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Response of *Ocimum basilicum* to moringa leaves extract, moringa seed cake and/or vermicompost

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ABSTRACT

Ocimum basilicum is one of the main economic medicinal plants crops and it is a culinary herb. Its essential oil has several biological and pharmacological impacts. Plant-derived bio-stimulants such as moringa leaves extract, moringa seed cake and vermicompost are known for improving the physiological processes in plants and so far increasing the growth and yield of plants. This study was conducted to evaluate the impact of foliar application of moringa leaves extract (0, 0.3 and 0.6 %) and soil application of moringa seed cake and/or vermicompost (100% moringa seed cake, 75% moringa seed cake + 25% vermicompost, 50% moringa seed cake + 50% vermicompost and 100 % vermicompost) on basil plants among two cuts during 2020 and 2021 seasons. Application of 75% moringa seed cake + 25% vermicompost + 0.3% moringa leaves extract resulted in the highest values of plant height, fresh and dry weight (g) and yield (ton ha^{-1}). While, the interaction between 100% moringa seed cake fertilization and 0.3% of moringa leaves foliar-spray gave the maximum phenolic content and antioxidant activity in both cuts. On the other hand, application of 50% moringa seed cake with 50% vermicompost and 0.3% moringa leaves extract gave the maximum values of oil percentage and yield (ml $plant^{-1}$ and L ha^{-1}) in both cuts of both seasons, with no significant differences between this treatment and 75% moringa seed cake + 25 % vermicompost + 0.3% moringa leaves extract. Additionally, the GC/MS analysis of oil showed trans-cinnamic acid, methyl ester as the main constituents of the essential oil, followed by L-camphor, cis-cinnamic acid, methyl ester then eucalyptol and β-linalool in both cuts. Application of 100% moringa seed cake without spraying moringa extract (0%) increased the biosynthesis of trans-cinnamic acid, methyl ester (54.93 and 60.33% for the first and second cuts, respectively). It could be concluded that, the application of 75% moringa seed cake + 25% vermicompost + 0.3% moringa leaves extract is the recommended treatment for growth and production as well as oil yield and quality of *O. basilicum* plants.

Keywords: *Ocimum basilicum*, moringa extract, moringa seed cake, vermicompost, plant-derived bio-stimulants

1. Introduction

Ocimum basilicum L. is a popular ornamental plant belongs to Lamiaceae family and known commonly as sweet basil (Javanmardi *et al*., 2002). In traditional medicine, basil's leaves and flowers are used to treat and alleviate nausea, flatulence and dysentery (Bilal *et al*., 2012). Its essential oil is beneficial for relieving rhinitis, spasms, colds and as a first aid remedy for snakebites and wasp stings (Baytop, 1984). *O. basilicum* has a wide range of pharmacological and biological properties that have been known in the pharmaceutical industry to produce numerous drugs. Basil has different biological activities such as, anti-inflammatory (Raina *et al*., 2016), anti-hyperlipidemic, antiplatelet (Amrani *et*

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al., 2009), antioxidant (Pandey *et al*., 2016), anticonvulsant (Nyugen *et al*., 2010), immunomodulatory (Okazaki *et al*., 2011), anti-thrombotic (Tohti *et al*., 2006), anti-microbial (Nguyen and Niemeyer, 2008), insecticidal (Aarthi and Murugan, 2010) and cytotoxicity (Kathirvel and Ravi, 2012) effects. As, sweet basil is rich with numerous active constituents, like phenolics, flavonoids, terpenoids, carbohydrates, saponins, cardiac glycosides, alkaloids and tannins (Gebrehiwot *et al*., 2015 and Nguyen *et al*., 2021). The main constituents of the essential oil are methyl cinnamate (cinnamic acid, methyl ester), linalool, methyl chavicol (Gangrade *et al*., 2000), 1,8, cineole (Omer *et al*., 2008), eugenol (Mondawi *et al*., 1984), camphor (Purkayastha and Nath, 2006), methyl eugenol (Chang *et al*., 2009), β-elemene (Benedec *et al*., 2009), β-ocimene (Vani *et al*., 2009), camphene (Anand *et al*., 2011), carvacrol (Belong*et al*., 2013), α-bergamotene (Stajkovic *et al*., 2007), α-cadinol (Hassanpouraghdam *et al*., 2010) and geranial (Wossa *et al*., 2008).

Using plant-derived bio-stimulants is one of the ways to raise the cultivated plants production, as it can promote plant growth and improve physiological processes that result in increasing growth, nutrient uptake and abiotic stress tolerance (Nouman *et al*., 2014). Moringa leaves extract contains numerous essential nutrients, as proteins, fibers, minerals, sugars, many antioxidants, phytohormones, free amino acids, free proline and vitamins (Howladar, 2014; Rady and Mohamed, 2015). These growth promoters affect the growth of plant in many ways and enhance the defense mechanism against abiotic stresses (Younis *et al*., 2018). Vegetative growth parameters, biomass yield and volatile oil content are increased by moringa leaves extract foliar application (Brockman, 2016).

Moringa oleifera seed cake is added to the fertilizer mix as a good natural biodegradable and biocompatible organic fertilizer suitable for applications on crops in the developing regions of the world where soil infertility is a major concern (Emmanuel *et al*., 2011). Plant growth is enhanced during a short period when soil is fertilized by moringa seed cake comparing to other organic matters which require long time for decomposition and use of caution. Moringa oil is extracted from the seeds by cold-pressing method and after that moringa seed cake is be ready. Moringa seed cake is rich in protein content (about 60%) and as a powder contains all the essential amino acids; phenylalanine, isoleucine, valine, tryptophan, threonine, methionine, lysine, leucine, arginine, histidine, tyrosine and cysteine (Jahn, 1988). Organic fertilizers derived from *Moringa oleifera* seeds processed with the appropriate procedure can improve the soil aeration and richness of indigenous invertebrates, specialized endangered soil species, beneficial arthropods, earthworms, microbes and symbionts (FAO, 2010).

Vermicomposting is a kind of organic farming by which earthworms breakdown organic waste materials, promote microbial activity and accelerate the soil mineralization at the same time.

Waste materials are converted by these activities into humus-like substances called vermicompost (Ansari and Sukhraj, 2010). Vermicompost is finely divided peat like material with perfect structure, aeration porosity and high water holding capacity. Vermicompost is an organic fertilizer that is rich in nutrients, poor in readily biodegradable carbon and relatively free of any plant and human pathogens (Dominguez and Edwards, 2011). It has greatly increased surface area, which provides greater area for microbial activity to take place and excellent adsorption and nutrients retention (Ansari and Ismail, 2012a and Ansari and Ismail, 2012b). Since vermicompost releases nutrients slowly, making it simple to be absorbed by plants and since it increases the soil's capacity to store moisture that results in better quality of crops production, so using vermicompost in organic farming would be an inevitable practice for sustainable agriculture for the coming years (Najar and Khan, 2013).

This work aimed to evaluate the impact of moringa leaves extract foliar application as well as the soil application of moringa cake and/or vermicompost on growth, production, essential oil and some chemical constituents of *Ocimum basilicum* (basil plant).

2. Materials and Methods

The field experiment was conducted at the Agricultural Experimental Station of National Research Centre in Nubaria district, west of the Nile Delta and located at latitude 30^{o} 30' 1.4" N, and longitude 30^{o} 19' 10.9" E, Egypt. A drip irrigation system was used during the two successive seasons of 2020 and 2021 to evaluate the impact of moringa leaves extract foliar application as well as the soil application of moringa cake and/or vermicompost on growth, production, essential oil and some active constituents of basil plant (*Ocimum basilicum*).

The basil seedlings with suitable size and good root system were obtained from Horticulture Research Institute, Agricultural Research Center, Egypt and were transplanted in the field on 15th and

29th of March 2020 and 2021, respectively with 25 cm adjusted to dripper lines, which were 1m apart. Air temperature and relative humidity of the experimental region during the growing period are illustrated in Table (1).

Table 1: Monthly average of metrological data of the experimental area during 2020 and 2021 seasons

Month	2020 season				2021 season			
	Air temperature °C			R.H. %	Air temperature °C			R.H. %
	Max.	Min.	Aver.		Max.	Min.	Aver.	
March	29	7	16	71	31	9	16	65
April	33	9	18	69	41	9	19	61
May	41	12	22	63	41	11	23	60
June	41	15	24	66	38	17	24	67
July	33	21	26	71	36	21	28	67
August	34	20	27	72	37	21	28	69
September.	36	21	27	72	38	18	26	63
October	33	16	24	71	33	16	23	65
November	31	12	19	74	30	13	20	75

R.H. Relative humidity

Representative soil samples were taken from two layers (15 and 30 cm) before cultivation and then analyzed according to the procedures mentioned by Jackson (1973) and the results are shown in Table (2).

Table 2: Mechanical and chemical analysis of the experimental soil

Soil depth	Clay %	Silt %	Sand %	Texture
15 cm	14.94	30.00	54.28	Sandy loam
30 cm	13.43	29.59	55.19	Sandy loam

	S.P %	$CaCo_3$ %	pH	EC mmhos	Millie equivalent/Liter						
					Cations				Anions		
					Ca^+	M^+	Na^+	K^+	CO_3^-	HCO_3^-	Cl^-
15 cm	52.6	8.12	8.2	2.54	8.5	6	10.9	0.6	Nil	2.6	11
30 cm	51.9	7.75	8.8	2.96	10	7	12.3	0.6	Nil	3.85	9.5

During soil preparation (three weeks before transplantation), vermicompost and moringa seed cake were added after being mixed with part of the surface soil and followed by irrigation. The proposed moringa seed cake was added according to Hemdan *et al*. (2021). The physical and chemical properties of moringa seed cake are shown in Tables (3). Moreover, the recommended doses of synthetic fertilizers by the Ministry of Agriculture and Land Reclamation in Egypt for the sandy soils were added.

Table 3: Physical and chemical properties of moringa seed cake

Properties	Values
Moisture content (%)	4.9
pH	4.8
EC (dS/m)	3.20
Organic matter (%)	79.8
Carbohydrate (%)	16.0
Protein (%)	24.0
C/N ratio	12.14
Macro element (%)	
Total Nitrogen	3.80
Phosphorus	0.61
Potassium	0.70
Magnesium	0.31
Micro element (ppm)	
Zinc	18.8
Iron	12.5
Manganese	40.0

Vermicompost material: Epigiec earthwoms, Tiger Worm (*Eisenia Fetida*), Red Worm (*Lumbriscus Rubellus*), African Night Crawler (*Eudrilus Eugeniae*) and Indian Blue (*Perionyx Excavatus*) were used in vermicomposting bedding system to convert different organic wastes (animal manure (rabbit + horse manure) + agriculture residues) into vermicompost. The composition of dry vermicompost is presented in Table (4).

Table 4: The chemical analysis of macro (%) and micro (ppm) nutrients of the vermicompost.

C/N ratio	Macro elements (%)				
	N	P	K	Ca	Mg
12.1	1.94	1.27	1.51	1.09	0.86
	Micro elements (ppm)				
	Fe	**Mn**	**Zn**	**Cu**	**B**
	4469	502	98	47	88

A factorial experiment was imposed in a completely randomized blocks design of all combinations between three concentrations of moringa leaves extract as foliar application (0, 0.3 and 0.6 %), four levels of moringa cake and/or vermicompost as soil application :100% moringa seed cake (4 ton ha^{-1}), 75% moringa seed cake + 25% vermicompost, 50% moringa seed cake + 50% vermicompost and 100 % vermicompost (7.5 ton ha^{-1}).

2.1. Preparation of ethanolic *Moringa oleifera* leaves extract

Moringa oleifera dried leaves were obtained from National Research Centre in Giza, Egypt and were extracted according to Elsayed *et al.,* (2022) with slightly modifications. Moringa leaves were coarsely powdered, then the powder (1000 g) were soaked in 4 liters of 70% ethyl alcohol and kept in tightly sealed vessels at room temperature in the dark for three weeks, then the mixture was filtered. The extraction of the residue was repeated 3 times in the same manner until we obtained a clear colorless supernatant. The extracted solvent was collected, then concentrated by rotary evaporator under reduced pressure at 50^{o} C until the solvent was completely removed. The crude extract was stored at 4°C until used.

The experiment included twelve treatments with three replications for each. The treatments were applied two times; the first spray was applied on 4th May and the second one was in 6th July of 2020 and 2021 seasons.

The first cut of the aerial parts was carried out on 9th June 2020 and 2021, while the second cut was performed in 1st August 2020 and 2021. The cutting of the aerial parts of each plant was done at 10 cm above the soil surface. Plant height (cm) as well as fresh and dry weight of aerial parts (g $plant^{-1}$ and ton ha^{-1}) were recorded.

Essential oil percentages of dry herb were determined by hydro-distillation using Clevenger-type apparatus according to the Egyptian Pharmacopoeia (1984) and the essential oil yield (ml $plant^{-1}$ and L ha^{-1}) were calculated. The resulted essential oil was separately dried over anhydrous sodium sulfate and was kept in the deep freezer till GC-MS analysis. To identify the main constituents and to determine their relative percentages, the essential oils were separately subjected for GC-MS analysis using gas chromatography-mass spectrometry instrument stands at the Department of Medicinal and Aromatic Plants Research, National Research Centre following the conditions mentioned by Omer *et al.,* (2022).

Total soluble phenols (mg g^{-1} dry weight) was determined according to Singleton *et al*., (1999). Antioxidant activity (%) was determined depending on the ability of the extract to scavenge DPPH free radicals according to the standard method (Tekao *et al*., 1994) and the suitable modifications of Kumarasamy *et al.,* (2007).

The recorded data were analyzed as completely randomized blocks design by analysis of variance (ANOVA) using the General Linear Models procedure of CoStat (Snedecor and Cochran, 1967). Least significant difference (LSD) test was applied at 0.05 probability level to compare the mean of the treatments.

3. Results and Discussion

3.1. Vegetative growth parameters

All vegetative parameters of *O. basilicum* responded significantly to foliar and soil applications as well as to their interactions in the first and second cuts in both seasons, except plant height in the first cut of the first season and in the second cut of both seasons which did not show significant increment to the interaction treatments as shown in Tables (5, 6 and 7). It was noticed that, plants weights in the second cut were higher than their weights in the first cut, this is because cutting activates the branching of the plant and thus increases the weight of the plant.

It is clear that all vegetative parameters of basil plants in both cuts of both seasons significantly reached its maximum values with the addition of 75% of moringa seed cake with 25% vermicompost, while their lowest values were resulted when plants were fertilized with 100% moringa seed cake. These results are in harmony with those of Anwar *et al.,* (2005) on french basil, Prabha *et al.,* (2007) on some medicinal plants, Emmanuel *et al*.(2011a) on maiz as well as Hemdan *et al.,* (2021) and El-Hadidy *et al.,* (2022) on Valencia orange trees.

This increase in growth and yield may be attributed to the high content of macro and micronutrients in moringa seed cake and vermicompost of which resulted in improved growth and yield of basil plants. The nutrients availability in the soil for plant uptake is increased significantly by the organic fertilizers. There is an indication that moringa seed cake not only can add nutrients to the soil, but also it acts as a scavenger of certain nutrients i.e. K, Mn, Cu and Ca (Emmanuel *et al*., 2011a). Moreover, Emmanuel *et al.,* (2011b) stated that the cake provides great support for the microbial growth and the soil's microorganisms activity, which may have also led to the release of additional nutrients in the soil. In addition, the richness and density of indigenous invertebrates, earthworms, beneficial arthropods, specialized endangered soil species, microbes and symbionts may be increased by using organic fertilizers derived and processed with the right procedure from *M. oliefera* seeds (FAO, 2010). The previous information could in turn clarify the importance of adding vermicompost combined with moringa seed cake.

Table 5: Effect of soil application of moringa seed cake and/or vermicompost combined with foliar application of moringa extract on plant height of *Ocimum basilicum* plants at the first and second cuts of 2020 and 2021 seasons

Treatment		**Plant height (cm) 1st cut**		**Plant height (cm) 2nd cut**	
Soil application	**Foliar application**	**1st season**	**2nd season**	**1st season**	**2nd season**
100% MSC	**ME0**	50.7	44.3	59.0	64.7
	ME1	61.3	51.7	70.3	71.7
	ME2	55.3	49.3	65.7	70.0
75%MSC+25%Vermi	**ME0**	61.3	47.3	67.3	68.7
	ME1	72.7	59.0	78.3	74.3
	ME2	66.3	54.3	71.7	71.7
50%MSC+50%Vermi	**ME0**	58.7	48.7	64.3	65.3
	ME1	70.0	54.7	76.3	71.0
	ME2	63.3	50.7	69.0	68.7
100%Vermi	**ME0**	54.0	48.7	62.0	66.3
	ME1	66.3	55.7	69.7	71.0
	ME2	58.0	52.7	65.3	69.7
L.S.D. at 5		**n.s.**	**1.88**	**n.s.**	**n.s.**
Soil application					
100% MSC		55.8	48.4	65.0	68.8
75%MSC+25%Vermi		66.8	53.6	72.4	71.6
50%MSC+50%Vermi		64.0	51.3	69.9	68.3
100%Vermi		59.4	52.3	65.7	69.0
L.S.D. at 5%		**1.10**	**1.09**	**1.46**	**1.17**
Foliar application					
ME0		56.2	47.3	63.2	66.3
ME1		67.6	55.3	73.7	72.0
ME2		60.8	51.8	67.9	70.0
L.S.D. at 5%		**0.95**	**0.94**	**1.26**	**1.01**

MSC: moringa seed cake, Vermi: vermicompost, ME: moringa extract

Table 6: Effect of soil application of moringa seed cake and/or vermicompost combined with foliar application of moringa extract onherb fresh and dry weight and yield of *Ocimum basilicum* plants at the first cut of 2020 and 2021 seasons

Treatment		Herb fresh weight (g plant^{-1})		Herb Dry weight (g plant^{-1})		Herb fresh yield (ton hectar^{-1})		Herb dry yield (ton hectar^{-1})	
Soil application	**Foliar application**	**1st season**	**2nd season**	**1st season**	**2nd season**	**1st season**	**2nd season**	**1st season**	**2nd season**
100% MSC	**ME0**	301.3	338.3	69.7	93.7	12.1	13.5	2.79	3.75
	ME1	465.0	591.3	101.3	157.0	18.6	23.7	4.05	6.28
	ME2	379.7	494.3	84.3	134.3	15.2	19.8	3.37	5.37
75%MSC+25%Vermi	**ME0**	448.3	597.3	99.0	157.3	17.9	23.9	3.96	6.29
	ME1	601.7	801.0	133.3	220.7	24.1	32.0	5.33	8.83
	ME2	557.7	670.7	122.7	188.0	22.3	26.8	4.91	7.52
50%MSC+50%Vermi	**ME0**	429.0	517.0	92.7	145.7	17.2	20.7	3.71	5.83
	ME1	571.7	664.0	120.0	181.3	22.9	26.6	4.80	7.25
	ME2	513.7	555.0	115.7	147.7	20.5	22.2	4.63	5.91
100%Vermi	**ME0**	397.7	394.7	84.7	120.0	15.9	15.8	3.39	4.80
	ME1	506.7	624.0	112.0	178.0	20.3	25.0	4.48	7.12
	ME2	413.3	467.7	87.7	137.7	16.5	18.7	3.51	5.51
L.S.D. at 5		**36.43**	**51.77**	**8.97**	**16.21**	**1.46**	**2.07**	**0.36**	**0.65**
Soil application									
100% MSC		382.0	474.7	85.1	128.3	15.3	19.0	3.40	5.13
75%MSC+25%Vermi		535.9	689.7	118.3	188.7	21.4	27.6	4.73	7.55
50%MSC+50%Vermi		504.8	578.7	109.4	158.2	20.2	23.1	4.38	6.33
100%Vermi		439.2	495.4	94.8	145.2	17.6	19.8	3.79	5.81
L.S.D. at 5%		**21.07**	**29.95**	**5.19**	**9.38**	**0.84**	**1.20**	**0.21**	**0.38**
Foliar application									
ME0		394.1	461.8	86.5	129.2	15.8	18.5	3.46	5.17
ME1		536.3	670.1	116.7	184.3	21.5	26.8	4.67	7.37
ME2		466.1	546.9	102.6	151.9	18.6	21.9	4.10	6.08
L.S.D. at 5%		**18.25**	**25.93**	**4.49**	**8.12**	**0.73**	**1.04**	**0.18**	**0.32**

MSC: moringa seed cake, Vermi: vermicompost, ME: moringa extract

The two levels of moringa leaves extract foliar application affected significantly all the vegetative parameters and led to values greater than control in both cuts of two seasons. All the values of vegetative parameters decreased significantly with increasing moringa leaves extract levels for all parameters, except basil fresh weight (g) and yield (ton ha^{-1}) in the second cut of the first season which decreased insignificantly. Our results agreed with Prabhu *et al.,* (2010) on *Ocimum sanctum*, Balakumbahan and Rajamani (2010) on *Cassia angustifolia*, Nouman *et al.,* (2011) on rangeland grass and Abdalla (2013) on *Eruca vesicaria*.

The previous result might be due to that moringa leaves extract is a source of protein, indole-3-acetic acid (IAA), cytokinin, gibberellins (GAs), zeatin, vitamins and various mineral elements (P, K, Ca, Mg, Fe, Cu, Mn and Zn). These compounds can be used effectively as a plant growth bio-stimulants (Howladar, 2014 and Rady *et al*., 2015). Moreover, proteins are essential for the protoplasm formation, while growth hormones favored rapid cell division, cell multiplication and enlargement. Besides that, the leaves contain high nutritional content of several macro elements as Mg (Yameogo *et al*., 2011). In addition, moringa leaves extract improves the photosynthetic apparatus which resulted in increasing the growth and productivity of plants (Latif and Mohamed 2016).

The maximum values of plant height, herb fresh and dry weights and yield were resulted from plants fertilized with 75% moringa seed cake + 25% vermicompost and sprayed with 0.3% moringa leaves extract. On the other hand, the minimum values were recorded with 100% moringa compost fertilization interacted with tap water (control) foliar application in both cuts, except the lowest herb fresh and dry weight and yield in the second cut of the second season were resulted from fertilization with 100% vermicompost and spraying with tap water.

The physical, chemical, biochemical and biological properties of the soil were improved by using the combination of moringa seed cake, vermicompost and moringa leaf extract, as it helped in enhanching the moringa seed cake efficiency on improving the quality of treated plants not only through increasing the organic matter in the soil and improving the soil's moisture-holding capacity (Arancon *et al*., 2004), but also by increasing the available micro and macro elements through its effect on soil pH, promotes the multiplication and proliferation of microorganisms in the soil, enhances the population of microbes and microbial enzymes activity (Loredana *et al*., 2015). It is well known that physical and chemical properties of sandy soil, soil water retention and biological functions are improved by exogenous applications of organic matter (Diacono and Montemurro, 2015 and Jain and Kalamdhad, 2020).

Table 7: Effect of soil application of moringa seed cake and/or vermicompost combined with foliar application of moringa extract on herb fresh and dry weight and yield of *Ocimum basilicum* plants at the second cut of 2020 and 2021 seasons

Treatment		**Herb fresh weight (g plant^{-1})**		**Herb Dry weight (g plant^{-1})**		**Herb fresh yield (ton hectar^{-1})**		**Herb Dry yield (ton hectar^{-1})**	
Soil application	**Foliar application**	**1st season**	**2nd season**	**1st season**	**2nd season**	**1st season**	**2nd season**	**1st season**	**2nd season**
	ME0	518.3	848.0	110.7	235.3	20.7	33.9	4.43	9.41
100% MSC	**ME1**	661.7	944.7	152.3	286.3	26.5	37.8	6.09	11.45
	ME2	629.7	897.7	137.0	247.0	25.2	35.9	5.48	9.88
	ME0	688.7	889.0	143.3	261.0	27.5	35.6	5.73	10.44
75%MSC+25%Vermi	**ME1**	785.3	1109.3	170.3	315.0	31.4	44.4	6.81	12.60
	ME2	768.7	971.7	165.7	274.3	30.7	38.9	6.63	10.97
	ME0	705.0	847.3	148.3	243.7	28.2	33.9	5.93	9.75
50%MSC+50%Vermi	**ME1**	735.3	1010.3	154.3	295.7	29.4	40.4	6.17	11.83
	ME2	728.0	951.0	151.0	273.3	29.1	38.0	6.04	10.93
	ME0	557.7	746.3	120.0	216.7	22.3	29.9	4.80	8.67
100%Vermi	**ME1**	694.0	1023.7	153.7	297.7	27.8	40.9	6.15	11.91
	ME2	684.7	890.7	149.3	256.0	27.4	35.6	5.97	10.24
L.S.D. at 5		**37.39**	**54.49**	**11.73**	**13.40**	**1.50**	**2.18**	**0.47**	**0.54**
Soil application									
100% MSC		603.2	896.8	133.3	256.2	24.1	35.9	5.33	10.25
75%MSC+25%Vermi		747.6	990.0	159.8	283.4	29.9	39.6	6.39	11.34
50%MSC+50%Vermi		722.8	936.2	151.2	270.9	28.9	37.4	6.05	10.84
100%Vermi		645.4	886.9	141.0	256.8	25.8	35.5	5.64	10.27
L.S.D. at 5%		**21.63**	**31.52**	**6.79**	**7.75**	**0.87**	**1.26**	**0.27**	**0.31**
Foliar application									
ME0		617.4	832.7	130.6	239.2	24.7	33.3	5.22	9.57
ME1		719.1	1022.0	157.7	298.7	28.8	40.9	6.31	11.95
ME2		702.8	927.8	150.8	262.7	28.1	37.1	6.03	10.51
L.S.D. at 5%		**18.73**	**27.30**	**5.88**	**6.71**	**0.75**	**1.09**	**0.24**	**0.27**

MSC: moringa seed cake, Vermi: vermicompost, ME: moringa extract

3.2. Total phenolics and antioxidant activity

Soil fertilization with 75% moringa seed cake + 25% vermicompost produced significantly the highest phenolic content and antioxidant activity in basil herb in both cuts (Table, 8). The obtained results of fertilization are in similarity to those observed by Hemdan *et al.,* (2021) and El-Hadidy *et al.,* (2022). These findings could be explained by the fact that moringa seeds contain a great content of antioxidant compounds like phenolics, flavonoids, photothynthetic pigments (chlorophyll and carotenoids) and vitamin C (Verma *et al*., 1976; Compaore *et al*., 2011 and Mukunzi *et al*., 2011). Besides that, organic fertilizers promote secondary metabolites such as phenolics, auxins and proteins (Saviozzi *et al*., 2002 and Bejan and Vișoiu, 2010).

Regarding the effect of moringa leaves extract, foliar application with tap water and 0.3% moringa leaves extract produced the greatest values of phenolics and antioxidant activity with no significant differences between the two treatments in the two cuts. These results of foliar application were found to be agreed with Taha *et al.,* (2015) and El-Rokiek *et al.,* (2019). The higher phenolic content and antioxidant activity in plants sprayed with moringa leaves extract might be attributed to its wide spectrum of phenolic and flavonoids compounds, ascorbic acid (Makkar and Becker, 1996), β-carotene, α-tochopherol (vitamin E) and antioxidant enzymes. Thus, the extract showed strong scavenging effect (Dasgupta and De, 2006; Sreelatha and Padma, 2009; Jacob and Shenbagaraman, 2011), so this extract can inhibit oxidative damage to major biomolecules and provide significant protection against oxidative damage by promoting the accumulation of higher levels of phenolic compounds and antioxidants (Abdalla, 2013).

The interaction between 100% moringa seed cake fertilization and 0.3% of moringa leaves foliar-spray application resulted in the maximum total phenolics and antioxidant activity in the first and second cuts, but antioxidant activity values did not show significant differences between this treatment and 75% moringa seed cake + 25% vermicompost treatment when sprayed with tap water in both cuts.

Table 8: Effect of soil application of moringa seed cake and/or vermicompost combined with foliar application of moringa extract on total phenolics and antioxidant activity of *Ocimum basilicum* plants at the first and second cuts of 2020 season

Treatment		**Total phenolics ($mg\ g^{-1}$)**		**Antioxidant activity (%)**	
Soil application	**Foliar application**	**1^{st} cut**	**2^{nd} cut**	**1^{st} cut**	**2^{nd} cut**
100% MSC	**ME0**	29.3	32.0	79.2	77.7
	ME1	33.0	38.8	83.3	85.5
	ME2	14.3	11.8	40.0	31.7
75%MSC+25%Vermi	**ME0**	30.9	36.2	82.4	83.2
	ME1	18.3	15.6	52.6	38.1
	ME2	30.7	35.2	80.4	81.9
50%MSC+50%Vermi	**ME0**	15.5	11.8	44.3	38.7
	ME1	24.1	23.4	66.3	64.1
	ME2	22.5	18.3	61.2	52.0
100%Vermi	**ME0**	22.7	19.2	62.6	57.8
	ME1	26.3	22.8	67.2	62.8
	ME2	22.5	15.4	62.2	45.0
L.S.D. at 5		**1.70**	**1.28**	**2.27**	**2.80**
Soil application					
100% MSC		25.5	27.5	67.5	65.0
75%MSC+25%Vermi		26.6	29.0	71.8	67.7
50%MSC+50%Vermi		20.7	17.8	57.3	51.6
100%Vermi		23.8	19.1	64.0	55.2
L.S.D. at 5%		**0.99**	**0.74**	**1.31**	**1.62**
Foliar application					
ME0		24.6	24.8	67.1	64.3
ME1		25.4	25.1	67.4	62.6
ME2		22.5	20.2	61.0	52.6
L.S.D. at 5%		**0.85**	**0.64**	**1.14**	**1.40**

MSC: moringa seed cake, Vermi: vermicompost, ME: moringa extract

3.3. Essential oil production

The effect of soil fertilization on essential oil percentage was significant in both cuts during the first and second seasons (Tables, 9 and 10). In the first cut of both seasons, the addition of 100% moringa seed cake resulted in the maximum essential oil percentage but there was no significant difference between this treatment and 50 % moringa seed cake + 50% vermicompost in the first season. While in the second cut of both seasons, plants fertilized with 100 % vermicompost produced significantly the highest essential oil percentage.

In regards to oil yield, it could be mentiond that 75% moringa seed cake + 25 % vermicompost application led to the highest essential values (ml $plant^{-1}$ and L ha^{-1}) in the first cut of both seasons. On the other hand, the highest essential oil yield (ml $plant^{-1}$ and L ha^{-1}) in the second cut of both seasons was produced from plants fertilized with 50% moringa seed cake + 50% vermicompost or 100% vermicompost with no significant differences between each other. These results are in accordance with those of Kazeminasab *et al.,* (2016) on *Melissa officinalis*, Amooaghaie and Golmohammadi (2017) on *Thymus vulgaris* and Greco *et al.,* (2021) on *Salvia officinalis*.

The remarkable influence of both fertilizers specially vermicompost on increasing essential oil (EO) production could be illustrated by enhancing N and P uptake, which are the crucial components for the primary and secondary metabolism in the majority of medicinal plants (Arif *et al*., 2016 and Greco *et al*., 2021). Additionally, the synthesis of terpenes precursors i.e., DMAPP (dimethylallyl pyrophosphate) and IPP (isopentenyl pyrophosphate) need ATP and NADPH as photosynthesis product. Thus, photosynthesis potential, which is affected positively by organic fertilizers, directly affects the of essential oil production. Moreover, glucose and CO_2 are the initial precursors in essential oils forming (Pandey *et al*., 2009).

Table 9: Effect of soil application of moringa seed cake and/or vermicompost combined with foliar application of moringa extract on essential oil production of *Ocimum basilicum* plants at the first cut of 2020 and 2021 seasons

Treatment		Oil percentage (%)		Oil yield (ml plant^{-1})		Oil yield (L hectar^{-1})	
Soil application	Foliar application	1st season	2nd season	1st season	2nd season	1st season	2nd season
100% MSC	**ME0**	3.46	3.18	2.41	2.98	96.4	119.4
	ME1	3.20	3.65	3.24	5.73	129.7	229.3
	ME2	3.52	3.52	2.97	4.73	118.8	189.1
75%MSC+25%Vermi	**ME0**	2.67	2.87	2.64	4.51	105.6	180.5
	ME1	3.22	3.13	4.30	6.91	171.9	276.3
	ME2	2.96	2.93	3.63	5.50	145.1	220.2
50%MSC+50%Vermi	**ME0**	3.23	2.93	3.00	4.27	119.9	170.9
	ME1	3.62	3.23	4.34	5.87	173.6	234.6
	ME2	3.00	3.13	3.47	4.61	139.0	184.4
100%Vermi	**ME0**	3.00	2.83	2.54	3.41	101.6	136.3
	ME1	3.34	3.15	3.75	5.61	149.8	224.4
	ME2	3.20	3.07	2.81	4.22	112.3	168.9
L.S.D. at 5		**0.251**	**n.s.**	**0.293**	**0.568**	**11.74**	**22.72**
Soil application							
100% MSC		3.39	3.45	2.87	4.48	114.9	179.2
75%MSC+25%Vermi		2.95	2.98	3.52	5.64	140.9	225.7
50%MSC+50%Vermi		3.28	3.10	3.60	4.92	144.2	196.6
100%Vermi		3.18	3.02	3.03	4.41	121.2	176.5
L.S.D. at 5%		**0.145**	**0.151**	**0.169**	**0.329**	**6.79**	**13.14**
Foliar application							
ME0		3.09	2.95	2.65	3.79	105.9	151.8
ME1		3.35	3.29	3.91	6.03	156.2	241.1
ME2		3.17	3.16	3.22	4.77	128.8	190.6
L.S.D. at 5%		**0.126**	**0.130**	**0.147**	**0.285**	**5.88**	**11.38**

MSC: moringa seed cake, Vermi: vermicompost, ME: moringa extract

Concerning the foliar application of moringa leaves extract, the highest essential oil percentage and yield (ml plant^{-1} and L ha^{-1}) in both cuts during both seasons were produced significantly from plants sprayed with 0.3% moringa leaves extract. No significant differences were observed between the treatment of 0.3% or 0.6% of moringa leaves extract in oil percentage at the first cut of the second season. These results are compatible with Abbas *et al.,* (2016) on *Salvia officinalis*, Abou-Sreea and Matter (2016) on *Foeniculum vulgare*, Ali *et al.,* (2018) on *Pelargonium graveolens* and Alkuwayti *et al.,* (2020) on *Ocimum basilicum*.

Increasing the essential oil by spraying the plants with moringa leaves extract may be attributed to its valuable components including phytohoromes, amino acids and nutrient elements that motivate the secondary metabolites accumulation (Ali *et al*., 2018). The phytohormones influence the terpenoids' pathway by stimulating the responsible biochemical and physiological processes (Bano *et al*., 2016).

From the combination treatments, it could be argued that, the treatment of 50% moringa seed cake + 50% vermicompost +0.3% moringa leaves extract gave the maximum values of oil percentage and yield (ml plant^{-1} and L ha^{-1}) in the first and second cuts of both seasons, even if there were no significant differences between this treatment and some other treatments especially 75% moringa seed cake + 25 % vermicompost + 0.3% moringa leaves extract or 100% vermicompost + 0.3% moringa leaves extract.

Table 10: Effect of soil application of moringa seed cake and/or vermicompost combined with foliar application of moringa extract on essential oil production of *Ocimum basilicum* plants at the second cut of 2020 and 2021 seasons

Treatment		Oil percentage (%)		Oil yield (ml plant^{-1})		Oil yield (L hectar^{-1})	
Soil application	**Foliar application**	**1st season**	**2nd season**	**1st season**	**2nd season**	**1st season**	**2nd season**
100% MSC	**ME0**	2.87	3.02	3.18	7.09	127.1	283.7
	ME1	3.52	3.47	5.35	9.94	214.2	397.4
	ME2	3.38	3.43	4.63	8.48	185.0	339.2
75%MSC+25%Vermi	**ME0**	2.77	3.05	3.97	7.98	158.6	319.1
	ME1	2.95	3.33	5.02	10.51	200.8	420.3
	ME2	2.84	3.28	4.71	9.00	188.3	359.8
50%MSC+50%Vermi	**ME0**	3.12	3.30	4.62	8.04	184.7	321.8
	ME1	3.60	3.80	5.55	11.23	222.1	449.3
	ME2	3.32	3.52	5.01	9.61	200.3	384.3
100%Vermi	**ME0**	3.37	3.40	4.04	7.37	161.6	294.7
	ME1	3.80	3.90	5.84	11.61	233.8	464.2
	ME2	3.53	3.70	5.28	9.47	211.1	378.8
L.S.D. at 5		**0.213**	**n.s.**	**0.416**	**n.s.**	**16.61**	**n.s.**
Soil application							
100% MSC		3.26	3.31	4.39	8.50	175.4	340.1
75%MSC+25%Vermi		2.85	3.22	4.56	9.16	182.6	366.4
50%MSC+50%Vermi		3.34	3.54	5.06	9.63	202.4	385.1
100%Vermi		3.57	3.67	5.06	9.48	202.2	379.2
L.S.D. at 5%		**0.123**	**0.118**	**0.241**	**0.434**	**9.61**	**17.32**
Foliar application							
ME0		3.03	3.19	3.95	7.62	158.0	304.8
ME1		3.47	3.63	5.44	10.82	217.7	432.8
ME2		3.27	3.48	4.91	9.14	196.2	365.5
L.S.D. at 5%		**0.107**	**0.102**	**0.208**	**0.376**	**8.32**	**15.00**

MSC: moringa seed cake, Vermi: vermicompost, ME: moringa extract

3.4. Essential oil constituents

The total identified compounds in the essential oil by GC-MS of all treatments reached more than 99.5% as shown in Tables (11 and 12). All treatments showed trans-cinnamic acid, methyl ester (trans-methyl cinnamate) as the main compound from all identified compounds, followed by L-camphor, cis-cinnamic acid, methyl ester (cis-methyl cinnamate), then eucalyptol and β-linalool in the first and second cuts. A similar pattern of findings has also been reported by Padalia *et al.,* (2017).

The maximum percentages of trans-cinnamic acid, methyl ester (54.93 and 60.33%, in the first and second cut, respectively) were resulted from plants fertilized with 100% moringa seed cake and sprayed with tap water. While, the lowest values (42.55 and 38.79%, in the first and second cut, respectively) were found in plants fertilized with 100% moringa seed cake and sprayed with 0.6% moringa leaves extract in the first cut and plants fertilized with 100% vermicompost and sprayed with 0.6% moringa leavesextract in the second cut, respectively.

It was noticed that, there is a negative correlation between trans-cinnamic acid, methyl ester and L-camphor, cis-cinnamic acid, methyl ester, eucalyptol and β-linalool in both cuts, especially in the 2nd cut. On the other hand, there is a positive correlation between L-camphor, cis-cinnamic acid, methyl ester, eucalyptol and β-linalool in both cuts. Positively correlated compounds may be synthesized by the same enzyme or by different products in the same synthetic pathway, whereas negatively correlated chemicals may have a substrate competition relationship or an upstream and downstream relationship in the same synthetic route (Zhang *et al.,* 2023).

Cinnamic acid is a monocarboxylic acid with the formula of $C_9H_8O_2$, consisting of an acrylic acid with a phenyl substituent at the 3-position. Cinnamic acid is produce by plants in two isomers form, trans- and cis-isomers (Yang*et al*., 1999 and Yin*et al*., 2003). trans-Cinnamic acid originates from the shikimic acid pathway through the deamination of phenylalanine by l-phenylalanine ammonia-lyase. trans-Cinnamic acid is abundant in plants and its hydroxylation to p-coumaric acid leads to a

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plethora of secondary metabolites formed along the phenylpropanoid pathway (Boerjan*et al*., 2003, Vogt, 2010, Vanholme*et al*., 2019 and del Río*et al*., 2020). The photoisomerization in plants of trans-cinnamic acid leads to the cis-isomer of cinnamic acid (Yin*et al*., 2003).

From the data in Tables (11 and 12), it's clear that oxygenated compounds and monoterpines values are higher than non-oxygenated compounds and sesquiterpenes, respectively and almost all used treatments did not show notable differences in all of them.

Table 11: Effect of soil application of moringa seed cake and/or vermicompost combined with foliar application of moringa extract on essential oil constituents of Ocimum basilicum plants at the first cut of 2021 season

RT	KI	Compounds	Area %											
			100% MSC + ME0	100% MSC + ME1	100% MSC + ME2	75% MSC + 25% Vermi +ME0	75% MSC + 25% Vermi +ME1	75% MSC + 25% Vermi +ME2	50% MSC + 50% Vermi +ME0	50% MSC + 50% Vermi +ME1	50% MSC + 50% Vermi +ME2	100% Vermi + ME0	100% Vermi + ME1	100% Vermi + ME2
4.10	**926**	**α-Thujene**	0.18	0.21	0.28	0.21	0.26	0.22	0.22	0.25	0.22	0.25	0.21	0.25
4.28	**933**	**1R-α-Pinene**	0.75	0.89	1.11	0.87	1.00	0.92	0.88	0.99	0.89	1.05	0.86	0.96
4.71	**950**	**Camphene**	1.37	1.29	1.70	1.37	1.82	1.31	1.50	1.59	1.42	1.66	1.38	1.59
5.27	**969**	**Sabinene**	0.41	0.53	0.54	0.46	0.63	0.54	0.44	0.55	0.46	0.55	0.43	0.49
5.41	**973**	**β-Pinene**	0.96	1.13	1.27	1.03	1.36	1.12	1.04	1.22	1.10	1.26	1.00	1.17
5.69	**982**	**β-Myrcene**	0.32	0.49	0.45	0.42	0.47	0.52	0.33	0.45	0.42	0.40	0.33	0.34
6.49	**1006**	**α-Terpinolene**	--	--	0.12	--	--	--	--	0.07	0.07	--	0.06	--
6.96	**1021**	**D-limonene**	1.33	1.53	1.68	1.45	1.69	1.52	1.45	1.59	1.48	1.58	1.34	1.51
7.06	**1024**	**Eucalyptol**	7.70	7.87	8.99	7.86	9.73	7.54	8.02	8.86	8.00	8.32	7.57	8.35
7.51	**918**	**β-Ocimene**	0.05	0.14	0.10	0.08	0.11	0.16	--	0.09	0.07	0.06	--	--
7.94	**1049**	**ϒ-Terpinene**	0.18	0.27	0.42	0.17	0.22	0.25	0.22	0.28	0.28	0.20	0.23	0.18
8.49	**1063**	**trans-Linalool oxide**	0.04	--	--	--	--	--	0.07	--	--	--	--	0.07
8.73	**1069**	**trans-β-Terpineol**	0.58	0.62	0.59	0.68	0.79	0.61	0.64	0.65	0.57	0.67	0.56	0.76
9.85	**1095**	**β-Linalool**	4.23	5.32	6.75	5.28	4.70	5.17	5.05	5.62	5.52	4.89	5.74	4.94
9.98	**1098**	**Cis-β-Terpineol**	0.07	0.08	--	0.14	0.10	0.08	0.08	0.08	0.07	0.06	0.06	0.11
11.62	**1139**	**L-camphor**	14.51	14.80	17.31	14.57	17.96	13.86	16.44	16.42	16.01	15.65	14.33	15.71
12.97	**1170**	**Borneol**	0.27	0.17	0.41	0.29	0.21	0.18	0.39	0.21	0.17	0.30	0.16	0.37
13.09	**1173**	**Terpinen-4-ol**	1.89	2.37	2.69	2.18	2.27	2.25	2.21	2.35	2.34	2.06	1.94	2.16
14.00	**1191**	**L-α-Terpineol**	0.45	0.54	0.54	0.49	0.62	0.50	0.48	0.56	0.49	0.48	0.46	0.54
18.65	**1294**	**Cis-cinnamic acid, methyl ester**	7.16	9.09	8.49	8.35	10.22	8.81	8.67	9.80	8.63	8.80	7.30	9.26
20.80	**1343**	**(-)-β-Bourbonene**	0.05	0.07	0.10	0.05	0.07	0.06	0.07	0.08	0.08	0.07	0.07	0.10
22.30	**1376**	**trans-cinnamic acid, methyl ester**	54.93	49.61	42.55	51.09	43.03	51.12	48.40	45.31	48.95	48.84	53.10	48.06
23.91	**1411**	**Humulene**	0.14	0.20	0.30	0.20	0.14	0.23	0.13	0.17	0.19	0.12	0.18	0.14
24.97	**1437**	**Germacrene D**	0.14	0.25	0.32	0.23	0.19	0.36	0.08	0.19	0.22	0.13	0.17	0.10
25.42	**1448**	**α-Bergamotene**	0.29	0.09	--	0.07	--	0.12	--	--	0.06	--	--	--
25.55	**1451**	**Elixene**	--	0.11	0.13	0.07	0.08	0.14	--	0.07	0.09	--	0.07	--
26.07	**1463**	**ϒ-Muurolene**	--	0.33	0.44	0.31	0.28	0.35	0.32	0.33	0.35	0.30	0.32	0.37
26.95	**1482**	**Calamenene**	--	--	--	--		--	--	--	--	--	--	0.06
29.22	**1537**	**Caryophyllene oxide**	0.80	0.57	0.96	0.75	0.54	0.55	1.10	0.80	0.58	0.82	0.77	0.86
29.37	**1540**	**Spathulenol**	0.16	0.16	0.22	0.19	0.20	0.16	0.23	0.20	0.17	0.17	0.17	0.19
31.89	**1600**	**tau.-Cadinol**	0.85	1.09	1.18	0.98	1.03	1.12	1.22	1.05	0.98	1.02	0.97	1.14
Monoterpines			**97.38**	**96.95**	**95.99**	**96.99**	**97.19**	**96.68**	**96.53**	**96.94**	**97.16**	**97.08**	**97.06**	**96.82**
Sesquiterpenes			**2.43**	**2.87**	**3.65**	**2.85**	**2.53**	**3.09**	**3.15**	**2.89**	**2.72**	**2.63**	**2.72**	**2.96**
Non-oxygenated copmounds			**6.17**	**7.53**	**8.96**	**6.99**	**8.32**	**7.82**	**6.68**	**7.92**	**7.4**	**7.63**	**6.65**	**7.26**
Oxygenated copmounds			**93.64**	**92.29**	**90.68**	**92.85**	**91.4**	**91.95**	**93**	**91.91**	**92.48**	**92.08**	**93.13**	**92.52**
Total of identified compounds			**99.81**	**99.82**	**99.64**	**99.84**	**99.72**	**99.77**	**99.68**	**99.83**	**99.88**	**99.71**	**99.78**	**99.78**

RT: Retention time, KI: Kovats index, MSC: moringa seed cake, Vermi: vermicompost, ME: moringa extract

Table 12: Effect of soil application of moringa seed cake and/or vermicompost combined with foliar application of moringa extract on essential oil constituents of *Ocimum basilicum* plants at the second cut of 2021 season

R.T.	KI	Compounds	Area %											
			100% MSC + ME0	100% MSC + ME1	100% MSC + ME2	75% MSC + 25% Vermi +ME0	75% MSC + 25% Vermi +ME1	75% MSC + 25% Vermi +ME2	50% MSC + 50% Vermi +ME0	50% MSC + 50% Vermi +ME1	50% MSC + 50% Vermi +ME2	100% Vermi + ME0	100% Vermi + ME1	100% Vermi + ME2
4.10	**926**	**α-Thujene**	0.21	0.41	0.32	0.37	0.34	0.39	0.38	0.35	0.40	0.36	0.43	0.38
4.28	**933**	**1R-α-Pinene**	0.86	1.57	1.32	1.37	1.38	1.48	1.45	1.49	1.47	1.40	1.64	1.29
4.71	**950**	**Camphene**	1.02	1.71	1.46	1.59	1.61	1.63	1.52	1.55	1.62	1.59	1.75	1.88
5.27	**969**	**Sabinene**	0.46	0.81	0.70	0.68	0.68	0.75	0.74	0.79	0.76	0.72	0.82	0.59
5.41	**973**	**β-Pinene**	0.92	1.57	1.37	1.34	1.33	1.44	1.45	1.53	1.45	1.44	1.61	1.43
5.69	**982**	**β-Myrcene**	0.48	0.78	0.66	0.66	0.65	0.74	0.73	0.75	0.76	0.74	0.85	0.48
6.49	**1006**	**α-Terpinolene**	--	--	--	0.08	--	--	--	--	--	--	--	0.08
6.96	**1021**	**D-limonene**	1.23	1.92	1.72	1.69	1.73	1.81	1.74	1.76	1.82	1.79	1.99	1.83
7.06	**1024**	**Eucalyptol**	5.94	9.01	6.46	7.69	7.81	8.21	8.08	7.66	8.34	8.15	9.02	10.02
7.51	**918**	**β-Ocimene**	0.16	0.24	0.22	0.24	0.20	0.25	0.24	0.24	0.26	0.22	0.26	0.09
7.94	**1049**	**ϒ-Terpinene**	0.29	0.41	0.35	0.42	0.35	0.43	0.37	0.33	0.41	0.40	0.49	0.29
8.49	**1063**	**trans-Linalool oxide**	--	--	--	--	--	--	--	--	--	--	--	0.08
8.73	**1069**	**trans-β-Terpineol**	0.53	0.85	0.62	0.63	0.68	0.71	0.78	0.75	0.83	0.69	0.77	0.86
8.80	**1071**	**4-Terpinenyl acetate**	0.08	0.12	0.10	0.13	0.11	0.14	0.15	0.14	0.18	0.11	0.16	--
9.85	**1095**	**β-Linalool**	4.86	6.85	5.11	6.66	6.48	6.29	5.35	5.51	6.85	5.93	8.32	5.71
9.98	**1098**	**Cis-β-Terpineol**	--	0.10	--	--	--	0.09	--	--	--	--	--	--
11.62	**1139**	**L-camphor**	10.96	15.54	12.41	13.25	14.20	13.73	13.39	13.07	14.09	13.55	15.52	18.71
12.97	**1170**	**Borneol**	0.13	0.17	0.11	0.18	0.15	0.17	0.16	0.17	0.18	0.15	0.20	0.24
13.09	**1173**	**Terpinen-4-ol**	1.93	2.69	1.98	2.25	2.34	2.44	2.35	2.07	2.48	2.47	2.80	2.54
14.00	**1191**	**L-α-Terpineol**	0.48	0.66	0.47	0.62	0.63	0.67	0.61	0.59	0.63	0.61	0.70	0.60
18.65	**1294**	**Cis-cinnamic acid, methyl ester**	6.00	7.38	7.40	7.19	7.80	8.04	8.80	8.17	7.89	7.70	8.34	10.56
20.80	**1343**	**(-)-β-Bourbonene**	--	--	--	--	--	0.19	--	--	--	--	--	0.09
22.30	**1376**	**trans-cinnamic acid, methyl ester**	60.33	43.12	53.17	49.49	47.66	46.51	48.14	48.89	46.01	48.73	39.71	38.79
23.91	**1411**	**Humulene**	0.30	0.38	0.36	0.27	0.36	0.35	0.30	0.39	0.30	0.25	0.39	0.18
24.97	**1437**	**Germacrene D**	0.36	0.48	0.40	0.32	0.46	0.43	0.37	0.39	0.38	0.33	0.52	0.18
25.42	**1448**	**α-Bergamotene**	0.15	0.19	0.17	0.16	0.17	0.19	0.19	0.17	0.18	0.17	0.27	--
25.55	**1451**	**Elixene**	0.19	0.27	0.24	0.20	0.26	0.25	0.24	0.26	0.24	0.22	0.35	0.08
25.97	**1460**	**Guaia-1(10),11-diene**	0.05	--	0.13	--	--	--	--	--	--	--	--	--
26.07	**1463**	**ϒ-Muurolene**	0.30	0.42	0.38	0.31	0.39	0.38	0.38	0.38	0.31	0.32	0.45	0.38
29.22	**1537**	**Caryophyllene oxide**	0.47	0.48	0.63	0.63	0.46	0.61	0.37	0.60	0.45	0.35	0.52	0.83
29.37	**1540**	**Spathulenol**	0.12	0.17	0.16	0.15	0.15	0.21	0.15	0.19	0.16	0.14	0.19	0.23
31.89	**1600**	**tau.-Cadinol**	0.95	1.38	1.35	1.20	1.24	1.33	1.21	1.40	1.22	1.13	1.48	1.34
Monoterpines			**2.89**	**3.77**	**3.82**	**3.24**	**3.49**	**3.94**	**3.21**	**3.78**	**3.24**	**2.91**	**4.17**	**3.31**
Sesquiterpenes			**96.87**	**95.91**	**95.95**	**96.53**	**96.13**	**95.92**	**96.43**	**95.81**	**96.43**	**96.75**	**95.38**	**96.45**
Non-oxygenated copmounds			**6.98**	**11.16**	**9.8**	**9.7**	**9.91**	**10.71**	**10.1**	**10.38**	**10.36**	**9.95**	**11.82**	**9.25**
Oxygenated copmounds			**92.78**	**88.52**	**89.97**	**90.07**	**89.71**	**89.15**	**89.54**	**89.21**	**89.31**	**89.71**	**87.73**	**90.51**
Total of identified compounds			**99.76**	**99.68**	**99.77**	**99.77**	**99.62**	**99.86**	**99.64**	**99.59**	**99.67**	**99.66**	**99.55**	**99.76**

RT: Retention time, KI: Kovats index, MSC: moringa seed cake, Vermi: vermicompost, ME: moringa extract

4. Conclusion

The combination of moringa seed cake, vermicompost and moringa leaves extract led to beneficial effects on growth, yield, essential oil production and essential oil constituents as well as phenolic compounds and antioxidant activity of *Ocimum basilicum* plants grown under newly reclaimed sandy soil conditions. In general, the most effective treatment was the addition of 75% moringa seed cake + 25% vermicompost + 0.3% moringa leaves extract. This combination can maintain productivity and environmental quality.

Conflict of interest

All authors declare that they have no conflict of interest.

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