Effect of Soil Solarization with Polyethylene Colored Sheets and Organic Manures on Lettuce Yield, Weed Growth, Soil Nutrients and Fungi

Samir. G. Al-Solimani, Fathy. S. El-Nakhlawy,
Sajid Mahmood*, Abdullatif A. Neamatallah
Arid Land Agriculture Department,
Faculty of Meteorology,
Environment and Arid Land Agriculture King Abdulaziz University,
Jeddah-80208, Saudi

Abstract*–This experiment aimed to evaluate the effect of soil solarization with transparent, black and white polyethylene sheets in combination with organic matters mixture (sludge, canola straw, wheat straw, sludge + canola straw, sludge + wheat straw, sludge + canola straw + wheat straw) on soil N, P, K contents, soil fungi population, weed growth and lettuce yield during two seasons (2009-2010). Results indicated that lettuce yield increased with solarization and the transparent sheets dominated with 21.92 and 20.004 t/ha followed by the black sheets with 19.72 and 17.08 t/ha compared with uncovered soil with least yield 14.76 and 11.76 t/ha, respectively, during the two seasons. Organic matters mixture also significantly increased the lettuce yield especially, sludge + canola straw dominated with 22.75 and 19.99 t/ha followed by sludge + canola straw + wheat straw giving 21.28 and 18.68 t/ha, respectively, during the two seasons. Wheat straw gave the least yield 12.81 and10.81 t/ha during the two seasons. Soil contents of N, P and K increased, and pH, EC, weed growth and fungi number decreased with solarization especially under transparent and black sheets. The pH and EC decreased with organic manures except with wheat straw and sludge + wheat straw which gave higher EC. Soil N, P, K increased with organic manures but not with canola and wheat straw. It is recommended to cover soil with transparent polyethylene sheets, and to amend it with organic manures for better yield of lettuce and control of weed and soil fungi.

Keywords: Colored polyethylene sheets, organic matter mixture, weeds, fungi, lettuce

I. INTRODUCTION

Solarization is a non-chemical disinfestations practice that effectively controls a wide range of soil-borne pathogens, insects and weeds [1,2]. Soil solarization controls many annual and perennial weeds; winter annual weeds seem to be especially sensitive to this practice, and control of winter annuals is often evident for more than one year following solarization [3, 4, 5]. Addition of fertilizers and organic amendments, especially composts or chicken manure can suppress soil borne plant pests [6, 1]. Soil solarization is based on the exploitation the solar energy for heating wet soil mulched with transparent polyethylene sheets to 40–55 ºC in the upper soil layer [2]. Thermal killing is the major factor involved in the pest control process, but chemical and biological mechanisms are also involved. The efficacy of the thermal killing is determined by the values of the maximum soil temperature and amount of heat accumulated. The use of organic amendments (manure, crop residues) together with soil solarization elevates the soil temperature by 1–3 ºC, and improves pest control due to a generation and accumulation of toxic volatiles [3, 4].

Mohammed et al. [7] observed variations in plant height and growth when he applied organic manure and compost in rice, and attributed this to variation in nutrient sources due to variation in the availability of the major nutrients. The available nutrients might have helped in enhancing leaf area of plants, which thereby resulted in higher photo-assimilation and dry matter accumulation [8, 9]. Yield increase of cabbage crop due to chicken manure amendment in solarized soils had been reported by Haidar and Sidahmed [10]. Soil solarization amended with goat manure at doses 0, 20 and 40 kg/ha gave weed average densities 58.25, 32.0, 22.0 plants/m2, respectively, and this is possibly due to soil heating and provoking of a chain reaction of chemical and microbial degradation which generated toxic liquid and volatile compounds that accumulated below the plastic mulching and act against soil flora and fauna [11, 3]. Likewise, Al-Solaimani et al. [12] observed decreased weed growth and fungal population under the cover of polyethylene sheet amended with organic manure in lettuce.

This study was aimed to examine the effect of soil solarization with transparent, black and white polyethylene sheets, and organic matters applied singly or incorporated together, on some soil chemical and physical properties, densities of fungi population and weed growth, and on yield of lettuce.

II. MATERIAL AND METHODS

The experiment was carried out in the Agricultural Research Station of King Abdulaziz University at Hada Al-Sham 120 km northeast Jeddah city, during two seasons 2009 and 2010.

Experimental Design

The experiment was implemented using the complete split randomized design with three replications, where polyethylene sheets (uncovered, transparent, black and white) representing the main-plots while organic materials representing the sub-plots.

Soil analysis

The soil experimental site was analyzed before and after covering the soil with the polyethylene sheets for its electric conductivity (EC), pH using pH meter, the organic matter using Walkeley and Black method as mentioned by Jackson [13], total nitrogen (N) using Kjeletec Auto1030, total phosphorus (P) and potassium (K) using Shelton and Harper [14] method. Also the number of soil fungi was determined using the successive dilution method described by Dhingra and Sinclair [15]. These parameters were also analyzed in the irrigation water and in the added organic materials.

Preparation of the experimental site and lettuce planting

The soil was ploughed twice at a depth of 30cm, leveled and then divided into 84 plots each (3x3 m), 28 plots for each replicate, each 21 plots for the 4 soil covering treatments. One fourth of the area was covered with transparent polyethylene sheets, and the others were covered with black, white sheets respectively, and the last was left uncovered. 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 K2O and 435 kg/ha urea in three doses. Drip irrigation system was used to irrigate the plants. Lettuce seedlings were prepared in the nursery, and were acclimatized for one month before being planted in the site.

Data collection

The lettuce plants from 1 m2 in each plot were selected, and the total yield was determined in kg/ha for each treatment during both seasons. The total fresh weight of weed growing in each replicate was determined after being collected three times by weeding during lettuce growth. The maximum temperatures were recorded in the covered and the uncovered soil under both types of sheets.

Statistical analysis

The statistical analysis of the data was carried out according to Little and Hills [16] running the analysis of variance. Comparison of means was carried using LSD 0.05 and combined analysis was carried out for the two seasons using SAS 2000 software.

III. RESULTS

The results of the analysis of variance (Table 1) showed high significant effect ($p<0.01$) of soil solarization by the colored polyethylene sheets, and the different organic matter mixtures, and their interactions on lettuce yield (t/ha) and weed growth (t/ha) during both seasons 2009 and 2010.

Lettuce Yield

As for the average lettuce yield table (2) showed the domination of the transparent polyethylene sheet in giving the highest lettuce yield (21.92 and 20.004 t/ha) during the two seasons, respectively, followed by the black sheets with 19.72 and 17.08 t /ha, and the white sheets gave 16.25 and 14.39 t/ha while the uncovered soil gave the least yield (14.76 and 11.76 t /ha) during both seasons, respectively. And as for the different organic matters treatments, the treatment sludge + canola straw dominated giving the highest lettuce yield (22.75 and 19.99 t/ha) during both seasons, respectively, followed by the sludge + canola straw + wheat straw with 19.63 and 14.42 t/ha and the treatment with the least yield value was the wheat straw alone with (12.8 and 10.81 t/ha) during the two seasons, respectively.

As for the interaction between the different colored polyethylene coverings and the organic matter mixture treatments on lettuce yield, the effect was significant during the second season only (Fig. 1) and the treatments giving the highest yield were (sludge + canola straw + wheat straw + transparent polyethylene sheets) followed by (sludge + canola straw + transparent polyethylene sheets) and the treatment with the lowest yield was wheat straw alone.

Table (1): Analysis of variance of lettuce yield and weed growth under the influence of polyethylene covering and organic matter mixtures and interactions between them during 2009 and 2010 seasons

*NS not significant at $p \le 0.05$; *significant at $p \le 0.05$; **significant at $p \le 0.01$*

Sources	DF	Yield (t ha^{-1})		Weed weight (t ha^{-1})	
		2009	2010	2009	2010
Replications	2	17.93 NS	7.79 NS	0.917 NS	21.55 NS
Solarization (different color sheets) (A)	3	222.39 **	262.93**	11.973 **	2013.52**
Exp. Error (a)	6	9.94	0.97	0.86	49.54
Organic materials mixtures(B)	6	148.62 **	134.91**	11.19 **	20.35**
(A + B)	18	4.58 NS	3.18**	1.67 **	7.56**
Exp. Error (b)	48	3.09	0.87	0.567	1.86

Weed growth

Table (1) showed high significant effects ($p<0.01$) of the colored polyethylene sheets, organic matter mixtures and their interaction on weed growth (t/ha) during the two seasons. The least average weed growth was attained by the transparent polyethylene sheets (0.545 and 0.95 t/ha) during both seasons, with significant differences from the other treatments followed by the black sheets (1.440 and 2.42 t/ha) and the white sheets with (7.562 and 10.81 t/ha), while the uncovered soil gave the highest weed growth (16.937 and 22.28 t/ha) during both seasons, respectively. Considering the effects of the different organic matters on weed growth, table (2) showed that the least weed growth attained with the sludge + canola straw mixture giving 5.123 and 7.11 t/ha, while the wheat straw alone and canola straw + wheat straw gave significantly highest weed growth 7.956 and 10.52 t/ha, and 7.46 and 10.1 t/ha during the two seasons, respectively. It can be seen that the highest lettuce yields were inversely proportional to the weed growth yields.

Figure (1) illustrated that transparent polyethylene amended with sludge or canola straw were the interactions with the significantly least weed growth (0.370 and 0.454 t/ha), respectively, followed by black polyethylene amended with sludge + canola straw giving 0.824 t/ha compared with interaction effect of uncovered soil + wheat straw that gave 18.999 t/ha weed during first season. During the second season 2010 the interactions with the least weed growth were the transparent polyethylene + sludge + canola straw + wheat straw with 0.360 t/ha, and the interaction with the highest weed yield was the uncovered soil + canola straw + wheat straw that gave 0.460 t/ha.

Table (2): Averages of lettuce yield and weed weight under the influence of polyethylene covering and organic matter mixtures and interactions between them during 2009 and 2010 seasons

Treatments	Yield (t ha^{-1})		Weed weight (t ha^{-1})	
	2009	2010	2009	2010
Soil solarization (colored sheets)				
Uncovered soil	14.76 d *	11.76 d	16.937 a	22.28a
White sheets	16.25 c	14.39 c	7.562 b	10.81b
Black sheets	19.72 b	17.08 b	1.440 c	2.42c
Transparent sheets	21.92 a	20.004 a	0.545 d	0.95d
Organic material mixture				
Sludge (S)	19.63 c	14.42 c	6.266 c	8.95c
Canola straw (CS)	18.54 c	16.35 d	6.414 c	9.23bc
Wheat straw (WS)	12.81 f	10.81 g	7.956 a	10.52a
S + CS	22.75 a	19.99 a	5.123 d	7.11d
S + WS	17.39 d	15.25 e	7.148 b	10.2ab
CS + WS	14.71 e	12.15 f	7.460 ab	10.1ab
S + CS + WS	21.28 b	18.68 b	5.979 c	7.71d

**Means with same letters are non-significant according to LSD (0.05)*

Effects on soil characteristics and number of fungi

Soil solarization effects

Table (3) illustrated that soil solarization significantly (p<0.01) affected all the soil characteristics (pH, N, P, K) and also the number of fungi in the soil with no significant effect on soil EC. The different polyethylene colored sheets and also the addition of organic matters mixtures showed high significant effects (p<0.01) on the studied soil characteristics and on soil fungi number. Table (4) showed that soil solarization led to significant reduction in pH from 8.64 before solarization to 7.07 after solarization. The soil nutrient contents N, P and K increased with solarization from 0.14 %, 0.022 % and 60.67 mg/kg to 0.15 %, 0.028 %, 66.01 mg/kg, respectively. The number of fungi in the soil also significantly decreased with solarization from 41520/g dry soil before solarization to 28102/g dry soil after solarization. The interaction effect was non-significant for studied parameters.

Polyethylene sheet colors effects

As for the soil pH the highest value (7.95) was attained with the uncovered soil and decreased significantly with the different sheet colors, but with no significant differences between them and reached its minimum value (7.76) under the transparent sheets. The soil EC reduced significantly from 3.48 in the uncovered soil to 2.79 dS m^{-1} under the transparent sheet. The soil content of N, P and K increased significantly with the transparent sheets giving the highest values, followed by the black sheets and white sheets over the uncovered soil gave the least values as follows; 0.158 %, 0.147 %, 0.138 %, 0.135 % for N, respectively, and 0.028 %, 0.025 %, 0.022 %, 0.020 for P, respectively, and 69.29, 63.52, 60.95, 59.60 mg/g for K, respectively. The different polyethylene colors also significantly reduced the number of soil fungi with the domination of the transparent sheets and decreased the soil fungi from 39938/g dry soil in the uncovered soil to 32186/g dry soil under the transparent sheets, 33173/g dry soil under the black sheets and 339747/g dry soil under the white sheets.

Organic manures effects

Table (4) illustrated that the soil pH ranged from the highest value (8.51) with the wheat straw followed by the pH value 8.34 and 7.78 under the effect of sludge + wheat straw and sludge + canola straw + wheat straw, respectively. The least pH value (7.26) was attained under the effect of canola straw. The highest values of EC were observed up to 4.24 and 3.38 dS m^{-1} under the effect of sludge and sludge + canola straw. However, application of canola straw + wheat straw significantly reduced the soil EC up to 2.38 dS m^{-1}. The highest soil N, P and K contents were recorded under the sludge treatment with averages of 0.18 %, 0.035 % and 67.25 mg/kg, respectively. The least concentrations of N, P and K in the soil were found under the effect of the wheat straw treatment with averages of 0.12 %, 0.017 % and 58.91 mg/kg, respectively. The least soil fungi number was attained under application of sludge + canola straw + wheat straw with average of 31567/g dry soil followed by sludge + canola straw with averages of 31874/g dry soil. However, the significantly higher fungi number was attained under the wheat straw application that gave 38239/g dry soil.

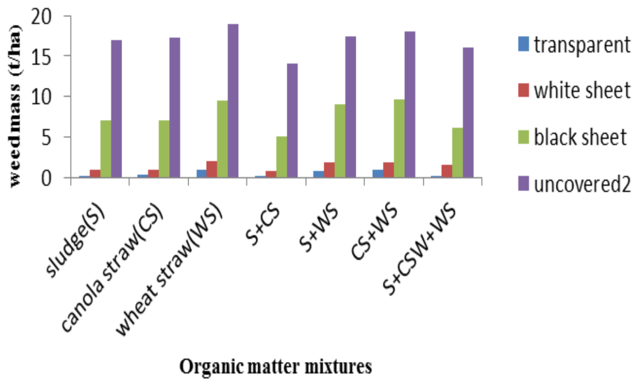

Fig. (1): Effect of interaction between soil covering and organic materials on weed mass (t/ha)

IV. DISCUSSION

The results obtained from this study revealed the importance of application of soil solarization using polyethylene colored sheets for increase of crop yield, soil nutrients and decrease in weed growth and number of fungi. Crop yield increased due to killing of great number of weed seeds and harmful micro-organisms as a result of accumulation of heat energy in the soil under the covering sheets [4, 5, 12], and improved nutrient availability to plant. Our study revealed that interaction of colored polyethylene sheets and organic mixtures had significant effect on reduction of weed growth and pathogenic soil borne fungi and subsequently enhanced the lettuce yield.

Table (3): Analysis of variance of the soil pH, EC, N, P, K, and number of fungi as affected by solarization by different colored polyethylene sheets, and organic matters

Sources	DF	pH	EC	N	P	K	Fungi number
Replicates	2	0.14 NS	2.20 NS	0.011 NS	0.0004 NS	2247.15 NS	985828682
Solarization (T)	1	103.65 **	0.01 NS	0.004 **	0.002 **	1149.66 **	7051462431**
Exp. error	2	0.42	6.61	0.00002	0.00002	3.98	23333006
Sheets (S)	3	0.29 *	4.3 **	0.004 **	0.0003 **	769.03 **	8326642204**
TxS	3	0.003 NS	0.02 NS	0.0000006 NS	0.0000006 NS	1.6 NS	197080112**
Exp. error	12	0.07	0.83	0.00002	0.00001	1.28	714859952
Organic mixtures (M)	6	4.58 **	9.34 **	0.009 **	0.0008 **	225.52 **	726789654**
TxM	6	0.04 NS	0.01 NS	0.000002 NS	0.00005 NS	0.01 NS	17202366NS
SxM	18	0.03 NS	1.07 NS	0.000002 NS	0.000006 NS	0.01 NS	107013932**
TxSxM	18	0.0008 NS	0.01 NS	0.000002 NS	0.000006 NS	0.01 NS	2532881
Exp. error	96	0.025	0.95	0.000001	0.00001	0.10	10769483

*NS not significant at $p \leq 0.05$; *significant at $p \leq 0.05$; **significant at $p \leq 0.01$*

Soil solarization also reported to improve the nutrient availability in soil and stimulation of beneficial microflora in the rhizosphere [17, 18]. Sofi et al. [5] reported that solarization with plastic sheet had significant effect on soil pH, EC, nutrient availability and soil microflora, thereby improving the cauliflower vigor. Similar effect of soil solarization on plant growth have been observed in many important crop plants like tomato and melon [18, 3], pepper and watermelon [4, 19], and lettuce [20, 12]. Previous studies suggested that soil solarization increased the crop yield due to improved NH4-N availability in soil [21, 22]. According to these authors soil solarization with polyethylene sheet and organic manure enhanced N mineralization of organic matter due to high temperature, thus, build up NH4-N in soil. Chen et al. [21] correlated the buildup of NH4-N in soil with decrease in nitrifying bacteria due to soil solarization. Solarization with polyethylene amended with organic manure was found positive in lettuce yield and soil nutrient contents compared to the use of each separately. Our results are in agreement with the results of other researchers [23, 3, 19].

Our results exhibited positive effect of soil solarization on weed control which validates those of many other studies [22, 24, 20, 4]. The significant reduction of weed cover was observed with SS with transparent plastic sheet coupled with sludge + canola straw. This reduction might be due to the high soil temperatures in the surface soil layers under polyethylene sheet cover. Temperature might probably higher due to higher SOM and moisture content in the solarized soil than non-solarized soil which improved heat conductivity of soil [4]. Also, organic manures with narrow C:N ratio were reported to produce phytotoxins such as ammonia that can reduce weed populations [25].

As demonstrated in various studies, the soil solarization decreased the soil borne pathogen diversity including bacteria and fungi [24, 3, 5] which cause root diseases during germination [26, 23]. In this study, soil solarization with transparent polyethylene sheet amended with the sludge + canola straw significantly reduced soil fungi numbers. The results are supported by finding of Bonanomi et al. [20] where soil solarization with both biodegradable and plastic films significantly decreased fungal and bacterial band richness. Among the solarizing treatments, biodegradable film showed the most negative effect on fungal diversity. The reduction in fungi numbers under amended solarized soils may be due to the accumulation of some toxic gasses. It is well documented that soil temperature rise under solarized soil amended with animal manure leads to emission of some gasses like ammonia or sulfur dioxide which negatively affect the fungi count [11, 27, 28].

Table (4): Means of pH, EC, soil N, P, K, and fungi number under effect of solarization with different colors of polyethylene sheets and organic matter mixtures

Treatments	pH	EC (dS m^{-1})	N (%)	P (%)	K (mg kg^{-1})	Number of fungi g^{-1}dry soil
Solarization						
Pre-solarization	8.64 a *	3.05 a	0.14 b	0.022 b	60.67 b	41520 a
Post-solarization	7.07 b	3.05 a	0.15 a	0.028 a	66.01 a	28102 b
Colored sheets						
Uncovered soil	7.95 a	3.48 a	0.135 d	0.02 c	59.61 d	39938 a
White sheets	7.88 a b	3.11 ab	0.138 c	0.025 b	60.95 c	33947 b
Black sheets	7.81 b	2.83 b	0.147 b	0.025 b	63.52 b	33173 c
transparent	7.76 b	2.79 b	0.158 a	0.028 a	69.29 a	32186 d
Organic mixtures						
sludge	7.34 e	4.24 a	0.18 a	0.035 a	67.25 a	33634 e
Canola straw	7.26 e	2.7 c	0.13 e	0.02 d	61.91 e	34433 d
Wheat straw	8.51 a	2.69 c	0.12 f	0.017 e	58.91 g	38239 a
S + CS	7.64 d	3.48 b	0.15 b	0.03 b	65.91 b	31874 f
S + WS	8.57 b	2.94 c	0.14 c	0.026 c	64.91 c	36521 c
CS + WS	7.87 c	2.38 c	0.135 d	0.02 d	60.25 f	37409 b
S + CS + WS	7.78 c	2.93 bc	0.14 c	0.025 c	64.25 d	31567 g

**Means with same letters are non-significant according to LSD (0.05)*

Our results indicated that soil solarization with polyethylene sheet and organic manure has significant effect on soil nutrient contents of nitrogen, phosphorus and potassium. These results are in conformity with the results of several workers [29, 17]. Sofi et al. [5] reported that Ca, Mg, N, P, K and C recorded in solarized soil was higher than in non-solarized.

V. CONCLUSION

Soil solarization using different colored polyethylene sheets and organic matters mixtures significantly increased lettuce yield and soil content of N, P and K, and reduced the weed growth and fungi numbers. However, covering the soil with transparent polyethylene sheets amended with sludge + canola straw dominated all other combinations of treatments in all studied parameters. It is recommended to solarize soil with transparent polyethylene sheets amended with sludge + canola straw for control of soil fungi, weed and for sustainable lettuce yield.

REFERENCES

[1] Kurt, K. and B. Amir (2004). Effect of soil solarization, chicken litter and viscera on populations of soil borne fungal pathogens and pepper growth. Plant Pathol. J., 3 (2) (2004), pp. 118–124

[2] Cimen, I; B. Turgay; V. Pirinc (2010). Effect of solarization and vesicular arbuscular mychorrizal on weed density and yield of lettuce (Lactuca sativa L.) in autumn season.Afr. J. Biotechnol., 9 (24) (2010), pp. 3520–3526.

[3] Lombardo, S., Longo, A.M.G., Lo Monaco, A., & Mauromicale, G. (2012). The effect of soil solarization and fumigation on pests and yields in greenhouse Tomatoes. Crop Protection, 37, 59-64

[4] Ozores-Hampton, M., McSorley, R., & Stansly, P.A. (2012). Effects of long-term organic amendments and soil sanitation on weed and nematode populations in pepper and watermelon crops in Florida. Crop Protection, 41, 106-112.

[5] Sofi, T.A., Tewari, A.K., Razdan, V.K., & Koul, V.K. (2014). Long term effect of soil solarization on soil properties and cauliflower vigor. Phytoparasitica, 42, 1–11. DOI 10.1007/s12600-013-0331-z

[6] Barbour EK, SA Hussein, MT Farran, DA Itani, RH Houalla, SK Hamadeh. 2002. Soil solarization: A sustainable agriculture approach to reduce microorganisms in chicken manure-treated soil. J. Sust. Agr. 19-95.

[7] Mohammed, A., A. Bakry, Y. R. A. Soliman and S. A. M. Moussa. (2009). Importance of micronutrients, organic manure and bio-fertilizer for improving maize yield and its components grown in desert sandy soil. Res. J. Agric. & Bio. Sci., 5 (1): 16-23.

[8] Swarup, A., and Yaduvanshi N.P.S.. (2000). Effect of Integrated nutrient management on soil properties and yield of rice in Alkali soils. J. Indian Soc. Soil Sci., 48: 279-282.

[9] Yadana, K. L., Aung, K. M., Takeo, Y., and Kazuo, O. (2009). The Effects of Green Manure (Sesbania rostrata) on the Growth and Yield of Rice, J. Fac. Agr., Kyushu Univ., 54 (2): 313–319.

[10] Haidar MA, MM Sidahmed (2000). Soil solarization and chicken manure for the control of Orobanche crenata and other weeds in Lebanon. Crop Prot 19 (2000) 169.

[11] Gamliel, A., Austerweil, M., Kritzman, G. (2000). Non-chemical approach to soilborne pest management- organic amendments. Crop Protection, 19: 847-853.

[12] Al-Solaimani, S.G., S. Mahmood, S. Ahmad, I. Duar, F.S. El-Nakhlawy, A.A. Nematullah. 2015. Effectiveness of Soil Solarization with Polyethylene Sheets & Organic Manure to Control Weeds & Fungi & to Increase the Lettuce Yield. Intl. J. Sci. Engin. Res. 6 (9): 303-308.

[13] Jackson, M.L. (1973). Soil Chemical Analysis. Delhi, India: Prentice-Hall, India.

[14] Shelton, W.R. and H.J. Harper (1965). A rapid method for the determination of total phosphorus in soil and plant material. Iowa State College Journal of Sci., 15: 403-413.

[15] Dhingra, O.B. and Sinclair, J.(1985). Plant pathology methods.Plant Diseases Research Technique, pp.355.

[16] Little, T. M. and F. J. Hills (1977). Agricultural experimental desighn and analysis. London Group Ltd.

[17] Mauromicale, G., Lo Monaco, A., Longo, A.M.G., & Restuccia, A. (2005). Soil solarization, a non-chemical method to control branched broomrape (Orobanche ramosa) and improve the yield of greenhouse tomato. Weed Sci., 53, 877-883.

[18] Scopa, A., V. Candido, S. Dumontet and V. Miccolis. 2008. Greenhouse solarization: effects on soil microbiological parameters and agronomic aspects. Scientia Horticulturae. 116: 98-103.

[19] Zayed, M.S., M.K.K. Hassanein, N.H. Esa, M.M.F. Abdallah (2013). Productivity of pepper crop(Capsicum annuum L.) as affected by organic fertilizer, soil solarization, and endomycorrhizae.Annals of Agricultural Sciences, vol.58,iss.2, pp.131-137.

[20] Bonanomi, G., M. Chiurazzi, S. Caporaso and G. Del Sorbo, G. Moschetti and S. Felice. 2008. Soil solarization with biodegradable materials and its impact on soil microbial communities. Soil Biology & Biochemistry. 40: 1989-1998.

[21] Chen, Y., Gamliel, A., Stapleton, J.J., & Aviad, T. (1991). Chemical, physical, and microbial changes related to plant growth in disinfested soils. In: Katan, J., DeVay, J.E. (Eds.), Soil Solarization. CRC Press, Boca Raton, pp. 103-129.

[22] Patricio, F.R.A., Sinigaglia, C., Barros, B.C., Freitas, S.S., Tessarioli Neto, J., Cantarella, H., & Ghini, R. (2006). Solarization and fungicides for the control of drop, bottom rot and weeds in lettuce. Crop Protection, 25, 31-38.

[23] Sunbol, Y. H.. & F.A. Al-Fasi (2006). Effect of Soil Solarization and Animal Manure Addition on the Biological Activity of Soil Microorganisms. African Studies Review, 28: 65-71.

[24] Culman, S.W., Duxbury, J.M., Lauren, J.G., & Thies, J.E. (2006). Microbial community response to soil solarization in Nepal's rice-wheat cropping system. Soil Biology & Biochemistry, 38, 3359-3371.

[25] Ozores-Hampton, M.P., Obreza, T.A., & Stoffella, P.J. (2001). Mulching with composted municipal solid waste for biological control of weeds in vegetable crops. Compost Sci. Utilization, 9, 352-361.

[26] Arora, A. and N.T. Yaduraju. 1998. High temperature effects on germination and viability of weed seeds in soil. Journal of Agronomy and Crop Science 181 (1): 35 – 43.

[27] Block, W.J., Lamers, J.G., Termorshuizen, A.J., & Bollen, G.J. (2000). Control of soil-borne plant pathogens by incorporating fresh organic amendments followed by trapping. Phytopathol. 90, 253-259.

[28] Benlioglu, S., O. Boz, A. Yildiz, G. Kaskavalci and K. Benlioglu. 2005. Alternative soil solarization treatments for the control of soil-borne diseases and weeds of strawberry in the Western Anatolia of Turkey. Journal of Phytopathology. 153, 423-430.

[29] Seman-Varner, R.,. McSorley, R., & Gallaher, R.N. (2008). Soil nutrient and plant responses to solarization in an agroecosystem utilizing an organic nutrient source. Renewable Agriculture and Food Systems. 23, 149-154. doi:10.1017/S1742170507002001G.