Repulsion of Cucumber Beetles in Cucumber and Squash Using Aluminum-coated Plastic Mulch

John S. Caldwell¹ and
Paul Clarke²

ADDITIONAL INDEX WORDS. *Acalymma vittata*, black plastic mulch, *Cucumis sativus*, *Cucurbita pepo*, *Diabrotica undecimpunctata howardi*

SUMMARY. Cucumber (*Cucumis sativus* L.) and squash (*Cucurbita pepo* L.) were grown in a replicated trial on three types of plastic mulch: solid black plastic mulch, solid aluminum-coated plastic mulch with a silver reflective appearance, and black plastic mulch with two aluminum-coated strips attached. Striped cucumber beetle (*Acalymma vittata* Fabricius) and spotted cucumber beetle (*Diabrotica undecimpunctata howardi* Barber) (Coleoptera: Chrysomelidae) counts on yellow sticky cards were obtained over eight weekly samplings. For cucumber, on the peak beetle population date, there were six times as many striped cucumber beetles in solid black plastic mulch as in aluminum-coated plastic mulch, and nearly three times as many as in black plastic mulch with aluminum strips. For squash, both striped and spotted cucumber beetle counts were significantly higher on solid black plastic mulch on three peak sampling dates than on aluminum-coated plastic mulch and black plastic mulch with aluminum strips, with counts 4.9 to 5.5 times higher in solid black plastic mulch than in aluminum-coated plastic mulch, and 2.2 to 2.6 times higher than in black plastic mulch with aluminum strips. Using a threshold of

15 beetles/sticky card, no insecticidal applications were needed on solid aluminum-coated mulch, while an average of 1.8 insecticidal applications were needed on solid black plastic mulch, and 0.8 insecticidal applications on black plastic mulch with aluminum strips. The cost of solid black plastic mulch and its insecticidal applications, \$186/acre (\$459/ha), was \$102/acre (\$252/ha) less than the cost of aluminum-coated plastic mulch without insecticidal application, \$288/acre (\$711/ha). However, squash fruit from plants grown on aluminum-coated plastic mulch could be direct marketed as pesticide-free, at a price 25% higher than fruit on which pesticide had been applied. For an average yield in Virginia of 600 boxes/acre (1,482 boxes/ha) [20 lb/box (9 kg/box)] of squash, this translates to a \$1,200/acre (\$2,964/ha) increase in revenue. Yield on aluminum-coated plastic mulch was delayed by one week, but there were no significant differences in cumulative yield over 14 harvests.

Striped and spotted cucumber beetles are major pests of cucurbits in Virginia, especially for farmers who do not use insecticides (Caldwell et al., 1995). Feeding damage on young cucurbit seedlings can be serious in May and June. Bacterial wilt [*Erwinia tracheiphila* (Smith) Bergey et al.] and squash mosaic virus are transmitted by these beetles (Matthews, 1991) and can cause serious problems when insecticides are not used.

Aluminum-coated plastic mulch has been known for many years to repel aphids, reduce and delay the incidence of aphid-transmitted virus diseases in squash, and increase total and marketable yield (Brown et al., 1993; Brown et al., 1996; Chalfant et al., 1977; Conway et al., 1989; Lancaster et al., 1987). It has also been shown in one study to reduce the incidence of striped and spotted cucumber beetles (Schalk et al., 1979), but it has not been widely used for cucumber beetle control. In 1996, there appeared to be few cucumber beetles in an observational plot of squash planted into aluminum-coated plastic mulch (P. Clarke, personal observation). In 1997, we established an experiment to determine the extent to which aluminum-coated plastic mulch repelled cucumber beetles. We report these results here in printed form, following a report to Virginia vegetable growers through the electronic exten-

We thank Kathy Birkhead for assistance in the field. The use of trade names in this publication does not imply endorsement of the products named or criticism of similar ones not mentioned. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

¹Associate professor, Department of Horticulture, Virginia Tech, Blacksburg, VA 24061-0327.

²Grower, Mountain Harvest Farm, Inc./Clarke Ag Plastics, Greenwood, VA 22943.

Fig. 1. Counts of striped cucumber beetles (StCB) and spotted cucumber beetles (SpCB) on yellow sticky traps placed in cucumber plantings grown on solid black plastic (BP), black plastic with aluminum strips (BAS), or solid aluminum-coated plastic (AL), Mountain Harvest Farm, Albemarle, Va., 1997. The count at each date indicates the number of beetles of the respective species accumulated after 1 week on both sides of the yellow sticky card in the planting on the respective type of plastic mulch. Values are means of four replications. Statistical analysis of differences is found in Table 1.

Table 1. Effects of solid black plastic mulch, solid aluminum-coated mulch, and aluminum strips placed on black plastic mulch on populations of striped and spotted cucumber beetles on yellow sticky traps in cucumber, Mountain Harvest Farm, Albemarle, Va., 1997.

Sampling date	Black plastic vs. solid aluminum and strips			Aluminum strips vs. solid aluminum		
	Spotted	Striped	Both	Spotted	Striped	Both
12 June	*	NS	*	NS	NS	NS
19 June	NS	**	**	NS	NS	NS
26 June	NS	NS	NS	NS	NS	NS
2 July	NS	NS	NS	NS	+	NS
10 July	NS	**	+	NS	NS	NS
17 July	+	*	*	NS	NS	+
24 July	NS	NS	NS	NS	NS	NS

NS, +, **, * Differences in counts nonsignificant, trend at $0.05 \leq P < 0.10$, or significant at $P \leq 0.05$ or 0.01 , respectively.

sion newsletter, Vegetable Growers News (Caldwell and Clarke, 1998), sent to Virginia extension agents and subscribing growers.

Materials and methods

Sixteen rows with three types of plastic mulch were laid in May 1997 on a field at Mountain Harvest Farm, Albemarle County, Virginia, that had been planted in cucurbits for the pre-

ceding five years. The three types of plastic mulch were: solid black plastic mulch [1 mil (0.025 mm) thickness, Tredegar Film Products, Richmond, Va.]; aluminum-coated plastic mulch with a silver reflective appearance [1.5 mil (0.038 mm) thickness, silver over clear, Clarke Ag Plastics, Greenwood, Va.]; and black plastic mulch onto which two aluminum-coated strips each 8 inches (20 cm) wide were attached with $1 \times 6 \times 1/8$ -inch ($25 \times 152 \times 3$ -mm)

staples, with 1 to 2 ft (0.3 to 0.6 m) between the strips. The plastic mulch was laid on rows with 5-ft (1.5-m) centers and 150-ft (45.7-m) length, in sets of four rows wide with a 10 ft (3.1 m) buffer space between each four-row set. Each 20-ft (6.1-m) wide four-row set was divided into three 50-ft (15.2-m) long sections, and one type of plastic mulch was randomly assigned to each section, for four replications of the three plastic mulch treatments. In each section, two rows were planted in 'General Patton' squash (Asgrow Seed, Kalamazoo, Mich.) and two rows were planted in Meteor cucumber (Asgrow Seed, Kalamazoo, Mich.). Both crops were directly seeded into the three types of plastic mulch on 8 May (initial seeding) and 24 May (spot reseeding), 1997.

From 5 June to 24 July, 6×6 -inch (15×15 -cm) yellow sticky-card traps (Olsen Products, Medina, Ohio) were attached weekly with $1/4$ -inch (6-mm) staples on 4-ft (1.2-m) tomato stakes at a height 2 ft (0.6 m) above the soil line. One trap was placed between the two rows of each crop in each treatment, for two traps per plot and 24 traps total in the field. One week later, numbers of striped and spotted cucumber beetles on both sides of each trap were counted, for a total of 8 sampling dates. Esfenvalerate (Asana, E.I. du Pont de Nemours & Co., Wilmington, Del.) was applied at the rate of 0.03 lb/acre ($0.03 \text{ kg} \cdot \text{ha}^{-1}$) of active ingredient when counts in a given treatment exceeded 15 beetles total of both species combined. This threshold was derived by correlation of sticky card counts with visual counts in squash in Virginia in 1996, and corresponded to a visual observation threshold of one beetle per plant (Caldwell et al., 1998). The latter threshold has been established in Indiana for control of bacterial wilt (Brust et al., 1996; Foster and Flood, 1995). Squash and cucumber fruits were harvested 14 times from 2 July to 6 August; squash yields are reported as numbers of 20-lb (9-kg) boxes.

Differences between treatments in numbers of cucumber beetle counts, numbers of squash and cucumber fruits, and numbers of boxes of squash fruit were analyzed by analysis of variance and orthogonal contrasts (black plastic mulch versus plastic mulch with aluminum (combined effect of treatments with solid aluminum and with attached strips); solid aluminum-coated plastic mulch versus black plastic with alumi-

Fig. 2. Counts of striped cucumber beetles (StCB) and spotted cucumber beetles (SpCB) on yellow sticky traps placed in squash plantings grown on solid black plastic (BP), black plastic with aluminum strips (BAS), or solid aluminum-coated plastic (AL) Mountain Harvest Farm, Albemarle, Va., 1997. The count at each date indicates the number of beetles of the respective species accumulated after 1 week on both sides of the yellow sticky card in the planting on the respective type of plastic mulch. Values are means of four replications. Statistical analysis of differences is found in Table 2.

Table 2. Effects of black plastic mulch, solid aluminum mulch, and aluminum strips placed on blade plastic mulch on populations of striped and spotted cucumber beetles on yellow sticky traps in squash, Mountain Harvest Farm, Albemarle, Va., 1997.

Sampling date	Black plastic vs. solid aluminum and strips			Aluminum strips vs. solid aluminum		
	Spotted	Striped	Both	Spotted	Striped	Both
12 June	*	*	*	+	NS	NS
19 June	*	**	**	NS	+	NS
26 June	**	*	*	NS	NS	NS
2 July	NS	+	NS	NS	NS	NS
10 July	NS	NS	NS	NS	NS	+
17 July	*	NS	NS	*	+	**
24 July	NS	NS	NS	NS	NS	NS

NS, +, *, ** Differences in counts nonsignificant, trend at $0.05 \leq P < 0.10$, or significant at $P \leq 0.05$ or 0.01 , respectively.

num strips) [PROC GLM of the Statistical Analysis System (SAS Institute, 1989)]; insect counts were transformed using the square root of $(x + 0.5)$ before analysis. Means of significant effects are reported using untransformed values (Gomez and Gomez, 1984). Partial budgeting was used to determine potential economic benefits. The cost of insecticidal application included the cost of rental of a tractor, sprayer, and driver (calculated for the time to apply to 1

acre), in addition to the cost of the insecticide. The cost of aluminum strips included labor time to cut a roll of aluminum-coated plastic mulch and apply strips, in addition to the cost of both types of plastic mulch (black and aluminum-coated) and staples for attachment.

Results and discussion

For cucumbers, there were the highly significant differences in striped

cucumber counts on 19 June between the solid aluminum-coated plastic mulch and black plastic mulch with aluminum strips compared to solid black plastic mulch. Counts on this date were 6 times higher in black plastic mulch (42 beetles/trap) than in the solid aluminum-coated plastic mulch (7 beetles/trap), and nearly 3 times higher than in the black plastic mulch with aluminum strips (15 beetles/trap). A similar trend for spotted cucumber beetles was seen on 12, 19, and 26 June and 2 July, but the differences were not statistically significant on any of these dates (Fig. 1, Table 1).

More dramatic differences were seen in squash. Both striped and spotted cucumber beetle counts were significantly higher on solid black plastic mulch on 12, 19, and 26 June (Table 2) than on solid aluminum-coated plastic mulch and on black plastic mulch with aluminum strips. Counts on 19 and 26 June were 4.9 and 5.5 times higher in solid black plastic mulch (40 and 23 beetles/trap) than in the solid aluminum-coated plastic mulch (8 and 5 beetles/trap), and 2.6 and 2.3 times higher than in the black plastic mulch with aluminum strips (15 and 10 beetles/trap). Smaller but still significant differences were similarly seen for spotted cucumber beetles. The concentration of striped cucumber beetles on solid black plastic mulch is particularly striking on 19 and 26 June. Although counts of cucumber beetles on these two dates were higher on the black plastic mulch with aluminum strips than on solid aluminum-coated plastic mulch, the differences between black plastic mulch with aluminum strips and solid aluminum-coated plastic mulch were not statistically significant (Fig. 2, Table 2).

Counts in solid aluminum-coated plastic mulch remained well below 15 beetles per sticky card, which as explained above we found in 1996 to correspond to one beetle per plant, the threshold established in Indiana for bacterial wilt transmission. These results suggest that use of solid aluminum-coated plastic mulch can reduce cucumber beetle populations below this threshold.

We made insecticidal applications using the above threshold of 15 beetles per sticky card. On a per plot basis, an average of 1.8 insecticidal applications were made on solid black plastic mulch, and 0.8 insecticidal applications were made on black plastic mulch with aluminum strips. The cost of solid black plastic mulch and insecticidal applications on

Fig. 3. Yields of squash grown on solid black plastic (BP), black plastic with aluminum strips (BAS), or solid aluminum-coated plastic (AL) Mountain Harvest Farm, Albemarle, Va., 1997. The yield for each period indicates the total number of boxes harvested during the period from squash grown on the respective type of plastic mulch. Values are means of four replications. Differences in yields between plastic types were not significant at any date except for a trend ($0.05 \leq P < 0.10$) on 2-7 July.

it, \$186/acre (\$459/ha), was \$102/acre (\$252/ha) less than the cost of using solid aluminum-coated plastic mulch, \$288/acre (\$711/ha). However, use of solid aluminum-coated plastic mulch permitted fruit to be direct marketed as pesticide-free, at a price 25% higher (\$10/box for squash) than fruit on which pesticide has been applied (\$8/box). Using an average yield in Virginia 600 boxes/acre of squash (O'Dell et al., 1994), this translates to a \$1,200/acre (\$2,964/ha) increase in revenue. This increase compares favorably with the added \$102/acre (\$252/ha) of expense for using solid aluminum plastic mulch.

During the 5-week period when the grower marketed squash from the trial field, he was able to obtain this \$2/box higher price for pesticide-free squash in sales through his own direct-market produce stand and to other local produce stand buyers. The grower has observed that this pesticide-free price markup is used in two farmers' markets in this area, as well as by two local gourmet and organic foods stores. This pesticide-free markup has also prevailed at other times when the base price level has been lower, \$6/box.

Even higher revenue could be obtained with the yields obtained in this trial of 1,567 boxes/acre (3,870 boxes/ha). There were no significant differences among treatments in overall yield,

although yield in the first week of harvest was reduced by 38% on solid aluminum-coated plastic mulch [185 boxes/acre (457 boxes/ha)] relative to solid black plastic mulch [297 boxes/acre (734 boxes/ha)] (trend at $0.05 \leq P < 0.10$) (Fig. 3). This delay in yield was likely due to the soil warming properties of solid black plastic mulch.

The use of solid reflective aluminum-coated plastic mulch could have several benefits for both conventional and organic vegetable growers. It could give conventional growers an alternative to insecticidal application that would enable them to market pesticide-free produce and thereby increase income. For organic growers, repulsion of cucumber beetles might keep their numbers low enough to avoid bacterial wilt, as was the case in this trial. In addition, the repulsive effect of reflective aluminum-coated plastic mulch may also reduce virus transmission by cucumber beetles and aphids, as other studies cited earlier have shown.

In this experiment, cucumber beetles faced a field with a mosaic of appearances. Plots with solid aluminum-coated plastic mulch, solid black plastic mulch, and black plastic mulch with aluminum strips were all adjacent to one another. More research is needed to determine whether beetles would be repelled from a field planted entirely in

solid aluminum-coated plastic mulch, or whether the repulsion is relative. In the latter case, solid black plastic mulch might be placed in occasional rows in the field as a trap strategy, to concentrate beetles in those rows, and preferential pesticide application be made on those rows only.

Literature cited

- Brown, J.E., J.M. Dangler, F.M. Woods, and K.M. Tilt. 1993. Delay in mosaic virus onset and aphid vector reduction in summer squash grown on reflective mulches. *HortScience* 28(9):895-896.
- Brown, J.E., R.P. Yates, C. Stevens, V.A. Khan, and J.B. Witt. 1996. Reflective mulches increase yields, reduce aphids and delay infection of mosaic viruses in summer squash. *J. Veg. Crop Prod.* 2(1):55-60.
- Brust, G.E., R.E. Foster, and W.G. Buhler. 1996. Comparison of insecticide use programs for managing the striped cucumber beetle (Coleoptera: Chrysomelidae) in muskmelon. *J. Econ. Entomol.* 89(4):981-986.
- Caldwell, J.S., J-P. Amirault, and A.H. Christian. 1995. Insect pests, beneficial insects, and cover crops of biological farmers. *HortScience* 30(4):806 (abstr.).
- Caldwell, J.S. and P. Clarke. 1998. Aluminum-coated plastic for repulsion of cucumber beetles. *Commercial Hort. Nsl.*, January-February 1998; <http://www.ext.vt.edu/departments/commhort/1998-02/1998-02-01.html>.
- Caldwell, J.S., S. Johnson, M. Lachance, and S. Stockton. 1998. Threshold monitoring, trap cropping, and aluminum mulch repulsion for management of cucumber beetles on cucurbits. *HortScience* 33(2):475 (abstr.).
- Chalfant, R.B., C.A. Jaworski, A.W. Johnson, and D.R. Sumner. 1977. Reflective film mulches, millet barriers, and pesticides: Effects on watermelon mosaic virus, insects, nematodes, soil-borne fungi, and yield of yellow summer squash. *J. Amer. Soc. Hort. Sci.* 102(1):11-15.
- Conway, K.E., B.D. McCraw, J.E. Motes, and J.L. Sherwood. 1989. Evaluations of mulches and row covers to delay virus diseases and their effects on yield of yellow squash. *Appl. Agr. Res.* 4(3):201-207.
- Foster, R. and B. Flood (eds.). 1995. Vegetable insect management. Meister Publ., Willoughby, Ohio.
- Gomez, K.A. and A.A. Gomez. 1984. Statistical procedures for agricultural research. 2nd ed. Wiley, New York.
- Lancaster, D.M., H.K. Whitam, and L.L. Black. 1987. Reflective mulch delays virus spread in summer squash. *La. Agr. Expt. Sta.* 30(3):16-17.
- Matthews, R.E.F. 1991. Plant virology. 3rd ed. Academic Press, San Diego, Calif.
- O'Dell, C.R., H. Snodgrass, and G. Groover. 1994. 45 selected costs and returns budgets for horticultural food crops production/marketing. Va. Coop. Ext. Publ. 438-898.
- SAS Institute, Inc. 1989. SAS/STAT user's guide, version 6. 4th ed. vol. 2. SAS Institute, Inc., Cary, N.C.
- Schalk, J.M., C.S. Creighton, R.L. Fery, W.R. Sitterly, B.W. Davis, T.L. McFadden, and A. Day. 1979. Reflective film mulches influences insect control and yield in vegetables. *J. Amer. Soc. Hort. Sci.* 104(6):759-762.