Proc. Fla. State Hort. Soc. 131:126–131. 2018.

Reflective Plastic Mulch As a Component of an Integrated Management Approach for Melon Thrips in Field-grown Cucumber

Mohammad A. Razzak*, Dakshina R. Seal, and Bruce Schaffer

Tropical Research and Education Center, University of Florida/IFAS, 18905 SW 280th St., Homestead, FL 33031

Additional index words: UV reflective plastic mulch, melon thrips, abundance, adult, larva

Melon thrips (*Thrips Palmi* Karny (Thysanoptera: Thripidae) is a serious pest of vegetable crops and ornamental plants. This pest is difficult to control because it is not very sensitive to commonly used insecticides. We evaluated the impact of different plastic mulches on the abundance of melon thrips in field grown cucumbers. In Fall 2015 and 2016, cucumbers were seeded in beds covered with metalized ultraviolet (UV) light reflective silver on white, UV-reflective silver on black, white on black, black on white, black on black, and a no mulch (control) in a randomized complete block design. Beginning three weeks after planting, the efficacy of the different mulches was compared weekly, based on the abundance of melon thrips in leaf samples. Significant reductions in the density of melon thrips were observed in the metalized reflective plastic mulch treatments compared to the other plastic mulch and control treatments. The highest numbers of melon thrips were observed in the white on black plastic mulch and the no mulch control treatments. The black plastic mulch treatments had an intermediate effect on reducing the number of melon thrips. The number of marketable fruit was approximately 60% higher when grown on silver reflective mulch than in the control treatment. Significantly greater number of cucumber fruit and earlier fruiting occurred in the reflective mulch than in the other treatments. These results suggest that reflective plastic mulch could be an important component of integrated pest management strategy for cucumber.

Cucumber is an economically important crop grown on 11,000 acres of land in Florida. Florida ranks number one in the United States for growing cucumber, with total sales of $66 million in 2015–16 (USDA–NASS, 2017).

Thrips palmi is an important pest of nearly all vegetable crops and some ornamental plants grown in fields and greenhouses (Seal and Baranowski, 1992; Seal and Sabines, 2012). *T. palmi* feeding often results in bronzing of leaves, stunting of whole plants, and scarring and distortion of the fruit, resulting in reduced marketable yield (Kawai, 1986; Seal et al., 2013; Tsai et al., 1995). In the absence of effective control measures, high populations of *T. palmi* can cause complete defoliation of host crops within a week of the onset of infestation and eventually can kill the host plants (Childers, 1997; Seal, 1997; Tsai et al. 1995). Feeding damage can sometimes lead to 70 to 90% economic losses (Bournier, 1983; Cardona et al., 2002). In the tropics, estimated crop losses from *T. palmi* infestation are 90% for cucumbers (Cooper, 1991). One *T. palmi* per cucumber leaf can cause a reduced number of tendrils, fewer leaves, and increased plant mortality. There was also a significant linear relationship between mean density and fruit scarring on cucumbers (Kawai, 1986; Suzuki and Miyara,1983).

Growers use different classes of insecticides as a primary tool to manage *T. palmi*. Repetitive foliar applications of chemicals from the same classes have resulted in unsatisfactory control of *T. palmi* (Seal et al., 2013). Also, demand for organic and chemical free produce is increasing worldwide. Therefore, it is important to develop integrated pest management (IPM) techniques to manage this pest and reduce the dependency on chemical control measures.

Plastic mulch can be a valuable component of an integrated management program for vegetable production. Plastic mulch reduces weed and disease pressure and provides efficient use of irrigation and fertilizer. Plastic mulch also increases the growth and yield of crops by modifying the microclimate of the root zone and ambient environment (Díaz-Pérez et al., 2007; Lamont, 1993; Reitz et al., 2003; Summers and Stapleton, 2002; Tindall et al., 1990). Optical properties of reflected light from various colored mulches can attract or deter insects by influencing their visual behavior (Antignus, 2014; Csizinsky et al., 1997; Csizinsky et al., 1999; Schalk and Robbins, 1987). Ultraviolet (UV)-reflective aluminum and silver mulches have been reported to effectively suppress infestation and disease transmission by a wide variety of insects including thrips (Brown and Brown, 1992; Greenough et al.,1990; Reitz et al., 2003; Scott et al., 1989; Tyler-Julian et al., 2015). Similar to some other insect species, melon thrips can discriminate between different light wave lengths and intensities (Fukushi, 1990). Melon thrips are detracted by reflected light in the ultraviolet spectrum (Nonaka and Nagai 1984). Metalized mirror mulch reduced the number of melon thrips on cucumber (Suzuki and Miyara, 1983). The number of both adults and larvae of *T. palmi* was significantly lower on 'Jalapeno' pepper grown on metalized UV-reflective silver mulches compared to other mulches and a no mulch control treatment (Razzak and Seal, 2017).

The authors would like to thanks James Colee, University of Florida/IFAS statistician for his assistance in analyzing the data.

*Corresponding author. Email: arazzak@juniv.edu; razzakufl@gmail.com; dseal3@ufl.edu

The present study was conducted to determine the effectiveness of different plastic mulches for managing melon thrips on field-grown cucumber. Leaf mineral nutrients from plants on the silver on black mulch and white on black mulch were investigated. Effects of different mulches on the yields of cucumber are also reported.

Materials and Methods

Field site, experimental design and mulch treatments. Field experiments were conducted at the University of Florida/IFAS, Tropical Research and Education Center (TREC) in Homestead during Fall 2015 and Fall 2016. There were four 62.48-m long beds, each consisting of 9.14-m long plots, six for each treatment; a 1.52 m buffer zone was maintained between plots. Each bed was considered as a block and was separated by 3.05 m of fallow soil. Each raised bed was 91 cm wide × 15 cm high.

Treatments were replicated four times in a randomized complete block design for five plastic mulch treatments and a no mulch control. Mulch treatments in this study were: 1) "metalized" plastic: silver infused top and black bottom; "silver-on-black" (Can-Shine N'Ripe, 1.25 mm); 2) "metalized" plastic: silver infused top and white bottom; "silver-on-white" (Can-Shine N'Ripe, 1.25 mm); 3) "Black" plastic: "black-on-black" (Can-Grow-XSB, 0.6 mm); 4) "black-on-white" (Can-Grow XSB, 0.9 mm); 5) "White" plastic: "white-on-black" (Can-Grow XSB, 0.9 mm); and 6) a no mulch control. The mulches are manufactured by Canslit Inc., Canada, and supplied by IMAFLEX USA Inc.

Crop establishment and management. Pre-plant granular fertilizer [8N–16P–16K, 1307 kg/ha (1166 lb/acre)] and a pre-emergence herbicide (halosulfuron methyl, 55 gm/ha, Sandea®) were applied before laying mulch on the beds. Cucumber seeds (*Cucumis sativus* L. var. 'Poinsett 76', Cucurbitaceae) were seeded (three seeds/hole) manually on 14 Nov. 2015 and 4 Nov. 2016. A 30.48 cm spacing was maintained between two seeding holes in each plot. Following germination, plants were thinned to one plant per hole. Plants were irrigated with a drip tube system twice a day, 9:30 –9:45 am and 3:30–3:45 pm. Three weeks after seeding, liquid fertilizer (3N–0P–101K) was injected through drip tubes using the rate mentioned in Vegetable Production Handbook of Florida 2015–16. No synthetic insecticides were applied in this experiment, however, *Bacillus thuringiensis*-based insecticides Dipel® DF (*B. thuringiensis* var. 'Kurstaki' strain ABTS-351, Certis USA) at 1120 g/ha and Xentari® DF (*B. thuringiensis* var. 'Aizawa') at 1120 g/ha (Valent Biosciences Co., Libertyville, IL) were applied to control Lepidopteran insects, particularly melon worm and pickle worm.

Leaf sampling for thrips. In 2015 and 2016, sampling began 21 days after planting (DAP) and continued weekly until the 8th week (49 DAP). Sampling was conducted by collecting five fully expanded leaves from the middle third of each plant, randomly selected from five plants in each plot. Sampled leaves were placed in a 1-L plastic cup with a thrips-proof lid. The cups were marked with block and mulch type. All sample cups were transported to the TREC vegetable IPM laboratory for further processing to separate melon thrips adults and larvae as described by Seal and Baranowski (1992). Following the separation, thrips were examined under a dissecting microscope at 10× to record the number of adults and larvae in each sample.

Leaf mineral nutrient analysis. As the highest and lowest number of thrips were recorded from the white on black mulch and both reflective mulches, respectively hence only two mulches, white on black and silver on black were selected for leaf tissue nutrient analysis. Fully expanded leaves of intermediate age from the middle section of plants were selected. Five leaves from each replication were collected and placed in a quart plastic bag marked with mulch type were brought to the IPM laboratory for further processing according to Kiggundu et al. (2012). Oven dried leaves were ground and sent to an analytical laboratory (Agro Services International Inc. Orange City, FL 32763) to determine the concentration macro nutrient element including nitrogen (N), phosphorus (P), and potassium (K).

Yield assessment. Five plants from the center of each plot were harvested to determine the number of marketable fruit. Fruit were harvested when the average weight of the fruit was about 150–200 g and the size was not less than 15.24 cm (6 in). Harvest was done at three-day intervals and continued until the death of plants. Six harvests were made in each year. Slightly deformed fruit were discarded at the time of harvesting.

Data analyses. Data were analyzed separately for adults and larvae and total number of (adults plus larvae) of melon thrips. Mean numbers of adults and larvae and total counts per five-leaf sample for each replicate of each treatment for each sampling date were compared using repeated measures analysis of variance (ANOVA). The number of thrips were subjected to a square root transformation before statistical analysis to meet the assumption of normality. Yield data were analyzed without transformation. Non-transformed means are presented in the tables. Data were analyzed using mixed model ANOVA with the main effects consisting of sampling date and mulch type and their interaction (PROC GLIMMIX model, SAS Institute Inc., version 9.3 and 9.4, Cary, NC, 2013). In the PROC GLIMMIX model, Kenward-Roger's method was used to compute degrees of freedom. Replicate and treatment factors (mulch) were considered as a random residual for repeated measures. For adults, larvae, and total number of *T. palmi* in each treatment at each sampling date, when the F value was significant, differences among means were separated using Tukey's HSD (Honestly Significant Difference) procedure in SAS (SAS Institute Inc. 2013). All data were analyzed at the 5% level of significant. No statistical analyses were performed for leaf tissue nutrient concentration because leaves from four replications of each treatment was considered as one sample.

Results and Discussion

Effects of mulch treatments on the number of melon thrips. In both 2015 and 2016, during all the sampling periods, UV-reflective silver mulches had significantly fewer adults, larvae and total melon thrips than the control and the white on black mulch treatments ($P < 0.05$) (Table 1). The highest number of adults, larvae and total number of melon thrips were observed in the control and the white on black mulch treatments, which were about four times greater than those on the reflective mulches. The black on black and black on white mulch were moderate in reducing the melon thrips population. The black on white mulch performed better than the black on black mulch in reducing the number of melon thrips (Table 1).

There was a significant interaction ($P < 0.05$) between date and mulch treatment for the number of melon thrips adults and larvae. In 2015, on the first and fourth sampling dates there were no significant differences ($P > 0.05$) in the number of adults among the different treatments, although mean number of adults

Table 1. Mean ± SE number[z] of melon thrips (*T. palmi*) adults, larvae and total numbers (adults plus larvae) per five leaf sample of cucumber grown on different plastic mulches and a non-mulch control across the sampling period.

	Thrips stage[y]					
	Adult		Larva		Total	
Mulch[x]	2015	2016	2015	2016	2015	2016
NM	359.0 ± 69.2 a	181.3 ± 40.8 a	1032.1 ± 192.8 a	972.3 ± 279.2 a	1391.1 ± 205.6 a	1153.5 ± 301.7 a
WB	270.2 ± 48.8 a	101.9 ± 20.4 ab	1145.7 ± 271.8 a	1006.2 ± 286.4 a	1415.9 ± 290.1 a	1108.0 ± 297.0 a
BB	100.4 ± 28.4 b	96.4 ± 26.3 bc	393.2 ± 94.5 b	751.6 ± 208.1 a	493.6 ± 103.5 b	848.0 ± 226.5 a
BW	150.2 ± 51.9 b	55.1 ± 13.0 bc	491.7 ± 135.7 b	358.1 ± 103.7 b	641.9 ± 158.4 b	413.2 ± 112.9 b
SW	84.5 ± 26.8 b	39.0 ± 11.9 c	262.2 ± 69.6 b	272.9 ± 94.6 b	346.7 ± 89.1 b	311.9 ± 104.0 b
SB	64.5 ± 19.0 b	39.4 ± 10.6 c	271.8 ± 73.1 b	223.2 ± 81.0 b	336.2 ± 88.5 b	262.6 ± 88.3 b
ANOVA results	$F_{5,18} = 15.51$ $P < 0.0001$	$F_{5,18} = 11.90$ $P < 0.0001$	$F_{5,15} = 20.35$ $P < 0.0001$	$F_{5,18} = 23.43$ $P < 0.0001$	$F_{5,18} = 23.71$ $P < 0.0001$	$F_{5,18} = 28.19$ $P < 0.0001$

[z]Means represent the numbers based on thrips counts from five sampling dates.
[y]Means within the same column followed by the same letters are not significantly different at $P \le 0.05$ according to Tukey's HSD tests.
[x]NM = no mulch, WB = white on black, BB = black on black, BW = black on white, SW = silver on white, and SB = silver on black.

was approximately four times higher in the control and white on black mulch treatments than in the reflective mulch treatments. The number of adults on 28 DAP, 35 DAP, and 49 DAP was significantly lower in the silver reflective mulch followed by black plastic mulch treatments (Table 2). In 2016, on the first two sampling dates, the number of adults was not statistically different ($P > 0.05$) among all treatments, although the mean number of adult was numerically greater in the control and white on black mulch than in the other treatments. On the subsequent sampling dates, compared with the white on black mulch and control treatments, the number of adults was significantly lowest in the metalized silver reflective mulch and black on white mulch. The mean number of adults in the black on black mulch was very close to that in the black on white mulch (Table 2).

On the first two sampling dates in 2015 and three sampling dates in 2016, there were no significant differences ($P > 0.05$) in the number of larvae among mulches and control treatments, although there were fewer larvae in the reflective mulch followed by black mulches. The mean number of larvae was larger in the white on black mulch and control treatments than in the other treatments (Table 3). In each year, on the following sampling dates (35 DAP, 42 DAP, and 49 DAP in 2015 and 42 DAP, 49 DAP in 2016), the number of larvae was significantly lower ($P < 0.05$) in the reflective mulch treatments than in the control and white on black mulch treatments. The number of larvae was always significantly highest ($P < 0.05$) in the control and white on black mulch treatments followed by black on black and black on white mulch (Table 3).

Overall in this study, when population size increased, treatment effects were more pronounced. Compared with the control and other mulch treatments, significantly lower numbers of melon thrips (adults, larvae, and total number) were observed in the reflective mulch treatments. Black mulch had an intermediate effect in reducing the melon thrips population. The lower number of thrips in the UV-reflective mulch treatments may have been due to the reflection of UV-light, which disrupted host finding and selection behavior of *T. palmi*. Our results are in agreement with the findings of previous researchers who studied thrips management using aluminum or silver reflective mulches in various cropping system (Greenough et al., 1990; Reitz et al.,

Table 2. Mean ± SE number of melon thrips adults (*T. palmi*) per five leaf sample of cucumber grown on different plastic mulches and a non-mulch control on different sampling dates.

		Sampling date[z]				
Year	Mulch[y]	21 DAP	28 DAP	35 DAP	42 DAP	49 DAP
2015	NM	25.3 ± 12.2 a	718.3 ± 215.3 a	463.8 ± 106.5 a	227.5 ± 61.3 a	360.0 ± 21.6 a
	WB	5.8 ± 3.3 a	298.3 ± 121.4 b	359.5 ± 136.6 ab	242.5 ± 66.1 a	445.0 ± 30.96 a
	BB	0.5 ± 0.5 a	37.5 ± 16.8 c	233.8 ± 104.7 abc	115.0 ± 19.4 a	115.0 ± 57.23 b
	BW	1.0 ± 0.7 a	23.8 ± 8.6 c	358.8 ± 228.4 ab	122.5 ± 36.4 a	245.0 ± 35.9 ab
	SW	6.0 ± 4.4 a	20.3 ± 10.0 c	166.3 ± 121.1 bc	80.0 ± 15.8 a	150.0 ± 24.2 ab
	SB	4.0 ± 2.4 a	12.0 ± 5.5 c	44.3 ± 11.3 c	77.0 ± 23.22 a	185.0 ± 59.5 ab
ANOVA results		$F_{5,89} = 0.42$ $P = 0.83$	$F_{5,89} = 17.69$ $P < 0.0001$	$F_{5,89} = 5.78$ $P = 0.0001$	$F_{5,89} = 1.73$ $P = 0.14$	$F_{5,89} = 3.98$ $P = 0.0003$
2016	NM	2.8 ± 0.9 a	18.5 ± 7.9 a	305.0 ± 98.9 a	302.5 ± 79.5 a	277.5 ± 63.0 a
	WB	5.8 ± 0.9 a	8.5 ± 1.6 a	182.5 ± 42.3 ab	147.5 ± 24.6 ab	165.0 ± 25.0 ab
	BB	0.5 ± 0.3 a	6.5 ± 2.2 a	77.5 ± 25.0 bc	122.5 ± 29.0 b	275.0 ± 61.2 a
	BW	1.3 ± 0.6 a	3.8 ± 1.5 a	77.8 ± 6.1 bc	87.5 ± 28.4 b	105.0 ± 35.7 b
	SW	1.0 ± 0.7 a	3.5 ± 1.6 a	23.0 ± 3.0 c	60.0 ± 18.3 b	107.5 ± 38.4 b
	SB	2.5 ± 0.9 a	1.5 ± 0.7 a	20.3 ± 5.6 c	70.0 ± 14.7 b	102.5 ± 25.4 b
ANOVA results		$F_{5,84} = 0.32$ $P = 0.90$	$F_{5,84} = 0.72$ $P = 0.61$	$F_{5,84} = 15.20$ $P < 0.0001$	$F_{5,84} = 7.38$ $P < 0.0001$	$F_{5,84} = 6.16$ $P < 0.0001$

[z]Means within the same column followed by the same letters are not significantly different at $P \le 0.05$ according to Tukey's HSD tests.
[y]NM = no mulch, WB = white on black, BB = black on black, BW = black on white, SW = silver on white, and SB = silver on black.

Table 3. Mean ± SE number of melon thrips larvae (*T. palmi*) per five leaf sample of cucumber grown on different plastic mulches and a non-mulch control on different sampling dates.

		Sampling date[z]				
Year	Mulch[y]	21 DAP	28 DAP	35 DAP	42 DAP	49 DAP
2015	NM	53.3 ± 26.9 a	337.8 ± 104.0 a	1772.5 ± 474.3 a	1782.5 ± 252.3 a	1264.5 ± 180.6 abc
	WB	21.3 ± 14.6 a	179.5 ± 35.1 a	1120.0 ± 407.5 a	2432.5 ± 667.3 a	1975.0 ± 460.7 a
	BB	32.3 ± 29.3 a	88.3 ± 23.4 a	193.0 ± 54.46 b	765.0 ± 188.0 b	887.5 ± 166.2 bc
	BW	3.8 ± 2.8 a	56.8 ± 17.5 a	305.3 ± 57.9 b	647.5 ± 192.7 b	1445.0 ± 278.4 ab
	SW	8.3 ± 2.8 a	40.0 ± 18.0 a	237.8 ± 137.0 b	482.5 ± 201.9 b	542.5 ± 114.4 c
	SB	7.0 ± 2.9 a	32.8 ± 18.3 a	109.5 ± 29.1 b	427.0 ± 122.2 b	782.5 ± 83.8 bc
ANOVA results		$F_{5,84} = 0.35$ $P = 0.88$	$F_{5,84} = 2.33$ $P = 0.06$	$F_{5,84} = 14.75$ $P < .0001$	$F_{5,84} = 13.13$ $P < 0.0001$	$F_{5,84} = 5.36$ $P = 0.0003$
2016	NM	11.0 ± 3.3 a	42.8 ± 13.9 a	122.5 ± 76.7 a	2390.0 ± 524.0 a	2295.0 ± 311.8 a
	WB	14.3 ± 5.2 a	46.5 ± 11.6 a	92.5 ± 72.5 a	2175.0 ± 400.4 a	2702.5 ± 321.2 a
	BB	1.3 ± 0.6 a	29.0 ± 13.6 a	72.5 ± 34.3 a	1910.0 ± 232.2 a	1745.0 ± 154.1 ab
	BW	0.8 ± 0.5 a	10.0 ± 6.2 a	39.8 ± 10.7 a	870.0 ± 170.9 b	870.0 ± 140.1 c
	SW	7.5 ± 6.5 a	63.8 ± 21.3 a	20.5 ± 7.8 a	217.5 ± 65.2 c	1055.0 ± 121.0 bc
	SB	8.3 ± 2.9 a	29.0 ± 12.3 a	35.8 ± 16.3 a	277.5 ± 100.9 c	765.0 ± 242.0 c
ANOVA results		$F_{5,90} = 0.24$ $P = 0.94$	$F_{5,90} = 0.52$ $P = 0.76$	$F_{5,90} = 0.63$ $P = 0.68$	$F_{5,90} = 38.28$ $P < 0.0001$	$F_{5,90} = 17.46$ $P < 0.0001$

[z]Means within the same column followed by the same letters are not significantly at $P \leq 0.05$ different according to Tukey's HSD tests.
[y]NM = no mulch, WB = white on black, BB = black on black, BW = black on white, SW = silver on white, and SB = silver on black.

Table 4. Mean ± SE number of melon thrips (*T. palmi*) on each sampling date per five leaf sample of cucumber grown on five different plastic mulches and a non-mulch control.

	Thrips stage[z]					
Sampling	Adult		Larva		Total	
date[y]	2015	2016	2015	2016	2015	2016
21 DAP	7.1 ± 2.7 d	2.3 ± 0.4 c	21.0 ± 7.2 d	7.2 ± 1.7 d	28.0 ± 8.8 d	9.5 ± 2.0 d
28 DAP	185.0 ± 65.2 c	7.0 ± 1.7 c	122.5 ± 28.3 c	36.9 ± 6.1 cd	307.5 ± 90.1 c	43.9 ± 6.5d
35 DAP	271.0 ± 56.5 ab	114.3 ± 26.6 b	614.7 ± 157.1 b	63.9 ± 18.2 c	885.7 ± 180.8 b	178.3 ± 39.7 c
42 DAP	144.1 ± 20.6 bc	131.7 ± 22.2 ab	1089.5 ± 196.0 a	1306.7 ± 214.1 b	1233.6 ± 209.9 a	1438.3 ± 225.2 b
49 DAP	250.0 ± 28.6 a	172.1 ± 22.6 a	1149.5 ± 133.6 a	1572.1 ± 174.3 a	1399.5 ± 150.9 a	1744.2 ± 187.7 a
ANOVA results	$F_{4,72} = 37.58$ $P < 0.0001$	$F_{4,72} = 115.70$ $P < 0.0001$	$F_{4,72} = 100.19$ $P < 0.0001$	$F_{4,72} = 292.32$ $P < 0.0001$	$F_{4,72} = 107.82$ $P < 0.0001$	$F_{4,72} = 348.16$ $P < 0.0001$

[z]Means within the same column followed by the same letters are not significantly different at $P \leq 0.05$ according to Tukey's HSD tests.
[y]On each sampling date, N = 24.

2003; Scott et al., 1989; Stavisky et al., 2002; Suzuki and Miyara, 1983). Throughout the sampling period, the control and white on black mulch had significantly more melon thrips than the other treatments, which was similar to the findings of and Csizinszky et al. (1997) and Nonaka and Nagai (1984).

In both years, regardless of mulch treatment, the number of adults, larvae, and the total number of *T. palmi* was significantly lower on 21 DAP and 28 DAP. The population density increased starting on the third sampling date (35 DAP). The melon thrips population peaked on the fourth and fifth sampling dates (Table 4). This population density pattern is in agreement with a report by Seal (1997). In contrast, Welter et al. (1990) reported that in Hawaii, melon thrips densities on cucumber did not peak until 63 DAP. The reason for the discrepancy in population density patterns between our and Seal's (1997) observations and those of Welter et al. (1990) may be attributable to the variation in agroecosystems between the three studies.

Leaf mineral nutrients. The slight differences in the amounts of macronutrients, nitrogen, phosphorus and potassium, in cucumber leaves (Fig. 1) corresponds with the findings of Díaz-Pérez

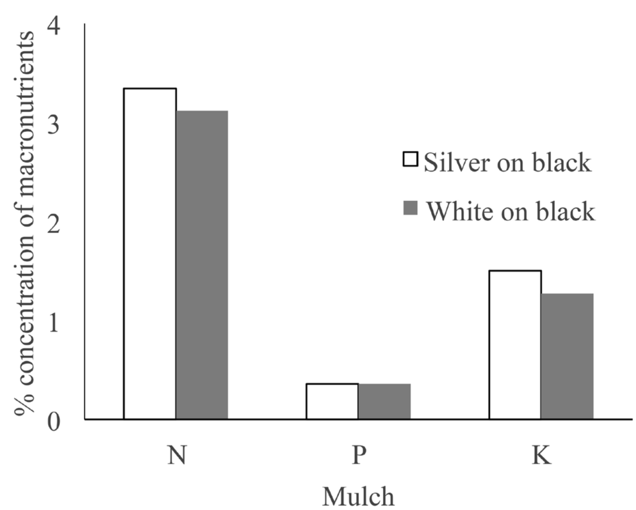

Fig. 1. Percent concentration (ppm) of macronutrient nitrogen (N), phosphorus (P) and potassium (K) in the leaf tissue of cucumber.

Table 5. Mean ± SE number of cucumber fruit from 5 plants from each plastic mulch and a non-mulch control.

	Treatment[z]						
Year	Silver on black	Silver on white	Black on black	Black on white	White on black	No mulch	ANOVA results
2015	20.0 ± 1.8 a[y]	20.0 ± 1.2 a	17.0 ±1.7 ab	16.5 ± 1.9 ab	13.3 ± 2.1 ab	10.8 ± 2.3 b	$F_{5,15}$ = 4.59; P = 0.01
2016	27.3 ± 1.1 a	23.3 ± 2.5 ab	17.5 ± 1.3 bc	16.2 ± 2.3 bc	13.5 ± 1.0 cd	7.8 ± 2.3 d	$F_{5,18}$ =14.03; P < .0001

[z]Means within the same row followed by the same letters are not significantly different at $P \leq 0.05$ according to Tukey's HSD test.
[y]Mean represent from six harvests and four replications of each treatment.

Table 6. Mean ± SE number of cucumber fruit from different plastic mulches and a non-mulch control treatment.

		Treatment[z]					
Year	Harvest date	Silver on Black	Silver on white	Black on black	Black on white	White on black	No mulch
2015[y]	2 Jan. 2016	10.5 ± 5.2 ab	11.0 ± 2.5 a	4.0 ±1.2 ab	6.8 ± 0.5 ab	5.0 ± 1.2 ab	2.3 ± 0.9 b
2016[x]	20 Dec. 2016	1.5 ± 0.3 ab	2.5 ± 1.2 a	0.5 ± 0.5 bc	0.3 ± 0.3 bc	0.3 ± 0.3 bc	0.0 ± 0.0 c
	24 Dec. 2016	5.0 ± 1.7 a	4.0 ± 1.1 a	2.8 ± 0.3 a	2.3 ±0.5 a	2.0 ± 0.4 a	0.0 ± 0.0 b
	25 Dec. 2016	2.3 ± 0.5 a	1.8 ± 0.3 ab	0.0 ± 0.0 c	0.0 ± 0.0 c	0.3 ± 0.3 bc	0.3 ± 0.3 bc
	27 Dec. 2016	6.8 ± 1.0 a	4.5 ± 0.5 ab	3.5 ± 1.3 ab	5.3 ± 1.2 ab	2.8 ± 1.0 bc	0.5 ± 0.3 c

[z]Means within the same row followed by the same letters are not significantly different at $P \leq 0.05$ according to Tukey's HSD test.
[y]Mean represent from 15 plants and four replications of each treatment.
[x]Mean represent from 5 plants and four replications of each treatment.

(2010). He reported that accumulation of mineral nutrients in the leaves and fruit of bell pepper were not significantly affected by plastic mulch.

Yield. For both years, significantly more marketable fruit were harvested from the silver reflective mulch treatments ($P < 0.05$) compared with the control treatment. The number of marketable fruit was moderate in the black and white on black mulch treatments (Table 5). Earlier fruiting occurred in the reflective mulches than the other treatments (Table 6). This observation is similar to the results reported by Brown et al. (1993) and Summers and Stapleton (2002).

Conclusions

Silver reflective mulch was highly efficient in reducing the density of melon thips, significantly increased the number of marketable fruit, and resulted in earlier fruit development than the other treatments. Plant growth assessed based on vine length and branch number, and dry biomass was also greatest in silver reflective mulch treatments (data not shown). The results of this study indicate that UV-reflecting mulch has great potential for integration into a management program for melon thrips in South Florida. Combining the use of silver reflective plastic mulch with biorational insecticides and biological control agents can significantly reduce the dependency on chemical insecticides.

Literature Cited

Antignus, Y. 2014. Management of air–borne viruses by "optical barriers" in protected agriculture and open field crops. Adv. in Virus Res. 90:1–33.

Bournier, J.P. 1983. A phytophagous insect: *Thrips palmi* Karny, an important pest of cotton in the Philippines. Cotton Fibers Tropical 38:286–289.

Brown, S.L. and J.E. Brown. 1992. Effect of plastic mulch color and insecticides on thrips populations and damage to tomato. HortTechnology 2:208–210.

Brown, J.E., J.M. Dangler, F.M. Woods, K.M. Tilt, M.D. Henshaw, W.A. Griffey, and M.W. West. 1993. Delay in mosaic virus onset and aphid vector reduction in summer squash grown on reflective mulches. HortScience 28:895–896.

Cardona, C., A. Frei, J.M. Bueno, J. Diaz, H. Gu, and S. Dorn. 2002. Resistance to *Thrips palmi* (Thysanoptera: Thripidae) in beans. J. Econ. Entomol. 95:1066–1073.

Childers, C.C. 1997. Feeding and oviposition injuries to plants. p. 505–537. In: T. Lewis (ed.). Thrips as Crop Pests. CAB. Wallingford, Oxon, UK.

Cooper, B. 1991. Status of *Thrips palmi* karny in Trinidad. FAO Plant Bul. 39:45–46.

Csizinsky, A.A., D.J. Schuster, and J.B. Kring. 1997. Evaluation of color mulches and oil sprays for yield and for the control of silverleaf whitefly, *Bemisia argentifolii* (Bellows and Perring) on tomatoes. Crop Prot. 16:475–481.

Csizinsky, A.A., D.J. Schuster, and J.E. Polston. 1999. Effect of ultraviolet reflective mulches on tomato yields and on the silver leaf white fly. HortScience. 34:911–914.

Díaz–Pérez, J.C., R. Gitaitis, and B. Mandal. 2007. Effects of plastic mulches on root zone temperature and on the manifestation of tomato spotted wilt symptoms and yield of tomato. Scientia Hort. 114:290–95.

Díaz–Pérez, J. Carlos. 2010. Bell pepper (*Capsicum annum* L.) grown on plastic film mulches: Effects on crop microenvironment, physiological attributes, and fruit yield. HortScience 45:1196–1204.

Dittmar, P.J., J.H. Freeman, and G.E. Vallad (eds.). 2015–2016. Vegetable production handbook of Florida. UF/IFAS extension, University of Florida, Gainesville. 248 p.

Fukushi, T. 1990. Color discrimination from various shades of grey in the trained blowfly, *Lucilia cuprina*. J. Insect Physiol. 36:69–75.

Greenough, D.R., L.L. Black, and W.P. Bond. 1990. Aluminum surface mulch: an approach to control of Tomato spotted wilt virus in solanaceous crops. Plant Disease 74:805–808.

Kawai, A. 1986. Studies on population ecology of *Thrips palmi* Karny. XI. Analysis of damage to cucumber. Jpn. J. Appl. Entomol. Zool. 30:12–16.

Kiggundu, N., K.W. Migliaccio., B. Schaffer., Y. Li., and J.H. Crane. 2012. Water savings, nutrient leaching, and fruit yield in a young avocado orchard as affected by irrigation and nutrient management. Irrig. Sci. 30:275–286.

Lamont, Jr., W.J. 1993. Plastic mulches for the production of vegetable crops. HortTechnology 3:35–39.

Nonaka, K. and K. Nagai. 1984. Ecology and control of the thrips infesting fruit vegetables. 8. Control of *Thrips palmi* using blue colored sticky ribbons. Kyushu Agric, Res. 44:119.

Razzak, M.A. and D.R. Seal. 2017. Effect of plastic mulch on the abundance of *Thrips palmi* Karny (Thysanoptera: Thripidae) and yield of 'Jalapeno' pepper in south Florida. Proc. Fla. State Hort. Soc. 130:124–128.

Reitz, S.R., E.L. Yearby, J.E. Funderburk, J. Stavisky, M.T. Momol, and S.M. Olson. 2003. Integrated management tactics for *Frankliniella* thrips (Thysanoptera: Thripidae) in field grown pepper. J. Econ. Entomol. 96:1201–1214.

SAS Institute. 2013. SAS/STAT 9.3 and 9.4 user's guide. SAS Institute. Cary, NC.

Schalk, J.M. and M.L.R. Robbins. 1987. Reflective mulches influence plant survival, production and insect control in fall tomatoes. HortScience. 22:30–32.

Scott, S.J., P.J. McLeod, F.W. Montgomery and C.A. Hander. 1989. Influence of reflective mulch on incidence of thrips (Thysanoptera: Thripidae, Phaleothripidae) in staked tomatoes. J. Entomol. Sci. 24:422–427.

Seal, D.R. and R.M. Baranowski. 1992. Effectiveness of different insecticides for the control of *Thrips palmi* karny. (Thysanoptera: Thripidae) affecting vegetables in south Florida. Proc. Fla. State Hort. Soc. 105:315–319.

Seal, D.R. 1997. Management and biology of *Thrips palmi* Karny (Thysanoptera: Thripidae), p. 161–181. In: K Bondari (ed.). New Developments in Entomology. Research Signpost, Scientific Information Guild, Trivandrum, India.

Seal, D.R. and C.M. Sabines. 2012. Combating melon thrips, *Thrips palmi* karny (Thysanoptera: Thripidae) in south Florida. Proc. Fla. State Hort. Soc. 125:196–200.

Seal, D.R., V. Kumar, G. Kakkar, and S.C. Mello. 2013. Abundance of adventive *Thrips palmi* Karny (Thysanoptera: Thripidae) populations in Florida during the first sixteen years. Fla. Entomol. 96:789–796.

Stavisky, J., J. Funderburk, B.V. Brodbeck, S.M. Olson, and P.C. Andersen. 2002. Population dynamics of *Frankliniella* spp. And tomato spotted wilt incidence as influenced by cultural management tactics in tomato. J. Econ. Entomol. 95:1216–1221.

Summers, C.G. and J.J. Stapleton. 2002. Use of UV reflective mulch to delay the colonization and reduced the severity of *Bemesia argentifolii* (Homoptera: Aleyrodidae) infestations in cucurbits. Crop Prot. 21:921–928.

Suzuki, H. and A. Miyara. 1983. Integrated control of *Thrips palmi* using silver–colored covering materials. (1) Loss assessment on cucumber. Proc. Assoc. Pl. Prot. Kyushu 29:77–80.

Tindall, J.A., H.A. Mills, and D.E. Radcliffe. 1990. The effect of root zone temperature on nutrient uptake of tomato. J. Plant Nutr. 13:939–956.

Tsai, J. H., B. Yue, S.E. Webb, J.E. Funderburk, and H.T. Hsu, 1995. Effects of host plant and temperature on growth and reproduction of *Thrips palmi* (Thysanoptera: Thripidae). Environ. Entomol. 24:598–1603.

Tyler–Julian, K.A., J.E. Funderburk, S.M. Olson and M.L. Paret. 2015. A stimulo–deterrent method of thrips and Tomato Spotted Wilt virus management in tomatoes. Acta Hortic. 1069:251–258.

U.S. Dept. of Agriculture–National Agricultural Statistics Service (USDA–NASS). 2016. Vegetables 2015 Summary (Feb. 2016). (http://usda.mannlib.cornell.edu/usda/nass/VegeSumm//2010s/2016/VegeSumm–02–04–2016.pdf). Accessed 2–13–18.

Welter, S.C., J.A. Rosenheim, M.W. Johnson, R.F.L. Mau, and L.R. Gusukuma–Minuto. 1990. Effects of *Thrips palmi* and Western flower thrips (Thysanoptera: Thripidae) on the yield, growth and carbon allocation pattern in cucumbers. J.Econ. Entomol. 83:2092–2101.