Response of *Trialeurodes abutiloneus* (Homoptera: Aleyrodidae) to Sweet Potato and Two Species of *Hibiscus*

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ABSTRACT Life history, survivorship, and adaptation of the bandedwinged whitefly, *Trialeurodes abutiloneus* (Haldeman), on sweet potato, *Ipomoea batatas* (L.) Lam, and two species of *Hibiscus* were studied in laboratory and screen houses. *T. abutiloneus* deposited significantly more eggs on cotton rose, *Hibiscus mutabilis* L. (10.3–11.3 eggs per female), and roselle, *Hibiscus sabdariffa* L. (10.1–11.8 eggs per female), than on sweet potato (6.1–7.3 eggs per female) in a choice test when the whiteflies were previously reared on cotton rose and roselle. Whereas, whiteflies originally reared on sweet potato deposited more eggs on sweet potato (10.4) than on cotton rose (7.3) and roselle (6.1). However, differences in oviposition among these three host plants were not significant in a no-choice test, regardless of their original host plants. Overall developmental times of *T. abutiloneus* were significantly longer on sweet potato (22.3–23.2 d) than on cotton rose (17.0–17.8 d) and roselle (17.1–17.4 d) independent of their original host plants. Survival rate of *T. abutiloneus* was only 12.3–21.4% on sweet potato compared with 71.5–87.2% on cotton rose and 77.7–90.3% on roselle. Linear regression analysis of the survival rates of all nymphal stages of *T. abutiloneus* on sweet potato after seven consecutive generations indicated that the survival rates increased (r^2 = 0.7419–0.8483), albeit the rates were slow. Thus, sweet potato proved to be a relatively poor host plant as well as a relatively nonpreferred one for *T. abutiloneus* compared with cotton rose and roselle.

KEY WORDS bandedwinged whitefly, *Hibiscus*, host plant adaptation, biology, life history

The bandedwinged whitefly, *Trialeurodes abutiloneus* (Haldeman), has been reported as an occasional pest of field crops and ornamental plants in the southern United States, especially of the family Malvaceae (Butler 1967, Clower et al. 1971, Clower and Watve 1973, Watve and Clower 1976, Johnson et al.1982). *T. abutiloneus* also acts as a vector of some clostroviruses such as tomato chlorosis virus (ToCV) (Wisler et al. 1998). Originally described from velvetleaf, *Abutilon theophrasti* Medic. = *Sida abutilon* L., *T. abutiloneus* now is considered a polyphagous feeder with ≈140 species of host plants, including many species in the genus *Hibiscus* (Russell 1948, 1963). Sweet potato, *Ipomoea batatas* (L.) Lam, is also recorded as a host plant of *T. abutiloneus* (Russell 1963, Mound and Halsey 1978). Other than a study by Butler (1967) of the development on cotton at different constant temperatures, little has been reported on the biology of *T. abutiloneus*, especially on noncotton hosts.

Sweet potato has proved to be a convenient host for study of *Bemisia argentifolii* Bellows & Perring and its parasitoids because leaves can be propagated individually in horticultural rooting cubes (Liu and Stansly 1995, 1996). However, we observed high levels of mortality in preliminary efforts to use the technique with *T. abutiloneus.* To determine the causes of high mortality, we had two objectives for this study: (1) to evaluate the preference of *T. abutiloneus* among two hibiscus hosts and sweet potato on oviposition, development, and mortality, and (2) to determine whether the whitefly could adapt to sweet potato, a nonpreferred host.

Materials and Methods

Whiteflies and Host Plants. Bandedwinged whitefly was originally collected from cotton rose (also called Confederate rose), *Hibiscus mutabilis* L., in Hendry County, FL. Whiteflies were cultured on cotton rose and roselle, *Hibiscus sabdariffa* L., in screen houses for almost 2 yr. A third colony of *T. abutiloneus* was also maintained on sweet potato, *Ipomoea batatas* (L.) Lam, 'Carolina Bunch', in a greenhouse for 8–10 generations for >6 mo.

Experiments were conducted both in walk-in screen cages and the laboratory. Screen cages (2 by 2 by 2 m) were enclosed with 52-mesh polyethylene screen (Lumite No. 5006204, Synthetic Industries, Gainesville, GA). The screen houses were maintained at 20–35°C, 70–95% RH, and a photoperiod of 14:10 (L:D) h during the period of study. Laboratory experiments were conducted in an air-conditioned insectary at 26.7 ± 2°C, 55 ± 5% RH, and photoperiod 14:10 (L:D) h. Voucher specimens of *T. abutiloneus* were deposited in the Insect Collection, Southwest Florida Research and Education Center, University of Florida, Immokalee and the Insect Collection, Texas

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Table 1. Oviposition (eggs/cm^2 ± SE) of *T. abutiloneus* on three different host plants for 48 h in no-choice and choice tests

Original host plant	No-choice test					Choice test				
	Cotton rose	Roselle	Sweet potato	F	P	Cotton rose	Roselle	Sweet potato	F	P
Cotton rose	10.9 ± 1.3aA	12.1 ± 2.1aA	10.3 ± 1.8aA	1.18	0.7215	11.3 ± 1.6aA	10.3 ± 2.2aA	6.5 ± 3.9bB	7.12	0.0015
Roselle	9.6 ± 1.2aA	12.8 ± 1.8aA	9.2 ± 1.0aA	1.71	0.5521	10.1 ± 0.7abA	11.8 ± 3.7aA	7.9 ± 1.8bB	6.43	0.0008
Sweet potato	9.1 ± 1.6aA	9.9 ± 3.2aA	10.7 ± 1.1aA	2.40	0.1427	7.3 ± 1.7bB	6.1 ± 1.9bB	10.4 ± 2.1aA	6.01	0.0108
F	1.24	1.68	2.12			8.64	14.04	7.89		
P	0.5876	0.1858	0.6724			0.0001	0.0001	0.0027		

Means in the same column with the same lower-case letters and in the same row with the same upper-case letters do not differ significantly at $P = 0.05$ (LSD, SAS Institute [1996]).

A&M University Agricultural Research and Extension Center at Weslaco, TX.

Oviposition. Choice and no-choice tests were conducted. Oviposition was evaluated on three species of host plants, cotton rose (variety unknown), roselle (variety unknown) and sweetpotato (Carolina Bunch) with whiteflies originally reared on each of the three host species.

In the no-choice test, 20 adult females with 10 males were confined in a leaf clip-on cage (4.2 by 2.5 by 2.5 cm, covering 15 cm^2) to the third fully expanded leaf from the terminal. Whiteflies were removed at 48 h and eggs deposited on the cage-covered area were counted under a stereomicroscope. There were nine treatments (three host plants × three original host plants) and each treatment had 10 cages (replications).

For the choice test, 10 whitefly-free plants of each of the three host species were placed in a walk-in screen cage. Cotton rose plants had 5–7 leaves and were 40–45 cm high, roselle had 20–25 leaves and about the same height as cotton rose, and sweet potato plants had 5–6 vines, each 20–50 cm long with 4–10 leaves each. All but the top three fully expanded leaves of cotton rose and roselle plants were removed. For sweet potato, three leaves from the fourth, fifth, and sixth nodes from the terminal were kept. Cotton rose and roselle plants were randomly placed on the ground and sweet potato plants were placed on cement blocks 40 cm high so that all plants were approximately at the same height. Each experiment had three treatments with ≈5,000 whitefly adults. The experiment had nine treatments and was repeated three times, each time with whiteflies previously reared on a different host plant of the three species tested. The leaves from each plant were collected 48 h after whitefly release, and number of whitefly eggs on 8 cm^2 leaf area (4 2 cm^2 leaf area from the two sides of the main vein of each leaf) was recorded using a stereomicroscope in the laboratory.

Development and Survivorship. Twenty adult *T. abutiloneus* were confined in a clip-on cage for 24 h to a leaf on one of the three host plants. There were nine treatments, three host plants × three original host plants. Each treatment had five leaves (clip-on cages). Adults were removed and 20 eggs were identified by an India ink mark on the leaf. Eggs were monitored daily for hatching, and subsequent stages for molting and mortality until adult emergence.

Adaptation to Sweet Potato. Sweet potato leaves at the fourth–seventh node from the top were detached from the vine and individually rooted in media cubes (Oasis, Smither-Oasis, Kent, OH) within cages made from 0.9-liter clear, plastic cups (Liu and Stansly 1995). The 9-cm top of each cup was covered with a 52-mesh polyethylene screen. An access hole (1.2 cm in diameter) on the side was plugged with a cork. Fifty whiteflies were collected from one of the three host plants and introduced into each cup-cage and removed after 24 h. Fifty eggs on each leaf were identified with an Indian ink mark on the leaf surface and monitored for hatching and subsequently for molting and mortality. Emerging adults were collected and reintroduced into cup-cages with a new sweet potato leaf. This procedure was repeated for six generations. Adult females from the sixth generation were given access for 24 h to cotton rose, roselle, or sweet potato (as controls) in leaf clip-on cage. Adults were removed and the subsequent (seventh) generation monitored as above.

Data Analysis. Numbers of eggs deposited, developmental times (d), and percentage survival rates were analyzed using analysis of variances, and means were separated using least significant difference (LSD) at $P = 0.05$ (SAS Institute 1996). Regression analyses were used to test the linear relationships between survival rate and generations of *T. abutiloneus* (PROC REG; SAS Institute 1996).

Results

Oviposition. In no-choice tests, no significant effects on number of eggs deposited were observed from either host of origin (F = 1.24–2.12; df = 2, 81; P = 0.1858–0.5876) or oviposition host (F = 1.18–2.40; df = 2, 81; P = 0.–1427-0.7215) (Table 1). In choice tests, *T. abutiloneus* females deposited more eggs on cotton rose and roselle than on sweet potato if the whiteflies were reared from cotton rose or roselle (F = 6.43–7.12; df = 2, 81; P = 0.0015–0.0008); whereas, whiteflies originally reared from sweet potato laid more eggs on sweet potato than on cotton rose and roselle (F = 6.01; df = 2, 81; P = 0.108). Similarly, *T. abutiloneus* females deposited more eggs on cotton rose and roselle than on sweet potato when they came from either cotton rose or roselle (F = 6.43–7.12; df = 2, 81; P = 0.0015–0.0008) except that whiteflies previously reared on sweet potato deposited more eggs on

Table 2. Developmental time of immature stages of *T. abutiloneus* on three different host plants with the adults that were originally reared on each of the three host plants

Host plant	Developmental time (days ± SE)						
	Eggs	First	Second	Third	Fourth	Pupa	Overall
				Previously reared on cotton rose			
Cotton rose	5.0 ± 0.0a	2.2 ± 0.1b	2.2 ± 0.4b	2.2 ± 1.2b	3.1 ± 0.5b	2.7 ± 0.2b	17.4 ± 0.6b
Roselle	4.8 ± 0.2a	2.3 ± 0.1b	2.1 ± 0.8b	2.2 ± 1.2b	3.1 ± 0.4b	2.7 ± 0.4b	17.2 ± 0.2b
Sweet potato	5.1 ± 0.1a	3.4 ± 0.8a	3.0 ± 0.2a	3.2 ± 1.2a	4.5 ± 0.8a	3.7 ± 0.8a	22.9 ± 1.1a
				Previously reared on roselle			
Cotton rose	5.0 ± 0.0a	2.3 ± 0.1b	2.2 ± 0.5b	2.3 ± 0.9b	3.2 ± 0.6b	2.7 ± 0.7b	17.7 ± 0.6b
Roselle	4.9 ± 0.1a	2.1 ± 0.1b	2.0 ± 0.5b	2.2 ± 1.0b	3.0 ± 0.9b	2.6 ± 0.6b	16.8 ± 0.2b
Sweet potato	5.0 ± 0.1a	3.2 ± 0.9a	3.1 ± 0.8a	3.1 ± 1.1a	4.6 ± 1.2a	3.5 ± 0.9a	22.5 ± 1.2a
				Previously reared on sweet potato			
Cotton rose	5.0 ± 0.1a	2.4 ± 0.1b	2.2 ± 0.4b	2.3 ± 0.9b	3.1 ± 0.5b	2.9 ± 0.2a	17.9 ± 1.8b
Roselle	5.0 ± 0.1a	2.1 ± 0.1b	2.1 ± 0.8b	2.3 ± 0.8b	3.2 ± 0.4b	2.8 ± 0.4a	17.5 ± 0.9b
Sweet potato	5.0 ± 0.1a	3.0 ± 0.8a	3.0 ± 0.2a	3.0 ± 1.0a	4.2 ± 2.1a	2.9 ± 0.8a	21.1 ± 2.0a

Means in the same subcolumn with the same letters do not differ significantly at $P = 0.05$ (LSD, SAS Institute [1996]).

sweet potato than on cotton rose and roselle ($F = 7.89$; df = 2, 81; $P = 0.0027$). These results indicated that *T. abutiloneus* females oviposited more eggs on the plants that they were previously reared on than the plants to which they were newly introduced.

Development and Survivorship. Eggs of *T. abutiloneus* developed at similar rates regardless of the host plants ($F = 0.89$–1.41; df = 2, 441; $P = 0.3745$–0.5988) (Table 2). Developmental times of all nymphal stages and pupae on sweet potato were significantly longer than on cotton rose and roselle ($F = 5.37$–10.15; df = 2, 441; $P = 0.01287$–0.0004) regardless of the host plants that they were previously reared from. Overall development duration of *T. abutiloneus* on sweet potato was >30% longer than on roselle or cotton rose. Although the nymphal stages and pupae developed slightly differently on the host plant that their parent adults fed on than on a different original host plant that their parent adults did not feed on, the overall developmental times for all immature stages did not differ significantly (Table 2).

All eggs hatched and survivorship of first instars was also high (96.9–99.8%) with no significant differences among treatments ($F = 1.89$; df = 2, 441; $P = 0.5427$) (Fig. 1). However, percentage survival rates on cotton rose and roselle were high (93.5–97.5%) compared with on sweet potato (76.9–80.2%). Similar results were observed for later instars and pupae. Overall survivorship from egg to adult on sweet potato was significantly lower (12.3–21.4%) than on the other two host plant species ($F = 34.31$–112.18; $P = 0.0001$). Original host plant had no significant effect on survivorship ($F = 0.91$; df = 2, 441; $P = 0.2487$).

Adaptation to Sweet Potato. Oviposition on sweet potato increased significantly ($r^2 = 0.64$, $P = 0.032$) over the seven generations from 4.9 to 7.6 eggs per female per day (Table 3). There was no significant change in development time for eggs, second or fourth instars over the seven generations, but first instars, third instars, and pupae developed significantly more rapidly with successive generations (Table 3).

Survivorship also increased for most stages and overall survivorship increased from 9.9% in the first generation to 24.0% in the sixth generation. The egg and third instar had no significant increases in survivorship over the seven generations (Fig. 2) with r^2-values ranging from 0.7419 to 0.8483. Nevertheless, relationships among the three host plants in terms of whitefly oviposition and development remained essentially the same after the seven-generation training on sweet potato (Table 4). The same could be said for

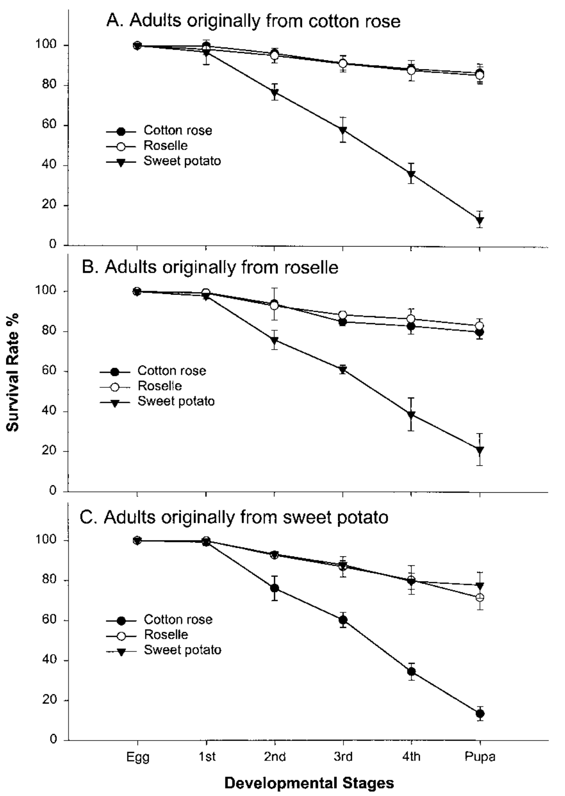

Fig. 1. Accumulated survival rates of all developmental stages of *T. abutiloneus* on three different host plant species after establishing on the three different host plants.

Table 3. Oviposition and development of *T. abutiloneus* on sweet potato, a nonpreferred host plant, for seven generations

Generation	Eggs/female, 24 h	Developmental time (days ± SE)						
		Eggs	First	Second	Third	Fourth	Pupa	Overall
1st	4.9 ± 0.4a	4.7 ± 0.2c	4.6 ± 0.5a	3.7 ± 0.4a	5.0 ± 0.8a	4.2 ± 0.5a	5.1 ± 0.3a	27.2 ± 1.1a
2nd	4.8 ± 0.5a	5.2 ± 0.1a	4.6 ± 0.3a	2.9 ± 0.1a	4.6 ± 0.6ab	4.4 ± 0.5a	4.3 ± 0.2b	25.9 ± 0.9ab
3rd	4.9 ± 0.4a	5.1 ± 0.0b	3.8 ± 0.3ab	2.8 ± 0.2a	2.8 ± 0.2c	4.1 ± 0.3a	3.5 ± 0.2b	22.0 ± 0.6c
4th	5.8 ± 0.5a	5.0 ± 0.0b	4.0 ± 0.2ab	3.1 ± 0.1a	3.4 ± 0.2bc	5.2 ± 0.4a	3.7 ± 0.1b	24.4 ± 0.6bc
5th	4.8 ± 0.6a	5.0 ± 0.0b	3.7 ± 0.2ab	2.9 ± 0.2a	3.0 ± 0.4c	4.0 ± 0.2a	3.6 ± 0.2b	22.1 ± 0.8c
6th	6.3 ± 0.7a	5.0 ± 0.0b	3.3 ± 0.1b	2.7 ± 0.1a	2.5 ± 0.1c	4.8 ± 0.3a	3.5 ± 0.3b	21.8 ± 0.5c
7th	7.6 ± 1.5a	5.0 ± 0.0b	3.6 ± 0.2a	3.0 ± 0.1a	3.2 ± 0.3a	4.8 ± 0.3a	3.6 ± 0.3a	23.2 ± 0.7a
Regression Parameters								
r^2	0.6366	0.0408	0.7855	0.3172	0.5954	0.1892	0.6008	0.5380
Intercept	4.0143	4.9430	0.4757	3.3571	4.8429	4.1429	4.7571	26.6714
Slope	0.3929	0.0143	−0.2036	−0.0857	−0.0336	0.0893	−0.2143	−0.7179
F	8.758	0.2130	18.315	2.323	7.358	1.116	7.525	5.822
P	0.0315	0.6641	0.0079	0.0188	0.0421	0.3294	0.0406	0.0606

Means in the same column followed by the same letters do not differ significantly at $P = 0.05$ (LSD, [SAS Institute 1996]).

survivorship on the three host plants after the adaptation period on sweet potato (Fig. 3). Therefore, although some adaptation could be documented, it was not enough to put sweet potato into the same category as the malvaceous hosts.

Discussion

Although considered a polyphagous species, *T. abutiloneus* prefers plants in the family Malvaceae as indicated by pest records as well as our results. However, we know little about what plant characteristics are responsible for whitefly preference or performance. Pubescence or trichome erectness has been cited as one factor determining whitefly preference (McAuslane et al. 1994, 1995; Chu et al. 1995; Heinz and Zalom 1995; Lambert et al. 1995, 1997). *T. abutiloneus* reportedly preferred pilose to glabrous cotton

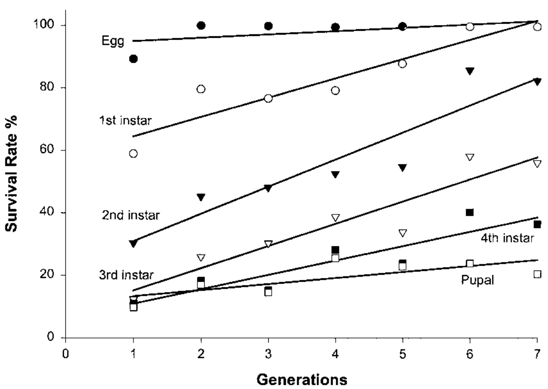

Fig. 2. Accumulated survival rates of all developmental stages of *T. abutiloneus* on sweet potato, a nonpreferred host plant, for seven generations. Regression analysis parameters: Egg, $r^2 = 0.4282$, intercept = 92.847, slope = 1.520, $P = 0.1585$; first instar, $r^2 = 0.8446$, intercept = 57.233, slope = 6.643, $P = 0.0096$; second instarm $r^2 = 0.8231$, intercept = 21.807, slope = 8.903, $P = 0.0125$; third instar, $r^2 = 0.8483$, intercept = 7.100, slope = 7.500, $P = 0.0091$; fourth instar, $r^2 = 0.8042$, intercept = 5.1733, slope = 5.060, $P = 0.0154$; pupal, $r^2 = 0.7419$, intercept = 9.000, slope = 2.8571, $P = 0.0275$.

cultivars (Butler and Muramoto 1967, Butler and Wilson 1984). Among the three host plant species, leaves of cotton rose have erect and dense trichomes, roselle leaves are quite glabrous, whereas sweet potato leaves are glabrous. Pubescence of these plant leaves may explain some of our observations on oviposition preference of *T. abutiloneus.*

Significant differences in development on different host plants (including sweet potato) in other whitefly species, such as *Bemisia tabaci* (Gennadius) and *B. argentifolii,* have been reported (i.e., Fransen 1990, Cohen et al. 1992, Tsai and Wang 1996), although mechanisms are not fully understood. Similar effects have been reported in *B. argentifolii* and *B. tabaci,* such as nitrogen content (Bentz et al. 1995), and pH (Berlinger et al. 1983). Additionally, the large leaves of cotton rose might provide better and more favorable micro-environmental conditions to the whiteflies, especially to the nymphal stages, than smaller and narrower leaves (Mound, 1962, Willmer 1986, Chu et al. 1995). In this study, we did note the occasional formation of a small tubercle (≈0.2–0.5 mm high with a diameter of 0.3–0.5 mm) at the site of stylet penetration on sweet potato leaves. Nymphs elevated on these tubercles died or developed extremely slowly compared with the nymphs feeding on unaffected sites. Perhaps tubercle formation signaled a hypersensitive response by the host plant that inhibited whitefly development.

Although *T. abutiloneus* is oligophagous compared with the polyphagous greenhouse whitefly, *Trialeurodes vaporariorum* (Westwood), its host-plant association between the whiteflies may be different (Byrne and Bellows 1991). van Lenteren and Noldus (1990) reviewed the preference and performance relationships between host-pant species and *T. vaporariorum* based on the studies of van Boxtel (1978, 1980), van de Morendonk and van Lenteren (1978), van Sas et al. (1978), Verschoor-van der Poel & Lenteren (1978), and Dorsman and van de Vire (1987). These studies indicate that the more a plant species is preferred, the greater the total number of eggs laid per female, the higher the oviposition rate, the higher the longevity of female, the shorter the developmental

Table 4. Oviposition and development of *T. abutiloneus* on preferred and nonpreferred host plants after having been reared on sweet potato leaves for 6 generations

Treatment	Eggs/female, 24 h	Developmental time (days ± SE)						
		Eggs	First	Second	Third	Fourth	Pupa	Overall
Sweet potato[a]	7.6 ± 1.5a	5.0 ± 0.0	3.6 ± 0.2a	3.0 ± 0.1a	3.2 ± 0.3a	4.8 ± 0.3a	3.6 ± 0.3a	23.2 ± 0.7a
Cotton rose	6.9 ± 0.7a	5.0 ± 0.0	2.4 ± 0.1b	2.0 ± 0.1b	2.1 ± 0.1b	3.1 ± 0.1b	2.5 ± 0.1b	17.2 ± 0.1b
Roselle	6.2 ± 0.6a	5.0 ± 0.0	2.2 ± 0.0c	1.9 ± 0.0b	2.1 ± 0.0b	3.3 ± 0.1b	2.4 ± 0.0b	16.9 ± 0.1b
F	1.52	—	7.29	4.70	7.74	9.23	12.21	16.53
P	0.2505	—	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

Means in the same column followed by the same letters do not differ significantly at $P = 0.05$ (LSD, [SAS Institute 1996]).
[a] Data also shown in Table 3 for comparison.

time from egg to adult, and the lower the mortality of individuals of all stages. Generally, polyphagous whiteflies performed better on their customary host plants compared with unaccustomed host plants. Some examples may indicate local selection for adaptation to relatively poor host plants. For instance, the whiteflies in Hungary developed best on Hungarian sweet pepper, which might reflect a long relationship between the whiteflies and the host plant. In contrast, the relatively newly invaded Dutch whiteflies did not perform well on indigenous cultivars. However, those whiteflies responded rapidly to selection and adaptation, displaying improved performance on sweet pepper within a few generations (van Boxtel 1980). In another study, van Boxtel et al. (1978) found that *T. vaporariorum* females originating from tomato plants have an advantage in oviposition and development over those from cucumber, and those from sweet pepper lived longer and laid more eggs than those from tomato and cucumber. Dorsman and van de Vire (1987) found that *T. vaporariorum* reared for a number of generations on gerbera, *Gerbera jamesonii* H. Bolus (variety unknown), developed faster and had lower mortality and greater longevity on gerbera than do whiteflies originally reared from tomato and reared for only one generation on gerbera. These results indicated that *T. vaporariorum* could improve their performance significantly in three generations on a host plant on which they were not originally reared.

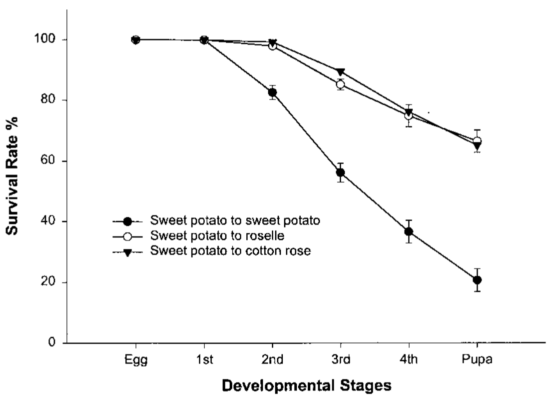

Fig. 3. Accumulated survival rates of all developmental stages of *T. abutiloneus* on three different host plant species after being reared on sweet potato for six generations.

Changes in reproductive capacity of *Bemisia tabaci* (Gennadius), another polyphagous species, after transfer between host plant species have been found (Gerling and Or, in van Lenteren and Noldus 1990). *B. tabaci* significantly increased its fecundity on cotton in three generations after it was transferred from lantana, *Lantana camara* L., suggesting that selection occurred for individuals that developed and reproduced well on cotton.

Although we were not able to produce so complete an alteration of preferences and performance of the less polyphagous *T. abutiloneus*, we could affect a significant change. We speculate that this species may have been originally restricted to Malvaceae but has since adapted to other hosts where malvaceous hosts have become rare. If so, the process is likely to continue and we could predict that the host range of *T. abutiloneus* will broaden with time.

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