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EFFECTS OF SOIL SOLARIZATION ON YIELD, ESSENTIAL OIL AND NUTRIENT CONTENT OF BASIL SPECIES

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Abstract

The effects of soil solarization on the yield, essential oil and NPK contents of two species of basil (*Ocimum basilicum* L. and *O. americanum* L.) were investigated in the field. Results indicated that fresh and dry weights of herbs, essential oil and its components as well as NPK content for both basil species increased under the soil solarization treatment.

Introduction

Soil solarization is a process in which soil temperature is increased by using solar radiation as an energy source. It was initially intended as a method for controlling soil pathogens (Katan *et al.* 1987) but research has shown that it has other effects on soil characteristics that can influence the performance of crops, such as nutrient concentration (Chen *et al.* 1991) and soluble organic matter content (Chen *et al.* 2000). Solarized soil resulted a significant increase in yield of essential oil and nutrient content of *Calendula officinalis* plants (Khalid *et al*. 2006). Solarization of soil increased availability of nutrients such as NPK for gerbera (*Gerbera jamesonii* L.) plants (Kaewruang *et al*. 1989). The genus *Ocimum* (Lamiaceae) includes at least 60 species and numerous varieties (Sirvastava 1982). It represents an important source of essential oil used in the food, perfumery, cosmetics and medicinal industries (Telci *et al.* 2006). So, an attempt was made to follow effect of soil solarization on the yield, essential oil content, and some nutrient content of two species of basil (*Ocimum basilicum* L. and *O. americanum* L.), economically important medicinal plants.

Materials and Methods

Experiments were carried out in a Delta region of Egypt during 2012 and 2013 seasons. The field was divided into 20 plots, the plot area was 4 m^2 (2 m × 2 m) each plot contained 4 lines (50 between each).The plots were divided equally into 2 groups for solarization and non-solarization.

During the first week of August of the two seasons, the soil was ploughed several times to provide uniform surface and then organic manure (50m^3/hectare from cow dung) was added. One day before mulching the soil was irrigated up to its field capacity since solarization is more effective in moist soil owing to the increased thermal sensitivity of resting structures and improved heat conduction. Solarized plots were covered with 20 µm thick transparent polyethylene plastic with 89% total visible transmittance and 20% IR absorption. Special care was taken to minimize the distance between the polyethylene sheets and soil to prevent air pockets that retard the soil heating process. Plastic sheets were laid on bare soil, stretched close to the soil surface and then anchored. Soil solarization was conducted from August 15 to September 30 in both seasons. After solarization, the sheets were removed carefully to avoid soil disturbance.

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In the first week of February during both seasons basil (*O. basilicum* and *O. americanum*) seeds were sown in nursery soil. In the third week of March during both seasons, the seedlings were transferred to the open field [solarized plot (5 plots for *O. basilicum* and 5 plots for *O. americanum*) and non-solarized plots (5 plots for *O. basilicum* and 5 plots for *O. americanum*)] adjusted to natural conditions. Eight weeks after transplanting the seedlings were thinned to three plants per hill. The planting distance was 25 × 50 cm.

At the full bloom stage, all plants were harvested twice during the growing season, by cutting the plants 5 cm above the soil surface (after 75 and 150 days from transplanting, respectively). Total fresh and dry herbs (g/plant) were recorded.

Aerial part was collected; air dried and was subjected to hydro-distillation (Clevenger 1928) to extract the essential oil. The essential oil was analyzed by using GC and GC/MS (Adams 2007).

Total nitrogen and phosphorus in leaves were determined using the methods described by the Association of Official Agricultural Chemists (AOAC 1970). Concentrations of K were determined according to Cottenie *et al.* (1982) and Gonzalez *et al.* (1973).

According to Snedecor and Cochran (1990), the averages of data were statistically analyzed using two way analysis of variance (ANOVA-2) and the values of least significant difference (LSD) at 1 and 5%. The applications of that technique were according to the STAT-ITCF program (Foucart 1982).

Results and Discussion

Fresh and dry weights (g/plant) of herbs were affected by basil species with or without soil solarization (Table 1). The fresh and dry weights of herbs in general increased under the soil solarization, especially of *O. americanum.* Highest yields at each season for all variables were obtained in the *O. americanum* × soil solarization (Table 1). The increases in the fresh and dry weights of herbs were significant for basil species, soil solarization and their interactions except the dry weight of herb × soil solarization which was insignificant during the second season. The increase in herb yield under soil solarization treatment may be due to combining organic amendments with soil solarization and is a no chemical approach to improvement of the control of soil borne plant diseases. Pathogen control in solarized amended soil is attributed to a combination of thermal killing and enhanced generation of biotoxic volatile compounds.

Essential oil percentage increased at soil solarization treatments during both seasons. The highest accumulation of essential oil as percentage was recorded at the soil solarization × *O. basilicum* (Table 2). The changes in essential oil (%) and yield were significant for soil solarization treatments. The changes in essential oil yield were more significant for basil species × soil solarization in the first season but it was insignificant in the second season (Table 2). Soil solarization can increase the organic compost decomposition process (Gamliel and Stapleton 1997). The results agreed with those of Parakasa Rao *et al.* (1997), who reported that combining organic amendments with soil solarization increased total essential oil yields of davana plant. Marculescu *et al.* (2002) revealed that the use of manure resulted active principal (essential oil) high in *Chrysanthemum balsamita* L. plant.

Twenty constituents were identified in essential oil extracted from *O. basilicum* aerial parts, accounting for 98.2 - 99.2% of total constituents, and belong to four chemical main classes. Oxygenated monoterpenes [OM] (84.1 - 84.2%) class was the major one, the remaining fractions as monoterpene hydrocarbons [MH] (4.7 - 5.0%), sesquiterpene hydrocarbons [SH] (5.1 - 6.0%) and oxygenated sesquiterpenes [OS] (4.0 - 4.3%) formed the minor classes (Table 3). The main constituents of *O. basilicum* essential oil as detected by GC/MS were linalool, 1,8-cineole, β-caryophyllene and caryophyllene oxide. The highest amount of the main constituents (70.1%, 4.3, 3.9 and 3.4%) resulted from the essential oil extracted from herbs treated with soil solarization. The chemical class of essential oil such as MH increased under soil solarization treatment and was recorded value of 5%. On the other hand, OM, SH and OS increased under control treatment which recorded the values of 84.2, 6.0 and 4.3%, respectively. However, the changes in most of

Table1. Effect of soil solarization on basil species and their interactions on herb yield.

Treatments	Species	Herb yield (g/plant)			
		Fresh weight		Dry weight	
		Season		Season	
		1st	2nd	1st	2nd
Without soil solarization	*O. basilicum*	927.3	921.8	198.3	189.5
	O. americanum	1432.7	1567.8	223.2	247.8
Overall without soil solarization		1180.0	1244.8	210.8	218.6
With soil solarization	*O. basilicum*	1136.9	1245.9	225.6	235.8
	O. americanum	1876.2	1987.5	288.9	298.7
Overall with soil solarization		1605.6	1616.7	257.3	267.3
Overall species	*O. basilicum*	1032.1	1083.6	212.0	212.7
	O. americanum	1654.5	1777.5	256.1	273.3
LSD at 0.05					
Soil solarization		61.4	55.6	9.5	8.7
Species		61.4	55.6	9.5	8.7
Soil solarization × species		86.9	78.9	13.3	NS

Table2. Effect of soil solarization on basil species and their interactions on essential oil.

Treatments	Species	Essential oil			
		(%)		Yield (g/plant)	
		Season		Season	
		1st	2nd	1st	2nd
Without soil solarization	*O. basilicum*	0.4	0.5	0.8	0.8
	O. americanum	0.3	0.4	0.7	1.2
Overall Without soil solarization		0.4	0.5	0.8	1.0
With soil solarization	*O. basilicum*	0.6	0.7	1.4	1.7
	O. americanum	0.5	0.6	1.6	1.8
Overall with soil solarization		0.6	0.7	1.6	1.8
Overall species	*O. basilicum*	0.5	0.6	1.1	1.3
	O. americanum	0.4	0.5	1.2	1.5
LSD at 0.05					
Soil solarization		0.1	0.1	0.3	0.2
Species		0.1	0.1	NS	0.3
Soil solarization × species		NS	NS	0.4	NS

The constituents were insignificant for soil solarization except the constituents of linalool, α-terpineol, geraniol, α-humulene, β-eudesmol (more significant), α-copaene, germacrene D and β-selinene. The changes in all essential oil classes were insignificant exception the SH class was more significant (Table 3).

Seventeen constituents were identified in essential oil extracted from *O. americanum* aerial parts, accounting for 97.3 - 98.7% of total constituents, and belong to four chemical main classes. MH (82.7 - 84.5%) class was the major one, the remaining fractions as OM (7.5 - 7.9%), SH (6.2 – 6.8%) and OS (0.1 - 0.3%) formed the minor classes (Table 4). the main constituents of *O. americanum* essential oil as detected by GC/MS were citral, cyclopentane methylene and cis-α-bisabolene. The highest amount of the main constituents (81.3, 2.3 and 2.9%) resulted from the essential oil extracted from herbs treated with soil solarization. The chemical classes of essential

Table3. Effect of soil solarization on essential oil constituents of *O. basilicum.*

No.	Constituents (%)	Class	RI	Solarization		LSD : 0.05
				Without	With	
1	Limonene	MH	1031	4.5	4.6	NS
2	cis-β-ocimene	MH	1041	0.2	0.4	NS
3	1,8-cineole	OM	1034	4.2	4.3	NS
4	Linalool	OM	1099	67.5	70.1	2.1
5	Camphor	OM	1150	5.8	5.9	NS
6	α-terpineol	OM	1191	1.9	0.8	0.3
7	Geraniol	OM	1255	2.8	1.3	0.6
8	Linalyl acetate	OM	1257	1.7	1.3	NS
9	Bornyl acetate	OM	1292	0.3	0.4	NS
10	α-copaene	SH	1379	0.4	0.2	0.1
11	α-cubebene	SH	1389	0.1	0.2	NS
12	β-caryophyllene	SH	1421	3.8	3.9	NS
13	α-humulene	SH	1457	0.6	0.2	0.2
14	Germacrene D	SH	1489	0.7	0.4	0.1
15	β-selinene	SH	1491	0.4	0.2	0.1
16	Caryophyllene oxide	OS	1584	3.3	3.4	NS
17	Viridiflorol	OS	1595	0.1	0.2	NS
18	β-eudesmol	OS	1656	0.3	0.1	0.1
19	α-cadinol	OS	1658	0.4	0.2	NS
20	α-bisabolol	OS	1689	0.2	0.1	NS
MH = Monoterpene hydrocarbon				4.7	5.0	NS
OM = Oxygenated monoterpenes				84.2	84.1	NS
SH = Sesquiterpene hydrocarbon				6.0	5.1	0.4
OS = Oxygenated sesquiterpene				4.3	4.0	NS
Total identified				99.2	98.2	

oil such as MH and OM increased under soil solarization treatment and were recorded values of 84.5 and 7.0%, respectively. On the other hand, SH and OS were increased under control treatment which recorded the values of 6.8 and 0.3%, respectively. The changes in the all constituents were insignificant for soil solarization except the constituents of citral, α-selinene, (-)-spathulenol and β-selinenol. The changes in essential oil classes such as MH were significant. The changes in OM class was insignificant while the changes in SH and OS classes were significant. (Table 4). Similar constituents were obtained from *O. basilicum* and *O. americanum* by Khalid (2006), Parida *et al.* (2014) and Mohamed *et al.* (2016). Soil solarization treatment significantly affected essential oil and its main constituents of *O. basilicum* and *O. americanum*, these results may be due to their effect(s) on enzyme activity and metabolism of essential oil production (Burbott and Loomis 1969).

Table 4. Effect of soil solarization on essential oil constituents of *O. americanum*.

No.	Constituents	Class	RI	Solarization		LSD: 0.05
				Without	With	
1	Linalylalcohol	MH	1102	1.9	1.8	NS
2	Vinylcyclooctane	MH	1470	0.8	0.9	NS
3	Citral	MH	1260	79.3	81.3	0.9
4	Humulene	MH	1441	0.7	0.5	NS
5	Cyclopentane, methylene	OM	925	2.2	2.3	NS
6	Caryophyllene	OM	1420	2.7	2.9	NS
7	α-bergamotene	OM	1421	0.8	0.9	NS
8	Vinylcyclohexane	OM	1490	1.2	1.1	NS
9	Nerol acetate	OM	1760	0.6	0.7	NS
10	Germacrene D	SH	1480	1.5	1.4	NS
11	β-bulnesene	SH	1508	0.5	0.3	NS
12	α-selinene	SH	1521	0.3	0.1	0.1
13	Cis-α-bisabolene	SH	1539	2.7	2.9	NS
14	β-elemene	SH	1581	0.3	0.2	NS
15	(-)-Spathulenol	SH	1641	0.4	0.1	0.1
16	Bicyclogermacrene	SH	1731	1.1	1.2	NS
17	β-selinenol	OS	1646	0.3	0.1	0.1
MH = Monoterpene hydrocarbon				82.7	84.5	1.0
OM = Oxygenated monoterpenes				7.5	7.9	NS
SH = Sesquiterpene hydrocarbon				6.8	6.2	0.2
OS = Oxygenated sesquiterpene				0.3	0.1	0.1
Total identified				97.3	98.7	

Table 5. Effect of soil solarization, basil species and their interactions on nutrient content.

Treatments	Species	Nutrient content (%)					
		N		P		K	
		Season		Season		Season	
		1st	2nd	1st	2nd	1st	2nd
Without soil solarization	*O. basilicum*	2.5	2.4	0.4	0.5	2.3	2.5
	O. americanum	2.3	2.1	0.9	0.8	2.9	2.7
Overall without soil solarization		2.4	2.3	0.7	0.7	2.6	2.6
With soil solarization	*O. basilicum*	3.9	3.6	0.8	0.9	2.7	3.1
	O. americanum	3.1	2.9	1.2	1.3	3.3	3.7
Overall with soil solarization		3.5	3.3	1.0	1.1	3.0	3.4
Overall species	*O. basilicum*	3.2	3.0	0.6	0.7	2.5	2.8
	O. americanum	2.7	2.5	1.1	1.1	3.1	3.2
LSD at 0.05							
Soil solarization		0.3	0.2	0.2	0.2	0.3	0.3
Species		0.3	0.2	0.2	0.2	0.3	0.3
Soil solarization × species		NS	NS	NS	NS	NS	NS

Table 6. Effect of soil solarization, basil species and their interactions on nutrient uptake.

Treatments	Species	Nutrient uptake (mg/g)					
		N		P		K	
		Season		Season		Season	
		1st	2nd	1st	2nd	1st	2nd
Without soil solarization	*O. basilicum*	5.0	4.8	0.8	0.9	4.5	4.7
	O. americanum	5.1	5.2	2.0	2.0	6.5	6.7
Overall without soil solarization		5.1	5.0	1.4	1.5	5.5	5.7
With soil solarization	*O. basilicum*	8.8	8.5	1.8	2.1	6.1	7.3
	O. americanum	9.1	8.7	3.5	3.4	9.5	11.0
Overall with soil solarization		9.0	8.6	2.7	2.8	7.8	9.2
Overall species	*O. basilicum*	6.9	6.7	1.3	1.5	5.3	6.0
	O. americanum	7.1	7.0	2.8	2.7	8.0	8.9
LSD at 0.05							
Soil solarization		0.3	0.2	0.2	0.3	0.6	0.7
Species		NS	NS	0.2	0.3	0.6	0.7
Soil solarization × species		NS	NS	NS	NS	1.1	NS

Soil solarization treatment caused an increase in measured nutrient content (NPK) and its uptake during both seasons for *O. basilicum* and *O. americanum* (Tables 5 and 6). The control treatment resulted in the lowest nutrient accumulation. The changes in nutrient content were significant for soil solarization treatment and it was insignificant for soil solarization × basil species interactions. The changes in nutrient uptake were significant for soil solarization treatment. The changes in PK uptake were significant for basil species but the change in N uptake was insignificant. The changes in NPK uptakes were insignificant for soil solarization × basil with the exception of K uptake which was significant at first season. These results are in accordance with those obtained by Khalid *et al.* (2006).

References

Adams RP 2007. Identification of Essential Oil Components by Gas Chromatography/Mass Spectrometry, 4th ed. Allured Publ. Corp., Carol Stream, IL.

Association of Official Agricultural Chemistry (AOAC) 1970. Official Methods Analysis. Washington, D.C., USA.

Burbott AJ and Loomis D 1969. Evidence for metabolic turnover monoterpene in peppermint. Plant Phys. **44**: 173-179.

Chen Y, Gamliel A, Stapleton JJ and Aviad T 1991. Chemical, physical, and microbial changes related to plant growth in disinfested soils, in soil solarization. CRC Press, Boca Raton, Florida.

Chen Y, Katan J, Gamliel A, Aviad T and Schnitzer M 2000. Involvement of soluble organic matter in increased plant growth in solarized soils. Bio. Fert. Soil **32:** 28-34.

Cottenie A, Verloo M, Kiekens L, Velghe G and Camerlynck R 1982. Chemical Analysis of Plant and Soil. Laboratory of Analytical and Agrochemistry, State Univ. Ghent. Belgium.

Clevenger JF 1928. Apparatus for determination of essential oil. J. Amer. Pharm. Ass. **17**: 346-349.

Foucart T 1982. Analyse factorielle, programmatiol sur microordinateur. Masson, ITCF, Paris.

Gamliel A and Stapleton JJ 1997. Improvement of soil solarization with volatile compounds generated from organic amendments. Phyt. **25**: 31-38.

Gonzalez C, Banez M, Wylle M and Sole J 1973. La Nutricion Miniral de le Vegetables. Fac. Agro., Univ. Catulica de Chile.

Kaewruang W, Sivasithamparam K and Hardy GE 1989. Effect of solarization of soil within plastic bags& on root rot of gerbera (*Gerbera jamesonii* L.). Pl. Soil **120**: 303 -306.

Katan J 1987. Soil solarization. *In:* Innovative approaches to plant disease control. Chet I (ed). John Wiley and Sons, New York.

Khalid KA 2006. Influence of water stress on growth, essential oil and chemical composition of herbs (*Ocimum* sp.). Int. Agrophys. **20**: 289 - 296.

Khalid KA, Yassen AA and Zaghloul SM 2006. Effect of soil solarization and cattle manure on the growth, essential oil and chemical composition of *Calendula officinalis* L. plants. J. App. Sci. Res. **2**: 142-152.

Marculescu A, Sand C, Barbu C, Babit HD and Hanganu D 2002. Possibilities of influencing the biosynthesis and accumulation of the active principals in *Chrysanthemum balsamita* L. Specie Roum. Biotech. Lett. **7**: 577-548.

Mohamed MA, Ibrahim ME, Wahba HE and Khalid KA 2016. Yield and essential oil of sweet basil affected by chemical and biological fertilizers. Res. J. Med. Plant 10 (3): 246-253.

Parakasa Rao EVS, Naryana MR and Rajeswara BR 1997. The effect of nitrogen and farm yard manure on yield and nutrient uptake in davana (*Artemisia pallens* Wall. ExD.C.). J. Herbs Spi. Med. Plants. **5**: 39-48.

Sirvastava AK 1982. Aromatic plants and its products. Farm Bull. Central Institute of Medicinal and Aromatic Plants, Lucknow, India **16**: 1-13.

Snedecor GW and Cochran WG 1990. Statistical Methods. 11th Ed. Iowa State Univ., Press. Ames, Iowa, USA.

Snyman HG, Jong DE and Aveling TAS 1998. The stabilization of sewage sludge applied to agricultural land and the effects on maize seedlings. Water Sci. Tech. **38**: 87-95.

Telci I, Bayram E, Yilmaz G and Avci B 2006. Variability in essential oil composition of Turkish basil (*Ocimum basilicum* L.). Bioch. Syst. Eco. **34**: 489-497.

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