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Response of Four Melon Varieties to Silverleaf Whitefly (Homoptera: Aleyrodidae) under Laboratory and Field Conditions

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ABSTRACT

The response of four varieties or breeding lines of melon (*Cucumis melo* L.) (cantaloupe) (Primo, TAM Sun, TAM Sun x gl [glabrous], and Hymark) to silverleaf whitefly, *Bemisia argentifolii* Bellows & Perring, was determined under laboratory conditions for infestation, oviposition, development and survivorship, and under field conditions for infestation of adults, eggs and nymphs of the whitefly. The response of the four melon varieties to yield and quality in the field was also evaluated. In choice tests in large cages, fewer silverleaf whitefly adults and eggs were found on Hymark than on TAM Sun, TAM Sun x gl and Primo. In no-choice tests in clip-on cages, fewer whitefly eggs were found on TAM Sun and TAM Sun x gl than on Hymark and Primo. Silverleaf whitefly immatures developed significantly faster on Primo (16.5 d) than on other three varieties (17.4-17.8 d). Natural percent mortality of silverleaf whitefly immatures on Hymark was as high as 60.1% compared with 13.8% on TAM Sun, and only 2.5 and 1.3% on TAM Sun x gl and Primo, respectively. Under field conditions, among the four varieties, Primo had the greatest numbers of silverleaf whitefly adults and red-eyed nymphs (pupae), and TAM Sun x gl had the least. Although TAM Sun had relatively more large melons than other varieties, it had fewer melons compared with the other three varieties.

RESUMEN

Se determinó la respuesta de 4 variedades o lineas mejoradas de melón (*Cucumis melo* L) (Primo, TAM Sun X gl [glabrous], y Hymark) a la infestación con mosquita blanca, *Bemisia argentifolii* Bellows & Perring, en condiciones de invernadero en lo referente a la infestación, oviposición, desarrollo y sobrevivencia, y bajo condiciones de campo para la infestación de adultos, huevos, y ninfas de la mosca blanca. La respuesta de las cuatro variedades de melón al rendimiento y calidad en el campo también fue evaluada. En pruebas de selección en jaulas grandes, se encontraron menos moscas blanca adultas y huevecillos en el cultivar Hymark que en el TAM Sun, TAM Sun X gl y Primo. En pruebas de no selección en jaulas prensiles, se encontraron menos huevecillos de mosquita blanca en TAM Sun y TAM Sun x gl que en Hymark y Primo. Los estadíos inmaduros de las mosquitas blancas se desarrollaron significativamente más rápido en Primo (16.5 d) que en las otras tres variedades (17.4 - 17.8 d.) El porcentaje de mortalidad natural de los estadíos inmaduros de la mosquita blanca en Hymark alcanzó el 60.1% en comparación con 13.8 % TAM Sun, y solo 2.5 Y 1.3 % en TAM Sun x gl y en Primo, respectivamente. Bajo condiciones de campo, entre las cuatro variedades, Primo presentó las mayores cantidades de adultos de mosquita blanca y de ninfas de ojos rojos (pupas), y TAM Sun x gl tuvieron las menores cantidades. Aunque TAM Sun produjo melones de tamaño relativamente mayor que las otras variedades, produjo menos melones en comparación con las otras tres variedades.

The silverleaf whitefly, *Bemisia argentifolii* Bellows & Perring, continues to be the most important insect pest for cucurbits, particularly on melon (*Cucumis melo* L.) (cantaloupe) in south Texas (Liu 2000). Host plant resistance has been a valuable tool for management of silverleaf whitefly on melon and many other crops (Riley 1995, Simmons and McCreight 1996). In recent years, many varieties, lines, and PIs have been studied under field conditions for whitefly resistance in south Texas, and the glabrous leafed varieties or lines have been found highly resistant to *B. argentifolii* (Riley 1995, Riley et al. 1998, McCreight and Simmons 1998, Riley et al. 2001). However, more detailed information on the response of the four varieties or breeding lines to whiteflies under laboratory and field conditions is needed.

The objectives of this study were to determine the performance of silverleaf whitefly on four different melon varieties with different resistant and susceptible characteristics under laboratory and field conditions.

MATERIALS AND METHODS

Melon Varieties. In this study, four melon varieties were selected based on their special characteristics of yield, quality, and resistance or tolerance to whiteflies (Wolff unpublished

Table 1. Numbers of silverleaf whitefly adults and eggs on four different varieties/hybrids of melon in the laboratory.

	Number of adults per leaf			
Variety	2 h	4 h	24 h	Eggs/leaf ± SE
TAM Sun	29.2 ± 10.3a	30.6 ± 7.6a	17.6 ± 3.6b	126.3 ± 16.5a
TAM Sun x gl.	29.8 ± 6.8a	25.4 ± 4.4a	28.8 ± 3.7ab	117.0 ± 26.5a
Primo	32.5 ± 6.8a	38.5 ± 7.7a	46.4 ± 9.4a	127.3 ± 16.2a
Hymark	17.3 ± 5.0b	19.8 ± 5.9b	23.0 ± 7.2b	81.0 ± 22.3b

Means in the same column followed by the same letters are not significantly different at $P = 0.05$ (SAS Institute 2003).

data). Hymark is a high yield and good quality variety with trichomes and is relatively resistant to whiteflies. TAM Sun has good yield and quality with trichomes and relatively tolerant to whitefly infestation (Riley et al. 1998, 2001). Primo had high yield and good quality with trichomes, and was considered susceptible to whiteflies (Riley 1995, Riley et al. 2001). TAM Sun x gl (glabrous) is a breeding line, with glabrous leaves, and is considered a whitefly resistant variety (D. Wolff, personal communication).

Adult Feeding and Oviposition Preference. The whitefly adults used in this study were originally collected from a melon field at the Research Farm, Texas Agricultural Experiment Station (TAES) at Weslaco, Texas. They were cultured on cabbage, collards and melons in an insectary at 25 ± 5º C, 55-95% RH with natural lighting. To avoid host adaptation and preference, only the whiteflies on collards were used in this study.

When the melon plants for each variety or line reached the 5-6 leaf stage, two fully expanded leaves (the 3rd and the 4th leaf from the terminal) were kept on each plant, and the terminal and other leaves were removed. A turning plate, 45 cm in diameter, made of poly-wood, was placed in the center of a large wood framed screened cage (50 x 50 x 50 cm). In the choice test, the two-leaf melon plants, each representing a variety or line, were coded and randomly placed around the circular plate, ≈ 3 cm apart. Whitefly adults were introduced into the cage at a rate of 50 adults per plant. Numbers of whitefly adults on each leaf were counted 4 and 24 h after introduction. Because the whitefly adults tend to aggregate between and within plants (Liu et al. 1993), the location of the plants or leaves inside the cage may influence the number of whiteflies on it. To avoid this bias, the leaves with the whiteflies were shaken after the adults were counted to force the whitefly adults to relocate their feeding or egg-laying position (leaves or plants). The turning plate was rotated, and randomly stopped, and the plants were relocated randomly inside the cages. Numbers of whitefly eggs on each leaf were also counted 24 h after the adult introduction. After all silverleaf whitefly eggs were counted on each leaf under a stereo microscope, the leaf area of each leaf was then measured using a portable area meter (LI 3000, LI- COR, Lincoln, NE). There were four cages, each representing a replicate.

Table 2. Numbers of eggs deposited by 20 silverleaf whitefly adult females on each of the four different varieties in 3 d.

Variety	Eggs ± SE
TAM Sun	39.3 ± 5.9b
TAM Sun x gl.	39.7 ± 9.1b
Primo	56.7 ± 3.3a
Hymark	46.50 ± 5.3a

Means in the same column followed by the same letters are not significantly different at $P = 0.05$ (SAS Institute 2003).

Oviposition, Development, and Survivorship on Different Melon Varieties. Twenty melon plants for each variety, one per pot, were maintained on a bench in a greenhouse. The plants were used for the experiment when the leaves were 30-40 cm^2. A leaf clip-on cage was placed on a fully expanded leaf, and 20 whitefly females (<24 h old) were introduced inside the cage. The whitefly adults were removed 4 h after the introduction. Whitefly eggs on the leaf were marked and coded. The eggs were monitored daily for nymphal

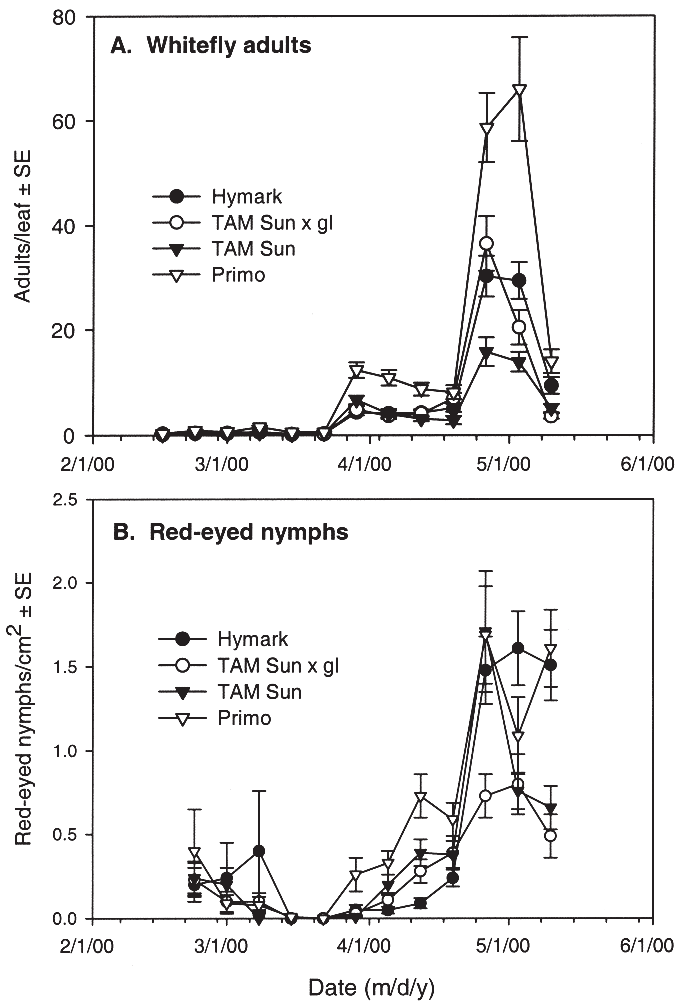

Fig. 1. Number of silverleaf whitefly adults and red-eyed nymphs on four melon varieties sampled over the spring growing season in 2000 (Weslaco, TX).

Table 3. Developmental time of silverleaf whitefly immatures on four melon varieties.

	Developmental time (days ± SE)			
Variety	Egg	Nymph	Pupa	All immatures
TAM Sun	5.26 ± 0.05a	8.92 ± 0.17a	3.52 ± 0.08c	17.73 ± 0.18a
TAM Sun x gl.	5.00 ± 0.00b	8.33 ± 0.1bc	4.04 ± 0.05a	17.37 ± 0.10a
Primo	5.00 ± 0.00b	7.85 ± 0.10c	3.68 ± 0.08bc	16.53 ± 0.11b
Hymark	5.24 ± 0.06a	8.63 ± 0.18ab	3.88 ± 0.27ab	17.78 ± 0.40a

Means in the same column followed by the same letter do not differ significantly at P = 0.05 (LSD, SAS Institute 2003).

Table 4. Natural percent mortality of immatures of silverleaf whitefly on four different varieties.

Variety	% natural mortality ± SE
TAM Sun	13.8 ± 5.3b
TAM Sun x gl.	2.5 ± 2.5c
Primo	1.3 ± 1.2c
Hymark	60.1 ± 8.7a

Means in the same column followed by the same letters are not significantly different at P = 0.05 (SAS Institute 2003).

hatching. After the first instar crawler hatched, the development of each nymphal stage was monitored daily until the adult emerged.

A no-choice test was conducted to determine the effects of different melon varieties on whitefly oviposition. Newly emerged whitefly adults were collected and sexed. Twenty females and 10 males were placed in a leaf clip-on cage (2 cm in diameter, and 1 cm in height) on a melon leaf. Four such cages, each as a replicate, were used for each of the four varieties. Numbers of eggs oviposited on each leaf were counted in 3 d.

Field Experiment. Melons were seeded in December 1999 in trays in a greenhouse. The seedlings (10-11 cm high) were transplanted in the field on 20 January 2000. The plants were irrigated, fertilized and treated with fungicides according to the general protocol for south Texas. Each plot was 12 m long with two separate rows 2 m wide, and 10-20 plants each. The plots were arranged in a randomized complete block design with four replications.

Sampling of *B. argentifolii* adults was conducted when the whitefly population had increased significantly. Thereafter, plants were sampled at 7-d intervals. When sampling adults, the melon leaf was gently turned, and all adults on the leaf were counted. When plants had more than six leaves, adults on the oldest leaf were counted, and when plants had less than six leaves, adults on the 4th or 5th leaf from the proximal were counted. For sampling nymphs, when plants had less than leaves, an oldest leaf was sampled; and when plants had more than leaves, a leaf at the 4th or 5th node from the proximal end was sampled. Pupae (red-eyed nymphs), empty pupal cases on four leaf-discs per leaf were also counted.

At maturity, melons from each plot were picked, counted, graded and weighed. Sugar contents from top and bottom portions of each of five melons per plot were measured with a handheld refractometer. Yield was determined in terms of total harvested melon in each of six size categories from each plot.

Data Analysis. Numbers of silverleaf whitefly adults, immatures and developmental times, as well as number of melons, and sugar contents were subjected to analysis of variance (ANOVA) (SAS Institute 2003), and means were separated using the least significant difference test (LSD) at P = 0.05.

RESULTS AND DISCUSSION

Feeding and Oviposition Preference of Whitefly Adults. Both the number of *B. argentifolii* adults and eggs on the different varieties differed significantly at 2, 4 and 24 h after whitefly introduction (Table 1). Of the four varieties, Hymark had the least number of whitefly adults at 2 and 4 h after whitefly introduction compared with the other three varieties (F = 3.03; df = 3, 40; P = 0.0391). At 24 h, the numbers of whitefly adults also differed significantly (F = 3.03; df = 3, 40; P = 0.0391). The number of adults on Primo was the greatest, but was not significantly different from that on TAM Sun x gl. Hymark had the least number of adults, but did not differ significantly from TAM Sun and TAM Sun x gl. Hymark also had fewer whitefly eggs than the other three varieties (F = 3.01; df = 3, 40; P = 0.0399).

The numbers of eggs deposited by 20 silverleaf whitefly females on the four melon varieties differed significantly (F = 21.60; df = 3, 15; P = 0.0135), and fewer eggs were deposited on TAM Sun and TAM Sun x gl than on Primo and Hymark (Table 2).

Development and Natural Survivorship. Silverleaf whitefly development was significantly different among the four varieties (Table 3). Whitefly eggs developed longer period on Hymark than on all other varieties (F = 3.30; df = 3, 40; P = 0.0389). Whitefly nymphs developed for the longest period on TAM Sun and Hymark, followed by those on TAM Sun x gl, with the shortest on Primo. In contrast, whitefly pupae on TAM Sun x gl developed significantly slower than on TAM Sun and Primo, but not slower than those on Hymark. Overall developmental durations of all immature stages were significantly shorter on Primo (16.5 d) than on the other three

Table 5. Seasonal averages of silverleaf whitefly adults and red-eyed nymphs on four varieties of melon (Spring 2000, Weslaco, Texas).

Variety	Adults per leaf	Red-eyed nymphs/cm^2
TAM Sun	4.12 ± 0.36cd	0.43 ± 0.05bc
TAM Sun x gl.	6.41 ± 0.67bc	0.31 ± 0.03c
Primo	14.28 ± 1.33a	0.62 ± 0.05a
Hymark	6.85 ± 0.62b	0.55 ± 0.05ab

Means in the same column followed by the same letters are not significantly different at P = 0.05 (SAS Institute 2003).

Table 6. Numbers of harvested melons among four melon varieties (Spring 2000, Weslaco, Texas).

	Melon per plot	% of melons in each size category					
		N30	N23	N18	N15	N12	N9
TAM Sun	25.0b	21.6	14.8	24.4	29.8	5.7	3.6
TAM Sun x gl.	40.8a	29.1	19.8	25.4	22.4	2.2	1.1
Primo	45.5a	27.9	25.6	24.6	18.2	2.8	0.9
Hymark	43.5a	19.3	29.7	23.6	22.9	2.7	1.8

Means in the same column followed by the same letters are not significantly different at $P = 0.05$ (SAS Institute 2003).

varieties (17.4-17.8 d).

The natural percentage mortalities of silverleaf whitefly from egg to adult emergence varied greatly among the varieties ($F = 23.82$; df = 3, 40; $P = 0.0001$). Approximately 60% of the immatures died on Hymark, compared with 13.8% on TAM Sun, and only 1.3 and 2.5% mortalities on Primo and TAM Sun x gl, respectively (Table 4).

Field Experiment. The numbers of silverleaf whitefly adults per leaf among the four varieties over 13 sampling dates are shown in Fig. 1A. The whitefly adult population was relatively low on the plants in all four varieties before late March, and increased gradually to mid April. The numbers of adults increased rapidly, and reached a peak in late April and early May. Among the four varieties, the numbers of adults per leaf were significantly different. The variety that had the least numbers of whitefly adults throughout the season was TAM Sun, a TAES variety. The variety that had the greatest number of whitefly adults was Primo, with as many as 66 adults per leaf were found on 3 May. Numbers of adults on Hymark and TAM Sun x gl were high, with >30 adults per leaf in late April and early May. Overall numbers of adults over the season were shown in Table 4. Primo had the most and TAM Sun had the fewest whitefly adults, and the difference between the two varieties was >3 fold.

The numbers of silverleaf whitefly red-eyed nymphs or pupae among the four varieties over 13 sampling dates are shown in Fig. 1B, and overall seasonal averages of adults per leaf and red-eyed nymphs (pupae) are shown in Table 5. Significant differences were found for red-eyed nymph among the four varieties. Primo and Hymark had more nymphs than TAM Sun and TAM Sun x gl, although there were no differences between TAM Sun and Hymark.

Numbers of melons harvested in each size category from each plot are summarized in Table 6. TAM Sun was the only variety that had fewer melons per plot than the other varieties ($F = 6.52$; df = 3, 12; $P = 0.0073$); although the percentages of melons in each size category among the four varieties were not significantly different ($P > 0.05$), it appeared that Hymark had the lowest percentage of small melons (N30).

Table 7. Harvested melon sugar contents of four melon varieties (Spring 2000, Weslaco, Texas)

Variety	Top	Bottom
TAM Sun	9.49a	9.41a
TAM Sun x gl	8.71a	8.36a
Primo	8.54a	8.15a
Hymark	9.07a	8.65a

Means in the same column followed by the same letters are not significantly different at $P = 0.05$ (SAS Institute 2003).

There were no significant differences for sugar content among the four varieties (Table 7), although it appears that TAM Sun and Hymark had higher sugar contents than the other two varieties.

Results from this study indicate that the response of the four varieties to silverleaf whitefly infestation differed, although the differences were not always statistically significant. Generally, TAM Sun and TAM Sun x gl had similar responses to silverleaf whitefly in number of adults and immatures, and natural mortalities of immatures. However, TAM Sun x gl had more melons than TAM Sun under field conditions. Silverleaf whitefly immatures developed faster on Primo than on the other three varieties, and the natural mortality on Primo was also lower than on TAM Sun and Hymark. Although numbers of silverleaf whitefly adult and immatures on Hymark were not significantly different from TAM Sun and TAM Sun x gl, the natural mortality of whitefly immatures was as high as 60.1% on Hymark compared with 13.8% on TAM Sun, and 2.5 and 1.3% on TAM Sun x gl and Primo, respectively. These results suggest that Hymark may have some degree of antibiosis. The antibiotic response to silverleaf whitefly by Hymark were similar to that found by Riley (1995) that Hymark had consistently lower nymph/egg ratios, high yield and only a moderate nymph infestation, but also responded with increased yields under whitefly control. TAM Sun was associated with moderate to relatively high numbers of silverleaf whitefly, had fewer melons, but had relatively more large melons.

Although silverleaf whitefly is still one of the most important pests on melons and other vegetable crops in south Texas, its levels of infestation and damage have dramatically decreased in recent years. Among the numerous factors in the whitefly integrated management programs which contribute to the whitefly population reduction, whitefly resistant and tolerant melon varieties have played significant roles (Liu, unpublished data). With the progress of the melon breeding program at the TAES at Weslaco (K. Crosby, unpublished data, Riley et al. 1998, 2001) and elsewhere (McCreight and Simmons 1998), more whitefly resistant and tolerant varieties will be available to local growers. It is expected that these whitefly resistant and tolerant varieties will play a more critical role in the management of silverleaf whitefly in south Texas in the future.

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