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Reflective Film Mulches Influences Insect Control and Yield in Vegetables[1]

J. M. Schalk[2], C. S. Creighton[2], R. L. Fery[3], W. R. Sitterly[4], B. W. Davis[5], T. L. McFadden[5], and Augustine Day[2]

U.S. Department of Agriculture, Charleston, SC 29407

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Abstract. **In field tests, the most effective film mulch in deterring insects and reducing insect damage to fruits was aluminum. The insects affected were aphids, brown stink bugs, aphid parasites, and *Diabrotica* spp. Mosaic virus diseases were reduced among aluminum-mulched squash (*Cucurbita pepo* L.) and cucumber (*Cucumis sativus* L.) plants. Plant growth, flowering, and fruiting were delayed in tomatoes (*Lycopersicon esculentum* Mill.) and southernpeas (*Vigna unguiculata* (L.) Walp.).**

The need of vegetable growers and home gardeners in the U.S. to control plant pests might be met by using reflective mulches. In fact, such mulches are known to reduce the incidence of aphid-borne viruses and to deter the approach to some species of pest (1, 2, 4, 5, 6, 9). As a result, their application in some areas of large-scale agriculture has been gradually expanding. However, some insects are repelled, and others may be attracted to these reflective surfaces. For example, aluminum mulches do produce practical reduction of aphid-transmitted mosaic viruses of squash (2, 4, 9); and thrips (*Frankliniella tritici:* (Fitch)) and a leafminer (*Liriomyza* sp.) were repelled when aluminized mulches were used with gladiolus and squash, respectively (10, 11). On the other hand, honey bees (*Apis mellifera* L.) and pickleworm (*Diaphania nitidalis* (Stoll)) were attracted to squash plants mulched with aluminum and brown paper mulches (2, 10). Apparently both the short and long light waves from reflective mulches contribute to the deterrent effect on such insects as aphids (7).

We therefore investigated the use of reflective mulches for general insect control by the small vegetable farmer and home gardener.

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[2]Research Entomologists, Vegetable Insects Laboratory, AR, SEA, USDA.

[3]Research Geneticist, U.S. Vegetable Laboratory, AR, SEA, USDA.

[4]Superintendent and Plant Pathologist, Clemson University Truck Crops Experiment Station.

[5]Agricultural Research Technicians, Vegetable Insects Laboratory, AR, SEA, USDA.

[6]Mention of a proprietary product does not imply endorsement by the USDA.

Materials and Methods

Four experiments were conducted during a 2-year period (1977 and 1978) in Charleston County, S. C. on Edisto *Glossaquic Hapludalfs* loamy sand and Seabrook *Aquic Udipsamments* loamy fine sand. Each plot consisted of 3 mulched rows spaced 2 m apart. Mulches were applied at the appropriate time (shortly before planting) by machine and were aluminum on paper, aluminized plastic, or white plastic. The controls were black plastic or no mulch (bare ground). Except for the mulches, normal commercial management practices were followed.

Experiment 1. Individual 6-m long plots were planted August 24 with either 'Poinsett' cucumber or 'Dixie' squash plants spaced 0.45 m apart. The design was a randomized complete block with 4 replicates. The mulches used were aluminum, aluminized plastic, and black plastic. Observations were made to determine pickleworm damage *(D. nitidalis),* incidence of the mosaic viruses (squash and cucumber mosaic viruses) and infestations of aphid and *Diabrotica* spp. and aphid parasites (Braconidae).

Experiment 2. 'Ferrys Round Dutch' cabbage was transplanted April 3 into 7.6 m long plots (0.3 m apart; 25 hills/plot). Subsequently, Dipel, a bacterial insecticide (*Bacillus thuringiensis* Berliner), was applied at a rate of 2.3 kg/ha on May 11, 19, 25, and June 1. For every insecticide-treated mulch plot there was an untreated control. A randomized complete block design with 4 replicates was used. The mulches were aluminum, aluminized plastic, white plastic, and black plastic. Weight and head diameter of the cabbage (8 plants/plot) and insect damage (10 heads/plot), and populations were determined.

Experiment 3. 'Walter' tomato plants were transplanted March 23 (spaced 0.6 m apart) into 7.3 m long plots with 12 plants/plot. The plants were staked and tied for harvesting ease according to commercial practice. The experimental design was a randomized complete block with 4 replicates. The 3 separate harvests of vine-ripened fruit coincided with commercial harvests. The weight and number of both marketable and unmarketable fruit (due to stink bug damage, other deformities, and over-ripe fruit) were determined, and plant height and aphid infestation were noted.

Experiment 4. Southernpeas ('Mississippi Silver', and breeding line CR 22-2-21) were hand planted on June 9 in 6 m long plots. Seeds were spaced 0.3 m between hills (28 hills/plot). The design was a split plot with 8 replicates; genotypes were the whole plot and mulches the subplot. Yield, initiation (earliness) of harvest, plant vigor, plant height, and plant emergence were determined. Populations of aphids were determined, and damage by mandibulate feeders, leafminer (*Liriomyza munda* (Frick)), cowpea curculio (*Chalcodermus aeneus* Boheman) and stink bug (*Nezara viridula* (L.)) was noted.

In all experiments, data were taken from a center row bordered on both sides by buffer rows. Insect counts were made 3 times during the season and numbers of plants sampled with 5/plot for experiments 1, 3 and 4, and 8/plot for experiment 2. In addition, 23 cm diameter trap pans painted Rustolium yellow were placed in center row plots of all crops, and insects trapped there were collected weekly until the harvests were completed. Also, for effective sampling of Coleoptera, a wood trap (14 cm wide × 22 cm high), painted yellow and covered with Stickem was placed in the center row. Coleoptera were recorded weekly.

Results

Experiment 1 (Table 1). More foliage and fruit of squash than of cucumber was injured by pickleworm; in fact fruit damage was 20 times greater. Less pickleworm damage to squash foliage occurred on those plots mulched with aluminum than on those mulched with black plastic. However, in the case of cucumber the amount of foliage damage was the same on all mulched plots. No differences in pickleworm damaged fruit of either squash or cucumber was noted among the mulch treatments. Thus the mulches were ineffective in deterring this important pest.

Aphid species in both crops were effectively repelled by the aluminum and by the aluminized plastic mulches, and the incidence of the mosaic virus complex was reduced in plots treated with these mulches. Banded and spotted cucumber beetles (*Diabrotica balteata* LeConte and *D. undecimpunctata howardi* Barber) were also repelled by the aluminum and aluminized plastic mulches. The braconid sp. complex (aphid parasites) also were repelled by the reflective mulches.

Experiment 2. No differences were found in % marketability of cabbage heads as a result of the mulches; however, marketability increased with insecticide treatment. Generally, numbers of larvae and pupae of the diamondback moth (*Plutella xylostella* (L.) were reduced only by the insecticide treatments. Factorial analysis revealed no interactions between mulches and the insecticide. Earliness, vigor, weight, and head diameter were not significantly affected by the treatments. No differences were found in the plant counts of eggs, larvae, and pupae of the cabbage looper (*Trichoplusia ni* (Hubner)), and imported cabbageworms (*Pieris rapae* (Linnaeus)) and the pan counts of aphids or braconids.

Experiment 3 (Table 2). Aluminum and aluminized plastic mulches repelled potato aphids (*Macrosiphum euphorbiae* (Thomas)) in tomatoes; plots with these treatments had the fewest insects collected from trap pans. Also, the reflective mulches reduced the number of fruits injured by the brown stink bug (*Euschistus* sp.). There were no differences among plots in the numbers of fruits damaged by tomato fruitworm (*Heliothis zea* (Boddie)).

The various treatments had no visible effect on days to flowering and plant vigor; however, reduced growth (height) and fruiting were evident early in the season (May 5) in the plots mulched with aluminum. At the final observation, 6-weeks from planting, all plants were of similar height. Also, during the first harvest, the weights and numbers of fruits were less in plots with aluminum mulch, but when all 3 harvest dates were combined, there were no differences.

Experiment 4 (Table 3). Percent emergence of breeding line CR 22-2-21 was greater than 'Mississippi Silver.' There was a significant interaction (P = 1%) between genotype and mulch treatments. Larger plant stands were achieved in plots treated with white plastic, aluminized plastic, and aluminum. Generally, plots with no mulch (bare ground) or with black plastic mulch were the least productive.

The plant canopy (height) as harvest approached was dependent on the type of mulch and the genotype. Breeding line CR 22-2-21 was consistently taller, and the taller plants were found in the plots treated with aluminized and white plastic mulches. However, in earlier observations (juvenile

Table 1. The influence of reflective mulches on pickleworm damage, incidence of mosaic virus, and infestations of aphids and *Diabrotica* in cucumber and squash plants (Test 1).

Treatment	Pickleworm damage: Foliage^z /plant	Pickleworm damage: Fruit infestation (No. holes/fruit)	Incidence of mosaic virus (%)/plot	Aphid infestation (count/plot)^y	Diabrotica infestation (count/plot)^y	Braconidae infestation (count/plot)^y
Squash						
Aluminum	2.9b^x	3.2a	12.8bc	15.3b	2.8c	1.0b
Aluminized plastic	3.4ab	4.5a	26.0ab	30.0b	5.0c	2.3ab
Black plastic	3.5a	3.3a	53.5a	60.0a	13.3ab	4.3a
Cucumber						
Aluminum	1.1c	.1b	2.3c	12.8b	5.0c	1.5b
Aluminized plastic	1.0c	.1b	15.3bc	27.3b	9.0b	1.5ab
Black plastic	1.1c	.3b	31.8ab	90.3a	16.5a	2.8ab
Source of Variation						
Plant species	**^{w}	**	NS	NS	**	NS
Mulch	NS	NS	*	**	**	*
Plant species × mulch	NS	NS	NS	NS	NS	NS

^{z}Rated on a scale of 1 (limited or no larval feeding) to 5 (heavy larval feeding).

$^y\sqrt{x + 0.5}$ transformation used in analysis. Collected in yellow trap pans or yellow Stickem traps.

^{x}Mean separation within columns by Duncan's multiple range at 5% level.

^{w}*, ** significant at the 5% and 1% levels respectively, NS not significant.

Table 2. The influence of reflective mulches on aphid infestations, stinkbug damage, plant height, fruit set, and first harvest yield of 'Walter' tomatoes (Test 3).

Treatment	Aphid infestation (count/plot)^z	Stinkbug fruit damage (%/plot)	Early season		First harvest yield (kg/plot)
			Plant height (cm)/plant	Fruit set/ plant	
Aluminum	3.5b^y	43c	46.5c	9.8b	7.7b
Aluminized plastic	8.5b	58bc	50.5b	19.3a	13.2a
White plastic	31.3a	78b	49.0b	17.3a	13.5a
Black plastic	26.8a	100a	52.3a	25.8a	15.5a

$^z\sqrt{x + 0.5}$ transformation used in analysis. Collected in yellow trap pans.

^{y}Mean separation within columns by Duncan's multiple range test.

Table 3. The influence of reflective mulches on % plant emergence, plant height, plant vigor, harvest initiation, total yield, chewing insect damage, leafminer infestation, cowpea curculio damage, and aphid infestation of 'Mississippi Silver' and CR 22-2-21, southernpeas (Test 4).

Treatment	Plant emergence (%/ plot)	Plant height (cm/ plot)	Plant vigor^z	Initiation of harvest (no. pods/ plot)	Total pod yield (g/plot)	Chewing insect^y (damage/ plant)	Leafminer infestation (no. tunnels/ plant)	Cowpea curculio damage (no. punctures/pod)	Aphid infestation^x (counts/ plot)
Mississippi Silver									
Aluminum	75.0bc^w	49.5cd	2.8a	29.0b	1051bc	2.6a	20.3cd	17.5bc	2.0b
Aluminized plastic	81.3b	58.5ab	1.9c	46.4a	1179abc	2.2abcd	19.0d	41.8a	2.3b
White plastic	81.3b	58.1ab	2.1bc	45.8a	1137bc	2.1abcd	23.4bcd	25.4bc	16.5a
Black plastic	65.6cd	48.4cd	2.9a	39.4ab	882cd	2.3abcd	35.8ab	35.0ab	26.8a
No mulch	58.0d	43.8d	2.7ab	31.5b	715d	2.4abc	21.5cd	6.5c	18.5a
CR 22-2-21									
Aluminum	94.2a	56.4bc	2.1bc	36.6ab	1358ab	2.6ab	29.6abcd	15.6bc	–
Aluminized plastic	95.5a	64.1a	1.4cd	46.9a	1468a	1.9d	24.5bcd	4.8c	–
White plastic	95.9a	59.6ab	1.9c	48.5a	1261ab	1.9cd	33.3abc	14.8bc	–
Black plastic	75.5bc	50.9cd	2.7ab	47.1a	1239ab	2.2abcd	39.3a	12.0bc	–
No mulch	93.7a	56.6bc	1.2d	49.8a	1125bc	2.1bcd	24.4bcd	11.0bc	–
Source of Variation									
Plant genotype	**^{v}	**	**	**	*	NS	NS	**	–
Mulch	**	**	**	**	**	**	**	*	–
Plant genotype × mulch	*	NS	*	NS	NS	NS	NS	**	–

^{z}Rated on a scale of 1 (good plant vigor) to 5 (poor plant vigor).

^{y}Rated on a scale of 1 (limited to no foliage damage by mandibulate insects) to 5 (severe foliage damage).

$^x\sqrt{x + 0.5}$ transformations used in analysis. Yellow pan traps stationed only in Mississippi Silver cv.

^{w}Mean separation within columns by Duncan's multiple range test.

^{v}*, ** significant at the 5% and 1% levels respectively. NS is not significant.

plants), the plant heights were greater in the control (bare ground) plots and in plots mulched with aluminized plastic and white plastic.

Plant vigor, based on color and growth development, of 'Mississippi Silver,' was apparently less than that of CR 22-2-21, and a significant interaction was observed between plant entries and mulches. Vigor was less in plots with black plastic and aluminum mulches. Moreover, when the phenological (anthesis and pod development) events were scrutinized, plants reared in plots treated with a aluminized plastic, bare ground (control), black plastic, and white plastic were significantly more vigorous than plants treated with aluminum because the aluminum mulch tended to retard anthesis of both entries.

The first harvest (based on maturity of 50-pod sample per plot) was significantly earlier for CR 22-2-21. Pod maturity of 'Mississippi Silver' was even further delayed in the plots treated with aluminum and bare ground; the other mulches did not cause the same delay. Gross yield of pods (intact) revealed that CR 22-2-21 had the higher yield and that the most effective mulches were aluminized plastic, aluminum, and white plastic. Total yields were lower in plots treated with black plastic and bare ground, and these did not differ significantly. No differences in yield of seeds were noted between plant genotypes; however, the highest yields were found in plots treated with aluminized plastic, white plastic, and aluminum.

Foliage injury due to mandibulate insects did not differ between genotypes; however, more damaged plants were found in plots treated with aluminum mulch. There were no differences among the remaining mulches. The number of leafminer tunnels was not significantly different between the genotypes, but more tunnels were counted in plants from plots treated with black plastic mulch. The pods of breeding line CR 22-2-21 are resistant to cowpea curculio feeding (3), and this was evident since the susceptible 'Mississippi Silver' received more damage from this insect. Also plots of this cultivar treated with black plastic and aluminized plastic mulch had more puncture damage. Feeding by the southern green stinkbug on pods was more evident on 'Mississippi Silver' than on CR 22-2-21, which appears to be less injured; there were no differences among the mulches.

The characteristic pod damage resulting when lepidopteran larvae feed through the pod into the seeds was probably done by the corn earworm *(H. zea)* which was the prevalent species found. 'Mississippi Silver' sustained almost 3 times as much of this type of damage as breeding line CR 22-2-21. The mulches had no effect on larval damage.

Yellow pan traps revealed that aphids were deterred by the aluminum and aluminized plastic mulches.

Discussion

Our research confirms the effect of reflective mulches in reducing aphid-borne virus diseases and repelling aphids (1, 2, 4, 5, 6, 8, 9 and 11). It also shows that *Diabrotica* spp. are repelled from cucurbits by these mulches, and that brown stink bug damage is reduced in tomatoes. This addition of *Diabrotica* to the list of arthropods that are repelled by reflective mulches may also mean that such mulches will reduce the incidence of bacterial wilt and cucumber mosaic of cucurbits; the vector (*Acalymma* sp.) is a beetle related to the genus *Diabrotica* that may have similar behavioral patterns relative to reflective mulches.

In general, reflective mulches hold promise in reducing insect populations and damage while increased yields may result. Also these mulches can be integrated easily into pest management programs. However, reflective mulches should not be recommended indiscriminantly until their impact on individual agriculture ecosystems is clearly understood.

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Adaptation of Ornamental Species to an Acid Soil High in Exchangeable Aluminum[1]

C. D. Foy[2] and N. C. Wheeler[3,4]

Plant Stress Laboratory, PPHI, U. S. Department of Agriculture, Beltsville, MD 20705

Additional index words. aluminum toxicity, Ca deficiency, P deficiency, alkaline soil

Abstract. **Sixty-nine species of ornamental plants were screened for Al tolerance in greenhouse pots of acid Tatum subsoil adjusted to different pH levels by liming. Species differed widely in tolerance to the unlimed soil at pH 4.1-4.4. For example, in one experiment the relative top yield on unlimed vs. limed soil (pH 4.3/pH 5.2) was 71% for *Dolichos lablab* L. (hyacinth bean); 63% for *Tropaeolum majus* L. (nasturtium); 62% for *Cleome spinosa* Jacq. (cleome); 59% for *Calonyction aculeatum* L. (moonflower); 18% for *Tagetes erecta* L. (marigold); 11% for *Cosmos sulphureous* Cav. (cosmos); 4% for *Calendula officinalis* L. (calendula); and 0.8% for *Chrysanthemum coronarium* L. (garland chrysanthemum). With the exception of cleome, the acid-soil-tolerant species were larger seeded than the sensitive species. Ornamental species also differed in tolerances to neutral-alkaline Tatum soil (pH 7.0-7.2). For example, relative top yields on high lime vs. low lime soil (pH 7.1/5.1) were 89% for marigold, 87% for cleome, 79% for calendula, 78% for hyacinth bean, 54% for nasturtium and 11% for garland chrysanthemum. Ornamental plants were classified according to suitability for strongly acid (pH 4.1-4.4), moderately acid (pH 5.1-5.4) or neutral to alkaline (pH 7.0-7.2) Tatum subsoil.**

Frequently ornamental plants are needed that can grow in strongly acid soils which, for various reasons, cannot be limed. Steep roadside banks and abandoned mine spoils are examples of sites on which the correction of soil acidity, particularly in subsoils, may be difficult or not economically feasible (1, 4).

The acid soil "infertility complex" is composed of many factors, including excesses of Al, Mn and other metallic cations, and deficiencies or unavailabilities of certain essential elements, particularly Ca and P (6, 8, 9). Below about pH 4.0 the H ion (low pH, *per se*) may also directly limit plant growth; at higher soil pH (4.0-5.5) the harmful effects of low pH on higher

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[2]Soil Scientist.

[3]Plant Ecologist, Environmental Seed Producers, Inc., El Monte, California.

[4]We are indebted to M. L. McCloud for plant analyses.