Effects of Straw and Leaf Mulches and Trickle Irrigation on the Abundance of Colorado Potato Beetles (Coleoptera: Chrysomelidae) on Potato in Connecticut[1]

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J. Entomol. Sci. 28(4):393-403 (October 1993)

ABSTRACT Straw mulch reduced the number of Colorado potato beetle, *Leptinotarsa decemlineata* (Say), larvae on potato during the first generation, and reduced the proportion of stems that were more than 50% defoliated compared to unmulched and unirrigated control plots. Leaf mulch and trickle irrigation did not affect number of larvae or the proportion of heavily defoliated plants compared to the control. None of the treatments significantly affected the number of adults per stem until the end of the first generation and none affected the number of egg masses, so the straw mulch must affect mortality or development of eggs and larvae. Both types of mulch and trickle irrigation increased yield relative to the control, perhaps due to lower soil temperature in a hot, dry year.

KEY WORDS *Leptinotarsa decemlineata*, Colorado potato beetle, mulch, irrigation.

Colorado potato beetle (CPB), *Leptinotarsa decemlineata* (Say), is the most important insect pest of potato, *Solanum tuberosum* L., in New England, where the rapid development of resistance to pesticides has made the search for alternative methods of control a necessity. One alternative that has been tested in southeastern states is the use of mulch. Zehnder and Hough-Goldstein (1990) showed that straw mulch reduced the density of adults, egg masses, and larvae early in the season in both rotated and non-rotated fields, reduced the number of insecticide treatments required to keep populations below the economic threshold, and increased soil moisture and tuber yield. The authors concluded that the additional profit from reduced insecticide use and increased yield justified the cost of the straw at $1.50 per bale (Zehnder and Hough-Goldstein 1990).

Riechert and Bishop (1990) found that a grass hay mulch decreased pest densities in several different vegetables, including potatoes. In their study in Tennessee, CPB density was 90% lower in mulched plots compared to bare ground plots. They attributed the generally lower pest densities to greater predation by spiders associated with the higher humidity and more moderate temperatures in mulched plots at the time of spider migration. This hypothesis was well-supported for many of the other pests, but they had little direct evidence of an effect of spider predation on the Colorado potato beetle.

[1] Accepted for publication 31 August 1993.

In Connecticut, hay and straw are expensive, costing $3.95 to $4.50 per bale at local agricultural supply stores. On the other hand, leaves are a potential mulch available free from urban and suburban leaf collection programs. The state of Connecticut now prohibits disposal of leaves and other yard waste in landfills, so many towns and some landscapers pay farmers to compost or otherwise dispose of leaves.

The objectives of this study were: 1) to determine whether straw mulch would reduce CPB abundance and increase yield under field conditions in Connecticut; 2) to determine if these effects are specific to straw mulch, or if leaf mulch would have similar results; and 3) to use trickle irrigation to see if theses effects are caused by differences in moisture, or directly by straw itself.

Materials and Methods

Field experiments were located at the Lockwood Farm, Hamden, CT. No potatoes had been grown on this farm for the previous 5 yr (although small areas of tomatoes, eggplants and wild hosts were present), and CPB abundance had declined since the field studies of CPB by Hare in 1978-1983 at the same location (Hare 1983, 1984). On 3 May 1991, 'Kennebec' potatoes were planted in 24 rows 24 m long, with 0.9 m between rows and 0.2 m between seed pieces in the row. They were hilled only once, to a depth of 10 cm, just after planting, because mulch and irrigation lines would interfere with hilling later in the season. This field was divided into 16 plots, 6 rows wide by 6 m long. These plots were assigned using a Latin square design to four treatments: straw mulch, leaf mulch, trickle irrigation, and control (without mulch or irrigation). Three bales of rye straw or 5 hectoliters of coarsely chopped leaves (of mixed species, from the Hamden town leaf collection) were applied 21 and 23 May to each of the mulched plots. The straw mulch was 10 cm in depth. The leaves were more difficult to spread evenly and varied in depth between 0 cm at the tops of the hills to 5 cm in the furrows. Trickle irrigation was applied with a Leaky Pipe system (Water Systems, Inc., Columbus, TX) with the hose running along the top of the hills in each row. The pressure modulator, flow rate, and water time were regulated to deliver the equivalent of 2.5 cm of water per week in gradual watering for 5 h each morning, beginning 11 June. The system was shut down from 22 and 27 June due to a leak in the main supply pipe, and the system was run all day on 29 June, delivering the equivalent of 2 cm of water that day to compensate for the previous week's deficit. After this breakdown, flow rates were periodically affected by air bubbles blocking the line.

The entire field was fertilized with 1200 kg/ha of 10-10-10 (N-P-K) before planting, and weeds were controlled with a pre-emergent application of 1.1 kg/ha (AI) of metribuzin. No insecticides or fungicides were used.

CPB adults, egg masses, small (less than 6 mm in length, corresponding to first and second instars) and large (greater than 6 mm, third and fourth instars) larvae were counted weekly by examining 10 primary stems randomly chosen from the center four rows and 5 m of row in each plot. These counts were transformed by log (x + 1) before analysis (Harcourt 1963).

Because defoliation appeared to vary tremendously within as well as between plots, I chose a method that yielded a rapid evaluation of the defoliation of many plants. Three observers independently chose 10 primary stems from the four center rows in each plot and evaluated whether or not each stem was greater than 50% defoliated. The proportion of these 30 stems that were greater than 50% defoliated was transformed by the arcsine square root before analysis.

Weekly soil moisture and temperature measurements were made between 9:30 a.m. and 1:00 p.m. EST at two sites in the two center rows of each plot. Soil moisture was measured at 30 cm in depth with a Lincoln soil moisture meter (Lincoln Instruments, Lincoln, NE), with a relative scale from 0 to 10, calibrated before each use so that it read 10 in saturated field soil. Because these measurements were relative they were analyzed using a non-parametric method, the Kruskal-Wallis test (Wilkinson 1988), with treatment used as the single factor. Data from each sample date was analyzed separately. Soil temperatures were measured with a bimetal thermometer (Reotemp Instruments, San Diego, CA) at a depth of 15 cm. Temperature measurements were averaged for each plot before analysis.

Sampling ended at the end of July because the plants in all plots suddenly wilted and died. Lesion nematodes, *Pratylenchus* spp., were extracted at densities of 12-30 nematodes per g of root and 58-105 per 50 cm^3 of soil (J. LaMondia, personal communication), and the fungus *Verticillium* spp. was isolated from stem in every plot (W. Elmer, personal communication), suggesting that the wilting and death were due to potato early dying disease, which is caused by an interaction of these two soil-borne pathogens (Martin et al. 1982).

One row from the center of each plot was dug 15 August with a single-row harvester to measure yield. Tubers were graded by size (grade A > 4.76 cm in diameter) and both grade A and grade B tubers were weighed. Yield of grade A potatoes and total yield were analyzed with analysis of variance (ANOVA) as a three factor mixed model, and contrasts were evaluated between each of the treatments and the control.

In order to reduce experiment-wise error in data collected repeatedly over the season, a hierarchical approach to analyzing the data was used. All quantitative data were analyzed by ANOVA with repeated measures (Wilkinson 1988). Only when these analyses indicated that treatment had a significant effect ($P < 0.05$) over the entire season and also interacted significantly with sample date was the hypothesis of an effect of treatment tested separately for each sample date, and contrasts between each of the treatments and the control were evaluated only for those dates where treatment was significant. When treatment had a significant effect over the season, but did not interact significantly with sample date, as was the case for large larvae, soil temperature, and proportion of stems 50% defoliated, then the sum (for large larvae) or the mean (for the other variables) over all sample dates was calculated, transformed, and analyzed with ANOVA, and contrasts between each of the treatments and the control were evaluated.

Results

Mulching and irrigation reduced soil temperature compared to the untreated control over the entire season (Fig. 1, Effect of treatment on temperature for the season: df = 3,6; F = 168.6; $P < 0.001$). The mean soil temperature over the season under straw mulch was 22.3 ± 0.23°C (s.d.), 22.9 ± 0.16°C under leaf mulch, 23.3 ± 0.41°C for irrigated, and 24.2 ± 0.26°C for the untreated control. Treatment did

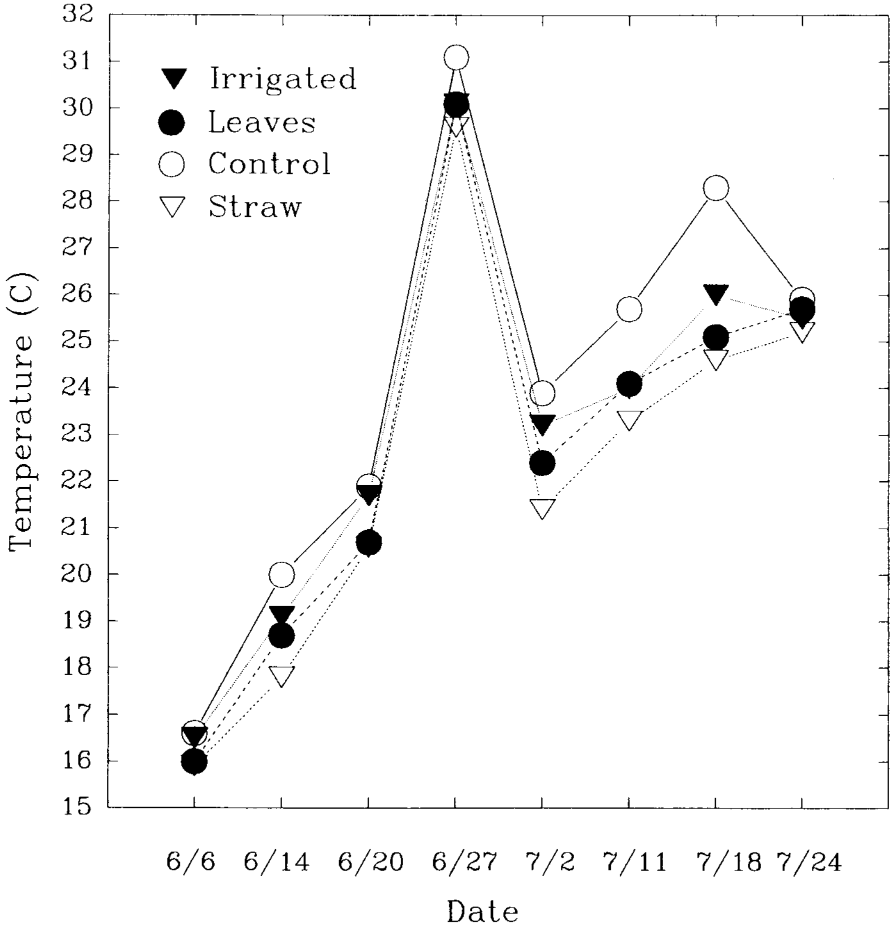

Fig. 1. Effect of irrigation and mulches on soil temperature.

not interact significantly with sample date (df = 21, 42; F = 1.6; $P = 0.1$), and the mean temperature over all sample dates was significantly different for each of the three treatments compared to the control (df 1, 6 throughout; straw versus control: F = 472.8, $P < 0.001$; irrigation versus control: F = 115.3, $P < 0.001$; leaf mulch versus control: F = 240.0, $P < 0.001$).

Soil moisture differed significantly among treatments on two dates, 2 July, when the median soil moisture index ranged from 2.0 for the two control plots to 3.5 for the irrigated plots and 11 July, when it ranged from 1.5 for the control to 3.5 for the leaf mulch plots. All four treatments had very low soil moisture (1.5 to 1.9 median soil moisture index) and high soil temperature (ranging from 29.6 ± 1.2°C for straw mulch to 31.1 ± 0.2°C for control) on 27 June; thus all treatments were exposed to environmental stress.

There were no significant differences in number of adults early in the season (Effect of treatment on number of adults: df = 3, 6 for all dates; 6 June: F = 1.2, P = 0.37; 14 June: F = 0.77, P = 0.55; 20 June: F = 0.86, P = 0.51), perhaps because the initial densities of the adults were very low in all treatments (Fig. 2). However, treatment of the plot significantly affected the number of adults over the entire season, and treatment also interacted significantly with date. Treatments differed significantly on only two dates, 11 July and 24 July. On these dates, the irrigated plots had significantly more adults than the control (df = 3, 6; 11 July: F = 8.0, P = 0.03; 24 July: F = 160.2, P < 0.001), and plots with leaf mulch also had more adults than the control (df = 3,6 July: F = 7.6, P = 0.03; 24 July: F = 56.1, P < 0.001). Adult density in the plots with straw mulch did not differ from the untreated control for 11 July (df 3,6; F = 2.5; P = 0.2), but these plots did have more adults than the control on 24 July (df = 1,6; F = 54.1; P < 0.001). Thus, there were no differences among treatments in number of adults until the first-generation adults emerged, and then the plots with leaf mulch and irrigation had more adults than the control (Fig. 2). The plots with straw mulch did not differ significantly from the control in number of adults until the end of July when they, too, had more adults than the control.

There were no significant differences in numbers of egg masses in the straw-mulched plots compared to the untreated control (Fig. 3). The number of egg masses per stem did not differ significantly among treatments over the entire season, nor was there an interaction between treatment and date.

The straw-mulched plots had a much lower peak of small larvae per primary stem than all three of the other treatments (Fig. 4), and this peak was also 1-2 wks later than the peaks in the other three treatments. For those dates where the density differed significantly by treatment, the plots with straw mulch had fewer small larvae than the untreated control plots (df = 1, 6 throughout; 14 June: F = 7.7; P = 0.03; 20 June: F = 37.2; P = 0.001). Neither the irrigated plots nor the plots with leaf mulch differed significantly in density of small larvae from the control for these dates (irrigated 14 June: F = 0.8, P = 0.4; irrigated 20 June: F = 0.3, P = 0.6; leaf mulch 14 June: F = 0.02, P = 0.9; leaf mulch 20 June: F = 0.1, P = 0.7).

Straw-mulched plots had fewer large larvae than the untreated control (Fig. 5). Because the treatment X date interaction was not significant, counts for individual dates were not analyzed separately, and only the sum over the season was analyzed. The sum of large larvae over the season was significantly affected by treatment (df = 3,6; F = 15.9, P = 0.003), and straw mulch had significantly fewer large larvae than the untreated control (df = 1,6; F = 25.7, P = 0.002), while there was no difference in numbers of large larvae between irrigated plots and the control (df = 1, 6; F = 0.9; P = 0.4) or between leaf mulch plots and the control (df = 1, 6; F = 0.3; P = 0.6).

Straw-mulched plots also had less defoliation than the other treatments (Fig. 6). The proportion of stems more than 50% defoliated was significantly affected by treatment over the entire season (df = 3,6; F = 4.6; P = 0.05), but the treatment X date interaction was not significant (df = 12, 24; F = 0.9; P = 0.5). Straw-mulched plots had a mean proportion defoliated over all five sample dates significantly less than the control (df = 1,6; F = 6.0, P = 0.05), but neither the irrigated plots (df = 1, 6; F = 0.35, P = 0.6) nor the leaf mulched plots (df = 1,6; F = 0.02; P = 0.9) differed from the control.

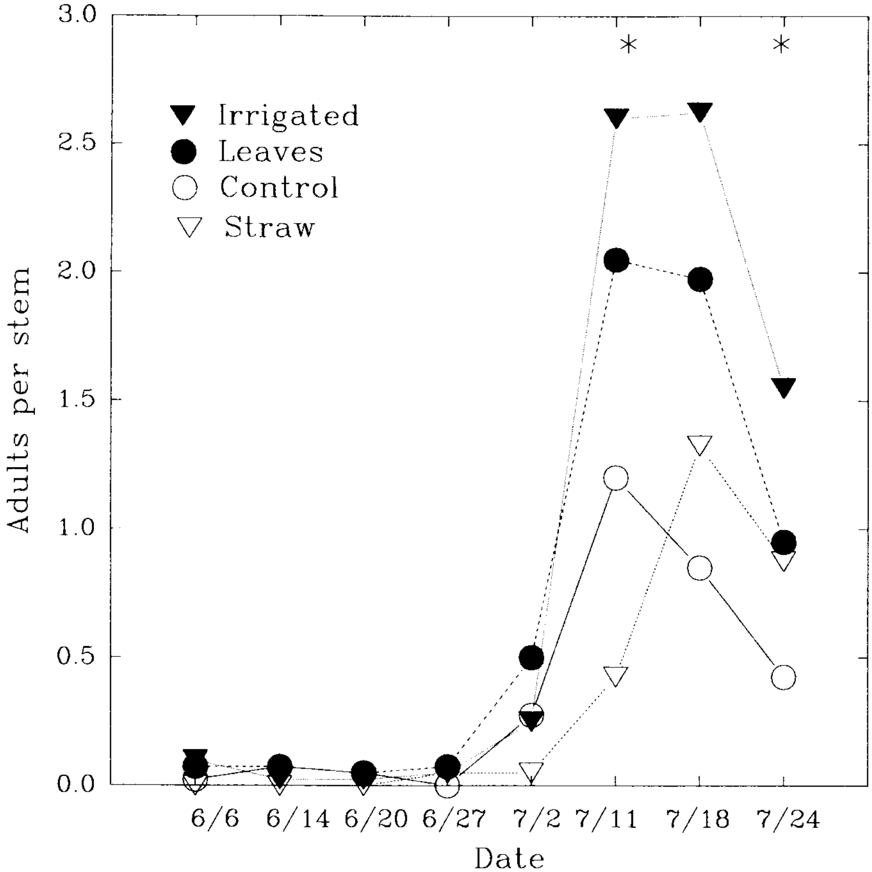

Fig. 2. Effect of irrigation and mulches on the number of Colorado potato beetle adults per primary potato stem. Treatment of the plot significantly affected the number of adults over the entire season (df = 3,6; F = 7.2; $P = 0.02$) and treatment also interacted significantly with date (df = 21,42; F = 1.9; $P = 0.04$). Asterisks indicate the two dates for which the number of adults differed significantly by treatment: 11 July (df = 3,6; F = 6.8; $P = 0.02$) and 24 July (df = 3,6; F = 54.2; $P < 0.001$).

Mulching and irrigation increased yield compared to the control, regardless of whether yield of grade A potatoes or total yield are compared (Table 1). For grade A potatoes, treatment significantly affected yield (df = 3, 6; F = 8.3; $P = 0.015$), and all three other treatments had a greater yield than the control (df = 1, 6; irrigated: F = 22.0, $P = 0.003$; leaf mulch: F = 12.5, $P = 0.012$; straw: F = 12.8, $P = 0.012$). Similarly, total yield was significantly affected by treatment (df = 3, 6; F = 6.7, $P = 0.025$), and all three other treatments had a significantly greater

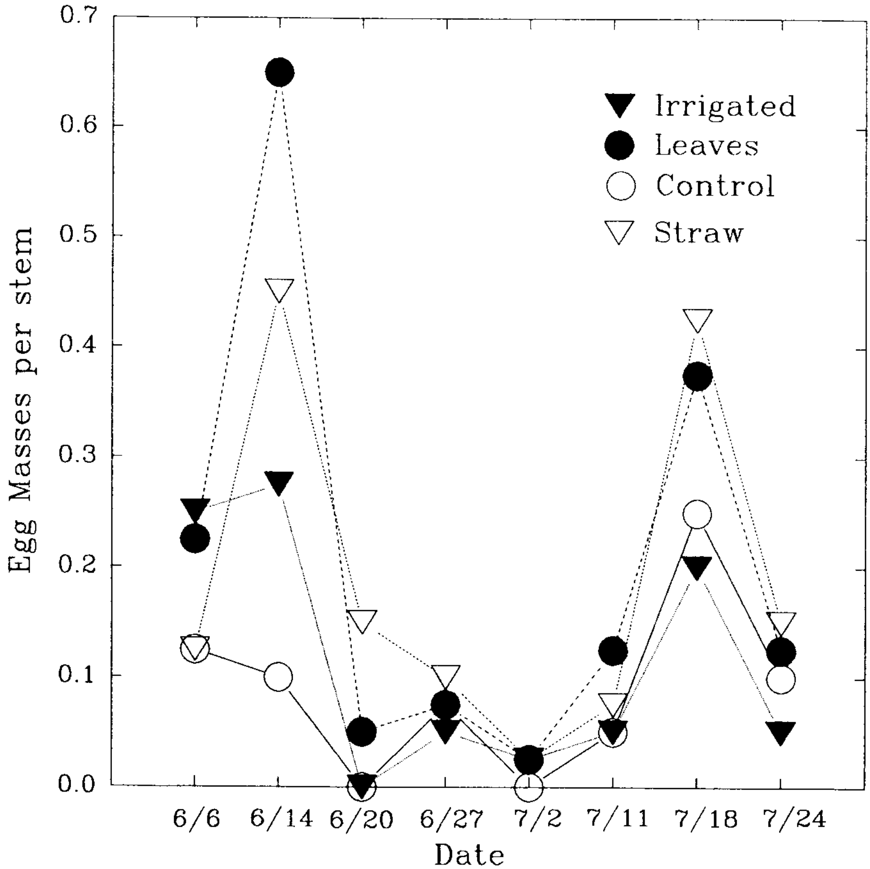

Fig. 3. Effect of irrigation and mulches on the number of egg masses per primary potato stem. The density of egg masses was not significantly different among treatments over the entire season (df = 3,6; F = 2.1; P = 0.20), and neither was there an interaction between treatment and date affecting egg masses (df = 21,42; F = 0.96; P = 0.53).

yield than the control (df = 1, 6; irrigated: F = 18.5, P = 0.005; leaf mulch: F = 8.7, P = 0.026; straw mulch: F = 9.3, P = 0.023).

Discussion

This study confirms that straw mulch reduces the density of CPB larvae in the first generation and reduces the rate of defoliation during that generation. However, these results differ from those of Zehnder and Hough-Goldstein (1990) because straw mulch did not significantly reduce the number of colonizing adults

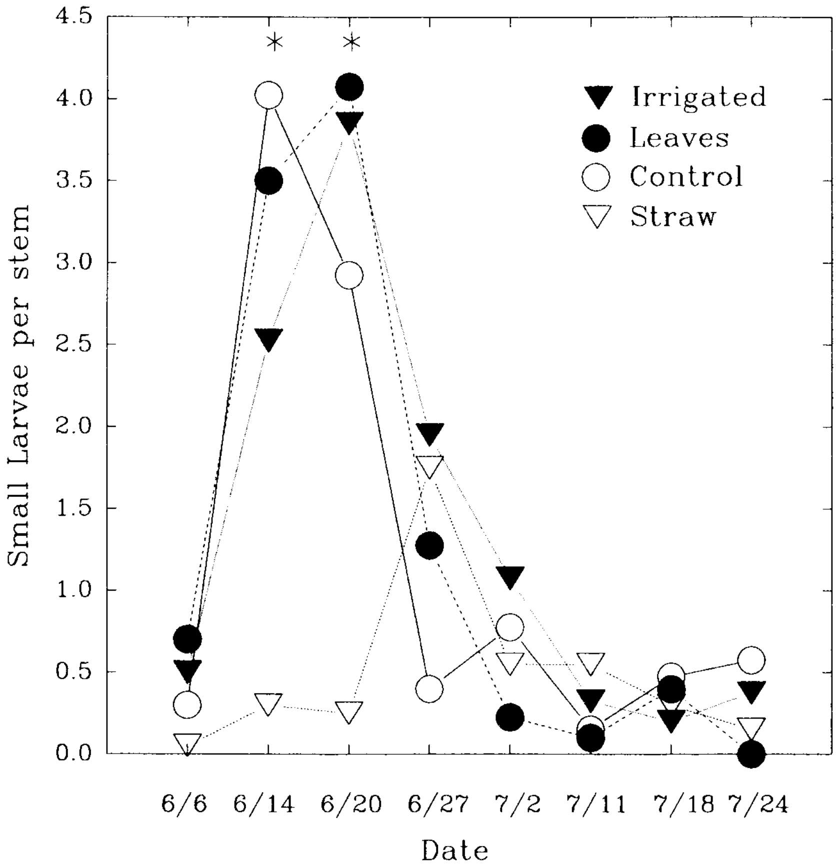

Fig. 4. Effect of irrigation and mulches on the number of small larvae (< 6 mm in length) per primary potato stem. The density of small larvae was significantly affected by treatment over the entire season (df = 3,6; F = 9.0; $P = 0.01$) and the treatment X date interaction was also significant (df = 21,42; F = 2.4; $P = 0.008$). Asterisks indicate the dates for which treatment was a significant factor: 14 June (df = 3,6; F = 5.2; $P = 0.04$) and 20 June (df = 3,6; F = 20.5; $P = 0.001$).

or egg masses at the beginning of the season. Although the lack of significant differences in colonizing adults may be due to generally low adult densities, these results suggest that factors affecting the mortality or developmental rates of eggs and small larvae differ in straw-mulched and non-mulched plots.

Leaf mulch and irrigation did not reduce the number of larvae of either stage or reduce the level of defoliation. Thus, the effect of mulching on numbers of CPB larvae depends on the type or depth of mulch used. All three of the treatments increased yield in a year when the plants were under stress from hot, dry weather, and early dying disease. Mulches and irrigation brought daytime soil

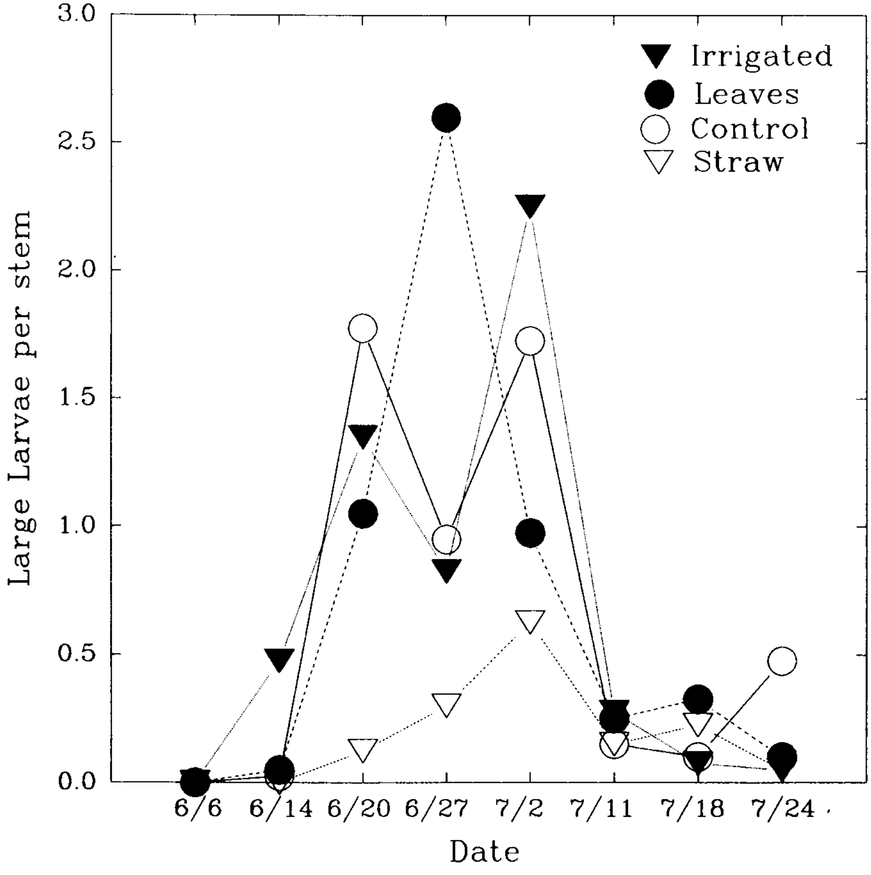

Fig. 5. Effect of irrigation and mulches on the number of large larvae (>6 mm in length) per primary potato stem. The density of large larvae differed significantly by treatment over the entire season (df = 3,6; F = 7.8; $P = 0.02$). The treatment X date interaction was not significant (df = 18,36; F = 1.7; $P = 0.09$), so counts for each date were not analyzed separately.

temperatures closer to the range of 15-20°C favorable for tuber bulking (Dripps and Smilowitz 1986).

Further studies of the effect of straw mulch on density of and defoliation by CPB should examine whether the straw affects predators of eggs and small larvae, such as *Coleomegilla maculata* (DeGeer) and *Lebia grandis* Henz (Groden 1989; Hazzard et al. 1991), as well as generalist predators such as spiders (Riechert and Bishop 1990). Another factor that may be important is whether straw affects the ability of larvae to climb back up onto a plant after being dislodged, dropping, or crawling off. Harcourt (1971) attributed most of larval mortality to two factors causing larvae to travel in search of a host: rainfall, which dislodges

Table 1. Yield ± standard deviation (in kg per 6-m row) of potatoes with and without mulch and trickle irrigation. Hamden, CT, 1991.

Treatment	Grade A	Total Yield
Untreated Control	2.8 ± 0.6	3.4 ± 0.6
Irrigated	5.2 ± 1.6	5.7 ± 1.5
Leaf Mulch	4.6 ± 1.1	5.0 ± 1.2
Straw Mulch	4.7 ± 1.0	5.0 ± 1.0

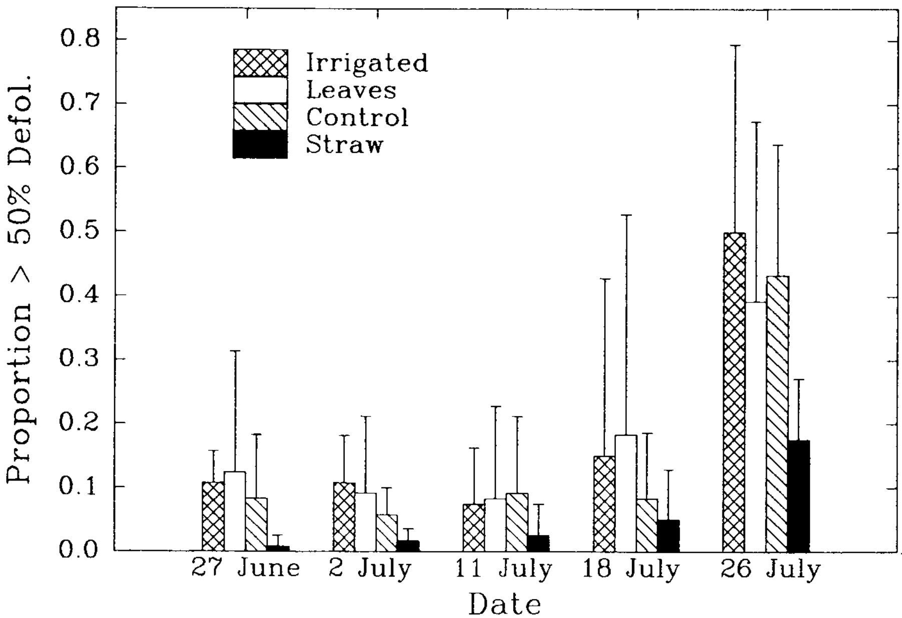

Fig. 6. Effect of irrigation and mulches on the proportion of primary stems with > 50% of leaf area defoliated. This measure of defoliation was significantly affected by treatment over the entire season (df = 3,6; F = 4.6; P = 0.05), but the treatment X date interaction was not significant (df = 12,24; F = 0.9; P = 0.5), so the proportions for each date were not analyzed separately.

younger larvae, and starvation, which causes older and larger larvae to abandon defoliated plants to search for more food.

Further studies of mulching of potatoes should separate the effects of the mulch on Colorado potato beetle and other insect pests from any possible effects on early dying and other plant diseases and on soil temperature and moisture (Zehnder and Hough-Goldstein 1990).

Acknowledgments

I thank E. Coleman (Small Farm Research Associates) for advocating research on mulches in New England; L. Cota, C. Phillips, D. Williams, and J. Howe for technical assistance; and R. Weseloh and C. Maier for reviewing the manuscript.

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