J. AMER. SOC. HORT. SCI. 120(5):778-784. 1995.

Color Mulches Influence Yield and Insect Pest Populations in Tomatoes

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Additional index words. Lycopersicon esculentum, aphids, thrips, whiteflies, tomato mottle virus, soil temperatures, plant height

Abstract. **Field studies were conducted for three seasons, Fall 1988 and Spring and Fall 1989, on the effect of six mulch colors: blue, orange, red, aluminum, yellow, and white (fall) or black (spring), on fruit yields and on insect vectors of Sunny' tomato *(Lycopersicon esculentum* Mill.). Plant growth and yields were inconsistent with mulch colors during the three seasons. In Fall 1988, in a once-over harvest, extra-large (≥ 70 mm diameter) and marketable fruit yields were higher (*P* ≤ 0.05) on blue than on the conventional white mulch. In Spring 1989, early marketable yields on red mulch were higher than on black mulch, and in Fall 1989, under high stress from tomato mottle virus (TMoV) transmitted by silverleaf whitefly *[Bemisia argentifolii* (Bellows and Perring)], seasonal yield of extra-large fruit was better on orange than white mulch. In Fall 1988 and 1989, fruit size and marketable yields were reduced on yellow mulch. Aphids (Aphididae), thrips (Thripidae), and whiteflies were counted monthly in traps placed on the mulched beds. Aphids were least numerous on the aluminum and yellow and most numerous on the blue mulch. Where differences occurred, the fewest thrips were captured on aluminum and the fewest whiteflies were captured on the yellow, aluminum and orange mulches. Although differences were not always significant, the fewest adult whiteflies also were observed on foliage of tomato plants grown on these latter three mulches. Later in the seasons, as plant foliage covered the mulch, differences in the number of insects captured were similar for all mulch colors. Low numbers of whiteflies on the orange and aluminum mulches early in Fall 1989 delayed virus symptom development and increased yields. Virus symptom development was not delayed and yields were low on the yellow mulch, in spite of the low number of whiteflies. When averaged over all mulch colors, extra-large and marketable fruit yields increased linearly with delayed symptom development. It is proposed that, under high insect stress, mulches should be selected for their effects on insects in addition to their effects on soil temperature and plant morphology.**

Tomatoes in Florida are grown on raised beds covered with polyethylene film (Geraldson et al., 1965). In the winter and spring, black, and in the summer and fall, white or white on black polyethylene film (mulch) is used. Mulch cover, especially various color mulch covers, create a specific microenvironment for the plants. The changes in microenvironment, compared to bare ground, include changes in root-zone temperature and in the quantity and quality of light reflected from the mulch surface back to the leaves (Decoteau et al., 1989; Lamont, 1993). The reflected energy from the mulch affects not only plant growth, development, fruit yields (Decoteau et al., 1989; Schalk et al., 1979), and the behavior of insects that visit the plants (Kring, 1972). Yellow and, to a lesser degree, orange mulches attracted green peach aphids *[Myzus persicae* (Sulzer)], while aluminum and silver mulches repelled aphids (Adlerz and Everett, 1968; Wolfenbarger and Moore, 1968). Thrips *[Thrips tabaci* (Lindeman)] and *Frankliniella* sp. were also repelled by reflective (aluminum or silver) mulches (Brown and Brown, 1992; Scott et al., 1989). Since aphids and thrips are important vectors of plant pathogenic viruses (Matthews, 1991), the property of mulches to attract or to repel insects can be very important in protecting plants from virus diseases. Mulch color may also influence the insect species that visit plants. For example, Schalk and Robbins (1987) found that aphids were repelled by aluminum mulch, but fruit injury increased due to tomato pinworm *[Keiferia lycopersicella* (Walsingham)] and tomato fruitworm *[Helicoverpa zea* (Boddie)]. The effect of mulch color on insect populations may be gradually reduced as the season progresses and the expanding plant foliage covers the mulch. Scott et al. (1989) reported that the effectiveness of aluminum mulch in reducing the number of thrips and *Frankliniella* sp. generally disappeared compared with black mulch and bare soil when lower leaves of tomatoes shaded the mulch.

There is no report in Florida on the effect of mulch color on tomato yields and tomato insect pest species. Studies were initiated to investigate the effect of mulch color on tomato yields and insect populations that infect tomatoes.

Materials and Methods

Studies were conducted during three seasons, Fall 1988 and Spring and Fall 1989 on Eau Gallie fine sand (sandy silicaceous, hyperthermic Alfic Haplaquod). The experimental design was a randomized complete block with three replications. Each treatment (mulch color) consisted of three adjacent mulched beds per block, each 9.15 m long, 72 cm wide, and 20 cm high, formed on 1.51-m centers. White on black (Fall 1988 and 1989) or black (Spring 1989) 38-µm-thick polyethylene film was laid on the beds. Before laying the mulch, each treatment received the equivalent of (in $kg \cdot ha^{-1}$) 322N, 61 P, 535 K, 0.82 B, 0.82 Cu, 4.92 Fe, 2.05 Mn, 0.05 Mo and 1.91 Zn. The soil was fumigated with Terr-0-Gas (66.6% methylbromide, 33.3% chloropicrin) at 239 $kg \cdot ha^{-1}$. Ten days later blue (197A 110 Royal Blue), orange (197A 123 Dutch Orange), red (211A 114 Vermillion), and yellow (197A 116 Jonquil) alkyd–oil finish paints (Ace Hardware Corp., Oak Brook, Ill.) and an aluminum paint (Kool Brite, Mobile Paint Mfg. Co.) were applied by a backpack sprayer to the top and sides of the

Received for publication 6 Sept. 1994. Accepted for publication 20 Apr. 1995. Florida Agricultural Experiment Station Journal series no. R-04000. 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.

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mulched beds. Paints were diluted 1:1 (v/v) with mineral spirits and applied at about 6.6 liters/100-m bed. In the spring, a 23-cm wide strip was left unpainted down the bed middle. Mulch in the control plots was left unpainted. Spectral reflectance from the mulches was determined by a spectrophotometer (Shimadzu-UV-210; Bausch and Lomb, Sarasota, Fla.) equipped with an integrating sphere. Two weeks after fumigation on 1 Sept. 1988 and 21 Feb. and 31 Aug. 1989; 5-week-old 'Sunny' tomato (Asgrow 674) seedlings, obtained from a commercial source, were transplanted in a single row per bed at a 72-cm spacing in Fall 1988 and Spring 1989, and at a 61-cm spacing in Fall 1989. Plants were staked and tied three times during the season. Plant pathogens were controlled by applying approved fungicides and bactericides weekly. Lepidopterous larvae were controlled by weekly applications of *Bacillus thuringiensis* (Berliner) (Dipel 2x or Javelin WG) and methomyl (Lannate) as needed. Plant heights on six adjacent plants in each plot were measured periodically. Soil temperatures at 10 cm deep were measured by AU-metal dial thermometers (Fisher Scientific, Pittsburgh) in each plot on weekdays between 1315 and 1545 HR. Reflected radiation from the mulch surface to the adaxial side of the leaves was measured on six plants in each color mulch treatment by a radiometer (LI-185A; LI-COR, Lincoln, Neb.) with a quantum sensor (Lambda Instrument Corp., Lincoln, Neb.) at 10 cm high. Measurements were made between 1100 and 1200 HR every other week at four locations (north, south, east, and west) until the expanding foliage covered the mulch. Insects were trapped in yellow water traps placed weekly for 24 h on the bed surface. Traps consisted of 12.7-cm, square plastic containers with 10.2-cm squares of yellow plexiglass in the bottoms and 30 ml of a water and detergent mixture. In Fall 1989, when the silverleaf whitefly *(Bemisia argentifolii* Bellows and Perring) transmitted tomato mottle virus (TMoV) severely infected plants (Polston et al., 1991), plants with apparent virus symptoms were tagged weekly. Whitefly adults were counted biweekly on three fully expanded leaves of each of five plants from the middle row of each plot. Crawlers and sessile nymphs were counted biweekly on the terminal leaflet of the seventh or eighth leaf from the top of each of 10 plants in the middle row of each plot.

Shoots with fully developed young compound leaves were collected for macro and microelement analyses in Spring 1989 at 43, 68, and 99 days after planting (DAP), and random samples of marketable grade fruit from each plot were taken for macro- and microelement analyses at the second harvest. Nitrogen was determined by a modified Kjeldahl method (Tecator, 1987), and all other elements were measured at the Univ. of Florida's Analytical Research Laboratory (Hanlon and deVore, 1989).

Fruit in the center rows from six consecutive plants were harvested once in 1988 due to tropical storm Keith and three times in weekly intervals in Spring and Fall 1989. Fruit were separated into marketable and cull, then marketable fruit were size-graded by a machine as extra large (270 mm in diameter); large (63.5 to 70.6 mm); and medium (57.2 to 64.3 mm). The number and weight of fruit in each grade were recorded. In Fall 1989, fruit yields were also recorded according to the date when apparent virus symptoms were first noticed.

Data were analyzed by ANOVA (SAS Institute, Cary, N.C.). When significant F values were found, means were separated by Duncan's multiple range test and a regression analysis was performed on the yields as affected by virus infection dates.

Results

Aluminum, yellow, white, and blue mulches reflected light in the B (400 to 500 nm) and the near ultraviolet (395 nm) region (Fig. 1). Orange and red mulches had no measurable reflected light in the B and near-B regions of the spectrum.

The quanta of photosynthetically active radiation ($\mu mol \cdot m^{-2} \cdot s^{-1}$) reflected from the mulches onto the plants in March and September

Table 1. Quanta of photosynthetically active radiation reflected from color mulches at 10 cm from the surface.

Date	Mulch color					
	Blue	Orange	Red	Aluminum	Black or white[z]	Yellow
	$\mu mol \cdot m^{-2} \cdot s^{-1}$ [y]					
Spring 1989						
27 Mar.	39 b[x]	33 b	37 b	131 a	37 b	114 a
19 Apr.	22 b	18 b	24 b	40 a	9 c	26 b
Fall 1989						
27 Sept.	74 c	89 c	74 c	167 a	111 bc	135 ab
24 Oct.	19 d	28 bcd	20 cd	46 a	36 b	30 bc

[z]Black mulch in spring and white in fall.
[y]Averaged over four locations per plant, six plants per mulch color and three replications.
[x]Mean separation within rows by Duncan's multiple range test, $P \leq 0.05$.

Table 2. Soil temperatures (°C) at 10 cm in plant beds covered with different colored polyethylene mulches, Fall 1989.

Date	Mulch color					
	Blue	Orange	Red	Aluminum	White	Yellow
	°C[z]					
22 Sept.	39.3 a[y]	37.2 c	38.5 b	34.5 d	37.3 c	34.8 d
5 Oct.	41.0 a	39.0 ab	40.5 ab	36.5 b	39.0 ab	36.5 b
2 Nov.	36.0 a	34.0 b	35.0 ab	31.0 c	34.0 b	31.5 c
17 Nov.	19.0 b	20.0 ab	21.0 ab	20.0 ab	21.5 a	21.5 a

[z]Averaged over three replications.
[y]Mean separation within rows by Duncan's multiple range test, $P \leq 0.05$.

Table 3. Tomato plant heights (cm) on selected dates after planting in soil covered with different colored polyethylene mulches.

Day after planting[z]	Mulch color: Blue	Orange	Red	Aluminum	White or black	Yellow
			cm			
Fall 1988						
36	59.4 b[y]	64.7 a	63.3 a	64.1 a	64.5 a	66.3 a
48	91.5 b	98.6 a	95.8 a	96.2 a	97.1 a	99.7 a
Spring 1989						
34	42.9 ab	44.8 a	42.2 b	42.3 b	42.7 ab	40.8 b
66	137.6 a	133.7 ab	124.3 d	130.2 bc	127.5 cd	132.9 ab
Fall 1989						
38	53.3 d	55.5 c	53.6 d	56.2 ab	57.3 ab	58.2 a
57	101.3 b	105.3 b	104.8 b	114.5 a	106.1 b	112.8 a

[z]Planting dates: 1 Sept. 1988 and 21 Feb. and 31 Aug. 1989.
[y]Mean separation within rows by Duncan's multiple range test, $P \leq 0.05$.

were highest from the aluminum and yellow mulches (Table 1). As the season progressed and plants expanded, the reflected radiation was reduced from all color treatments, but the reflected energy from the aluminum was still the highest.

Soil temperatures from September to early November were highest under the blue mulch, reaching 41C on 5 Oct. (Table 2). During the same period, soil temperatures under the aluminum and yellow mulches were 4.5 to 5C lower than under the blue mulch. In mid-November, soil temperature dropped to 19C under the blue and to 21.5C under the white and yellow mulches.

There were significant differences in plant heights with the color mulches in all three seasons (Table 3). In Fall 1988, at 36 and 48 DAP, plants grown on the blue mulch were shorter than on any other mulch. In Fall 1989 at 57 DAP, plants on the blue mulch were again shorter than plants on aluminum and yellow mulches. During Spring 1989, however, plants at 66 DAP were tallest (137.5 cm) on the blue mulch and shortest (124.3 cm) on the red mulch.

The number of axillary shoots was similar among all mulch colors (data not shown).

In Fall 1988, when fruit were harvested once on 1 Dec. due to tropical storm Keith, extra-large fruit yield on the blue mulch was higher than on any other mulch (Table 4). Marketable yield in the once over harvest was also highest with the blue mulch (47.7 $t \cdot ha^{-1}$). Marketable yields on red (38.2 $t \cdot ha^{-1}$) and on orange (34.6 $t \cdot ha^{-1}$) mulches were similar to yields on blue mulch, while yields on white, aluminum, and yellow mulches were lower than on blue mulch. In Spring 1989, early yields of extra-large fruit were higher on aluminum and red than on yellow and blue mulch. For the season, higher yields of extra-large fruit were recorded on aluminum and black than on blue and orange mulches. Early marketable yields were also higher on red than on black, yellow, and blue mulches, but for the season marketable yields were similar with all six mulch colors. In Fall 1989, when the whitefly-transmitted TMoV infected the plants, early yields of extra-large fruit were higher on the white than on blue or yellow mulch. Seasonal yields of extra-large fruit were highest on orange mulch and lowest on yellow mulch. Early yields of marketable fruit in Fall 1989 were highest on the white mulch and lowest on the red, blue, and yellow mulches. For the season, highest yield was recorded on the orange and lowest yield on the yellow mulch. In Fall 1989, yields of extra-large and marketable fruit, averaged over the six mulch colors, also depended on the first appearance of TMoV symptoms (Table 5). Extra-large and marketable fruit yields per plant were twice as high when virus symptoms appeared 61 to 77 DAP than during the first 30 DAP. Extra-large fruit yields increased linearly according to the equation $y = 0.675 + 0.112x$, and marketable yields increased $y = 1.682 + 0.396x$, with delayed virus infection symptoms, where x is infection date ($P \leq 0.05$).

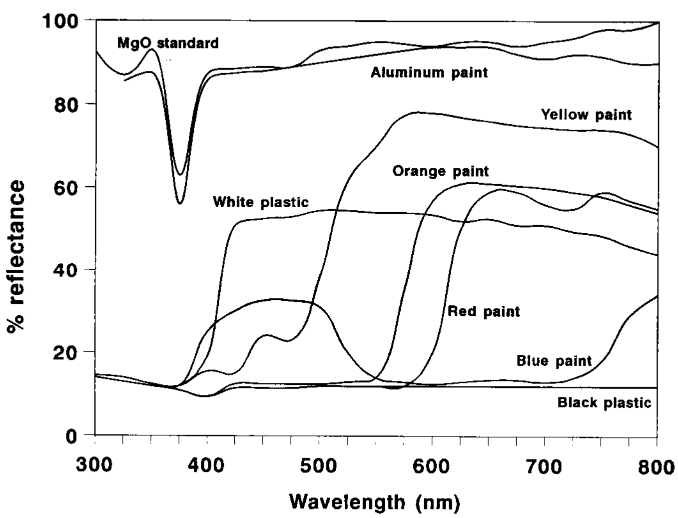

Fig. 1. Spectral reflectance characteristics of painted and nonpainted polyethylene mulches. MgO standard = 100%.

Number of aphids, thrips, and whiteflies trapped on the color mulches per replication in each month during the three seasons are given in Tables 6-8. In each of the three seasons, the fewest aphids were trapped on the aluminum and, in Spring and Fall 1989, on the yellow mulch (Table 6). Aphids were more numerous during September in Fall 1988 and during March in Spring 1989 than later in the season and during Fall 1989.

The average number of thrips counted in the traps was far larger in the spring than in the fall (Table 7). In Spring 1989, the blue mulch attracted the largest and aluminum mulch the smallest number of thrips. Regardless of the mulch color, thrips were present in largest numbers during March, and their number greatly decreased during April and May. In Fall 1988 and 1989, the seasonal average number of thrips per replication was equal to or less than one per trap on the various mulches.

The number of whiteflies trapped during Fall 1988 was statistically similar on all mulch colors (Table 8). The average number of whiteflies for the season ranged from 5 per trap on the orange to 14 per trap on the red mulch. In Spring 1989, fewer numbers of whiteflies were counted early in the season (March) on yellow and aluminum than on blue, black, and red mulches. As the season

Table 4. Early and total yields of 'Sunny' tomato grown on different colored mulches.

Mulch color	Early[z] 1989 Spring	Early[z] 1989 Fall	Season's total 1988 Fall[y]	Season's total 1989 Spring	Season's total 1989 Fall
		$t \cdot ha^{-1}$			
Extra-large fruit yield[x]					
Blue	0.9 c[w]	4.8 bc	16.1 a	26.5 b	16.4 ab
Orange	7.0 ab	6.0 abc	9.1 b	24.7 b	20.5 a
Red	9.0 a	5.7 abc	7.7 b	32.4 ab	9.8 bc
Aluminum	9.1 a	6.6 abc	6.0 b	48.2 a	8.7 bc
White or black[v]	7.4 ab	8.6 a	9.5 b	48.1 a	10.1 bc
Yellow	5.4 b	3.7 c	6.2 b	33.6 ab	5.5 c
Marketable yield					
Blue	3.9 c	5.6 c	47.7 a	98.3 a	33.0 ab
Orange	15.1 ab	6.7 bc	34.6 abc	95.7 a	44.0 a
Red	16.7 a	6.3 c	38.2 ab	102.5 a	33.5 ab
Aluminum	13.8 ab	10.8 ab	26.0 bc	116.8 a	42.8 ab
White or black[v]	12.3 b	12.1 a	31.1 bc	115.5 a	36.6 ab
Yellow	12.2 b	5.6 c	21.9 c	108.5 a	30.8 b

[z]First weekly harvest.
[y]Once-over harvest.
[x]Extra-large fruit: ≥70 mm in diameter.
[w]Mean separation in columns by Duncan's multiple range test, $P \leq 0.05$.
[v]White in fall and black in spring.

progressed, numbers of trapped whiteflies gradually increased on all six mulches and, in May, ranged from 57 per trap on the yellow to 119 per trap on the red mulch. In Fall 1989, when the whitefly-transmitted TMoV reached epidemic proportions, fewer whiteflies were found early in the season (August and September) in traps on yellow, orange, and aluminum than on white, blue, and red mulches. Similarly, fewer adults were observed on plants growing on yellow, orange, and aluminum mulches than other mulches, although differences were not always significant (Table 9). This would suggest that the captures in yellow traps generally reflected the number of whitefly adults on foliage and, therefore, the trapping results can be validly compared across the different color mulches. The numbers of trapped and observed adults increased as the season progressed until, in November, the number of whiteflies found on traps were similar regardless of mulch color. Nevertheless, fewer adults were observed on plants growing on yellow and orange mulches than on red or white mulches. The numbers of nymphs on plants growing on yellow, orange, or aluminum mulches were lower than those on plants on the other mulches, although few significant differences were detected.

There were only small and nonsignificant differences in macro- and micronutrient concentrations in shoots and in fruit with the various mulch colors. For example, in Spring 1989 at harvest (99 DAP), N concentration in shoots ranged from 2.81% with the orange to 3.34% with the aluminum mulch, P from 0.23% with blue to 0.27% with black mulch, and K from 2.14% with the aluminum to 3.05% with the red mulch.

Residual concentrations of macro- and microelements in soil were also similar with mulch treatments and are not presented here.

Discussion

The differences in plant growth and yields observed on the same mulch color between the three seasons may have been due to

Table 5. Proportion of-plants with first signs of virus infection and effect of virus infection date on marketable yield and fruit size, Fall 1989.

Mulch color	Proportion of plants with first signs of virus infection[z] (DAP[y]) 1–30	31–60	61–77	Marketable yield, Virus infection date (DAP) 1–30	31–60	61–77	Season avg	Extra-large yield, Virus infection date (DAP) 1–30	31–60	61–77	Season avg
		%			kg/plant				kg/plant		
Blue	22	78	---	3.1	3.2	---	3.1 ab[x]	1.3	1.7	---	1.5 ab[x]
Orange	---	89	11	---	4.1	6.2	4.6 a	---	1.5	4.4	1.9 a
Red	6	83	11	0.9	3.6	4.1	3.5 ab	0.2	1.0	0.6	0.9 bc
Aluminum	---	78	22	---	3.7	6.1	4.1 ab	---	0.5	1.2	0.8 bc
White	22	78	---	2.6	3.6	---	3.4 ab	0.5	1.0	---	0.9 bc
Yellow	6	83	11	3.8	2.6	3.5	2.8 b	0.4	0.4	0.7	0.5 c
Average for all colors	9	81	9	2.6	3.5	5.2	---	0.8	1.1	1.6	---

[z]Total no. of plants: 18 per mulch color and 108 for the six mulch colors.
[y]DAP = days after planting; seedlings transplanted on 31 Aug.
[x]Mean separation by Duncan's multiple range test, $P \leq 0.05$.

Table 6. Average number of aphids (Aphididae) counted per trap on color mulches during three consecutive seasons.

	Mulch color					
Season	Blue	Orange	Red	Aluminum	White or black[z]	Yellow
1988 September	3.0 a[y]	0.5 ab	0.8 ab	0.1 b	2.0 a	0.5 ab
October	0.5 ab	0.3 ab	0.4 ab	0.3 b	1.0 a	0.4 ab
November	0.0 a	0.0 a	0.2 a	0.0 a	0.0 a	0.0 a
Seasonal average per trap	1.0 a	0.3 b	0.4 b	0.1 b	1.2 a	0.3 b
1989 March	3.0 a	3.0 a	2.0 ab	0.0 c	2.0 abc	0.6 bc
April	0.5 a	0.3 ab	0.1 b	0.1 b	0.3 ab	0.0 b
May	0.0 b	0.7 a	0.0 b	0.0 b	0.2 b	0.0 b
Seasonal average per trap	2.0 a	1.0 a	0.6 b	0.0 c	0.8 b	0.2 c
1989 August	0.0 b	0.7 a	0.0 b	0.0 b	0.3 ab	0.0 b
September	0.3 b	0.5 ab	1.0 a	0.0 b	0.2 b	0.2 b
October	0.5 ab	0.5 ab	0.8 a	0.0 b	0.8 a	0.0 b
November	0.7 ab	0.3 b	1.3 a	0.0 b	0.3 b	0.0 b
Seasonal average per trap	0.4 ab	0.5 ab	1.0 a	0.0 b	0.5 ab	0.1 b

[z]White in fall and black in spring.
[y]Mean separation within rows by Duncan's multiple range test, $P \leq 0.05$.

several factors. In Fall 1988, plants on blue mulch were relatively shorter than in Spring 1989 (Table 3), yet extra-large fruit yields on blue mulch, relative to other mulch colors, were higher in fall than spring (Table 4). The reason for the differences in plant heights between the spring and fall plantings on the blue mulch may be due to the different effect of blue color on plants under high and low light intensities and the effect of the increased far-red to red (FR/R) light ratio of the blue mulch on the seedlings (Decoteau and Friend, 1991; Ham et al., 1991; Salisbury and Ross, 1984). In the fall under high light intensity, plants were shorter because the upward reflected energy in the blue region of the spectrum had an overriding effect of the FR region of the light that promotes stem elongation. Early in the spring under relatively low light intensity, the FR/R ratio increased and resulted in increased plant heights.

In Fall 1989, the effect of mulch colors on plant growth was confounded by the whitefly-transmitted TMoV that affected plant heights, regardless of mulch color. In Spring 1989, the reduced fruit size and reduced early marketable yields on the blue mulch may also have been due to the large number of thrips that was attracted to the blue mulch early in the season (Table 7). Whiteflies were also attracted to the blue mulch in large numbers in Spring and Fall 1989 (Table 8). Consequently, in areas where thrips and whiteflies are likely to infest tomatoes, blue mulch is not recommended.

These studies confirmed the beneficial effect of red mulch compared to the conventionally used black mulch in increasing the early marketable yield and fruit size in the spring, (Decoteau et al., 1989). For the season, however, yields were similar or better with aluminum and black than with red mulch (Table 4). In Spring and

Table 7. Average number of thrips (Thripidae) counted per trap on color mulches during three consecutive seasons.

	Mulch color					
Season	Blue	Orange	Red	Aluminum	White or black[z]	Yellow
1988 September	1.0 ab	0.3 b[y]	0.4 b	0.3 b	2.0 a	0.4 b
October	1.0 a	0.5 b	0.4 b	0.3 b	0.8 ab	0.8 ab
November	2.0 a	0.0 b	0.0 b	0.3 ab	0.2 ab	0.8 ab
Seasonal average per trap	1.0 a	0.3 b	0.3 b	0.3 b	1.0 a	0.6 b
1989 March	354.0 a	137.0 b	53.0 b	22.0 b	109.0 b	159.0 b
April	5.0 ab	4.0 ab	3.0 ab	4.0 ab	9.0 a	2.0 b
May	1.0 a	1.0 a	1.0 a	1.0 a	0.3 a	0.2 a
Seasonal average per trap	144.0 a	57.0 b	23.0 cd	9.0 d	41.0 bc	65.0 b
1989 August	1.0 a	0.7 a	1.0 a	0.0 a	2.0 a	0.0 a
September	0.5 a	0.0 a	0.7 a	0.2 a	0.5 a	0.3 a
October	0.5 a	0.2 a	0.0 a	0.2 a	0.5 a	0.0 a
November	0.3 a	0.3 a	0.3 a	0.0 a	0.0 a	0.7 a
Seasonal average per trap	0.5 a	0.2 ab	0.4 ab	0.1 b	0.6 a	0.2 ab

[z]White in fall and black in spring.
[y]Mean separation within rows by Duncan's multiple range test, $P \leq 0.05$.

Table 8. Average number of whiteflies *(Bemisia* sp.) counted per trap on color mulches during three consecutive seasons.

Season	Blue	Orange	Red	Aluminum	White or black[z]	Yellow
	Mulch color					
1988 September	8 a	3 a[y]	8 a	3 a	4 a	4 a
October	20 ab	8 b	24 a	11 b	16 ab	18 ab
November	8 a	5 a	20 a	21 a	5 a	20 a
Seasonal average per trap	10 a	5 a	14 a	8 a	8 a	11 a
1989 March	7 a	4 ab	6 a	2 b	7 a	1 b
April	28 a	19 a	29 a	16 a	26 a	18 a
May	89 ab	68 ab	119 a	73 ab	94 ab	57 b
Seasonal average per trap	23 ab	23 b	38 a	22 bc	32 ab	19 c
1989 August	23 a	2 b	22 a	3 b	25 a	2 b
September	26 a	9 b	21 a	7 b	27 a	6 b
October	16 ab	16 ab	21 a	10 ab	15 ab	6 c
November	33 a	32 a	34 a	20 a	24 a	17 a
Seasonal average per trap	23 a	14 b	22 a	10 bc	22 a	7 c

[z]White in fall and black in spring.
[y]Mean separation within rows by Duncan's multiple range test, $P \leq 0.05$.

Fall 1989, many whiteflies were found in traps on the red mulch. Since whiteflies are the vectors of TMoV, which severely reduces fruit size and yield, especially in the fall, red mulch should not be used for tomatoes in Florida.

That fewer aphids, thrips, and whiteflies were counted in the traps on aluminum mulch compared to other mulches agrees with earlier reports on the insect-repellant characteristic of aluminum (Schalk and Robbins, 1987; Scott et al., 1989). Therefore, aluminum mulch may be useful for tomato production where aphid and thrips are a problem during the growing season.

Yields on yellow mulch in both fall seasons were very poor. The low yields of extra-large and marketable fruit in Fall 1989, when TMoV reduced yields, is particularly puzzling because fewer whiteflies were trapped or observed on plants growing on the yellow mulch (Tables 8 and 9). Furthermore, marketable yields did not increase with delayed virus infection as recorded with other mulch colors (Table 5). The poor yields on the yellow mulch, therefore, may have been the result of the light-reflectant characteristics of this mulch. Yellow mulch reflects more red (photosynthetic), but less far-red photomorphogenetic) light of the spectrum (Coufal et al., 1984; Decoteau and Friend, 1991), and that may have resulted in reduced yields. Based on these results, yellow mulch cannot be recommended for tomatoes.

Traps and plants on the orange and aluminum mulches also had few whitefly adults during August and September (Tables 8 and 9), but plants on the aluminum and orange mulches, unlike those on the yellow mulch, had no apparent virus infection signs during the first 30 DAP. The relatively high yields recorded on the orange and aluminum mulches under high virus stress may be due then to the whitefly-repellant characteristics of the orange and aluminum mulches that allowed the young plants to grow and develop free of virus disease. Later in the season, when the expanded plant foliage covered the mulch, whiteflies were not repelled by mulch color, and, by November, all plants had virus symptoms on all mulch treatments (Table 5). It is important, therefore, that under high insect stress, the insect-repellant, soil-microclimate-modifying, and photobiologically beneficial effects of the mulch be considered when a mulch color is selected for tomato production.

Table 9. Average number of whiteflies *(Bemisia argentifolii)* on foliage of tomato plants grown on color mulches during Fall 1989.

Month	Blue	Orange	Red	Aluminum	White or black[z]	Yellow
	Mulch color					
		No. adults per 15 leaflets[y]				
September	21.7 a	2.2 c	14.7 ab	3.0 c	12.8 ab	6.2 bc
October	11.7 a	5.2 b	7.5 ab	6.8 b	8.5 ab	8.3 ab
November	16.7 b	16.7 b	24.0 a	20.0 ab	25.0 a	16.3 b
Seasonal average	16.7 a	6.3 c	13.7 ab	7.9 c	13.5 ab	9.1 bc
		No. nymphs per 10 leaflets[y,x]				
September	30.7 a	30.0 a	35.3 a	7.3 a	37.0 a	13.7 a
October	37.7 ab	26.7 ab	38.3 a	12.8 b	34.2 ab	23.0 ab
November	49.7 a	20.7 a	43.7 a	44.0 a	42.3 a	38.0 a
Seasonal average	38.9 a	26.0 ab	38.9 a	19.3 b	36.9 ab	24.4 ab

[z]White in fall and black in spring.
[y]Data transformed square root of number of adults plus 0.5, but data presented in original scale.
[x]Mean separation within rows by Duncan's multiple range test, $P \leq 0.05$.

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