Overwintering and Cold Tolerance of *Bemisia argentifolii* (Homoptera: Aleyrodidae) in Coastal South Carolina[1]

Alvin M. Simmons and Kent D. Elsey

USDA-ARS, U. S. Vegetable Laboratory, 2875 Savannah Highway, Charleston, SC 29414 U.S.A.

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ABSTRACT Populations of *Bemisia argentifolii* Bellows and Perring in the Charleston, SC area declined sharply during December and remained low through March and April in a two-year study (1991-92). Populations of this whitefly increased slowly during spring with highest populations on collard (*Brassica*) and potato. Infestations of *B. argentifolii* were present in 13 of 14 greenhouses at 10 commercial nurseries that were monitored. Eggs were more cold-tolerant than adults and nymphs, respectively, at temperatures of -2°, - 6°, and -10°C.

KEY WORDS *Bemisia argentifolii, Bemisia tabaci,* sweetpotato whitefly, cold tolerance, overwintering

In the United States, *Bemisia argentifolii* Bellows and Perring, a whitefly, has become an important and often devastating pest of vegetables in Florida and in the irrigated Southwest deserts. This whitefly, also called silverleaf whitefly, is synonymous with strain B of the sweetpotato whitefly, *B. tabaci* (Gennadius) (Bellows et al. 1994).

Bemisia argentifolii has spread to greenhouses in the northern United States (Freeman 1988, Stimmel and Wheeler 1988) and may be a potential pest of field horticultural crops in these areas (Broadbent et al. 1989). However, little is known of the cold tolerance of *B. argentifolii* and its overwintering dynamics in areas of the United States where freezing temperatures regularly occur during the winter. Information is needed on the winter survivability of *B. argentifolii* adults, nymphs, and eggs to help assess the risk of *B. argentifolii* attacking spring vegetables, and to provide an estimate of the time during the growing season when severe outbreaks may be expected.

Several thousand hectares of spring and fall vegetables are grown near Charleston, SC, which has a climate with hot, humid summers and mild winters. Frost and occasionally freezing temperatures may occur from mid-December to late February. Research was conducted to assess population trends of *B. argentifolii* during winter, and to examine its ability to survive the winter and establish populations in the spring in the Charleston, SC area.

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Materials and Methods

Trapping and Field Populations. In 1990-1991, adjacent plantings (10 September) of collard ('Vates'), canola ('Delta'), and mustard ('Curly Leaf') were arranged into two 12-row by 38-m blocks at the U. S. Vegetable Laboratory farm in Charleston, SC. A 16-cm^2 yellow sticky trap (Olson Products, Inc.) was placed on the center row of each block, in the horizontal plane, 15 cm above the ground on a clay pot. Two sticky traps also were placed in a 7-row planting of tomato (53 m long) and a 9-row planting of turnips (49 m long). Traps were examined for *B. argentifolii* daily, except weekends and national holidays, from 25 October 1990 to 14 April 1991. Fresh traps were used after each sampling. Additionally, 25 leaves were collected weekly from each crop, and the presence or absence of nymphs and eggs was recorded.

A sticky trap also was placed in each of three patches (approximately 10 m^2 - 100 m^2) of naturally-occurring wild radish, *Raphanus* sp., a possible winter host of *B. argentifolii,* which is common in the Charleston area from October through May. Wild radish is attractive for oviposition by *B. argentifolii* and the nymphal developmental time on wild radish is as short as on collard, a preferred host (Elsey, unpublished). Traps were examined and replaced, as noted above, from 12 December 1990 to 2 May 1991, and 10 leaves from the mid-to-low stratum were examined weekly for the presence or absence of eggs and nymphs.

In 1991 and 1992, populations of *B. argentifolii* were monitored on two additional plantings of collard from August through March. In one planting, 'Vates' collard seedlings were transplanted 13 August to two 8-row by 15-m long plots. A sticky trap was placed in each plot and the number of adult whiteflies was recorded three times each week. Whiteflies also were recorded weekly on three plants per plot for a total of 48 plants. A plant was randomly sampled from each plot by taking one leaf from the upper third and one from the lower third of the plant, and the total number of whitefly eggs and nymphs was determined by direct count. Adult populations were estimated from 28 August until 11 March. Numbers of eggs and nymphs were recorded from 15 September to 11 March, and the sticky traps were operated from 3 September to 13 April.

A second planting (28 August) of collard was made at the Clemson University Coastal Research and Education Center, located about 2 km from the first planting, and consisted of 7 rows, each 106 m long. Four sticky traps were evenly spaced along the length of the field and the number of adults captured was recorded as noted above. Numbers of adults, nymphs, and eggs were determined as in the first planting from 11 October to 18 March.

A sticky trap was placed in each of three wild radish patches at the U. S. Vegetable Laboratory and four wild radish plots at the Coastal Research and Education Center, from 6 December until 1 June. Ten leaves per plot were examined, as above, weekly for eggs and nymphs from 31 January until 20 May.

Populations in Spring Vegetables. Seven vegetable crops were transplanted or seeded into plots, each consisting of four 10-m rows, on 19 and 20 February 1991 and 10 March 1992. Plots were replicated four times in a randomized block design. In 1991, the crops included transplanted 'Vates' collard and 'Great Lakes' lettuce, and direct-seeded 'Hybrid 7' spinach, "Purple Top' turnip, and 'Kennebec' potato planted with tuber pieces. In 1992, the plot design was similar except that plots of transplanted 'Floradade' tomato and 'Curly Leaf' mustard were added. Number of adult *B. argentifolii* was determined weekly on five random selected plants per plot from 24 April to 23 May in 1991, and on five random sample units of 0.25 linear m of row from 15 April to 23 May 1992 by direct observation of whole plants. Three leaves on each of five randomly selected plants per plot were checked weekly for eggs and nymphs during May 1991. In 1992, one lower leaf was collected from 5 randomly selected plants and the numbers of eggs and nymphs were determined. Total numbers of adults and nymphs for the duration of the experiments were subjected to a two-way analysis of variance and Fisher's LSD at $P < 0.05$ to separate means.

Nursery Greenhouse Survey. Whitefly, *B. argentifolii,* infestations were monitored in 14 greenhouses at 10 commercial nurseries in Berkeley, Charleston, and Dorchester counties, and one at the Coastal Plain Experiment Station in Charleston County during the winter and spring of 1991. The greenhouses contained several species of annual and perennial ornamentals and some vegetables. Two to four 16-cm^2 yellow sticky traps were placed vertically above benches and plant beds, replaced weekly, and taken to the laboratory to determine the number of adult whiteflies captured. Monitoring extended from 18 January to 3 May.

Cold Tolerance Determination. Cold tolerance of *B. argentifolii* was evaluated by exposing eggs, nymphs, and adults at -10°, -7.5°, and -5°C in a refrigerated water bath containing 50% water and 50% ethylene glycol for varying durations. Whiteflies were obtained from a culture maintained in the greenhouse and reared on mixed plantings of canola, collard, tomato, eggplant, and squash. Adult whiteflies (50-60) were placed in each of five snap-tight dishes (60 × 10 mm) with a film of stopcock grease applied to the lid's edge. A disk of black blotting paper in each dish increased whitefly visibility. Dishes with whiteflies were placed in a wire rack and submerged in the water bath at the desired temperature for the various exposure periods. Upon removal from the bath, the blotting paper was moistened and the whiteflies were held for 24 h at 25°C. Adults not moving after 24 h were considered dead. To assess the cold tolerance of eggs and nymphs, flats of collard seedlings were exposed in a whitefly-infested greenhouse for 24 h. Leaflets with eggs and nymphs were held in the cold bath as described for adults, and were then incubated at 25°C until hatching or adult eclosion was completed. Mortality was calculated from eggs or nymphs not advancing to the next stage as compared with untreated insects held at 25°C. Data were subjected to probit analysis by the POLO-PC program (Russell et al. 1977).

Results and Discussion

The pattern of adult *B. argentifolii* populations was similar in the 1991 and 1992 winter seasons. Moderate populations during the fall declined rapidly based on sticky trap catch and direct observation on plants during November and December (Fig. 1). By January, the number of adults was low and continued to be barely perceptible until April or May. Egg and nymphal populations were low on collard, mustard, canola, and turnip during the autumn of 1990

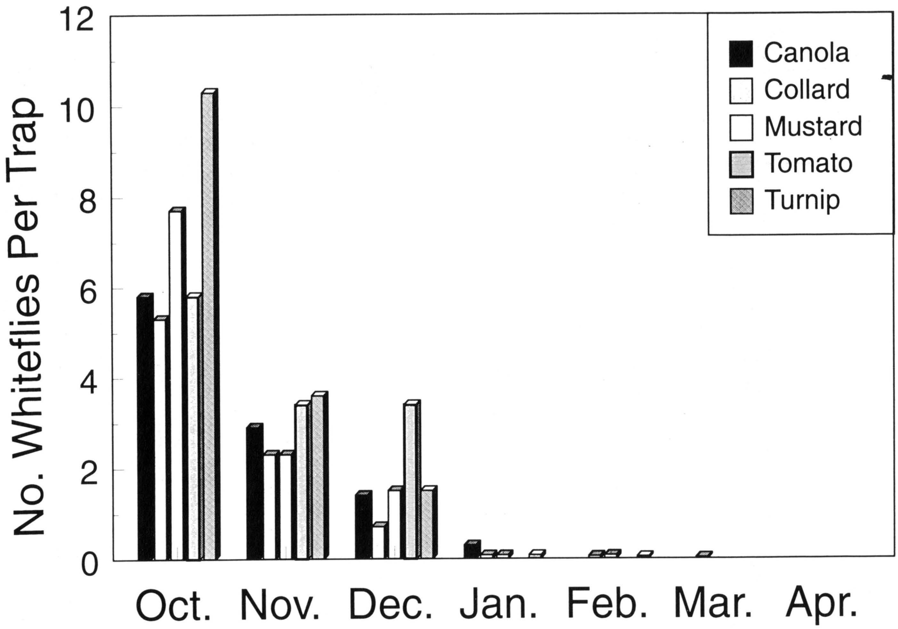

Fig. 1. Mean number of adult *B. argentifolii* captured per month on yellow sticky traps in plots of assorted vegetables during autumn, winter, and spring of 1990-1991; tomato was only sampled through January.

and declined steadily until none was found mid-January through March 1991. In 1991-1992, nymphal and egg populations declined on collard plantings (Fig. 2), even though the plants remained succulent until spring. Winter temperature for both years was mild with positive departures from the historical average (Table 1).

In wild radish, low numbers of *B. argentifolii* adults were captured. In January 1991, only 0.09 adult was caught per trap, but none was trapped in February, March, or April. In 1992, no *B. argentifolii* were trapped in January through March, but 0.17 per trap was caught in April and 0.4 per trap in May. Densities of immature whiteflies were very low on wild radish during both winters. Eggs were found in January 1991, but none thereafter. No eggs or nymphs were found on wild radish leaf samples between January and June in 1992.

Other studies have shown a decrease in whitefly populations during cooler months. Coudriet et al. (1985) found a decline in egg and nymph populations on lettuce in the Imperial Valley, CA from late-October to early-January. Ohnesorge et al. (1981) found a sharp decrease in abundance of immature *B. tabaci* on tomato during winter in the Jordan River Valley and suggested the decline may

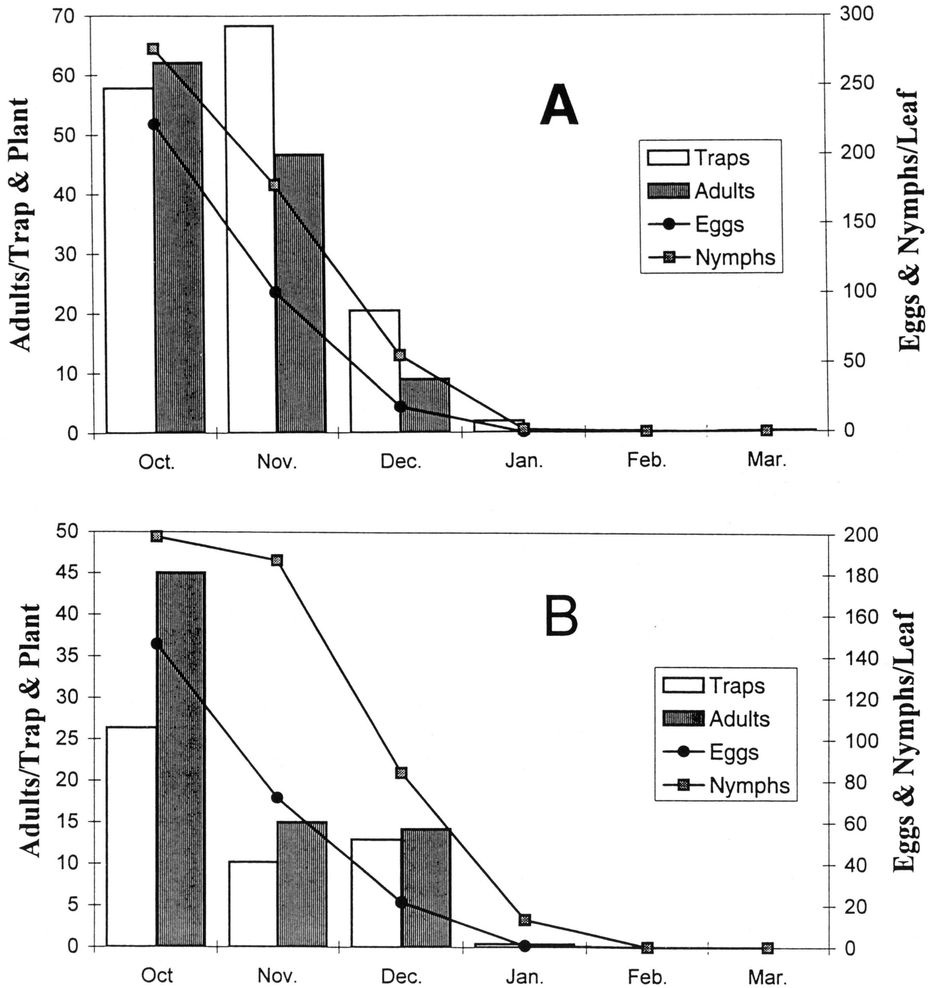

Fig. 2. Density of different stages of *B. argentifolii* on two field plantings of collard during autumn and winter of 1991-1992. (Traps = adults on traps; Adults = adults on plant); A = Coastal Research and Education Center and B = U. S. Vegetable Laboratory site.

be from a dilution effect of more vegetation available during the winter months and decline in oviposition with cooler temperature. Gerling (1984) observed a decline of *B. tabaci* numbers on wild and cultivated plants in late winter and spring in Israel. In the Yuma Valley, Watson et al. (1992) found that numbers of adults and immature *B. tabaci* decreased sharply on broccoli, cauliflower, and lettuce as the temperature dropped during the winter. In general, winter temperatures at those locations were slightly warmer than in Charleston.

Table 1. Temperature data (°C) for November 1990 to March 1992, Charleston, South Carolina.

Month	Year	Mean	Low	Departure from historical mean
November	1990	15.8	1.7	+ 2.0
	1991	13.3	-0.5	+ 0.4
December	1990	13.6	-0.5	+3.5
	1991	12.4	-2.2	+2.4
January	1991	10.4	-1.7	+1.6
	1992	9.7	-3.9	+0.9
February	1991	12.7	-7.2	+2.8
	1992	12.8	0.5	+2.9
March	1991	16.9	1.7	+3.2
	1992	14.4	1.1	+0.7

Densities of *B. argentifolii* adults in spring vegetable crops were low in April of 1991 and 1992, but increased during May (Fig 3). In 1991, significantly ($P < 0.05$) more adult whiteflies were found on collard and potato than on the other three crops (Fig. 3). Again in 1992, more whiteflies were observed on collard and potato than on any of five other crops; numbers were intermediate for tomato (Fig. 3). Gerling (1984) also found that potato was a favorable crop for population increases of *B. tabaci* during the spring in Israel.

Populations of *B. argentifolii* were found in all but one of the commercial and research greenhouses (Table 2). Densities were consistently high only at the research greenhouse, perhaps because it had more favorable hosts as compared with the other greenhouses. Much of the greenhouse space in the commercial nurseries was used for ornamental plants, such as shrubs, that were not conducive to whitefly buildup. During warm spring weather, most of the nurseries opened greenhouse doors and vents, enabling whitefly populations to disperse. Sale and movement of plants from these greenhouses may be one of the ways of augmenting field populations during early spring.

Exposure of *B. argentifolii* stages to subfreezing temperatures indicated that short periods of exposure in the 0° to -6°C range had little effect (Table 3). As the temperature approached -10°C, the duration of time required to cause significant mortality shortened dramatically. The egg stage was the most tolerant at all temperatures tested, especially at -2 and -6°C. Large nymphs appeared to be the least tolerant stage to exposures of -2 and -6°C. Low temperature impeded eclosion. In many cases, nymphal development continued after removal from the cold bath, but teneral adults were either not able to fracture the integument or succeeded only in partial emergence.

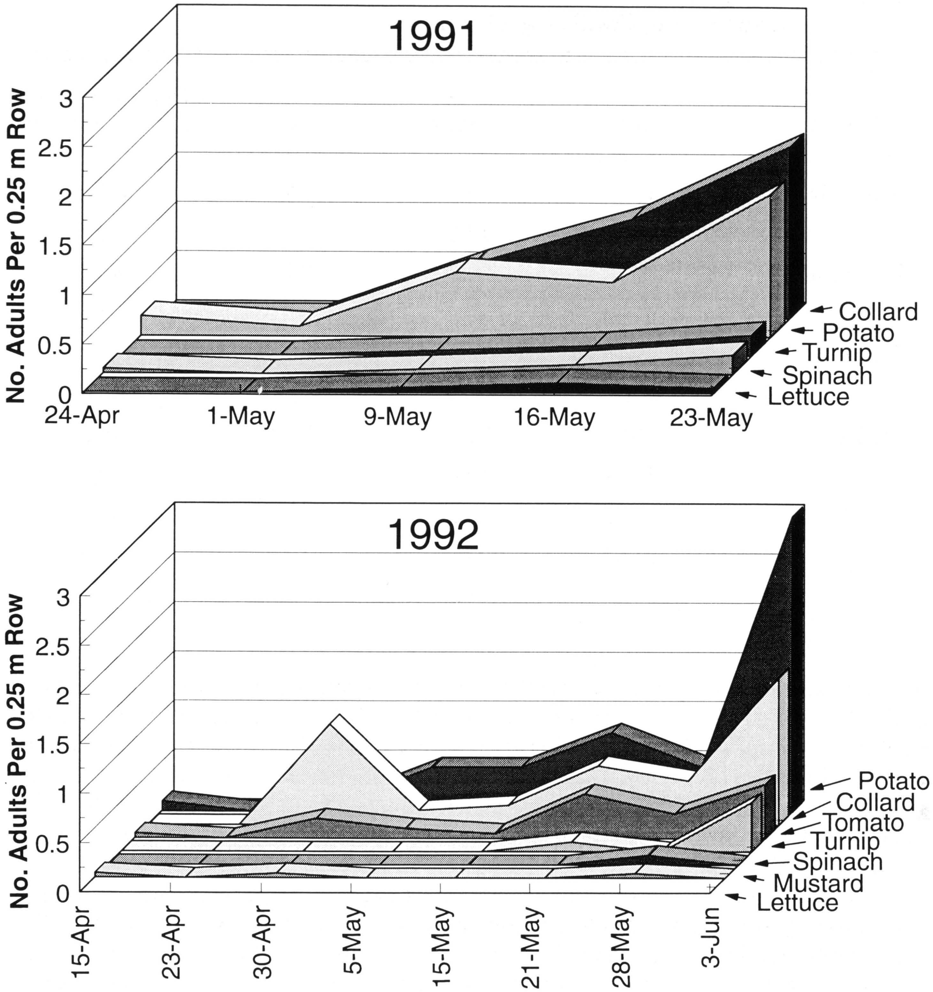

Fig. 3. Density of *B. argentifolii* adults per 0.25 m of row on assorted spring field vegetables in 1991 and 1992.

Table 2. Infestation of *B. argentifolii* at greenhouses near Charleston, SC from 18 January to 3 May 1991.

Location* (county)	No of houses	No of traps	% Sample Dates with adults	Range of mean no. adults/trap
Berkeley	1	2	23	0-163
	2	2	23	0-19
	3	2	50	0-22
Charleston	1	2	93	0-91
	2	1	69	0-97
Charleston	1	3	100	15-153
	2	2	79	0-141
Charleston	1	3	71	0-330
	2	2	57	0-20
Charleston	1	2	92	0-24
Charleston	1	4	86	0-13
Charleston	1	2	71	0-11
Dorchester	1	2	79	0-80
Dorchester	1	1	0	0-0
Charleston**	1	2	100	11-700

* Each listed location represents an individual nursery.
** Greenhouse at Coastal Research and Education Center; others are commercial greenhouses.

Table 3. Lethality of exposure to low temperature on *B. argentifolii* eggs, nymphs, and adults.

Stage	Temp °C	LT_{50} (FL)*	LT_{90} (FL)*	Slope (SEM)
Egg	- 2	4608.0 (4467.6 - 4728.0)	5838.0 (5676.0 - 6041.4)	12.42 (0.86)
	- 6	1419.0 (698.6 - 1843.8)	2377.8 (1830.0 - 5138.4)	5.72 (0.43)
	-10	29.9 (9.5 - 47.2)	106.1 (67.8 - 309.7)	2.33 (0.14)
Nymph	- 2	1174.2 (318.6 - 1897.8)	3448.2 (2117.4 - 1695.6)	2.74 (0.16)
	- 6	66.1 (19.6 - 100.7)	227.0 (154.2 - 582.0)	2.39 (0.24)
	-10	23.9 (20.2 - 27.3)	55.2 (47.1 - 69.3)	3.52 (0.25)
Adult	- 2	2604.5 (2172.0 - 2970.0)	3972.0 (3402.0 - 5694.0)	7.02 (0.44)
	- 6	129.4 (117.8 - 137.9)	162.2 (151.4 - 182.7)	13.05 (1.08)
	-10	15.1 (9.6 - 21.0)	56.5 (37.1 - 137.7)	2.24 (0.14)

* Time is in minutes; Limits expressed at the 95% level (except -10°C for egg and -6°C for nymph which are at the 90% level.

Winters were mild during this study, with the coldest period consisting of several hours in the -7° to -5°C range on 16 February. Based on results of the subfreezing test (Table 3), such conditions should result in little mortality. Thus, other factors, such as reduced oviposition at low temperature (as suggested by Ohnesorge et al. 1981), reduced development (low threshold for egg and nymph is about 13°C, Enkegaard 1993), and prolonged exposure to low temperature may be responsible for reduced winter populations. Indeed, insect mortality or population growth may balance on the effect temperature has on a specific life stage or event, such as molting or oviposition (Whitman 1986). Temperatures lower than those tested in the laboratory occur in Charleston. Occasionally, temperatures as low as -12°C are attained. Even with favorable host plants and mild temperatures, *B. argentifolii* winter populations decline. Migration from nursery greenhouses and transplanting infested seedlings are probably important sources of *B. argentifolii* on spring crops in coastal South Carolina. Also, weed species may serve as an important reservoir of spring infestation. It is not known if *B. argentifolii* can enhance its tolerance to low temperature by cold-hardening. Further studies are required to track cold tolerance of this species through time, and to identify additional factors that enhance its survivorship in cold climates.

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