Effects of Living and Synthetic Mulch on the Population Dynamics of Whiteflies and Aphids, Their Associated Natural Enemies, and Insect-Transmitted Plant Diseases in Zucchini

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ABSTRACT Living and synthetic mulches were evaluated for control of the silverleaf whitefly, *Bemisia argentifolii* Bellows and Perring, and aphids in zucchini plantings. Two living mulches, buckwheat, *Fagopyrum esculentum* Moench, and white clover, *Trifolium repens* L., and two synthetic mulches (reflective and white) were evaluated during the fall of 2002 and 2003. Results from pan-traps, yellow sticky traps, and foliar counts showed that reflective and buckwheat mulches consistently had fewer numbers of adult whiteflies and aphids compared with the standard white mulch treatments. In 2003, a significant increase in the abundance of natural enemies was recorded in all treatments. Living mulch treatments had higher natural enemy populations than synthetic mulch and bare-ground treatments. However, there were no differences in the species diversity of natural enemies found between treatments. The effectiveness of mulches for controlling immature whitefly numbers and the incidence of squash silverleaf disorder were inconsistent between years. Additional data taken at the end of the 2003 season revealed that two viral strains (PRSV-W and WMV-2) were present in the field. However, visual symptoms associated with these viral diseases did not occur until the end of the season.

KEY WORDS mulch, whitefly, aphid, zucchini, natural enemies

CUCURBITS ARE A MAJOR VEGETABLE crop grown in Florida. During the 2002–2003 field season, Florida growers harvested >18,000 ha of cucurbits, valued at more than $170 million (NASS 2004). Despite these numbers, rising costs associated with preventing insect related problems, combined with cheaper imports from Mexico, have threatened the production and value of many Florida cucurbits. Currently, crop–plant physiological disorders and insect-transmitted diseases have become serious problems for many growers around the state.

One of the most damaging plant physiological disorders in cucurbits is squash silverleaf (SSL) disorder. SSL is associated with the feeding of immature whiteflies, *Bemisia argentifolii* Bellows and Perring, and is characterized by silvering of the adaxial leaf surface and blanching of fruit (Yokomi et al. 1990, Costa et al. 1993, Jiménez et al. 1995). Variations in the feeding densities of immature whiteflies have been shown to affect the severity of SSL symptoms, which can develop in as little as 14 d (Yokomi et al. 1990, Schuster et al. 1991, Costa et al. 1993).

The most important vectors of plant viruses include aphids, which have been known to transmit 275 different viral diseases (Nault 1997). Crops in the Cucurbitaceae are highly susceptible to several of these insect-transmitted viruses. Important viruses affecting cucurbits in Florida include zucchini yellow mosaic virus (ZYMV), watermelon mosaic virus-2 (WMV-2), cucumber mosaic virus (CMV), and papaya ringspot virus-watermelon strain (PRSV-W) (Adlerz 1978, Provvidenti et al. 1984, Purcifull et al. 1988). Symptoms of these viruses include pronounced reduction in growth; the occurrence of yellowing, mosaic, and blistering of leaves; and reduced fruit set (Demski and Chalkley 1974, Lisa et al. 1981). In addition, the fruits harvested from infected plants are often malformed and distorted, rendering them unmarketable (Blua and Perring 1989).

Several aphid species have been associated with transmitting these viruses in a stylet-borne nonpersistent manner (Coudriet 1962, Lisa et al. 1981, Adlerz 1987, Castle et al. 1992). Stylet-borne viruses are characterized by having no latent period within the vector and having an infectivity time of a few hours or days. This, coupled with the rapid acquisition and inoculation of the virus during brief test probes into the plant epidermis, can allow rapid spread throughout a given area.

In addition to transmitting viruses and causing plant disorders, heavy infestations of whiteflies and aphids generally cause a reduction in plant vigor (Barlow et al. 1977, Buntin et al. 1993). The excretion of honeydew by these insects can serve as an important me-

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dium for promoting growth of sooty mold fungi (*Capnodium* spp.), which can further reduce plant vigor and yield (Byrne and Miller 1990, Palumbo et al. 2000). The unpredictability and severity of these cucurbit pests and associated diseases in conjunction with injury from secondary pests makes efficient management strategies necessary in a cucurbit production system.

Currently, pesticides play a major role in the pest management of cucurbits. However, this control strategy can become problematic, because frequent use of insecticides can significantly increase production costs as well as increase the potential for resistance. In addition, a heightened awareness of the harmful effects of pesticides to nontarget organisms and the environment has led many to search for alternative methods to regulate pests in cucurbits.

Several studies have evaluated both living and synthetic mulches independently for control of whiteflies (*B. argentifolii*) or aphids. These studies have shown successful reduction in population densities of whiteflies and aphids while delaying the onset and spread of associated insect-borne diseases (Brown et al. 1993, Summers et al. 1995, Hooks et al. 1998, Summers and Stapleton 2002). Hooks et al. (1998) found that living mulches were effective in reducing multiple pest complexes and the incidence of associated diseases. Recently, Summers et al. (2004) found that colonization by *B. argentifolii* and the incidence of aphid-transmitted diseases were reduced over reflective mulch compared with unmulched plots.

Some debate exists as to which mulching system (i.e., living mulch or synthetic reflective) offers the best potential for management of whiteflies and aphids. Our hypothesis was that the use of living and synthetic (reflective) mulches would suppress the activity of whiteflies and aphids, thus reducing viral infection and the occurrence of plant disorders. The specific objective for this research was to study the effects of living and synthetic (reflective) mulch on the population dynamics of whiteflies and aphids, their associated natural enemies, and insect-transmitted plant diseases. Also, identifying which mulching system offers the best habitat for these beneficials could help shape production practices in the future.

Materials and Methods

Field research was conducted at the University of Florida, Plant Science Research and Education Unit located in Citra, FL, during the fall growing season. Trials were conducted using standard production practices. Zucchini, *Cucurbita pepo* L., cultivar Ambassador, were planted from seeds on raised beds spaced 1.2 m apart. Mulches used during these studies included two synthetic mulches (white and reflective), two living mulches (buckwheat and white clover), and a bare ground (control). Buckwheat, *Fagopyrum esculentum* Moench, and white clover, *Trifolium repens* L., mulches were seeded by hand. In 2002, individual plot size was 15 by 14 m and sown with eight rows. Living mulches were planted 1 d after zucchini seeding on top of rows. In 2003, because of time constraints and labor reduction, individual plot size was reduced to 14 by 12 m and sown with seven rows. Living mulches were seeded 1 wk before zucchini planting between rows to allow a greater establishment period and to reduce competition between the living mulch and zucchini plants. Treatments were replicated four times in a randomized complete block design, with blocks spaced 15 m apart.

Trap Sampling. Adult whiteflies were monitored using unbaited Pherocon AM traps (Yellow Sticky, YS; Great Lakes Integrated Pest Management [IPM], Vestaburg, MI) placed within interior zucchini rows. Trap heights were adjusted relative to plant height. Each treatment plot contained a total of three YS traps. One trap was placed in the center of the treatment plot, and two others were placed at opposite ends of the treatment plot forming a diagonal line. All YS traps were placed in the field 2 wk after zucchini planting. YS traps were left in the field for a 24-h duration once per week until final harvest.

Alate aphids were monitored using blue water pan-traps (Packer Ware Bowls, Gainesville, FL). Pan-traps had a diameter of 15.5 cm and contained ≈250 ml of 5% detergent solution (Colgate-Palmolive Co., New York, NY). Traps were placed at mid-plant height within interior zucchini rows. Three water pan-traps were used per plot. Traps were placed in the field 2 wk after zucchini planting. The arrangement of the water pan-traps and the time period in which they were exposed in the treatment plots were similar to YS traps. In 2003, clear water pan-traps (Pioneer/Tri-State Plastics, Dickson, KY) were used in addition to blue pan-traps. Clear pan-traps were square, with a diameter of 15.5 cm. One clear water pan-trap was placed in the center of each plot and treated in a similar manner as the blue pan-traps.

Foliar Sampling. Nine plants from each plot were randomly selected for counting adult whiteflies and aphids (apterae and alate). Foliar sampling was initiated 4 wk after planting and conducted weekly until final harvest. One leaf was sampled per zucchini plant, which was partitioned according to plant stratum (upper, $n = 3$; medium, $n = 3$; lower, $n = 3$ leaves), allowing a total of 9 leaves sampled per plot (36 leaves/treatment). If aphid densities were high (>100 per leaf), counts were taken from one-half of the leaf and used to estimate the number on the whole leaf. All whitefly adults, aphids, and other pest species encountered on the leaf surfaces were recorded.

To estimate the number of whitefly nymphs, 1-in-diameter circular leaf disks were removed using a cork borer from nine leaves (selected from foliar counts). Leaves were stored in plastic bags and transported to the laboratory in an ice chest. Leaf disks were removed from one side of a leaf halfway between the leaf tip and petiole and halfway between the mid-vein and leaf edge (Gould and Naranjo 1999). Leaf disks were removed in the Fruit and Vegetable IPM laboratory, and examined under a ×40-dissecting microscope. All whitefly nymphs encountered on the leaf surfaces were recorded.

Natural Enemy Sampling. Natural enemies were sampled using in situ counts. Leaves from six plants in each plot were randomly selected. In 2002, nine leaves from each plant were randomly selected, and in 2003, six leaves from each plant were randomly selected for visual identification of beneficial arthropods. Sampling was initiated 4 wk after planting and conducted weekly until the end of the season.

Physiological Disorder Evaluation. Visual observations for symptoms of squash silverleaf disorder were recorded weekly from 10 randomly selected zucchini plants within the interior rows of each treatment plot. The percentage of plants displaying visual symptoms of silverleaf (silvering on adaxial leaf surface) was taken until the end of the season. Silverleaf symptoms were rated on the new leaf growth, with the severity rated on a scale of 0–5 as indicated by Paris et al. (1987).

Disease Identification. Leaves from four randomly selected plants exhibiting virus infection (i.e., yellowing, mosaic, blistering) were collected from each plot (16 leaves per treatment), and taken to the University of Florida, Vegetable Entomology Laboratory for disease identification. Each sample was tested for eight viral diseases using enzyme-linked immunosorbent assay (ELISA) procedures specific for each virus. The viral diseases that plants were tested for included CMV, PRSV-W, squash mosaic virus (SMV), tobacco streak virus (TSV), tomato spotted wilt virus (TSWV), watermelon leaf mottle virus (WLMV), WMV-2, and ZYMV. All plates containing samples were marked for visual positives and read on an ELISA plate reader (Bio-Tek, Winooski, VT).

Statistical Analyses. Data from arthropod counts and physiological disorder and disease sampling were analyzed by repeated measures analysis of variance (ANOVA) using the SAS GLM procedure. All data were square root transformed to stabilize variances, and means were separated with least significant difference test (LSD) $\alpha = 0.05$ (SAS Institute 2002). In addition, predators and parasitoids were visually recorded and identified to order in the field. The number of insects identified in each order is presented as percentage of the total number of insects identified for the year. Similarly, pest individuals were recorded in the same manner with aphids and whiteflies replacing the title Heteroptera.

Results

Trap Sampling. In 2002, YS traps within plots containing white mulch had significantly more whitefly adults, *B. argentifolii*, than the bare ground (control), reflective, clover, and buckwheat treatments (Table 1). Traps within buckwheat mulch plots had significantly fewer adult whiteflies compared with all other treatments. Similarly in 2003, YS traps within buckwheat mulch had significantly fewer adult whiteflies than white, clover, and bare-ground treatments (Table 1). Throughout the 2003 season, traps within reflective mulch had significantly fewer whitefly adults compared with all other treatments.

Table 1. Mean ± SEM no. adult whiteflies per YS trap in zucchini at Citra, FL, for all sampling dates

	2002	2003
White	15.4 ± 1.8a	3.6 ± 0.5a
Reflective	9.8 ± 1.2c	1.1 ± 0.2c
Buckwheat	7.7 ± 1.1d	1.8 ± 0.2b
Clover	10.3 ± 1.5bc	4.6 ± 0.7a
Bare ground (control)	13.4 ± 1.8b	4.3 ± 0.6a

Means followed by the same letter are not significantly different ($P = 0.05$, LSD test).

For 2002, $F = 5.75$; df = 4,84; $P < 0.0004$; for 2003, $F = 13.21$; df = 4,72; $P < 0.0001$.

During 2002, blue pan-traps within white mulch treatments caught significantly more alate aphids compared with each of the other treatments, which did not differ significantly (Table 2). Similarly in 2003, more alate aphids were caught over white mulch compared with all other treatments (Table 2). Unlike in 2002, blue pan-traps within reflective mulch had significantly fewer alate aphids than white, buckwheat, and clover, but was borderline insignificant with the bare-ground treatment. Similarly, the number of alate aphids trapped in clear pan-traps was also significantly less in reflective than white, bare ground, and clover but was similar to the buckwheat mulch treatment (Table 2). In 2003, the total number of alate aphids captured in clear pan-traps compared with the number captured in blue pan-traps was not significantly different ($F = 3.6$; df = 1,4; $P = 0.0573$). However, when comparing these traps by treatment, significant differences were found between trap types in bare ground using the LSD test for pairwise comparison ($t = -2.76$, $Pr > t = 0.0060$).

Foliar Sampling. In 2002, plants within white mulch had significantly more adult whiteflies than buckwheat and clover but had similar numbers to reflective mulch and bare-ground treatments (Table 3). The number of apterous and alate aphids did not differ significantly between treatments (Table 3). In 2003, the number of adult whiteflies and apterous aphids did not differ significantly between treatments (Table 3). However, significantly fewer alate aphids were recorded on plants in reflective mulch compared with white, clover, and bare-ground treatments but had similar numbers to buckwheat (Table 3). Data col-

Table 2. Mean ± SEM no. alate aphids per pan-trap in zucchini at Citra, FL, for all sampling dates

	2002	2003	2003 (clear pan-traps)
White	1.5 ± 0.2a	0.8 ± 0.1a	1.2 ± 0.3a
Reflective	0.3 ± 0.1b	0.2 ± 0.1c	0.2 ± 0.1c
Buckwheat	0.5 ± 0.1b	0.4 ± 0.1b	0.3 ± 0.1bc
Clover	0.5 ± 0.1b	0.4 ± 0.1b	0.8 ± 0.3ab
Bare ground (control)	0.5 ± 0.1b	0.3 ± 0.1bc	0.9 ± 0.2a

Means followed by the same letter are not significantly different ($P = 0.05$, LSD test).

For 2002, blue pan-traps, $F = 27.82$; df = 4,84; $P < 0.0001$; for 2003, blue pan-traps, $F = 9.12$; df = 4,72; $P < 0.0001$; for 2003, clear-pan traps, $F = 4.3$, df = 4,72; $P = 0.0036$.

Table 3. Mean ± SEM no. aphids and whiteflies per zucchini leaf in Citra, FL, for all sampling dates

	Whiteflies (adult)	Aphids (apterous)	Aphids (alate)
		2002	
White	12.6 ± 2.3a	0.5 ± 0.3	0.2 ± 0.1
Reflective	12.3 ± 3.1a	0.2 ± 0.1	0.2 ± 0.1
Buckwheat	5.9 ± 1.6b	0.6 ± 0.4	0.1 ± 0.1
Clover	5.7 ± 1.7b	0.2 ± 0.2	0.4 ± 0.1
Bare ground (control)	8.9 ± 1.8ab	0.5 ± 0.2	0.3 ± 0.1
		2003	
White	4.1 ± 0.9	8.5 ± 3.4	1.0 ± 0.2b
Reflective	2.6 ± 0.7	2.1 ± 0.9	0.1 ± 0.0c
Buckwheat	2.9 ± 0.8	4.4 ± 1.7	0.7 ± 0.2bc
Clover	4.5 ± 0.9	11.7 ± 3.9	2.0 ± 0.7a
Bare ground (control)	7.1 ± 1.5	7.3 ± 2.2	1.8 ± 0.5a

Means followed by the same letter are not significantly different ($P = 0.05$, LSD test).

For adult whiteflies in 2002, $F = 4.37$; df = 4,72; $P < 0.0032$; for apterous aphids in 2002, $F = 0.90$; df = 4,72; $P = 0.4705$; for alate aphids in 2002, $F = 1.45$; df = 4,72; $P = 0.2265$; for adult whiteflies in 2003, $F = 2.47$; df = 4,32; $P = 0.0641$; for apterous aphids in 2003, $F = 2.08$; df = 4,32; $P = 0.1064$; for alate aphids in 2003, $F = 7.95$; df = 4,32; $P < 0.0001$.

lected from both field seasons revealed that aphids and whiteflies were the dominant pests recorded in the field. In 2002, whiteflies comprised the majority (85%) of pest individuals sampled (Fig. 1a), whereas in 2003, aphids comprised the majority (63%) of pest individuals (Fig. 1b). In addition, leaf-mining flies (Diptera: Agromyzidae) were a minor pest in 2003 but were never recorded in 2002 (Fig. 1a and b).

In 2002, there were no significant differences in the number of immature whiteflies found between treatments ($F = 1.81$; df = 4,312; $P = 0.1262$). Similarly, in 2003, there were no significant differences in the number of immature whiteflies found between treatments ($F = 1.20$; df = 4,208; $P = 0.3101$). However, significantly more immature whiteflies were recorded on the lower plant stratum of zucchini plants compared with the middle or top plant strata for all treatments in 2002 ($F = 75.39$; df = 2,6; $P < 0.0001$; Fig. 2a) and 2003 ($F = 26.6$; df = 2,6; $P = 0.0010$; Fig. 2b).

Natural Enemies. In 2002, there were no significant differences in the number of natural enemies found between treatments (Table 4). In 2003, clover mulch had significantly higher numbers of natural enemies than white, reflective, and bare ground but had similar numbers to buckwheat mulch (Table 4). Data collected from both field seasons showed that arthropods in the order Araneae were the dominant natural enemy (Fig. 3a and b). These representations of the percentage of natural enemies found within the field showed more arthropod abundance in 2003.

Physiological Disorder Evaluation. In 2002, significantly more symptoms of SSL were recorded in plants grown on bare ground than in white, reflective, and clover but had similar scores to buckwheat mulch (Table 5). Throughout the season, plants on reflective mulch had significantly less severe symptoms of silverleaf than all other mulch treatments with the exception of clover (Table 5). During 2003, plants on white and reflective mulches had significantly more severe symptoms of SSL than all other treatments, whereas plants on bare ground and clover mulch had significantly less symptoms (Table 5).

Disease Identification. Data taken at the end of the 2003 season revealed that two viruses, PRSV-W and WMV-2, were present in the field. ELISA tests found four cases of PRSV-W within plants on the bare ground and clover mulch treatments, and one case of PRSV-W was found in the white, reflective, and buckwheat mulch (Fig. 4). Two cases of WMV-2 were found within plants on the bare-ground treatments, and one case (WMV-2) was found in the clover mulch (Fig. 4). There were no significant differences in the number of virus-infected plants between treatments ($F = 1.37$; df = 7,19; $P = 0.3007$).

Discussion

Insect Response to Mulches. During the 2002 field season, results from trap catches showed that white mulch consistently had higher populations of adult whiteflies and alate aphids compared with the other mulch treatments, including bare ground (control). However, the 2003 field season revealed no significant differences between white mulch, clover, and bare-ground (control) treatments with respect to YS and clear pan-trap catches. These results are consistent with Adlerz and Everett (1968), who showed that white (polyethylene) mulches had higher populations of aphids compared with reflective mulch and bare ground. Traditionally, farmers have used white or white on black mulches in Florida for fall cucurbit production. It is unclear why adult whiteflies and alate aphids responded strongly to white mulch, because previous research has shown that they are attracted to yellow colors in the visible light spectra (Mound 1962).

Overall, both trap and foliar counts showed that plants grown on reflective and buckwheat mulches consistently had fewer adult whiteflies and aphids compared with the other mulch treatments, including bare ground. The suppression of whiteflies and aphids by reflective mulch was not surprising. There have been several reports of the use of reflective mulches to suppress whitefly and aphid activities (Adlerz and Everett 1968, Wolfenbarger and Moore 1968, Csizinszky et al. 1995, Summers et al. 2004). Reflective mulch is currently being suggested as an alternative to conventional pesticides and white or black synthetic mulches to suppress whitefly and aphid activities in selected vegetable crops. The suppression of adult whiteflies and aphids on zucchini plants with buckwheat mulch has also been observed in Hawaii (Hooks et al. 1998). However, information on whether or not their findings were applicable to north Florida situations was unavailable. Buckwheat is an annual plant that completes its life cycle in Florida in 6 wk. It flowers profusely and attracts beneficial insects to the cucurbit crop. Buckwheat may have potential in sustainable (organic) cucurbit production in Florida in the future as more research is conducted. Clover

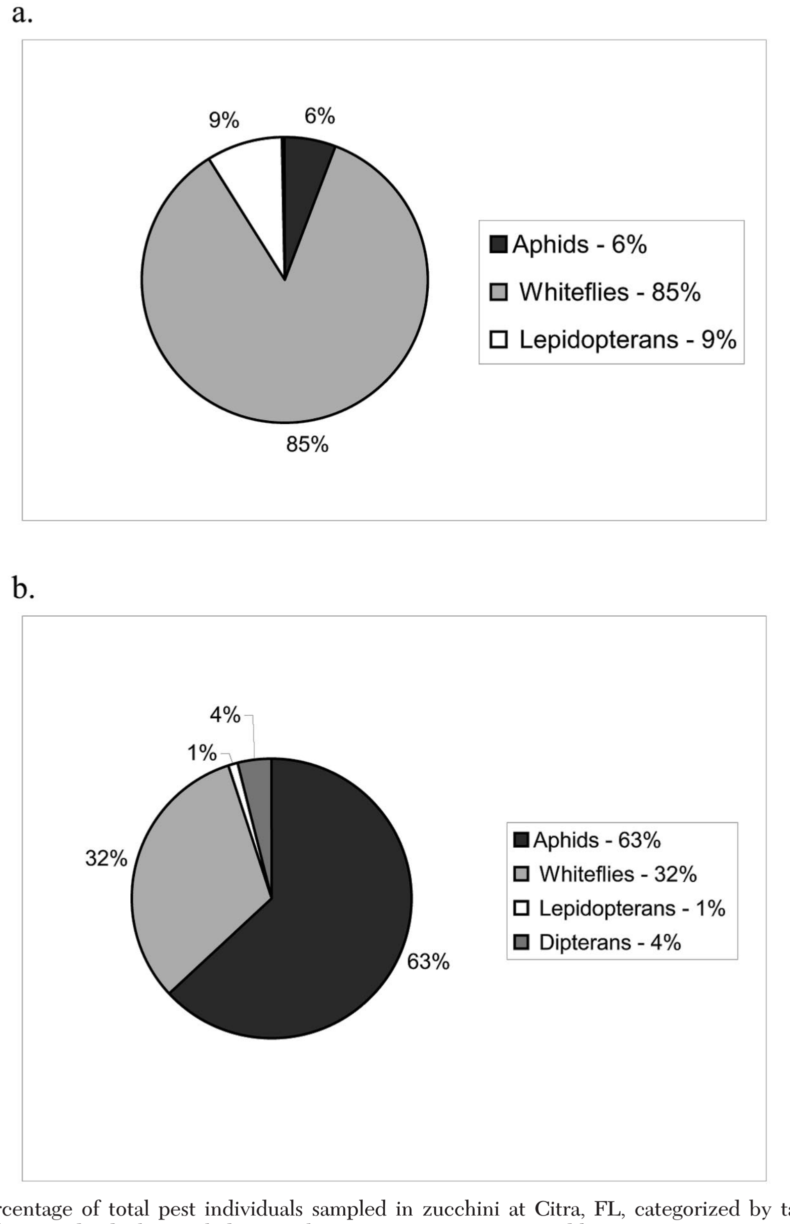

Fig. 1. (a) Percentage of total pest individuals sampled in zucchini at Citra, FL, categorized by taxon (2002). (b) Percentage of total pest individuals sampled in zucchini at Citra, FL, categorized by taxon (2003).

mulch was difficult to establish and does not seem to be suitably adapted to north Florida conditions. As a result, its use is not appropriate in north Florida cucurbit production systems.

The effectiveness of mulches for controlling immature whitefly numbers and the incidence of SSL were inconsistent between years. This may be a function of differences in population pressure caused by environmental conditions. The total average whitefly adult and nymph populations were higher in 2002 than in 2003. Similarly, silverleaf severity was higher in 2002 compared with 2003.

Plant Strata. Plant strata played an important role in feeding location of immature whiteflies. During 2002 and 2003, it was clear that the location of immature whiteflies was restricted to the lower plant strata for all treatments. These results are consistent with Simmons (1994), who saw 90–95% of *Bemisia tabaci* eggs and nymphs on the lower plant strata of various crops. Higher nitrogen content in older leaves (Bentz et al. 1995) or increased protection from pesticides, natural enemies, and environmental factors offered by leaves located on the lower plant strata (Chu et al. 1995, Liu and Stansly 1995) may have played a role in the location of nymphal whiteflies. Similarly, older zucchini leaves have less dense trichomes, which can allow for easier oviposition of eggs and attachment by nymphs (Butler et al. 1986, Kishaba et al. 1992, McAuslane

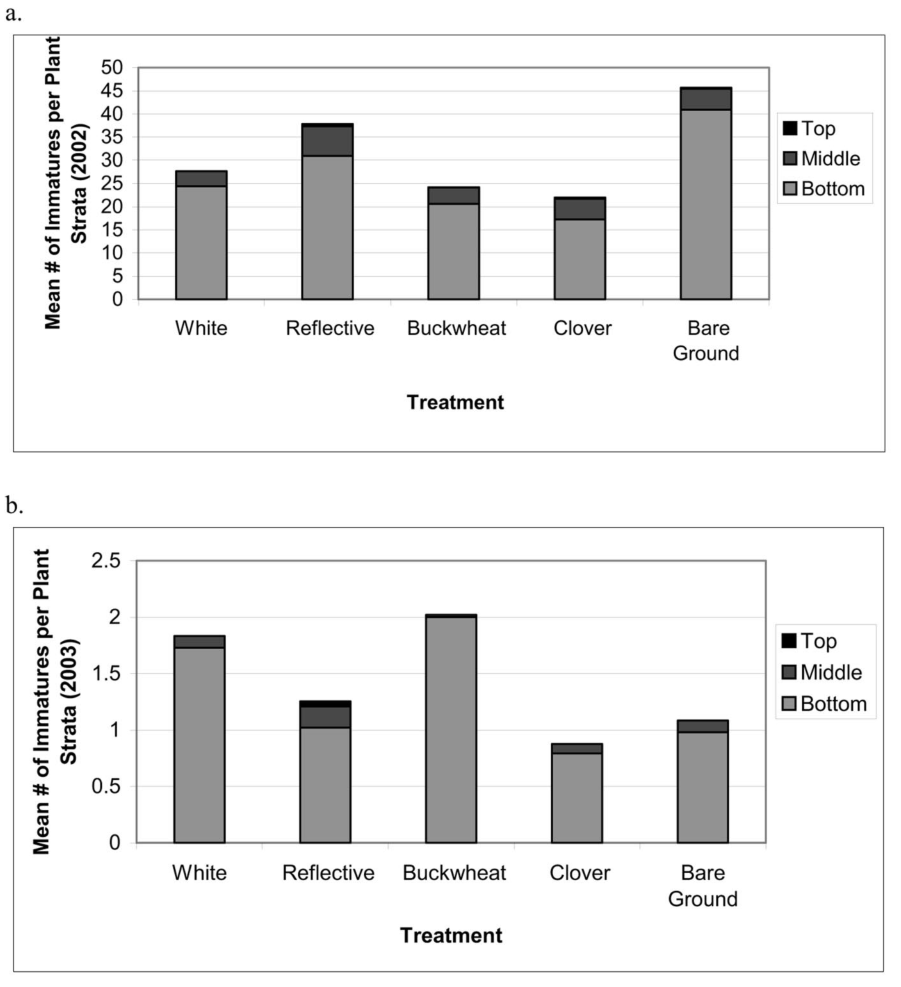

Fig. 2. (a) Populations of immature whiteflies on zucchini plant strata in Citra, FL (2002). (b) Populations of immature whiteflies on zucchini plant strata in Citra, FL (2003).

1996). In either case, more research must be conducted so that efficient sampling and control of nymphal *B. argentifolii* populations can occur in zucchini and other cucurbit crops. Management tactics involving monitoring or chemical controls should be directed to the lower leaves because the majority of immature whiteflies are restricted to this area.

Table 4. Mean ± SEM no. natural enemies per zucchini leaf in Citra, FL, for all sampling dates

	2002	2003
White	0.04 ± 0.02	0.33 ± 0.0bc
Reflective	0.04 ± 0.02	0.26 ± 0.0c
Buckwheat	0.02 ± 0.01	0.41 ± 0.1ab
Clover	0.01 ± 0.01	0.48 ± 0.1a
Bare ground (control)	0.06 ± 0.02	0.28 ± 0.0bc

Means followed by the same letter are not significantly different ($P = 0.05$, LSD test).

For 2002, $F = 2.13$; df = 4,72; $P = 0.0852$; for 2003, $F = 2.72$; df = 4,60; $P = 0.0377$.

Natural Enemies. In 2003, a significant increase in the abundance of natural enemy species was seen throughout all treatments. The reasons why such a high abundance was seen in 2003 is unknown, but differences in ambient temperature and rainfall may account for some of the variations observed. Living mulch treatments had higher natural enemy populations than the synthetic mulch and bare-ground treatments. These results support the natural enemy hypothesis proposed by Root (1973) that increased plant diversity leads to increased natural enemy densities. However, there were no differences in the diversity of natural enemies found between treatments (data not shown). Understanding which natural enemies are present with respect to the various mulch treatments allow for future research to be conducted on the efficiency of these insects with appropriate mulch treatments for control of zucchini pests and prevents unnecessary efforts to introduce natural enemies that are already present.

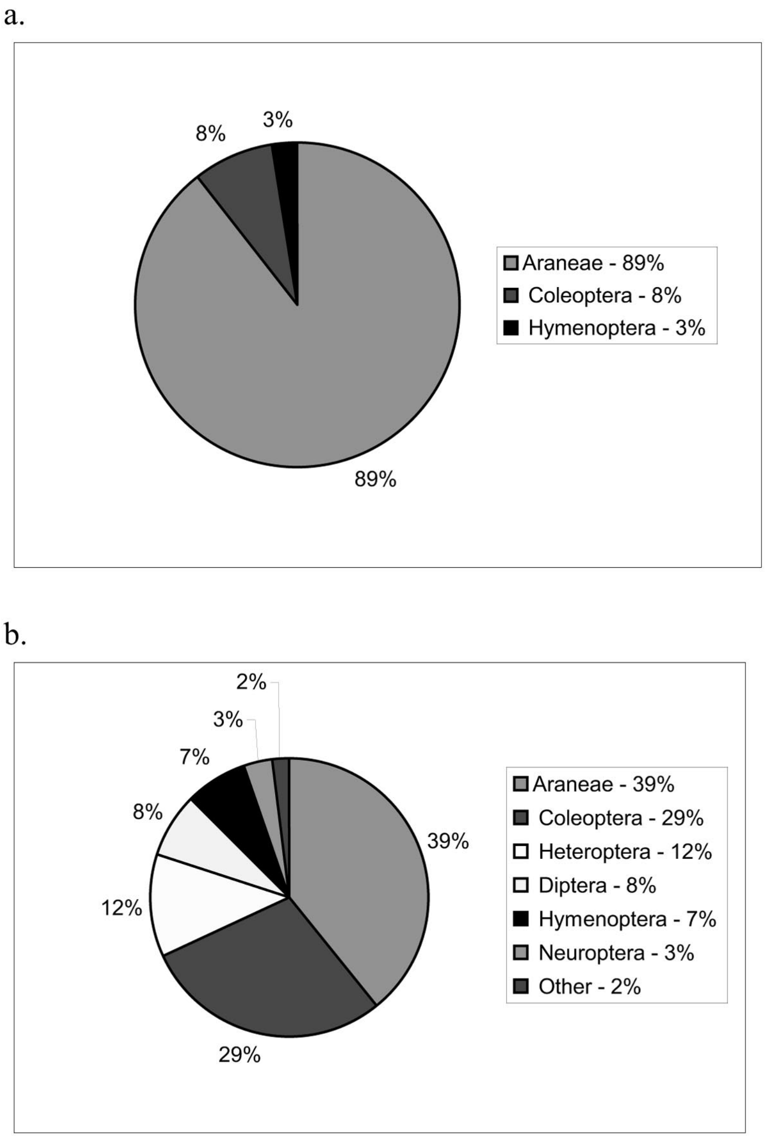

Fig. 3. (a) Percentage of total natural enemies sampled in Citra, FL, categorized by order (2002). (b) Percentage of total natural enemies sampled in Citra, FL, categorized by order (2003).

Physiological Disorder and Plant Disease. The incidence of SSL disorder was inconsistent between years. These inconsistencies may have been influenced by a number of factors, such as the variability of insect numbers between years and weather. The fact that relatively few nymphal whiteflies are needed to induce SSL may have also compounded the problem. Additionally, throughout the 2002 and 2003 field seasons, no detrimental effects on plant growth were observed from SSL symptoms. It is unclear why SSL disorder never became a problem because a number of negative physiological factors are known to occur.

Table 5. Mean ± SEM silverleaf score per treatment in zucchini at Citra, FL, for all sampling dates

	2002	2003
White	4.1 ± 0.1b	1.5 ± 0.1a
Reflective	3.7 ± 0.1c	1.4 ± 0.1a
Buckwheat	4.2 ± 0.1ab	1.1 ± 0.1b
Clover	3.9 ± 0.1c	1.0 ± 0.1bc
Bare ground (control)	4.4 ± 0.1a	1.0 ± 0.1c

Means followed by the same letter are not significantly different ($P = 0.05$, LSD test).

For 2002, $F = 12.19$; df = 4,48; $P < 0.0001$; for 2003, $F = 11.50$; df = 4,72; $P < 0.0001$.

In 2002, zucchini plants never exhibited visual symptoms associated with viral diseases. This may have been caused in part by the low incidence of aphids seen within the field for that year. Despite high aphid numbers and the occurrences of two associated

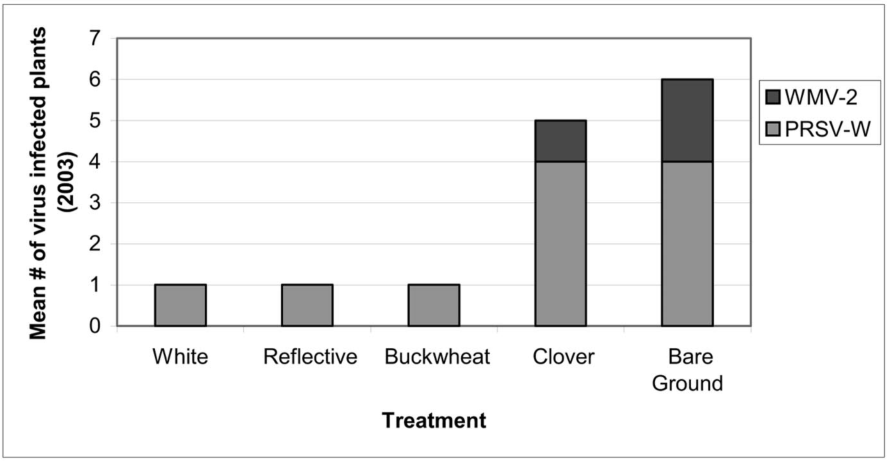

Fig. 4. Mean number of virus infected plants per treatment in Citra, FL (2003).

viral diseases in 2003, visual symptoms of WMV-2 and PRSV-W did not occur until zucchini matured and did not seem to have an effect on plant growth. Although white mulch had a greater incidence of pests, it had only one case of PRSV-W. Adlerz and Everett (1968) noted that, although more aphids were caught over white mulch compared with reflective and bare ground, the incidence of viral diseases was significantly less than the bare ground. They believed that this occurred because one or more of the aphid species attracted to white mulch were not effective in virus transmission. Overall, no significant differences were found between the different mulch treatments.

Economics. Ease of incorporation can play a central role for whether or not a particular tactic is incorporated into an IPM program. The cost of buckwheat seeds used for both field seasons was $74. Although buckwheat is an annual, it can be managed so that it produces seed throughout the year and does not require subsequent planting later in the season. White clover, a perennial, plus innoculant cost $68 for both field seasons. Alternately, white mulch cost $120, and reflective mulch was $145 for both field seasons.

Although the costs of living mulches were less than synthetic mulches, they required additional upkeep and management. For instance, living mulches required additional water and had to be maintained so that they did not become a weed problem later in the year. Overall, synthetic mulches were easier to maintain and required no establishment period before zucchini were planted. In addition, no special watering features or additional drip lines were needed in plots treated with synthetic mulch.

In our experiments, it seems that the net gains with respect to the suppression of whiteflies and aphids with living mulches were erased when the additional upkeep and management were taken into consideration. More research is needed on potential choice of living mulch suited for Florida conditions before living mulches are recommended. It seems for now that reflective mulch in combination with a reduced-risk insecticide may offer a better alternative to manage whiteflies and aphids in northcentral Florida zucchini plants.

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