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EFFECT OF SOME METHODS FOR CONTROLLING WEEDS AND WILT DISEASES ON THE PRODUCTIVITY OF GERANIUM PLANTS

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ABSTRACT: Geranium (*Pelargonium graveolens* L'Herit ex Ait.) plants infected with root rot and wilt diseases were collected from different locations of Behira, Ismailia and Minia Governorates, Egypt. *Fusarium*, *Macrophomina*, *Rhizoctonia* and *Pythium* were isolated from the infected plants. The results showed that *F. oxysporum* recorded the highest isolated rate, followed by *R. solani*, *F. solani*, *M. phaseolina* and *Pythium* sp. The effect of various concentrations of marjoram and peppermint essential oils on the mycelial growth of the isolated fungi was tested *in vitro*. Marjoram and peppermint oils completely inhibited the growth of *F. oxysporum, F. solani*, *R. solani* and *Pythium* sp. at the concentration of 5 ml/l. A Field experiment was conducted at the Experimental Farm of Agricultural Research Station, Malawy, Minia Governorate, Egypt, during two successive seasons of 2020 and 2021 to study the effect of different weed control methods (un-weeded control, clover cover yield, hand hoeing and black plastic mulch) on weeds biomass. The results indicated that all weed control treatments significantly decreased the weight of grassy broad-leaf weeds and total weeds compared to the un-weeded control. Moreover, all weed control treatments and plants treated with the essential oils of marjoram and peppermint as well as the biocides (*Bacillus subtilis* and *Trichoderma harzianum*) significantly decreased the wilt disease incidence and improved the vegetative growth, yield and volatile oil of geranium plants. The results indicated that plastic mulch was the most effective in reducing wilt incidence as well as increasing all growth characteristics and productivity of volatile oil, while the highest disease incidence and the lowest growth and yield were recorded under un-weeded treatment. The application of the marjoram essential oil or biocide *B. subtilis* resulted in the lowest incidence of wilt disease and the highest increase in the growth, herb yield, essential oil yield and main components of essential oil. The highest growth characters and volatile oil were recorded with either black plastic mulch and marjoram essential oil or with *B. subtilis* treatment.

Keywords: Geranium, *Pelargonium graveolens,* L'Herit. ex Ait., black plastic mulch, hoeing, cover yield, biocide, essential oil, *Trichoderma harzianum, Bacillus subtilis*.

INTRODUCTION

Geranium (*Pelargonium graveolens* L'Herit ex Ait) belongs to Geraniaceae Family. It is characterized by a wide appeal and ability tolerance to different climates, and continuous flowering throughout the summer and early winter in most of the world Schoellhorn (2003). Geranium plants have many benefits within the medical and pharmaceutical fields and chemical industries (Lis-Balchin, 2002 and Saraswathi *et al.,* 2011). Geranium volatile oil has a high economic value in the international markets due to its very rose-like perfume in addition to its medicinal importance in bleeding, wounds, ulcers, colic and diarrhoea Matthews (1995). Geranium oil consists mainly of citronellol and geraniol and their esters (Cavar and Maksimovi, 2012). The parts used are leaves and flowering herbs, and the volatile oil is used in perfume cosmetics, aromatherapy and food industry (Saraswatihi *et al*., 2011). It has also, insect repellant, antimicrobial and antibacterial activities (Galea and Hancu, 2014).

Geranium plants are exposed to harm by several soil pathogens, causing severe losses in plant productivity and quality (Daughtrey *et al.*, 1995; El-Gamal, 1995 and Douglas, 2003). Root rot is one of the most important diseases that reduces the production of geranium plants (Gullino and Wardlow, 1999 and Gravel *et al*., 2009) as plants are infected with root diseases caused by various soil fungi (Szczech, 1999 and Douglas, 2003) as *Fusarium oxysporum*, which causes wilt and root rot in many plants (Mc Govern, 2015). Therefore, wilting and root rot diseases that affect geranium plants must be detected and combated early.

Mulching is one of the effective and safe methods to reduce pests, soil-borne diseases and weed infestation. Mulches may be inorganic (black polyethylene and geotextile mulches), organic (wood, bark, and leaves), or living turf grass, rye, and clover. Mulching involves covering the soil with a layer of material around the crop, which prevents light required for the germination of small-seeded weeds (Teasdale and Mohler, 2000). Polyethylene mulch, marigold as living mulch and fungicide application resulted in an effective control of blight of tomato caused by *Alternaria solani* (Jambhulkar *et al.*, 2012). Living mulches are cover yields that are planted between the rows of a main yield and are maintained as a living ground cover during the growing of the main yield. Although living mulches are sometimes referred to as cover yields, they grow at least part of the time simultaneously with the yield. In addition to providing adequate cover to reduce soil erosion and increase soil water infiltration, legume living mulches improve soil nutrient status by adding organic nitrogen which improves soil properties (Mohammadi *et al.*, 2012). Plastic mulching had a positive effect on reduced weeds, disease incidence of fusarium wilt and increased the yield of cumin plants (Abdallah *et al*.,2019).

Essential oil is a very effective method for controlling plant diseases. Volatile oils are compounds which have great importance in inhibiting the growth of pathogens in plants. It is possible that essential oils could be used in plant disease control as antimicrobial compounds and have important uses because they are safe status (Ormancey *et al*., 2001) and could be used as alternative anti-fungal and anti-bacterial treatments (Jobling, 2000; Karapinar, 1985 and Nanir and Kadu, 1987). Juglal *et al*. (2002) studied the effectiveness of essential oils to control the growth of mycotoxins and found that, marjoram, peppermint, clove, cinnamon and oregano were able to inhibit the growth of *Fusarium moniliforme* and *Aspergillus parasiticus*. El-Mougy *et al*. (2007) reported that geranium, mint, rose and lemon essential oils caused a significant reduction in root rot and wilt incidence of bean plants. Abdel-Kader *et al.* (2011) stated that caraway, peppermint and marjoram essential oils were found to have an inhibitory effect on mycelial growth of *F. solani, R. solani, M. phaseolina* and *S. rolfsii.*

Biological methods are used to reduce the application of chemical fungicides to control geranium root rot, the fungicide and pesticide residues in plants may have effects on human health. Trichoderma and fungi Gliocladium or bacteria Pseudomonas and Bacillus have been used for biocontrol of soil-borne pathogens (Reddy, 2016). Also, on gladiolus bio-agent strains of *Pseudomonas* spp. and *Trichoderma* spp. controlled *Fusarium oxysporum* (Naqvi and Ahmad, 2012). In geranium plants, Trichoderma controlled *R. solani* Reddy (2016). Beneficial microorganisms such as *Pseudomonas spp*. and *Trichoderma spp*. suppress Pythium root rot and significantly increased the vegetative characteristics of geranium plants (Gravel *et al*., 2009). Bacillus is used to resist infection with fusarium fungus and maintain environmental health through sustainable agriculture (Khan *et al*., 2017).

MATERIALS AND METHODS

Isolation and identification of the associated fungi:

Infected geranium plants showing wilt and root rot symptoms were collected from Beheira, Ismailia and Minia plantations during the 2020/2021 growing seasons. Infected roots were thoroughly washed several times with tap water, then cut into small pieces and surface sterilized by immersing in 1% sodium hypochlorite for 2 minutes, washed several times with distilled water and dried between folds of sterilized filter papers. The surface sterilized pieces were then plated onto potato dextrose agar (PDA) medium in Petri-dishes. The Petri dishes were incubated at 27±1ºC for 7 days. The growing fungi were purified using single spore or hyphal tip techniques and identified according to their morphological and cultural characteristics. The identification was gently supported by the staff of Mycol. Res. Dept. and Plant Dis. Survey., Plant Pathol. Res. Inst., ARC, Giza, Egypt.

Pathogenicity test:

Pathogenicity test was conducted on all the isolated soil fungi, *i.e. Fusarium oxysporum*, *F. solani, Macrophomina phaseolina*, *Pythium* sp. and *Rhizoctonia solani*. Sandy clay soil (1 sand: 1 clay) was sterilized by a 5% formalin solution for one week, then left to dry for two weeks before use. Tested fungi were separately cultured on autoclaved sorghum grains medium (100 g sorghum + 100 ml water), at 27±1 °C for 15 days. Soil infestation with the isolated fungi was applied at 1% w/w, which was thoroughly mixed with the upper soil surface in plastic pots (20 cm diameter). Pots were watered till saturation one week before sowing to enhance the colonization of the fungi. Geranium cuttings were surface sterilized using 0.1% sodium hypochlorite for one minute, then washed with sterilized distilled water and left to dry. Pots were planted with 2 cuts for each. All treatments were replicated three times. Disease incidence was recorded as percentages of pre-, post-emergence damping-off and wilt 25, 45 and 90 days after planting, respectively using the following formula (Seif El-Eslam *et al*., 2003).

$$\text{Disease incidence (\%)} = \frac{\text{Number of infected plants}}{\text{Total number of plants}} \times 100$$

Fungi were re-isolated from the infected plants and compared with the original isolates.

Evaluation the effect of the essential oil emulsions on the mycelial growth of tested fungi *in vitro*:

Essential oils of marjoram and peppermint were obtained from Medicinal and Aromatic Plants Res. Dept., Hort. Res. Instit., ARC, Giza, Egypt. The essential oil suspensions were prepared by adding 10 ml of any essential oil and 5 ml of non-ionic surfactant (tween 80) slowly under gentle stirring until a homogeneous mixture was formed, then, sterilized water (85 ml) was added to reach the final mixture of each oil to 100 ml, to enhance distribution and complete incorporate the essential oils and stirred using a magnetic stirrer for 30 min.

The efficacy of volatile oils in reducing fungal growth was tested. The prepared emulsion of the essential oils was added to sterilized PDA flasks before solidification to obtain the proposed concentrations of 1, 2, 3, 4 and 5 ml/l medium. The bactericide Chloramphenicol, (0.1 mg/l) was added to the medium to avoid bacterial contamination. Three plates (9 cm in diam.) containing potato dextrose agar (PDA) medium were separately inoculated with discs (5-mm-diam.) taken from the edge of 7 days old culture of any of *Fusarium oxysporum, F. solani, Macrophomina phaseolina, Pythium* sp. and *Rhizoctonia solani,* isolated from geranium plants. Petri dishes were incubated at 25℃. Percentages of fungal growth inhibition were calculated when the fungal growth of the control plates (without treatments) completely covered the plates according to the formula suggested by Topps and Wain (1957) as follows:

$$\text{Inhibition \%} = \frac{A - B}{A} \times 100$$

A= The linear growth (cm) in the control treatment

B= The linear growth (cm) of treated fungus

Field experiments:

Field experiments were carried out at the Experimental Farm of Agricultural Research Station, Malawy, Minia, Egypt during the two successive seasons of 2020 and 2021 to evaluate the effect of different weed control treatments (un-weeded, mulch cover crop, hoeing and mulch black plastic), treatment with two commercial biocides (*Trichoderma harzianum* and *Bacillus subtilis*) and essential oil suspension (peppermint and marjoram) on the disease incidence, and crop parameters of geranium plants.

Cuttings of geranium were washed several times with distilled water and soaked for 30 minutes in the suspension of biocide Trichoderma (1 ml contains 30×10^6 CFU of *Trichoderma harzianum),* biocide bacillus (1 ml contains 30×10^6 CFU of *Bacillus subtilis*), suspensions of marjoram essential oil, peppermint essential oil and water served as a control treatment.

The biocides were applied at a concentration of 4 ml/l (obtained from the Central Lab. of Organic Agric., ARC), whereas essential oil suspensions were applied at a concentration of 5 ml/l. The soaked cuttings were air-dried at room temperature for one hour before planting, according to a previous study of Hassanin *et al.* (2017). Cuttings were planted on October 20th in both seasons. These plants were treated with the first treatment after 45 days after planting, the second treatment was conducted a month later and the third was added after a month from the first cut and the fourth was added one month later in each season. The recommended dose of nitrogen was applied at a rate of 450 kg/fed using ammonium sulphate (20.5% N), phosphorus was applied and mixed with the soil before planting at a rate of 300 kg/fed using calcium super phosphate (15.5% P_2O_5 P), potassium was applied at a rate of 150 kg/fed using potassium sulphate (48% K_2O).

The layout of the experiment was a split-plot design with three replicates for each treatment, cuttings were planted in plots, each plot consisted of 5 rows, and the cuttings were planted in 60 × 30 cm. The main plots were the weed control treatments and the subplots were the plant treatments.

Treatments:

Weed control treatments:

1. Un-weeded treatment as a control.
2. Hand hoeing three times at 20, 40 and 60 days from sowing.
3. Black polyethylene mulch of plastic films (25-micron thickness) was applied manually. Polyethylene sheets were covered on the rows. Holes were prepared on the plastic sheet in a certain space of each plant. Geranium cuttings were planted in the previously prepared holes.
4. Cover yield plots included clover *(Trifolium alexandrinum*) as the living mulch was planted on November 1st at the rate of 30 kg clover seeds/fed. Clover seeds were planted on either side of the geranium rows.

Plant treatments:

1. Water as a control treatment.
2. Peppermint essential oil.
3. Marjoram essential oil.
4. Biocide Trichoderma (1 ml contains 30 × 10^6 CFU of *T. harzianum).*
5. Biocide Bacillus (1 ml contains 30 × 10^6 CFU of *B. subtilis*).

In each season, plants were harvested twice in May and October, by cutting at 10 cm height above the soil surface.

Data recorded:

Weed measurements:

Weeds were assessed by hand-pulling from 1 m^2 plots at 80 days after planting geranium cuttings. These weeds were chosen randomly from each plot and identified as species according to Täckholm (1974), then divided into two groups: (1) annual grassy weeds and (2) annual broad-leaved weeds. The fresh weight (g/m^2) of each group as well as the total annual weeds were measured.

Frequency percentage of the isolated fungi:

$$\text{Frequency (\%)} = \frac{\text{No. of fungal colonies for each isolated fungus}}{\text{Total No. of fungal colonies for the isolated fungi}} \times 100$$

Disease incidence:

The incidence of wilt disease geranium was determined 90 days after planting and calculated by the following formula:

$$\text{Incidence of wilt (\%)} = \frac{\text{Number of infected plants}}{\text{Total number of plants}} \times 100$$

Vegetative growth and yield:

Vegetative growth characters [plant height (cm), number of branches, fresh and dry weights (g/plant), fresh yield (ton/fed)]. The volatile oil percentage was determined in the fresh herb according to (British Pharmacopoeia., 1963), oil yield and oil components were determined in the second cut of the second season and was analyzed using DsChrom 6200 Gas Chromatograph according to the methods of Hoftman, 1967 and Tranchan, 1969).

Data were statistically analyzed according to the method described by (Snedecor and Cochran, 1980). The least significant difference test was used for comparison between means of treatments.

RESULTS AND DISCUSSION

Isolation and identification of the associated fungi:

Three fungal genera, *i.e. Fusarium*, *Macrophomina* and *Rhizoctonia* were isolated from infected samples of geranium plants. Samples showed root rot and/or wilt symptoms were collected from different locations of South Tahrir, Elkassasin and Malawy districts, representing Beheira, Ismailia and Minia Governorates, respectively during the 2020 growing season. Isolated fungi were purified and identified as: *Fusarium oxysporum* Schlecht, *Fusarium solani* (Mart.) Appel & Wollenw, *Macrophomina phaseolina* (Tassi) Goid. and *Rhizoctonia solani* Kuhn. Results in Table (1) indicate that *F. oxysporum* recorded the highest mean frequency of fungi isolated (40.19%), followed by *R. solani* (28.27%), *F. solani* (16.62%) and *M. phaseolina* (14.92%). Only *F. oxysporum* was isolated from wilted plants. On the other hand, the other fungi isolated from geranium plants suffered from root rot. *F. oxysporum* was the most frequently isolated fungus in Beheira and Minia Governorates followed by *R. solani* in Ismailia governorate. The fungus, *F. solani* was not isolated from Ismailia Governorate. The widespread of these diseases seem to be a function of environmental factors. Minia Governorate (Malawy district) is characterized by having a clay soil texture while Beheira (South Tahrir district) and Ismailia Governorates

Table 1. Fungi isolated from infected geranium plants collected from different governorates during 2020 growing season and their frequency.

Isolated fungi	% Frequency of fungi at governorate				Symptoms
	Beheira	Ismailia	Minia	Mean	
Fusarium oxysporum	39.73	37.14	43.70	40.19	Wilt & root rot
F. solani	26.00	00.00	23.87	16.62	Root rot
Macrophomina phaseolina	11.29	23.28	10.19	14.92	Root rot
Rhizoctonia solani	22.98	39.58	22.24	28.27	Root rot
Total	100.00	100.00	100.00	100.00	-

(El-kassasin district) are characterized by having a sandy soil texture. *Fusarium* spp. recorded higher frequency as compared with the other fungi isolated from the three governorates indicating its ability to survive in most soil types. Such findings go in accordance with the obtained data by Hilal *et al.* (1993).

Pathogenicity test:

All tested fungi were found to be pathogenic to geranium plants with different percentages of disease incidence (Table, 2). The highest disease incidence percentage (46.67%) after 45 days from planting was caused by *M. phaseolina* isolate No. (1). Meanwhile, *R. solani* isolate No. (1) and *F. oxysporum* isolate No. (1) recorded the highest disease incidence percentages (46.67%) after 90 days after planting. On the other hand, symptoms of wilt caused by *F. oxysporum* appeared 90 days from planting. *R. solani* (1) *and M. phaseolina* (1) were the least percentages of survival of plants (26.66%). These results are similar to that reported by (Hilal *et al*., 1993 and Nada *et al.*, 2014).

Effect of weed control treatments:

Weed characteristics:

The existing widespread weed species in the experimental field in both growing seasons (2020 and 2021) included two species of annual grassy weeds (*Avena* sp. and *Phalaris minor* L.) and broad-leaved weeds (*Brassica nigra* L., *Sonchus oleraceus* L., *Chenopodum albam* L., *Malva parviflora* L., *Melilotus indica* L., *Coronopus squamatus* L. and *Euphorbia helioscopia* L.). All weed control treatments significantly decreased the weight of grassy weeds, broadleaf weed and their total 60 days after planting as compared to the un-weeded control (Table, 3). The highest reductions in the weight of grassy weeds, broadleaf weeds and their total were obtained with black polyethylene mulch which were decreased by 99.5, 99.7 and 99.67%, respectively, in the first season and 98.9, 99.8 and 99.68%, respectively in the second one, followed by hand hoeing as decreased by 95.7, 98.8 and 98.17% in the first season and 88.0, 97.5 and 93.49%, respectively in the second one, then cover yield which was decreased by 83.2 and 90.4 and 88.93% in the first season, and 89.1, 96.3 and 95.22% in the second one, respectively compared to un-weeded treatment as shown in Table (3).

The effect of black polyethylene mulch in controlling weeds was reported by Ricotta and Masiunas, 1991, who mentioned that, black polyethylene mulch application for weed control for basil and rosemary was the best weed control. Reductions in weed weight were reported with clover living mulch and increased soybean yield by 91% relative to weedy control plots (Ilnicki and Enache, 1992). Moreover, (Chase and Mbuya, 2008) reported that weed weight was lowest with rye and black oat living mulches when used in organic broccoli production. Mulching and cover crops control weeds through their physical presence on the soil surface by shading, allelopathic activity and blocking the light required for the germination of many small-seeded weed species or by competing for water and nutrients (Teasdale and Mohler, 1993). Also, Fadlallah *et al.* (2017) showed that, mulching with black plastic sheets could be a

Table 2. Percentages of pre- and post-emergence damping-off as well as wilt infection caused by the tested fungi, 45 and 90 days after planting, respectively.

Fungi	% Disease incidence after		Survivals (%)
	45 days	90 days	
***Fusarium oxysporum* (1)**	13.33	46.67	40.00
***Fusarium oxysporum* (2)**	6.67	26.67	66.66
***Fusarium oxysporum* (3)**	13.33	26.67	60.00
***F. solani* (1)**	26.67	26.67	46.66
***F. solani* (3)**	13.33	13.33	73.34
***Macrophomina phaseolina* (1)**	46.67	26.67	26.66
***Macrophomina phaseolina* (2)**	33.33	26.67	40.00
***Macrophomina phaseolina* (3)**	33.33	13.33	53.34
***Rhizoctonia solani* (1)**	26.67	46.67	26.66
***Rhizoctonia solani* (2)**	20.00	33.33	46.67
***Rhizoctonia solani* (3)**	20.00	26.67	53.33
Control (without fungus)	0.00	0.00	100.00
LSD (0.05)	1.36	3.04	-

(1) Beheira Governorate isolate
(2) Ismailia Governorate isolate
(3) Minia Governorate isolate

Table 3. Effect of weed control treatments on weight of grassy weeds, broad leaved weeds and total weeds (g/m^2) during 2020 and 2021 seasons.

Treatments	The weight of the annual weeds (g/m^2)											
	1st season						2nd season					
	Grassy weeds	Reduction %	Broad leaf weeds	Reduction %	Total weeds	Reduction %	Grassy weeds	Reduction %	Broad leaf weeds	Reduction %	Total weeds	Reduction %
Un-weeded	204.30	0.00	803.70	0.00	1008.00	0.00	313.00	0.00	1763.00	0.00	2076.00	0.00
Hand hoeing	8.70	95.70	9.70	98.80	18.40	98.17	37.70	88.00	43.30	97.50	135.20	93.49
Plastic mulch	1.00	99.50	2.30	99.70	3.30	99.67	3.30	98.90	3.30	99.80	6.60	99.68
Cover crop	34.30	83.20	77.30	90.40	111.60	88.93	34.00	89.10	65.30	96.30	99.30	95.22
LSD (0.05)	35.80		108.90		38.96		56.21		176.30		223.00	

good controlling application on annual weeds for spearmint and geranium plants. Abdallah *et al.* (2019) found that plastic mulch and hoeing were the best weed control for cumin plants.

Field experiment:

Disease incidence:

The most commonly observed wilt disease symptoms in plants were yellowing, browning, and wilting of lower leaves, possibly with some internal vascular discoloration in the stem. Data listed in Tables (4) reveal that wilt incidence was significantly affected by the different weed control treatments, cutting treatment and their interaction. Wilt incidence ranged from 1.1-7.7% in the different weed control treatments during the second growing season.

The highest disease incidence was recorded in the un-weeded plots (7.7%), while the lowest disease incidence (1.1%) and the maximum percentage of survived plants (98.9%) were recorded in plastic mulched plots. This treatment was closely followed by plots with cover yield and

Table 4. Effect of weed control treatments and geranium cutting treatment on wilt incidence (%) and the survived plants (%) during the first season 2020.

Cutting treatment (B)	Wilt incidence (%)					Survived plants (%)				
	Weed control treatments (A)									
	Unweeded control	Hand hoeing	Plastic mulch	Cover crop	Mean	Un-weeded control	Hand hoeing	Plastic mulch	Cover crop	Mean
	First season (2020)									
Control	16.0	13.3	10.7	10.7	12.7	84.0	86.7	89.3	89.3	87.3
Peppermint oil	5.3	1.3	0.0	1.3	2.0	94.7	98.7	100.0	98.7	98.0
Marjoram oil	1.3	0.0	0.0	0.0	0.3	98.7	100.0	100.0	100.0	99.7
Trichoderma	5.3	1.3	0.0	1.3	2.0	94.7	98.7	100.0	98.7	98.0
Bacillus	4.0	0.0	0.0	1.3	1.3	96.0	100.0	100.0	98.7	98.7
Mean	6.4	3.2	2.1	2.9		93.6	96.8	97.9	97.1	
L.S.D at 5%										
A	0.6					1.2				
B	0.2					1.0				
A×B	0.8					1.3				
	Second season (2021)									
Control	16.0	10.7	5.3	5.3	9.3	84.0	89.3	94.7	94.7	90.7
Peppermint oil	10.7	1.3	0.0	0.0	3.0	89.3	98.7	100.0	100.0	97.0
Marjoram oil	5.3	0.0	0.0	0.0	1.3	94.7	100.0	100.0	100.0	98.7
Trichoderma	5.3	0.0	0.0	1.3	1.7	94.7	100.0	100.0	98.7	98.3
Bacillus	1.3	1.3	0.0	1.3	1.0	98.7	98.7	100.0	98.7	99.0
Mean	7.7	2.7	1.1	1.6		92.3	97.3	98.9	98.4	
L.S.D at 5%										
A	0.6					1.0				
B	0.3					1.3				
A×B	0.7					1.7				

showed (1.6%) disease incidence in the second growing season.

Weed control can play a role in reducing disease incidence which can ultimately reduce fungicide use. Jambhulkar *et al.* (2012) found that plastic mulching reduced the early blight of tomato by hindering the conidial movement. Reducing disease incidence by cover was reported by several authors. Ristaino *et al.* (1997) reported that a wheat cover crop reduced the Phytophtora blight of peppers due to reduced dispersal of propagules of the causal agent. Moreover, a hairy vetch and Austrian winter pea cover crop reduced fruit rot incidence in tomato plants compared to plants in fallow plots Nyochembeng *et al.* (2014).

Similarly, soaking geranium cutting in essential oils of marjoram and peppermint at a concentration of (5 ml/l) significantly decreased the percentages of wilted plants, as compared to the control. Marjoram essential oil was more effective than peppermint oil in reducing the percentages of disease incidence Table (4). Furthermore, the application of marjoram oil resulted in the highest percentages of the survived plant when compared with other treatments during both seasons. These findings are in agreement with an earlier report on similar effects of essential oils on the reduction of wilt and root rot incidence in green beans (El-Mougy *et al.*, 2007). The efficacy of essential oils as antifungal agents is well documented. The major constituents of marjoram essential oil were determined to be cis-sabinene hydrate and terpinene-4-ol which comprise more than 60% of the oil constituents Gharib (2006). Several of these components were previously tested for their biological activity against a number of fungi. In this respect, Terzi *et al.* (2007) found that terpinen-4-ol, gamma-terpinene and 1,8-cineole, the principal components of *Melaleuca alternifolia* essential oil had highly inhibitory effect against the mycelial growth of some pathogenic fungi and among the tested compounds, terpinen-4-ol was the most effective one. Hence, it could be suggested that the antifungal activity of marjoram oil is due to the presence of the main component terpinene-4-ol in the oil. Moreover, Edris and Farrag (2003) confirmed the inhibitory effect of menthol (one of the major constituents in peppermint essential oil) on the growth of the fungi *Sclerotinia sclerotiorum* and *Rhizopus stolonifer*, and they stated that menthol was the only constituent responsible for the antifungal properties of peppermint essential oil. The antifungal activity might be due to the highly lipophilic nature of terpenes and low molecular weight that lead to disrupting of the cell membrane, causing cell death or inhibiting the sporulation and germination of the fungi (da Silva Bomfim *et al.*, 2015).

The application of Trichoderma and Bacillus significantly reduced the incidence of wilt disease Tables (4). Bacillus was more effective than Trichoderma in reducing the disease incidence resulting in a higher percentage of survived plants during the first season (Table, 4) whereas, the effects of these treatments were similar during the second season. Bacillus proved to be an effective biocontrol agent against a broad range of plant pathogens. Podile and Prakash (1996) showed that groundnut seeds bacterized with *B. subtilis* caused a reduction in the disease incidence of crown rot in infested soil with *Aspergillus niger*, suggesting a possible role of *B. subtilis* in biological control of *A. niger*. *B. subtilis* antagonizes fungal pathogens by producing antifungal peptides that cause lysis of the phytopathogenic fungal cell wall (Gong *et al.*, 2014). *Bacillus* species are also capable of producing enzymes like chitinase having a very strong lytic activity (Zhao *et al.*, 2014). Disease suppression induced by *Trichoderma* spp. was reported by Aghnoom *et al*. (1999) who mentioned that cumin seeds treated with *Trichoderma harzianum* T2 isolate, lowered disease incidence caused by *F. oxysporum* f.sp. *cumini* by 65.4% and this treatment was found to be more effective than seed treatment with fungicides. Moreover, Tawfik and Allam (2004) mentioned that the lowest percentage of cumin infection was found in pre-sowing seed treatment with *T. harzianum*. Disease suppression could be due to competition for nutrients. Trichoderma has a superior capacity to mobilize and take up soil nutrients compared to other organisms (Mohiidin *et al.*, 2010).

Additionally, the interaction between weed control treatments and cuttings treatment was also significant (Table, 4). Plants were completely free from wilt incidence in all weed control treatments of geranium cuttings soaked in marjoram essential oil (5 ml/l) in both seasons. Also, there was no occurrence of the disease in hoeing and plastic mulch plots with cuttings soaked in *B. subtilis* and peppermint oil in the 1st season.

It was observed from the results of this study, that the efficacy of marjoram and peppermint essential oils were similar to the commercial biocides Trichoderma and Bacillus in controlling wilt disease.

Vegetative growth characteristics:

Data exhibited in (Tables, 5-9) showed the effect of weed control treatments, geranium plant treatments and their interactions on vegetative growth characteristics of *Pelargonium graveolens*, L'Herit ex Ait. plants [plant height, number of branches/plant, fresh weight (g/plant), dry weight (g/plant) and yield fresh weight (ton/fed)] in the two cuts in both seasons. The highest vegetative growth characteristics were recorded in plants grown in plastic mulched plots, followed by hoeing and then cover crop plots, while the lowest ones were obtained under un-weeded control. Plastic mulch followed by hoeing significantly improved vegetative growth characteristics which might be due to the effect of weed control, as reduced weed competition for light, water and nutrients. The obtained results are in agreement with those of Ashrafuzzaman *et al.* (2011) and Pradeep *et al.* (2017). Also, Ricotta and Masiunas (1991) found that the yield of basil and rosemary were significantly increased in polythene mulched plots than in un-mulched plots. Black plastic mulching was found to

Table 5. Effect of weed control treatments, essential oils and bioagents on plant height (cm) of geranium plants during 2020 and 2021 seasons.

Treatments (B)	Weed control treatments (A)									
	Un-weeded control	Cover crop	Hoeing	Plastic mulch	Mean	Un-weeded control	Cover crop	Hoeing	Plastic mulch	Mean
					First season					
			First cut					Second cut		
Control	45.70	47.37	47.72	56.95	49.44	43.45	44.65	45.90	53.82	46.96
Peppermint oil	66.98	62.18	63.65	69.02	65.46	61.55	56.38	58.72	63.67	60.08
Marjoram oil	60.62	67.78	65.55	74.28	67.06	52.37	63.65	63.68	69.82	62.38
Trichoderma	67.35	66.38	66.97	73.90	68.65	63.07	61.25	62.48	67.62	63.61
Bacillus	64.70	68.75	68.03	76.95	69.61	61.72	63.78	64.22	71.32	65.26
Mean	61.07	62.49	62.38	70.22		56.43	57.94	59.00	65.25	
LSD (0.05)										
A			3.31					2.30		
B			2.58					2.33		
A × B			5.17					4.67		
					Second season					
Control	54.55	56.85	59.85	59.70	57.74	49.88	52.58	56.42	56.10	53.75
Peppermint oil	74.78	68.61	69.70	76.69	72.45	65.28	64.05	64.96	68.65	65.74
Marjoram oil	65.63	75.20	76.42	88.35	76.40	62.28	70.04	73.33	79.64	71.32
Trichoderma	76.18	68.83	76.07	81.41	75.62	67.75	65.52	72.22	73.76	69.81
Bacillus	71.70	77.18	82.67	90.02	80.39	66.42	71.86	76.38	83.28	74.49
Mean	67.09	68.32	71.57	77.36		61.34	63.82	67.17	70.69	
LSD (0.05)										
A			3.03					4.06		
B			2.87					2.55		
A × B			5.75					5.10		

Table 6. Effect of weed control treatments, essential oils and bioagents on number of branches of geranium plants during 2020 and 2021 seasons.

Treatments (B)	Weed control treatments (A)									
	Un-weeded control	Cover crop	Hoeing	Plastic mulch	Mean	Un-weeded control	Cover crop	Hoeing	Plastic mulch	Mean
					First season					
			First cut					Second cut		
Control	8.52	9.20	9.97	9.87	9.39	10.32	13.75	14.12	14.87	13.27
Peppermint oil	10.38	10.55	14.41	12.88	12.06	15.52	16.45	16.28	17.88	16.53
Marjoram oil	9.43	14.36	16.02	17.40	14.30	13.80	18.85	19.65	20.82	18.28
Trichoderma	11.63	13.77	15.51	17.00	14.48	16.65	18.17	19.33	20.15	18.58
Bacillus	10.32	14.75	16.55	18.48	15.03	15.27	19.13	20.33	21.70	19.11
Mean	9.83	12.06	14.06	14.67		13.85	17.02	17.59	18.63	
LSD (0.05)										
A			3.42					1.13		
B			1.21					0.94		
A × B			2.43					1.88		
					Second season					
Control	11.54	12.25	13.65	13.74	12.80	13.56	14.48	15.65	15.48	14.79
Peppermint oil	14.68	15.77	16.55	17.57	16.14	16.42	17.50	18.00	19.75	17.92
Marjoram oil	13.53	17.13	17.78	20.58	17.26	17.28	18.42	19.68	21.15	19.13
Trichoderma	16.40	16.45	17.45	19.32	17.41	15.33	18.65	21.20	22.47	19.41
Bacillus	14.63	17.70	18.48	21.40	18.05	16.05	19.81	21.27	22.80	19.98
Mean	14.16	15.86	16.78	18.52		15.73	17.77	19.16	20.33	
LSD (0.05)										
A			0.75					0.58		
B			0.82					0.78		
A × B			1.64					1.57		

Table 7. Effect of weed control treatments, essential oils and bioagents on fresh weight (g/plant) of geranium plants during 2020 and 2021 seasons.

Treatments (B)	Weed control treatments (A)									
	Un-weeded control	Cover crop	Hoeing	Plastic mulch	Mean	Un-weeded control	Cover crop	Hoeing	Plastic mulch	Mean
	First season									
	First cut					**Second cut**				
Control	441.20	475.70	496.92	502.41	479.06	476.35	496.95	508.50	516.67	499.62
Peppermint oil	509.23	531.60	554.48	612.98	552.07	560.90	578.49	606.80	634.43	595.16
Marjoram oil	568.55	645.85	659.13	680.87	638.60	583.28	655.18	682.45	702.63	655.89
Trichoderma	553.98	612.45	634.28	661.20	615.48	567.71	623.38	651.78	682.90	631.44
Bacillus	590.55	671.97	682.23	711.93	664.17	633.38	697.19	697.68	725.30	688.39
Mean	532.70	587.51	605.41	633.88		564.32	610.24	629.44	652.39	
LSD (0.05)										
A			18.44					15.05		
B			15.73					16.87		
A × B			31.47					33.75		
	Second season									
Control	473.52	483.42	513.02	518.97	497.23	485.28	493.11	518.80	522.38	504.89
Peppermint oil	528.70	555.38	554.48	646.42	571.25	561.70	588.30	653.78	654.28	614.52
Marjoram oil	596.48	649.63	660.02	709.89	654.01	612.08	674.03	696.58	711.63	673.58
Trichoderma	572.50	621.08	644.20	674.17	627.99	597.54	646.28	678.00	686.20	652.01
Bacillus	608.20	681.33	691.67	719.93	675.28	625.63	698.57	714.10	724.43	690.68
Mean	555.88	598.17	612.68	653.88		576.45	620.06	652.25	659.78	
LSD (0.05)										
A			10.99					19.24		
B			11.63					13.33		
A × B			23.27					26.66		

Table 8. Effect of weed control treatments, essential oils and bioagents on fresh weight (t/fed) of geranium plants during 2020 and 2021 seasons.

Treatments (B)	Weed control treatments (A)									
	Un-weeded control	Cover crop	Hoeing	Plastic mulch	Mean	Un-weeded control	Cover crop	Hoeing	Plastic mulch	Mean
	First season									
	First cut					**Second cut**				
Control	9.71	10.47	10.93	11.05	10.54	10.48	10.93	11.19	11.37	10.99
Peppermint oil	11.20	11.70	12.20	13.49	12.15	12.34	12.73	13.35	13.96	13.10
Marjoram oil	12.51	14.21	14.50	14.98	14.05	12.83	14.41	15.01	15.46	14.43
Trichoderma	12.19	13.47	13.95	14.55	13.54	12.49	13.71	14.34	15.02	13.89
Bacillus	12.99	14.78	15.01	15.66	14.61	13.93	15.34	15.35	15.96	15.15
Mean	11.72	12.93	13.32	13.95		12.41	13.42	13.85	14.35	
LSD (0.05)										
A			0.40					0.33		
B			0.34					0.37		
A × B			0.69					0.74		
	Second season									
Control	10.42	10.64	11.29	11.42	10.94	10.68	10.85	11.41	11.49	11.11
Peppermint oil	11.63	12.22	12.20	14.22	12.57	12.36	12.94	14.38	14.39	13.52
Marjoram oil	13.12	14.29	14.52	15.62	14.39	13.47	14.83	15.32	15.66	14.82
Trichoderma	12.60	13.66	14.17	14.83	13.82	13.15	14.22	14.92	15.10	14.35
Bacillus	13.38	14.99	15.22	15.84	14.86	13.76	15.37	15.71	15.94	15.20
Mean	12.23	13.16	13.48	14.39		12.68	13.64	14.35	14.52	
LSD (0.05)										
A			0.24					0.42		
B			0.25					0.29		
A × B			0.51					0.58		

Table 9. Effect of weed control treatments, essential oils and bioagents on dry weight (g/plant) of geranium plants during 2020 and 2021 seasons.

Treatments (B)	Weed control treatments (A)									
	Un-weeded control	Cover crop	Hoeing	Plastic mulch	Mean	Un-weeded control	Cover crop	Hoeing	Plastic mulch	Mean
	First season									
	First cut					Second cut				
Control	126.36	136.16	142.41	143.72	137.16	142.24	148.37	151.92	154.16	149.17
Peppermint oil	145.88	152.25	158.79	175.69	158.15	167.65	172.88	181.30	189.49	177.83
Marjoram oil	162.63	184.90	188.67	195.06	182.82	174.08	195.71	203.79	209.78	195.84
Trichoderma	158.36	175.33	181.59	189.49	176.19	169.61	186.26	194.69	203.90	188.62
Bacillus	168.86	192.35	195.48	203.82	190.13	189.14	208.18	208.43	216.61	205.59
Mean	152.42	168.20	173.39	181.56		168.54	182.28	188.03	194.79	
LSD (0.05)										
A			6.33					4.17		
B			3.07					5.1		
A × B			9.05					10.2		
	Second season									
Control	140.29	143.17	151.82	153.51	147.20	140.78	142.96	150.57	151.41	146.43
Peppermint oil	156.40	164.26	164.20	191.30	169.04	162.88	170.56	189.55	189.84	178.21
Marjoram oil	176.67	192.38	195.30	210.01	193.59	177.57	195.52	202.03	206.45	195.39
Trichoderma	169.33	183.75	190.64	199.61	185.83	173.27	187.39	196.56	198.98	189.05
Bacillus	179.97	201.63	204.69	213.16	199.86	181.49	202.61	207.01	210.02	200.28
Mean	164.53	177.04	181.33	193.52		167.20	179.81	189.14	191.34	
LSD (0.05)										
A			3.28					5.47		
B			3.55					3.9		
A × B			7.1					7.1		

enhance vegetative growth of geranium plants due to maintaining high soil water contents thus improving water use efficiency, optimizing soil temperature and resistance of weeds (Bond and Grundy, 2001 and Tarara, 2000). Also, Abdallah *et al.* (2019) found that, plastic mulching had a positive effect on the suppression of weeds, reduced disease incidence of fusarium wilt and increased the growth and yield of cumin plants. However, the growth parameters and yield of geranium plants were significantly lower in the case of cover crop plots than those grown under plastic mulch or hoeing but higher than the un-weeded control treatment. This decrease in growth parameters of geranium plants may be due to competition with clover as a living mulch. Living mulch may compete with growth of the main crop (Domange, 1993). Also, Chase and Mbuya (2008) reported that living mulches were effective in inhibiting weed biomass, but reduced the broccoli growth, and thus the yield decreased. Marks (1993) suggested that reduced growth of the main crop might be due to competition for water or essential nutrients, or the living mulch may be having an allelopathic effect, therefore, living mulches must be managed carefully to reduce their competition with the crop.

Results presented in Tables (5-9) indicated that treatment with any of the two essential oils (marjoram and peppermint) or biocontrol agent (Bacillus and Trichoderma) significantly increased vegetative growth characteristics of plants [plant height, number of branches/plant, fresh weight (g/plant), dry weight (g/plant) and yield fresh weight (ton/fed)] compared to those of the control, in the two cuts in both seasons. The highest growth and yields of plants were obtained with bacillus application and followed by, marjoram oil application. The effect of essential oils on increasing the yield of geranium may be due to the role of its active components in resisting wilt diseases. Essential oils and their components are gaining increasing interest because of their relatively safe status, low toxicity for people and the environment due to their natural properties, and their effect on pathogenic microorganisms (Burt, 2004; Dafererea *et al*., 2000 and Mohamed *et al.*, 2006). The oils displayed great potential of antifungal activity as a mycelial growth inhibitor against the tested phytopathogenic fungi such as *B. theobromae, R. solani*, *Pythium irregulare*, *Ceratocystis pilifera*, *Phragmidium violaceum*, *Colletotricum capsici*, *Phytophthora capsici*, *F. solani* and *F. oxysporum* (Bittner *et al.*, 2009; Hossain *et al*., 2008 and Markson *et al.*, 2011). Barrera-Necha *et al.* (2009) emphasized that the effects of essential oils inhibited the mycelial growth of *Fusarium*. Abdel-Kader *et al*. (2011) indicated that the clove, caraway, thyme and peppermint essential oils used resulted in a significant reduction of root rot incidence of bean. Also, Abdallah *et al.* (2019) found that marjoram essential oil controlled wilt cumin disease. Essential oils can be related to the activity of many components such as phenols, thymol and carvacrol (Carmo *et al.*, 2008; Gallucci *et al*., 2014; Fayaz *et al.*, 2017; Shabana *et al*., 2017 and Elkhwaga *et al.*, 2018). The suggested mechanism is that monoterpene alcohols disrupt the permeability of the fungal plasma membrane and inhibit the respiration process on mitochondrial membrane (Cox *et al*., 2000 and Deba *et al*., 2008).

Moreover, the application of biological controls (Bacillus and Trichoderma) improved the growth and yield of geranium plants due to their significant reduction of root rot incidence. Similar results showing the promoting effect on the growth of plants due to the treatment with bio-agent were reported by Haggag and Abdel-latif (2001), Weller (2007), Harman (2006), Alwathnani and Perveen (2012), Sallam *et al.* (2013) and Sivasakthi *et al.* (2014), where *Trichoderma harzianum* and *Pseudomonas fluorescens* strains had the ability to increase plant growth, and this increase was attributed to reducing negative effects on the diseased root or may be due to the production of plant growth promoters (auxins, gibberellins and cytokines), stimulation of nutrient uptake, producing siderophores and antibiotics to protect plants from harmful rhizosphere organisms. Biological controls are successful for controlling various plant diseases (Wright *et al.*, 2003 and El-Mougy and Abdel-Kader, 2008). *Bacillus subtilis* has been widely used for plant growth promotion in a number of ways including its ability to produce phytohormones such as IAA, gibberellins, cytokinins and increase root and shoot cell division and elongation (Idris *et al.*, 2004). Also, increasing the availability of N, P, and Fe in the soil (Kim *et al.*, 2011 and Ortíz-Castro *et al.*, 2014) as well as its ability to produce volatile organic compounds which play a significant role in promoting plant growth by regulating the synthesis or metabolism of phytohormones (Tahir *et al.*, 2017). Abdel-Kader *et al*. (2011) concluded that the application of essential oils combined with bioagent *T. harzianum* is considered an applicable, safe and cost-effective method for controlling such soil-borne diseases. Khan *et al*. (2017) found beneficial strains of *Bacillus* due to their ability to produce a range of metabolites that enhanced plant growth and reduce pathogen attack, either by inhibition of fungal growth. Abdallah *et al.* (2019) found that biocontrol agents reduced disease incidence of Fusarium wilt and enhanced the vegetative growth and yield of cumin plants. Generally, the antagonistic mechanisms through which biological control may be related to direct parasitism lead to the death of the pathogen, competition on nutrients and space and production of cytotoxic compounds such as antibiotics or toxic volatiles (Heydari and Pessarakli, 2010 and Omara *et al*., 2018).

Regarding the effect of the interaction between weed control treatments and essential oils (marjoram and peppermint) or commercial biocides (Bacillus and Trichoderma), they had a positive effect on growth and yield (Tables, 5-9). Maximum values were obtained from plastic mulch and hoeing plots with geranium essential oil or bacillus, but the lowest values of growth and yield were recorded in those plants grown under un-weeded control and un-treated in the first and the second cuts in each season. Similar results were obtained by Abdallah *et al.* (2019) who found that maximum values of cumin yield were obtained from plastic mulch and hoeing plots with seeds soaked in marjoram essential oil or Rhizo-N.

These results showed that weeded control with the application of essential oils and biological controls may be important because they are one safe and cost-effective method for controlling soil-borne diseases.

Volatile oil productivity:

Volatile oil percentage:

It is clear from data presented in Table (10) that in each cut in the first season, weed control treatments showed an insignificant effect on the volatile oil % of plants, while the methods of weed control (plastic mulch, hoeing and cover crop) had a significant effect on volatile oil % in the two cuts in the second season compared to un-weeded control only. On the other hand, the application of essential oils (marjoram and peppermint) or biocontrol agents (Bacillus and Trichoderma) showed a significant effect on volatile oil percentage compared to untreated plants in each cut in the two seasons. The highest percentage of volatile oil was recorded for the plants treated with marjoram oil and followed by peppermint oil. Treatment with a biocontrol agent led to an increase in the volatile oil compared to the control, but with less effect than that treated with essential oils. Regarding the effect of interaction between weed control treatments and essential oils (marjoram and peppermint) or commercial biocides (Bacillus and Trichoderma), data listed in Table (10) showed that in both seasons, the highest volatile oil percentage was obtained in plants grown under plastic mulch and treaded with marjoram oil, followed by using hoeing method with marjoram oil treatment.

Table 10. Effect of weed control treatments, essential oils and bioagents on volatile oil % of geranium plants during 2020 and 2021 seasons.

Treatments (B)	Weed control treatments (A)									
	Un-weeded control	Cover crop	Hoeing	Plastic mulch	Mean	Un-weeded control	Cover crop	Hoeing	Plastic mulch	Mean
	First season									
	First cut					Second cut				
Control	0.07	0.08	0.08	0.07	0.08	0.06	0.07	0.08	0.08	0.07
Peppermint oil	0.11	0.11	0.12	0.13	0.12	0.11	0.11	0.13	0.13	0.12
Marjoram oil	0.12	0.12	0.13	0.14	0.13	0.12	0.12	0.14	0.15	0.13
Trichoderma	0.09	0.10	0.10	0.10	0.10	0.09	0.10	0.11	0.11	0.10
Bacillus	0.10	0.09	0.10	0.11	0.10	0.10	0.10	0.11	0.10	0.10
Mean	0.10	0.10	0.10	0.10		0.10	0.10	0.11	0.11	
LSD (0.05)										
A			0.01					0.01		
B			0.01					0.01		
A × B			0.02					0.02		
	Second season									
Control	0.06	0.07	0.07	0.08	0.07	0.07	0.09	0.07	0.08	0.08
Peppermint oil	0.11	0.12	0.12	0.13	0.12	0.12	0.13	0.13	0.14	0.13
Marjoram oil	0.12	0.14	0.14	0.15	0.14	0.13	0.14	0.15	0.16	0.15
Trichoderma	0.08	0.11	0.10	0.11	0.10	0.10	0.11	0.12	0.13	0.12
Bacillus	0.09	0.10	0.10	0.11	0.10	0.11	0.11	0.11	0.12	0.11
Mean	0.09	0.11	0.11	0.12		0.11	0.12	0.12	0.13	
LSD (0.05)										
A			0.01					0.01		
B			0.01					0.01		
A × B			0.02					0.02		

Volatile oil yield ml/plant and oil yield (l/fed):

Data presented in Tables (11 and 12) indicated that the application of weed control treatments (plastic mulch, hoeing and cover crop), essential oils (marjoram and peppermint) and biocontrol agents (Bacillus and Trichoderma) had a beneficial effect on oil yield ml/plant and oil yield (l/fed). The highest volatile oil yield was observed in the plants grown under plastic mulch and followed by the hoeing method, then cover crop than in the un-weeded control in both cuts in the first and the second seasons.

Treatments of essential oils or biocontrol agents had the best significant effect on the oil yield (ml/plant) and oil yield **(**l/fed) of geranium plants compared to untreated ones. The highest oil yield was observed by marjoram essential oil treatment. From the data shown in Tables (11 and 12), it was found that peppermint oil has a similar effect with bacillus treatment on the oil yield ml/plant and oil yield/fed.

In general, essential oils (marjoram and peppermint), as well as biocontrol agent (Bacillus and Trichoderma) treatments increased the volatile oil content in geranium plants than that in the control, as these results were in agreement with (Lu *et al*., 2017; Sadeghi *et al.*, 2017; Omara *et al*., 2018 and Ghazi *et al.*, 2018).

Concerning the interaction between weed control treatments and essential oils (marjoram and peppermint) or commercial biocides (Bacillus and Trichoderma) on oil yield in both seasons, all treatments increased compared to those plants grown under un-weeded and untreated. The highest volatile oil yield was observed by using black plastic mulch and treaded by marjoram essential oil, followed by the hoeing method and marjoram essential oil treatment.

Volatile oil constituents:

The results of the analysis of the geranium volatile oil are given in. Eleven components could be identified. Citronellol was the most important component followed

Table 11. Effect of weed control treatments, essential oils and bioagents on volatile oil yield (ml/plant) of geranium plants during 2020 and 2021 seasons.

Treatments (B)	Weed control treatments (A)									
	Un-weeded control	Cover crop	Hoeing	Plastic mulch	Mean	Un-weeded control	Cover crop	Hoeing	Plastic mulch	Mean
	First season									
	First cut					**Second cut**				
Control	0.31	0.38	0.40	0.35	0.36	0.29	0.35	0.41	0.43	0.37
Peppermint oil	0.56	0.57	0.65	0.78	0.64	0.63	0.64	0.77	0.80	0.71
Marjoram oil	0.65	0.73	0.83	0.90	0.78	0.66	0.75	0.89	1.00	0.83
Trichoderma	0.51	0.65	0.66	0.70	0.63	0.52	0.65	0.75	0.75	0.67
Bacillus	0.61	0.63	0.66	0.78	0.67	0.65	0.67	0.77	0.72	0.70
Mean	0.53	0.59	0.64	0.70		0.55	0.61	0.72	0.74	
LSD (0.05)										
A			0.05					0.06		
B			0.06					0.06		
A × B			0.12					0.13		
	Second season									
Control	0.30	0.34	0.38	0.40	0.36	0.34	0.43	0.38	0.43	0.40
Peppermint oil	0.56	0.65	0.67	0.82	0.68	0.66	0.78	0.83	0.94	0.80
Marjoram oil	0.67	0.85	0.90	0.99	0.85	0.76	0.93	1.00	1.07	0.94
Trichoderma	0.50	0.69	0.66	0.78	0.66	0.59	0.74	0.81	0.90	0.76
Bacillus	0.55	0.66	0.69	0.77	0.67	0.67	0.77	0.81	0.85	0.78
Mean	0.52	0.64	0.66	0.75		0.60	0.73	0.77	0.84	
LSD (0.05)										
A			0.05					0.06		
B			0.05					0.04		
A × B			0.11					0.08		

Table 12. Effect of weed control treatments, essential oils and bioagents on volatile oil yield (l/fed) of geranium plants during 2020 and 2021 seasons.

Treatments (B)	Weed control treatments (A)									
	Un-weeded control	Cover crop	Hoeing	Plastic mulch	Mean	Un-weeded control	Cover crop	Hoeing	Plastic mulch	Mean
					First season					
			First cut					Second cut		
Control	6.79	8.37	8.71	7.73	7.90	6.27	7.62	8.93	9.35	8.04
Peppermint oil	12.34	12.45	14.23	17.1	14.03	13.97	14.01	16.95	17.68	15.65
Marjoram oil	14.28	16.16	18.16	19.88	17.12	14.57	16.47	19.61	22.04	18.17
Trichoderma	11.27	14.22	14.52	15.49	13.88	11.53	14.4	16.52	16.48	14.73
Bacillus	13.43	13.8	14.53	17.16	14.73	14.41	14.82	16.9	15.94	15.52
Mean	11.62	13.00	14.03	15.47		12.15	13.46	15.78	16.30	
LSD (0.05)										
A			1.18					1.25		
B			1.37					1.45		
A × B			2.75					2.90		
					Second season					
Control	6.6	7.4	8.27	8.75	7.76	7.45	9.42	8.43	9.56	8.72
Peppermint oil	12.42	14.26	14.64	18.01	14.83	14.41	17.26	18.22	20.62	17.63
Marjoram oil	14.7	18.68	19.83	21.76	18.74	16.65	20.37	21.89	23.65	20.64
Trichoderma	10.97	15.25	14.54	17.18	14.49	13	16.31	17.88	19.82	16.75
Bacillus	12.07	14.47	15.23	16.89	14.67	14.66	16.92	17.79	18.59	16.99
Mean	11.35	14.01	14.50	16.52		13.23	16.06	16.84	18.45	
LSD (0.05)										
A			1.33					1.43		
B			1.21					0.88		
A × B			2.42					1.77		

by geraniol and then eugenol (Table, 13). The application of weed control treatments were more effective oil components compared to in those under unweeding, the highest values of the three main components (citronellol, geraniol and eugenol) were recorded with used hand hoeing method, following black plastic mulch, and then cover yield method.

Also, the treatments with essential oils and biocontrol agents were more effective as increased the value of the three main components compared to in control. The highest values of citronellol, geraniol and eugenol were obtained by marjoram oil treatment followed by peppermint oil treatment.

The interaction effect between weed control (black plastic mulch, hand hoeing and cover yield) treatments and essential oils (marjoram and peppermint or commercial biocides (Bacillus and Trichoderma) on the three main volatile oil components are show in Table (13). The highest values were recorded with the used hoeing method and treated with marjoram essential oil followed with hoeing method and treated by peppermint essential oil treatment. On the other hand, commercial biocides (Bacillus and Trichoderma) they had no clear role on the values of the three main volatile oil components.

In general, essential oils (marjoram and peppermint) and biocontrol agent (Bacillus and Trichoderma) treatments caused sharp increase in vegetative growth such as plant height, number of branches, herb yield, and oil yield of geranium plants, similar results were found by (Lu *et al*., 2017; Sadeghi *et al*., 2017 and Omara *et al*., 2018). Also, on geranium plants, Ghazi *et al.* (2018) stated that *B. subtilis* and *T. harzianum* as well as essential oils treatments increased plant growth such as plant height, branches, leaves number, and oil yield.

Table 13. Effect of weed control treatments, essential oils and bioagents on components oil of geranium plants in first cut in second season.

Treatments	Compounds (%)										
	∝-Pinene	P-cymene	Iso-menthone	Linalool	Citronyl Formate	Geeranyl Formate	Citronellol	Geraniol	Geranylbutrate	Eugenol	B-Caryophyllene
Unweeded (Control)	1.28	5.75	7.38	7.33	5.32	3.11	18.85	10.89	2.88	8.97	6.03
Plastic mulch (PM)	1.32	4.53	8.97	8.31	0.68	3.45	21.50	14.40	2.18	10.66	1.96
Hoeing (H)	1.67	5.22	7.79	7.70	8.19	1.57	23.50	15.30	2.13	12.21	6.54
Cover crop (CC)	0.41	1.51	4.11	5.14	2.86	3.06	18.50	13.20	2.52	10.25	6.95
Peppermint oil (PO)	0.33	1.32	4.27	4.21	5.82	2.40	28.78	24.44	1.87	11.71	4.16
Marjoram oil (MO)	0.56	2.36	5.76	0.10	6.28	3.08	30.75	25.27	2.62	11.36	2.63
Trichoderma (Trich.)	2.31	3.00	5.63	3.42	8.31	3.53	19.74	14.17	2.65	10.97	2.02
Bacillus (Baci.)	0.49	1.36	6.58	6.22	10.34	8.21	17.87	12.24	2.80	10.50	5.99
PM + PO	0.58	4.56	4.37	7.34	3.31	3.10	29.86	25.88	2.89	8.99	4.03
PM + MO	0.53	1.51	5.82	5.50	7.72	5.54	31.17	27.10	1.75	10.26	1.38
PM + Trich.	0.32	1.30	4.27	4.21	7.75	5.50	22.78	21.44	1.87	12.73	4.14
PM + Baci.	1.55	5.37	5.76	2.10	6.28	3.06	22.75	20.47	2.64	11.38	6.61
H + PO	1.40	4.72	5.61	7.52	4.28	3.44	33.62	28.43	1.03	6.34	1.99
H + MO	0.51	2.37	2.76	3.10	6.35	2.06	33.75	30.47	1.64	9.38	5.61
H + Trich.	1.28	2.76	3.37	5.34	2.31	3.13	22.86	20.88	2.96	11.99	6.01
H + Baci.	0.52	1.90	5.14	4.50	7.41	4.56	21.17	18.10	2.75	10.25	6.39
CC + PO	1.64	1.47	5.37	4.83	5.54	2.13	27.79	20.29	3.62	8.00	2.73
CC + MO	1.20	5.72	4.61	3.32	4.48	3.74	28.15	22.43	2.03	6.24	1.69
CC + Trich.	0.58	4.86	3.97	6.41	3.31	3.10	22.86	19.88	3.39	9.69	6.01
CC + Baci.	0.41	3.50	5.74	5.30	6.11	5.26	20.17	16.10	2.75	10.15	5.39

CONCLUSION

It can be concluded that weed control with essential oils and biocontrol agent application reduced geranium wilt disease compared to the control. Essential oils and microbial treatments not only reduced the fungal infection but also enhanced the vegetative growth and oil yield. The highest herb and oil yield were obtained under plastic mulch and marjoram essential oil or *B. subtilis* treatment.

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تأثير بعض طرق مقاومة الحشائش و أمراض الذبول على انتاجية نباتات العتر

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تم جمع نباتات عتر مصابة بأمراض الذبول من أماكن مختلفة لمحافظات البحيرة والإسماعيلية والمنيا في مصر، وتم عزل فطريات *Fusarium*، *Macrophomina*، *Rhizoctonia* و *Pythium* من النباتات المصابة. و أظهرت النتائج أن أعلى معدل من العزل كان فطر *F. oxysporum* يليه *F. solani* ثم *M. phaseolina* و *Pythium* sp.. أُجرى إختبار معملي لدراسة تركيزات من زيوت البردقوش والنعناع الفلفلي على تثبيط نمو الفطريات المعزولة عند تركيز ٥ مل فى اللتر. أجريت التجربة الحقلية فى محطة بحوث ملوي محافظة المنيا في موسمين متتاليين ٢٠٢٠ و ٢٠٢١ لدراسة تأثير الطرق المختلفة لمقاومة الحشائش (التغطية بالبلاستك الأسود، العزيق، محصول مغطي، كنترول). أوضحت النتائج أن حميع طرق مقاومة الحشائش أدت إلى انخفاض معنوى لوزن الحشائش النجيلية وعريضة الأوراق والحشائش الكلية بالمقارنة بالكنترول. وكذلك وجد أن إستخدام طرق مقاومة الحشائش والمعاملة بالزيوت الطيارة (البردقوش والنعناع الفلفلي) وكذلك المبيد الحيوي (الباسيللس و الترايكودرما) له تأثير معنوي على مقاومة الإصابة بأمراض الذبول وزيادة النمو الخضري ومحصول العشب والزيت الطيار و مكوناته. وكانت أقل نسبة إصابة بمرض الذبول وأعلى معدل نمو ومحصول وزيت طيار مع التغطية بالبلاستك الأسود وأعلى نسبة إصابة بمرض الذبول وأقل محصول من العشب والزيت نتجت بالغير معاملة بطرق مكافحة الحشائش. وأدت المعاملة بزيت البردقوش الطيار أو فطر الباسيللس أقل نسبة إصابة بمرض الذبول وأعلى معدل نمو و محصول وزيت طيار. أعلى إنتاج نمو خضري و محصول وزيت طيار نتجت بإستخدم بلاستك البولي إيثيلين مع المعاملة بزيت البردقوش أو فطر الباسيللس.