# LIFE HISTORY OF *BEMISIA ARGENTIFOLII* (HOMOPTERA: ALEYRODIDAE) ON *HIBISCUS ROSA-SINENSIS* (MALVACEAE)

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ABSTRACT

Oviposition, development and survivorship of *Bemisia argentifolii* Bellows & Perring, were evaluated on two cultivars of hibiscus (*Hibiscus rosa-sinensis* L.), 'Brilliant Red' and 'Pink Versicolor'. *B. argentifolii* deposited significantly more eggs and survivorship of nymphs was significantly greater in choice tests on 'Pink Versicolor' than on 'Brilliant Red'. Overall developmental time of *B. argentifolii* from egg to adult eclosion was longer on 'Brilliant Red' than on 'Pink Versicolor'. Although not all differences between the two cultivars were statistically significant, 'Brilliant Red' could be considered a less favorable host for silverleaf whitefly than 'Pink Versicolor'. However, based on the intrinsic rate of increase ($r = 0.105$) and finite rate of increase ($\lambda = 1.22$) of *B. argentifolii*, even 'Pink Versicolor' was a poor host for *B. argentifolii* compared to published values for eggplant, tomato, sweet potato, cucumber, garden bean, or collard.

Key Words: silverleaf whitefly, sweetpotato whitefly, oviposition, development, hibiscus, greenhouse, rate of increase

RESUMEN

Se evaluaron las tasas de oviposición, desarrollo y sobrevivencia de *Bemisia argentifolii* Bellows & Perring en dos variedades de tulipán (*Hibiscus rosa-sinensis* L.), 'Brilliant Red' y 'Pink Versicolor'. En pruebas de elección, *B. argentifolii* depositó significativamente más huevecillos sobre 'Pink Versicolor' que sobre 'Brilliant Red', y la tasa de sobrevivencia de ninfas fue significativamente mayor en la primer variedad que en la segunda. El desarrollo del huevecillo hasta la eclosión del adulto duró más en la variedad del tulipán 'Brilliant Red' que en 'Pink Versicolor', a pesar de que las diferencias no eran siempre significativas entre estadíos. Aunque las diferencias entre las dos variedades de tulipán no fueron significativas, se puede considerar que la variedad 'Brilliant Red' es un hospedero menos favorable para el desarrollo de esta especie de mosca blanca que 'Pink Versicolor'. Sin embargo, tampoco 'Pink Versicolor' actuó como un huésped óptimo para el desarrollo de *B. argentifolii* según el criterio de la tasas de incremento intrínseco y finito ($r = 0.105$ y $\lambda = 1.22$ respectivamente), en comparación con los valores publicados para su desarrollo en berenjena, tomate, camote, pepino, frijol o col rizada.

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*Bemisia argentifolii* Bellows & Perring, formerly known as sweetpotato whitefly, *B. tabaci* (Gennadius) Strain 'B', was recognized as a greenhouse pest of ornamentals (poinsettia, *Euphorbia pulcherrima* Willd.) (Hamon and Salguero 1986, Price et al. 1986) even before becoming a major pest of field crops and vegetables (Perring *et al.*, 1993). Ornamental plants infested with whiteflies risk rejection in both domestic and international markets (Alderman 1987, Schuster et al. 1996), and even the presence of empty exuviae is considered unacceptable (N. Rechcigl, Yoder Brothers, personal communication). These marketing realities exacerbate the impact of *B. argentifolii* on ornamental hosts including hibiscus (*Hibiscus rosa-sinensis* L.).

Development of management systems for *B. argentifolii* has been aided by biological studies in field crops (Avidov 1956, Azab et al. 1971, Butler et al. 1983, Bethke et al. 1991, von Arx et al. 1983), vegetables (Sharaf 1984, Tsai and Wang 1996), and some ornamental plants (Enkegaard 1993, Fransen 1990, Oetting and Buntin 1996), but not hibiscus. Host plant resistance might be a viable management strategy for hibiscus, but no sources of resistant germplasm have been identified. However, it is commonly believed that whiteflies are more problematic on cultivars with light-colored flowers and foliage than the traditional red flowered dark foliage varieties (N. Rechcigl, Yoder Brothers, Inc., personal communication). In a preference study of 12 hibiscus cultivars in Texas, Meagher and Estrada (1994) found that 'Cooper II', 'Ross Estey' and 'Dainty White' had the lowest numbers of eggs and nymphs, and 'Joanne', 'Gold Dust', 'Butterfly', 'Mary Morgan', and several others had the greatest population 6 weeks after initial infestation with *B. argentifolii*.

The objectives of this study were: (1) to compare whitefly oviposition and development on two most common cultivars of hibiscus in Florida, (2) to evaluate additional life history characteristics on one of these cultivars, and (3) to use this information to suggest ways of integrating host plant resistance and biological control into current management practices.

## Materials and Methods

### Host Plants and Whitefly

Two cultivars of hibiscus (*Hibiscus rosa-sinensis* L.) were used, 'Brilliant Red' (red blooms, dark green foliage and considered whitefly tolerant), and 'Pink Versicolor' (pink blooms, lighter foliage and considered susceptible). All plant materials were provided by Yoder Brothers Inc., Parish, FL. Cuttings (15-cm high) were individually planted in 15-cm plastic pots using standard media (Metro-Mix 300 growing medium, Grace Sierra, Horticultural Products Company, Milpitas, CA). *B. argentifolii* have been maintained on a mixture of several host plants: collard (*Brassica oleracea* L. var. *acephala*, 'Georgia LS'), tomato (*Lycopersicum esculentum* Miller, 'Lanai'), and sweet potato (*Ipomoea batatas* L., 'Carolina Bunch') in an air-conditioned greenhouse for >5 years, and were identified as strain 'B' of sweetpotato whitefly, *B. tabaci* (Gennadius), before the new species name was designated.

### Feeding and Oviposition Preference

Choice and non-choice tests were conducted to compare the feeding and oviposition preference of *B. argentifolii* adults on the two hibiscus cultivars. Eight plants for each cultivar were selected, and 3 leaves from the top of the plant of similar age were removed from each plant, leaving a total of 24 leaves from each cultivar, or 48 leaves total. Six leaves, 3 from each cultivar, were randomly selected, labeled with India ink, and inserted in one of 6, 20-ml glass vials which had been taped together to form a "leaf-wheel" as described in Liu and Stansly (1995). The leaf wheels were individually placed into cages (60 × 60 × 60 cm) into which 120 adult females of *B. argentifolii* (20 adult females per leaf) were introduced. Numbers of *B. argentifolii* adult females and eggs on each leaf were recorded 24 h later. Leaf area was measured using a leaf area meter (Li-Cor 2000, Lincoln, NE) and data expressed as adult females and eggs per $cm^2$ leaf area. The experiment included 8 replicates (leaf wheels) for a total of 48 leaves. Six leaves from each of the same cultivar were collected and arranged in each leaf wheel for the no-choice control.

Development and Survival of Immatures

Hibiscus cuttings (15-20 cm high) of 'Pink Versicolor' and 'Brilliant Red' were individually transplanted in plastic pots (15-cm in diameter) filled with Metro-Mix 300 growing medium. Plants were watered with 0.4% (wt.:vol.) Stern's Miracle-Gro (an all purpose water soluble plant food with N-P-K: 15-30-15) (Stern's Miracle-Gro Products, Port Washington, NY) twice per week and grown to approximately 40 cm high with 4-5 fully expanded leaves. Old leaves were removed so that only the two top fully expanded leaves remained. *B. argentifolii* adults (60 unsexed) collected from the greenhouse colony, were introduced into clip-on cages (4 cm in diameter) for oviposition, and were removed 2 h later to optimize uniformity of subsequent stages. Indian ink was used to place an identifying mark next to 20 whitefly eggs on each of 8 leaves per cultivar. Infested plants were placed in 60 × 60 × 60 cm cages and development and survivorship of each whitefly was recorded daily until all live whiteflies had emerged.

Life Table

*Bemisia argentifolii* pupae were collected from an insectary colony on 'Pink Versicolor'. Small confinement cages were made from gelatin capsules (No. 000, Torpac, Fairfield, NJ) on which the closed end of the narrow half was removed to form a tube which was held in place on the leaf by a piece of double-stick cellophane tape (15 × 15 × 2 mm, Double-sided Mounting Tape, Ace Hardware, Oak Brook, IL) into which a capsule-sized hole had been punched. The wider capsule half was used as the cage cover (Fig. 1). A cage was placed on the abaxial surface of the top fully expanded young leaf of a potted 'Pink Versicolor' plant (45-50 cm high). A pair of male and female whitefly adults having emerged 14 h earlier was introduced into the gelatin capsule

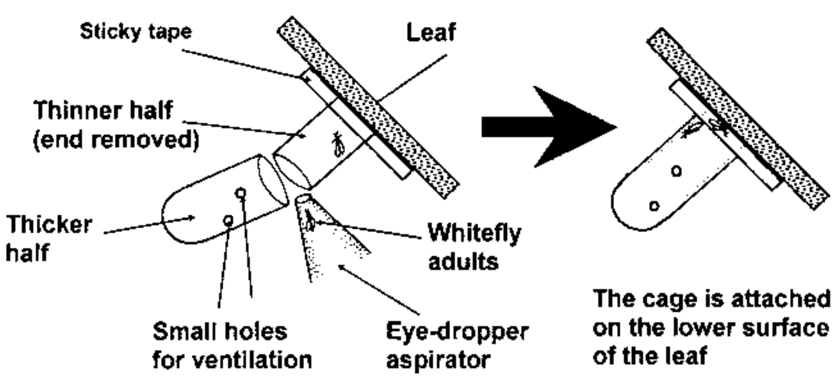


Fig. 1. The gelatin capsule cage and the setup used to determine the life table parameters of *B. argentifolii* on hibiscus leaf.

cage with an aspirator and moved to a new capsule cage on a fresh leaf every 24 h. Eggs were counted daily using a 14× hand lens and were coded with a number and date using India ink on the nearby leaf surface. Daily monitoring continued until all viable eggs had hatched and all nymphs had pupated. Following pupation, leaf sections bearing pupae were excised and placed individually in glass vials (2 × 4 cm), themselves placed on moist paper towels in a plastic tray until adult emergence. Emerged adults were counted and sexed as described by Gill (1993). The process was initiated with 40 male-female pairs, but only 25 pairs were included in the final data analysis, the remaining pairs having been either lost, physically damaged, or infertile. A life table was constructed using sex ratio, survivorship, and age-specific fecundity of adults and survivorship and developmental of all immature stages to calculate intrinsic rate of increase ($r$), finite rate of increase ($\lambda$), net reproductive rate ($R_o$), mean generation time (T), and doubling time ($DT$) (Birch 1948), calculated with a computer program by Hulting et al. (1990).

### Data Analysis

Data for oviposition and feeding preference of *B. argentifolii* adults on the two hibiscus cultivars were subjected for analysis of variance, and the means were separated using the least significant difference test (LSD) at $P = 0.05$ (SAS Institute 1995).

## RESULTS

### Adult Feeding and Oviposition Preference

Choice-Test. When given a choice, significantly more *B. argentifolii* adult females were found feeding on 'Pink Versicolor' than on 'Brilliant Red' ($F = 6.08$, df = 1, 23; $P = 0.0175$) (Table 1). Oviposition was also significantly greater on 'Pink Versicolor' than 'Brilliant Red' ($F = 4.42$; df = 1, 23; $P = 0.041$). However, adult fecundity did not differ significantly on the 2 cultivars ($F = 0.25$; df = 1, 23; $P = 0.616$).

No-Choice Test. Significantly more adults were again observed on 'Pink Versicolor' ($F = 6.93$; df = 1, 23; $P = 0.017$, Table 1). However, number of eggs on leaves, and number of eggs deposited per adult female were not significantly different between the two cultivars ($F = 0.89$; df = 1, 23; $P > 0.885$ for eggs/$cm^2$ leaf area, and $F = 0.01$; df = 1, 23; $P = 0.961$ for eggs/adult female).

### Immature Development and Survivorship

*B. argentifolii* developed almost 2 d faster on 'Pink Versicolor' (22.3 d) than on 'Brilliant Red' (24.1 d) ($F = 23.59$; df = 1, 1728; $P = 0.0001$) with egg and first instar contributing to the difference (Table 2). It was interesting that the most significant differences occurred in length of the egg stage, 6.3 d on 'Pink Versicolor', and 6.7 d on 'Brilliant Red' ($F = 43.97$; df = 1, 318; $P = 0.0001$). Among nymphal stages, developmental times were not significantly different between the two cultivars except for third instar ($F = 11.55$; df = 1, 281; $P = 0.0008$) where the difference was equal (0.4 d) to that observed in egg development. Adult emergence occurred from 19-32 d after oviposition on 'Pink Versicolor' and 19-35 d on 'Brilliant Red'. Estimates for survivorship of immatures in this test were 91.45% on 'Pink Versicolor' compared to 89.79% on 'Brilliant Red', with no significant difference ($F = 2.21$; df = 1, 7; $P = 0.07$). Age specific survivorship on 'Pink Versicolor' and 'Brilliant Red' was not significantly different ($P > 0.05$), and therefore values for the two cultivars were combined (Fig. 2). All eggs

TABLE 1. OVIPOSITION AND FEEDING PREFERENCE OF *B. ARGENTIFOLII* ON 2 HIBISCUS CULTIVARS: ADULT FEEDING AND OVIPOSITION.

| | Mean ± SE | | | |
|---|---|---|---|---|
| | 'Pink Versicolor' | 'Brilliant Red' | *F* | *P* |
| | Two-cultivar Choice Test | | | |
| Adults/cm² | 1.67 ± 0.23a | 0.94 ± 0.18b | 6.08 | 0.017 |
| Eggs/cm² | 1.45 ± 0.31a | 0.72 ± 0.16b | 4.42 | 0.041 |
| Eggs/adult | 9.17 ± 1.03a | 8.36 ± 1.24a | 0.25 | 0.616 |
| | No-Choice Test | | | |
| Adults/cm² | 1.67 ± 0.15a | 1.18 ± 0.11b | 6.93 | 0.011 |
| Eggs/cm² | 1.01 ± 0.21a | 0.97 ± 0.16a | 0.89 | 0.885 |
| Eggs/adult | 9.75 ± 0.31a | 9.59 ± 2.34a | 0.01 | 0.961 |

Means in the same row followed by the same letter do not differ significantly ($P > 0.05$, LSD [SAS Institute 1995]).

hatched successfully; survivorship through successive nymphal stadia was estimated at 96.9%, 92.2%, 88.8%, 84.1%, with 83.4% of the cohort emerging as adults.

## Life Table

The estimate for adult longevity was 9.27 ± 0.13 d (range: 4-26 d) (Fig. 3) with 50% adult females surviving for 9-10 d, and >10% for >20 d. Preovipositional period was 0.25 ± 0.01 d (range: 0-1 d). Oviposition varied greatly, and average eggs per female were noticeably fewer than the previous test.

TABLE 2. DEVELOPMENT OF IMMATURE STAGES OF *B. ARGENTIFOLII* ON TWO HIBISCUS CULTIVARS IN THE LABORATORY (26.7°C, RH 55%, 14:10 [L:D] H)

| | 'Pink Versicolor' | | 'Brilliant Red' | | | |
|---|---|---|---|---|---|---|
| Stage | n | Days ± SE | n | Days ± SE | *F* | *P* |
| Egg | 160 | 6.3 ± 0.6b | 160 | 6.7 ± 0.5a | 43.97 | 0.0001 |
| First instar | 157 | 4.2 ± 0.7a | 153 | 4.3 ± 1.1a | 1.64 | 0.2015 |
| Second instar | 147 | 2.3 ± 0.5a | 148 | 2.4 ± 1.1a | 1.66 | 0.1982 |
| Third instar | 145 | 2.7 ± 0.9b | 139 | 3.1 ± 1.1a | 11.55 | 0.0008 |
| Fourth instar | 138 | 2.6 ± 1.0a | 131 | 2.9 ± 2.4a | 1.64 | 0.2016 |
| Pupa | 136 | 3.8 ± 0.8a | 131 | 4.3 ± 2.9a | 3.34 | 0.0686 |
| Total | | 22.3 ± 1.6b | | 24.1 ± 2.2a | 23.59 | 0.0001 |

Means in the same row followed by the same letters do not differ significantly ($P > 0.05$, LSD [SAS Institute 1995]).

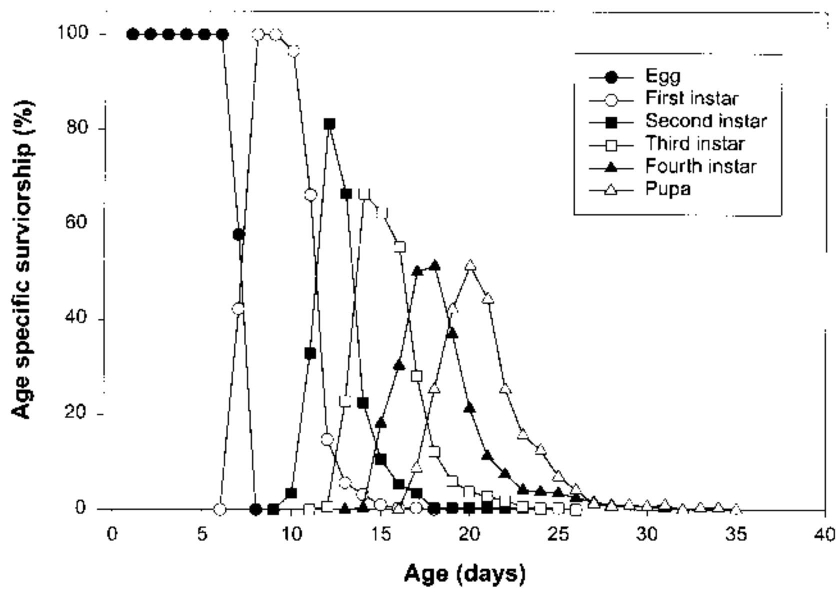


Fig. 2. Age-specific survivorship of *Bemisia argentifolii* immatures on hibiscus ('Pink Versicolor' and 'Brilliant Red') in the laboratory.

Life table parameters for *B. argentifolii* on 'Pink Versicolor' were as follows (Table 3): sex ratio (female: male) 1:0.923, or 52% female (n = 1780), intrinsic rate of increase ($r$ = 0.105) and net reproductive rate ($R_0$ = 17.0). These latter two were lowest of any published values (Tsai and Wang 1996, van Giessen et al. 1995). On the other hand, generation time ($T$ = 27.0 d) and doubling time ($DT$ = 6.6 d) were higher than previously published values (Tsai and Wang 1996).

## Discussion

*Bemisia argentifolii* showed some preference in choice and even no-choice tests for oviposition and feeding on 'Pink Versicolor' compared to 'Brilliant Red', possibly due to the thicker and waxier leaf cuticle, and darker green leaf color typical of latter cultivar. If these characteristics were not tightly linked to flower color they might be transferred to cultivars with the desired light flower shades, thereby possibly reducing whitefly population growth rate.

Compared with other life table parameters of *B. argentifolii* reported from other host plants (Tsai and Wang 1996), *B. argentifolii* also had lower reproductive rate and finite rate of increase, longer generation times, and doubling time. Longevity of *B. argentifolii* on hibiscus (9.3 d) was <50% that on eggplant (24.0 d), and tomato (20.6 d), and also less than on sweet potato (16.6 d), garden bean (13.4 d), or even cucumber (9.9 d).

Small differences in $r$-values can make remarkable differences in expected population growth over time. For example, $r$-values on tomato reported by Tsai and Wang (1996) and van Giessen et al. (1995) were 0.153 and 0.122, respectively. Given a stable age distribution, the estimated whitefly population with $r$ = 0.153 from a single female would reach 3873 in a period of 2 generations (54 d), while with $r$ = 0.122, number of whiteflies would only be 726, a 5.3-fold difference.

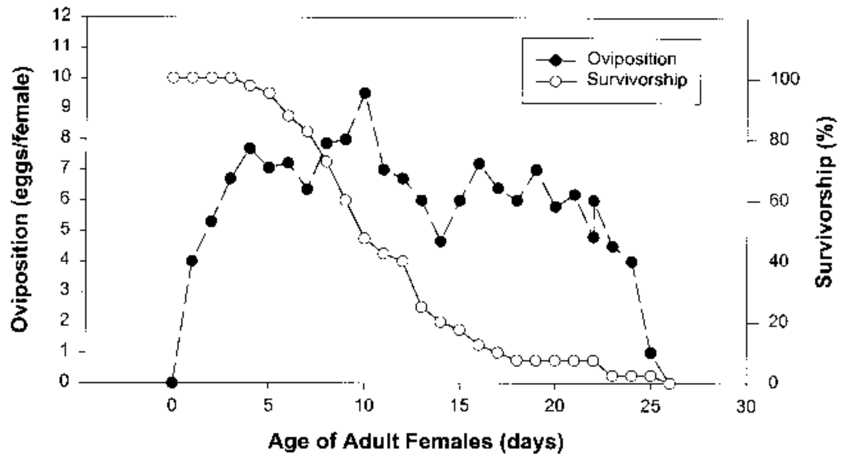


Fig. 3. Survivorship (%) and oviposition of *Bemisia argentifolii* adult females on hibiscus ('Pink Versicolor') in the laboratory.

Performance of *B. argentifolii* on 'Brilliant Red' as indicated by several life history parameters was not as good as that on 'Pink Versicolor'. These parameters on 'Pink Versicolor' were approximately 11% greater than those on 'Brilliant Red', including: (1) oviposition rate per female (9.2 verses 8.4), developmental rate (24 d verses 22 d), and (3) survivorship (91.5% verses 89.8%). Therefore, the *r*-value of *B. argentifolii* on 'Brilliant Red' was simulated based on a series of $l_x m_x$ from the whitefly data on 'Pink Versicolor' with a factor of 11% reduction. To compare the population growths of *B. argentifolii* on the 2 cultivars over time, the number of *B. argentifolii* at time $t$ ($N_t$) could be calculated as $N_t = N_o e^{rt}$, where $N_o$ is the initial number of whiteflies, $r$ is the intrinsic rate of increase, and $t$ is the time (d). With a logical and biologically sound assumption of $r = 0.090$ for *B. argentifolii* on 'Brilliant Red', the whitefly population growth on 'Pink Versicolor' from a single female would be 2.25 folds as many as that on 'Brilliant Red' (290 verses 129) in 54 d, or in ≈2 generations.

Given these life history parameters whitefly populations should build up relatively slowly on hibiscus compared to other hosts, and therefore should be easier to manage to whatever population level. Unfortunately, the level of control required in the ornamental market is extremely high. Nevertheless, there could be opportunities early in the crop cycle to utilize biological control and other non-chemical management tactics, given the relatively poor host quality of hibiscus for *B. argentifolii*. In addition, host quality might be further decreased by incorporating foliage characteristics typical of cultivars such as 'Brilliant Red'.


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TABLE 3. COMPARISON OF LIFE TABLE PARAMETERS OF *B. ARGENTIFOLII* ON SEVERAL HOST PLANTS.

| Host plants | Intrinsic rate of increase, *r* | Net reproductive rate, $R_o$ | Generation time, *T* | Doubling time, *DT* | Reference |
|---|---|---|---|---|---|
| Hibiscus | 0.105 | 17.0 | 27.0 | 6.6 | This study |
| Eggplant | 0.192 | 128.2 | 25.6 | 3.6 | Tsai & Wang 1996 |
| Tomato | 0.153 | 64.3 | 27.2 | 4.5 | " " " " " " " " " " " " " |
| Sweet potato | 0.138 | 34.6 | 26.3 | 5.1 | " " " " " " " " " " " " " |
| Cucumber | 0.131 | 19.8 | 23.2 | 5.4 | " " " " " " " " " " " " " |
| Garden bean | 0.120 | 24.7 | 27.0 | 5.8 | " " " " " " " " " " " " " |
| Tomato | 0.122 | — | — | — | Van Giessen et al. |
| Collard | 0.138 | — | — | — | 1995 |
| Eggplant | 0.145 | — | — | — | " " " " " " " " " " " " " |

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