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Effect of organic fertilization on productivity of some newly introduced basil varieties under Siwa Oasis conditions

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ABSTRACT

A split-plot design field trial was carried out on *Ocimum basilicum* L. plants at Siwa Oasis, Egypt, during the 2018 and 2019 seasons to study the effect of organic fertilization, cultivation of some foreign varieties, and their combination on yield. The main plots included applying two compost manure levels before planting (24 and 48 m^3/hectare). Subplots included cultivating five basil varieties (local and four foreign varieties: lime basil, smuglyanka basil, purple basil, and purple ruffles basil). The results revealed that applying compost manure at the highest level significantly increased herb and oil yield attributes over the lowest level. The evaluation of varieties showed that the purple ruffles and purple varieties were the most tolerant to abiotic stresses and recorded the significantly maximum herbage and oil yield. The essential oil chemical composition was affected by the interaction within treatments and harvest time. Applying 48 m^3 compost/hectare and cultivation of foreign purple variety should be recommended in this region to produce the best yield quantity and quality characteristics (oil of high linalool of 50.95%–75.01% and minimum estragole of 0.00%–0.02%, as well as attractive flavor and color) which could promote exports.

1. INTRODUCTION

Sweet basil (*Ocimum basilicum* L., family: Lamiaceae) is a valuable spice and medicinal and aromatic crop cultivated in many countries worldwide. The global statistics of basil production are quite difficult to get. Nevertheless, the top three exporter countries in the global basil market are China, India, and Germany. China is ranked 1st with the share in export of 27.25%, whereas it is ranked 7th with the import of 3.42%. India is ranked 2nd with a stake in the export of 11.38%, and it is ranked 6th through the import share by 3.49%. Germany is ranked 3rd with the export percentage of 6.96%, while it is ranked 2nd with the stake in import of 12.08%. Egypt is ranked 4th with a share in export of 4.54%, and it is ranked 42nd with an import percentage of 0.26% [1].

In Egypt, basil is cultivated on a wide scale compared to other medicinal and aromatic plants. The country's production is 7,000 tons with very little consumption inside. The area of basil farms is nearly 3,078 hectares, and the majority of production is for export, where shipping markets are expanding from the Europe to the USA and neighboring countries. The local rich flavor variety is currently farmed and exported to outside markets with Egyptian basil's brand name. However, introducing foreign varieties for cultivation in the country relying on world market demand and richness in other famous flavors is also considered important for growing trade [2–5]. Some of the favorable foreign varieties are (i) lime basil, (ii) smuglyanka basil, (iii) purple basil, and (iv) purple ruffles basil [6–8].

Nowadays, basil planting is extended to newly reclaimed lands through the Egyptian desert for increasing production and improving quality. One of the surest methods for growing basil under the harsh environs of newly reclaimed lands is adding adequate organic nutrition to ensure high quality. Different organic amendments can improve physical and chemical soil properties besides increasing soil microbial activity. It favors plant growth and provides a slow and steady supply of nutrients for plants as nutrients are bound in organic molecules that require the ongoing action of soil microbes to release them [9–15]. It is also essential to determine the most suitable varieties for each region according to its climatic conditions. The genus *Ocimum* is characterized by

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significant morphological and chemical composition variability [16].

Siwa Oasis in the Western Desert of Egypt (about 50 km East of the Libyan border) in the Sahara Desert represents promised and newly reclaimed lands for the cultivation of many medicinal and aromatic plants. The current research gap is that there is no available information on Siwa Oasis farmers concerning optimal amounts of organic fertilizers they should apply to basil plants and the best basil varieties they should cultivate. As a result, this study objective investigates the effect of manure additive and evaluates the cultivation of some foreign varieties to compare with local basil and their combination to reach the highest productive characteristics under this region's condition.

2. MATERIALS AND METHODS

This field trial was carried out during the two successive seasons of 2018 and 2019 in the Experimental Farm of the Desert Research Center at Khamisa Village (29.21° N and 25.40° E), Siwa Oasis, Egypt [17]. The farm's soil and irrigation water analyses are presented in Table 1. Also, the meteorological data of Siwa Oasis are presented in Table 2.

The investigation layout was a split-plot design as the main plots included adding two compost manure levels before planting (24 m^3/hectare as recommended dose [18–20] and 48 m^3/hectare). At the same time, the subplots involved cultivating five basil varieties (local basil and four foreign varieties: lime basil, smuglyanka basil, purple basil, and purple ruffles basil) (Fig. 1). The seeds of lime and purple ruffles were obtained from Burpee Seeds Company, USA. The seeds of smuglyanka and purple varieties were obtained from SeDeK and Gavrish Seeds Companies, Moscow. The source of local basil seeds was obtained from the Egyptian Ministry of Agriculture and Land Reclamation. Compost manure was added to the sandy soil through soil preparation; the analysis of compost manure is shown in Table 1. The used organic fertilizer was made from a plant source. The laboratory analyses of soil, water, and compost manure samples were carried out as described by [21,22].

Seeds were sown in the nursery on 15 March; seedlings were transplanted in the field on 1 May for both seasons. Cultivation was achieved under a drip irrigation system in rows 75 cm apart and 30 cm within hills as one seedling per hill. All agricultural practices were conducted as stated by the Egyptian Ministry of Agriculture and Land Reclamation [23]. The herbage was harvested at flowering three times per season on 12 July (first cut) and 15 September (second cut) as well as on 17 December (third cut). Least significant difference (LSD) test at 0.05 was used to compare the average means of treatments [24].

The following data were collected at each harvest time.

2.1. Growth and Yield Parameters

Plant height (cm), fresh herb yield (ton/hectare), and dry herb yield (ton/hectare) were assessed.

2.2. Essential Oil

2.2.1. Essential oil percentage

The essential oil percentage was estimated using a Clevenger apparatus for the air-dried herb by hydrodistillation [25].

2.2.2. Essential oil yield per hectare (l)

This was calculated as follows: essential oil yield per plant × number of plants/hectare.

2.2.3. Essential oil chemical constituents

Essential oil samples of the second season were analyzed using gas chromatography-mass spectrometry instrument stands at the Laboratory of Medicinal and Aromatic Plants, National Research Center, Egypt, with the following specifications: device: a Trace

Table 1: Analyses of soil, irrigation water of the experimental farm, and compost manure.

Mechanical analysis of soil			
Sand (%)	**Silt (%)**	**Clay (%)**	**Soil texture**
92.91	5.21	1.88	Sandy

Chemical analysis of soil										
pH	**E.C. (ppm)**	**O.M. (%)**	**Soluble anions (meq/l)**				**Soluble cations (meq/l)**			
			CO_3^{--}	**HCO_3^-**	**Cl^-**	**SO_4^{--}**	**Ca^{++}**	**Mg^{++}**	**Na^+**	**K^+**
7.50	2,624.00	0.51	-	3.61	31.32	6.10	8.61	7.50	0.22	24.70

Chemical analysis of well water									
pH	**E.C. (ppm)**	**Soluble anions (meq/l)**				**Soluble cations (meq/l)**			
		CO_3^{--}	HCO_3^-	Cl^-	SO_4^{--}	Ca^{++}	Mg^{++}	Na^+	K^+
7.20	2,931.00	-	1.79	33.90	13.86	11.58	11.52	25.64	0.81

Chemical analysis of compost manure										
pH	**EC (ppm)**	**O.M. (%)**	**C/N ratio (%)**	**N (%)**	**P (%)**	**K (%)**	**Fe (%)**	**Mn (%)**	**Zn (mg/kg)**	**Cu (mg/kg)**
8.15	5,192.00	33.21	1:12.35	1.56	0.11	1.08	0.22	0.10	163.00	27.10

Table 2: Means of the meteorological data of Siwa Oasis during the seasons of 2018 and 2019.

Month		Air temperature (°C)			Humidity (%)	Precipitation (mm)	Wind (km/hour)
		Maximum	Minimum	Average			
Winter season	22 to 31December	19.20	10.00	14.60	65.00	0.00	15.33
	January	21.00	7.00	14.00	53.50	1.50	21.24
	February	25.50	7.00	16.25	50.50	2.10	17.98
	1 to 19 March	31.00	8.50	19.75	38.70	0.20	19.85
Mean		24.18	8.13	16.15	51.93	0.95	18.60
Spring season	20 to 31 March	30.00	9.00	19.50	46.33	0.00	23.23
	April	34.50	10.00	22.25	47.50	0.00	18.99
	May	41.50	13.50	27.50	34.50	0.00	17.82
	1 to 20 June	33.00	18.50	25.75	35.19	0.00	19.58
Mean		34.75	12.75	23.75	40.88	0.00	19.91
Summer season	21 to 30 June	38.00	21.00	29.50	38.01	0.00	14.45
	July	39.00	23.00	31.00	42.00	0.00	18.73
	August	42.00	24.00	33.00	42.50	0.00	16.34
	1 to22 September	38.00	22.00	30.00	50.93	0.00	19.31
Mean		39.25	22.50	30.88	43.36	0.00	17.21
Autumn season	23 to 30 September	34.00	19.00	26.50	46.57	0.00	13.89
	October	32.50	14.50	23.50	48.50	0.00	18.34
	November	28.50	11.00	19.75	49.00	0.00	18.44
	1 to 21 December	24.00	6.00	15.00	58.34	0.00	25.11
Mean		29.75	12.63	21.19	50.60	0.00	18.95

Figure 1: Cultivated varieties at different growth stages.

GC Ultra Gas Chromatographs (Thermo Scientific Corp., USA) coupled with a Thermo mass spectrometer detector (ISQ Single Quadrupole Mass Spectrometer). The Gas Chromatography (GC)/Mass Spectrometry (MS) system was equipped with a Trace-5 mass spectrometer (TR-5MS) column (30 m × 0.32 mm i.d., 0.25 µm film thickness). Analyses were carried out using helium as a carrier gas at a flow rate of 1.3 ml/minute at a split ratio of 1:10 at the following temperature program: 80°C for 1 minute; rising at 4°C/minute to 300°C, and held for 1 minute. The injector and detector were held at 220°C and 200°C, respectively. Diluted samples (1:10 hexane, v/v) of 1 µl of the mixtures were continuously injected. Mass spectra were obtained by electron ionization at 70 eV, using a spectral range of m/z 45–450. Identification of the compounds depended on comparing the retention times with those of authentic samples, and a library mass spectrum was built up from pure substances, components of known oils, and MS literature data [26–31].

3. RESULTS AND DISCUSSION

3.1. Effect of Organic Fertilization

Data presented in Tables 3–5 revealed that increasing compost manure to 48 m^3/hectare significantly increased plant height and fresh and dry herb yields (ton/hectare) in all cuts. The change percentages over control treatment were 9.27%, 25.95%, and 26.83%; 10.19%, 19.22%, and 20.19%; and 8.28%, 32.73%, and 29.73% for the first, second, and third cuts, respectively. Likewise, the obtained results in Tables 6–7 showed that increasing the amount of applied manure to soil significantly boosted the accumulation of essential oil percentage and oil yield among all cuts of the two seasons. The change percentage over control treatment was 20.37% and 53.41%; 19.15% and 43.56%; 15.39% and 40.92% for the first, second, and third cuts, respectively. On the other side, the lowest compost level (24 m^3/hectare) offered the lowermost parameters. The increment in essential oil yield may be due to the increment of essential oil % and/or mass production of herb.

The enhancing effect of organic fertilization on basil crops under the oasis environments can be due to its role in stress alleviation in plants. This area has poor sandy dune saline soil, irrigation by well with saline water, and a semiarid climate. Thus, the application of organic matter has several benefits there. It releases nutrients slowly, maintains the soil's structural stability, protects the soil against erosion, and improves physical, chemical, and biological properties to increase the overall soil fertility and, consequently, increase plant growth with more metabolites [32,33]. The successful role of organic fertilization on sustainable productivity, improving the quantity and quality of basil yield, agrees with numerous researches [34–45].

3.2. Effect of Varieties

According to data presented in Tables 3–5, there were remarkable variations between basil varieties in vegetative growth and yield. The significantly highest fresh herb yield/hectare and dry herb yield/hectare were got by purple ruffles variety during the first, second, and third cuts, respectively, followed by purple variety. On the other hand, the lime and smuglyanka varieties showed

Table 3: Effect of compost manure levels, varieties, and their interaction on plant height (cm) (mean values of two successive seasons).

Compost levels	Varieties	1st cut (12th July)	2nd cut (15th September)	3rd cut (17th December)
24 m^3/hectare	Local	24.00	29.83	29.50
	Smuglyanka	39.00	44.00	42.00
	Lime	20.83	27.00	24.00
	Purple	29.00	35.33	33.67
	Purple ruffles	36.00	42.50	39.83
Mean		29.77	35.73	33.80
48 m^3/hectare	Local	27.50	34.67	32.67
	Smuglyanka	41.67	48.17	44.00
	Lime	23.00	30.00	25.50
	Purple	32.33	39.00	38.83
	Purple ruffles	38.17	45.00	42.00
Mean		32.53	39.37	36.60
Over all means of varieties	Local	25.75	32.25	31.09
	Smuglyanka	40.34	46.09	43.00
	Lime	21.92	28.50	24.75
	Purple	30.67	37.17	36.25
	Purple ruffles	37.09	43.75	40.92
LSD at 0.05	Compost levels	1.66	1.43	1.23
	Varieties	2.63	2.26	1.94
	Compost levels × varieties	3.71	3.19	2.75

Table 4: Effect of compost manure levels, varieties, and their interaction on fresh herb yield (ton/hectare) (mean values of two successive seasons).

Compost levels	Varieties	1st cut (12th July)	2nd cut (15th September)	3rd cut (17th December)
	Local	1.13	3.10	2.22
	Smuglyanka	0.69	2.13	0.99
24 m^3/hectare	Lime	0.82	2.44	1.35
	Purple	1.61	4.31	2.93
	Purple ruffles	2.30	5.98	3.51
Mean		1.31	3.59	2.20
	Local	1.60	3.65	3.15
	Smuglyanka	0.89	2.53	1.55
48 m^3/hectare	Lime	0.98	2.78	1.80
	Purple	2.07	5.36	3.74
	Purple ruffles	2.69	7.08	4.37
Mean		1.65	4.28	2.92
	Local	1.37	3.38	2.69
Over all means of varieties	Smuglyanka	0.79	2.33	1.27
	Lime	0.90	2.61	1.58
	Purple	1.84	4.84	3.34
	Purple ruffles	2.50	6.53	3.94
	Compost levels	0.07	0.22	0.12
LSD at 0.05	Varieties	0.12	0.34	0.17
	Compost levels × varieties	0.17	0.48	0.26

Table 5: Effect of compost manure levels, varieties, and their interaction on dry herb yield (ton/hectare) (mean values of two successive seasons).

Compost levels	Varieties	1st cut (12th July)	2nd cut (15th September)	3rd cut (17th December)
	Local	0.34	0.90	0.68
	Smuglyanka	0.19	0.59	0.32
24 m^3/hectare	Lime	0.26	0.71	0.48
	Purple	0.53	1.29	1.01
	Purple ruffles	0.73	1.72	1.19
Mean		0.41	1.04	0.74
	Local	0.49	1.07	0.93
	Smuglyanka	0.25	0.73	0.49
48 m^3/hectare	Lime	0.30	0.81	0.62
	Purple	0.72	1.58	1.29
	Purple ruffles	0.84	2.05	1.48
Mean		0.52	1.25	0.96
	Local	0.42	0.99	0.81
Over all means of varieties	Smuglyanka	0.22	0.66	0.41
	Lime	0.28	0.76	0.55
	Purple	0.63	1.44	1.15
	Purple ruffles	0.79	1.89	1.34
	Compost levels	0.02	0.07	0.05
LSD at 0.05	Varieties	0.05	0.10	0.07
	Compost levels × varieties	0.07	0.14	0.10

Table 6: Effect of compost manure levels, varieties, and their interaction on essential oil percentage (mean values of two successive seasons).

Compost levels	Varieties	1st cut (12th July)	2nd cut (15th September)	3rd cut (17th December)
24 m^3/hectare	Local	0.64	0.58	0.45
	Smuglyanka	0.30	0.24	0.19
	Lime	0.41	0.30	0.24
	Purple	0.51	0.46	0.38
	Purple ruffles	0.83	0.75	0.70
Mean		0.54	0.47	0.39
48 m^3/hectare	Local	0.79	0.70	0.49
	Smuglyanka	0.37	0.30	0.24
	Lime	0.52	0.40	0.37
	Purple	0.60	0.52	0.42
	Purple ruffles	0.95	0.89	0.75
Mean		0.65	0.56	0.45
Over all means of varieties	Local	0.72	0.64	0.47
	Smuglyanka	0.34	0.27	0.22
	Lime	0.47	0.35	0.31
	Purple	0.56	0.49	0.40
	Purple ruffles	0.89	0.82	0.73
LSD at 0.05	Compost levels	0.02	0.01	0.02
	Varieties	0.03	0.02	0.03
	Compost levels × varieties	0.04	0.03	0.04

Table 7: Effect of compost manure levels, varieties, and their interaction on essential oil yield/hectare (l) (mean values of two successive seasons).

Compost levels	Varieties	1st cut (12th July)	2nd cut (15th September)	3rd cut (17th December)
24 m^3/hectare	Local	2.22	5.33	3.11
	Smuglyanka	0.45	1.33	0.45
	Lime	0.89	2.22	1.33
	Purple	2.67	5.78	4.00
	Purple ruffles	6.22	12.89	8.45
Mean		2.49	5.51	3.47
48 m^3/hectare	Local	4.00	7.56	4.45
	Smuglyanka	0.89	2.22	1.33
	Lime	1.78	3.11	2.22
	Purple	4.45	8.45	5.33
	Purple ruffles	8.00	18.22	11.11
Mean		3.82	7.91	4.89
Over all means of varieties	Local	3.11	6.45	3.78
	Smuglyanka	0.67	1.78	0.89
	Lime	1.34	2.67	1.78
	Purple	3.56	7.12	4.67
	Purple ruffles	7.11	15.56	9.78
LSD at 0.05	Compost levels	0.24	0.38	0.19
	Varieties	0.38	0.60	0.31
	Compost levels × varieties	0.53	0.84	0.43

lower measurements than the local ones. The increments of purple ruffles over local variety were 82.48% and 88.10%; 93.20% and 90.91%; 46.47% and 65.43% for the first, second, and third cuts, respectively. The increments in the purple variety over local basil were 34.31% and 50%; 43.20% and 45.46%; 24.16% and 41.98% for the first, second, and third cuts, correspondingly. Regarding the effect on essential oil yield, the results presented in Tables 6–7 revealed that only purple ruffles and purple variety produced the significantly maximum oil yield over the local basil. The purple ruffles oil increased by 128.62%, 90.91%, and 158.73% respecting the first, second, and third cuts. Besides, the purple basil oil increments were 14.47%, 10.39%, and 23.55% concerning the first, second, and third cuts, respectively. Meantime, the other foreign varieties of lime and smuglyanka showed lower measurements than the local basil.

The superior productivity of purple ruffles and purple varieties can result from their more tolerance of abiotic stresses than other varieties under existing environments. This area has high temperatures during the summer months and moderate temperatures in autumn and spring, in addition to saline soil and saline irrigation resource. Purple basils contain high concentrations of total anthocyanins, flavonoid compounds that increase plant resistance to abiotic stresses. Anthocyanins play a role in foliar photoprotection during stress impairing photosynthesis such as heat, salinity, and excess solar radiation stresses and consequently contribute to high basil yield [46–52]. Also, these results are in harmony with the literature that points out that variation between basil cultivars for herb growth and oil yield characteristics may be attributed to genetic diversity due to hybridization, targeted cultivation, and breeding practices for desired results morpho-chemotypes [53–57].

3.3. Effect of the Interaction Between Organic Fertilization and Varieties

Concerning the interaction between organic fertilization and varieties, the significantly pronounced increments in fresh and dry herb yields resulted by cultivation purple ruffles variety under application of compost at 48 m^3/hectare, followed by application 48 m^3 compost/hectare and planting purple variety than other treatments in both cuts (Tables 3–5). Correspondingly, the increasing percentages of the first treatment mentioned above were 138.05% and 147.06%; 128.39% and 127.78%; 96.85% and 117.65% for the first, second, and third cuts, respectively. Also, the second previous treatment's increment percentage was 83.19% and 111.77%; 72.90% and 75.56%; 68.47% and 89.71% concerning the first, second, and third cuts, respectively. Furthermore, the recorded essential oil data (% and l/hectare) aligned with the vegetative growth. The significantly highest quantities of oil yield were obtained by adding 48 m^3 compost/hectare to purple ruffles variety plants, followed by adding 48 m^3 compost/hectare for purple variety (Tables 6–7). Similarly, these increments of 48 m^3 compost/hectare and planting purple ruffles variety were 260.36%, 241.84%, and 257.24% for the first, second, and third cuts, respectively. The increment percentages of 48 m^3 compost/hectare and planting purple variety over local basil were 100.45%, 58.54%, and 71.38% about the first, second, and third cuts, successively.

Here, there is a significant rise in yield because treatments of fertilizing with 48 m^3 compost/hectare and cultivating anthocyanin-rich varieties can be due to their combined stimulatory effect on plant growth under stresses, as discussed before. Also, it is noteworthy that essential oil yield varied according to harvest time as the maximum quantity of oil was distilled from the summer cut followed by autumn and then spring ones. These findings align with numerous investigators' opinions that basil biomass and oil yield parameters vary depending on environmental conditions, agriculture practices, and genetic variability [58–63].

Moreover, data presented in Table 8 showed the influence of the interaction between treatments on essential oil constituents (second cut, summer cut), and the identified compounds are clarified below.

Concerning the treatment of fertilization with compost at 24 m^3/hectare and planting local basil variety, the main components of the oil were 1,8-cineole (56.86%), l-linalool (11.13%), and cinnamic acid methyl ester (8.45%). Regarding the treatment of applying compost at 48 m^3/hectare and planting local variety, the major components of the oil were 1,8-cineole (46.47%), cinnamic acid methyl ester (22.53%), and l-linalool (10.04%). As for the treatment using compost at 24 m^3/hectare and planting lime variety, the high compounds of oil were cinnamic acid methyl ester (17.83%), bornyl acetate (12.17%), l-linalool (11.99%), citral (9.47%), and nerol (9.15%), whereas for the treatment using compost at 48 m^3/hectare and planting lime variety, the high oil compounds were citral (22.85%), l-linalool (20.60%), nerol (17.77%), (−)-caryophyllene oxide (10.00%), and estragole (0.66%). Regarding the treatment of adding compost at 24 m^3/hectare and cultivating smuglyanka variety, the maximum compounds of oil were camphor (40.19%), 1,8-cineole (18.83%), and l-linalool (17.04%); on the other side, regarding the treatment of adding compost at 48 m^3/hectare and cultivating smuglyanka variety, the maximum compounds of oil were l-linalool (35.09%), camphor (28.69%), and 1,8-cineole (19.73%). In connection with the treatment of adding compost at 24 m^3/hectare and cultivating purple variety, the rich aroma constituents were l-linalool (54.11%) and 1,8-cineole (31.53%), while in the treatment of adding compost at 48 m^3/hectare and cultivating purple variety, the rich aroma constituents were l-linalool (50.95%) and 1,8-cineole (29.67%). As for the treatment of using compost at 24 m^3/hectare and farming purple ruffles variety, the chief aroma components were l-linalool (35.83%), 1,8-cineole (14.21%), and estragole (1.79%). Meanwhile, for treatment of using compost at 48 m^3/hectare and farming purple ruffles variety, the chief aroma components were l-linalool (36.77%), 1,8-cineole (14.50%), and estragole (1.83%).

Also, data presented in Table 9 show the influence of the interaction between treatments on essential oil chemical composition (third cut, autumn cut), and the identified compounds are clarified below.

About the treatment of compost at 24 m^3/hectare and growing local basil variety, the most components of the oil were cinnamic acid methyl ester (30.07%), 1,8-cineole (21.12%), l-linalool (17.21%), bornyl acetate (13.25%), and tau-cadinol (10.09%). On the other hand, increasing compost to 48 m^3/hectare and growing the local variety, the most components of the oil were cinnamic acid methyl ester (44.55%), 1,8-cineole (23.58%), l-linalool (12.64%), and

Table 8: Effect of the interaction between treatments on essential oil composition (%) (2nd cut-summer cut).

No.	Compounds	RT	Local variety		Lime variety		Smuglyanka variety		Purple variety		Purple ruffles variety	
			24	48	24	48	24	48	24	48	24	48
			%	%	%	%	%	%	%	%	%	%
1	Thujene	4.09	0.22	0.17	-	-	0.23	0.40	-	-	1.70	1.84
2	α-Pinene	4.27	1.55	1.47	0.86	0.89	1.75	0.98	0.76	0.75	2.20	1.65
3	Camphene	4.68	0.45	0.39	-	-	2.26	1.30	-	-	-	-
4	Sabinene	5.23	0.87	0.78	-	-	-	-	0.57	0.47	-	-
5	β-Pinene	5.37	2.66	2.40	-	-	0.69	0.99	1.99	1.76	1.90	1.32
6	α-Terpinene	6.54	0.17	-	-	-	-	-	-	-	-	-
7	1,8-Cineole	6.98	56.86	46.47	3.42	4.22	18.83	19.73	31.53	29.67	14.21	14.50
8	ç-Terpinene	7.89	0.33	0.26	-	-	-	-	-	-	-	-
9	Linalool oxide	8.91	2.04	1.45	-	2.17	3.42	-	1.59	1.34	-	-
10	Fenchone	9.05	-	-	1.02	0.94	-	-	-	-	-	-
11	L-Linalool	9.67	11.13	10.04	11.99	20.60	17.04	35.09	54.11	50.95	35.83	36.77
12	Camphor	11.35	0.53	0.47	-	-	40.19	28.69	-	0.53	-	-
13	Nerol oxide	11.47	-	-	-	0.82	-	-	-	-	-	-
14	endo-Borneol	12.33	1.19	1.06	1.63	-	2.18	0.56	-	0.35	0.30	-
15	Isopulegol	12.45	-	-	0.70	-	-	-	-	-	-	-
16	4-Terpineol	12.67	3.03	2.43	3.24	-	-	-	-	-	0.76	0.94
17	Linalyl propionate	13.39	0.69	-	-	1.88	-	-	0.61	-	-	-
18	α-Terpineol	13.49	-	0.68	1.99	-	-	-	-	0.68	-	-
19	Estragole	13.67	-	-	-	0.66	-	-	-	-	1.79	1.83
20	n-Octyl acetate	14.09	-	-	1.93	-	-	-	-	-	-	-
21	Nerol	14.61	-	-	9.15	17.77	-	-	-	-	-	-
22	Citral	15.26	-	-	9.47	22.85	-	-	-	-	-	-
23	Bornyl acetate	16.79	4.57	4.46	12.17	-	0.62	0.73	-	-	0.55	0.86
24	Neryl acetate	17.29	-	-	3.05	2.11	-	-	-	-	-	-
25	Myrtenyl acetate	18.55	0.27	-	-	-	-	-	-	-	-	-
26	Copaene	20.35	-	-	0.88	-	-	-	-	-	0.85	0.70
27	Acetic acid, 2-ethylhexyl ester	20.59	-	-	-	3.47	-	-	-	-	-	-
28	(−)-α-Bourbonene	20.71	-	-	-	-	0.82	0.61	-	-	1.50	2.24
29	α-Elemene	21.03	-	0.15	-	-	0.95	0.84	0.26	0.35	-	-
30	trans-Caryophyllene	22.17	-	-	-	1.94	0.35	0.45	0.35	0.88	2.00	1.99
31	Calarene	22.55	0.22	0.17	-	-	-	-	0.24	0.36	-	-
32	Ledene oxide-(II)	22.66	-	-	-	-	-	-	-	-	1.39	2.27
33	trans-α-Bergamotene	22.75	3.16	2.88	7.53	6.21	-	-	3.12	4.30	2.75	2.84
34	α-Guaiene	22.83	-	-	-	-	0.70	-	-	-	-	-
35	α-Humulene	23.68	-	-	-	1.36	1.16	1.28	0.76	1.08	2.85	2.78
36	Germacrene-D	24.75	-	0.20	-	-	1.08	1.13	0.51	0.57	-	-
37	Cinnamic acid methyl ester	24.88	8.45	22.53	17.83	-	-	-	-	-	3.54	3.76
38	trans-α-Farnesene	24.90	-	-	1.65	-	-	-	0.18	0.24	-	-
39	Farnesene epoxide	25.29	-	-	-	-	-	-	-	-	0.85	0.77
40	ç-Elemene	25.32	-	-	-	-	0.33	0.25	0.23	0.38	-	-
41	Bicycloelemene	25.34	-	-	-	-	-	-	-	-	0.84	0.87
42	Guaia-1(10),11-diene	25.56	-	-	-	-	-	-	0.31	0.46	-	-
43	Germacrene- A	25.82	-	-	-	-	0.74	0.64	0.58	0.66	-	-

continued

No.	Compounds	RT	Local variety		Lime variety		Smuglyanka variety		Purple variety		Purple ruffles variety	
			24	48	24	48	24	48	24	48	24	48
			%	%	%	%	%	%	%	%	%	%
44	ç-Cadinene	26.10	0.79	0.71	-	-	-	-	0.35	-	0.90	0.95
45	ç-Muurolene	26.14	-	-	1.35	-	1.41	1.55	-	0.49	-	-
46	Junipene	26.50	-	-	-	-	-	-	-	-	0.74	0.82
47	α-Bisabolol	26.87	-	-	-	-	-	-	-	-	2.75	1.81
48	Farnesol	27.32	-	-	-	-	-	-	-	-	2.89	2.91
49	α-Bisabolene	27.34	-	-	-	0.74	-	-	-	-	-	-
50	Veridiflorol	28.33	-	-	-	0.83	-	-	0.93	1.77	1.35	-
51	Trans-Z-α-Bisabolene epoxide	28.44	-	-	-	-	-	-	-	-	2.73	2.57
52	13-Octadecenal	29.50	-	-	-	-	-	-	-	-	1.89	1.79
53	(−)-Caryophyllene oxide	29.96	0.45	0.30	7.80	10.00	1.78	1.83	0.19	0.34	2.62	2.87
54	Humulene oxide	30.00	-	-	1.26	-	1.12	1.27	0.15	0.30	-	-
55	Zierone	30.21	-	-	-	-	-	-	-	-	1.79	1.96
56	p-Mentha-2,5-dien-7-ol, cis	30.48	-	-	-	-	-	-	-	-	1.65	1.85
57	Bergamotol, Z-α- trans	30.92	-	-	-	-	-	-	-	-	1.85	1.92
58	(+)-3-Carene	31.21	-	-	-	-	-	-	-	-	0.95	0.70
59	.tau.-Cadinol	31.32	0.37	0.53	1.08	0.54	2.35	1.68	0.68	1.32	2.08	1.92
	Total identified compounds		100	100	100	100	100	100	100	100	100	100
	Total hydrocarbon compounds		10.42	9.58	12.27	11.14	12.47	10.42	10.21	12.75	19.18	18.7
	Total oxygenated compounds		89.58	90.42	87.73	88.86	87.53	89.58	89.79	87.25	80.82	81.3

RT = Retention time.

Table 9: Effect of the interaction between treatments on essential oil composition (%) (3rd cut-autumn cut).

No.	Compounds	RT	Local variety		Lime variety		Smuglyanka variety		Purple variety		Purple ruffles variety	
			24	48	24	48	24	48	24	48	24	48
			%	%	%	%	%	%	%	%	%	%
1	α-Pinene	4.27	1.18	2.11	0.59	0.68	-	-	-	0.01	1.00	0.30
2	Camphene	4.68	-	-	-	-	0.04	0.08	-	-	-	-
3	β-Pinene	5.37	0.05	0.08	-	-	-	-	0.08	0.10	-	-
4	1,8-Cineole	6.98	21.12	23.58	10.80	13.42	20.37	19.43	15.80	16.12	17.63	27.48
5	Linalool oxide	8.91	-	-	0.23	0.08	0.09	-	1.46	-	-	0.06
6	α-Myrcene	9.15	0.22	0.09	-	-	-	-	0.09	-	-	-
7	Geraniol formate	9.55	-	-	-	-	-	-	-	-	0.56	-
8	L-Linalool	9.67	17.21	12.64	15.30	16.71	65.66	63.76	78.13	75.01	26.66	38.08
9	trans-Geraniol	10.10	-	-	-	-	0.56	0.45	-	-	-	0.19
10	Camphor	11.35	-	-	-	-	4.41	2.86	-	-	-	-
11	p-Menthane-1,8-diol	12.08	-	0.71	-	-	-	-	0.02	-	-	-
12	α-Ocimene	12.15	0.06	0.70	-	-	-	-	-	-	-	-
13	endo-Borneol	12.33	-	-	-	-	0.11	0.13	-	-	-	-
14	1-Octyn-3-ol	12.57	-	-	-	-	-	-	-	0.02	-	0.02
15	4-Terpineol	12.67	2.60	9.64	-	-	-	-	0.02	0.01	-	-
16	2-Cyclooctyl-2-propanol	13.03	-	-	-	-	0.09	-	-	-	-	-
17	Undecane	13.27	-	-	-	-	-	0.08	-	-	-	-

continued

No.	Compounds	RT	Local variety		Lime variety		Smuglyanka variety		Purple variety		Purple ruffles variety	
			24	48	24	48	24	48	24	48	24	48
			%	%	%	%	%	%	%	%	%	%
18	α-Citronellol	13.56	-	-	-	-	-	-	-	-	-	0.01
19	Estragole	13.67	-	-	0.84	0.93	-	-	0.02	0.02	8.61	29.32
20	n-Octyl acetate	14.09	-	-	0.20	1.00	-	-	-	-	-	-
21	α-Fenchyl acetate	14.15	-	0.32	-	-	-	-	0.03	-	0.05	-
22	2-Methyl-3-buten- 2-ol	14.32	-	0.06	-	-	-	-	-	-	-	-
23	1,6-Heptadien-4-ol	14.41	-	0.05	-	-	-	-	-	-	-	-
24	Nerol	14.61	-	-	12.79	13.20	-	-	-	-	-	-
25	Terpendiol II	14.77	2.11	-	-	-	-	-	-	-	-	-
26	4-Undecyne	14.81	-	-	012	0.08	-	-	-	-	-	-
27	Citral	15.26	-	-	30.50	32.62	-	-	-	-	-	-
28	Verbenol	15.29	-	-	0.54	0.35	0.05	-	-	-	-	-
29	Myrcenol	15.56	-	-	-	-	-	-	-	0.10	-	-
30	p-Menth-1-en-8-ol	16.09	-	-	0.91	0.40	0.09	0.26	0.12	0.01	-	-
31	1-Octyl acetate	16.66	-	-	-	-	-	-	0.10	-	-	-
32	n-Nonyl acetate	16.72	-	-	-	-	-	-	-	0.09	-	-
33	Bornyl acetate	16.79	13.25	-	-	-	-	-	-	-	-	-
34	Dihydrocarvyl acetate	16.93	-	-	-	-	-	-	0.01	0.01	0.03	-
35	Neryl acetate	17.29	-	-	1.30	2.20	-	-	-	-	-	-
36	Linalyl acetate	19.00	-	-	0.65	0.41	-	-	0.01	-	-	0.02
37	Copaene	20.35	0.18	-	-	-	-	-	-	-	0.52	-
38	α-Bourbonene	20.71	-	-	-	-	-	-	0.06	0.15	-	-
39	Geranyl acetate	20.74	-	-	-	-	0.24	0.17	-	-	-	-
40	Eugenol	20.79	-	-	-	-	-	-	0.10	0.15	-	-
41	α-Elemene	21.03	-	-	-	-	-	0.66	-	-	0.84	-
42	Widdrene	21.76	-	-	-	-	-	-	-	-	4.61	-
43	trans-Caryophyllene	22.17	-	-	0.75	1.63	0.19	-	0.06	1.79	1.33	0.47
44	Calarene	22.55	-	-	-	-	-	-	-	-	8.67	-
45	Aromadendrene	22.58	-	-	-	-	0.15	-	-	-	-	-
46	Valencene	22.60	-	-	-	-	0.02	-	-	-	-	-
47	trans-α-Bergamotene	22.75	-	-	3.00	3.11	0.06	-	-	-	11.76	2.11
48	α-Guaiene	22.83	-	-	-	-	-	0.24	-	-	1.47	-
49	α-Selinene	22.90	-	-	-	-	0.02	-	-	-	-	-
50	Humuladienone	22.95	-	-	-	-	0.26	-	-	0.39	-	-
51	ç-Dodecalactone	23.10	-	-	0.24	0.18	-	-	-	-	-	-
52	α-Humulene	23.68	-	0.09	-	1.03	0.04	0.16	1.77	1.96	1.06	0.20
53	cis-α-Bisabolene	23.71	-	-	0.39	0.45	0.06	0.19	-	-	-	-
54	α-Bulnesene	24.24	-	-	-	-	0.04	-	-	-	-	-
55	Germacrene-D	24.75	-	0.30	0.51	0.73	0.12	0.42	0.14	0.14	3.27	0.14
56	α-Amorphene	24.87	-	0.58	-	-	-		-	-	-	-
57	Cinnamic acid methyl ester	24.88	30.07	44.55	2.08	2.26	0.21	0.30	0.04	0.38	-	-
58	trans-α-Farnesene	24.90	0.08	-	-	-	0.03	-	0.02	0.04	-	-
59	Iso-isopulegyl acetate	25.06	-	-	-	-	-	0.06	-	-	-	-
60	Farnesene epoxide	25.29	-	-	0.29	0.35	-	-	-	-	0.08	0.02
61	Nerolidol	25.60	-	-	0.91	1.84	0.04	-	0.01	-	-	-
62	Germacrene- A	25.82	-	-	-	-	-	-	-	-	-	0.09

continued

No.	Compounds	RT	Local variety		Lime variety		Smuglyanka variety		Purple variety		Purple ruffles variety	
			24 %	48 %	24 %	48 %	24 %	48 %	24 %	48 %	24 %	48 %
63	Globulol	25.86	-	-	-	-	-	-	-	-	-	0.50
64	Myrtenol	26.00	-	-	-	-	-	-	0.06	-	-	-
65	ç-Cadinene	26.10	-	-	0.36	0.18	-	-	-	-	0.05	-
66	ç-Muurolene	26.14	-	-	-	-	-	-	-	-	-	0.69
67	Longipinene epoxide	26.25	-	-	-	-	-	-	0.08	0.01	-	0.12
68	Dihydromyrcene	26.29	-	0.05	0.11	0.14	-	-	-	-	-	-
69	Spathulenol	26.33	0.74	-	-	-	-	0.26	-	0.39	3.70	-
70	2,6-nonadienol	26.60	-	-	-	-	2.79	-	-	-	0.07	-
71	8-Hydroxylinalool	26.67	-	-	-	-	-	-	0.08	-	-	-
72	4,6-Decadiene	26.68	-	-	0.57	1.82	-	-	-	-	-	-
73	Cubenol	26.79	-	-	0.40	0.31	0.08	0.82	-	0.14	-	-
74	10-Dodecyn-1-ol	26.80	-	0.02	-	-	-	-	-	-	-	-
75	α-Bisabolol	26.87	-	-	0.22	0.19	0.02	-	0.20	-	-	-
76	R-Limonene	26.94	0.03	-	-	-	-	-	-	-	-	-
77	Farnesol	27.32	0.11	-	3.22	3.51	-	0.65	0.04	0.05	0.06	0.07
78	α-Himachalene	27.41	-	-	-	-	-	7.37	-	-	-	-
79	ë-Cadinene	27.45	-	-	-	-	-	-	1.32	-	-	-
80	Limonene dioxide	27.57	-	-	-	-	-	-	-	1.60	-	-
81	α-Eudesmol	27.60	-	-	-	-	-	0.14	-	-	-	-
82	α-Cedrenoxide	28.09	-	-	-	-	-	0.11	-	-	-	-
83	Veridiflorol	28.33	-	-	-	-	0.09	-	-	0.58	6.40	-
84	Trans-Z-α-Bisabolene Epoxide	28.44	-	-	0.30	0.19	0.09	0.59	0.07	0.13	-	0.11
85	cis-Lanceol	28.89	-	-	-	-	0.04	-	-	-	-	-
86	Methyl 7,9-octadecadiynoate	28.97	-	-	-	-	-	-	-	0.05	-	-
87	Cedr-8-en-13-ol	29.05	-	-	-	-	-	-	-	-	0.08	-
88	Aromadendrene oxide-(2)	29.28	-	-	-	-	-	0.17	-	0.08	-	-
89	(+)-Oxo-α-ylangene	29.60	-	-	-	-	-	0.05	-	-	-	-
90	(−)-Caryophyllene oxide	29.96	0.90	0.13	-	-	2.35	0.52	-	0.15	1.49	-
91	Bergamotol, Z-α-trans	30.92	-	-	-	-	0.03	-	0.06	0.32	-	-
92	.tau.-Cadinol	31.32	10.09	4.30	-	-	1.56	-	-	-	-	-
93	2,5-Dimethylhex-3-yne-2,5-diol	31.47	-	-	-	-	-	0.07	-	-	-	-
	Total identified compounds		100	100	100	100	100	100	100	100	100	100
	Total hydrocarbon compounds		1.80	4.00	18.28	9.85	0.77	9.20	3.54	4.19	34.58	4.00
	Total oxygenated compounds		98.20	96.00	81.72	90.15	99.23	90.80	96.46	95.81	65.42	96.00

RT = Retention time.

4-terpineol (9.64%). Regarding supplying compost at 24 m^3/hectare and planting lime variety, the majority compounds of oil were citral (30.50%), l-linalool (15.30%), nerol (12.79%), and 1,8-cineole (10.80%). Besides supplying compost at 48 m^3/hectare and planting lime variety, the majority compounds of oil were citral (32.62%), l-linalool (16.71%), and nerol (13.20%). For the treatment of adding compost at 24 m^3/hectare and cultivating smuglyanka variety, the principal fragrant oil components were l-linalool (65.66%) and 1,8-cineole (20.37%), while the treatment of adding compost at 48 m^3/hectare and cultivating smuglyanka variety, the principal oil components were l-linalool (63.76%) and 1,8-cineole (19.43%). Concerning fertilization with compost at 24 m^3/hectare and planting purple variety, the maximum oil fractions were l-linalool (78.13%) and 1,8-cineole (15.80%). For fertilization with compost at 48 m^3/hectare and planting purple variety, the maximum oil fractions were l-linalool (75.01%) and

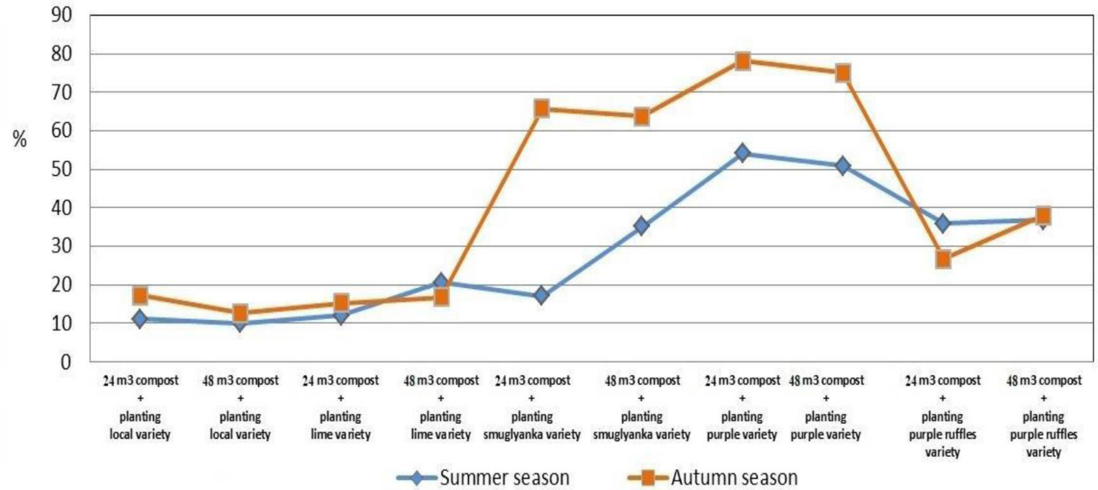

Figure 2: Effect of interaction between treatments on linalool content of essential oil.

1,8-cineole (16.12%). Concerning using compost at 24 m^3/hectare and cultivating purple ruffles variety, the high oil constituents were l-linalool (26.66%), 1,8-cineole (17.63%), calarene (8.67%), and estragole (8.61%). On the contrary, using compost at 48 m^3/hectare and cultivating purple ruffles variety, the high oil constituents were l-linalool (38.08%), estragole (29.32%), and 1,8-cineole (27.48%).

These results revealed that although the local basil oil is considered a linalool chemotype, its chemical composition was affected by the high salinity found under this location and its meteorological data. The dominated oil components were 1,8-cineole and cinnamic acid methyl ester while containing poor linalool (Fig. 2). Thus, high linalool chemotype varieties were required.

Secondary metabolites of medicinal and aromatic plants have great importance. Linalool-rich essential oils exhibit various biological activities such as antimicrobial, anti-inflammatory, anticancer, and antioxidant properties. Several *in vivo* studies have confirmed different effects of linalool on the central nervous system. Application of linalool enhances a specific scent to domestic products such as soaps, detergents, and shampoos. Linalool is also an essential compound for the industrial production of various fragrance chemicals and a lead compound in synthesizing vitamins A and E [64–67].

The GC/MS analysis revealed that smuglyanka, purple, and purple ruffles oils were linalool chemotypes except for lime oil which was citral chemotype (Fig. 2). Also, the results indicated that increasing soil organic matter boosted some oil components' accumulation while decreasing others. Besides, oils of the autumn season contained higher linalool and lower 1,8-cineole than summer ones. Likewise, the autumn season's extracted oils had higher cinnamic acid methyl ester and citral contents than summer ones for local and lime basil, respectively.

Estragole is another component that determines oil quality and safety. The leaves of basil and basil oil are possibly unsafe when taken by mouth as a medicine in the long term. These contain estragole, a chemical that may increase the risk of getting liver cancer. It is suspected to be carcinogenic and genotoxic [68,69]. Thus, low or poor estragole basil oils are preferred commercially [70]. The given data in Tables 8 and 9 showed that all treatments contained no traces of estragole (less than 1%) except for the treatments of compost at 24 or 48 m^3/hectare and cultivating purple ruffles variety (1.79%–29.32%). These percentages increased as organic fertilization increased in the autumn cut than in summer one.

The results are in harmony with previous studies [71–73], which mentioned that aroma components of basil oil differ according to cultivation practices, chemotype, and season effect. Additionally, the detected essential oil compounds by GC/MS analysis are in harmony with previous studies [74,75].

From the preceding data and Figure 2, yield attributes of varieties at 48 m^3 compost/hectare could be summarized as follows:

- Local basil: total fresh herb yield 8.40 tons/hectare, total dry herb yield 2.49 ton/hectare, oil percent 0.49%–0.79% (third and first cuts, resp.), total oil yield 16.01 l/hectare, oil linalool content 10.04%–12.64% (second and third cuts, resp.), oil estragole content 0.00%, and typical basil flavor.
- Purple ruffles basil: total fresh herb yield 14.14 tons/hectare, total dry herb yield 4.37 tons/hectare, oil percent 0.75%–0.95% (third and first cuts, resp.), total oil yield 37.33 l/hectare, oil linalool content 36.77%–38.08% (second and third cuts, resp.), oil estragole content 1.83%–29.32% (second and third cuts, resp.), and flavor reminiscent of cinnamon and licorice.
- Purple basil: total fresh herb yield 11.17 tons/hectare, total dry herb yield 3.59 tons/hectare, oil percent 0.42%–0.60% (third and first cuts, resp.), total oil yield 18.23 l/hectare, oil linalool content 50.95%–75.01% (second and third cuts, resp.), oil estragole content 0.00%–0.02% (second and third cuts, resp.), and clove flavor.
- Smuglyanka basil: total fresh herb yield 4.97 tons/hectare, total dry herb yield 1.47 tons/hectare, oil percent 0.24%–0.37% (third and first cuts, resp.), total oil yield 4.44 l/hectare, oil linalool content 35.09%–63.76% (second and third cuts, resp.), oil estragole content 0.00%, and clove flavor.
- Lime basil: total fresh herb yield 5.56 tons/hectare, total dry

herb yield 1.73 tons/hectare, oil percent 0.37%–0.52% (third and first cuts, resp.), total oil yield 7.11 l/hectare, oil linalool content 20.60%–16.71% (second and third cuts, resp.), oil estragole content 0.66%–0.93% (second and third cuts, resp.), oil citral content 22.85%–32.62% (second and third cuts, resp.), and citrus flavor.

Accordingly, the purple basil had the best quantity and quality parameters. It yielded higher fresh and dry herb yields/hectare, oil yield/hectare, maximum linalool, minimum estragole, and another attractive flavor than the local basil. Also, purple basil had a suitable color during autumn and spring. Therefore, purple basil cultivation is recommended for different investment purposes. Its leaves have a beautiful, coppery glow, and slightly spicy taste with a strong clove flavor. It is used in salads, for pesto, and adding beautiful color to dishes. It contains many vitamins, minerals, and fiber. It is used medicinally for its antioxidants and antibacterial properties; oil boosts the immune system and combats aging and skin ailments. It is suitable for fresh or dry production and preparing delicious flavored tea blends [76,77]. Also, oil of this variety is a rich source for the isolation of linalool compound.

Finally, research should be achieved on lime basil variety to improve its productivity to supply the local markets with this valuable citrus flavor resource.

4. CONCLUSION

Based on the split-plot design of this experiment, we studied the effect of organic fertilization, varieties, and their interactions on basil at Siwa Oasis. We endorsed producing maximum yield characters (higher fresh and dry herb yields/hectare, higher oil yield/hectare, maximum oil in linalool and minimum in estragole, and different pleasant flavors and colors than the local basil) by the following:

(I) Adding 48 m^3/hectare compost manure before planting.
(II) Cultivating the imported purple variety.
(III) Combination within adding 48 m^3/hectare compost and cultivating the purple variety.

5. AUTHOR CONTRIBUTIONS

All authors made substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; took part in drafting the article or revising it critically for important intellectual content; agreed to submit to the current journal; gave final approval of the version to be published; and agree to be accountable for all aspects of the work. All the authors are eligible to be an author as per the international committee of medical journal editors (ICMJE) requirements/guidelines.

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The authors report no financial or any other conflicts of interest in this work.

8. ETHICAL APPROVALS

This study does not involve experiments on animals or human subjects.

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