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Soil Solarization with Different Polyethelene Layers Amended with Animal Manure Effects on Soil Nutrients, Fungi, Weed and Yield of Cabbage (Brassica Oleracea)

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Abstract:- **This study was carried out in the Agricultural Research Station of King Abdulazia University at Hada Al-Sham, northeast of Jeddah Saudi Arabia, for studying of the effects of Solarization of the soil with polyethylene sheets (1-layer and 2-layers) amended with animal manure (AM) as organic matter at rate of 30 t/ha on the nitrogen (N), phosphorus (P) and potassium (K) content of the soil, and on soil pH and electric conductivity (EC) and number of fungi and weed growth before and after Solarization. Also the effects were determined on cabbage (Brassica oleracea) growth components and cabbage yield during two seasons (2015-2016). The results showed significant increase in soil N, P and K pre and post-solarization. Soil content of N, P and K increased significantly particularly under 2-layer sheets. There was significant decrease in soil fungi population and weed growth after Solarization. Fungi population was significantly reduced with soil covering with 2-layer sheets, and with depth from 0-15 to 15-30 cm compared to 1-laer sheet and uncovered soil. Cabbage growth components and yield were significantly increased with soil Solarization amended with 30 t/ha AM. Cabbage head length, roundness index and stem diameter were significantly increased with Solarization and AM amendment with domination of the 2-laer polyethylene sheets. Cabbage yield increased at a rate of 90% at 2-layer sheets solarisation compared to the uncovered soil. It is recommended to cover soil with polyethylene sheets one or two sheets amended with 30t/ha AM for better yield of cabbage plants and control of weed and soil fungi.**

Key words: Soil Solarization , Animal Manure, Soil Nutrients, Fungi, Weed, Cabbage plant

INTRODUCTION

Soil Solarization is an environmentally friendly method of using of the sun energy to kill pests in the soil like fungi and weeds. Air and soil temperatures of soil covered with polyethylene sheets was compared with air and soil temperatures of uncovered soil for 30 days, and the solarized soil reached much higher temperature up to 180 °F than the nonsolarized soil with only 120 °F (Masabni and Franco, 2012). Soil was covered with polyethylene sheets for 5 weeks and after 4 weeks of removal of the sheets 90 germinated seeds were found in the nonsolarized plots and none in the solarized plots (Stapleton et al. 2000). Covering the soil with polyethylene sheets controlled soil borne plant pests and weeds, promoted early maturation of crops and increased crop yield (Ahmad et al. 1996; Al-Solaimani and Sunboul, 2000; Sarker et al. 2004). AS a result of soil solarization the maximum temperature of the soil ranges between 42 and 55°C at depth of 5 cm and from 32 t0 37°C at depth of 45cm, and control of soil pests is usually best at the upper 10-30 cm depth of soil (Elmore et al. 1997). Elmore et al. (1997) also reported that repeated daily heating during solarization kills many plant pathogens , nematodes and weed seeds and seedlings. In a study carried out by (Khan et al. 2003) they found that soil solarization successfully controlled weed growth and killed weed seeds before germination, and soil borne pathogens, and increased rice. Covering the soil with transparent polyethylene sheets for 30 days improved the soil structure and enhanced availability of nitrogen and other essential plant nutrients and biological control of soil borne pathogens such as, root knot nematodes, Fusarium sp. etc. The soil solarization technique practiced by (Sunbul and Al-Solaimani, 2004) after covering the soil with polyethylene sheets for 2 weeks resulted in eradication of the fungi Pythium and Fusarium , and after 4 weeks their number decreased even more to reach 50 and 38% at depth of 10 and 20 cm respectively. On the other hand the addition of organic matter to solarized soil made significant increase in soil pH value and macro-elements such as N, P and K contents (Tang et al. 2005). Also application of organic manure to soil allows plant nutrients to be more available to plants, improving soil physical conditions, decrease soil microbes and leads to better growth and yield of crops (Stapleton et al. 1985). The addition of organic matter to solarized soil increased the availability of nutrient to plants and gave good rice yield (Ozores-Hampton, et al. 2005). Growth of Meloidogyn sp., Tylenchorhynchus sp. and Trichodorus sp. was reduced by 66.6% - 100%, 50% - 80% and 83.5% - 87.5%, respectively under soil solarization (Zaid et al., 2005). The growth of the weed (Amarunthus retroflexus L.) was reduced to less than 10% within 2 weeks under soil covering with clear plastic sheets (Ozores-Hampton et al., 2005). Potato yield increased after soil solarization for 65 days due to improvement of water use efficiency in the semi-arid region of China (Zhao et al., 2012). Legumes grain yield faba bean (Vicia faba) and

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chickpea (Cicer arietinum) increased by 300-900% due to N availability as a result of soil solarization but soil pH did not affected with solarization (Mauromicale, et al. 2005).
This study was conducted to test the effect of soil solarization with transparent polyethylene sheets amended with organic manure on soil temperature, soil pH, soil EC, weed growth, nutrient availability and yield of cabbage (Brassica oleracea).

Materials and Methods

This experiment was carried out in the Agricultural Research Station of King AbdulAziz University at Hada Al-Sham northeast Jeddah city, Saudi Arabia during two seasons 2015-2016 and 2016-2017.

Experimental Design:

Complete split randomized design with three replications , was applied with the polyethylene sheets representing the main-plots , and the animal manure (AM 0 and 30t/ha) the sub-plots.

Preparation of the experimental site:

The soil was ploughed twice at a depth of 30cm , leveled and then divided into 12 plots each(3x3m), 4 plots for each replicate, each 2 plots for one sheet with 0 and 30 ton/ha AM and 2 for the two sheets with 0 and 30 tons/ha. Each covered and uncovered treatment contained 2 treatments of AM rates (0, and 30 t/ha) AM. Each plot was divided into 3 rows, 70cm between rows and 60cm between plants. The plots were fertilized using 217 kg/ha P, 150 kg/ha K2O and 435 kg/ha urea at three rates, and drip irrigation was used. Before covering the plots were watered deeply, and after covering the the plastic edges were buried in the soil to trap the heat.

Soil analysis:

The experimental site soil was analyzed before and after soil covering at both depths, 0 – 15 and 15 - 30cm ,for its electric conductivity (EC), pH value with use of pH meter, the organic matter was determined using Walkeley and Black method as mentioned by Jackson(1973), total nitrogen(N) was analyzed using Kjeletec Auto1030, total phosphorus(P) and potassium(K) were determined using Shelton and Harper(1965) method. Also the number of soil fungi was determined using the successive dilution method described by Dhingra and Sinclair(1985). These parameters were also analyzed in the irrigation water and in the added AM

Temperature degrees during soil solarizatio:

Results in figure (1) show that the maximum air temperature during solarization 15/8 - 15/10/20015 reached 45.5ºC, and soil maximum temperature reached 60, 55 and 44ºC at depth of 5 cm for the two polyethylene sheet, one polyethylene sheet and without cover respectively. Maximum soil temperature under 2- sheet polyethylene increased by 11% thn that under 1-sheet polyethylene, and by 16% than the uncovered soil in the soil surface. Temperature decreases with increase in depth.

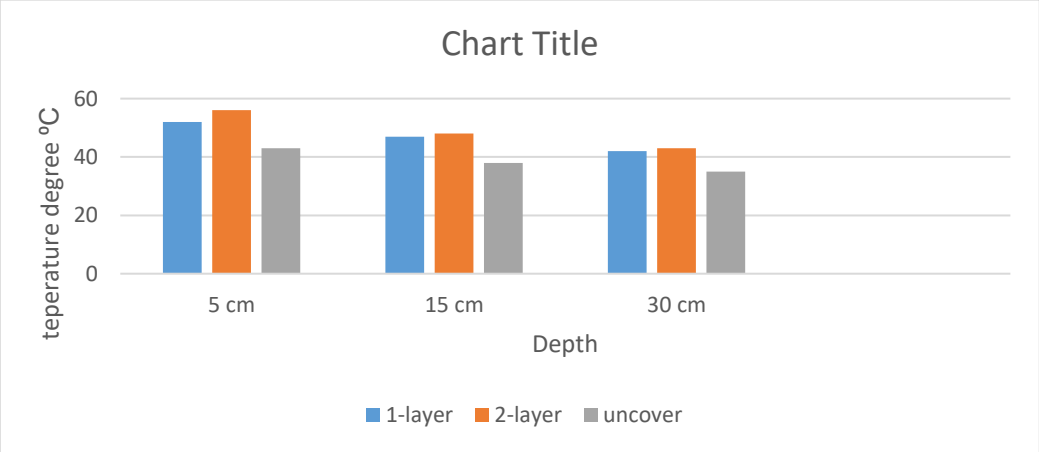

Figure (1): maximum soil temperatures under solarization at different depths

Cabbage planting :

Cabbage seedlings were prepared in the nursery , and were acclimatized for one month before being planted in the site.

Sample collection:

Five plants were selected randomly from each plot after maturation, to take the different measurements (head characters, stem characters, root length, leaf area index, and total yield).
The whole plant weight was measured for the five samples (Fig. 18) and Figure (19). Each sample of the five samples of each plant was separated separately into head, leg, leaves and roots. The measurements were then taken moist for different plant parts (heads, leaves, stalks and roots)). The length and thickness of the head, the diameter of the rotational factor, the length of the inner leg (inside the head), the outer stem and the length of the root were measured (20) and the five plant samples and their different parts (leaves of the root roots) were dried. It also estimated its dry weight. The leaves, stems and roots were dried in a 75 ° C oven for 72 hours. The heads were dried in the oven 75 ° C for 5 days.

Total yield:

All the remaining plants in the plots were collected, and the total yield was determined in kg/ha for each treatment during both seasons.

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Weed growth:

Weed growing in each replicate was collected three times by hand during cabbage growth and its weight determined. Soil temperature degrees were recorded in the uncovered and covered soil at 5,15 and 30 cm depth Fig. 3).

Statistical analysis:

The statistical analysis of the data was carried out according to the type of the design (ANOVA) according to Little and Hills,1977, running the analysis of variance, and comparison of means using LSD 0.05, and combined analysis was carried out for the two seasons using SAS2000.

Results

Characteristics of the soil and fungi population before and after

soil solarization and addition of animal manure:

Before soil solarization:

Soil plant nutrients N, P and K, and number of fungi significantly increased with addition of animal manure up to 30 t/ha compared to control, but animal manure and depth have no effect on soil EC and pH. On the other hand, soil N, P and K, and fungi population decreased with increase in depth from 0-15 to 15-30 cm (table 1).

After soil solarization:

The results showed that there was a significant increase in the soil content of nitrogen, potassium and phosphorus, and the decrease in the number of fungi in the solarized soil, whether it was covered with one layer or two layers compared to the uncovered soil with a greater effect when covering with transparent polyethylene with two layers rather than with one layer(Table 2). And figure (1) shows that temperature degree under the 2-layer sheets was higher than that under one layer, then comes the uncovered soil, so that is why fungi numbers were significantly lower under 2-layers transparent polyethylene sheets compared to 1-layer sheets and uncovered soil. Also the results indicated that addition of animal manure to the soil significantly increased nutrients N, P, K, and soil EC with reduction in fungi number and soil pH. Also it was observed that fungi number, P content and soil EC were lower in soil depth 15-30 cm compared to soil depth 0-15 cm. , while soil N and K content and soil pH were not affected with soil depth.

Table (1): soil analysis before solarization

Characters	t/ha	pH	EC dis/m	N %	P %	K (mg/kg)	Fungi/gm dry soil
Animal manure (t/ha)	0	7.8 a	2.262 a	0.104 b	0.018 b	56.888 b	46631.1 b
	30	7.7 a	2.558 a	0.144 a	0.030 a	86.667 a	67333.3 a
Soil depth (cm)	0-15	7.8 a	2.854 a	0.128 a	0.024 a	70.889 a	66853.3 a
	15-30 cm	7.7 a	1.966 a	0.120 a	0.023 a	72.667 a	47111.1 a

Table (2): soil analysis after solarization

Treatment		pH	EC dis/m	N %	P %	K (mg/kg)	Fungi/gm dry soil
solarization	uncover	7.8 a	2.63 a	0.126 a	0.020 b	60.00 b	17387.0 a
	1-layer	7.8 a	3.14 a	0.151 ab	0.025 ab	70.00 b	10331.8 b
	2-layers	7.8 a	2.05 a	0.16 a	0.035 a	83.60 a	2023.8 c
Animal manure	0 t/ha	8.6 a	1.81 b	0.111 b	0.020 b	56.26 b	14537..7 a
	30 t/ha	7.0 b	3.40 a	0.181 a	0.033 a	86.13 a	5290.6 b
Soil depth	0-15 cm	7.8 a	3.16 a	0.150 a	0.031 a	69.73 a	13856.8 a
	15-30 cm	7.8 a	2.05 b	0.147 a	0.022 b	73.02 a	5971.5 b

Weed Growth:

Weed growth (Fresh weight) was significantly reduced by soil solarization, with a domination of the 2 layers giving a reduction of 61.5% over the one layer with 39.8% compared to the uncovered soil (Table 3). Weed fresh weight was also significantly reduced when the solarized soil was amended with 30 t/ha AM, reaching a reduction of up to 49.6% compared to the soil without AM (control). High weed growth occurred during the second season than the first season.

Table 3. Effect of solarization and animal manure (AM) addition on weed fresh weight during two seasons (2015-2016/2016-2017)

Treatment	**weed fresh weight (kg/9m)**
seasons	
2015-2016	**0.54b**
2016-2017	**3.41 a**
Solarization with polyethylene sheets	
uncover	**2.9 a**
1-layer	**1.88 ab**
2-layers	**1.15 b**
Animal manure (t/ha)	
0	**2.58 a**
30	**1.36**

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Growth rate of the cabbage crop

Fresh and dry weight

The results showed a significant increase in wet and dry weight of the cabbage plant and its parts under use of soil solarization transparent polyethylene sheets, whether one layer or two layers compared to the uncovered soil with the domination of the two layers to the one layer polyethylene sheets as regards fresh weight of heads, leaves, stems and the whole plant, and the dry weight of head, leaves, roots and whole plant (Table 4). The head fresh weight increased by 101.8 and 52.1% in the soils covered with two layers and one layer, respectively. The total fresh weight of the whole plant increased by 99.1 and 48.2% in the two-layer and one-layer soils, respectively. Dry weight increased by 52 and 101.7%, respectively.

The results also showed the effect of adding animal manure on the fresh and dry weight of cabbage plant and its various parts, these parameters increased significantly by addition of 30 ton / ha compared with the treatment without animal manure (zero ton / ha). The fresh weight of the cabbage plant and its different parts was not significantly affected by the season (Table 4).

Figure (26) shows the effect of the interaction between solarization of the soil and the addition of animal manure on the dry weight of whole plant. Soil solarization using either one layer or two layers was better than the non-covered soil, and addition of 30 tons / ha of animal manure was better than 0 ton/ha for dry weight of cabbage whole plant.

Table (4): Means of Fresh and dry weight of cabbage plants (heads, leaves, stems, roots) under different layers of polyethylene and different rates of animal manure during two seasons (2015-2016/2016-2017)

Treatment	Fresh weight (gm/5plants)					Dry weight (gm/5 plants)				
	Head	Leaves	stem	root	Whole plant	Head	Leaves	stem	root	Whole plant
seasons										
2015-2016	11416.7a	7781.6a	1067.56a	472.49a	20870a	1141.6a	573.47a	127.01a	573.47a	2415.6a
2016-2017	11723.8a	7820.7a	1067.35a	490.31a	20529a	1172.4a	564.99a	124.28a	564.99a	2426.7a
Solarization with polyethylene sheets										
uncover	7648.7c	5561.7c	723.08c	379.4b	13931c	764.9c	390.23c	69.96b	390.23c	1615.30c
1-layer	11630.0b	7500.4b	1105.27b	472ab	20642b	1163.0b	558.1b	117.76a	558.1b	2396.96b
2-layers	15431.7a	10341.3a	1374.01a	592.8a	27740a	1543.2a	759.36a	148.7a	759.36a	3210.62a
Animal manure (t/ha)										
0	8336b	6147b	831.63b	362.14b	15676b	833.6b	431.83b	89.43b	431.93b	1786.79b
30	14805a	9455.3a	1303.27a	600.66a	26163a	1480.5a	706.63a	134.84a	706.63a	2415.6a

Means with similar letters have no significant differences between them at 5% according to LSD

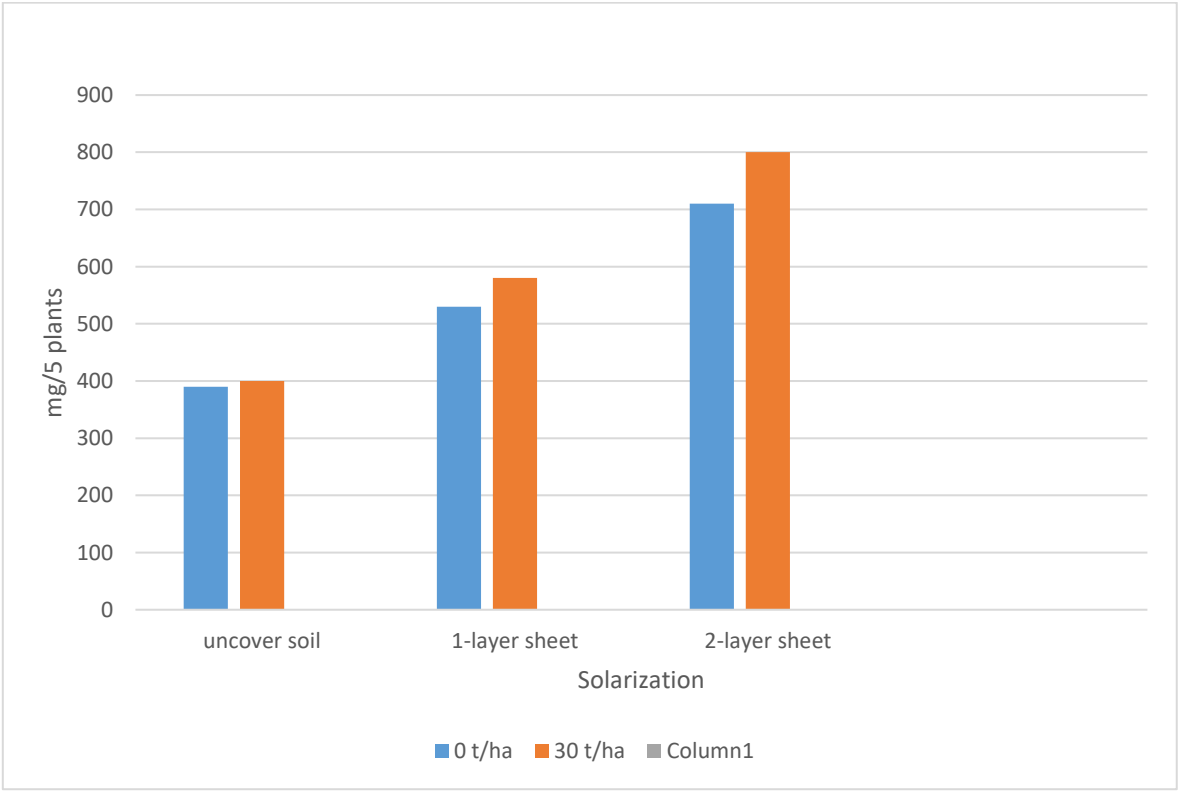

Fig (2): Effect of animal manure rates and solarization with different layers on dry whole plant dry weight

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Leaf area index (LAI):

The results showed an increase in the leaf area index of the cabbage plant when covered with two layers of transparent polyethylene followed by one layer for comparison. The results also showed the effect of adding animal manure on the leaf area index of the cabbage plant, which significantly increased by 30 tons / ha. (Table 4).

Yield and yield components:

Head, stem and root characteristics:

The results (table 5) showed a significant increase in the characteristics of the head of the cabbage plant when covered with polyethylene, whether it was a layer or two layers compared to the uncovered soil, with the superiority of the coverage of two layers on one layer (Table 5). The head length increased by 35.7 and 83.7% and head diameter by 9.1 and 43.6 % in the soil covered with 1-layer and 2-layers transparent polyethylene sheets, respectively. Also there are significant increase in the characteristics of the head of the cabbage plant with amendment with animal manure. Figure (3) shows the effect of the interaction between solarization of the soil and the addition of animal manure on the head rotation coefficient of the cabbage plant. Under soil solarization either with one layer or two layers it was found to be superior to non-covered soil with the domination of addition of 30 tons / ha of animal manure compared as regards head rotation coefficient.

Root growth:

Results in table (5) illustrates significant increase in root length under coverage of soil with transparent polyethylene sheets compared to uncovered soil, with domination of the 2-layer treatment to 1-layer treatment by 75% increase and to the uncovered soil by almost 90%. Also addition of animal manure at rate of 30 ton/ha significantly dominated soil with 0 ton/ha AM.

Yield weight (kg/ha):

The results showed that the yield of the cabbage plant when covered with two layers of transparent polyethylene sheets significantly increased and exceeded the one layer and the uncovered soil treatments by 237.2% and 347.5% respectively. The results also showed the effect of adding animal manure on the cabbage crop yield which increased at the addition of 30 tons / ha compared to the treatment without animal manure. (Table 5).

Table(5): Means of head characters(head length and diameter-rotation index)and stem characters(stem length and diameter-inner stem dia.),root length ,LAI and yield of cabbage plants under soil solarization and different AM rates during two seasons(2015-2016/2016-2017).

characters source of difference	Head characters			Stem characters(cm)			Root length(cm)	LAI(m2/m2)	Yield (kg/ha)
Season	Head length(cm)	Head diam.(c)	Rotation index	Stem length(cm)	Stem Diam.(c)	Inner stem diam(cm)			
2015-2016	13.4 a	19.23a	1.45a	9.11a	4.3a	6.15a	18.87a	5.85a	108731a
2016-2017	13.97a	19.84a	1.43a	8.97a	4.31	6.32a	19.35a	5.95a	111655a
Solarization with polyethylene sheets									
Uncovered soil	9.8c	13.33c	0.96c	6.36c	3.12c	4.45c	13.46c	4.45	32845c
1-layere sheet	13.28b	19.14b	1.45b	8.77b	4.21b	6.06b	18.36b	5.89b	110765b
2-layer sheet	17.97a	26.14a	1.9a	11.99a	5.59a	8.21a	25.52a	7.35a	146968a
Animal manure (t/ha)									
0	10.8b	15.18b	1.13b	7.27b	3.57b	5.004b	15.21b	4.76b	140999a
30	16.57a	23.89a	1.75a	10.81a	5.05a	7.48a	23.01	7.03a	79387b

Means with similar letters do not have significant differences between them at 5%

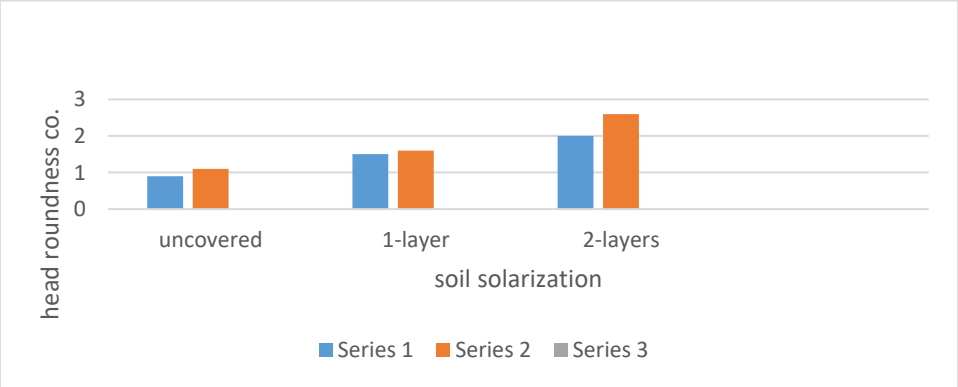

Fig (3): Effect of animal manure rates and solarization with different layers on cabbage head roundness

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DISCUSSION

The results obtained in this research study showed that the soil temperature significantly increased under soil solarization with polyethylene sheets amended with animal manure or without AM. pH value was not affected by soil solarization with polyethylene sheets or with depth from 0-15 to 15-30 cm, but soil pH was reduced when soil solarization was amended with animal manure (AM). The electrical conductivity (EC) on the other hand did not show any significant variation under soil solarization. The soil EC increased slightly when soil cover was amended with animal manure, and decreased with increase in soil depth from 0-15 to 15-30 cm. The increase in soil temperature with solarization agrees with the results obtained by many researchers, (Masabni and Franco, 2012) recorded increase in soil temperature under solarization up to 180°F compared to 120°F in uncovered soil, and also (Elmore et al. 1997) recorded increase in temperature due to soil solarization compared to uncovered soil. Mauro et al.(2015) recorded 8.0-13.2 °C soil temperature rise under solarization alone (at 5cm depth), and 4.1-9.3°C (at 15cm depth), and after addition of organic matter prior to solarization temperature of solarized soil further increased at both 5 and 15 cm soil depths (by up to 4.3 ◦C, on average). This result also agrees with the result of Ben-Yephet et al. (1987). The negative effect of solarization on soil pH agrees with the finding of (Mauromicale, et al. 2005) who detected no effect of solarization on soil pH value. The soil nutrients N, P, K significantly increased with soil covering with transparent polyethylene sheets and increased more significantly under 2-layer covering and with addition of animal manure (AM) at rate of 30 t/ha. The release of nutrients in the soil by soil solarization and addition of animal manure may be due to the high temperature generated acting on the animal manure and decomposing it. These releases on nutrients under soil solarization and addition of animal manure was administered by many researchers (Shelvin et al. 2004; Benlioglu et al. 2005; Raj and Upmanyu, 2005; Sunbol, 2006;; Al-Solaimani et al.,2006; Al-Solaimani et al. 2007; Al-Khamsan,2007). Scopa et al., 2009; Mauromicale et al., (2010, 2011) found increased minerals availability and improved crops yield performances due to soil solarization and amendment of organic matter.

Number of soil borne fungi was significantly reduced by soil solarization compared to control reaching its maximum reduction under 2-layer sheets. This is due to the high rise in soil temperature under the covered soil which have negative effects on fungi population. This is in agreement with (Khan et al. 2003) who found eradication of root knot nematodes, Fusarium sp. due to solarization, and with (Sunbul and Al-Solaimani, 2004) who detected eradication of the fungi Pythium and Fusarium , after covering the soil with polyethylene sheets. Escherichia coli was rapidly decreased after one week of solarization and was completely eradicated after 8 weeks of solarization (Berry and wells, 2012). Weed growth was significantly reduced by soil solarization due to rise in temperature, facts which agree with the findings of (Elmore et al. 1997; Khan et al.2003). Yield and yield components of cabbage plants (head and stem characters, root length, LAI) was significantly enhanced and increased under soil solarization and application of animal manure particularly under 2-layer sheet covering, and this may have been resulted from enrichment of the soil with more nutrients especially N, P and K, and reduction of weed growth, and increase in soil water content, thus making the soil conditions more favorable for better plant growth and yield. The increase in cabbage yield with soil solarization and AM addition agrees with work of many researchers, (Ozores-Hampton et al. 2005) found solarization increasing production of watermelon and rice, (Zhao et al., 2012) reported increase in potato yield, (Mauromicale, et al. 2005) found significant increase in legumes grain yield faba bean (Vicia faba) and chickpea (Cicer arietinum) as a result of covering soil with transparent polyethylene sheets. The effect of soil solarization combined with soil organic amendment increased plant growth and yield (Keinath, 1996, and Gamliel and Stapleton, 1997). Mauro et al.(2015) recorded increase in tomato yield from 3.43 kg plant−1 in unsolarized soil up to (6.58 kg FWplant−1) under soil solarization, and to peak up to (9.44 kg plant−1) after organic supplementation prior to solarization.

So it can be said that soil solarization causes physical, chemical and microbiological modifications within the soil, stimulating root growth, increasing crop yield and improving the product quality in a number of vegetable crops (Stapleton and DeVay, 1984; Chellemi and Rosskopf, 2004; Camprubi et al., 2007), and all these effects are improved with application of 2-layer transparent polyethylene sheets and when soil solarization is combined with organic fertilization (biofumigation) (Matthiessen and Kirkegaard, 2006), because of the higher temperatures reached within the soil (Simmons et al., 2013) along with the release of volatile compounds (Gamliel and Stapleton, 1993; Klein et al., 2007).

Conclusion

Covering the soil with transparent polyethylene sheets (soil solarization) with one layer or two layers significantly raised soil and air temperature, affected the chemical characteristics of the soil particularly soil electric conductivity (EC), its fungi population , weed growth and cabbage plant yield and yield components. Under amendment of soil solarization with organic matter (AM) at a rate up to 30 t/ha the effects on these studied parameters were more pronounce particularly under solarization with 2-layer sheets. The soil plant nutrients N, P, K, were gradually and significantly increased, and soil fungi population and weed growth significantly reduced, reaching their maximum under solarization with 2-layer polyethylene sheets compared to the control (noncovered soil). No significant increases were noticed in soil EC and pH due to soil solarization and AM additions. Cabbage plant yield and yield components (head and stem characters,root length, LAI, and yield weight) increased significantly with solarization with2-layer sheets incorporated with AM during the two seasons. It can be recommended to cover soil with one layer or two layers transparent polyethylene sheets for better yield of cabbage plant.

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