Plant Archives Vol. 20 Supplement 1, 2020 pp. 1641-1647 **e-ISSN:2581-6063 (online), ISSN:0972-5210**

EFFECT OF SOIL SOLARIZATION FOR WEED MANAGEMENT IN *ABELMOSCHUS ESCULENTUS* L. MOENCH

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Abstract

Soil solarization is a non-chemical method in which the soil is heated to lethal temperature by using solar radiation for weed control. It can be an alternative to agricultural chemicals that have significant environmental risk and pose negative impact on the beneficial soil micro-organisms. In the present study, efficacy of soil solarization process was dependent on length of solarization period and temperature. The inhibitory effect of different duration of soil solarization on weed plants was in the order: 8 weeks > 6 weeks > 4 weeks > control. Maximum number of leaves/plant, pod number, pod length and weight, seed number and weight of seeds/pod of *Abelmoschus esculentus* L. Moench were observed in the pots which were filled with soil that was solarized upto 8 weeks. Hence, the high productivity of *Abelmoschus esculentus* can be obtained by the utilization of soil solarization process in agricultural fields.

Key words: *Abelmoschus esculentus,* soil solarization, weed management.

Introduction

India is an agricultural country and about sixty five percent of the population still relies on agriculture for employment and livelihood. Weeds are unwanted plants and these are also known as silent robbers of plant nutrients, soil moisture, solar energy and space which would otherwise be available to the main crop (Gage and Schwartz-Lazaro, 2019). Approximately 10% of plant species are weed species and they reduce the quality and quantity of agricultural production and produce allergens which adversely affect the health of the human - beings and animals (Kostov and Pacanoski, 2007). Weeds are different from other pests as the presence of weeds is relatively constant whereas outbreaks of insects and disease pathogens are sporadic (Gianessi and Sankula, 2003). The presence of weed in the crop fields reduces the crop yield and quality of forage or make them unpalatable or even poisonous to livestock (Anon, 2013). The total annual loss of agricultural produce in India due to weeds 45%, insects 30%, diseases 20% and other pests 5% (Rao, 2000). Weeds can be controlled in the crop fields by hand weeding, application of pesticides and use of cultural practices such as crop rotation (Sims *et al.,* 2018). All the above mentioned methods are time-consuming, costly and not feasible for weed control at large scale (Agahiu *et al.,* 2011). There are reports that farmers use more than two million tonnes of chemical pesticides each year for the protection of crops against pests worldwide (Mathur, 1999). Pesticides are not only expensive for farmers in developing countries but continuous use of pesticides pollute environment, water, soil and agricultural produce and causes toxicity in the succeeding crop (Yardim and Edwards, 2002). It has been found that long-term exposure of pesticides causes harmful effects on human health such as immune suppression, hormone disruption, reproductive abnormalities and cancer etc (Agarwal *et al.,* 2015). Increasing public concern on environmental issues requires alternative pest management strategies which are safe, eco-friendly and cost effective. Hence, there is an urgent need for alternative solution for weed control such as soil solarization, alone or in combination with other methods (Cohen *et al.,* 2008).

Soil solarization is a non-chemical, hydrothermal method of soil disinfestation in which soil captures the radiant energy of sunlight under the transparent polyethylene sheet (Kapoor, 2013; Gill and Garg, 2014; Cohen *et al.,* 2019). The solar energy heats the soil and

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when the soil moisture is adequate inside the polythene sheet, heat pasteurizes the soil and kills the harmful pests but leaves the intact population of beneficial soil microbes which promotes the plant growth (Lombardo *et al.,* 2012). The utilization of soil solarization technique for controlling weeds is a potential step to reduce the dependence on chemicals and synthetic pesticides (Ghosh and Dolai, 2014). In India, abundant solar radiation is available almost round the year but the practice of soil solarization is not popular in farming communities. Gill *et al.,* (2013) reported that soil solarization is a safe pest management practice for small and marginal farmers as it has potential to increase the crop yield.

Abelmoschus esculentus L. is commonly known as okra, ladies finger or bhindi. Bhindi is a warm season vegetable crop and it belongs to the family Malvaceae. Okra is a nutritious vegetable as it contains fiber, vitamins and minerals such as calcium, iron and potassium etc. Okra contains flavonoid antioxidants such as beta-carotene, xanthine and lutein (Akanbi *et al.,* 2010). The mucilage present in the pods of *Abelmoschus esculentus* L. has several medicinal properties and it can be used as emollient, laxative and expectorant (Khan *et al.,* 2000). Okra is known to aid in prevention of several diseases such as diabetes, high cholesterol level, constipation, asthma and colon cancer etc. Weeds are the major constraint in the production of *Abelmoschus esculentus* L. as the yield loss in okra due to weeds varied from 40 to 80% depending on the type of weed flora and their stage (Sharma and Patel, 2011). The uncontrolled weed growth reduces pod yield in okra by 88-93% as compared to weed free crop (Melifonwu, 1999). Earlier workers have reported the use of soil solarization technique in reducing weed population (Gill *et al.,* 2009) but unfortunately no work has been done to study the effect of soil solarization process for weed control in okra. Keeping this in view, the present work was carried out to study the effect of different solarization period (4, 6 and 8 weeks) on the weeds present in the soil used for the cultivation of okra and impact of different solarization period on the growth and productivity of *Abelmoschus esculentus*.

Materials and methods

The present experiment was conducted in the Plant Physiology Laboratory, Amity Institute of Biotechnology, Amity University, Noida, India.

Experimental design

Soil solarization treatment

Soil samples were collected from two different sites, mixed properly and passed through a 2 mm sieve in order to give uniform sample. The four plots were prepared in which one plot was kept as control (unsolarized) and three different plots were kept for solarization process for 4,6 and 8 weeks respectively. The fertilizer NPK was also added in the plots. A clear and transparent polythene sheet (1 mil = 0.001 inch or 0.025 mm thickness) was used for solarization process as thin polythene sheet provides better heating. The soil used for solarization process was free of clods and crop debris and it was thoroughly watered to a depth of 12-15 inches because wet soil conducts heat better than dry soil (Kapoor, 2013). The polythene sheet for soil solarization process was tightly applied on the soil surface to minimize air gaps and damage from wind. The polythene sheet was regularly inspected and entry into the plots covered with polythene sheet was avoided.

Assessment of soil temperature

During solarization, soil temperature was recorded continuously once a day (at 12:00 PM) for 8 weeks at 5 and 10 cm depth respectively by using a digital electronic thermometer. The plastic sheet was removed after 4, 6 and 8 weeks respectively of solarization period and treated soil was kept in black polythene bags for further use.

Pot study

Certified, healthy and uniform seeds of okra (*Abelmoschus esculentus* L. Moench var. Pusa Makhmali) were procured from Indian Agricultural Research Institute (IARI), New Delhi. Seeds of okra were thoroughly washed with tap water to remove dirt and dust for 5 min. The okra seeds were surface sterilized with 10:1 distilled water/ bleach (commercial NaOCl) solution for 5 min to avoid microbial contamination and then washed 6 - 7 times with distilled water (ISTA, 2008). Thirty seeds were divided into three replicates of 10 seeds each and seeds were soaked for 12 hours in distilled water before sowing.

The earthen pots of 25 cm deep and 25 cm in diameter were filled with equal weights of 12 kg of sandy loam soil. The NPK fertilizer was also added in the soil. Ten viable seeds of okra (*Abelmoschus esculentus* L. Moench var. Pusa Makhmali) per pot were sown about 3 cm deep in the pots and thin layer of soil was applied. The plants were thinned to five plants per pot at 12 DAS (days after sowing) and crop was irrigated every second day during summer season.

Identification of weed

Regular observation was made to study the presence of weed both in unsolarized (control) and solarized pots.

Growth parameters

The different growth parameters of *Abelmoschus esculentus* L. Moench var. Pusa Makhmali such as number of leaves/plant, pod length, height of the plant, pod weight, seed number/pod and seed weight/pod were recorded at 45 DAS which were grown in unsolarized (control) and solarized soil (4, 6 and 8 weeks) respectively.

Statistical analysis

All the experiments were carried out in triplicate. One way ANOVA was carried out for all the data generated from the experiment using GPIS package (GRAPHPAD, California, USA).

Results and Discussion

In the present study, four plots were prepared in which one plot was kept as control (unsolarized) and three different plots were kept for solarization process for 4, 6 and 8 weeks respectively. The effect of different period of soil solarization was studied on the weed population in *Abelmoschus esculentus* L. Moench. The maximum soil temperature was reported at a depth of 5 cm in comparison to 10 cm of the soil after different duration of soil solarization (Fig. 1). At 5 cm depth, highest soil temperature 54^0C was observed under polyethylene sheet covered plots after 8 weeks whereas it was only 35^0C in the control plots. At 10 cm depth, maximum soil temperature 47^0C was observed after 8 weeks whereas it was only 29^0C in the control plots. In both depths, soil temperature was higher in solarized plots as compared to unsolarized (control) plot.

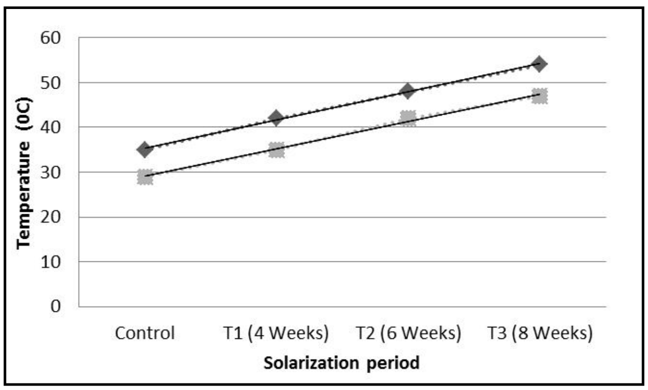

Fig. 1: Measurement of temperature at different depths of control (unsolarized) and solarized soil.

Where T_1, T_2 and T_3 indicate soil solarization treatment for 4, 6 and 8 weeks respectively.

The weeds such as *Avena fatua, Amaranthus spinosus, Chenopodium album, Convolvulus arvensis, Cynodon dactylon, Cyperus rotundus, Digera arvensis, Echinochloa colona, Parthenium hysterophorus* and *Sorghum halepense* were observed in the control (unsolarized) pots cultivated with okra seeds (Table 1). After 4 weeks of soil solarization, *Avena fatua, Cynodon dactylon, Cyperus rotundus* and *Parthenium hysterophorus* were observed but after 6 weeks of soil solarization only *Cynodon dactylon* and *Parthenium hysterophorus* weeds were observed with less number of weed seedlings. No weeds were observed in the pots containing soil which was solarized upto 8 weeks (Table 2). The eight weeks duration of soil solarization was regarded as the best treatment as it completely reduced weed seedlings in comparison to the untreated control. It has been observed that higher weed infestation brings severe competition for light which may reduce stomata number, photosynthetic ability of the crop and crop yield (Fabro and Rhodes, 1980).

The different growth parameters of *Abelmoschus esculentus* such as number of seedlings/pot, number of leaves/plant, height of the plant, pod length and weight, seed number/pod and seed weight/pod were analyzed at 45 DAS in the pots treated with solarized and unsolarized (control) soil. The soil solarization for 8 weeks increased the okra yield and it was effective for controlling the weeds. Maximum number of weed seedlings were observed in control pots (Fig. 2).

The number of leaves/plant was significantly reduced in control and it may be due to the competition of crop

Table 1: Type of a weed present in unsolarized and solarized soil.

S.No.	Weed	Common name	Plant Family	Growth of weed
1.	*Avenafatua*	Wild oat	Poaceae	Annual grass
2.	*Amaranthusspinosus*	Thorny amaranth	Amaranthaceae	Annual broad leaf weed
3.	*Chenopodium album*	Bathua	Chenopodiaceae	Annual weed
4.	*Convolvulus arvensis*	Bind weed	Convolvulaceae	Perennial herb
5.	*Cynodondactylon*	Bermuda grass	Poaceae	Perennial grass
6.	*Cyperusrotundus*	Nut sedge	Cyperaceae	Perennial sedge
7.	*Digeraarvensis*	Lesua	Amaranthaceae	Annual weed
8.	*Echinochloacolona*	Jungle ricegrass	Poaceae	Annual grass
9.	*Partheniumhysterophorus*	Gajarghans	Asteraceae	Annual weed
10.	*Sorghum halepense*	Johnson grass	Poaceae	Perennial grass

Table 2: Intensity of the weeds present in unsolarized and solarized soil.

S. No.	Weed	Degree of occurrence of weeds			
		Control(Unsolarized soil)	T_1 (4 weeks)	T_2(6 weeks)	T_3(8 weeks)
1.	*Avenafatua*	+++	++	-	-
2.	*Amaranthusspinosus*	+++	-	-	-
3.	*Chenopodium album*	+++	-	-	-
4.	*Convolvulus arvensis*	+++	-	-	-
5.	*Cynodondactylon*	+++	++	+	-
6.	*Cyperusrotundus*	+++	++	-	-
7.	*Digeraarvensis*	+++	-	-	-
8.	*Echinochloacolona*	+++	-	-	-
9.	*Partheniumhysterophorus*	+++	++	+	-
10.	*Sorghum halepense*	+++	-	-	-

Where T_1, T_2 and T_3 indicate soil solarization treatment for 4, 6 and 8 weeks respectively.
Signs such as -= No weed, + = Low weed occurrence, ++ = Medium weed occurrence, +++ = High weed occurrence

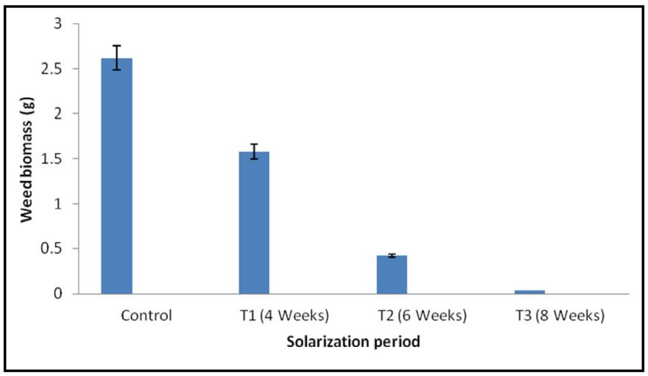

Fig. 2: Weed biomass in control (unsolarized) and solarized soil cultivated with *Abelmoschus esculentus* L.
Where T_1, T_2 and T_3 indicate soil solarization treatment for 4, 6 and 8 weeks respectively.

seeds with weed seeds. Significant increase 12, 25 and 75% in leaf number/plant was observed in T_1, T_2 and T_3 treatment respectively over the control plants. The increase in pod length in $T_{1,}$ T_2 and T_3 treatment was 12.16, 24.32 and 48.65% respectively over the control (Table 3). Growth of the plants can be determined best by taking plant height into consideration. The plant height exhibited increasing trend in treatment over control. A significant increase in plant height 8.69, 17.39 and 21.74% was observed in T_1, T_2 and T_3 treatment respectively over control okra plants. The pod weight was also increased in treatment with maximum increase 41.55% in T_3 treatment. The increase in number of okra seeds/pod was observed 12, 24 and 36% with $T_{1,}$ T_2 and T_3 treatment respectively. Maximum 74.77% increase in seed weight/ pod was observed in T_3 treatment over control.

The total biomass and yield of *Abelmoschus esculentus* L. was higher in the pots containing solarized soil in comparison to unsolarized soil (Figure-3 and 4). The inhibitory effect of different duration of soil solarization on weeds in the pots cultivated with *Abelmoschus esculentus* L. seeds was in the order: 8 weeks > 6 weeks > 4 weeks > control.

Temperature has a significant influence on physiological and biochemical processes of plants. During solarization period approximately 85-95% of radiation from

Table 3: Effect of soil solarization on the growth parameters of *Abelmoschus esculentus* L. Moench at 45 DAS.

S. No.	Growth parameters	Control	Duration of solarization (Weeks)		
			T_1(4 Weeks)	T_2(6 Weeks)	T_3(8 Weeks)
1.	Plant height (cm)	$46^a \pm 0.18$	$50^a \pm 0.23$(8.69)	$54^a \pm 0.67$(17.39)	$56^a \pm 0.95$(21.74)
2.	Leaf number / plant	$8^c \pm 0.04$	$9^c \pm 0.07$(12.5)	$10^c \pm 0.09$(25)	$14^a \pm 0.10$(75)
3.	Pod length/pod (cm)	$7.4^b \pm 0.03$	$8.3^c \pm 0.09$(12.16)	$9.2^c \pm 0.16$(24.32)	$11^a \pm 0.28$(48.65)
4.	Pod diameter (cm)	$7.2^b \pm 0.01$	$8.1^c \pm 0.03$(12.5)	$8.4^c \pm 0.07$(16.67)	$8.8^c \pm 0.09$(22.22)
5.	Pod weight (g)	$9.82^c \pm 0.08$	$10.76^c \pm 0.10$(9.57)	$12.73^c \pm 0.21$(29.63)	$13.90^c \pm 0.57$(41.55)
6.	Number of pods/plant	$4.8^d \pm 0.02$	$5.2^b \pm 0.05$(8.33)	$5.9^d \pm 0.06$(22.92)	$6.8^c \pm 0.08$(41.67)
7.	Seed number/pod	$25^a \pm 0.09$	$28^a \pm 0.15$(12)	$31^a \pm 0.27$(24)	$34^a \pm 0.86$(36)
8.	Seed weight / pod (g)	$2.18^d \pm 0.02$	$3.05^b \pm 0.04$(39.91)	$3.24^d \pm 0.06$(48.62)	$3.81^d \pm 0.09$(74.77)

Values are mean of three replicates ± sem.
Figures in parentheses indicate percent stimulation over control.
Where T_1, T_2 and T_3 indicate soil solarization treatment for 4, 6 and 8 weeks respectively.Different letters in each group show significant differences at $P < 0.05$.

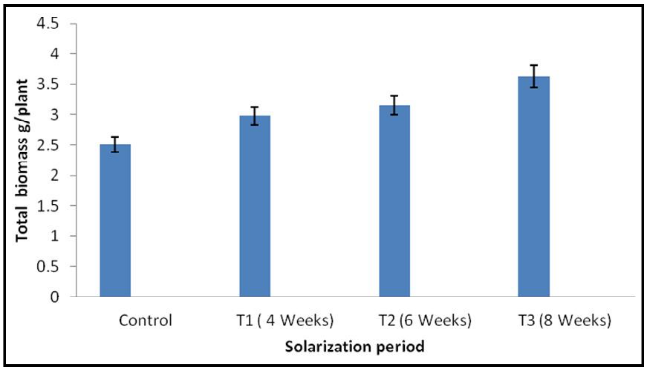

Fig. 3: Total biomass of *Abelmoschus esculentus* L. in control (unsolarized) and solarized soil.
Where T_1, T_2 and T_3 indicate soil solarization treatment for 4, 6 and 8 weeks respectively.

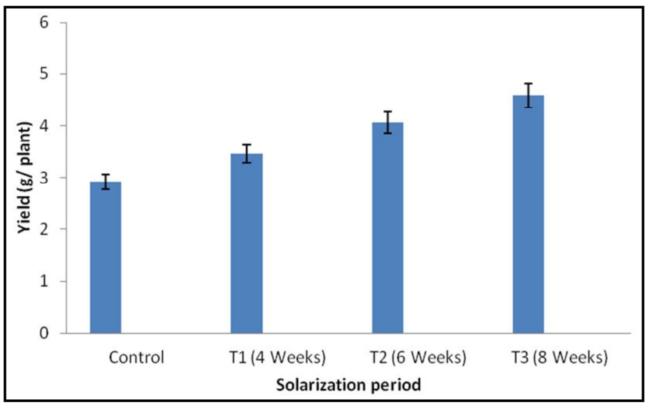

Fig. 4: Yield (g/ plant) of *Abelmoschus esculentus* L. in control (unsolarized) and solarized soil.
Where T_1, T_2 and T_3 indicate soil solarization treatment for 4, 6 and 8 weeks respectively.

sunlight penetrates the soil and raises the soil temperature (Lamont, 2005). Soil solarization technology can increase soil temperature to the lethal level in the top soil where most of the viable weed seeds are present (Soumya *et al.,* 2004). This process does not leave any toxic residues in the soil and it is not harmful for beneficial microbes present in the soil. It has been observed that growth of *Abelmoschus esculentus* was significantly increased when grown in solarized soil in comparison to non-solarized soil (Table 3). The soil solarization process speeds up the breakdown of the organic materials present in the soil and increases the amount of soluble nutrients such as nitrate, ammonium, calcium, magnesium, potassium and fulvic acid which are essential for the growth of plants. The addition of organic matter in the soil before solarization process increases the efficacy of the solarization process for the control of weeds. The high temperature may cause changes in enzyme activity, membrane structure, carbohydrate and protein metabolism of the pests (Singla *et al.,* 1997). Horowitz *et al.,* (1983) reported high concentration of CO_2 in the soil atmosphere during solarization process which can induce seed dormancy and reduction in the number of weed seedlings. The decline in the viability of weed seeds during solarization process depends on the soil temperature and exposure time (Lalitha *et al.,* 2003). Moya and Furukawa (2000) reported that soil solarization technique reduced the growth of *Amaranthus hybridus, Galinsoga parviflora, Medicago arabica, Stellaria media, Sonchus oleraceus* and *Coronopus didymus*.

Katan (1981) found better growth and development of plants and higher number of flowers in ornamental crops treated with solarized soil as compared to unsolarized soil. Gruenzweig *et al.,* (1993) reported that increased growth response and yield of plants due to soil solarization may be related with the number of physiological changes such as increased photosynthetic activity, high protein level, accelerated tissue development and delayed senescence (Abdallah, 2000). Pinkerton *et al.,* (2000) found an increase of soil temperature from 2-3°C in solarized soils amended with chicken manure. Solarization process has increased the yield of several crops such as faba bean (Mauromicale *et al.,* 2001), tomato (Sahile *et al.,* 2005), soybean (Megueni *et al.,* 2006), potato (Ngakou *et al.,* 2006) and table beet (Gasoni *et al.,* 2008). Wang *et al.,* (2008) found that solarization treatment increased broccoli yield by 64% as compared with the non-solarization treatment. Cimen *et al.,* (2010) reported that soil solarization provides excellent control of soil-borne pathogens with significant increase in yield of pepper plant. The increase in temperature of soil allows effective weed control without any adverse impact on environment and no hazards to field workers. Soil solarization is a cost-effective and safe practice which can be an important component for weed management strategy in the crop fields.

Conclusion

Soil solarization is simple, safe, cost-effective and eco-friendly technology for weed control in *Abelmoschus esculentus* L. Unfortunately in our country most of the farmers are not aware about the application of soil solarization technology for weed management and safe crop production. Hence there is an urgent need for the popularization of the soil solarization process among the farmers through the workshops and mass awareness programmes. Furthermore, impact of soil solarization on the biochemical components of the crop plants should be identified before long-term adaptation of this alternative weed management strategy.

Acknowledgement

The author is thankful to Prof. Chanderdeep Tandon, Director, Amity Institute of Biotechnology, Amity University, Noida for offering laboratory and library facilities to carry out this study.

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