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# Soil Solarization for Managing Weeds in Cabbage *Brassica Oleraceae* var *Capitata* in Trinidad and Tobago

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**Abstract:** A study was conducted to evaluate the effectiveness of soil solarization at the University Field Station (UFS), Trinidad and Tobago, in a cabbage (*Brassica oleraceae* var. *capitata*) field naturally infested with weeds**.** Well prepared pre-irrigated plots 2.4m × 5.4m were covered with 4mm thick clear polyethylene sheeting for the duration of seven weeks from the14$^{th}$ February to 3$^{rd}$ April, 2007. Cow manure was incorporated at a rate of 500m$^3$/ ha in some solarized plots. Non-solarized plots were either treated with pre-emergent pendimethalin at a rate of 4.2L /ha three days after transplanting; treated with glyphosate two weeks before transplanting at a rate of 5L/ha in a stale seedbed preparation or were hand weeded. The cabbage variety salvation was transplanted on the 4$^{th}$ April, 2007. At the end of 10 weeks solarized plots were more effective in controlling weeds. Clear plastic give the best weed control (97.6%) followed by clear plastic + manure (96%) with pendimethalin giving 85.6% control. However, pendimethalin gave a more consistent control of weeds for the duration of the crop. At all stages of assessment of the soil weed seed bank there was no significant difference in the weed count. Clear plastic had the highest yield of 36.45 t/ha and was significantly different from all other treatments. This yield was almost twice that of stale seedbed which gave the next best result of 18.75 t/ha. Pendimethalin had the lowest yield of 4.563 t/ha and seemed to have an adverse effect on the growth of cabbage. Cabbage grew more vigorously on solarized plots. Clear plastic yielded the highest dry matter up to week eight, followed by clear plastic + manure and stale seedbed. At week 10 however stale seedbed produced the highest dry matter of 1.695 kg/m$^2$ but did not differ significantly from clear plastic (1.655 kg/m$^2$). Ten weeks after transplanting there was no significant difference in the weed dry matter among treatments although clear plastic had the lowest dry matter of 0.5g/ m$^2$. Soil temperature during solarization was generally higher in plots with only clear plastic than those with manure, averaging 38.86 $^o$C and 37.69 $^o$C respectively between the 43$^{rd}$ and 48$^{th}$ day. Soil solarization with clear plastic can be used as an effective means of managing weeds in cabbage and to increase crop yield.

**Keywords:** Soil solarization; *Brassica oleraceae* var *capitata* cvs. salvation; weed composition; weed biomass

## 1. Introduction

The management of weeds in vegetable production is a major challenge for many farmers in Trinidad and Tobago and the Caribbean. Brathwaite (1994) noted that weeds are the most underestimated pests in agriculture. Weeds cause both direct and indirect losses in all crops particularly during their early development (Brathwaite, 1994; Bridgemohan, 1991). In the Caribbean an estimated 20% food loss is attributed to weeds (Hammerton, 1981). Most of it is sustained during the critical period of the first one fourth to one third of the growing period of the crop (Kasasian and Seeyave, 1969). Data presented by Brathwaite (1994) showed that losses caused by uncontrolled weed growth in selected crops in Trinidad and Tobago range from 30 – 72% in *Glycine max* (soyabean) and *Brassica oleraceae* var. *capitata* (cabbage) respectively. The management of weeds requires a large outlay of chemicals, equipment and man hours. According to Hammerton (1984) farmers spent 30% of total labour on land preparation which almost invariably involves the destruction of weeds and another 30% on post-planting weed control.

A range of weed management strategies are employed by Caribbean farmers. Manual weeding though effective and commonly used is expensive and time consuming (Yaduraju and Mishra, 2004). This is especially so in low input systems where most of the weed control is done manually with reliance on hands, hoes and cutlasses (Akobundu, 1987). The drudgery associated with weed management especially in low input food production systems make farming unattractive (Akobundu, 1987). Tillage inevitably aids in the management of weeds but is hardly used deliberately for this purpose. Pre-emergent herbicides are not widely used in vegetable production. While more farmers are using post-emergent herbicides in vegetable production to manage weeds in the interrows, crop injury frequently occurs and weeds in the intrarows are removed by hand. The use of herbicides is very effective and economical in managing weeds but they pollute the ecosystem (Yaduraju and Mishra, 2004). Other weed management strategies such as mulching with black polyethylene films and stale bed preparation are not practiced consistently on a large scale. Soil solarization with clear polyethylene plastic is seldom used as a strategy for managing weeds and other pests in the Caribbean. It has been shown, however, to be an effective method for managing weeds in vegetable crops (Abu-Gharbieh, 1991; Abu-Imaileh, 1991; Saghir, 1997).

According to Yaduraju and Mishra (2004) soil solarization is a special mulching technique developed in the seventies by Katan and associates in Israel, where moist soil is covered by thin transparent polyethylene film during the summer months for several weeks to trap the heat and disinfest the soil. This hydro-thermal process results in elevation of temperatures to levels that are lethal to many soil-borne pathogens, insects and weeds and causes other physical and biological changes in soil which are beneficial to the crop. Combining organic amendments with soil solarization enhances the effects of solarization by generation of biotoxic volatile compounds, a process referred to as biofumigation (Katan, Grinstein and Gamliel, 1998; Elmore et. al., 1997).

The use of soil solarization as a means of managing weeds in Caribbean farming systems needs to be further investigated. This is particularly so because the region is located in the tropical zone where radiant energy is high throughout the year. This method of managing weeds must be compared with other strategies currently used by farmers in the Caribbean. The impact of solarization on the soil seed bank and on crop growth and yield must be assessed together with the economic implications of using this method compared with other weed management strategies.

*Brassica oleraceae* var. *capitata* is a major vegetable grown by farmers in the Caribbean. Brathwaite (1994) reported that cabbage does not compete well with weeds. Yield loss due to uncontrolled weeds was highest for cabbage (72%) when compared with other vegetables such as *Glycine max*, *Solanum melongene* (egg plant), *Vigna unguiculata* (cowpea) and *Capsicum annuum* (sweet pepper). Weeds also harbour other insect pests such as *Plutella xylostella* (Diamond back moth) which severely injures the crop reducing the marketable yield. It is therefore important to maintain a weed free cabbage crop in order to obtain high marketable yields.

The present investigation was carried out to assess the effectiveness of soil soilarization in managing weeds in cabbage compared with other weed management strategies currently employed by farmers in the Caribbean namely, stale seedbed preparation using glyphosate (Roundup), pre-emergent pendimethalin (Herdadox) and hand weeding; assess the influence of soil solarization on cabbage growth and yield in relation to the other methods of weed management mentioned above and monitor the effect of soil solarization on the soil weed seed bank against the selected weed management practices presently used in the Caribbean.

## 2. Materials and Methods

The experiment was conducted at the University Field Station (UFS) located at Valsayn, Trinidad in the dry to early wet season (February – June, 2007). The soil type at the field station is a River Estate Loam soil classified in the sub-group Fluventic Eutropepts. It is a flat, alluvial, sandy-loam soil with free internal drainage.

The field was naturally infested with weeds that were evenly distributed. The major weed species were *Echinochloa colona* (Jungle rice), *Brachiaria mutica* (Para grass), *Cyperus* sp. (nutgrass), *Parthenium hysterophorus* (Whitetop), *Eleusine indica* (Fowlfoot grass) and *Amaranthus dubius* (Bhaji). The bed was brush cut, ploughed and rotor tilled. The experimental area was pre- irrigated to field capacity using an overhead sprinkler system.

Treatments included clear polyethylene plastic (CP); clear polyethylene plastic + cow manure (CPM) incorporated at a rate of $500m^3$/ ha before solarization; Pre-emergent pendimethalin (Herbadox 40EC) – (PEN) at a rate of 4.2L /ha (a.i.) three days after transplanting; Glyphosate (Roundup) applied at a rate of 5L/ha two weeks before transplanting in a stale seedbed preparation (SS) and a hand weeded control (HW). These five treatments were arranged in a completely randomized design and replicated five times in plots measuring 2.4m × 5.4m.

One day after irrigation clear polyethylene sheeting, 4mils thick × 3m wide was placed over the plots to be solarized and remained in place for seven weeks. At the end of the solarization period the plastic was removed and the crop was established on all plots using transplants. Transplants of *Brassica oleraceae* var *capitata* cv. salvation which were raised in sterile pro-mix potting medium in Styrofoam cell trays for six weeks were planted with minimal soil disturbance at a spacing of 30cm x 30cm. Weeds on plots with pre-emergent and hand weeded treatments were removed during the last week of solarization in preparation for crop establishment. All other plots were weeded at the end of week four. Insect pest and disease control was carried out as deemed necessary. Granular compound fertilizer (Blaukorn – 12% N, 12% $P_2O_5$, 17%$K_2O$, 2% MgO, 6% S, 5% CaO, 0.2% Fe, 0.02% B, 0.01% Zn, plus traces of Mg, Cu, and Mb ) was applied at planting and at four weeks after transplanting at a rate of 208 $kg/ha^{-1}$.

Two guard rows were used along the periphery of each plot and all data were taken from the four center rows. The soil weed seed bank was determined using the Tray Method. Soil samples of approximately 1 kg consisting of eight cores, were collected from each plot to a depth of 15 cm with an auger of 2.5 cm diameter, before and after solarization and at harvest of *Brassica oleraceae* var *capitata* cv. salvation. Weed seeds were allowed to germinate until the seed bank was exhausted. The number of weeds that germinated were recorded.

Weed control was evaluated visually using a rating scale where 0 indicated no control of weeds to and 10 represented complete weed control as shown in Table 1. This was later converted to a percentage (0-10 being equal to 0-100). Visual scoring was done by 2 persons separately and the data pooled by standing on either side of the plot and recording the means of their scores to obtain an unbiased assessment. Crop growth data was collected every two weeks. Three plants on each plot were randomly selected for measurements on crop growth for the first six weeks of the crop. Plant height and width were the parameters considered. Height was measured from the soil surface to the youngest fully open leaf. Two perpendicular measurements of the width were taken and the average recorded. Weed dry matter was recorded at week four and ten from a quadrat, 30 cm × 30 cm, thrown randomly in the center rows of each plot. Crop yield was taken from the four center rows on each plot. Soil temperature was recorded at a depth of 15 cm from the 23rd to the 48th day of solarization using the HOBO[1] soil thermometer.

**Table 1.** Qualitative scale for visual rating of treatment effects of weed control on weeds score scale of 0 to 10.

| **Effect** | **Rating** | **Effect on Weeds** |
|---|---|---|
| None | 0 | No control |
| Slight | 1 | Very poor control |
| | 2 | Poor control |
| | 3 | Fair control |
| Moderate | 4 | Deficient control |
| | 5 | Deficient to moderate control |
| | 6 | Moderate control |
| Severe | 7 | Satisfactory control |
| | 8 | Good control |
| | 9 | Good to excellent control |
| Complete | 10 | Complete control |

(Adapted from the European System of Weed Control Evaluation)

All data was subjected to analysis of variance (ANOVA), and means were separated by the Least Significant Difference (LSD) test at the 5% probability level (Gomez and Gomez, 1984) using the statistical software SPSS 12.0 for Windows.

## 3. Results and Discussion

### 3.1 Effect of Temperature on Weed Control

Table 2 shows the mean soil temperature at 2 p.m. at a depth of 15 cm from day 43 to 48 of solarisation. The highest temperature of 38.86 $^{o}$C was recorded for clear plastic. This was significantly different from all other treatments. Clear plastic + manure was next, reaching 37.69 $^{o}$C which was significantly different from pendimethalin (30.61 $^{o}$C), stale seedbed (30.02 $^{o}$C) and hand weeding (29.28 $^{o}$C) respectively. Although the temperature difference between pendimethalin, stale seedbed and hand weeding did not vary much, consecutive treatments were significantly different from each other. Research has shown that the addition of organic matter may increase soil temperature by 1.5 to 3.0 $^{o}$C (Katan et al. 1998) compared to solarized treatments without organic manure although this not occur in this trial. The temperature was taken during the latter stages of solarization to avoid disrupting the process. Temperatures would have been higher during the early stages.

[1] HOBO, Onset Computer Corp., 470 MacArthur Blvd., Bourne MA 02532, USA

 

**Table 2.** Mean soil temperature at 2 p.m. at a depth of 15 cm from day 43 to 48 of solarization

| Treatments | Mean Temperature ($^{o}C$) 43rd – 48th day of Solarization |
|---|---|
| Clear Plastic | 38.86±4.68[a] |
| Clear Plastic + Manure | 37.69±3.44[a] |
| Hand Weeding | 29.28±4.51[b] |
| Pendimethalin | 30.61±4.39[b] |
| Stale Seedbed | 30.02±4.54[b] |

Means having the same letter within each column are not significantly different according to Tukey's test ($p<0.05$)

At the end of 10 weeks solarized plots (clear plastic and clear plastic + manure) gave the best weed control (97.60 and 96.00% respectively) and were significantly different from the other treatments. Pendimethalin had 85.60% control and was significantly different from stale seedbed and hand weeding. However, pendimethalin gave a more consistent control of weeds for the duration of the crop (Table 3) and only a few large weeds needed to be rogued at the end of week seven while the other plots had to be weeded at the end of week four.

At the end of four weeks, pendimethalin gave the best control of weeds (92.80%) and was significantly different from all other treatments. Clear plastic gave the next best weed control (84.40%) at week four and was significantly different from the other treatments. There was no significant difference in the level of weed control with hand weeding, clear plastic + manure and stale seedbed after four weeks. The sustained levels of weed control over the 10 week period with clear plastic mulch and clear plastic mulch + manure can be attributed to increased soil heating. Weeds were clearly affected by these treatments over the period.

Table 4 shows that all treatments had significantly lower weed dry matter than clear plastic + manure (240.98g/$m^2$) at four weeks after transplanting. There was no significant difference in weed dry matter among the other treatments. Pendimethalin had the lowest weed dry matter (1.47g/$m^2$). Ten weeks after transplanting there was no significant difference in the weed dry matter among treatments. Clear plastic had the lowest dry matter of 0.5g/ $m^2$ while the hand weeded control had the highest dry matter (158.6g/$m^2$). After 4 weeks weed dry matter (g/$m^2$) was reduced significantly under the clear plastic + manure treatment. The manure may have stimulated weed growth under the clear plastic earlier.

Soil temperatures increase much faster under clear plastic as the incident short wave radiation is transmitted through it and absorbed directly by the soil (Khan et al. 2003). Pokharel and Hammon (2010) reported that soil solarization at 37 °C for at least 2-4 weeks almost completely prevents the emergence of germinating weed seeds of many annual weeds. The efficacy of this hydro-thermal process for weed control in the field is increased by providing irrigation at least 2-3 weeks prior to applying the solarization treatment. In this trial irrigation was applied one day before the soil solarization treatments were applied. Henceforth, rainfall was very low for the duration of the trial even after the removal of the polyethylene sheeting. The average recorded temperature between January to June was 31.6 $^{o}C$, average rainfall was 9.56 mm and the relative humidity was 69.1 %. Temperatures of up to 69 $^{o}C$ between 1.3 – 5.0 cm soil depth and 42 $^{o}C$ at 20 cm have been reported for 7-28 days in midsummer (Egley, 1983; Rubin and Benjamn, 1984; Cohen and Rubin, 2007). The weed control efficacy is usually well correlated with increased temperature and moisture levels under solarized treatments. Lower temperatures during the trial may have therefore been as a result of lower rainfall levels.

The addition of manure to the clear plastic may have augmented the biocidal activity of the soil solarization process through the possible generation of phytotoxic and volatile compounds thus increasing the heat-carrying capacity of the soil and enhancing the effect of solarization as described by Elmore et al. 1997 and Cohen and Rubin, 2007.

**Table 3.** Mean weed control score percentage over 10 week period

| Treatments | Mean weed control score percentage over 10 weeks | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** |
| **Clear Plastic** | 98.80±0.45[ns] | 97.80±0.45[ns] | 93.80±2.58[a] | 84.40±8.61[a] | 100.00±0.00[a] | 100.00±0.00[a] | 99.20±0.45[a] | 98.80±0.84[a] | 98.00±0.71[a] | 97.60±2.19[a] |
| **Clear Plastic + Manure** | 99.00±0.00 | 96.20±1.30 | 83.20±7.98[a] | 62.00±17.53[b] | 100.00±0.00[a] | 100.00±0.00[a] | 99.20±0.45[a] | 98.20±0.84[a] | 97.40±0.89[a] | 95.80±1.78[a] |
| **Hand Weeding** | 99.00±0.00 | 97.60±0.54 | 84.00±4.18[a] | 56.00±8.21[b] | 100.00±0.00[a] | 99.20±0.83[a] | 96.00±2.54[a] | 89.20±6.05[b] | 76.20±15.99[b] | 47.00±26.83[c] |
| **Pendimethalin** | 98.80±0.45 | 97.60±1.34 | 96.20±1.09[a] | 92.80±3.11[a] | 90.60±3.36[b] | 89.60±3.71[b] | 87.80±5.45[b] | 85.40±6.73[b] | 69.00±12.94[b] | 41.00±15.96[c] |
| **Stale Seedbed** | 98.20±1.78 | 95.60±3.21 | 77.00±12.04[b] | 60.00±10.61[b] | 100.00±0.00[a] | 100.00±0.00[a] | 98.20±0.54[a] | 96.60±2.79[ab] | 92.40±3.28[a] | 85.60±7.60[b] |

In the columns, “ns” indicates that values are not different according to Tukey’s test ($p<0.05$)

 

**Table 4.** Mean weed dry matter (g/m$^2$) in weeks 4 and 10

| Treatments | Weed dry matter (g/m$^2$) | |
|---|---|---|
| | **4** | **10** |
| Clear Plastic | 5.60±0.95$^c$ | 0.48±0.09$^e$ |
| Clear Plastic + Manure | 217.00±12.29$^a$ | 28.30±4.45$^d$ |
| Hand Weeding | 51.30±3.72$^b$ | 142.00±19.6$^a$ |
| Pendimethalin | 1.32±0.29$^c$ | 95.70±7.62$^b$ |
| Stale Seedbed | 56.80±8.86$^b$ | 9.90±1.62$^c$ |

Means having the same letter within each column are not significantly different according to Tukey's test ($p<0.05$)

## 3.2 Soil Weed Seed Bank

At all stages of assessment of the soil weed seed bank there was no significant difference in the weed count. After solarization the number of weed seeds that germinated were reduced greatly in all treatments indicating a "weakening effect" as described by Cohen and Rubin (2007). This could have been as a result of the depletion of the weed seed bank on the non-solarized plots due to the germination of weeds during the seven week solarization period. Elevated temperatures may have induced changes in the seed coats and/or metabolic processes that induced germination and increased the seed's sensitivity to phytotoxic volatiles and microbial attack as described by Cohen and Rubin (2007). At harvest there was an increase in the weed count in all treatments which resulted from the seed rain from flowering weeds which was slightly lower in the solarized plots (Table 5). Cohen and Rubin (2007) explained that the thermal effect may cause a direct transition of the weed seed in the seed bank from the dormant or non dormant seeds to non-viable seeds or an indirect transition from the dormant seeds to non-dormant and then to the non-viable state. Egley (1983) also described two phases of the deterioration process where sublethal temperatures promotes germination by breaking dormancy of hard-seeded species and the next phase described by Cohen and Rubin (2007) involving direct thermal killing of seedlings.

**Table 5.** Soil weed seed bank counts

| Treatments | Mean weed count (seeds/kg soil) | | |
|---|---|---|---|
| | **Before Solarization** | **After Solarization** | **At Harvest** |
| Clear Plastic | 39.80±14.77$^{ns}$ | 6.80±4.26$^{ns}$ | 86.60±49.06$^{ab}$ |
| Clear Plastic + Manure | 39.40±8.64 | 6.00±4.47 | 76.00±24.15$^b$ |
| Hand Weeding | 48.00±14.3 | 8.00±6.04 | 111.00±19.65$^a$ |
| Pendimethalin | 48.00±46.41 | 6.80±8.43 | 105.20±78.56$^a$ |
| Stale Seedbed | 38.20±18.64 | 6.40±5.89 | 98.80±39.97$^a$ |

In the columns, "ns" indicates that values are not different according to Tukey's test ($p<0.05$)

## 3.3 Effect of Soil Solarization on Cabbage Growth and Yield

As outlined by Elmore et al., (1997), cabbage grew more rapidly on solarized plots during the first six weeks. For the first four weeks plants had significantly wider spread on solarized plots (Table 6). Clear plastic had a width of 43.9 cm and was significantly different from all other treatments.

The clear plastic + manure treatment was next with 36.5 cm and was significantly different from hand weeding and pendimethalin. All treatments were significantly different from pendimethalin which seemed to have a negative impact on crop growth. After six weeks however, there was no significant difference in plant width among the treatments.

There was no significant difference in cabbage height during the first two weeks. At the end of the fourth and sixth week, solarized plots produced taller plants and were significantly taller than hand weeding and pendimethalin respectively. Plants with clear plastic + manure were the tallest after six weeks (21.2 cm).

**Table 6.** Mean cabbage growth over a 6-week period

| Treatments | Plant Width (cm) | | | Plant Height (cm) | | |
|---|---|---|---|---|---|---|
| | 2 | 4 | 6 | 2 | 4 | 6 |
| Clear Plastic | $18.10 \pm 2.51^{a}$ | $43.9 \pm 4.99^{a}$ | $44.00 \pm 6.16^{ns}$ | $6.10 \pm 1.41^{ns}$ | $13.04 \pm 1.79^{a}$ | $21.00 \pm 3.74^{a}$ |
| Clear Plastic + manure | $14.85 \pm 4.83^{a}$ | $36.5 \pm 7.14^{b}$ | $46.70 \pm 9.78$ | $5.46 \pm 1.21$ | $12.06 \pm 2.74^{a}$ | $21.20 \pm 2.58^{a}$ |
| Hand Weeding | $11.48 \pm 2.47^{ab}$ | $28.9 \pm 6.16^{b}$ | $41.70 \pm 8.18$ | $4.68 \pm 1.25$ | $9.30 \pm 2.99^{ab}$ | $14.94 \pm 5.85^{ab}$ |
| Pendimethalin | $8.84 \pm 2.00^{b}$ | $20.00 \pm 5.03^{c}$ | $40.00 \pm 6.55$ | $3.58 \pm 0.92$ | $6.32 \pm 1.70^{b}$ | $11.80 \pm 3.11^{b}$ |
| Stale Seedbed | $13.19 \pm 1.56^{a}$ | $34.30 \pm 2.38^{b}$ | $44.00 \pm 2.33$ | $4.60 \pm 1.45$ | $10.30 \pm 2.11^{a}$ | $17.40 \pm 4.50^{a}$ |

Means having the same letter within each column are not significantly different according to Tukey's test ($p<0.05$)

Table 7 shows the mean cabbage dry matter kg/m$^2$. After two weeks clear plastic had the highest dry matter of 0.015 kg/m$^2$ and was significantly different from all other treatments. Clear plastic + manure had the next highest dry matter of 0.009 kg/m$^2$ but only differed significantly from pendimethalin with 0.004 kg/m$^2$. Clear plastic maintained the highest dry matter up to week eight, followed by clear plastic + manure, stale seedbed, hand weeding and pendimethalin respectively (Table 7). This shows the effect of soil solarization in increasing early crop growth (Yaduraju and Karma, 1997). At week eight however, there was no significant difference in the dry matter among the treatments. At week 10 stale seedbed produced the highest dry matter of 1.695 kg/m$^2$ but did not differ significantly from clear plastic (1.655 kg/m$^2$). Clear plastic was significantly different from hand weeding and Pendimethalin which had the lowest dry matter of 1.15 kg/m$^2$. The largest increase in dry matter occurred between week eight and ten where it doubled in almost all treatments. This period coincided with the process of head formation and bulking up in cabbage but could have also been attributed to the increased rain fall during this period.

**Table 7.** Mean cabbage dry matter (kg/m$^2$)

| Treatments | Mean cabbage dry matter (kg/m$^2$) | | | | |
|---|---|---|---|---|---|
| | 2 | 4 | 6 | 8 | 10 |
| Clear Plastic | $0.015^{a}$ | $0.163^{a}$ | $0.641^{a}$ | $0.780^{a}$ | $1.655^{a}$ |
| Clear Plastic + Manure | $0.009^{b}$ | $0.152^{a}$ | $0.596^{a}$ | $0.698^{b}$ | $1.314^{b}$ |
| Hand Weeding | $0.006^{b}$ | $0.068^{c}$ | $0.284^{c}$ | $0.560^{c}$ | $1.150^{c}$ |
| Pendimethalin | $0.004^{b}$ | $0.042^{c}$ | $0.215^{c}$ | $0.467^{c}$ | $1.190^{c}$ |
| Stale Seedbed | $0.006^{b}$ | $0.119^{b}$ | $0.410^{b}$ | $0.652^{b}$ | $1.695^{a}$ |

Means having the same letter within each column are not significantly different according to Tukey's test ($p<0.05$)

 

In keeping with results obtained by Ricci et al. (2000), clear plastic had the highest yield of 36.45 t/ha and was significantly different from all other treatments. This yield was almost twice that of stale seedbed which gave the next best result of 18.75 t/ha (Table 8). The yield from Stale seedbed was significantly different from clear plastic + manure and pendimethalin. Clear plastic + manure yield also differ significantly from pendimethalin which had the lowest yield of 4.56 t/ha. The addition of cow manure seemed not to have enhanced the effectiveness of solarization on cabbage yield as anticipated (Katan, Grinstein and Gamliel, 1998; Elmore et. al., 1997). Even though the field was irrigated to field capacity, the cow manure was dry when it was incorporated and seemed not to have absorbed and retained sufficient moisture, which would have reduced soil heat conductivity (Yaduraju and Mishra, 2004).

**Table 8.** Mean cabbage yield (t/ha)

| Treatments | Mean Yield (t/ha) |
|---|---|
| Clear Plastic | 36.45±52.07[a] |
| Clear Plastic + Manure | 9.73±46.34[c] |
| Hand Weeding | 4.56±57.98[c] |
| Pendimethalin | 18.75±60.47[b] |
| Stale Seedbed | 13.21±60.80[b] |

Means having the same letter within each column are not significantly different according to Tukey's test ($p<0.05$)

## 4. Conclusion

Soil solarization with clear plastic can be used as an effective means of managing weeds in cabbage and to increase crop yield. Although the plastic is costly and requires time to install and remove, it saves having to use herbicides and hand weeding. Whereas pendimethalin gave the longest control of weeds, crop growth and yield were severely affected.

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