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Influence of Different Garlic Treatments on Controlling Basal Stem Rot, Root Rot and Infection by Broomrape in Geranium Plants.

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Two field experiments were conducted to evaluate the efficacy of different garlic treatments against basal stem rot, root rot and broomrape of geranium and its productivity at the Exp. Farm of Sids Hort. Res. Stat., Agric. Res. Center, Beni-Sweif governorate during 2016 and 2017 growing seasons. It was observed that using garlic as intercropping with geranium, soil amendment in addition to spraying garlic extract effectively controlled basal stem and root rot as well as decreased the infection by broomrape. These treatments enhanced plant growth, oil and its chemical composition, where, intercropping of garlic with geranium plants as a treatment gave the highest mean values of oil (%) and oil yield (kg/fed.), respectively for the two plant cuts followed by soil amendment with garlic and spraying geranium plants with garlic extract.

Keywords: garlic, basal stem rot; root rot; broomrape; intercropping; soil amendment; garlic extract; geranium.

Geranium (*Pelargonium graveolens*, L.) is a very important aromatic plant belongs to the Geraniaceae family, mainly cultivated for its essential oil (Eiasu *et al.*, 2012), which possesses high economic value in international market because of its very profound and strong rose-like fragrance used in perfumery, cosmetics and other flavoring industries in addition to its medicinal importance like wounds healing, ulcers disorders as well as treatment of dysentery, diarrhea and colic (Matthews, 1995 and Prins *et al.*, 2010). Geranium is now substantial aromatherapy oil used as balancing oil for both mind and body (Dorman and Deans 2000). Essential oil which is mainly extracted from leaves by steam and /or water distillation techniques (Rajeswara Rao *et al.*, 1996) positively correlates to herbage yield (Singh, 1999 and Motsa *et al.*, 2006). Geranium is attacked by basal stem rot and root rot caused by *Fusarium* spp., *Pythium ultimum*, *Rhizoctonia solani* and *Machrophomina phaseolina*, which considered the most serious pathogens affecting the horticultural crop in Egypt and worldwide (Kalra *et al.*, 1992; El-Gamal, 1995; Haggag and Abdel-Latif, 2001 and Adolf, 2016) leading to significant losses every season.

Orobanche species are obligate chlorophyll-lacking root parasites, which cause great damage to many cultivated crops all over the world (Joel *et al.*, 2007 and Parker, 2009 and Parker, 2012). Losses in some crops can reach more than 95% in highly infested fields (Abbes *et al.*, 2007and Kharrat *et al.*, 2010) depending on host susceptibility, level of infestation, and environmental conditions. In Egypt, geranium is severely attacked by *O. ramose* causing in some fields important yield losses. A wide variety of control methods, *i.e.*, physical, cultural, chemical, and biological methods have been explored against soil borne pathogens and broomrape, but most of them are ineffective or insufficiently selective to the majority of susceptible crops (Joel *et al.*, 2007). The lack of efficient control methods can lead to a significant build up the weed seed bank. The seeds can remain viable for 20 years or more in the absence of the host plant (Kebreab and Murdoch, 1999). The effect of trap crops on broomrape plays great role in stimulating seed germination, but do not attacked themselves by the parasites. Crop rotation with potential trap crops for number of years, say 5-10 years deplete soil seed bank of *Orobanche* infestation. *Orobanche* parasitic weeds assumed to be reduced by 30% in every growing season, growing trap crops for two consecutive seasons reduced soil seed bank of *Orobanche* species by 60% (Linke *et al.*, 1991 and Lüpez-Granados & Garcfa-Torres, 1991). Trap crops or non-host plants may stimulate the germination of its seeds but cannot infect and thus reduce density of seeds in the soil due to suicidal germination (Acharya, 2013). Garlic (*Allium sativum*) as trap crop has been shown to be effective on controlling broomrape (Abebe *et al.*, 2005) and soil borne fungal pathogens (Mercado and Rodriguez, 2001 and Sealy *et al.*, 2007). As well as improves plant growth (Noghani *et al.*, 2013, Singh *et al.*, 2013 and Cheng *et al.*, 2016).

This study was conducted to evaluate the potential of different treatments of garlic to control basal stem rot, root rot and broomrape in geranium and their effects on its productivity.

Materials and Methods

Two field experiments were conducted under natural infestation with the causal of basal stem rot and root rot of geranium and the broomrape in the Exp. Farm of Sids Hort. Res. Stat., Agric. Res. Center, Beni-Sweif governorate during 2016 and 2017 growing seasons to evaluate the efficacy of different treatments of garlic against these diseases and the parasite broomrape as well as their effects on productivity of geranium. Soil texture was a clay loam and was analyzed for physical and chemical properties (Jackson, 1958) and the results are presented in (Table, 1).

Table (1). Analysis of the soil in 2016 and 2017.

Seasons	Particle size distribution*			Textural Class	Chemical properties**					
	Clay %	Silt %	Sand %		OM %	EC, dSm^{-1} (at 25°C)	Available (ppm) N	P	K	pH
2016	48.78	33.11	18.11	Clay	1.68	1.12	41.00	11.18	210.3	7.7
2017	48.10	33.61	18.29	Clay	1.80	1.03	36.00	10.60	224.6	7.8

Garlic cloves (cv. Balady) and geranium cuttings 15 cm long with at least three leaves taken from stock plant stems were obtained from the Exp. Farm of Sids Hort. Res. Stat. The experiment was designed in a randomized complete blocks design, with three replications in plots 3 × 3.5 m containing 5 rows 70 cm apart. During both experimental seasons, the following treatments of garlic were applied as follows:

T1: Cuttings treatment, soaking in garlic extract + foliar spray with garlic extract (5 %).
T2: Intercropping of garlic with geranium.
T3: Soil amendment with air dried garlic leaves.
T4: Soil amendment with air dried garlic leaves + foliar spray with garlic extract (5 %).
T5: The fungicide Rizolex-T + the herbicide Roundup star.
T6: Untreated as control.

For preparation of garlic extract: Fifty grams of garlic cloves were homogenized by blender in 200 ml of ethanol (96%) and distilled water (20:80, v:v) for 10 min, then left in dark glass bottles for 72 h for tissue maceration. The extracts were filtered through thin cheesecloth sheets. The final extracts were collected separately in other dark glass bottles and left at room temperature for ethanol evaporation. The collected extracts were then stored in a refrigerator at 5°C until needed (El-Mougy and Abdel-Kader, 2007).

For intercropping: garlic cloves were planted in the opposite side of row at 15 cm apart on 15th September and geranium cuttings were planted in 1st of November in the two seasons.

For soil amendments: Leaves of garlic (collected before ten days from harvest) were air-dried under shade and grounded. The specified dried and grounded leaves were then mixed thoroughly in a layer 15 cm below the soil surface at the rate of 4 ton per fed., 90 kg /fed. of urea were added to amended soil and watered to facilitate decomposition of organic matter (Hussain *et al.*, 2011). Two weeks after amendment, geranium cuttings were planted in amended plots.

In each season, the soil was mechanically ploughed and planked twice. During the preparation for cultivation, calcium super-phosphate (15.5 % P_2O_5) was added at the rate of 200 kg/fed. Geranium cuttings were soaked in garlic extract (5 %) for half an hour before planting. Cuttings soaked in the fungicide Rizolex-T 50% WP. (active ingredient: Tolclofos-methyl + thiram), Sumitomo Chemical Company Co, Ltd, Osaka, Japan. at the concentration of 2g/l for half hour were included as a chemical control. The treated and untreated cuttings were planted on 1st of November in the two experimental seasons on rows at 30 cm spacing between cuttings. The herbicide Roundup star (Glyphosate-K 44.1) at the rate of 50 cm^3/fed. was applied to geranium plants as soon as the broomrape appears above the soil surface and the second treatment was after one month from the first application.

Other weeds were removed by manual operations as needed and plants were irrigated regularly as necessary, throughout the growing season in order to maintain constant growth. The plants were sprayed with the garlic extract (5%) every 15 days one month after planting. All agricultural practices were carried out according to the recommendation of Agric. Ministry for the production of garlic and geranium crops.Disease incidence and severity were estimated as follow:

Disease incidence:

The percentages of disease incidence were recorded as the number of diseased plants relative to the number of growing plants for each treatment, and then the average of disease incidence was calculated. Reduction in disease incidence was calculated using the following formula:

$$\text{Reduction \%} = [C\text{-}T] / C \times 100$$

Where: C and T are the percentages of disease incidence in control and treated plants, respectively.

Disease severity:

Disease severity was estimated at the end of each experiment based on the progress of yellowing and root rot and rotting using the rating scale according to a 0-5 scale of Shahzad & Ghaffar (1992) with minor modification where 0=0, l=> 0 -10, 2=>10-25, 3=>25-50, 4=>50- 75 and 5=>75-100%.

$$\text{Disease severity \%} = [\Sigma (n \times c)]/ (N \times C) \times 100$$

Where: n = Number of infected plants, c = Category number, N = Total number of examined plants and C = The highest category number of infections.

Plant samples and measurements

A random sample of five plants was taken from each experimental treatment during each of the cuts on 1st July and 1st October for blooming of geranium plants at the two seasons. The following parameters, *i.e.*, plant height (cm), number of branches/plant, herb fresh weights (g/plant) and ton /fed. as well as chlorophyll A and B and carotenoids content and essential oil percentage, oil yield and its components.

Essential oils extraction:

One hundred gram of fresh geranium leaves were hydrodistilled in a Clevenger apparatus according to Guenther (1961) in triplicate. Essential oil percentage was determined. The essential oils were collected and dehydrated over anhydrous sodium sulphate and kept in a refrigerator until GC analysis.

Gas chromatographic analysis (GC) of the essential oils:

The GC analysis of the volatile oil samples was carried out using gas chromatography instrument. DsChrom 6200 Gas Chromatograph equipped with a flame ionization detector, Column: BPX-5, 5% phenyl (equiv.) polysillphenylene-siloxane 30m × 0.25mm ID x 0.25µm film., Sample size: 1ìl, Temperature program

ramp increases with a rate of 10ºC / min from 70º to 200ºC, Detector temperature (FID): 280°C, Carrier gas: nitrogen, Flow rate: N2 30 ml/min; H2 30 ml/min; air 300 ml/min. Main compounds of the volatile oils were identified by matching their retention times with those of the authentic samples injected under the same conditions. The relative percentage of each compound was calculated from the area of the peak corresponding to each compound.

The isolation of essential oils and gas chromatographic analysis were carried out at the Medicinal and Aromatic Plants Res. Dept. Laboratory, Hort. Res. Ins., ARC.

Statistical analysis

Data collected were analyzed using analysis of variance (ANOVA) using MSTAT-C software. Differences among treatments means were performed by Duncan' s multiple range test (Snedecor and Cochran, 1989).

Results

Data in Table (2) indicate that geranium plants had significant lower basal stem rot levels due to the different garlic treatments tested compared with untreated control. Geranium plants intercropped with garlic showed the highest effect on reducing disease incidence, which caused 80.0 % in the 1st growing season and 87.6% reduction in the 2nd growing season. The efficacy was similar the efficiency of the fungicide treatment (Rizolex-T), which caused 86.8 and 93.6% reduction in basal stem rot incidence during the two growing seasons, respectively. However, soil amended with garlic and sprayed with garlic extract resulted in moderate reduction to the diseased plants, *i.e.,* 73.2 % in the 1st growing season and 81.3% in the 2nd growing season followed by the treatment of soil amended with garlic only with no significant difference between them. The least effective treatment was cuttings treatment, soaking in garlic extract + foliar spray which recorded 46.8 and 56.2% reduction in disease incidence in the two growing seasons, respectively.

Results in Tables (3 and 4) demonstrate that all garlic treatments significantly reduced the incidence and severity of root rot of geranium plants compared to untreated control. In the 1st growing season, the highest effective treatment for reducing incidence and severity of root rot was the treatment of the fungicide Rizolex-T + the herbicide Roundup star followed by intercropping of garlic with geranium, being 76.0 and 65.6% disease incidence and 90.3 and 83.6 % disease severity. Moderate reduction in geranium root rot was observed when geranium sown in soil amended with garlic then sprayed the geranium leaves with garlic extract. This action was followed by amendment the soil with garlic only without significant differences. The corresponding mean values of reduction in disease incidence were 45.0 and 39.1 % and those of disease severity were 60.2 and 52.8 %, respectively. Meanwhile, treatment of geranium cuttings and spraying the leaves

with garlic extract gave the lowest reduction in this concern, being 12.8 and 22.7 %, respectively. The same trend was observed in the 2nd growing season.

Table (2): Effect of different garlic treatments on incidence of geranium basal stem rot during the two growing seasons (2016 and 2017).

Treatments	1st season		2nd season	
	Disease incidence %	Reduction* %	Disease incidence %	Reduction* %
Cuttings treatment + foliar spray	13.3 b	46.8	11.7 b	56.2
Intercropping	5.0 de	80.0	3.3 de	87.6
Soil amended with garlic	8.3 c	66.8	6.7 c	74.9
Soil amended with garlic + foliar spray	6.7 cd	73.2	5.0 cd	81.3
Rizolex-T + Roundup star	3.3 e	86.8	1.7 e	93.6
Control	25.0 a	---	26.7 a	---

* Reduction % related to the control.
Means designed by the same letter at each cell are not significantly different at the 5% level according to Duncan's multiple range test.

Table (3): Effect of different garlic treatments on incidence of geranium root rot during the two growing seasons (2016 and 2017).

Treatments	1st season		2nd season	
	Disease incidence %	Reduction* %	Disease incidence %	Reduction* %
Cuttings treatment + foliar spray	31.2b	12.8	28.3b	26.7
Intercropping	12.3de	65.6	8.6 de	77.7
Soil amended with garlic	21.8c	39.1	17.9c	53.6
Soil amended with garlic + foliar spray	19.7c	45.0	14.0c	63.7
Rizolex-T + Roundup star	8.6e	76.0	6.8e	86.4
Control	35.8a	---	38.6a	---

* Reduction % related to the control.
Means designed by the same letter at each cell are not significantly different at the 5% level according to Duncan's multiple range test.

Table (4): Effect of different garlic treatments on disease severity of geranium root rot during the two growing seasons (2016 and 2017).

Treatments	1st season		2nd season	
	Disease severity %	Reduction* %	Disease severity %	Reduction* %
Cuttings treatment + foliar spray	20.8b	22.7	16.5b	42.9
Intercropping	4.4 de	83.6	3.0de	89.6
Soil amended with garlic	12.7c	52.8	9.3c	67.8
Soil amended with garlic + foliar spray	10.7c	60.2	7.5c	74.0
Rizolex-T + Roundup star	2.6e	90.3	2.1e	92.7
Control	26.9a	---	28.9a	---

* Reduction % related to the control.

Means designed by the same letter at each cell are not significantly different at the 5% level according to Duncan's multiple range test.

The broomrape spikes count, and weight/plot were significantly reduced due to garlic treatments tested than the untreated control (Table, 5). Among garlic treatments, intercropping of garlic with geranium plants significantly showed very remarkable reduction in spikes count and weight of broomrape by 30.3 and 40.5 %, respectively in the 1st growing season and generally the fungicide Rizolex-T + the herbicide Roundup star treatment was the most efficient in this regard, which significantly reduced the broomrape spikes count by 41.2 % and the weight by 57.1%. Moderate reductions were found in plots received garlic as soil amendment + spraying geranium plants with garlic extract followed by treatment of soil amendment with garlic only without significant difference. The corresponding mean values of reduction in spikes count were 17.3, 15.9% and weight, being 30.2, 28.6, respectively. Treating geranium cuttings and spraying the leaves with garlic extract was the lowest efficient treatment in controlling broomrape, which statistically was not differed than the control treatment. The same trend was observed in the 2nd growing season.

Table (5): Effect of different garlic treatments on some broomrape parameters during the two growing seasons (2016 and 2017).

Treatments	1st season				2nd season			
	Spikes number /plot	Reduction* %	Weight (kg/plot)	Reduction* %	Spikes number /plot	Reduction* %	Weight (kg/plot)	Reduction* %
Cuttings treatment + foliar spray	1064b	4.3	11.7a	7.1	1045b	23.8	10.8b	23.4
Intercropping	775d	30.3	7.5c	40.5	579d	57.8	6.7d	52.5
Soil amended with garlic	935c	15.9	9.0b	28.6	857c	37.5	8.4c	40.4
soil amended with garlic + foliar spray	920c	17.3	8.8bc	30.2	844c	38.5	7.8cd	44.7
Rizolex-T + Roundup star	654e	41.2	5.4d	57.1	508e	63.0	4.2e	70.2
Control	1112a	---	12.6a	---	1372a	---	14.1a	---

* Reduction % related to the control.
Means designed by the same letter at each cell are not significantly different at the 5% level according to Duncan's multiple range test.

Effect of different garlic treatments on plant growth and yield parameters

Results presented in Table (6) indicate that the different garlic treatments tested significantly increased geranium plant height (cm) and number of branches/plant compared to the untreated control. In the 1st growing season, the highest geranium plants and maximum number of branches per plant were recorded by fungicide and herbicide treatment followed by intercropping of garlic with geranium plants, without significant differences. The corresponding mean values for plant height were 98.00, 72.67 cm for the first cut & 94.00, 71.67 cm for the second cut and No. of branches, being 20.00, 25.00 & 17.00, 21.33 for the two plant cuts, respectively. While, treated geranium cuttings and spraying the leaves with garlic extract gave the least plant height, being 82.00, 56.67 cm and No. of branches per plant, being 13.67 and 17.33, respectively for the two plant cuts. The same trend was observed in the second growing season.

Table (6): Effect of different garlic treatments on plant height (cm) and number of branches/plant for geranium during the two growing seasons (2016 and 2017).

Treatments	Plant height (cm)		Number of branches/plant	
	1st cut	2nd cut	1st cut	2nd cut
1st season				
Cutting treatment + foliar spray	82.00c	56.67d	13.67bc	17.33d
Intercropping	94.00ab	71.67ab	17.00ab	21.33b
Soil amended with garlic	87.67bc	62.33c	14.67bc	18.67c
Soil amended with garlic + foliar spray	87.67bc	66.67bc	16.00b	20.33b
Rizolex-T + Roundup star	98.00a	72.67a	20.00a	25.00a
Control	74.00d	53.00d	11.33c	15.00e
2nd season				
Cutting treatment + foliar spray	70.67d	60.67c	12.33d	15.00cd
Intercropping	78.00ab	72.67a	17.33a	19.67ab
Soil amended with garlic	73.33cd	65.33b	13.33c	16.33bc
Soil amended with garlic + foliar spray	74.67bc	71.67a	15.33b	16.67bc
Rizolex-T + Roundup star	80.67a	74.00a	18.00a	20.67a
Control	64.00e	50.00d	10.33e	12.33d

Means designed by the same letter at each cell are not significantly different at the 5% level according to Duncan's multiple range test.

It is obvious from data illustrated in Table (7) that all tested treatments of garlic showed an increase in the fresh weight of herb/plant. In the first growing season, the highest fresh weight values were obtained with the fungicide and herbicide treatment followed by intercropping of garlic with geranium plants with significant difference between both. The corresponding mean values of herb fresh weight per plant were 920.0, 890.0 g whereas, they were 18.40 and17.80 ton per fed., respectively in the first cut. Meanwhile, these figures were 760.0, 726.7 g/plant and 15.20, 14.53 ton/fed., respectively in the second plant cut. Moderate mean values of fresh weight of the herb for the two cuts were obtained due to soil amendment with garlic and spraying geranium plants with garlic extract followed by soil amendment with garlic only treatment. Moreover, treated geranium cuttings and spraying the leaves with garlic extract gave the lowest mean values of herb fresh weight (780.0, 620.0 g/plant and 15.60, 12.40 ton/fed., respectively for the two plant cuts). The same trend was also true for the second growing season.

Table (7): Effect of different garlic treatments on geranium fresh weight during the two growing seasons (2016 and 2017).

Treatments	Herb fresh weight (g/plant)		Herb fresh weight (ton/fed.)	
	1st cut	2nd cut	1st cut	2nd cut
1st season				
Cutting treatment + foliar spray	780.0e	620.0e	15.60e	12.40e
Intercropping	890.0b	726.7b	17.80b	14.53b
Soil amended with garlic	830.0d	670.0d	16.60d	13.40d
Soil amended with garlic + foliar spray	863.3c	693.3c	17.27c	13.87c
Rizolex-T + Roundup star	920.0a	760.0a	18.40a	15.20a
Control	708.3f	506.7f	14.17f	10.13f
2nd season				
Cutting treatment + foliar spray	670.0d	520.0d	13.40d	10.40d
Intercropping	766.7b	620.0b	15.33b	12.40b
Soil amended with garlic	710.0c	543.3d	14.20c	10.87d
Soil amended with garlic + foliar spray	730.0c	583.3c	14.60c	11.67c
Rizolex-T + Roundup star	790.0a	656.7a	15.80a	13.13a
Control	620.0e	463.3e	12.40e	9.27e

Means designed by the same letter at each cell are not significantly different at the 5% level according to Duncan's multiple range test.

Regarding to oil percentage and oil yield of geranium, the tested garlic treatments resulted in a significant increment in oil % and oil yield (kg/fed.) in both seasons as shown in Table (8). In the first growing season, intercropping of garlic with geranium plants treatment gave the highest mean values of oil % (0.19& 0.18 %) and oil yield (33.83&26.20 kg/fed., respectively for the two plant cuts followed by soil amendment with garlic and spraying geranium plants with garlic extract treatment without significant differences between them, being 0.19 & 0.18 % oil percentage and 32.10&24.47 kg/fed. oil yield, respectively for the two plant cuts. Whereas treated geranium cutting and spraying the plants with garlic extract gave the lowest mean values of oil percent (0.15 & 0.17 %) and oil yield (26.47 & 21.43 kg/fed.), respectively for the two plant cuts. The same trend was observed in the second growing season.

Table (8): Effect of different garlic treatments on oil percentage and oil yield of geranium during the two growing seasons (2016 and 2017).

Treatments	Oil %		Oil yield (kg/fed.)	
	1st cut	2nd cut	1st cut	2nd cut
1st season				
Cutting treatment + foliar spray	0.15c	0.17a	26.47bc	21.43c
Intercropping	0.19a	0.18a	33.83a	26.20a
Soil amended with garlic	0.18ab	0.18a	28.07ab	24.47ab
Soil amended with garlic + foliar spray	0.19a	0.18a	32.10ab	24.60ab
Rizolex-T + Roundup star	0.16bc	0.15b	29.47ab	22.80bc
Control	0.15c	0.14b	21.77c	14.50d
2nd season				
Cutting treatment + foliar spray	0.15ab	0.12ab	20.57ab	14.07b
Intercropping	0.17a	0.14a	26.10a	17.73a
Soil amended with garlic	0.16ab	0.13a	23.40a	14.23b
Soil amended with garlic + foliar spray	0.17a	0.14a	24.60a	14.50ab
Rizolex-T + Roundup star	0.14ab	0.12ab	22.70a	15.80ab
Control	0.13b	0.10b	16.13b	8.97c

Means designed by the same letter at each cell are not significantly different at the 5% level according to Duncan's multiple range test.

Chlorophyll content:

Results illustrated in Table (9) exhibit that all the tested garlic treatments exerted significant effects on the chlorophyll content of geranium plants. The highest chlorophyll A values (16.20, 15.40 mg g^{-1}), chlorophyll B (12.00, 15.40 mg g^{-1}) and carotenoids content (5.47, 4.27 mg g^{-1}) were recorded in the treatment of the fungicide + the herbicide followed by treatment of intercropping of garlic with geranium plants without significant difference between both. The corresponding mean values of chlorophyll A were 15.87 & 14.80 mg g^{-1}, chlorophyll B, 11.67 & 11.60 mg g^{-1}. Meanwhile, contents of carotenoids were 5.13 & 3.87 mg g^{-1}, respectively for the two plant cuts. Treated geranium cuttings and spraying the plants by garlic extract gave the lowest impact on leaf chlorophyll content with an average of 14.77 & 14.00 mg g^{-1}, 10.33 & 9.90 mg g^{-1} for chlorophyll A and B and 4.40 & 2.80 mg g^{-1} leaf fresh weight for carotenoids content, respectively for the two plant cuts. The same trend was also true for the second growing season.

Table (9): Effect of different garlic treatments on chlorophyll content and carotenoids in geranium leaves during the two growing seasons (2016 and 2017).

Treatments	Chlorophyll A (mg g^{-1})		Chlorophyll B (mg g^{-1})		Carotenoids (mg g^{-1})	
	1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut
1st season						
Cutting treatment + foliar spray	14.77de	14.00de	10.33c	9.90c	4.40c	2.80de
Intercropping	15.87ab	14.80b	11.67ab	11.60a	5.13ab	3.87ab
Soil amended with garlic	15.60bc	14.53bc	11.47b	10.80b	4.93abc	3.43bc
Soil amended with garlic + foliar spray	15.27cd	14.20cd	11.13b	10.60b	4.67bc	3.20cd
Rizolex-T + Roundup star	16.20 a	15.40a	12.00a	11.53a	5.47a	4.27a
Control	14.47e	13.53e	9.93c	9.53c	3.60d	2.43e
2nd season						
Cutting treatment + foliar spray	14.00bc	13.80d	9.67d	9.53c	3.93d	3.37cd
Intercropping	15.17a	14.57ab	10.77ab	10.47a	4.73ab	4.53a
Soil amended with garlic	14.43b	14.27bc	10.33bc	10.17ab	4.60bc	4.00b
Soil amended with garlic + foliar spray	14.37b	13.97cd	10.00cd	10.00b	4.40c	3.63bc
Rizolex-T + Roundup star	15.40a	14.93a	11.20a	10.50a	4.93a	4.67a
Control	13.37c	13.00e	8.57e	9.33c	3.33e	2.97d

Means designed by the same letter at each cell are not significantly different at the 5% level according to Duncan's multiple range test.

Essential oils constituent:

Quality of essential oil depends on the relative composition of different ingredients. Data in Table (10) indicate that the content of principle ingredients was influenced by different garlic treatments, which increased the main chemical compositions of the essential oil compared to the untreated control.

Gas chromatographic analysis of the volatile oil compounds from geranium essential oil herb, revealed the existence of 14 compounds from the identified compounds. The main components in geranium herb oil samples studied were citronellol (27.58-

36.93%), geraniol (17.14-23.79%), sesquiterpenols (5.01-12.46 %), limonene (2.21-7.58 %) and linalool (1.58-7.64 %). A comparison between composition of geranium oil shows that plants which intercropped with garlic gave the highest content of citronellol (36.93 & 31.99%) and geraniol (23.79 & 23.52 %), respectively for the two plant cuts followed by treatment of garlic-amended soil and spraying geranium plants by garlic extract as it gave 34.34 & 22.53%, respectively in the first plant cut and 31.62 & 22.14 %, respectively in the second plant cut. The maximum values of sesquiterpenols (9.00 & 12.46 %), limonene (7.57 & 6.78 %) and linalool (7.64 & 7.01 %) were obtained as a result of treatment of garlic-amended soil and spraying geranium plants by garlic extract, respectively for the two plant cuts.

Table (10): GC analysis for volatile oils obtained from the 1st and 2nd cuts in the 1st season (2016).

Compounds	Treatments											
	Cutting treatment + foliar spray		Intercropping		Soil amended with garlic		Soil amended with garlic + foliar spray		Rizolex-T + Roundup star		Control	
	1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut
α-pinene	2.36	2.29	2.34	1.63	3.28	0.86	1.01	1.70	1.48	4.68	2.11	1.38
P-Cymene	1.24	4.54	3.53	2.99	3.74	1.63	4.66	4.66	3.37	1.28	2.34	3.59
Limonene	2.98	3.36	6.11	5.86	3.26	2.97	7.58	6.31	5.40	5.05	2.21	2.24
Linalool	6.30	3.95	7.57	6.78	1.58	3.46	7.64	7.01	4.67	3.03	2.21	2.37
α-terpineol	0.68	0.74	4.13	6.85	7.54	6.97	0.78	5.95	6.64	5.03	7.37	7.43
Citronellol	30.65	29.53	36.93	31.99	33.98	31.10	34.34	31.62	33.74	27.58	30.34	28.59
Geraniol	20.15	18.00	23.79	23.52	21.67	21.65	22.53	22.14	21.98	18.77	18.19	17.14
Geranial	1.48	2.94	3.79	2.48	4.64	3.40	1.25	3.09	4.06	2.79	2.32	2.57
Eugenol	1.83	1.98	1.76	1.37	1.19	1.60	2.56	3.54	2.79	1.63	2.05	1.70
β-caryophyllene	2.17	2.31	2.79	1.02	2.71	3.01	1.82	1.83	2.40	3.43	2.74	2.01
Citronellylformate	2.84	1.93	1.98	2.87	2.53	2.58	1.05	2.68	2.65	4.24	1.88	2.04
Geranylformate	2.26	2.07	2.80	3.71	2.61	1.84	2.39	2.10	3.21	2.65	2.22	3.72
Sesquiterpenols	7.66	8.97	8.81	12.18	7.99	7.32	9.00	12.46	8.37	9.42	5.01	8.38
Rose oxide	1.38	1.43	2.37	1.91	1.84	4.91	2.42	3.31	2.95	2.35	1.31	2.89
Unknown	4.37	3.48	3.66	4.93	4.23	4.61	3.90	4.15	5.20	5.81	5.42	5.05
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Discussion

Many researchers have been carried out experiments to find alternative to fungicides and safe methods to control plant diseases. Thus, natural plant products are important sources of new agro-chemicals for the control of plant diseases. It is known that various natural plant products can reduce populations of soil borne pathogens and control disease development. These plant products have potentials as

environmentally safe alternatives and as components in integrated pest management programs (Slusarenko *et al.*, 2008). Our study demonstrated that all the tested garlic treatments significantly caused different degrees of reducing basal stem rot and root rot of geranium compared to the control. These results are in accordance with those obtained by several investigators (Haggag and Abdel-Latif, 2001; Prasad *et al.*, 2010; Mohamed *et al.*, 2012 and Adolf, 2016). Intercropping garlic with geranium plants showed the highest efficacy in this concern. This result is in line with the reports of Shahiduzzaman (2015) and Yasmin (2016). The active component was identified as allicin, a diallylthiosulfinate (2-propenyl-2-propenethiol sulfonate) (Rahman *et al.*, 2006). Two hypotheses explain the mechanisms responsible for the suppression of soil borne pathogens by garlic cultivation have been proposed. The first hypothesis implicates the involvement of antimicrobial compounds released from roots of garlic plants (Zhang *et al.*, 2013). It is well known that the antifungal properties of Alliaceous plants are due to the sulfur content and other phenolic compounds (Rivlin, 2001). The second hypothesis, based on the known importance of the soil microbiome in the suppression of soil-borne diseases (Rosenzweig *et al.*, 2012 and Shen *et al.*, 2015), implicates microorganisms associated with garlic plants in the suppression of soil borne diseases. Intercropping with garlic plants (*A. sativum*), changes the bacterial diversity and structure of the soil (Zhou *et al.*, 2011 and Ahmad *et al.*, 2013). Rhizosphere microbial communities are directly influenced by the root exudates of host plants and differ across plant species (Gardner *et al.*, 2011 and Li *et al.*, 2014). Therefore, they hypothesized that rhizospheres of Alliaceous plants harbor unique microbial communities and that some of the predominant microorganisms are involved in the suppression of soil borne diseases induced by garlic cultivation.

The present study demonstrated that intercropping garlic with geranium significantly reduced broomrape to extend level compared to the untreated control. This result is in line with the reports of Acharya (2013). Abu-Shall and Ragheb (2014) reported a reduction in *O.crenata* emerged spikes amounting to 42% when the cultivar Aquadulce was intercropped with garlic. The possible role of non-host test crops in reducing *Orobanche* seed viability could be that i) crops exude stimulant(s) for suicidal seed germination (Sauerborn, 1991) and ii) crops exude chemicals, which in association with suitable microorganisms acquire stimulatory nature for broomrape seed germination (Wegmann *et al.*, 1991).

Meanwhile, the present study demonstrated that intercropping garlic with geranium significantly increased the vegetative growth of geranium plants. This result is in agreement with that reported by Noghani *et al.* (2013). Cheng *et al.* (2016) reported that diallyl disulfide (DADS) is a volatile organosulfur compound derived from garlic (*A. sativum* L.), which is responsible for promotion root growth of tomato plants through increased the cell length of root meristem and enhanced the mitotic activity of meristematic cells in seedling root tips as indicated from cytological observations and thus increased the cell numbers in the meristem and

enlarged the length of the meristematic zone in the root. Also they observed that the content of gibberellic acid and indole-3-acetic acid in tomato roots increased as the diallyl disulfide (DADS) concentration increased which may be caused by promotion of the expression of IAA biosynthesis genes FZYs (Expósito-Ródriguez*et al.*, 2007, 2011).Exogenous auxins are thought to induce rapid elongation in plant tissues by increasing the mechanical extensibility of the cell wall (Cosgrove, 1993; Karcz *et al.*, 1999; Martínez *et al.*, 2011 and Polak *et al.*, 2011). Gibberellins (GAs) play indispensable roles in seed germination, normal root development and keeping roots long and slender (Thomas *et al.*, 2005).

Conclusion

It was observed from this study that using garlic as intercropping with geranium or soil amendment and spraying the plants by its extract effectively controlled the basal stem and root rot as well as decreased the broomrape number, weight and enhanced the growth, oil and chemical composition of geranium plant.

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تأثير معاملات الثوم المختلفة على مكافحة أمراض عفن قاعدة الساق وعفن الجذور والاصابة بالهالوك فى نباتات العتر

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اجريت التجربة فى المزرعة البحثية بمحطة بحوث البساتين بسدس - مركز البحوث الزراعية - محافظة بنى سويف خلال موسمي ٢٠١٦ و ٢٠١٧ تحت ظروف العدوى الطبيعية فى الحقل لدراسة تأثير فعالية معاملات مختلفة من الثوم على الاصابة بعفن قاعدة الساق وأعفان الجذور والهالوك وكذلك تاثيرها على انتاجية العتر، وقد لوحظ أن تحميل الثوم مع العتر أو اضافته للتربة مع رش نباتات العتر بمستخلص الثوم كان أكثر المعاملات فعالية فى مقاومة عفن قاعدة الساق وأعفان الجذور وكذلك أدى الى تقليل الاصابة بالهالوك بالاضافة الى زيادة نمو نباتات العتر ومحصول الزيت والتركيب الكيميائى للزيت الناتج.