.59 b	5.99 ab	5.00 c	5.21 A
Mean	2.97 D	4.73 B	4.99 AB	5.18 A	4.46 C	

**Yield of the dried herb per m<sup>2</sup>.**

Data in table (9) illustrate the effect of different sources of nutrient solution and different rates of vermicompost on yield of dried herb of sweet marjoram grown in sand culture. Regarding the effect of nutrient solution source, in both seasons, data showed that CN.S. recorded the highest yield values followed by CN.S.+V.L., and V.L. respectively, also differences among treatments were significant.

Regarding the effect of vermicompost rate, in the first season, data indicated that V.C. 30% recorded the highest yield values then V.C. 20%, V.C. 40%, V.C. 10% and V.C. 0% respectively. Moreover, there were significant differences

among treatments. Similar trends were recorded in the second season except that the difference between V.C. 10% and V.C. 40% was not significant.

Regarding the effect of interaction, in both seasons, (V.C. 30% with CN.S.) recorded the highest yield values while the lowest values were obtained from (V.C. 0% with V.L.).

#### Yield of aromatic oil per m<sup>2</sup>.

Data in table (10) illustrate the effect of different sources of nutrient solution and different rates of vermicompost on yield of aromatic oil/ m<sup>2</sup> of sweet marjoram grown in sand culture. Regarding the effect of nutrient solution source, data collected from both seasons indicated that the highest yield of aromatic oil/ m<sup>2</sup> was obtained from CN.S. followed by CN.S. + V.L. then V.L., and all differences among treatments were significant.

Regarding the effect of vermicompost rate, in the first season, data clarified that increasing vermicompost rate from zero to 40% increased the yield of aromatic oil/ m<sup>2</sup>; V.C. 40% recorded the highest yield followed by V.C. 30% without significant difference between both of them, while V.C. 0% recorded the lowest yield. Similar trends were observed in the second season.

Regarding the effect of interaction, in first season, data showed that (V.C. 30% with CN.S.) recorded the highest yield of aromatic oil, while (V.C. 0% with V.L.) recorded the lowest yield. Similar trends were observed in the second season.

**Table (9): Effect of different nutrient solution sources and vermicompost rates on yield of the dried herb (kg/m<sup>2</sup>) of sweet marjoram grown in sand culture**

Source of the nutrient solution	Vermicompost rates in sand culture					Mean
	V.C. 0% (control)	V.C. 10%	V.C. 20%	V.C. 30%	V.C. 40%	
<b>First season (2019)</b>						
CN.S.(control)	1.32 f	1.93 c	1.94 c	2.20 a	1.95 c	1.87 A
V.L.	0.77 i	1.03h	1.39 e	1.21 g	1.25 g	1.13 C
CN.S. +V.L.	1.30 fg	1.85 d	1.83 d	2.04 b	1.81 d	1.77 B
Mean	1.13 E	1.60 D	1.72 B	1.81 A	1.67 C	
<b>Second season (2020)</b>						
CN.S.(control)	1.27 g	1.88 c	1.84 cd	2.13 a	1.87 c	1.80 A
V.L.	0.72 j	1.00 i	1.39 f	1.17 h	1.23 gh	1.10 C
CN.S. +V.L.	1.24 gh	1.86 c	1.78 d	1.98 b	1.67 e	1.71 B
Mean	1.08 D	1.58 C	1.67 B	1.76 A	1.58 C	

**Table (10): Effect of different nutrient solution sources and vermicompost rates on yield of aromatic oil (ml/ m<sup>2</sup>) of sweet marjoram grown in sand culture**

Source of the nutrient solution	Vermicompost rates in sand culture					Mean
	V.C. 0% (control)	V.C. 10%	V.C. 20%	V.C. 30%	V.C. 40%	
<b>First season (2019)</b>						
CN.S.(control)	5.76 i	10.48 e	11.68 d	14.48 a	13.68 b	11.2 A
V.L.	2.88 k	4.72 j	7.52 g	6.80 h	8.16 fg	6.00 C
CN.S. +V.L.	5.28 ij	8.32 f	10.24 e	12.56 c	12.48 c	9.76 B
Mean	4.64 D	7.84 C	9.84 B	11.28 A	11.44 A	
<b>Second season (2020)</b>						
CN.S.(control)	5.12 g	10.16 c	10.64 c	13.76 a	13.2 a	10.56 A
V.L.	2.56 h	4.48 g	7.04 ef	6.40 f	7.20 e	5.52 C
CN.S. +V.L.	4.96 g	8.4 d	10 c	11.44 b	11.04 bc	9.20 B
Mean	4.24 D	7.68 C	9.2 B	10.48 A	10.48 A	



### Percentage of the aromatic oil .

Data in table (11) illustrate the effect of different sources of nutrient solution and different rates of vermicompost on aromatic oil % in sweet marjoram grown in sand culture. Regarding the effect of nutrient solution source, in both seasons, the highest aromatic oil% was obtained from CN.S. followed by CN.S. +V.L. then V.L., and all differences among treatments were significant.

Regarding the effect of vermicompost rate, in both seasons, data indicated that increasing vermicompost rate from zero to 40% increased aromatic oil %; V.C. 40% recorded the highest percentage while V.C. 0% recorded the lowest percentage. Moreover, differences among treatments were significant.

Regarding the effect of interaction, in both seasons, (V.C. 40% with CN.S.) recorded the highest aromatic oil %, while the lowest aromatic oil % was obtained from (V.C. 0% with V.L.).

**Table (11): Effect of different nutrient solution sources and vermicompost rates on aromatic oil % in sweet marjoram grown in sand culture**

Source of the nutrient solution	Vermicompost rates in sand culture					Mean
	V.C. 0%(control)	V.C. 10%	V.C. 20%	V.C. 30%	V.C. 40%	
<b>First season (2019)</b>						
CN.S.(control)	0.43 ef	0.54 d	0.60 c	0.66 b	0.70 a	0.59 A
V.L.	0.38 f	0.46 e	0.54 d	0.56 d	0.65 b	0.52 C
CN.S. +V.L.	0.41 f	0.45 e	0.56 d	0.61 c	0.69 ab	0.54 B
Mean	0.41 E	0.48 D	0.57 C	0.61 B	0.68 A	
<b>Second season (2020)</b>						
CN.S.(control)	0.41 ef	0.54 d	0.58 cd	0.64 b	0.71 a	0.57 A
V.L.	0.36 g	0.45 e	0.51 d	0.54 d	0.59 c	0.49 C
CN.S. +V.L.	0.40 f	0.45 e	0.56 cd	0.58 cd	0.66 b	0.53 B
Mean	0.39 E	0.48 D	0.55 C	0.59 B	0.65 A	

### Percentages of main components in the aromatic oil.

Data in table (12) illustrate the effect of different sources of nutrient solution and different rates of vermicompost on percentages of main components in the aromatic oil of sweet marjoram grown in sand culture (average of two seasons).

#### Regarding Terpinene-4-ol%

Data showed that increasing vermicompost rate from zero to 40% increased Terpinene-4-ol% in the produced volatile oil regardless the source of the nutrient solution applied.

Concerning the effect of interaction between vermicompost rate and source of the nutrient solution, data illustrated that the highest Terpinene-4-ol % has been recorded in (V.C. 40% with CN.S.) followed by (V.C. 40% with CN.S.+V.L.), while (V.C. 0% with V.L.) recorded the lowest percentage.

#### Regarding cis-sabinene hydrate%

Data showed that increasing vermicompost rate from zero to 40% increased cis-sabinene hydrate % in the produced volatile oil regardless the source of the nutrient solution applied.

Concerning the effect of interaction between vermicompost rate and source of the nutrient solution, data showed that (V.C. 40% with CN.S.) recorded the highest cis-sabinene hydrate %, while (V.C. 0% with V.L.) recorded the lowest percentage.

#### Regarding $\gamma$ -terpinene%

Data indicated that increasing vermicompost rate from zero to 40% increased  $\gamma$ -terpinene% in the produced volatile oil regardless the source of the nutrient solution applied.

Concerning the effect of interaction between vermicompost rate and source of the nutrient solution, data showed that (V.C. 40% with CN.S.) recorded the highest  $\alpha$ -terpinene% followed by (V.C. 40% with CN.S.+V.L.), while (V.C. 0% with CN.S. +V.L.) recorded the lowest percentage.

**Regarding  $\alpha$ -terpinene%**

Data showed that increasing vermicompost rate from zero to 40% increased  $\alpha$ -terpinene % in the produced volatile oil regardless the source of the nutrient solution applied.

Regarding the effect of interaction between vermicompost rate and source of the nutrient solution, data showed that (V.C. 40% with CN.S.) recorded the highest  $\alpha$ -terpinene % followed by (V.C. 40% with CN.S.+V.L.), while (V.C. 0% with V.L.) recorded the lowest percentage.

**Regarding p-cymene %**

Concerning CN.S., data illustrated that increasing vermicompost rate from zero to 30% increased p-cymene % in the produced volatile oil then the percentage decreased when vermicompost rate reached 40%.

Concerning both V.L. and CN.S + V.L., data showed that increasing vermicompost rate from zero to 40% increased p-cymene % in the produced volatile oil

Moreover, data illustrated that the highest p-cymene % has been recorded in (V.C. 30% with CN.S.) followed by (V.C. 40% with CN.S.+V.L.), while (V.C. 0% with V.L.) recorded the lowest percentage.

**Regarding Sabinene %**

Concerning CN.S., data illustrated that increasing vermicompost rate from zero to 30% increased Sabinene % in the produced volatile oil then the percentage decreased when vermicompost rate reached 40%.

Concerning both V.L. and CN.S + V.L., data showed that increasing vermicompost rate from zero to 40% increased sabinene % in the produced volatile oil

Furthermore, data illustrated that the highest sabinene % has been recorded in (V.C. 30% with CN.S.) followed by (V.C. 40% with CN.S.+V.L.), while (V.C. 0% with V.L.) recorded the lowest percentage.

**Table (12): Effect of different nutrient solution sources and vermicompost rates on percentages of main components in the aromatic oil of sweet marjoram grown in sand culture**

Treatments		The main components of Volatile oil (%)					
Source of nutrient solutions	Vermicompost rates in sand culture	Terpinen-4-ol	cis-sabinene	$\gamma$ -terpinene	$\alpha$ -terpinene	p-cymene	Sabinene
CN.S. (control)	V.C. 0%	17.50	9.32	9.04	7.45	6.58	7.56
	V.C. 10%	20.10	13.15	12.18	8.60	6.80	7.62
	V.C. 20%	21.08	13.48	15.54	11.18	7.29	8.04
	V.C. 30%	21.51	17.81	15.49	12.89	9.89	9.10
	V.C. 40%	23.24	18.48	16.44	12.95	8.81	7.82
V.L.	V.C. 0%	16.20	6.45	8.85	4.35	6.00	4.33
	V.C. 10%	17.82	6.89	10.83	4.44	6.16	4.56
	V.C. 20%	19.49	11.14	11.37	4.47	6.23	5.10
	V.C. 30%	20.39	12.70	12.37	7.24	6.69	5.79
	V.C. 40%	20.48	13.40	15.08	8.21	7.25	6.23
CN.S. +V.L.	V.C. 0%	17.00	6.74	8.00	8.23	6.20	6.20
	V.C. 10%	19.81	12.67	9.06	8.22	6.40	6.21
	V.C. 20%	20.58	15.59	13.48	9.51	7.48	7.63
	V.C. 30%	21.47	16.56	14.83	11.11	8.95	7.73
	V.C. 40%	21.75	16.73	15.75	12.30	9.66	8.26

### Nitrogen percentage in leaves.

Data in table (13) illustrate the effect of different sources of nutrient solution and different rates of vermicompost on nitrogen % in leaves of sweet marjoram grown in sand culture. Regarding the effect of nutrient solution source, data collected from both seasons indicated that the highest N% was recorded from CN.S. followed by CN.S. +V.L. without significant difference between both of them. While V.L. recorded the lowest percentage.

Regarding the effect of vermicompost rate, data showed that the highest N% was recorded from V.C. 30%, V.C. 40%, V.C. 20%, V.C. 10% and V.C. 0% respectively. Furthermore, differences among treatments were significant except the difference between V.C. 20% and V.C. 40% in both seasons.

Regarding the effect of interaction, in both seasons, (V.C. 30% with CN.S.) recorded the highest N%, while the lowest percentage was obtained from (V.C. 0% with V.L.).

**Table (13): Effect of different nutrient solution sources and vermicompost rates on nitrogen % in leaves of sweet marjoram grown in sand culture.**

Source of the nutrient solution	Vermicompost rates in sand culture					Mean
	V.C. 0% (control)	V.C. 10%	V.C. 20%	V.C. 30%	V.C. 40%	
<b>First season (2019)</b>						
CN.S.(control)	1.44 cd	1.68 b	1.79 a	1.81 a	1.72 b	1.69 A
V.L.	1.27 e	1.30 e	1.32 e	1.38 d	1.43 d	1.34 B
CN.S. +V.L.	1.49 c	1.66 b	1.67 b	1.78 a	1.70 b	1.66 A
Mean	1.40 D	1.55 C	1.59 B	1.66 A	1.62 B	
<b>Second season (2020)</b>						
CN.S.(control)	1.49 cd	1.73 b	1.88 ab	1.93 a	1.79 b	1.76 A
V.L.	1.38 d	1.36 d	1.39 d	1.50 cd	1.53 c	1.43 B
CN.S. +V.L.	1.58 c	1.75 b	1.74 b	1.89 ab	1.75 b	1.74 A
Mean	1.48 D	1.61 C	1.67 BC	1.77 A	1.69 B	

### Phosphorus percentage in leaves.

Data in table (14) illustrate the effect of different sources of nutrient solution and different rates of vermicompost on phosphorus % in leaves of sweet marjoram grown in sand culture. Regarding the effect of nutrient solution source, data collected from both seasons showed that the highest P% was recorded from CN.S. followed by CN.S. +V.L. without significant difference between both of them. On contrary, V.L. recorded the lowest P%.

**Table (14): Effect of different nutrient solution sources and vermicompost rates on phosphorus % in leaves of sweet marjoram grown in sand culture**

Source of the nutrient solution	Vermicompost rates in sand culture					Mean
	V.C. 0% (control)	V.C. 10%	V.C. 20%	V.C. 30%	V.C. 40%	
<b>First season (2019)</b>						
CN.S.(control)	0.27 c	0.30 bc	0.35 a	0.36 a	0.28 c	0.31 A
V.L.	0.18 e	0.19 de	0.19 de	0.22 d	0.27 c	0.21 B
CN.S. +V.L.	0.30 bc	0.31 b	0.31 b	0.32 b	0.26 c	0.30 A
Mean	0.25 C	0.27 BC	0.29 AB	0.30 A	0.27 BC	
<b>Second season (2020)</b>						
CN.S.(control)	0.28 cd	0.32 bc	0.38 a	0.38 a	0.29 c	0.33 A
V.L.	0.18 e	0.17 e	0.18 e	0.24 d	0.28 cd	0.21 B
CN.S. +V.L.	0.31 bc	0.33 b	0.33 b	0.34 b	0.29 c	0.32 A
Mean	0.26 D	0.27 CD	0.30 B	0.32 A	0.29 BC	

Regarding the effect of vermicompost rate, data from the first season indicated that the highest P% was obtained from V.C. 30%, followed by V.C. 20% then both V.C. 10% and V.C. 40%, while V.C. 0% recorded the lowest percentage. On the second season, data illustrated that V.C. 30% recorded the highest P%, then V.C. 20%, V.C. 40%, V.C. 10% and V.C. 0% respectively.

Regarding the effect of interaction, in the first season, both (V.C. 30% with CN.S.) and (V.C. 20% with CN.S.) recorded the highest P%. On the other hand, (V.C. 0% with V.L.), (V.C. 10% with V.L.) and (V.C. 20% with V.L.) recorded the lowest P%. Similar trends were observed in the second season.

#### Potassium percentage in leaves.

Data in table (15) illustrate the effect of different sources of nutrient solution and different rates of vermicompost on potassium % in leaves of sweet marjoram grown in sand culture. Regarding the effect of nutrient solution source, in both seasons, data illustrated that CN.S. recorded the highest K% then V.L. and CN.S. +V.L. respectively. Furthermore, differences among treatments were significant.

Regarding the effect of vermicompost rate, in the first season, collected data indicated that V.C. 30% recorded the highest K%, then V.C. 20%, V.C. 40% and V.C. 10%, while V.C. 0% recorded the lowest percentage. Moreover, differences among treatments were significant except the difference between V.C. 20% and V.C. 40%. Similar trend was observed in the second season except that there was no significant difference between V.C. 10% and V.C. 40%.

Regarding the effect of interaction, in both seasons, the highest K% was obtained from (V.C. 30% with CN.S.), while both (V.C. 0% with V.L.) and (V.C. 10% with V.L.) recorded the lowest percentages for K in leaves.

**Table (15): Effect of different nutrient solution sources and vermicompost rates on potassium % in leaves of sweet marjoram grown in sand culture**

Source of the nutrient solution	Vermicompost rates in sand culture					Mean
	V.C. 0% (control)	V.C. 10%	V.C. 20%	V.C. 30%	V.C. 40%	
<b>First season (2019)</b>						
CN.S.(control)	1.61 e	1.87 b	1.85 bc	2.08 a	1.87 bc	1.86 A
V.L.	1.53 f	1.54 f	1.62 de	1.62 de	1.63 de	1.59 C
CN.S. +V.L.	1.62 de	1.63 de	1.81 c	1.88 b	1.68 d	1.72 B
Mean	1.59 D	1.68 C	1.76 B	1.86 A	1.73 B	
<b>Second season (2020)</b>						
CN.S.(control)	1.62 d	1.87 b	1.81 bc	2.04 a	1.87 b	1.84 A
V.L.	1.47 e	1.47 e	1.60 d	1.63 d	1.62 d	1.56 C
CN.S. +V.L.	1.61 d	1.69 cd	1.76 c	1.85 b	1.61 d	1.70 B
Mean	1.57 D	1.68 C	1.72 B	1.84 A	1.70 BC	

#### 4. DISCUSSION

Regarding the effect of nutrient solution source on sweet marjoram grown in sand culture, obtained results indicated that chemical nutrient solution (CN.S.) recorded the highest values during the experimental time such as plant height, number of branches /plant, Fresh and dry weights of the aerial parts /plant, yields of the fresh and dry herb/ m<sup>2</sup>, yield of aromatic oil/ m<sup>2</sup>, percentage of the aromatic oil, and N,P,K % in leaves. This may be a result to the fact that the chemical nutrient solution contains macro and micro nutrients were easily available for plants, and in its optimum levels for plants and the balance between the composition of the chemical nutrient solution and the nutrition needs of the sweet marjoram comparing with the vermi-liquid as an organic source of the nutrient solution.

Abul-Soud, *et al.*, (2015a) studied the effect of vermicompost as an alternative organic substrate mixed with different mineral substrate perlite, vermiculite and sand (20 : 80% v/v) compared to peat moss + perlite (50 : 50% v/v) combined with different sources of nutrient solutions (vermicompost-tea, compost-tea and chemical) on the growth and yield of strawberry. Their results indicated that superior results of the chemical nutrient solution comparing with the other organic sources (vermicompost-tea, compost-tea); The balance between the chemical nutrient solution composition and nutrient requirements of strawberry plays a vital role in the highest results of vegetative, yield and quality characteristics as well as N, P and K contents of strawberry leaves compared to the composition of vermicompost-tea and compost-tea that had significant available amounts of plant nutrients but not in balance to meet strawberry requirements.

Al-Redhaiman *et al.*, (2005) investigated the influence of different nutrient sources (inorganic source and chicken manure, rabbit manure extracts as a natural organic source in addition to Al-Bostan liquid solution as an artificial organic fertilizer source.) on mineral accumulation and growth of lettuce plants under hydroponic condition. They noticed that the highest fresh and dry weight of lettuce head was observed with inorganic fertilizer solution followed by rabbit manure extract followed by Al-Bostan liquid solution.

Regarding the effect of different vermicompost rates on sweet marjoram grown in sand culture, obtained results illustrated that increasing vermicompost rate from 10% to 30 % increased plant height, no. of branches, fresh & dry weights of aerial parts per plant and yield of fresh & dried herb per m<sup>2</sup>. Then the results recorded lower values when vermicompost rate reached 40%. This could be a result to increase vermicompost rate led to increase the organic content of sand that promoted the plant growth and increased the availability of plant nutrients. This could be useful till specific rate then the increase may be harmful due to increase vermicompost rate increased the salinity or changing the pH around the roots.

Several studies assessed the effects of vermicompost amendments in potting substrates on seedling emergence and growth of a wide range of marketable fruits cultivated in greenhouses as well as on growth, yields. Providing that all nutrients are supplied by mineral fertilization, studies show greatest plant growth responses when vermicompost constituted a relatively small proportion (10 to 20%) of the total volume of the substrate mixture, with higher proportions of vermicompost in the mixture not always improving plant growth (Subler *et al.*, 1998, Atiyeh *et al.*, 2000 and Arancon *et al.*, 2005).

Using of vermicompost as a natural fertilizer having a number of advantages over chemical fertilizers, possibly due to better physical properties, higher microbial and enzymatic activity and higher content of available nutrients. Producers accept vermicompost is greater than that of compost (Abul-Soud *et al.*, 2014). Atiyeh *et al* (2002) further speculate that the growth responses observed may be due to hormone-like activity associated with the high levels of humic acids and humates in vermicompost; there seems a strong possibility that plant growth regulators which are relatively transient may become adsorbed on to humates and act in conjunction with them to influence plant growth. Vermicompost increase the nutritional quality of some vegetable crops such as tomatoes (Gutiérrez-Miceli *et al.*, 2007).

Abul-Soud *et al.*, (2015a) studied the effect of adding vermicompost in different rates to mineral substrates (perlite – sand) for enhancing the physical and chemical properties of mineral. Eight treatments were presented in three different rates of vermicompost (15%, 30 % and 45%) mixed with perlite and sand, and compared results with sand 100% and perlite 100% (control without vermicompost) under low tunnels conditions. Results of this study illustrated that increasing the vermicompost rate with sand and perlite from 0 to 45 led to increase of the organic matter content of different mixtures. The increase of organic matter in perlite mixtures was higher than sand mixture as a result of low bulk density of perlite compared to sand. As well as, increase of the organic matter is favorable, but it has a limit for the positive effect, otherwise it could create negative impacts. Also increasing the rate of vermicompost resulted in increasing EC level and pH number of substrates that also could create negative impacts on the vegetative, yield and quality properties of strawberry.

## 5. CONCLUSION

From the above mentioned results and discussion it could be concluded that even chemical nutrient solution recorded the highest values for vegetative growth, yield and chemical measurements. For that chemical nutrient solution could be considered as the most suitable nutrient solution for sweet marjoram. Nevertheless it's better to use mixture of chemical nutrient solution and vermi-liquid (50%:50%) because its results were very close to the chemical nutrient solution and it's more healthier; because the amount of chemicals used in this nutrient solution have been reduced into the half amount only comparison with chemical nutrient solution.

Moreover, adding vermicompost rate by 30% to sand culture recorded the highest values for plant height, number of branches /plant, Fresh and dry weights of the aerial parts per plant, yields of the fresh and dry herb per m<sup>2</sup>, yield of aromatic oil/ m<sup>2</sup> (V.C. 40% recorded higher values for yield of the aromatic oil per m<sup>2</sup> than V.C. 30% but the difference between both of them was not significant), and N,P,K % in leaves.

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