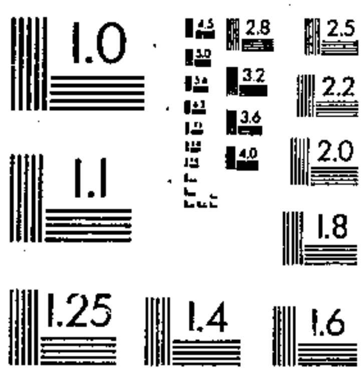
TB 1707 (1986) USDA TECHNICAL BULLETINS UPDATA
BEMISIA TABACI (GENNADIUS), A PEST OF COTTON IN THE SOUTHWESTERN UNITED
BUTLER, G D ET AL 1 OF 1

# START



United States Department of Agriculture

Agricultural Research Service

Technical Bulletin Number 1707

# *Bemisia tabaci* (Gennadius), a Pest of Cotton in the Southwestern United States

ABSTRACT

Butler, G.D., Jr., and T.J. Henneberry. 1985. *Bemisia tabaci* (Gennadius), a pest of cotton in the Southwestern United States. U.S. Department of Agriculture, Technical Bulletin No. 1707, 19 p.

The development rate of the sweetpotato whitefly (*Bemisia tabaci* (Gennadius)) was determined in the laboratory. The egg stage varied from 22.5 days at 16.7°C to 5.0 days at 32.5°. The period from egg laying to adult appearance varied from 65.1 days at 14.9° to 16.6 days at 30.0°. Thus this insect can maintain itself at a slow rate of development at relatively low temperatures and develop very rapidly at high summer temperatures. Peak emergence of adults at 26.7° occurred from 6 to 9 a.m.

Overwintering adults were observed on cheeseweed (*Malva parviflora* L.), prickly lettuce (*Lactuca serriola* L.), sowthistle (*Sonchus asper* (L.) J. Hill), and sunflower (*Helianthus annuus* L.). The Imperial Valley, Calif., had more overwintering adults on the plants examined than did Blythe, Calif., or Poston and Yuma, Ariz. By the end of March, these insects had left the weed hosts and had become established on squash, watermelons, and cantaloups.

At Poston, 700 *Bemisia* adults were collected in 5-1/2 hours on a single trap in a newly planted lettuce field on August 30, 1982. This illustrates how the insect disperses, mainly from cotton, into fall lettuce fields or other vegetable crops, and how it can pose a severe threat to seedlings if any of the adults are viruliferous.

Sticky traps were used to collect *Bemisia* adults in several agricultural areas. The number trapped increased 617-fold during the 100-day sampling period. Populations increased at a greater rate at Phoenix, Ariz., than at Yuma, Ariz., or Brawley, Calif.

Vacuum samples of adults showed that cotton fields near squash, cantaloup, or watermelon fields had much higher *Bemisia* populations than fields not near such alternate hosts. The average population in cotton doubled every 6 to 10 days during the summer. Cotton varieties with pubescent leaves had significantly more *Bemisia* adults than those with glabrous leaves.

KEYWORDS: *Bemisia*, biology, cotton, development rate, overwintering, population increase, Southwestern United States, sweetpotato whitefly, temperature.

CONTENTS



---




Copies of this publication may be purchased from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

ARS has no additional copies for free distribution.

Issued January 1986

# Bemisia tabaci (Gennadius), a Pest of Cotton in the Southwestern United States

By G. D. Butler, Jr., and T. J. Henneberry[1]

The sweetpotato whitefly (Bemisia tabaci (Gennadius)) has been reported as a serious pest of cultivated crops in Central America, the West Indies, South America, Africa, and Asia (Russell 1957). The insect was described from tobacco in Greece in 1889 and has since been reported from 315 host plants worldwide (Mound and Halsey 1978, Anonymous 1981), including 172 in Egypt (Azab et al. 1970), 52 in Israel (Avidov and Harpaz 1969), 115 in the Sudan (Gameel 1972), and 87 in Taiwan (Ghong 1969). Additional hosts have been reported in the United States (Coudriet et al. 1984, pers. commun.).

The large number of cultivated and weed hosts of B. tabaci should be considered as well as abiotic and biotic factors in understanding the seasonal distribution and population dynamics of the insect. In early studies, Husain and Trehan (1933) and Husain et al. (1936) reported from India that the first brood of B. tabaci emerges in mid-January from such weeds as Convolvulus arvensis, Euphorbia spp., and cultivated Brassica spp. The insects subsequently spread to Hibiscus spp., cucurbits, and cotton by early April. Peak populations in cotton occur in July and August, declining through September and October. At the end of the cotton season, B. tabaci adults return to Brassica spp., Solanum spp., and various weed species. Eggs and nymphs remain on alternate hosts through the winter, but numbers of adults decline. Johnson et al. (1982) reported similar host sequences in southern California, as did Melamed-Madjar et al. (1979) in Israel and Nachapong and Mabbit (1978) and Mabbit (1978) in Thailand.

[1]Respectively, research entomologist and Director, Western Cotton Research Laboratory, Agricultural Research Service, U.S. Department of Agriculture, 4135 East Broadway Road, Phoenix, AZ 85040.

Thus short-distance movement within and between cultivated crops, weed host plants, or both is well documented, and designing management systems to suppress the insect is difficult. The development of control strategies is further complicated by the fact that long-range dispersal of B. tabaci adults has also been documented by aircraft-mounted net collections at great heights. Moreover, the density of the airborne insects may increase severalfold to reach economic levels during redistribution as a result of the concentrating effect of vertical convection currents and horizontal air movement associated with weather fronts (Joyce 1983).

Husain and Trehan (1933), Mound (1963), Habib and Farag (1970), Azab et al. (1971), and Gameel (1972) described the morphological characters of the various stages of B. tabaci, and Mound and Halsey (1978) reviewed the whiteflies of the world. Husain and Trehan (1933) in India, Avidov (1956) in Israel, Azab et al. (1971) and El-Helaly et al. (1971) in Egypt, and Gameel (1974, 1978) in the Sudan reported on several aspects of the biology of B. tabaci. A brief summary of their findings regarding the biology of the species follows.

## BIOLOGY

The biology of B. tabaci has been studied by several workers. These insects emerge from pupae through a T-shaped break in the dorsal pupal wall mostly during the day. Adults begin feeding immediately after emergence and mate within 1 to 2 days. Unfertilized females are parthenogenetic producing male progeny (arrhenotokous reproduction). The preoviposition period may vary from 1 to 22 days under insectary and field conditions depending on the temperature. At 24.5° to 28°C, the average preoviposition period is 1.6 days. The eggs are laid singly on the underside or top of the leaf if populations are high (Ohnesorge et al. 1981). The incubation period varies from 3 to 33 days depending on the temperature and the host. For example, on sweet-potatoes at controlled temperatures of 22.3°, 28.0°, and 31°, the incubation periods are 10.7, 7.1, and 5.9 days, respectively. Development of the first, second, and third larval stages and the pupal stage is completed in 3, 2, 1.9, and 4.7 days at 31° and in 4.5, 2.7, 2.6, and 6.2 days at 25.4°. Some adults live only 1 to 2 days; however, in general, longevity of males ranges from 2 to 34 and females 8 to 60 days depending on the temperature. Development is variable according to the host (Coudriet et al., pers. commun.).

Gameel (1978) reported that eggs on cotton hatched in 20.5 and 5.2 days, respectively, at 15° and 40°C. The egg hatch was reduced 62 percent at 15° and 59 percent at 40°, but it ranged from 92 to 98 percent at 25° to 35°. In the field, the first, second, third, and fourth larval instars developed in 2-4, 4-8, 4-8, and 4-8 days, respectively. Adult males were shorter lived (13.0 days) than females (61.5 days) on cotton from September to December in the Sudan.

POPULATION INCREASE AND CONTROL MEASURES

*Bemisia tabaci* populations are characterized by a rapid increase and intercrop movement in multicrop agricultural systems. Rapid population buildup occurs in spite of high natural mortality during the crawler stage and first larval instar (Horowitz et al. 1982). Butler et al. (1985) found that populations doubled every 6 to 10 days during the summer in California and Arizona cotton fields.

Rates of increase from Gerling (1967) at Indio, Calif., during 1964 indicated *b* values in a regression equation of 0.146 and 0.129 for *B. tabaci* population increases in treated and untreated cotton fields, respectively, and 0.073 in 1965 in untreated fields, starting with low populations in both years. Gerling et al. (1980) at Kefar Aza, Israel, in 1977, reported a population increase of *b* = 0.087. Also in Israel, adults increased at a rate of 0.077 in untreated cotton and 0.075 in cotton adjacent to sunflower (Melamed-Madjar et al. 1979, 1982).

The distribution of *B. tabaci* within the plant canopy on the underside of leaves, as well as its high reproductive potential, contributes to the difficulty in controlling the insect with conventional spray application methods. Mabbit et al. (1980) found *B. tabaci* adults distributed on cotton plant leaves in all stages of development, with no marked zone of infestation. Most of the insects, however, were on expanded leaves 3 to 10 (top to bottom) of the main stem of the plant. In some areas of the world, promising results have been obtained with systemic insecticides (Dahiya and Singh 1982, Melamed-Madjar et al. 1984). Chemical control was reviewed and evaluated by Sharaf (1984). Total reliance on it must be considered a temporary solution until more is learned about the biology, ecology, and population dynamics of the species.

Gerling et al. (1980) reported from Israel that *B. tabaci* populations in cotton planted in May began to increase in July, with peak populations occurring in September and decreasing thereafter. Only two parasite species were found. *Encarsia lutea* (Masi) reached peak populations in early September and *Eretmocerus mundus* Mercet approximately 1 week later. Highest *B. tabaci* populations until mid-July were on the sixth or seventh leaf, but became variable thereafter.

The role of natural enemies in regulating *B. tabaci* populations is unknown. However, worldwide outbreaks have appeared to intensify with the use of synthetic organic insecticides (Anonymous 1981) and suggest that natural enemies have an outstanding role in limiting population development. A recent review of published natural enemy records shows that all reported parasites, except two, are Aphelinidae in the genera *Eretmocerus*, *Encarsia*, *Prospaltella*, and *Pteroptrix* (Anonymous 1981). Chrysopid, coccinellid, and several phytoseiid mite species are reported predators, and a single fungal pathogen is known. The report indicates that assessment of parasite activity is complex and is highly variable depending on the plant substrate. Most natural enemy records pertain to cotton, and information is scarce on other cultivated and weed hosts. Possibly more effective parasites can be found if the origin of B. tabaci, which is unclear, can be established. Mound and Halsey (1978) reported 35 species in this genus. Since the largest number of species occur in the Palearctic and Oriental regions, they may provide additional natural enemies.

Several whitefly species are commonly found in cotton fields in Arizona and California (Gerling 1967). The two most common are the bandedwinged whitefly (Trialeurodes abutilonea (Haldeman)) and B. tabaci. The former is considered a minor pest and may have an essential role in the cotton ecosystem as prey or as a parasite host for natural enemies that suppress other insect and mite pests (Butler 1967). Bemisia tabaci, although reported from cotton in Arizona as early as 1926 (Russell 1957), has also been considered a minor pest, but has attained economic infestation levels during several cotton-growing seasons in recent years (Butler et al. 1983).

Gerling (1967) reported that whiteflies in southern California seldom reached economic levels except when insecticide applications were applied to cotton and suggested that natural regulating factors were important in maintaining low population levels of the pest. We found all development stages of B. tabaci as well as its parasites on Malva parviflora L. in the same locale. This insect moved from M. parviflora to cotton in May, reached peak populations in August or September, and declined thereafter.

Economic infestation levels in cotton can result in losses from transmission of cotton leaf crumple virus (Dickson et al. 1954), feeding damage (Husain and Trehan 1933), reduced yield (Mound 1965b), and lint contamination with honeydew and associated fungi (Gerling et al. 1980). Furthermore, in multicrop agroecosystems in the desert growing areas of California, B. tabaci transmits agents resulting in cotton leaf curl, lettuce infectious yellows, and squash leaf crumple diseases, one or more of which have been identified from 12 cultivated crops and 14 weed or ornamental hosts (Duffus and Flock 1982). Bird and Maramorosch (1978) reviewed the worldwide involvement of B. tabaci as a vector of agents causing plant diseases. During 1981, total estimated losses of several millions of dollars from diseases occurred as a result of B. tabaci infestations in multicrop cotton, sugar beets, squash, melons, and iceberg lettuce systems (Johnson et al. 1982).

The potential of the insect becoming a serious established pest in the United States stimulated us to conduct studies to provide information on its basic biology, population development, overwintering hosts, and seasonal distribution. This information is essential before efficient and effective suppression technology can be developed. This bulletin is a report of these studies.

## METHODS AND MATERIALS

### Laboratory Studies, 1981-82

#### Development Rates

Bemisia tabaci adults were collected in the field at the Cotton Research Center, Phoenix, Ariz., during the fall of 1981. Eggs were obtained by confining adults on cotton seedlings in 0.473-liter paper cartons with a sponge bottom. A slit in the sponge accommodated the seedling stem growing in a 5-cm-diameter plastic pot. After 24 hours, the B. tabaci adults were removed. Cotton plants were placed in each of nine cabinets held at constant temperatures from 14.9° to 36.0°C $\pm$ 1. Each of three additional cabinets had fluctuating temperatures, with a gradual daily change of about 16.0° and averages of 33.1°, 34.8°, and 35.3° between maximal and minimal temperatures of 24.4° to 43.3°. Temperatures were programmed by cams to follow those calculated with the program MACLIM in Stapleton et al. (1974), which estimates average hourly temperatures from maximal and minimal temperatures. Typical Arizona temperature fluctuations were used. Vitalite fluorescent lamps provided a 14-hour photophase.

The cotton leaves were examined daily, and the first stage larval crawlers were counted until all eggs had hatched. Later, the leaves were examined daily for empty pupal skins, which were marked with a felt pen to indicate adult emergence. At the two high fluctuating temperatures, after an extended 2-week emergence period, no further adults emerged for a week. Since the pupae were still present, the plants were transferred to cabinets at 25°C and observed daily for the appearance of adults.

An algorithm utilizing a sigmoid function (Stinner et al. 1974) was used with the results from the rearing studies to calculate equations for determining temperature-dependent growth rates for the egg stage and the egg-to-adult stage. Development of the whiteflies in Egypt and that of *B. tabaci* obtained in these studies were compared by using the linear regression equation, $\hat{y} = a + bX$, where $\hat{y}$ is the reciprocal of the number of days and $X$ is the temperature in °C, with an $F$ test of the homogeneity of regression coefficients (Steele and Torrie 1960).

Time of Adult Emergence and Longevity, Oviposition, and Egg Hatch

Time of emergence was determined by aspirating all adults from leaves of cotton plants infested with all stages of the insect and contained in cages made of 473-$cm^3$ paper cartons with nylon cloth tops and sponge bottoms. Cages were held at 26.7°C with a 14-hour photophase starting at 6 a.m. The adults were removed from about 6 p.m. to 8 p.m. on 11 days during January 20 to February 27, 1982. Newly emerged adults were sexed, recorded, and removed beginning the following morning at about 6 a.m. and at about 1- to 1.5-hour intervals each day until 6 p.m.

Oviposition, longevity, and egg hatch were determined by collecting adults as described and isolating 5 pairs per cage in each of 40 cages. Cages were made from plastic vials, 2.5 cm in diameter by 7.5 cm long, with plastic lids. A 0.6-cm-diameter hole was cut in the lid to accommodate a 10-$cm^3$ vial containing water. Petioles of leaves trimmed to about 2.5 $cm^2$ were placed in the vials. Holes about 1.3 and 0.6 cm in diameter were cut in the side of the plastic cage body. The 1.3-cm hole was covered with nylon screen to provide air, and the 0.6-cm hole accommodated a small cork stopper, which when removed allowed access for aspiration of *B. tabaci* for transfer to fresh leaves at the 3-day intervals when eggs were counted. In 10 days, the number of hatched eggs was recorded. Records were kept of the day each insect died. Cages as described were held in temperature-controlled cabinets at 26.7° and 32.2°C.

The time oviposition occurred was determined by collecting insects emerging between 6:30 and 8 a.m. on each of 3 days. At 9 a.m. on the day of emergence, five pairs, on an average, were placed in each of five oviposition cages (previously described). The eggs laid were counted at 1- to 2-hour intervals until 6 p.m. and at 6 a.m. the following morning. This procedure was followed for 3 days for each of the experiments. Cages with *B. tabaci* were held at constant temperatures under the same conditions as used in the study of adult emergence.

## Field Studies, 1981-84

Overwintering and Spring Plant Hosts

During the winter and spring of 1982, a search was made for *B. tabaci* on various plants in several agricultural areas of Arizona and California. This search in both weed and crop areas was quantified by recording the number of adults found in 5- to 10-minute observation periods.

## Intercrop Movement

Short-term exposure studies were conducted with sticky traps[2] at 1- to 11.5-hour intervals during August and September 1982 to determine the flight of B. tabaci from cotton into newly planted fall crops. These traps were made of 15- by 30-cm yellow cardboard that was sticky coated on both sides. They were placed in cantaloup, squash, or lettuce fields adjacent to cotton.

## Rates of Population Increase

Sticky traps. Sticky traps were impaled vertically 15 cm from the ground on stakes at several locations in Brawley, Calif., and Yuma and Phoenix, Ariz. They were exposed for 2 days each week, after which they were wrapped in transparent polyethylene so they could be handled, shipped, and placed under a binocular microscope for counting the B. tabaci. Six traps were located next to cotton, melon, guayule, and sugar beet fields at the Imperial Valley Conservation Research Center, Brawley, and five traps on canal banks from 0.8 to 4 km southwest of the Center from May 31 to September 12. One sticky trap was placed next to a cotton field at Yuma from May 31 to September 5. Four traps were located at the edge of a cotton field at the University of Arizona Cotton Research Center, Phoenix, on May 31. Two additional traps were next to a second cotton field on June 2 and trapping continued until September 5.

Vacuum collections. Starting July 9 and continuing through September 18, one to four vacuum samples per field were taken at approximately weekly intervals in cotton fields at Brawley, Westmorland, and Ripley, Calif., and at Somerton, Yuma, N. Gila Valley, Parker, and Poston, Ariz. Fields were selected at random, and no attempt was made to identify growers to obtain detailed insecticide histories of the nearly 100 cotton fields sampled. In cotton fields with sandy soil or alternate row irrigation, vacuum samples were taken while walking down a row, starting 6 meters from the field edge. In other fields, sampling the outside rows permitted collection in the same area of the field each week, even during irrigations.

A gasoline-operated generator provided electric power to a portable vacuum cleaner. The nozzle of the vacuum cleaner was fitted with a metal holder for an 800-cc cylindrical plastic food container with a nylon screen cloth bottom to collect and hold the B. tabaci insects. A 1.5-mm mesh aluminum screen top was placed over the container to keep out larger insects and cotton debris.

Vacuum sampling was started in the fields at 8 a.m. and generally completed by noon. Single samples were collected for 2 minutes. When B. tabaci populations were very high at Brawley, 1-minute samples were collected. At the end of the collecting time, the screen top of the container was replaced with a solid top, and high temperatures killed the insects in the containers. Bemisia tabaci adults were counted under a dissecting microscope.

The rates of increase in the number of B. tabaci were compared using the linear regression equation $\hat{y} = a + bX$, where $\hat{y}$ is the log of the number of adults trapped or adults per 2-minute vacuum sample and $X$ is the Julian date. The rate of increase of different populations was compared by using homogeneity of regression equations. Differences were considered significant if the $F$ value exceeded the 5 percent level.

## Effects of Cultural Practices on B. tabaci populations

The effect of cotton plant irrigation and nitrogen supply on B. tabaci was determined in six replicated field plots at Phoenix, Ariz. Vacuum collections were made in plots irrigated with either 10 or 15 cm of water at 14-day intervals. In each treatment, 0, 69, or 138 units of nitrogen were added to the irrigation water, and in one treatment, 65 additional units were added as a foliar application.

[2]Sticky Strips, Olson Products, Inc., Medina, OH 44358.

*Bemisia tabaci* populations were compared in different cotton types. Adults were vacuum collected north of Westmorland, Calif., on July 21-22, 1982, at both ends of a field in which eight commercial cotton cultivars were planted in four-row plots randomized in four blocks. One end of the field was sampled again on August 8. The same cotton types arranged in an identical experimental design were also sampled at Poston, Ariz., on August 14. A variety test at Tempe, Ariz., was sampled on July 31. This test included eight smooth-leaf and eight hairy cotton strains, and cultivars were arranged in four randomized blocks of four-row plots.

One set of leaf samples was collected on July 21 from all the cultivar plots at Westmorland. A single large basal leaf was collected at the 6th to 8th node below the top of 25 plants from each of the 8 cultivars in the 4 replicates. The immature *B. tabaci* insects per leaf were counted with the aid of a 10X magnifier.

Data in all experiments were statistically treated using the analysis of variance and Duncan's new multiple range test to determine the significance between treatment averages (Duncan 1955). A correlation coefficient was used to compare the number of adults collected in 2-minute vacuum samples with the number of immature forms per leaf in the cotton types study.

## RESULTS

### Laboratory Studies

#### Development Rates

The duration of the egg stage varied from 22.5 days at 16.7°C to 5.0 days at 32.5° (table 1). At 36.0°, the eggs failed to hatch. At the fluctuating high temperatures of 24.4° to 43.3°, the eggs required approximately the same time to hatch as at 30° and 32.5°. Similar incubation periods have been reported on cotton (Husain and Trehan 1933), sweetpotato and potato (El-Helaly et al. 1971, Azab et al. 1971), and eggplant (Avidov 1956) hosts in India, Egypt, and Israel. The Stinner et al. (1974) algorithm was used to describe the

Table 1.--Average duration of egg and egg-to-adult stages of *B. tabaci* at different constant and fluctuating temperatures

| Temperature (°C) | Egg stage: Individuals | Egg stage: Duration ± SD | Egg-to-adult stage: Individuals | Egg-to-adult stage: Duration ± SD |
|---|---|---|---|---|
| | Number | Days | Number | Days |
| Constant: | | | | |
| 14.9 | ... | ... | 309 | 65.1 ± 6.2 |
| 16.7 | 263 | 22.5 ± 2.0 | 190 | 48.7 ± 5.3 |
| 20.0 | 477 | 11.5 ± 0.7 | 239 | 34.7 ± 4.0 |
| 22.5 | 409 | 9.9 ± 0.7 | 125 | 27.8 ± 1.3 |
| 25.0 | 1,100 | 7.6 ± 0.7 | 220 | 23.6 ± 1.4 |
| 27.5 | 687 | 6.1 ± 0.6 | 173 | 17.8 ± 0.9 |
| 30.0 | 1,784 | 5.4 ± 0.6 | 200 | 16.6 ± 1.6 |
| 32.5 | 832 | 5.0 ± 0.2 | ... | ... |
| 36.0 | 443 | No hatch | ... | ... |
| Fluctuating: | | | | |
| 33.1 (24.4-40.6) | 651 | 5.8 ± 0.5 | 1,098 | 22.4 ± 3.6 |
| 34.8 (27.2-42.8) | 558 | 5.6 ± 0.7 | 76 | 26.2 ± 3.4 |
| 35.3 (26.7-43.3) | 419 | 5.3 ± 0.4 | 110 | 27.5 ± 4.4 |

results at both constant and fluctuating temperatures (table 2), and large $r^2$ values indicated good fits. By using the values of the algorithm at the constant temperature and determining the average development time for the egg stage with the 24-hour temperatures in each of the fluctuating temperatures, the calculated average duration was 6.4, 6.5, and 6.8 days at 33.1°, 34.8°, and 35.3° average temperatures, respectively. These estimates were about 1 day longer than observed.

The period from egg laying to adult appearance varied from 65.1 days at 14.9° to 16.6 days at 30.0°C (table 1). At fluctuating temperatures of 24.4° to 40.6°, 27.2° to 42.8°, and 26.7° to 43.3°, the time from egg to adult development was significantly lengthened. Evidence was obtained at the high fluctuating temperatures of 26.7° to 43.3° of an aestivation or cessation of development activity due to high temperature, in which 74 percent of 291 pupae delayed their development. When transferred to cabinets at 25°, they immediately continued to develop into the adult stage.

El-Helaly et al. (1971) reported development times of larval instars and the pupal stage on sweetpotato leaves of about 11.6 and 16.0 days at 31° and 25.4°C, respectively, and similar rates on potato leaves. Husain and Trehan (1933) found that completion of a life cycle on cotton varied from 14 to 107 days and that generations occurred each 14 to 21 days during April to September, when average maximal and minimal temperatures were about 37° to 29°. Similar results were reported by Avidov (1956) on eggplant and Azab et al. (1971) on sweetpotato.

Table 2.--Values for temperature-dependent algorithm[1] simulation of development rate ($R_t$) of *B. tabaci* at egg and egg-to-adult stages at constant and fluctuating temperatures

| Stage and temperature (°C) | *n* | *TOPT* | *A* | *B* | *C* | $R^2$ | $X^2$ |
|---|---|---|---|---|---|---|---|
| Egg: | | | | | | | |
| Constant........ | 7 | 32.5 | 5.039 | −0.220 | 0.222 | 0.997 | 0.216 |
| Constant and fluctuating... | 10 | 32.5 | 5.129 | −0.230 | 0.211 | 0.962 | 0.290 |
| Egg-to-adult: | | | | | | | |
| Constant........ | 7 | 30.0 | 3.829 | −0.155 | 0.087 | 0.996 | 0.267 |
| Constant and fluctuating... | 10 | 30.0 | 3.628 | −0.130 | 0.102 | 0.977 | 1.551 |

[1]Stinner et al. (1974). $R_t = C/(1 + e^{A + Bt1})$, where $R_t$ = rate of development (1/time) at temperature *t*; *C* = (maximal development rate) x ($e^{A + B\ TOPT}$), i.e., the asymptote; *TOPT* = temperature at which the maximal developmental rate occurs; *A* and *B* = empirical constants; $t^1 = t$, for $t < TOPT$; $t^1 = 2 \times TOPT - t$, for $t > TOPT$; $R^2$ = linear correlation coefficient; and $X^2$ = chi-square.

Values for the Stinner et al. (1974) algorithm, which uses a sigmoid function with the relationship inverted when the temperature is above an optimum, are given in table 2 for the egg and egg-to-adult stages. By using these values at constant temperatures and determining the average development at each of the 24-hour temperatures for each of the fluctuating temperatures, the calculated average duration was 25.0, 26.7, and 28.5 days for egg-to-adult stages at 33.1, 34.8, and 35.3°C average temperature, respectively. These estimates were about 1 and 2 days longer than observed but clearly show the increase in the development rate at high temperatures. The duration of the egg-to-adult stage on cotton in our constant-temperature cabinets was similar to that reported by Azab et al. (1971) on sweetpotato in an outdoor insectary in Egypt, using daily average temperatures during each generation ($F = 0.914$, $df = 2, 16$, $P > 0.5$) (fig. 1).

The development rate for *B. tabaci* was also compared with that of the bandedwinged whitefly, both at constant

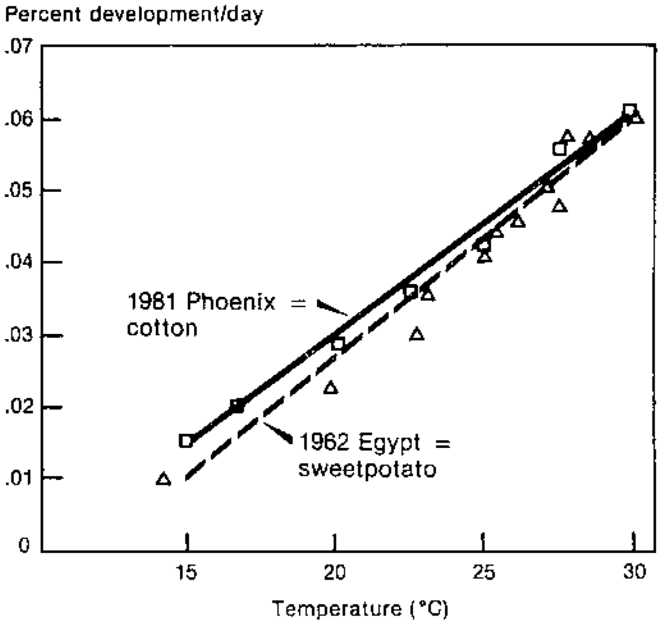



Figure 1.--Comparison of rate of development of *B. tabaci* from egg to adult in relation to greenhouse temperature on sweetpotato in Egypt in 1962 and on cotton in constant-temperature cabinets at Phoenix, Ariz., in 1981.

temperatures as determined by Butler (1967). The rates were significantly different ($F = 56.6$ with 2 and 8 $df$). *Bemisia tabaci* developed from egg to adult 4 days faster at 20° and 8 days faster at 30°C than the bandedwinged whitefly.

Time of Adult Emergence and Longevity, Oviposition, and Egg Hatch

Peak emergence (76 percent) of male and female *B. tabaci* adults occurred from 6 to 9 a.m. at 26.7°C (table 3). Husain and Trehan (1933) reported that maximal emergence occurred between 8 and 11 a.m. and none from 7 p.m. to 7 a.m. Azab et al. (1971) found most emergence was from 8 a.m. to 12 m. and was reduced at night.

The average number of eggs per female was 81 and 72 at 26.7° and 32.2°C, respectively. These results indicate higher oviposition than the average 28 to 43 eggs per female reported by Husain and Trehan (1933). However, Avidov (1956) reported that a single *B. tabaci* female laid 300 eggs on eggplant, and Azab et al. (1971) reported average oviposition of 161 eggs per female on sweetpotato leaves. Of the eggs laid at 26.7°, 68 percent hatched, and 75 percent of the eggs laid at 32.2° hatched. Males lived, on an average, 7.6 and 11.7 days and females 8.0 and 10.4 days at 26.7° and 32.2°, respectively. Azab et al. (1971) also reported that males were shorter lived than females. Longevity ranged from 2 to 17 and 8 to 60 days for males and females, respectively, at variable seasonal temperatures.

*Bemisia tabaci* adults placed in oviposition cages 1 to 2.5 hours after emergence began egg laying at 26.7°C within 1.5 to 3 hours in two of the experiments but between 4 and 11 hours in one experiment. Numbers of eggs laid per cage were as follows:

| | |
|---|---|
| 6-9 a.m. ................ | $1.5 \pm 2.0$ |
| 9-12 m. .................. | $1.3 \pm 1.5$ |
| 12-6 p.m. ................ | $8.7 \pm 9.8$ |
| 6-6 a.m. ................ | $2.4 \pm 2.9$ |

Table 3.--Average number of *B. tabaci* adults emerged per day, percent total emergence, and percent males and females at different times of day at 26.7°C[1]

| Emergence period | Adults per day | Total emergence | Males | Females |
|---|---|---|---|---|
| | Number | Percent | Percent | Percent |
| 6-9 a.m. | 115 | 76 | 38 | 62 |
| 9-12 m. | 18 | 12 | 34 | 66 |
| 12-3 p.m. | 6 | 4 | 49 | 51 |
| 3-6 p.m. | 0 | 0 | .. | .. |
| 6-6 a.m. | 13 | 8 | 53 | 47 |
| Total | 152 | 100 | .. | .. |

[1]Averages of 11 daily observations during each time period.

## Field Studies

### Overwintering and Spring Plant Hosts

Overwintering *B. tabaci* adults were observed in the Phoenix area on cheeseweed (*Malva parviflora* L.) and prickly lettuce (*Lactuca serriola* L.) during January and February 1982. In other agricultural areas during February to April, cheeseweed and prickly lettuce, which also probably included sowthistle (*Sonchus asper* (L.) J. Hill) (according to E. Natwick, pers. commun.), were the most common plants on which *B. tabaci* adults were overwintering (table 4). At one location, sunflower (*Helianthus annuus* L.) had many adults, but sunflowers were not seen in other locations. The Imperial Valley had more overwintering *Bemisia* adults on the plants examined than at Blythe, Poston, or Yuma. By the end of March, these insects had left the weed hosts and had become established on squash, watermelons, and cantaloups.

### Intercrop Movement

Short-term sticky-trap collections of *B. tabaci* and bandedwinged whiteflies are shown in table 5. In the August 21-22 collections, 23 percent of the whiteflies were *B. tabaci*, whereas in the following week 72 percent were *B. tabaci*. This indicates that the species collected can vary widely in a short time. The collection of 700 *Bemisia* adults in 5-1/2 hours on a single sticky trap in a newly planted lettuce field shows the heavy influx of the insect into fall lettuce fields, mainly from cotton, and the severe threat to the lettuce seedlings if many of the adults are viruliferous. The problem of controlling such an influx with any kind of insecticide program is also apparent. Since almost no banded-winged whiteflies were in the cotton, the adults of this species were coming from some other host.

### Rates of Population Increase

*Sticky traps*. The average number of *B. tabaci* adults collected on traps adjacent to different cultivated crops at the Brawley Research Center increased at a similar rate from late May through early September, and the results were combined (table 6). The regression equation was $\hat{y} = -7.81 + 0.062X$, $r^2 = 0.91$, $n = 15$. The rate of increase in numbers of *B. tabaci* collected on the

Table 4.--Number of B. tabaci adults observed during February to April 1982 on various host plants at several Arizona and California locations

| Date | Location | Plant | Adults searched |
|---|---|---|---|
| | | | Number per minute |
| Feb. 15-16.... | Imperial Valley, Calif. | Sunflower........ | 42/10; small plants 113/10 |
| | | Cheeseweed;...... in alfalfa. | 71/15; 67/10, 54/10, 31/10 |
| | | Prickly lettuce;. in alfalfa.[1] | 7/10; 24/10, 23/10, 13/10 |
| Feb. 22....... | Blythe, Calif...... | Cheeseweed....... | 4/10, 4/10, 1/10 |
| | | Prickly lettuce.. | 4/10, 0/5 |
| Feb. 23....... | Poston, Ariz....... | Cheeseweed....... | 13/10, 11/10, 4/10 |
| | | Prickly lettuce.. | 0/5 |
| Mar. 29....... | Yuma, Ariz......... | Cheeseweed....... | 0/10, 0/10 |
| | | Prickly lettuce.. | 0/10, 0/10, 0/10, 0/5 |
| | | Sugar beet....... | 0/5 |
| Apr. 1........ | Imperial Valley.... | Sunflower........ | 0/5, 0/5, 4/10, 2/10, 0/5 |
| | | Cheeseweed....... | 0/5, 0/5, 0/5, 2/5 |
| | | Prickly lettuce.. | 0/5 |
| | | Watermelon....... | 4/10, 3/10, 8/10 |
| | | Squash........... | 0/10, 65/10, 20/10 |
| | | Cantaloup........ | 1/10, 0/10, 0/5 |
| | | Convolvulus...... | 6/10 |
| Apr. 2........ | Blythe............. | Cheeseweed....... | 0/5, 0/5 |
| | | Prickly lettuce.. | 0/5 |
| | | Cantaloup........ | 0/5, 0/5, 0/5 |
| | | Sunflower........ | 0/5 |

[1]Prickly lettuce probably also included sowthistle.

traps 0.8-4 km from the Research Center ($\hat{y} = -8.35 + 0.066X$, $r^2 = 0.87$, $n = 15$) was not significantly different from the rate of increase at the Research Center. The regression equation for the two sets of data ($\hat{y} = -8.14 + 0.064X$, $r^2 = 0.93$, $n = 30$) is shown in figure 2 (Brawley). The numbers of B. tabaci trapped increased 617-fold during the 100-day sampling period. The rate of increase in numbers of B. tabaci in sticky trap collections at Yuma ($\hat{y} = -7.46 + 0.065X$, $r^2 = 0.82$, $n = 12$) was similar to that observed at Brawley. Numbers of B. tabaci caught on sticky traps adjacent to cotton at two locations at Phoenix were similar, and the regression equation from the combined data ($\hat{y} = -14.65 + 0.087X$, $r^2 = 0.93$, $n = 24$) shows that the increase was significantly greater than that at either Yuma or Brawley.

Vacuum collections. Early-season B. tabaci populations were variable at different locations in California and Arizona (table 7). Vacuum samples in cotton fields at Brawley and Westmorland, Calif., showed high early-season populations. The area had numerous squash, cantaloup, and watermelon fields. In contrast, few B. tabaci adults were collected in vacuum samples in cotton fields at Somerton, Yuma, and N. Gila Valley, Ariz., in early-season sampling, where few, if any, squash, cantaloups, or watermelons were grown. Vacuum samples

Table 5.--Short-term (1-11.5 hours) collections of B. tabaci and bandedwinged whitefly adults on sticky traps in cantaloup, squash, or lettuce fields adjacent to whitefly-infested cotton fields at several locations in Arizona and California during August and September 1982

| Location | Date | Exposure time | B. tabaci | Bandedwinged whiteflies |
|---|---|---|---|---|
| | Aug. | | Number | Number |
| N. Gila, Ariz..... | 21 | 0830-1130 | 55 | 72 |
| | | 0845-1130 | 23 | 34 |
| Yuma, Ariz........ | 21 | 1300-1600 | 3 | 6 |
| | | 1300-1600 | 62 | 33 |
| S. Ripley, Calif.. | 22 | 0800-1545 | 110 | 382 |
| | | 0800-1600 | 118 | 412 |
| S. Blythe, Calif.. | 22 | 0830-1530 | 30 | 278 |
| S. Ripley......... | 20-21 | ......... | 109 | 522 |
| SW. Poston, Ariz.. | 22 | 0915-1445 | 8 | 12 |
| | | 0915-1445 | 5 | 6 |
| | | 0915-1445 | 8 | 14 |
| | | 0930-1500 | 7 | 8 |
| | | 0930-1500 | 11 | 25 |
| | | 0930-1500 | 14 | 31 |
| Total...... | | | 563 | 1,835 |
| S. Gila........... | 28 | 0800-1215 | 50 | 31 |
| N. Gila........... | 28 | 0830-1200 | 81 | 31 |
| | | 0840-1200 | 48 | 45 |
| Yuma.............. | 28 | 1300-1830 | 12 | 10 |
| | | 1300-1830 | 43 | 37 |
| | | 1415-1830 | 8 | 60 |
| S. Ripley......... | 29 | 0830-1210 | 55 | 30 |
| | | 0830-1200 | 39 | 40 |
| | 30 | 0630-1700 | 49 | 24 |
| | | 0630-1700 | 68 | 16 |
| | | 0630-1700 | 43 | 18 |
| S. Blythe......... | 30 | 0645-1645 | 11 | 82 |
| SW. Poston........ | 30 | 0900-1430 | 533 | 212 |
| | | 0900-1430 | 111 | 46 |
| | | 0915-1445 | 702 | 49 |
| | | 0915-1445 | 54 | 2 |
| Total...... | | | 1,907 | 733 |
| | Sept. | | | |
| N. Gila........... | 10 | 1015-1245 | 2 | 6 |
| | | 1015-1245 | 10 | 10 |
| Yuma.............. | 10 | 1345-1645 | 25 | 10 |
| | | 1345-1645 | 13 | 9 |
| | | 1345-1645 | 5 | 7 |
| S. Ripley......... | 14 | 0700-1830 | 59 | 38 |
| | | 0700-1830 | 19 | 7 |
| | | 0700-1830 | 9 | 15 |
| S. Blythe......... | 14 | 0710-1815 | 15 | 11 |
| SW. Poston........ | 14 | 1130-1530 | 24 | 2 |
| | | 1130-1530 | 67 | 2 |
| | | 1145-1545 | 2 | 2 |
| | | 1145-1545 | 3 | 2 |
| Total...... | | | 253 | 121 |

Table 6.--Average number of *B. tabaci* adults per sticky trap per 2 days in Brawley, Calif., and Yuma and Phoenix, Ariz., from May to September 1982

| Date | Brawley: On Research Center | Brawley: Off Research Center[1] | Yuma | Phoenix: Location 1 | Phoenix: Location 2 |
|---|---|---|---|---|---|
| May 31-June 6... | 3 | 3 | 7 | 2 | ..... |
| June 7-13....... | 9 | 16 | 6 | 3 | 1 |
| 14-20....... | 18 | 7 | 11 | 1 | 1 |
| 21-27....... | 15 | 28 | 28 | .... | 1 |
| 28-July 4... | 49 | 122 | 94 | 2 | 6 |
| July 5-11....... | 54 | 18 | 454 | 3 | 3 |
| 12-18....... | 77 | 81 | 350 | 6 | 7 |
| 19-25....... | 33 | 44 | 544 | 6 | 10 |
| 26-Aug. 1... | 501 | 221 | 1,330 | 41 | 19 |
| Aug. 2- 8....... | 195 | 271 | ..... | 56 | 36 |
| 9-15....... | 153 | 93 | 638 | Rain | Rain |
| 16-22....... | 1,360 | 1,089 | ..... | 420 | 348 |
| 23-29....... | 870 | 876 | 1,120 | 777 | 598 |
| 30-Sept. 5.. | 1,570 | 3,203 | 1,500 | 559 | 1,122 |
| Sept. 6-12....... | 2,580 | 5,887 | ..... | .... | ..... |

[1]Traps 0.8-4 km from Research Center.

Table 7.--Average number of *B. tabaci* adults caught per 2-minute vacuum collection in cotton fields in California and Arizona, 1982

| Sampling location | Samples | Sampling date: July 9 | July 16 | July 23 | July 30 | August 6 | August 13 | August 20 | August 27 | September 4 | September 11 | September 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Number | | | | | | | | | | |
| California | | | | | | | | | | | | |
| SW. Brawley...... | 16 | 268 | 176 | 648 | ... | 1,615 | ... | ... | 1,830 | ... | ... | ... |
| E. Brawley....... | 12 | 147 | ... | 252 | ... | 989 | ... | ... | 322 | ... | ... | ... |
| N. Westmorland... | 12 | ... | 169 | 181 | ... | 320 | ... | ... | 1,313 | ... | ... | ... |
| Ripley........... | 20 | 1 | 2 | 34 | ... | 69 | 115 | 125 | 128 | ... | 71 | 132 |
| Arizona | | | | | | | | | | | | |
| Somerton......... | 12 | 5 | 2 | ... | 7 | ..... | 22 | ... | 33 | ... | ... | ... |
| Yuma............. | 18 | 24 | 44 | ... | 130 | ..... | 85 | 179 | 120 | ... | 84 | ... |
| N. Gila Valley... | 7 | 53 | ... | ... | 373 | ..... | 442 | ... | 374 | ... | 324 | ... |
| SE. Parker....... | 8 | 42 | 92 | 183 | ... | 471 | 660 | 211 | 507 | ... | 159 | 507 |
| SW. Parker....... | 6 | 5 | 43 | 86 | ... | 400 | 804 | 390 | 436 | ... | 207 | 364 |
| Poston-200....... | 10 | <1 | 1 | ... | 20 | ..... | 220 | 386 | ..... | 597 | ... | ... |
| Poston-600....... | 8 | 25 | 15 | 92 | 698 | ..... | 1,549 | 1,065 | ..... | ... | ... | ... |
| S. Poston........ | 5 | ... | <1 | 1 | ... | 11 | 28 | 50 | 65 | ... | 235 | 529 |
| Average.............. | | 57 | 54 | 185 | 246 | 554 | 436 | 344 | 513 | 597 | 149 | 383 |

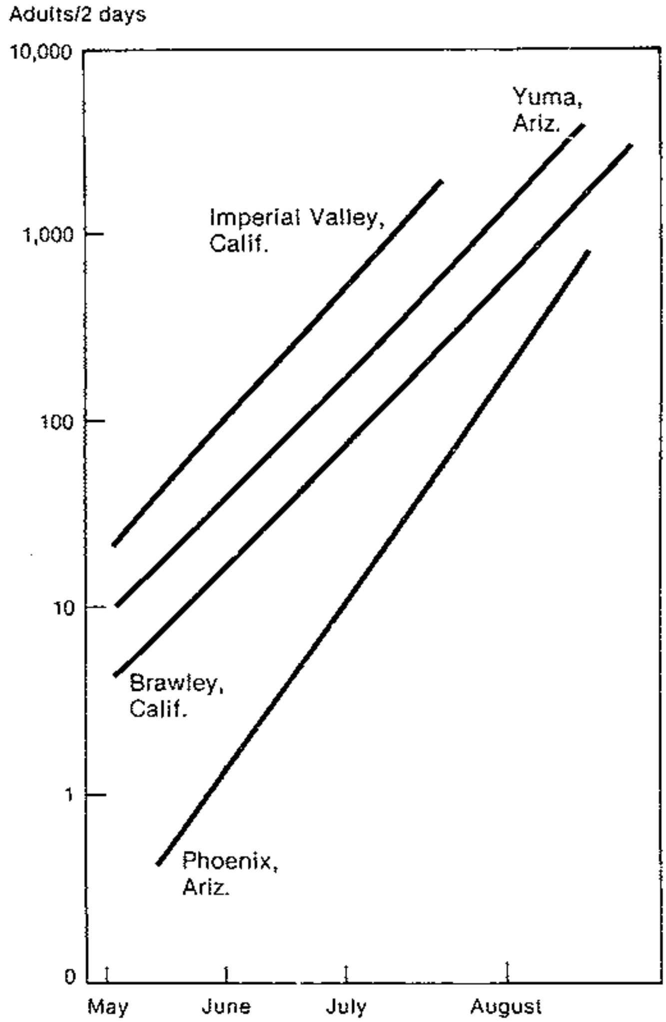



Figure 2.--Regression lines for number of B. tabaci adults collected on sticky traps at four locations, 1982.

in cotton fields adjacent to cantaloup fields at Parker, Ariz., showed high populations by late July, whereas cotton fields at Ripley, Calif., and S. Poston, Ariz., where no cantaloups were grown, had much lower populations. Thus the proximity of squash, cantaloup, and watermelon fields to cotton affected the early-season buildup of B. tabaci in cotton. These results are similar to those in Israel, where populations increased on sunflowers and potatoes, which were planted earlier than cotton, and adults migrated to adjacent cotton August with foliar applications of nitrogen (table 8). These results are similar to those reported by Joyce (1958) for B. tabaci and Joyce (1961) for Empoasca libyca (Bergevin & Zanon).

Irrigation treatments under the conditions of the study did not appear to affect B. tabaci populations.

fields (Melamed-Madjar et al. 1979). These Israeli authors also referred to similar observations of B. tabaci movement between crops in Iran, Turkey, and Sudan.

The linear regression equations of the increase in numbers of B. tabaci collected in vacuum samples during July and August show that populations increased exponentially (figs. 3 and 4). One group of fields at S. Poston illustrates this point. The first and final (79 days later) vacuum samples had an average of 0.02 and 529 B. tabaci, respectively ($b$ = 0.103, $n$ = 8, $r^2$ = 0.94). The data for all fields sampled in our studies showed an average rate of B. tabaci increase of 0.097 ± 0.030. Fields in the Parker and Poston areas had an average $b$ of 0.121, which gave a doubling of the population every 6 days, whereas fields in Brawley and Westmorland averaged 0.059, probably because populations were relatively high at the start of sampling, but the population doubled every 10 days. Estimates of the rates of increase calculated from Gerling (1967) at Indio, Calif., during 1964 gave $b$ values of 0.146 and 0.129 in the treated and untreated fields, respectively, and 0.073 in 1965 in untreated fields, starting with low populations in both years. Gerling et al. (1980) at Kefar Aza, Israel, in 1977, reported a population increase of $b$ = 0.087. Also in Israel, adults increased at a rate of 0.077 in untreated cotton and at 0.075 in cotton adjacent to sunflower (Melamed-Madjar et al. 1979, 1982). Thus increases in B. tabaci populations in 1982 in Arizona and California were similar to those observed in other studies.

Effects of Cultural Practices on B. tabaci Populations

Cotton plant, water, and nitrogen supply. The highest numbers of B. tabaci were found in plots treated twice in

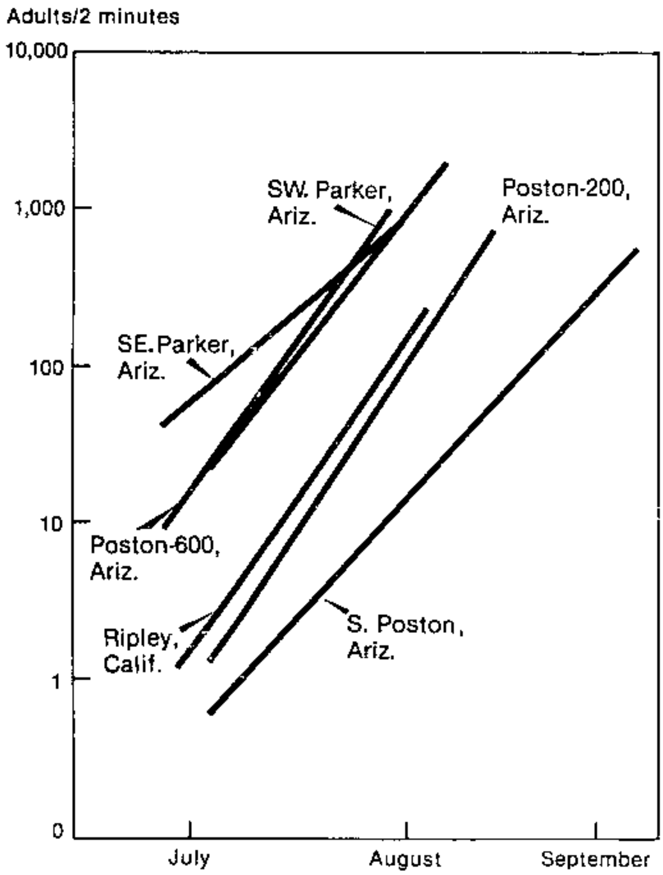



Figure 3.--Regression lines for number of B. tabaci adults collected from cotton in 2-minute vacuum samples in Imperial County, Calif., and in Yuma County, Ariz., 1982.

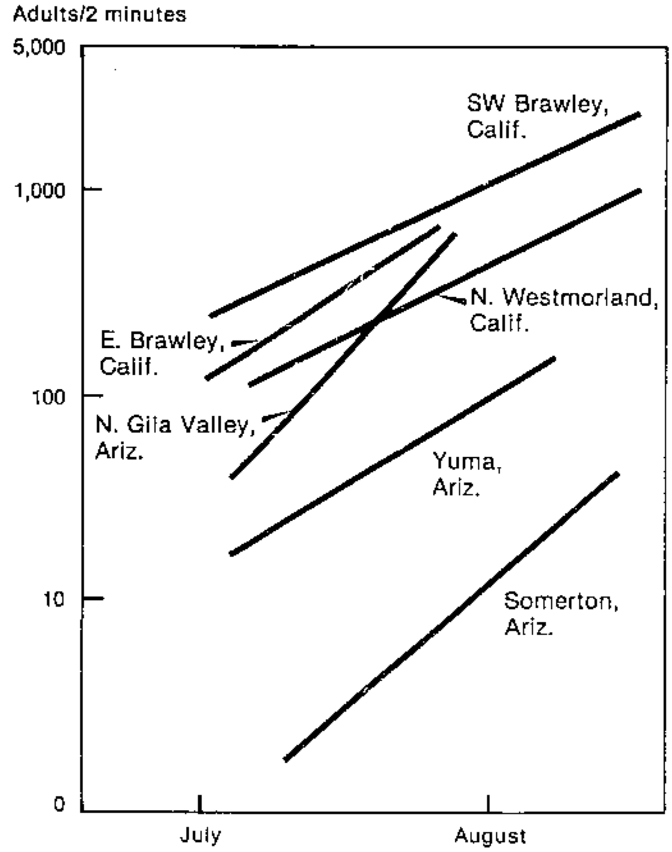



Figure 4.--Regression lines for number of B. tabaci adults collected from cotton in 2-minute vacuum samples in Riverside County, Calif., and in La Paz County, Ariz., 1982.

Cotton type. At Poston, Ariz., the highest numbers of B. tabaci adults were vacuum collected in 'Stoneville 825' and the lowest number in 'Deltapine 90' (Butler and Henneberry 1984). Numbers collected in 'Deltapine 61,' 'Deltapine 7613,' and 'Deltapine 62' were not significantly greater than in Deltapine 90. The Deltapine 90, Deltapine 61, and Deltapine 62 plants have semismooth leaves with relatively few hairs compared with the pubescent leaves of Stoneville 825, 'Deltapine 41,' and, to a lesser extent, Deltapine 7613 and 'Deltapine 70.' These last two had the highest number of B. tabaci adults in vacuum samples at Westmorland, Calif., along with Stoneville 825 and Deltapine 41. Visual counts of immature forms per leaf at Westmorland agreed well in number with the vacuum collections of adults ($r$ = 0.79). Deltapine 7613 had fewer immature forms than expected based on the high number of adults collected. This cultivar is variable in a number of its characteristics, including pubescence. The immature B. tabaci population in Deltapine 41 and Deltapine 70 was generally found on only 2 to 4 leaves of the 25-leaf samples and those infested leaves were pubescent. In these cultivars, a small percentage of the plants had leaves with dense hairs.

The average numbers of B. tabaci adults vacuum collected per 2 minutes in all smooth cotton leaf type and all pubescent cotton leaf type at Tempe, Ariz., were 11 and 25, respectively. Within the smooth leaf types, numbers of adults vacuum collected ranged from 5.8 to 23.3 per 2-minute sample and within the semismooth and pubescent cotton leaf types from 18.8 to 36.7 per 2 minutes.

Table 8.--Average number[1] of B. tabaci adults collected in 2-minute samples in cotton plots with different nitrogen and water levels at Phoenix, Ariz., Sept. 2, 1982

| Treatment | | B. tabaci |
|---|---|---|
| Water | Nitrogen | adults |
| | Units | Number |
| Normal......... | 0 | 674 b |
| | 138 | 554 b |
| | [2]203 | 1,123 a |
| Average.................... | | 784 a |
| Low............ | 0 | 732 ab |
| | 69 | 700 b |
| | 138 | 914 ab |
| Average.................... | | 782 a |

[1]Averages of 6 replicates. Averages not followed by same letter are significantly different according to Duncan's Multiple Range Test (P=0.05).

[2]Foliar application of 65 and 138 units added to irrigation water.

DISCUSSION

During the winter, B. tabaci adults were found on several weed hosts. Other investigators observed limited reproduction on some weed hosts, but the first marked increase in populations apparently took place on such spring crops as squash, watermelons, and cantaloups. Flights of adults, as determined by sticky-board collections, occurred in late April and early May at Brawley, Yuma, and Phoenix. Vacuum collections of adults in cotton in mid-July indicated that the size of the B. tabaci populations was directly associated with the proximity of the cotton to spring squash, watermelon, and cantaloup fields. Populations in cotton generally increased exponentially during July and August. In some fields, with a minimum of insecticide use, such as at south Poston, small initial populations in mid-July continued a uniform buildup to the end of September, when honeydew and mold were common. In other areas, such as Yuma, Somerton, north Gila Valley, Ripley, and southeast and southwest Parker, there generally was no continued buildup during August and September. The causes of the decline of populations in cotton in August may include insecticide applications, heavy rains, parasites, or other factors. In several areas, heavy flights of B. tabaci were observed during August and September. Short-term sticky-trap collections for a few hours per day showed that both Bemisia and bandedwinged adults were flying in large numbers into fall vegetable fields.

Growth rates of B. tabaci during July and August averaged $b = 0.084$ or 5 times that of Lygus hesperus Knight (Butler and Wardecker 1970) and Heliothis zea (Boddie) and 3.5 times that of Trichoplusia ni (Hübner) (Butler et al. 1974). The relative uniform population growth each year of these economically important insect species has important implications for pest management programs. First, such programs are designed to maintain populations below economic injury thresholds by reducing the rate of buildup. Our observations on B. tabaci show that the rate of buildup is rather uniform from area to area and thus may be difficult to suppress. Second, the number of individuals in the spring is very important. The presence of weed or cultivated hosts in the spring in an area will determine the size of the initial population immigrating into cotton in early summer and thus affect the level at which the B. tabaci increase will start. A further factor that makes control with conventional aerial insecticide applications ineffective is the selective positioning of the insects on the underside of leaves. Several reports indicate that B. tabaci outbreaks have intensified on a worldwide basis since the use of synthetic organic insecticides (Anonymous 1981).

Some of the variation in numbers of B. tabaci collected in fields in the present studies at the different locations is accounted for because they were adjacent to cantaloup or other crops planted earlier than cotton and known to be *B. tabaci* hosts. During August, high populations occurred in some insecticide-treated fields, whereas in others, insecticide treatments significantly reduced numbers of *B. tabaci*. Johnson et al. (1982) discussed the difficulties in obtaining control on cotton with conventional aerial insecticide applications, which may explain these observations. These authors reported that although adults may be killed, the waxy coating of the immature forms and their location on the underside of leaves result in poor control because of ineffective insecticide delivery systems. On the other hand, several fields showed marked reductions in the absence of insecticide applications. One such field was untreated during most of August, and after a peak vacuum sample collection of 813 adults on August 11, the number collected dropped to 70 on August 23, and the collection contained more *B. tabaci* parasites than *B. tabaci* adults. Parasites were also abundant in samples from other fields in the area.

Gerling (1967) observed declines in *B. tabaci* populations at Indio and Westmorland, Calif., in mid-August 1964 and 1965, and reported a significant increase in the percentage of parasitism, indicating that natural enemies can have a significant impact in regulating *B. tabaci* populations late in the growing season. Other factors also appear to affect their population dynamics; for example, during 1982, several areas received heavy summer rainstorms that seemed to reduce their numbers.

In any event, *B. tabaci* populations in the present study as well as in other parts of the world are characterized by a rapid increase and intercrop movement in multicrop agricultural systems. The role of natural enemies in regulating population levels of *B. tabaci* and the interaction of insecticides are poorly understood. The insect is an efficient vector of agents inducing disease in several cultivated crops (Bird and Maramorosch 1978, Duffus and Flock 1982). Studies are urgently needed to develop control technology through an understanding of the population dynamics of *B. tabaci* and its natural enemies on cultivated crops as well as alternate weed hosts.

The data in this report reinforce the earlier study of Mound (1965a), which showed that both immature forms and adults of *B. tabaci* were more abundant in cottons with pubescent leaves than in smooth-leaved cottons. This phenomenon also has been observed with the banded-winged whitefly (Butler and Muramoto 1967, Jones et al. 1975, and Lambert et al. 1982). Although pubescence is an important characteristic in determining the abundance of whiteflies, other physical and biotic factors may affect the success of the settling of crawlers and survival of young larvae (Horowitz et al. 1982).

SUMMARY

The sweetpotato whitefly (*Bemisia tabaci* (Gennadius)) has become a serious pest of cotton and other crops in Arizona and California as in many other parts of the world. In California during 1981, it caused an estimated $100 million in damage to crops. In cotton, *B. tabaci* transmits a virus disease, cotton leaf crumple, and secretes honeydew, which makes the cotton sticky and unacceptable for spinning. Large populations build up in cotton during the summer and then disperse to other crops, such as fall vegetables, where they transmit several other serious virus diseases.

In this study, several sampling techniques were used, which showed that *B. tabaci* adult populations develop in cotton at a relatively uniform, rapid rate over a wide area. These populations on cotton doubled every 6 to 10 days during the summer. The life history of the insect was studied at various temperatures, and the rate of development of the egg and the egg-to-adult stage was determined in relation to temperature. Observations were also made on early-spring plant hosts.

The results show the widespread distribution of the pest and how it develops throughout the year, at times explosively. Its control can be assisted by protecting insect predators and some specific parasites when controlling other cotton pests. A major natural suppression factor during the summer is heavy rains.

LITERATURE CITED

Anonymous. 1981. Possibilities for the use of biotic agents in the control of the whitefly, Bemisia tabaci. Biocontrol News and Information, Commonwealth Institute Biological Control 2:1-7.

Avidov, Z. 1956. Bionomics of the tobacco white fly (Bemisia tabaci Gennad.) in Israel. Katvim 7:25-41.

______ and I. Harpaz. 1969. Plant pests of Israel. 549 p. Israel University Press, Jerusalem.

Azab, A.K., M.M. Megahed, and D.H. El-Mirsawi. 1970. On the range of host-plants of Bemisia tabaci (Genn.). Bulletin Entomological Society Egypte 54:219-326.

______ M.M. Megahed, and D.H. El-Mirsawi. 1971. On the biology of Bemisia tabaci (Genn.). Bulletin Entomological Society Egypte 55:305-315.

Bird, J., and K. Maramorosch. 1978. Viruses and virus diseases associated with whiteflies. Advances Virus Research 22:55-110.

Butler, G.D., Jr. 1967. Development of the bandedwing whitefly at different temperatures. Journal Economic Entomology 60:877-878.

______ and T.J. Henneberry. 1984. Bemisia tabaci: Effect of cotton leaf pubescence on abundance. The Southwestern Entomologist 9:91-94.

______ T.J. Henneberry, and T.E. Clayton. 1983. Bemisia tabaci (Homoptera:Aleyrodidae): Development, oviposition, and longevity in relation to temperatures. Annals Entomological Society America 76:310-313.

______ T.J. Henneberry, and E.T. Natwick. 1985. Bemisia tabaci: 1982 and 1983 populations in Arizona and California cotton fields. The Southwestern Entomologist 10:20-25.

______ and H. Muramoto. 1967. Bandedwing whitefly abundance and cotton leaf pubescence in Arizona. Journal Economic Entomology 60:1176-1177.

______ T.R. Pfrimmer, and J.W. Davis. 1974. A model to describe the uniform buildup of populations of adult bollworms and cabbage loopers. Environmental Entomology 3:978-980.

______ and A.L. Wardecker. 1970. Temperature and the development of eggs and nymphs of Lygus hesperus. Annals Entomological Society America 64:144-145.

Dahiya, A.S., and R. Singh. 1982. Bio-efficiency of some systemic insecticides against jassid, thrips and whitefly attacking cotton. Pesticides 16(12):13-15.

Dickson, R.C., M. McD. Johnson, and E.F. Laird, Jr. 1954. Leaf crumple, a virus disease of cotton. Phytopathology 44:479-480.

Duffus, J.E., and R.A. Flock. 1982. Whitefly-transmitted disease complex of the desert Southwest. California Agriculture 36:4-6.

Duncan, D.B. 1955. Multiple range and multiple F tests. Biometrics 11:1-42.

El-Helaly, M.S., A.Y. El-Shazli, and F.H. El-Gayer. 1971. Biological studies on Bemisia tabaci Genn. (Homopt.:Aleyrodidae) in Egypt. Zeitschrift Angewandte Entomologie 69:48-55.

Gameel, O.I. 1972. A new description, distribution, and hosts of the cotton whitefly, Bemisia tabaci (Gennadius) (Homoptera Aleyrodidae). Revue Zoologie et Botanique Africaines 86:50-64.

______ 1974. Some aspects of the mating and oviposition behaviour of the cotton whitefly, Bemisia tabaci (Genn.). Revue Zoologie et Botanique Africaines 88:784-788.

______ 1978. The cotton whitefly, Bemisia tabaci (Genn.), in the Sudan Gezira. In Third Seminar on the Strategy for Cotton Pest Control, May 8-10, 1978, p. 111-131. CIBA-Geigy, Basel, Switzerland.

Gerling, D. 1967. Bionomics of the whitefly-parasite complex associated with cotton in southern California (Homoptera:Aleyrodidae; Hymenoptera:Aphelnidae). Annals Entomology Society America 60:1306-1321.

______ U. Motro, and R. Horowitz. 1980. Dynamics of Bemisia tabaci (Gennadius) (Homoptera:Aleyrodidae) attacking cotton in the coastal plain of Israel. Bulletin Entomology Research 70:213-219.

Ghong, Y. 1969. Host plant and morphological variation of Bemisia tabaci (Gennadius) (Homoptera:Aleyrodidae) in Taiwan. Plant Protection Bulletin, Taiwan 2:23-32.

Habib, A., and F.A. Farag. 1970. Studies on nine common aleurodids of Egypt. Bulletin Entomological Society Egypte 54:1-41.

Horowitz, R., H. Podoler, and D. Gerling. 1982. Population dynamics (life tables) of Bemisia tabaci under field conditions. Phytoparasitica 10:4.

Husain, M.A., and K.N. Trehan. 1933. Observations on the life-history, bionomics, and control of the whitefly of cotton (Bemisia gossypiperda M & L). Indian Journal Agricultural Science 3:701-753.

______ K.N. Trehan, and P.M. Verma. 1936. Studies on Bemisia gossypiperda, M & L. No. 3: Seasonal activities of Bemisia gossypiperda M & L (The whitefly of cotton) in the Punjab. Indian Journal Agricultural Science 4:893-903.

Johnson, M.W., N.C. Toscano, H.T. Reynolds, and others. 1982. Whiteflies cause problems for southern California growers. California Agriculture 36:24-26.

Jones, J.E., D.F. Clower, M.R. Milam, and others. 1975. Resistance in upland cotton to the bandedwinged whitefly, Trialeurodes abutilonea (Haldeman). In Proceedings Beltwide Cotton Production Research Conference, 1973, Phoenix, Arizona, p. 98-99.

Joyce, R.J.V. 1958. Effect of the cotton plant in the Sudan Gezira on certain leaf-feeding insect pests. Nature 182:1463-1464.

______ 1961. Some factors affecting the number of Empoasca lypica (de Berg) infesting cotton in the Sudan Gezira. Bulletin Entomology Research 52:191-232.

______ 1983. Aerial transport of pests and pest outbreaks. European and Mediterranean Plant Protection Organization Bulletin 13:111-119.

Lambert, L.J., J.N. Jenkens, W.L. Parrot, and J.C. McCarty. 1982. Greenhouse technique for evaluating resistance to the bandedwinged whitefly (Homoptera:Aleyrodidae) used to evaluate thirty-five foreign cotton cultivars. Journal Economic Entomology 75:1166-1168.

Mabbit, T.H. 1978. A review of the economic insect pests of cotton in Thailand. Description, infestation, and control. I. Cotton whitefly (Bemisia tabaci Gennadius). In Cotton Pest Management Project, Department of Agriculture, Bangkok Report, No. 13, p. 1-12.

______ M. Nachapong, and J. Mekdaeng. 1980. The within-canopy distribution of adult cotton whitefly (Bemisia tabaci Gennadius) incorporating economic thresholds and meteorological conditions. Thailand Journal Agricultural Science 13:97-108.

Melamed-Madjar, V., M. Chen, and D. Rosilio. 1984. Screening insecticides against the tobacco whitefly, Bemisia tabaci, on cotton, using a leaf cage laboratory method. Phytoparasitica 12:119-125.

______ S. Cohen, M. Chen, and others. 1979. Observations on populations of Bemisia tabaci Gennadius (Homoptera:Aleyrodidae) on cotton adjacent to sunflower and potato in Israel. Israel Journal Entomology 18:71-78.

______ S. Cohen, M. Chen, and others. 1982. A method for monitoring Bemisia tabaci and timing spray applications against the pest in cotton fields in Israel. Phytoparasitica 10:85-91.

Mound, L.A. 1963. Host-correlated variation in Bemisia tabaci (Gennadius) (Homoptera:Aleyrodidae). Proceedings Royal Entomological Society London 38:171-180.

______ 1965a. Effect of leaf hair on cotton whitefly populations in the Sudan Gezira. Empire Cotton Growing Review 42:33-40.

______ 1965b. Effect of whitefly (Bemisia tabaci) on cotton in the Sudan Gezira. Empire Cotton Growing Review 42:290-294.

______ and S.H. Halsey. 1978. Whitefly of the world. 340 p. British Museum (Natural History), London, and J. Wiley and Sons, Inc., New York.

Nachapong, M., and T. Mabbit. 1978. A survey of some wild hosts of Bemisia tabaci Genn. around cotton fields in Thailand. Thailand Journal Agricultural Science 12:217-222.

Ohnesorge, B.N., N. Sharaf, and T. Allawi. 1981. Population studies on the tobacco whitefly Bemisia tabaci Genn. (Homoptera: Aleyrodidae) during the winter season. II. Some mortality factors of the immature stages. Zeitschrift Angewandte Entomologie 92:127-136.

Russell, L.M. 1957. Collection records of Bemisia tabaci (Gennadius) in the United States. U.S. Department of Agriculture, Cooperative Economic Insect Report 25:229-230.

Sharaf, N. 1984. Chemical control of Bemisia tabaci. (Abstract) XVII International Congress of Entomology, Hamburg.

Stapleton, H.N., D.R. Buxton, F.L. Watson, and others. 1974. Cotton: A computer simulation of cotton growth. Arizona Agricultural Experimental Station Technical Bulletin 206, 124 p.

Steele, R.G.D., and J.H. Torrie. 1960. Principles and procedures of statistics. 481 p. McGraw-Hill Book Company, New York.

Stinner, R.E., A.P. Gutierrez, and G.D. Butler, Jr. 1974. An algorithm for temperature-dependent growth rate simulations. Canadian Entomologist 106:519-524.

END