Managing *Bemisia argentifolii* on Spring Melons with Insect Growth Regulators, Entomopathogens and Imidacloprid in South Texas

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ABSTRACT

Two insect growth regulators (IGRs) (pyriproxyfen [Knack®] and buprofezin [Applaud®]), two *Beauveria bassiana* insecticides (Mycotrol® and Naturalis-L®), and imidacloprid (Admire®) were applied to control silverleaf whitefly, *Bemisia argentifolii* Bellows & Perring, on spring cantaloupe in the Lower Rio Grande Valley of Texas. Five biweekly applications of IGRs and 10 weekly applications of fungal insecticides alone did not provide satisfactory control of whiteflies. IGRs and fungal insecticides alone could be used in the early season at a weekly or biweekly frequency depending on the pressure of *B. argentifolii*. Three biweekly applications of IGRs and five biweekly applications of fungal insecticides, plus one soil application of imidacloprid significantly reduced whitefly populations. Imidacloprid applied at transplanting protected the plants in the early season, but did not reduce whitefly populations after the mid-season, whereas imidacloprid applied at mid-season significantly reduced whitefly populations. Imidacloprid applied at both transplanting and mid-season provided the best control of whiteflies.

RESUMEN

Se estudió la eficacia de la aplicación de imidacloprid (Admire ®) y de dos reguladores de crecimiento de insectos (RCIs) (pyriproxyfen [Knack ®] y buprofezin [Applaud ® y Naturalis-L ®) para controlar la mosquita blanca de alas plateadas, *Bemisia argentifolii* Bellows & Perring, en melón en el ciclo de primavera en el Bajo Valle del Río Grande de Texas. Cinco aplicaciones de RCIs a intervalos de 2 semanas y diez aplicaciones semanales de solamente insecticidas fúngicos no controlaron satisfactoriamente a las mosquitas blancas. Los insecticidas fúngicos y los RCIs por separado podrían ser usados durante la estación temprana con una frecuencia de una o dos semanas dependiendo de la presión de *B. Argentifolii.* Tres aplicaciones de RCIs a intervalos de 2 semanas y cinco aplicaciones de insecticida fúngicos a intervalos de 2 semanas, mas una aplicación al suelo de imidacloprid redujeron significativamente las poblaciones de las mosquitas blancas. El imidacloprid aplicado durante el transplante protegió las plantas en la estación temprana, pero no redujo las poblaciones de las mosquitas blancas en la segunda mitad de la estación, mientras que el imidacloprid aplicado a la mitad de la estación redujo significativamente las poblaciones de estos insectos. El imidacloprid aplicado tanto al momento del transplante así como a la mitad de la estación brindó el mejor control para las mosquitas blancas.

Additional index words: biorational insecticides, biological control, microbial insecticides, sweetpotato whitefly, silverleaf whitefly, melon

The silverleaf whitefly, *Bemisia argentifolii* Bellows & Perring (formerly known as the sweetpotato whitefly, *B. tabaci* [Gennadius], strain B) has been, and is still, a devastating pest of melons and other crops in the Lower Rio Grande Valley of Texas (Riley and Sparks 1993, Liu 2000, Liu et al. 2000) and of other vegetable and field crops in the southern United States (Henneberry et al. 2000). The development of insecticide resistance by *B. argentifolii* and increasing regulation of chemical pesticide use have sparked interests, research and investments in alternative management strategies, including biorational insecticides and entomopathogenic fungi (Henneberry et al. 2000).

Fungal insect pathogen products, Mycotrol® (Mycotech) and Naturalis-L® (Troy Bioscience), two different strains of *Beauveria bassiana* (Balsamo) Vuillemin, are relatively effective against *B. argentifolii* (Lacey et al. 1996, Liu et al. 1999). These two strains have been commercialized as microbial insecticides against *Bemisia* and other whitefly species in greenhouse-grown ornamentals and field crops (Lacey 1996). With good coverage, frequent applications and suitable environmental conditions, *B. bassiana* products (Mycotrol or Naturalis-L) can be effective against *B. argentifolii* nymphs and pupae.

Insect growth regulators (IGRs), which selectively target

whiteflies and not their natural enemies, have been successfully used for controlling numerous pest insects. Pyriproxyfen (Knack® by Valent USA), a juvenile analog, is effective against *B. argentifolii* and safe to parasitoids (*Encarsia pergandiella* Howard and *E. transvena* [Timberlake]) (Liu and Stansly 1997), and has been used to control *B. argentifolii* on cotton (Ishaaya and Horowitz 1992). Buprofezin (Applaud® by AgrEvo, Wilmington, DE), a chitin inhibitor, has been widely used against *B. argentifolii* on cotton in the southwestern US (Dennehy and Williams 1997). Buprofezin has been labeled against whiteflies on melons, and pyriproxyfen has potential to be labeled against whiteflies on melons and vegetables.

Imidacloprid, a systemic insecticide produced by Bayer Corporation (Kansas City, MO), has offered control of whiteflies, aphids and other insects for several years in the United States (Mullins 1993, Stansly et al. 1998, Williams et al. 1996). The material is a chloronicotinyl, which attacks the nervous system of whiteflies and other insects, and causes the insects to stop feeding. The commercial products, Admire® (applied to soil at planting or through drip irrigation systems, or soil injection during growing season), and Provado® (applied as foliar sprays), have been available on cotton and many vegetables since 1993. Because of its effectiveness against the whitefly, imidacloprid (Admire®) has been used extensively in Texas and elsewhere (Riley 1994, Stansly 1996, Williams et al. 1996). Imidacloprid is still effective against *B. argentifolii* in south Texas and elsewhere (Castle et al. 1996, Farias Larios et al. 1997, Stansly et al. 1998, Liu 2000); however, field application data in Arizona showed that the same concentration of imidacloprid caused lower efficacies to whiteflies than before (Williams et al. 1996). Several strains of *B. argentifolii* collected from the Almeria region of Spain showed significantly less mortality at the diagnostic dose for imidacloprid than the susceptible strains (Cahill et al. 1996, Elbert et al. 1996). Growers and scientists are concerned that the whitefly may become resistant to imidacloprid and could again increase to very high densities. It is important to integrate other insecticides with imidacloprid to prolong the life span of imidacloprid; thus, by optimizing its use and delaying resistance development.

The objective of this study was to develop a season-long *B. argentifolii* management program on spring melon (cantaloupe) with application of fungal insecticides and IGRs in the early season and application of imidacloprid in the mid- and/or late-season.

MATERIALS AND METHODS

Cantaloupe and Field Experiment Design. Cantaloupe ("Perlita") was seeded on 8 January 1998 in trays in a greenhouse. The seedlings (10-11 cm high) were transplanted in the field on 22 January. The plants were irrigated, fertilized and treated with fungicides according to the accepted protocol for south Texas. Each plot was 12 m long with two separate rows (2 m or 80 in wide), and 10 plants per row in each plot. The plots were arranged in a randomized complete block design with 4 replicates.

Materials and Treatments. The two fungal insecticides tested were Mycotrol WS (Mycotech, Butte, MT) at 1.12 kg/ha (1 lb/ac) and Naturalis-L (Troy Bioscience, Phoenix, AZ) at 1.12 kg/ha (1 lb/ac). The two IGRs tested were pyriproxyfen (Knack® 0.86 EC, Valent USA, Walnut Creek, CA) at 4.7 g (AI) /ha (10 oz/ac) and buprofezin (Applaud® 70 WP, Aventis, Wilmington, DE) at 0.4 kg (AI)/ha (0.5 lb/ac). Imidacloprid (Admire® 2F, Bayer, Kansas City, MO) was applied through the drip irrigation lines at 0.14 kg [AI]/ha (14 oz/ac). The 12 treatments consist of 5 groups (Table 1): (1). Mycotrol or Naturalis-L sprayed weekly starting from 4 March to 8 May for 10 weekly applications; (2), Mycotrol or Natural-L sprayed weekly for 6 weeks, and then Imidacloprid injected on 14 April; (3), pyriproxyfen or buprofezin applied biweekly for 5 times (4, 18 March, 2, 14, April and 1 May); (4), pyriproxyfen or buprofezin applied biweekly for 3 times, and then imidacloprid was injected on 14 April; and (5). imidacloprid injected at transplanting only (22 Jan.), in the mid-season only

Table 1. Efficacy of some biorational insecticides on *Bemisia argentifolii* adults on cantaloupe in south Texas (Weslaco, Spring 1998).

		Mean adults[y] per leaf											
Treatments[z]		3/3	3/10	3/18	3/24	3/31	4/6	4/13	4/21	4/28	5/6	5/11	5/18
1. Mycotrol	alone	3.1a	2.7b	7.8a	6.7ab	13.5b	8.1c	16.5b	15.5b	18.5bc	12.8bc	18.8c	21.6b
2. Mycotrol	Imidacloprid (4/14)	2.5a	2.1b	9.2a	5.6ab	11.9bc	10.2bc	18.6b	11.2bc	5.3c	4.1c	8.9d	3.1c
3. Naturalis-L	alone	2.0a	5.5a	1.2b	10.2a	5.8c	7.5c	16.9b	15.9b	21.9b	28.6b	31.3b	42.1a
4. Naturalis-L	Imidacloprid (4/14)	1.9a	6.6a	4.5ab	7.3ab	18.8b	19.8b	20.4b	8.6c	9.2c	3.6c	4.5d	2.3c
5. Pyriproxyfen	alone	2.8a	5.1a	1.5b	7.5ab	7.0c	14.4b	5.8b	10.3b	11.0bc	22.9b	25.1b	46.9a
6. Pyriproxyfen	Imidacloprid (4/14)	2.1a	4.4a	2.2b	6.8ab	5.5c	18.6b	8.9b	8.5c	3.6c	2.9c	8.8d	5.2c
7. Buprofezin	alone	2.5a	4.8a	1.3b	6.1ab	6.9c	20.3b	6.7b	24.4b	35.4b	34.0b	30.9b	39.6a
8. Buprofezin	Imidacloprid (4/14)	3.5a	6.3a	4.1ab	10.1a	3.4c	8.1c	15.6b	7.4c	2.6c	0.8c	6.2d	7.8c
9. Imidacloprid	transplanting	0.2b	0.1b	0.2b	1.0b	3.8c	0.6d	10.1b	6.2c	24.9bc	23.2b	65.0a	52.8a
10.Imidacloprid	transplanting & mid-season (4/14)	0.2b	0.5b	0.4b	0.9b	2.5c	3.3d	9.3b	6.1c	2.1c	1.1c	0.5d	1.6c
11.Inidacloprid	mid-season (4/14)	3.8a	3.5a	10.3a	11.2a	25.6a	41.2a	94.4a	12.5bc	6.3c	5.8c	4.2d	4.1c
12. Untreated		2.1a	1.3ab	9.6a	10.5a	38.9a	36.6a	70.0a	125.9a	136.7a	137.7a	62.6a	56.6a

[z]Imidacloprid was applied on 22 January, at transplanting, and/or 14 April, at mid-season.

[y]Means followed by the same letters did not differ significantly at P=0.05 (LSD, SAS Institute 1996).

Table 2. Efficacy of some biorational insecticides on *Bemisia argentifolii* nymphs and pupae on cantaloupe in south Texas (Weslaco, Spring 1998).

		Mean live nymphs and pupaey per 10 cm2 leaf area						
Treatments[z]		3/4	3/18	4/1	4/13	4/27	5/11	5/25
1. Mycotrol	alone	0.6a	1.9a	1.2c	3.2bc	6.7b	9.7b	23.3b
2. Mycotrol	Imidacloprid (4/14)	0.7a	4.0a	3.5b	2.1c	3.1c	3.5c	4.2cd
3. Naturalis-L	alone	1.6a	3.1a	8.9ab	5.6b	7.5b	16.9ab	16.8b
4. Naturalis-L	Imidacloprid (4/14)	1.1a	2.2a	5.1b	4.4bc	2.3c	2.5c	10.3bc
5. Pyriproxyfen	alone	0.3a	5.3a	1.2c	8.1a	8.4b	15.1ab	6.1c
6. Pyriproxyfen	Imidacloprid (4/14)	0.8a	4.1a	12.2a	10.1a	2.2c	3.9c	6.2c
7. Buprofezin	alone	1.2a	3.3a	9.6ab	6.7b	6.3b	10.4b	14.8b
8. Buprofezin	Imidacloprid (4/14)	0.8a	2.9a	5.1b	4.4bc	1.7c	6.1bc	5.5c
9. Imidacloprid	transplanting	0.5a	0.4b	0.7c	1.0d	0.9d	2.9c	5.2c
10.Imidacloprid	transplanting & mid-season (4/14)	0.1a	0.3b	0.6c	0.8d	0.4d	1.2d	1.4d
11.Inidacloprid	mid-season (4/14)	0.1a	3.5a	8.9ab	12.4a	2.2c	2.8c	2.3d
12. Untreated		0.1a	2.6a	7.6ab	16.7a	18.0a	24.3a	35.7a

[z]Imidacloprid was applied on 22 January, at transplanting, and/or 14 April, at mid-season.
[y]Means followed by the same letters did not differ significantly at P=0.05 (LSD, SAS Institute 1996).

(14 April), or at transplanting (22 Jan.) and mid-season (14 April). Untreated plots were used as controls. Treatments were replicated 4 times and arranged in a randomized complete block design. Mycotrol, Naturalis-L, pyriproxyfen and buprofezin were sprayed using 1 overhead and 2 lateral TXSS18 hollow-cone spray tips (Spraying System, Wheaton, IL) at 2068 kPa (300 psi) with 374 l/ha (40 gal/ac) delivery rate.

Whitefly Sampling. Sampling was initiated 2 weeks after transplanting. After initiation of foliar application, plants were sampled on 7-day intervals, and 1 day before the insecticide application. Ten plants per plot were randomly selected, whitefly adults on the third leaf from the apical meristem were counted by the leaf turn method (Palumbo et al. 1994). When plants had ≤6 leaves, adults on the oldest leaf was sampled; and when plants had ≥6 leaves, adults on the 4th or 5th leaf from the proximal to the base of the plant were counted. When plants had ≤6 leaves, the oldest leaf was removed from each of the 10 plants; and when plants had ≥6 leaves, a leaf at the 4th-5th node from the proximal to the base of the plant were sampled. Large nymphs (3rd and 4th instars) and pupae (re-eyed nymphs) per 4 leaf-disks (2-cm diameter or 3.14-cm^2 leaf area per leaf disk) per leaf were counted under a stereo microscope in the laboratory.

Data Analysis. Numbers of adults per leaf and live nymphs and pupae per leaf disk from each of the 10 leaves (10 plants) from each plot were subjected to analysis of variance (ANOVA), and the means were separated using the least significant difference test (LSD) at $P = 0.05$ (SAS Institute 1996).

RESULTS AND DISCUSSION

Whitefly populations on the experimental plants were high during the entire season, and numbers of adults among the treatments were significantly different on all sampling dates (Table 1). Mycotrol, Naturalis-L, pyriproxyfen and buprofezin, when used alone, reduced the adult population, but did not reduce populations below the economic threshold of 3 adults per leaf. In the fungal insecticides or IGRs treatments with imidacloprid applied in the mid-season, numbers of whitefly adults on the plants was significantly reduced but remained greater than the economic threshold.

Generally, the treatments with Imidacloprid at transplanting had the lowest whitefly population before the mid-season. The treatment of imidacloprid applied twice, one at transplanting and the other in the mid-season, had the least number of adults averaged across the season, which was normally below or slightly greater than the economic threshold. For the treatments treated with imidacloprid in the mid-season, the treatments were the same as the untreated control prior to mid-season. Number of adults on these treatments was above threshold in the early season (same as the untreated control). However, number of adults on the plants was still above threshold after the application of imidacloprid, although the overall whitefly population was significantly lower than the untreated control, the fungal insecticides and IGRs used alone.

The number of live nymphs and pupae and empty pupal cases was significantly different among treatments (Table 2). Ten weekly applications of Mycotrol and Naturalis-L alone reduced the whitefly population but did not reduce the population below the economic threshold of 0.5 large nymphs per 0.76 cm^2 (Riley and Palumbo 1995). Although the whitefly population on the plants treated with 5 biweekly applications of pyriproxyfen and buprofezin alone was generally significantly lower than on untreated plants, numbers of whitefly nymphs in these two treatments were relatively high by the end of the test. Multiple applications of Mycotrol, Naturalis-L, pyriproxyfen and buprofezin in the early season followed by a mid-season application of imidacloprid, significantly reduced the numbers of nymphs and pupae on the plants, but even in some of these treatments numbers of nymphs were still above the economic threshold, and even were significantly different from imidacloprid alone at mid-season.

The three treatments of imidacloprid provided best control of nymphs and pupae, and the treatment with two applications (at transplanting and in the mid-season) normally had the least numbers of whiteflies. Imidacloprid applied at transplanting was effective against *B. argentifolii* before the mid-season, but

did not give adequate whitefly control after the mid-season, and its effectiveness lasted about 10-11 weeks of the 16-17-week season. Imidacloprid applied once in the mid-season had relatively more whiteflies than other treatments before the mid-season (untreated) and generally had more whiteflies after the mid-season although these umbers might not be statistically significant. Imidacloprid applied twice, at transplanting and in the mid-season, provided the best control of both whitefly adults and immatures, although in some sampling dates numbers of whiteflies on the cantaloupe plants were slightly greater than the economic threshold. Interestingly, both adults and immatures on the plants treated with imidacloprid at the end of the season were greater than the economic threshold. This could be explained in that the healthy green plants treated with effective insecticides attracted more whitefly adults from the nearby dead or dying plants which were not treated with insecticides or treated with ineffective insecticides.

Generally, during the early spring in south Texas, melon plants are small and whitefly population on the plants are also relatively low because of the low temperature. At this period, whiteflies can be easily detected. When whitefly populations reach the action threshold level on these small plants, foliar application of a biorational insecticide would be more effective because it is easier to obtain good spray coverage. With the rapid foliage growth from the mid- to late-season, spray coverage of insecticides becomes more difficult. At present, growers use imidacloprid at planting or transplanting as a furrow or drip application in the soil to control *B. argentifolii*, aphids and other pest insects (Riley 1994). The spring season for melon lasts 16-20 weeks. Previous studies indicated that imidacloprid protects the plants for the 8-10 weeks leaving the plants unprotected for 6-12 weeks (Liu 2000). Thus, with application of imidacloprid at planting or transplanting, growers sometimes have to use other insecticides to control the whiteflies in the late-season. However, foliar application of insecticides after the mid-season becomes more difficult because the large leaves and dense canopy make good spray coverage difficult.

Based on the results from this study, we concluded that Mycotrol and Naturalis-L, the two fungal insecticides applied alone were not as effective against the whiteflies as expected and were also not economical. Applications of these fungal insecticides applied in the early season and imidacloprid in the mid-season significantly reduced whitefly population, but was still higher than the economic threshold. Pyriproxyfen and buprofezin, the two IGRs applied alone, were moderately effective against *B. argentifolii*. Applications of these IGRs in the early season and imidacloprid in the mid-season provided similar results as applications of fungal insecticides and imidacloprid. Therefore, a season-long whitefly management programs may be achieved by foliar applications of more effective insecticides in the early season when whitefly populations are low, and application of imidacloprid in or before the mid-season. In addition, if melon viral disease is not a concern and whitefly pressure is not high, application of imidacloprid at mid-season may be adequate so that grower could be able to save insecticide and application costs for the early season.

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