Journal of Agricultural Technology 2013 Vol. 9(7):1863-1872
Available online http://www.ijat-aatsea.com
ISSN 1686-9141

Evaluation of soil solarization and amendments as production practices for lettuce and vegetable soybean in northern Thailand

Robert J. McGovern[1*], Worawan Chaleeprom[2], Witcha Chaleeprom[2], Pnitpim McGovern[1] and Chaiwat To-anun[3]

[1]NBD Research Co., Ltd., Lampang, Thailand; [2]Maejo University, Faculty of Agricultural Production, Chiang Mai, Thailand, [3]Department of Plant Pathology, Chiang Mai University, Chiang Mai, Thailand

Robert J. McGovern, WorawanChaleeprom, WitchaChaleeprom, Pnitpim McGovern and Chaiwat To-anun (2013) Evaluation of soil solarization and amendments as production practices for lettuce and vegetable soybean in northern Thailand. Journal of Agricultural Technology 9(7):1863-1872.

Soil solarization was evaluated alone and in combination with aqueous suspensions of *Trichoderma*sp. or earthworm compost, as preplant practices for vegetable soybean and lettuce in Northern Thailand. Solarization was conducted for 2 months in May through July using 30-um-thick, clear, UV-stabilized, LDPE mulch applied to 6 x 0.8 x 0.013 m and 6 x 1.0 x 0.012 m (LxWxH) beds at sites in Lamphun and Sankampaeng, respectively. Following mulch removal, 5 L/m^2 of a 1:20 dilution of each of the two soil amendments was applied at seeding (soybean, 'AGS 292') or transplanting (lettuce, 'Butterhead MJ 7'). Soil temperatures were increased by solarization at each depth measured. Solarization and the two soil amendments produced non-significant yield increases in lettuce. Soybean yield was significantly increased by solarization and in some cases the effectiveness of solarization was increased by combination with the soil amendments compared with the non-treated control and commercial standard. Soil solarization significantly reduced weed coverage of beds by about 90% at both sites that lasted through harvest.

Keywords: soil solarization, biological control, weed management, *Trichoderma*, earthworm compost, sustainable agriculture

Introduction

Soil solarization has been evaluated in many countries over the past three decades as a non-chemical, sustainable method for managing soilborne plant pests including plant pathogens and weeds. Solar soil disinfestation uses clear mulch to trap solar radiation to elevate soil temperatures which inactivate plant pests. This technique is of interest because of its relatively benign

[*]Corresponding author: Robert J. Mc Govern, email: rjtmcgov@gmail.com

environmental impact compared with other preplant practices such as fumigation (Katan and Devay, 1991; McGovern and McSorley, 1997; McGovern, 2010). The greatest temperature increase resulting from solarization occurs near the soil surface, in the upper 10-30 cm of soil. Successful soil solarization can heat the upper 5 cm of soil to temperatures of 45-55^{o}C or higher, which may be more than 10^{o}C greater than temperatures at 15-20 cm (Katan, 1981; McGovern and McSorley, 1997).

Reduction of pests by soil solarization has been attributed to both direct and indirect modes of action. Direct pest inactivation may occur if the temperature/exposure time is sufficient, or pests may be weakened by exposure to sublethal temperatures (DeVay and Katan, 1991; McGovern and McSorley, 1997; Stapleton and DeVay, 1986). Indirect reduction of pest densities may occur because of the increase of antagonistic micro- organisms, including those which are thermophilic/thermotolerant or can rapidly recolonize solarized soil. (Gamliel and Katan, 1991; Mc Govern and McSorley, 1997; Stapleton and DeVay, 1982, 1984).Solarization may also change the physical structure and chemical composition of soil and lead to increased soil moisture levels, accumulation of volatiles, and changes in the soil gas composition which are detrimental to pests, and/or increased nutrient availability for plants (Katan, 1981; Patricio *et al*., 2006; Stapleton and DeVay, 1983). Removal of nutrient sources may also help to lower pest densities.

Typically solarization is conducted for one month or longer during the summer in areas with little attendant cloud cover or precipitation (Katan, 1980). Results with solarization have been variable in summer in subtropical and tropical locations with frequent rainfall including peninsular Florida (McGovern and McSorley, 1997). The rainfall pattern in Thailand is similar to that of Florida with the greatest precipitation occurring in April through October (World Weather Information Service, 2008-2009). Combination of solarization with other practices such as the application of biological controls and various other soil amendments has in some cases resulted in an enhancement of the effectiveness of the technique (McGovern and McSorley 1997; McGovern, 2010).

Research on soil solarization in Thailand has been limited to management of bacterial wilt in tomato caused by *Ralstoniasolanacearum* (Phitthayarachasa *et al*., 2009).To our knowledge this technique has not been employed in the field in Northern Thailand. Fumigation in the country is generally limited to postharvest uses and pre-plant techniques available to control soilborne pests include pesticide application, biological control, host resistance and crop rotation. Our research objective was to evaluate the individual and combined effects of soil solarization in summer and soil amendments (*Trichoderma*sp. or earthworm compost) as pre-plant practices for vegetable soybean and lettuce in Northern Thailand.

Materials and methods

Experimental sites

Fields in Lamphun and Sankampaeng, Northern Thailand consisting, respectively, of sandy loam and clay loam were used for the evaluation of soil solarization. The field in Lamphun was part of an organic farm that produced vegetables and rice. The field in Sankampaeng was in a commercial farm used for vegetable soybean, rice and mango production. The weed population at the Lamphun site consisted of about 85% boad-leafs and 15% grasses while the field in Sankampaeng had an extremely high nutsedge (*Cyperus*spp.) density (~100 plants/0.09 m^2).

Experimental treatments

A randomized complete block design was used for the research with four replications (raised beds) in Lamphun and six replications (raised beds) in Sankampaeng. The bed dimensions (length x width x height) at Lamphun were 6.0 x 0.8 x 0.013 m and at Sankampaeng 6.0 x 1.0 x 0.012 m. Soil solarization was conducted from 26 May to 21 July at Lamphun and from19 May to 23 July, 2009 at Sankampaeng using clear**,** 30- µm-thick, UV-stabilized, LDPE solarization mulch (E1302, A. A. Politiv Ltd., Einat, Israel).

Soil amendments consisted of *Trichoderma* sp. (Chiangmai Pest MangementCenter, Chiang Mai, Thailand) and earthworm compost (Department of Soils and Environmental Resources, Maejo University, Chiang Mai, Thailand). Five liters of an aqueous suspension of the amendments (1:20, W/V) were applied to beds after seeding (vegetable soybean) and transplanting (lettuce). An equal volume of water was applied to control (non-amended) plots. A standard grower cultural regime was also included at the vegetable soybean site for comparison with the experimental treatments. Although this cultural regime was proprietary it followed generally accepted practices for production of vegetable soybean in Asia (Lal *et al.*, 2001). The nutsedge pressure was so high that the herbicide paraquat (GramoxoneInteon®, Syngenta Crop Protection, Inc.) was applied to all beds prior to planting where solarization was not employed.

Twenty 3-week-old transplants of lettuce (*Latucasativa*L.) cv. Butterhead MJ 7 were planted per plot in Lamphun. One hundred and fourteen seeds of vegetable soybean (*Glycine max* L. Merrill) cv. AGS 292 treated with the fungicide mefenoxam (Apron®, Syngenta Crop Protection, Inc.) were planted per plot in Sankampaeng. Apron was applied for prevention of downy mildew (*Peronosporamanshurica*) in the vegetable soybean and has activity against other chromistan fungi such as *Pythium*and *Phytophthora*. Except for the standard grower treatment for vegetable soybean no fertilizer was applied to any of the plots at either site. Plants were irrigated by rainfall irrigation system.

Data acquisition

Soil temperatures were measured at 3:00 pm during solarization at 5, 15 and 23 cm in a non-solarized (control) and solarized plot at each site by means of soil thermometers. The mulch was removed at the termination of solarization and the weed density (% bed coverage) was recorded. Lettuce plants were harvested and weighed on a per plot basis on 20 Aug, 2009. Soybeans were harvested on 23 Sept, 2009 and the total weight of soybeans per plot was determined. In addition, plant fresh weight, the number and weight of 2- and 3-seeded pods and Brix was determined based on five plants per plot.

Treatment means were separated using Fisher's Protected LSD Test following analysis of variance (Anonymous, 2004). Arc-sine square root transformation was used where appropriate on percentage data prior to statistical analysis (Gomez and Gomez, 1984); non-transformed data is presented.

Results and discussions

Solarization using clear mulch increased the soil temperatures at 5, 15 and 23 cm compared to non-mulched soil at both sites (Figures 1-4). However, temperatures required for rapid inactivation of many plant pests (≥ 50 C) only occurred at the shallowest depths, 5 and 15 cm, in this research. No effect on weed control was observed due to application of either of the soil amendments. Solarization significantly reduced weed density (% bed coverage) of broad leaf weeds and grasses at Lamphun and nutsedge at Sankampaeng by about 90% (Figure 5). The weed control exhibited by solarization persisted through the entire growing season at both sites; this was noteworthy in the case of nutsedge which is considered to be one of the world's most difficult-to-control weeds (Holm *et al.*, 1977). Control of *Cyperus* spp. by summer solarization was reported in Florida (Chase *et al.* 1999). A temperature of 60°C required to rapidly (1 hour) kill purple nutsedge tubers was not achieved in this research (Smith and Fick, 1937). However, an oscillating temperature regime with a daily maximum of 50°C shown to be lethal to tubers of both purple and yellow nutsedge (Chase, 1999) was achieved on a number of days at both sites.

All treatments produced non-significant increase in lettuce yield compared with the control (Table 1). The solarization treatments at this site were subjected to damage by errant cows until fences were set up around the experiment. In spite of rapid repairs to the mulch with clear plastic tape, it was possible that such repeated damage compromised the effectiveness of solar heating and led to unexpected variability in the experiment. Application of earthworm compost or *Trichoderma* sp. suspensions failed to increase biomass, or weight and number of 2- and 3-seeded pods; earthworm compost significantly decreased the weight of 3-seeded pods (Table 2). Solarization alone significantly increased plant biomass and soybean pod yield compared to the non-treated control and standard commercial treatment. Combining solarization with earthworm compost significantly increased the number and weight of 3-seeded pods compared to the non-treated control and commercial standard treatment. Combination of solarization with *Trichoderma*significantly increased the weight of 3-seeded pods compared with the non-treated control and commercial treatment and the number and weight of 2-seeded pods compared with the non-treated control. Brix was unaffected by the treatments. Singh *et al.* (2004) observed an increase in yield of soybeans from solarization conducted for 5 weeks in India but the technique failed to control various grass and broadleaf weed species throughout the growing season (Singh *et al*., 2004). An increase in soybean biomass and seed yield following solarization for 2 months in Cameroon has also been reported (Megeuni *et al*., 2006).

These preliminary experiments indicated that soil solarization may have potential as a pre-plant treatment for crop production in Thailand alone and in combination with certain soil amendments even during the rainy season. This research needs to be repeated and the evaluation of solarization in the country needs to be expanded to other crops and pests including plant pathogens and nematodes and evaluated at different times of the year.

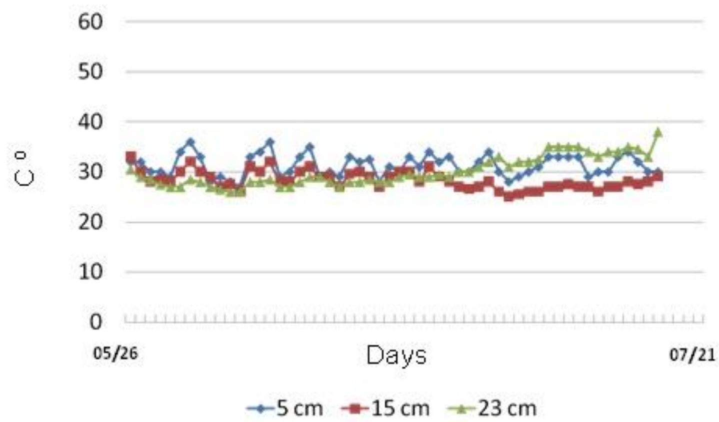

Fig. 1. Soil temperatures at Lamphun – bare soil (3:00 pm)

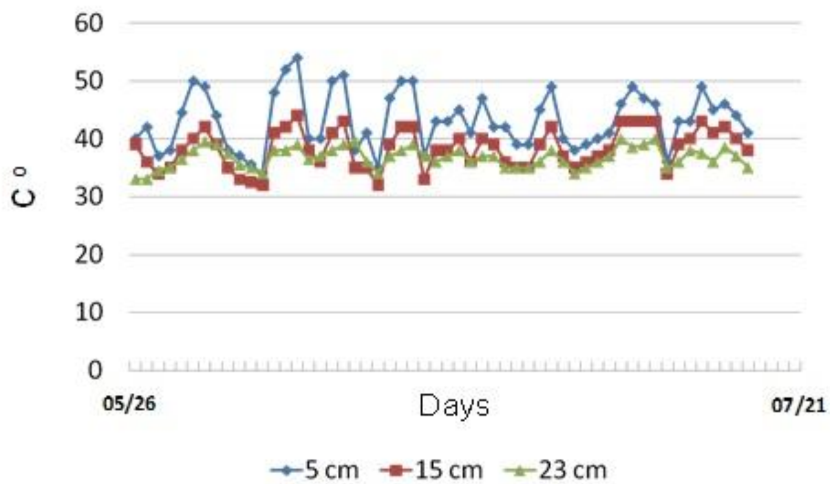

Fig. 2. Soil temperatures at Lamphun – clear plastic mulch (3:00 pm)

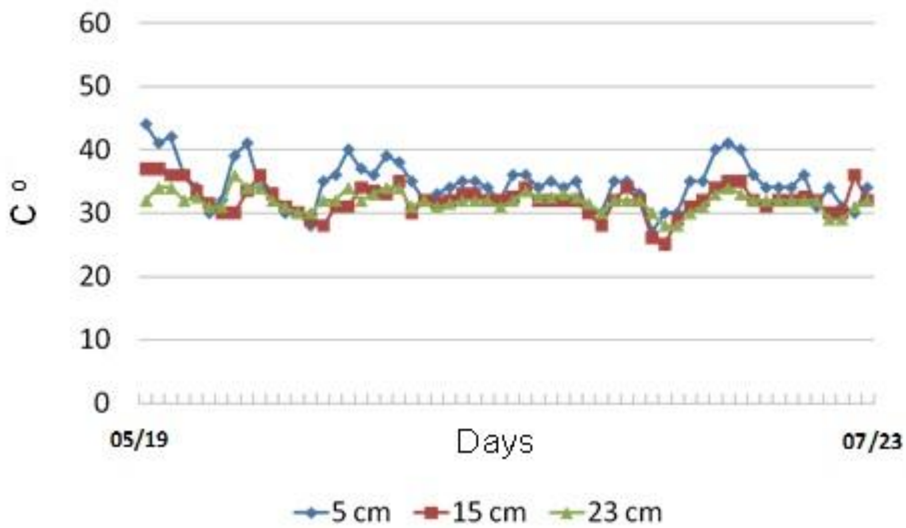

Fig. 3. Soil temperatures at Sankampaeng – bare soil (3:00 pm)

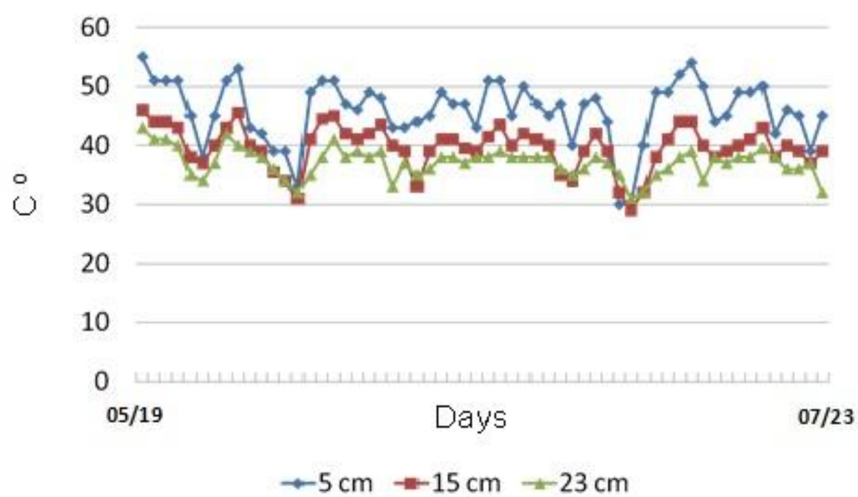

Fig. 4. Soil temperatures at Sankampaeng - clear plastic mulch (3:00 pm)

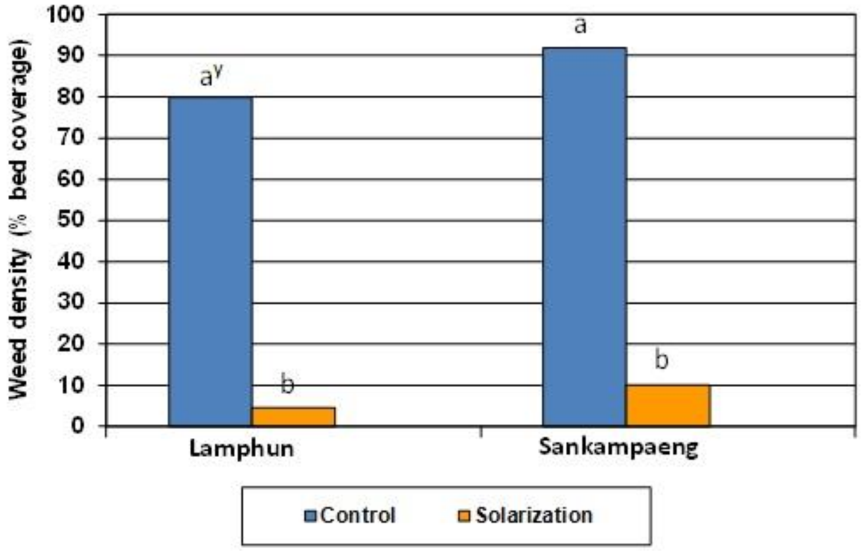

Fig. 5. Effect of soil solarization on weed density[x] at Lamphun and San Kampaeng, Thailand - 2009
[x]The weed population at Lamphun was about 85% broadleafs and 15% grasses and at Sankampaeng about 100% nutsedge.
[y]Different letters indicate that the means are significantly different at $P<0.05$ by Fisher's Protected LSD

Table 1. Effect of soil solarization and amendments[x] on yield in 'Butterhead MJ 7' lettuce Lamphun, Thailand, 2009

Treatment	Weight (g)/plot
Control	677.0 a[y]
Control + earthworm compost	840.5 a
Control + *Trichoderma*sp.	717.5 a
Solarization	727.5 a
Solarization + earth. compost	812.5 a
Solarization + *Trichoderma*sp.	853.8 a

[x]Amendments were applied as an aqueous suspension (1:20, W/V) to soil.
[y]Means followed by the same letter are not significantly different ($P<0.05$) by Fisher's Protected LSD Test.

Table 2. Effect of soil solarization and amendments[x] on growth and yield in vegetable soybean 'AGS292', San Kampaeng, Thailand, 2009

Treatment	Plant biomass/5 plants (g)	Soybean pod yield/plot (kg)	No. 3-seeded pods/5 plants	Wt. 3-seeded pods/5 plants (g)	No. 2-seeded pods/5 plants	Wt. 2-seeded pods/5 plants (g)	Brix
Control*[y]	163 b[z]	4.1 b	26.4 bc	100 c	82.2 bc	215 bc	27.4 a
Control+ earthworm compost (EC)*	152 b	4.3 b	16.6 c	64 d	67.2 c	191 c	28.2 a
Control+ *Trichoderma**	172 b	4.2 b	24.6 bc	99 c	78.8 bc	228 bc	27.0 a
Solarization	203 a	6.0 a	31.0 ab	122 bc	89.2 ab	250 ab	27.2 a
Solar+EC	210 a	6.1 a	39.2 a	156 a	94.6 ab	264 ab	26.2 a
Solar+Trich	210 a	6.5 a	34.4 ab	142 ab	99.8 a	281 a	27.4 a
Commercial Standard*	175 b	4.8 b	25.0 bc	100 c	85.4 ab	235 abc	28.0 a

[x]Amendments were applied as an aqueous suspension (1:20, W/V) to soil.
[y] *Indicates that herbicide (paraquat) was applied for nutsedge control.
[z]Means followed by the same letter are not significantly different ($P<0.01$) by Fisher's Protected LSD Test.

Acknowledgements

The authors wish to thank Lanna Agro Industry Co., Ltd (LACO), Sankampaeng and Suan Buddha Dharma Foundation, Lamphun for providing the experimental sites, the (Chiangmai Pest Mangement Center, Chiang Mai, Thailand) and earthworm compost (Department of Soils and Environmental Resources, Maejo University, Chiang Mai, Thailand) for providing the *Trichoderma* sp. and earthworm compost, respectively, Ithzak Esquier, Israel Ministry of Agriculture and A. A. Politiv Ltd., Einat, Israel for providing and transporting the solarization mulch and Kessinee Kaeomala, Hattaya Pukdee and Karan Kanmai for technical assistance.

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(Received 22 November 2013; accepted 22 December 2013)