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Soil Solarization Timing Effects on Yield of Cabbage (*Brasssica olera*) & Eggplant (*Solanum melongena* L.) and as a Weed Control

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ABSTRACT

Background: Soil solarization or covering proved to be a good method for soil water conservation and leads to a peter yield and controls soil pests & grasses. **Objective:** Therefore, an experiment was conducted at the Agricultural Research Station of King Abdulaziz University at Hada Al-Sham, 120 km northeast of Jeddah City, to study the effect of soil solarization by transparent polyethylene sheets amended with 30 t/ha animal manure (AM) at different months (April-May, June-July and August-September) on some soil chemical properties, weed growth and yield and yield components of cabbage and eggplant plant during two seasons 2011 and 2012. **Results:** The highest effect was reported during August-September, then June-July on soil content of (nitrogen phosphorus, potassium), fungi population and weed fresh weight. Cabbage head, stem and root characters were improved significantly, and also yield increased up to (26.9%) at August-September. Similar observation was reported with eggplant that solarization at August-September significantly increased eggplant fruit and yield weight at rates of 65.4%-60.1% and 65.56%-60.7% respectively compared to control. **Conclusion:** It is recommended to apply soil solarization with transparent polyethylene sheets amended with 30 t/ha AM during August-September for control of soilborne fungi, weed growth and better cabbage and eggplant yield.

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INTRODUCTION

Soil solarisation using transparent polyethylene sheets is widely applied throughout the world (Ioannou, 2000; McGovern *et al*., 2003) for increasing soil temperature degrees up to 11 C^{o} to control agricultural pests (Dubey, 1992) and soil depths temperature at 5, 15 and 25 cm with an increase up to 8.8, 7.8 and 4.8 ^{0}C respectively compared to the non-solarized soil (Chellimi *et al*., 1994). Soil solarization increases rate of nutrients in plant tissues like nitrogen (Al-Solaimani and Sunbol, 2000), due to the changes it causes on soil chemical characteristics, thus increasing the availability of nutrients especially after the addition of organic materials (Stapleton, 2000). Soil mulching of greenhouses with polyethylene caused variations in soil temperature ranging between 12 – 16 ^{0}C, and this rise in soil temperature leads to degradation and mineralization of the organic matter to nitrogen , phosphorus , and to the other organic nutrients and make them available to plants (Lal, 1975; Philip and Vries, 1975; Hasson and Hussain, 1987). Soil solarization strongly reduced weed density and biomass in both greenhouse and field (Candido *et al*., 2012).The use of chicken manure with soil solarization significantly reduced potato scab in potato and Veticillium wilt (Conn and Lazaroits, 1999). Soil solarization for 65 days after sowing potato was ideal to optimize soil moisture and soil temperature and in turn to improve potato productivity and water use efficiency in the semi-arid region of China (Zhao *et al*., 2012). Cattle dung and compost when applied to soil improve organic matter contents, nutrients and the physical properties of soil, and suppressed some pathogens (Elmore *et al*., 1997; Klonsky and Tourte, 1998). The suitability and usefulness of animal manures and organic matter has been attributed to high availability of NPK content, and improvement of the physical properties of the soil as well (Nasef *et al*., 2004; Palada *et al*., 2004; Khalid and Shafei, 2005) and water conservation (Maynard, 1994; Debosz *et al*., 2002). Covering the soil with polyethylene and plant straw retarded very much the soil water evaporation, conserved soil moisture, controlled grasses and gave fast plant growth and high yield of peanut (Ramakrishna *et al*., 2006).

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The aim of this research is to evaluate the influence of soil solarization with transparent polyethylene sheets amended with 30 t/ha animal manure at different months of the year (April-May, June-July and August-September) on some soil chemical characteristics, fungi population, weed growth and on cabbage (*Brassica oleracea*) and eggplant (*Solanum melongena* L.) yield and yield components during two seasons (2011-2012).

MATERIAL AND METHODS

The experiment was carried out in the Agricultural Research Station of King AbdulAziz University at Hada Al-Sham 120km northeast Jeddah city, during two seasons 2010-2011 and 2011-2012. The experiment was implemented using the complete split randomized design with three replications, with the solarization dates (April-May, June-July and August- September) representing the main-plots, and the animal manure (AM) rates (0 and 30 t/ha) the sub-plots. The experiment site was ploughed twice at a depth of 30cm, leveled and then divided into 24 plots each (3x3m), 8 plots for each replicate, each 2 plots for one mulching treatment. Each covering treatment was represented by two AM rates (0, 30 t/ha). The plots were covered with the polyethylene sheets (transparent), 10microns in thickness. Each plot was divided into 3 rows, 70 cm between rows and 60 cm between plants. The plots were fertilized using 217 kg/ha P, 150 kg/ha K_2O and 435 kg/ha urea at three rates, and drip irrigation was used. The soil experimental site was analyzed before and after covering the soil with the polyethylene sheets at both depths, 0 – 15 and 15 – 30 cm, for its electric conductivity (EC), pH using pH meter, the organic matter using Walkeley and Black method as mentioned by (Jackson, 1973), total nitrogen (N) using Kjeletec Auto1030, total phosphorus (P) and potassium (K) 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. Cabbage and eggplant seedlings were prepared in the nursery, and were acclimatized for one month before being planted in the site. Five plants were selected randomly from each plot after maturation, to take measurements on whole plant characteristics, yield and yield components. All the remaining plants in the plot were collected at last for determination of the total yield. The total fresh weight of weed growing in each replicate was determined after being collected three times by hand. Soil temperature degrees were recorded in the uncovered and covered soil at 5,15 and30 cm depth after 4, 8 and 12 weeks (Fig. 1).

Statistical analysis:

The statistical analysis of the data was carried out according to the type of the design (ANOVA) according to Little and Hills 1997, running the analysis of variance, and comparison of means using LSD $P \leq 0.05$, and combined analysis was carried out for the two seasons using SAS (2006).

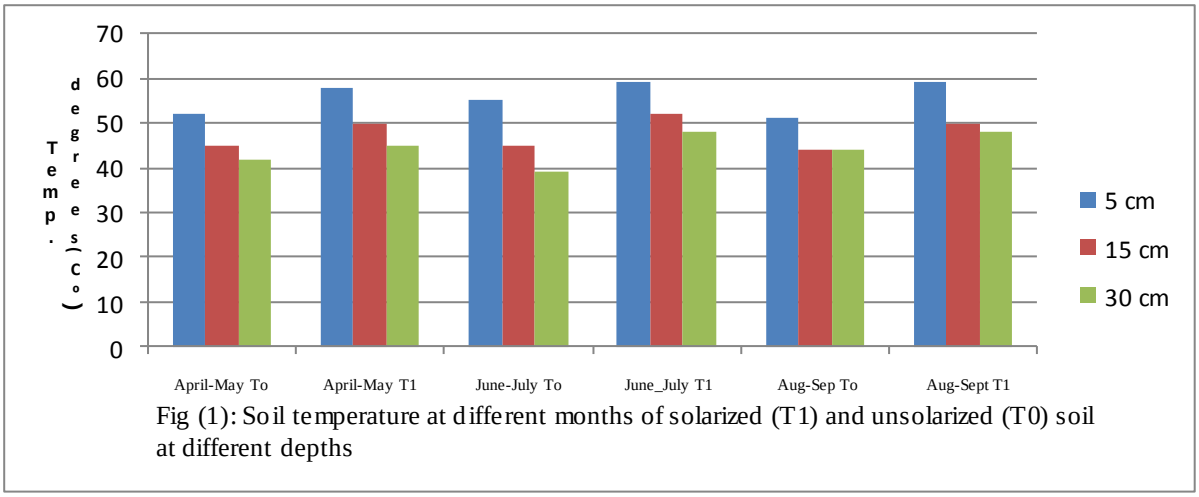

Fig (1): Soil temperature at different months of solarized (T1) and unsolarized (T0) soil at different depths

Results:

Pre solarization results indicated significant increases in soil content of the nutrients N, P and K, and a reduction in number of fungi and in EC with the addition of animal manure up to 30 t/ha compared to control. Soil pH was not affected by AM addition, but fungi population, and K decreased with increase in depth from 0-15 to 15-30 cm (table 1). However, post soil solarization showed significant increases of soil content of N, P and K and a decrease in fungi numbers with the solarization date August-September, followed by June-July, then April-May respectively compared to the control (uncovered soil). Fungi population was reduced at rates of 86.0%, 78.0% and 41.8% at the three dates respectively. However, there was reduction of P, K and fungi

population with increase in depth from 0-15 to 15-30 cm, and the depth did not affect soil content of N, EC and pH (table 2). Result obtained on weed growth (table 3) indicated high growth of weeds during the second season than the first season. However, Weed growth (Fresh weight) was significantly reduced by soil solarization amended with 30 t/ha AM during the date August-September, compared to June-July and April-May, with percentage of 54.8%, 46.6% and 20.2% respectively compared to the uncovered soil.

Table 1: Effect of animal manure rates and soil depth on means of pH, EC, soil content of N, P, K and fungi number pre soil solarization at different months.

Characters		pH	EC (d mose/m)	N (%)	P (%)	K (mg/kg)	Fungi No/gm dry soil
Animal manure (t/ha)	0	7.85a	1.94a	0.09b	0.021b	65.66b	49688b
	30	7.86a	1.47b	0.13a	0.031a	96.00a	80036a
Depth(cm)	0-15	7.82a	1.65a	0.12a	0.026a	89.33a	83818a
	15-30	7.89a	1.76a	0.10a	0.024a	72.33b	45906b

Means followed by the same letter are not significantly different according to LSD at P≤ 0.05

Table 2: Effect of animal manure rates and soil depth on means of pH, EC, soil content of N, P, K and fungi numbers post soil solarization at different months.

characters		pH	EC (d mose/m)	N (%)	P (%)	K (mg/kg)	Fungi No/gm dry soil
Date of covering (polyethylene)	uncovered	7.88a	2.24a	0.075c	0.011b	52.00c	32812a
	April-May	7.68a	2.12a	0.11bc	0.023a	76.50b	19091b
	June-July	7.85a	1.73a	0.17ab	0.021a	92.83a	7211bc
	Aug-Sept	7.85a	1.21a	0.19a	0.027a	95.50a	4602c
Animal manure (t/ha)	0	8.62a	1.74a	0.17a	0.017a	64.87b	20789a
	30	7.01a	1.91a	0.01b	0.024a	93.54a	11069b
Depth(cm)	0-15	7.81a	2.10a	0.15a	0.024a	86.54a	21043a
	15-30	7.82a	1.55a	0.13a	0.017b	71.87b	10814b

Means followed by the same letter are not significantly different according to LSD at P≤ 0.05

Table 3: Effect of solarization and animal manure addition on weed fresh weight.

characters	Season		Solarization				Animal manure(t/ha)	
	First	Second	uncovered	April-May	June-July	Aug-Sept	0	30
Fresh weight(kg/9m^2)	1.46b	2.72a	2.85a	1.92b	1.83b	1.76b	2.42a	1.76b

Means followed by the same letter are not significantly different according to LSD at P≤ 0.05

Results indicated gradual but not significant increases in leaf area index (LAI), head, stem, root and yield of cabbage with solarisation at the dates April-May, June-July, August-September compared to the uncovered soil, with the date August-September dominating. Also these characters increased significantly with increase of AM rates from 0 to 30 t/ha. Cabbage head length and diameter increased by 29.6 and 21.7% and cabbage yield at a rate of 81.5% under solarization during August-September compared to control. The second season dominated the first in regard to head length and diameter and in inner stem diameter. However, the first season dominated the second season giving the highest cabbage yield (table 4).

Table 4: 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 different months.

characters	Head characters			Stem characters(cm)			Root length (cm)	LAI (m2/m2)	Yield (kg/ha)
	Head length (cm)	Head diam. (cm)	Rotation index	Stem length (cm)	Stem diam. (cm)	Inner stem diam (cm)			
Season									
2011	13.93b	19.29b	1.39a	9.85a	5.80a	7.17b	18.52a	1.68a	1073.7a
2012	16.51a	21.58a	1.31b	10.65a	5.41a	9.31a	19.77a	1.88a	1037.2a
Solarization									
Uncovered	12.98c	17.97c	1.40a	8.78c	4.91c	7.09c	16.14b	.896b	904.5b
April-May	14.91b	20.60b	1.38a	10.22b	5.53b	9.00ab	18.82ab	.938ab	1037.9ab
June-July	16.27a	21.26ab	1.31a	10.92ab	5.93a	8.86ab	19.95a	1.01ab	1130.9a
Aug-Sept	16.71a	21.92a	1.31a	11.07a	6.06a	9.60a	21.67a	1.76a	1147.8a
Animal manure (t/h)									
0	12.28b	16.53b	1.36a	8.25b	4.49b	6.62b	15.56b	.801b	850.0b
30	18.15a	24.34a	1.34a	12.25a	6.72a	9.86a	22.73a	1.14a	1260.7a

Means followed by the same letter are not significantly different according to LSD at P≤ 0.05

Significant differences were detected in number of eggplant flowers & fruits and eggplant fruit characteristics with solarization at the different dates with the highest increases being at August-September (82.0% and 81.7%), followed by June-July (63.4% and 57.9%) and April-May (49.1% and 49.0%) respectively. Also number of flowers and fruits increased significantly with addition of 30 t/ha AM, reaching a rate of 80.5% and 54.2% respectively. Similar result was obtained in fruit length and thickness. Eggplant fruit weight and yield recorded significantly the highest values during solarization at August-September and June-July with no significant difference between them, reaching increases at rates of 65.4%-60.1% and 65.56%-60.7% respectively compared to the uncovered soil. The addition of animal manure had significant increase in fruit weight and yield at rates of 26.8% and 26.6% respectively (table 5).

Table 5: Means of number of flowers and fruits, fruit length and thickness, fruit and yield weight of eggplant under soil solarization and 30 t/ha AM during different months.

characters	Flower number	Fruit number	Fruit characteristics(cm)		Fruit wt. Gm/5plants	Yield Kg/ha
			Length	Thickness		
Season						
2011	62.49a	30.72a	9.37a	6.04b	3388.5a	8471.2a
2012	59.59a	24.23a	9.43a	7.73a	2944.6a	7361.4a
Solarization						
Uncovered	41.12c	15.28c	6.57c	4.57d	2313.3c	5783.3c
April-May	61.25b	22.83b	8.19b	5.77c	2818.2b	7045.5b
June-July	67.08b	24.02b	11.31a	7.77b	3704.4a	9260.0a
August-September	74.82a	27.84a	11.52a	8.52a	3830.3a	9576.5a
Animal manure (t/ha)						
0	43.57b	17.69b	9.08b	6.42b	2793.9b	6984.7b
30	78.51a	27.27a	9.72a	6.89a	3539.2a	8848.4a

Means followed by the same letter are not significantly different according to LSD at P≤ 0.05

Discussion:

Soil solarization with polyethylene sheets at different months, with the addition of animal manure (AM) up to 30 t/ha has significantly increased soil content of N, P, K and decreased soil fungi population and weed fresh weight with no significant effects on soil EC and pH. This may be due to soil enrichment with nutrients especially N, P and K after the addition of AM. Reduction in fungi population and weed fresh weight under solarization amended with the addition of AM is probably due to rise in temperature and the emission of toxic gasses which were trapped under polyethylene sheets, thus adversely affecting fungi and weed and retarding their growth. The fungi and weed growth reduction was more pronounce during the months of June, July, August and September. This may be due to the high rise in temperature degrees during these months compared to the other dates, which in turn had adverse effect on soilborne fungi and weed growth (Dubey, 1992; Chellimi *et al*., 1994; Al-Masoom *et al*., 1993; Arora and Yaduraju, 1998; Nasef *et al*., 2004; Palada *et al*., 2004; Khalid and Shafei, 2005; Al-Solaimani *et al*., 2006; Al-Khamsan, 2007). Sunbol (2004) found complete eradication of the fungi *Pythium* and *Fusarium* after covering soil for two weeks, and found 92.5% reduction in weed growth compared to control under soil solarization amended with green manure(Sunbol, 2006). Similar result was demonstrated by (Al-Khamsan, 2007) and (Candido *et al*., 2012). The enhancement by soil solarization and the addition AM on yield and yield components is probably due to the favorable soil conditions created by solarization and animal manure, thus enriching soil with more nutrients especially N, P and K, eradicating soil borne pests, reducing weed growth and improving soil water conservation (Al-Khamsan, 2007).

Conclusion:

Soil solarization with transparent polyethylene sheets for different months (April-May, June-July, August-September) has significantly affected the chemical characteristics of soil, its fungi population, weed growth, yield and yield components. When soil solarization was incorporated with animal manure, the effects on these studied parameters were more pronounce. Cabbage yield components (head length, head diameter, stem length and root length) and eggplant yield increased significantly during the application of soil solarization in (August –September) period. It is more effective to apply soil solarization with transparent polyethylene sheets amended with animal manure during certain time of the year for improvement of soil nutrients, control of fungi & weed, and increase of cabbage and eggplant yield.

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