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# Soil insecticides, plastic mulch and adult control as methods of reducing populations of larval *Aulacophora similis* (Coleoptera; Chrysomelidae) in cantaloupe fields

(*Keywords:* melon, pesticide, cultural control, economic threshold, Micronesia)

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**Abstract.** Two experiments were undertaken to determine ways of controlling larval populations of *Aulacophora similis* Olivier on cantaloupe in Guam in the Mariana Islands. In the first experiment, three soil insecticides were tested with or without black plastic mulch. Carbofuran reduced the number of larvae initially but no differences were observed as the fruit matured. Chlorpyrifos and diazinon had no effect on larval populations. Larvae were more abundant under black plastic mulch. In the second experiment, carbofuran, black plastic, and control of adults whenever a threshold of 1 per 10 plants was exceeded, were tested in all combinations. Black plastic did not affect the number of larvae in the second experiment, but did provide a barrier which kept larvae from damaging the melons lying on the plastic. The yield of melons increased as a result of both plastic mulch and carbofuran use. The data suggest that control of adults resulted in significant reductions in larval numbers, but considerable damage to fruit still occurred at the defined action threshold.

## 1. Introduction

Chrysomelid beetles of the genus *Aulacophora* are pests of cucurbits throughout the warmer regions of the Old World. So-called cucumber beetles, together with aphid and thrips have been identified as the most destructive insect pests of cucurbit crops in south-east Asia (FAO, 1989). Several Pacific countries also report that *Aulacophora* spp. are highly destructive to cucurbit crops (Waterhouse and Norris, 1987). One of the most widespread species is *Aulacophora similis* Olivier, which is distributed from the Malay archipelago to American Samoa (Maulik, 1929; Waterhouse and Norris, 1987). In Micronesia it occurs in the Mariana Islands, Yap, and Palau (Gressitt, 1955).

Cucurbits comprise the largest acreage of cash crops grown in Guam, and are also a major crop in the Commonwealth of the Northern Mariana Islands. Of the cucurbits, the most important crops are watermelons and cucumbers, followed by melons including cantaloupe (Guam Department of Commerce, 1990). Cantaloupes and related melons sell for a high price, but many farmers are reluctant to grow them because of pest problems which frequently result in poor yields. A very important insect pest is *A. similis*. Adult beetles invade the crop early, and are capable of defoliating small plants when the latter are aggregated. Later in the season the adults feed on the flowers and the leaves, but only cause serious damage if they are exceptionally abundant. The larvae produced by these adults feed on the roots of the plants and on the undersides of melon where the fruit contacts the soil. In cantaloupe, the larvae tunnel in the main root, occasionally extending into the stem. High populations will kill plants. Larvae also bore into the rind of the melons, ruining the appearance of the fruit and, more importantly, allowing entry of decay organisms. No information is available on the impact of *A. similis* on yield of cantaloupe. In India, control of *A. foveicollis* Lucas increases yields four-fold (Singh and Gill, 1979). Waterhouse and Norris (1987) considered the adults of *Aulacophora* beetles to be the more damaging stage, but, on Guam, the larvae appear to be more damaging to cantaloupe. Examination of farm fields shows that many melons are damaged by larval tunnelling and that plants frequently die from root damage before the melons are ripe.

Adult beetles are readily controlled by carbaryl at labelled rates for beetles, but frequent applications must be made to maintain the beetle population at a low level. Moore *et al.* (1992) tested a watermelon IPM system on several farms on Guam, and reported that adult *A. similis* were the insects that most often required treatment. No methods of controlling larval *A. similis* are known. Seed treatment with carbofuran is reported to control *A. foveicollis* (Sinha and Chakrabarti, 1983), suggesting that some insecticides may be effective against immature *Aulacophora* spp. Black plastic mulch is used by some farmers in the Marianas for weed control in melon, and it is suggested that this might also affect larval numbers. We set up an experiment to test the effects of soil insecticides and plastic mulch on the abundance of the larval stage of *A. similis* on cantaloupe on Guam. We also did a preliminary assessment of the effectiveness of an arbitrary action threshold of one adult beetle per 10 plants, which was the threshold used by Moore *et al.* (1992), to see if it adequately reduced larval populations in cantaloupe.

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## 2. Materials and methods

Cantaloupes, *Cucumis melo* cv. Burpee Hybrid, were planted on 10 January 1991, in Barrigada, Guam, on a heavy clay soil. Hills were spaced 1 m apart with 1·2 m between rows. Hills were thinned to three plants per hill about the time the third true leaf appeared. Experimental plots consisted of three 12·8 m rows. Drip lines were used to irrigate the plants. Three soil insecticides, diazinon (3·7 kg a.i./ha), chlorpyrifos (as Lorsban® at 1·8 kg a.i./ha) and carbofuran (as Furadan® at 0·9 kg a.i./ha) were broadcast as granules in the treated plots prior to planting, and there was also an untreated control. Application rates were those recommended on the labels for use on melon at the time the experiment was performed, or in the case of chlorpyrifos, which is not registered for use on melon, the rate recommended for corn rootworm control. Soil temperature was not specifically measured, but the mean air temperature on Guam averages 27°C with differences of only 1–2 degrees from month to month. All soil treatments and the control were tested both under mulch and in bare soil in order to perform a two-way analysis of variance to examine the effects of insecticide and mulch. A 1 m wide strip of black plastic mulch was used. The treatments were randomly arranged within blocks, and each block was replicated four times.

A second experiment was initiated on 15 April 1991, at the same site with the following modifications: the powdery mildew-resistant variety 'Premium Hybrid' was grown, only carbofuran was tested, and the entire experiment was repeated in two fields about 50 m apart with four replicates of each treatment in each field. In one field adult beetles were controlled with carbaryl every time more than one beetle per 10 plants was found. In the second field, no specific treatment for adult beetles was implemented, although other pests were controlled if necessary. Both fields were treated with dimethoate on May 9 and 29 for aphids, and the adult beetle suppression field was treated with carbaryl on May 23 and June 5 for beetle control. Dimethoate reduced beetles to some extent also, although the impact was not known. Melons started to mature on June 12.

In both experiments, beetles' eggs, larvae and pupae were counted by removing a soil core centred upon a plant. A 15·24 cm diameter coffee can with both ends removed was pressed 10 cm into the soil and the cylinder of soil was removed, bagged, and transferred to the laboratory. The soil was soaked for 30 min in soapy water to break up any clumps, passed through a large soil sieve to remove stones, and thereafter rescreened through a 0·5 mm mesh sieve to remove fine silt, water, and soap. The small sieve retained eggs and larvae of *A. similis*. The soil remaining in the sieve was then placed in a basin, covered to a depth of 5 cm with a saturated sugar solution, and thoroughly stirred. All floating material was removed by sieving with a fine organdy net and examined under 10× magnification. All immature beetle stages were counted. Three samples were taken from each plot on each occasion and the total of all three was summed to yield one sample for analysis. In addition, in the second experiment, the number of beetle larvae that were associated with the fruit were counted by lifting fruits that were at least 10 cm in length, and counting the number of larvae on the soil or in the fruit. Ten fruit were checked per plot. In the mulched plots, the sample was split so that about half the melons sampled were on the plastic mulch and half were on the soil. Soil samples were taken 60 and 80 d.a.p. in the first experiment, and at 80 d.a.p. in the second experiment.

In the first experiment, differences in the number of immature beetles were analysed by a two-way analysis of variance (PROC GLM, SAS Institute, 1985) with mulch and soil insecticide being the two factors analysed. In the second experiment, data for each field were analysed separately by the same method. The two sites were compared with a *t*-test using the data from each of the treatment plots as one measurement. The adult treatment comparison was unreplicated. The beetles are highly mobile and are readily killed by insecticide treatments in nearby plots (Schreiner and Nafus, 1992), so large areas are needed to test the effects of different adult control strategies. There was insufficient land available to allow more than one replication of this portion of the experiment.

## 3. Results

Yield data were not available for the first experiment because most of the plants died around 75–85 days after planting. This was partly a result of beetle larvae feeding on the roots, and partly a result of severe powdery mildew. Heavy rainfall occurred during the last 2 weeks of the second experiment and many melons were damaged by southern blight. Only the total number of melons produced per plot, and not the weights, was available for analysis. The large number of fruits which rotted made it impossible to weigh the melons accurately.

### 3.1. *Effects of insecticides*

Two insecticides, diazinon and chlorpyrifos, had no significant effect on the abundance of beetle larvae in soil samples taken in the January 10 1991 experiment (Table 1). At 60 d.a.p., the number of larvae in carbofuran plots was 18% of that in the other plots, although the difference was not significant because the beetle populations were highly clumped and variance was high. By 80 d.a.p. the number of larvae in the soil samples was almost six times higher and there was no significant difference in larval numbers between the plots treated with carbofuran and the other plots.

In the second experiment, data were not taken at 60 d.a.p. There was no difference in the number of larvae between carbofuran and untreated plots by 80 d.a.p. (Tables 2 and 3). Carbofuran did not reduce the numbers of larvae under the fruit or the percentage of melons damaged by beetle larvae. However, about 40% more melons were produced in the plots treated with carbofuran. The difference in yield was significant in the field

*Table 1. Effects of soil treatment and plastic mulch on numbers of larval* A. similis, *10 January 1991 experiment. Means ± standard deviations*

| | Number of larvae/soil sample | | | |
|---|---|---|---|---|
| | 60 days after planting | | 80 days after planting | |
| | Black plastic mulch | No mulch | Black plastic mulch | No mulch |
| Soil insecticide | | | | |
| Carbofuran | 0·5 ± 0·6 | 0·0 ± 0·0 | 9·2 ± 4·0 | 0·2 ± 0·5 |
| Chlorpyrifos | 1·7 ± 2·9 | 1·4 ± 2·6 | 11·3 ± 4·0 | 3·8 ± 2·8 |
| Diazinon | 2·2 ± 2·2 | 1·0 ± 1·7 | 9·8 ± 6·7 | 3·0 ± 3·6 |
| None | 1·5 ± 1·7 | 0·2 ± 0·5 | 10·0 ± 6·3 | 1·2 ± 0·5 |
| Analysis of variance | | | | |
| *F*Insecticide | 0·945 (d.f. 3, 24; *P* = 0·4) | | 0·604 (d.f. 3, 24; *P* = 0·6) | |
| *F*Mulch | 1·513 (d.f. 1, 24; *P* = 0·2) | | 27·259 (d.f. 1, 24; *P* = 0·001) | |
| *F*Interaction | 0·143 (d.f. 1, 24; *P* = 0·9) | | 0·113 (d.f. 1, 24; *P* = 0·9) | |

*Table 2. Effects of soil treatment, plastic mulch and adult control on numbers of larval* A. similis, *15 April 1991 experiment. Site 1. Adult beetles not controlled. Variables are means ± standard deviations. The* F-value *for the interaction between mulch and insecticide was calculated for all variables but was in no case significant*

| Variable | Soil insecticide | Mulch type: Black plastic | None | Analysis of variance |
|---|---|---|---|---|
| Mean no. of larvae per soil sample | Carbofuran | 5·7 ± 2·6 | 1·5 ± 1·0 | *F*Insecticide = 0·01 (d.f. 1, 25, *P* = 0·9) |
| | None | 4·2 ± 4·3 | 3·2 ± 2·1 | *F*Mulch = 3·55 (d.f. 1, 25, *P* = 0·08) |
| Mean no. of larvae under a melon (whole plot) | Carbofuran | 0·7 ± 0·9 | 3·1 ± 1·6 | *F*Insecticide = 0·06 (d.f. 1, 25, *P* = 0·9) |
| | None | 1·3 ± 1·4 | 2·7 ± 0·9 | *F*Mulch = 14·06 (d.f. 1, 25, *P* = 0·01) |
| Mean no. of larvae under a melon (melons on soil) | Carbofuran | 1·2 ± 1·4 | 3·1 ± 1·6 | *F*Insecticide = 0·20 (d.f. 1, 25, *P* = 0·7) |
| | None | 2·3 ± 2·7 | 2·7 ± 0·9 | *F*Mulch = 1·62 (d.f. 1, 25, *P* = 0·3) |
| Percentage of damaged melons (whole plot) | Carbofuran | 31 ± 19 | 61 ± 20 | *F*Insecticide = 0·37 (d.f. 1, 25, *P* = 0·6) |
| | None | 25 ± 17 | 56 ± 21 | *F*Mulch = 10·44 (d.f. 1, 25, *P* = 0·007) |
| Percentage of damaged melons (on soil) | Carbofuran | 51 ± 28 | 61 ± 20 | *F*Insecticide = 0·39 (d.f. 1, 25, *P* = 0·6) |
| | None | 40 ± 37 | 56 ± 21 | *F*Mulch = 0·91 (d.f. 1, 25, *P* = 0·4) |
| Number of melons | Carbofuran | 28 ± 1 | 21 ± 4 | *F*Insecticide = 14·93 (d.f. 1, 25, *P* = 0·003) |
| | None | 20 ± 1 | 15 ± 6 | *F*Mulch = 11·90 (d.f. 1, 25, *P* = 0·005) |

with higher beetle counts (Table 2), and close to significant in the field with the lower beetle counts (Table 3).

### 3.2. *Effects of mulch*

The number of beetle larvae in the soil samples was higher in the plots mulched with black plastic (Tables 1–3). In the first experiment, at 60 d.a.p. the difference was not significant (Table 1), but by 80 d.a.p. the overall number of larvae in the field had increased dramatically, and there were five times more larvae around the roots of mulched than unmulched plants. This difference was highly significant (Table 1). In the second experiment, the differences were not significant, although there were more larvae under the black plastic in both fields (Tables 2 and 3).

Despite the higher number of larvae in the soil, fewer larvae were found underneath melons in the plastic mulch plots if melons from the whole plot were considered. The difference was significant in the field with the higher larval beetle counts (Tables 2 and 3). The plastic mulch formed a barrier between the soil-inhabiting larvae and the melons, and reduced larval access to the fruit. The melons lying on the soil between the mulched rows had similar numbers of larvae under them as was observed in unmulched plots (Tables 2 and 3). Only one or two melons in the whole field that were growing on the plastic mulch had larvae under them. The proportion of fruit damaged by the beetle was high in all plots. The percentage of damaged melons was higher in the unmulched plots, although the difference was only significant in the field with the higher beetle larvae counts. The total number of melons produced was significantly higher in the mulched plots.

*Table 3. Effects of soil treatment, plastic mulch and adult control on numbers of larval* A. similis, *15 April 1991 experiment. Site 2. Adult beetles controlled if more than 1 per 10 plants. Variables are means, ± standard deviations. The F-value for the interaction between mulch and insecticide was calculated for all variables but was in no case significant*

| | | Mulch type | | |
|---|---|---|---|---|
| Variable | Soil insecticide | Black plastic | None | Analysis of variance |
| Mean no. of larvae per soil sample | Carbofuran | 1·2 ± 2·5 | 2·0 ± 1·4 | *F*Insecticide = 1·15 (d.f. 1, 25, *P* = 0·3) |
| | None | 2·5 ± 3·0 | 7·5 ± 11·9 | *F*Mulch = 0·83 (d.f. 1, 25, *P* = 0·4) |
| Mean no. of larvae under a melon (whole plot) | Carbofuran | 0·3 ± 0·5 | 0·5 ± 0·3 | *F*Insecticide = 0·73 (d.f. 1, 25, *P* = 0·4) |
| | None | 0·4 ± 0·4 | 0·6 ± 0·4 | *F*Mulch = 0·37 (d.f. 1, 25, *P* = 0·06) |
| Mean no. of larvae under a melon (melons on soil) | Carbofuran | 0·5 ± 0·8 | 0·5 ± 0·3 | *F*Insecticide = 0·01 (d.f. 1, 25, *P* = 0·9) |
| | None | 0·6 ± 0·7 | 0·6 ± 0·4 | *F*Mulch = 0·12 (d.f. 1, 25, *P* = 0·7) |
| Percentage of damaged melons (whole plot) | Carbofuran | 17 ± 14 | 30 ± 6 | *F*Insecticide = 0·16 (d.f. 1, 25, *P* = 0·7) |
| | None | 25 ± 25 | 28 ± 14 | *F*Mulch = 1·10 (d.f. 1, 25, *P* = 0·3) |
| Percentage of damaged melons (on soil) | Carbofuran | 28 ± 21 | 30 ± 6 | *F*Insecticide = 0·0 (d.f. 1, 25, *P* = 0·9) |
| | None | 30 ± 36 | 28 ± 14 | *F*Mulch = 0·0 (d.f. 1, 25, *P* = 0·9) |
| Number of melons | Carbofuran | 24 ± 6 | 21 ± 2 | *F*Insecticide = 4·46 (d.f. 1, 25, *P* = 0·058) |
| | None | 20 ± 5 | 13 ± 5 | *F*Mulch = 3·99 (d.f. 1, 25, *P* = 0·07) |

*Table 4. Comparison of site with no adult control with site where adult beetles were controlled every time beetles exceeded 1 per 10 plants. Variables are means ± standard deviations*

| | Mean no. of larvae/soil sample | Mean no. of larvae under melons | Percentage of damaged melons | Number of melons |
|---|---|---|---|---|
| Site without adult control | 3·7 ± 3·0 | 2·0 ± 1·5 | 43 ± 23 | 21 ± 6 |
| Site with adult control | 3·3 ± 6·2 | 0·5 ± 0·4 | 25 ± 15 | 19 ± 6 |
| *F* | 4·36 | 15·06 | 2·30 | 1·08 |
| Probability | 0·007 | 0·001 | 0·12 | 0·9 |

### 3.3. *Effects of adult control*

The number of immature beetles in the soil samples and under melons was significantly lower in the field where adults were treated (Table 4). The percentage of damaged fruits was lower in the treated field, but the difference was not significant. One quarter of all the melons in the field treated to reduce *A. similis* adults were damaged by beetle larvae. Because the adult treatment was not replicated one cannot be certain that the reductions in larval numbers were caused by suppression of the adult. There was no significant difference in the total number of melons produced per plot between the treated and untreated fields.

## 4. Discussion

Counting the number of larvae under melons was an easier and more accurate method of monitoring larval densities than sampling the soil. Soil counts indicated the beetle larvae were highly aggregated. Each soil sample destroyed one plant, and this plus the amount of labour involved in processing a sample precluded our taking enough samples to reduce the variance. Turning fruit over allowed more samples to be taken per plot without damaging the plants, and provided higher and more consistent counts of larvae.

None of the soil insecticides tested in these experiments provided season-long control of *A. similis* larvae. Diazinon and chlorpyrifos did not have any lasting effect on *A. similis* larvae, and data from previous experiments suggested that granular diazinon actually increased the number of larvae in the field, presumably by killing ants or other predators more effectively than it killed beetle larvae (Schreiner and Nafus, 1992). Carbofuran, which is effective against *A. foveicollis* in India, reduced larval populations in the 60 day sample and increased the number of melons reaching harvestable size by about 40%. After 60 days, carbofuran lost its effectiveness, however, and by harvest time the number of beetle larvae under melons was the same in treated and untreated plots, and the proportion of melons with beetle damage underneath was similar. Re-application would be necessary for season-long protection, but at the time of the experiments granular carbofuran was labelled only for preplant application on melon in the United States of America. Since that time melons have been removed from the carbofuran label. Guam follows USA labelling laws which precludes applications in this location at this time. In any case, we were reluctant to recommend general use of granular carbofuran as a standard control measure because of safety and environmental concerns. Carbofuran is extremely toxic, and farmers must be well-informed and use proper safety equipment to prevent accidental poisonings. In addition, although carbofuran generally breaks down quickly, it has been implicated in fish kills and water contamination (Trotter *et al.*, 1991). Much of the farmland on Guam is on thin soil on top of upraised limestone, which holds the sole source aquifer for the island. Information on the leaching and breakdown rate of carbofuran in the soils of Guam is needed before any use could be recommended for local farmers.

Plastic mulch has a variety of influences on the crop habitat including raising soil temperatures and, in the case of opaque mulches, controlling weeds. Some of the environmental alterations significantly improve yields by creating more favourable conditions for crop growth. In the second experiment, about 30% more melons, or about 4500 additional melons per hectare, were produced in the plots mulched with black plastic. Thus, even in the tropics, plastic mulch can improve melon yields significantly.

The use of plastic mulch both alters environmental conditions and changes the appearance of the crop background. These changes affect not only the crop, but the insects associated with it. Several insects that feed on the foliar portions of cucurbits and other crops are known to be affected by plastic mulch (Loebenstein *et al.*, 1975; Wyman *et al.*, 1979; Greenough *et al.*, 1990), as well as at least one root pest, the cabbage maggot, *Delia radicum* (L.) (Diptera; Anthomyiidae). Cabbage maggot populations are lower under plastic mulch (Matthews-Gehringer and Hough-Goldstein, 1988). Understanding the changes in the altered environment is critical for the proper management of crop pests. In our experiments, the effects of plastic mulch on *A. similis* larvae were not consistent between trials, with higher numbers of larvae under the black plastic mulch in one set of experiments, but no differences in a second. In part, we suspect the differences were related to soil moisture conditions. Eggs and larvae of *A. foveicollis* are affected by soil moisture conditions and irrigation practices (Melamed-Madjar, 1960). In dry soil, eggs suffer heavy mortality from desiccation and larvae move upwards or downwards in relation to the degree of saturation. In saturated soils, larvae move to the surface and will feed on fruit in contact with the ground. In our experiments, soil moisture conditions may have affected locations of the larvae with respect to the plastic mulch. The first experiment took place during dry weather and the soil outside the irrigation zone was very dry. Under the plastic mulch the soil retained more water and larvae may have concentrated in this zone or survival may have been improved. In the second experiment, it rained during the last part of the growing cycle, and the soil was moist outside the plastic as well as underneath. No difference in the number of larvae in mulched or unmulched treatments was found. The results are consistent with those obtained from a different experiment done in the wet season with cucumber (Nafus and Schreiner, unpublished data). The soil was saturated in that experiment, and twice as many larvae were found in unmulched plots compared with ones covered with black plastic. Thus, plastic mulch alters soil moisture conditions at the surface, and this in turn may affect the distribution and abundance of *A. similis* larvae near the plant base. Growers need to be aware of this, and take it into consideration in managing their crop. If conditions are dry, larvae may be more abundant near the plant base if mulch is used, making it more important to suppress adult populations. If the soil is wet outside the mulch, larval populations will be more evenly distributed or even reduced under the mulch, and less intensive adult control may be required. In all instances, plastic mulch was an effective barrier between the larvae in the soil and the melons. Those melons lying on the plastic mulch, about half the melons in the spacing used in this experiment, had little damage from larvae.

Controlling adult beetles reduced the number of larvae in the field, as there were fewer larvae in the soil samples and under the melons in the treated field in the second experiment. However, even in the treated field one quarter of the melons were damaged by *A. similis* larvae, indicating that for cantaloupe, an action threshold of one beetle per 10 plants, checked once a week, was too high. On watermelon, for which the action threshold was originally set, larvae scrape the outside skin and scar it, but tend not to penetrate into the fruit. The action threshold may be suitable for watermelon, but it is too high for cantaloupe.

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