VARIATION IN BEMISIA TABACI POPULATIONS, BASED ON HOST PLANT ASSOCIATIONS, DEVELOPMENTAL STATISTICS AND GROWTH PARAMETERS IN EGYPT

Malak F. Gergis and Khakaf M. Adam
Plant Prot. Res. Inst., Dokki,
Giza, Egypt

Abstract

The sudden outbreaks of sweetpotato whitefly *Bemisia tabaci* (Genn.) on cotton, vegetable crops, ornamental and medical plants in Egypt through the last few years and the surgence of the pest as a major pest and virus vector, prompted investigation into the variation among whitefly populations in developmental biology, behaviour, host expansion, growth statistics and insect interactions on a wide basis. Recent studies have also prompted a renewed interest in the concept of biotypes of *B. tabaci*. The coincidental emergence of the so called new poinsettia strain "B" biotype or the new species *Bemisia argentifolii* (Pellows & Perring) and resulting impact on agricultural productivity have also reaffirmed the need to understand more about fundamental differences among populations of *B. tabaci*. Biological and ecological procedures, i.e., thermobility coefficients, thermal require-ments and age specific survived and fecundity parameters, were used to determine these variations among populations of various hosts and locations in Middle Egypt.

Results suggest that whiteflies are of two groups but recently derived from the same source. The data also verify the occurrence of the strain "B" in Middle Egypt agricultural areas.

The implications of this introduction on virus epidemiology and crop production in those areas are discussed.

Introduction

The sweetpotato whitefly *Bemisia tabaci* (Genn.) continues to be a deva-stating pest of cotton, vegetable crops, medical and ornamental plants and greenhouse crops in Egypt (Makadey et al, 1994) and all over the world (Cock, 1986 and Byrne et al, 1990). In most cultivated areas, sequential planting of cole crops, cucurbits, cotton, tomato, alfalfa and potato offers a continuum of year-around susceptible host material and the opportunity for whiteflies to move within and among cropping systems to expand population development.

In cotton, attention is currently being directed toward *B. tabaci* as a pest as it produces honeydew exudate which promotes development of sooty mold fungi (*Alternaria* spp. and *Caldosporium* spp.) (Johnson et al, 1981 and Hudkinson, 1989) and inhibits photosynthesis. The problem of particular concern is that of sticky cotton that severely reduces cotton lint quality (Carter, 1990).

The reasons for the change in status of *B. tabaci* in Egypt from a member of the indigenous insect population to a major pest and important virus vector are not completely understood, but it may be related in part to the emergence of a new biotype.

Bemisia tabaci was first described as a pest of sweetpotato, only slightly more than one hundred years ago (Cock, 1986). Many additional species of *Bemisia* have been described worldwide (Martin, 1987). Recently, two *B. tabaci* biotypes have been described in Ivory Coast based upon both host preference and differential isozyme patterns (Burban et al, 1992 and Brown, 1992).

In Israel, isozyme differences were documented for several populations of agricultural importance and variability was attributed in part to differential pesticide resistance (Wool and Greenberg, 1990). Similar analysis of populations in Colombia revealed patterns of *Bemisia tabaci* collected from distinct geographic regions (Wool et al, 1991).

In contrast, a new biotype with a broad host range and host association (high fecundity) with poinsettia *Euphorbia heterophylla* Pluch has recently become of paramount importance in the US and Caribbean basin (Costa et al, 1992). The biotype is distinguishable from the indigenous population by the ability of induced phytotoxic disorder in *Cucurbita* species (Costa and Brown, 1990), *Brassica* species (Brown et al, 1992b) and tomato (Schuster et al, 1990). This biotype has been termed "B" biotype which has lately been confirmed as a new species nominated as *B. argentifolii* (Bellows & Perring) (Bellows et al, 1994).

In Egypt, the lack of information on whitefly behaviour, biology, genetics and physiology has limited the utility and application of the term biotype or strain to *B. tabaci* as an insect pest species. Presently, it is not known whether differences in *B. tabaci* populations extemporaneously ascribed to plant host preference arise as result of nongenetic polyphenism, or polymorphic or polygenic variation and/or of geographical restrictions. Indeed, some *B. tabaci* populations may eventually be recognized as host races, while others may be defined as geographic races with less dependence on host association (Deih and Bush, 1984).

A greater appreciation of interspecific differences among whiteflies and a more definitive understanding of the parameters and consequences of biotype level variation are needed for *B. tabaci*. Nevertheless, the recent surgence of *B. tabaci* as an important virus vector and pest of a wide range of agricultural crops has likely provided the impetus to accomplish some of these goals, and thus learn more

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about fundamental aspects of whitefly biology and important geographical patterns.

The objectives of our study were to quantify some thermal statistics, growth parameters and host plant associations of whitefly populations among various host plant species in Middle Egypt and to make a preliminary identification of whitefly biotypes or strains. In addition, host-choice and virus-vector capabilities were compared.

Materials and Methods

Data were collected in commercial fields of cotton and vegetable crops in Minia governorate (Middle Egypt) during 1994 and 1995 seasons. Eleven host plant species were used in the present study: tomato, potato, melon, cucumber, clover, cotton, eggplant, capiscum, squash, lettuce and coli. Studies were replicated in more than one location for each host plant under different weather and control conditions. Moreover, treatments were repeated several times over the season to be tested under a wide variety of temperature.

Development:

Small clamp-on cages described by Prabahker et al, 1985 were modified to permit observation of whiteflies. The bottom of a (0.3 liter) plastic vial was cut off and discarded. The opened bottom of the vial was fixed with a hot-glue gun to one side of the spring clamp. A hole was punched in the vial cap with a hole punch and covered with screening to provide ventilation. All testing was done in the field. Leaves were cleaned before placing into the cage to exclude the natural enemies. No insecticide treatments were carried out in these experiments.

Multi-choice studies:

Whitefly adult numbers per leaf of the tested host plants were recorded and used as a criteria for feeding preference. Meanwhile, the immature numbers were used as a parameter for oviposition site preference.

No-choice studies:

Leaves free of adult whiteflies but containing pupae were taken from each host plant in different treatments during the afternoon. Before use each leaf was placed in a round friction-sealed plastic petri dish (6.5 cm diameter, 2 cm high). Enough leaves were treated in this manner to insure obtaining virgin individuals.

One virgin female and two male adults that emerged by the following morning were caged in the center of the bioaxial surface of a fully expanded leaf. Whiteflies from each population were tested on the plants of the same host species. Ten replicates for each treatment were set up on successive days and continued until approximately twenty replicates were completed. Males that died over the course of experiment were replaced, however, the replicate ended if a female died. Replicates were changed to new leaves every other day and number of eggs was recorded.

Thermal threshold and constants were estimated according to the methods of Sevacherian et al (1976) and Park (1988). Survivorship and fecundity patterns were obtained from cohorts of ten to fifteen adults for each treatment and the following statistics, described by Birch (1948), were derived from our data: intrinsic rate of natural increase (r_m), finite rate of increase (λ) and population doubling time (DT).

Host plant associations:

Final distribution of whitefly on the plants is determined by whitefly preference following feeding rather than attraction while landing. In most of the cases, a positive correlation exists between *B. tabaci* population and the spread of persistent and semi persistent viruses. The growth rate of popula-tions can be used as parameters for host suitability (Hastings, 1980). This rate can be measured directly or estimated through autecological experiments for *B. tabaci* development time, pre-adult mortality, fecundity and longevity. Host plant suitability and consequently pest feeding and oviposition lead to high performance, expressed in high population growth and development parameters as well as longer feeding periods and as a result increased capabilities as virus vector.

Transmission efficiency:

The two populations were compared for the ability to transmit two different whitefly-transmitted geminiviruses of tomato. Non-viruliferous adult *B. tabaci* were allowed 24, 48 and 72 hr acquisition-access feeding period (AAF) on virus-infected tomato plants. Either 2, 5 or 10 inoculative whiteflies were transferred to healthy tomato seedlings using an aspirator and caged on test plants for a 3-day inoculation-access feeding period (IAF). Whiteflies were killed and plants were maintained in an insect-free cage for 4 weeks. Test plants were evaluated for development of characteristic virus symptoms and transmission efficiencies were calculated. Tomato leaf curl virus and yellow leaf curl mosaic virus were the two viruses used in these experiments. In order to reduce variability which could result from differences in host feeding preferences of the two populations (biotypes), a host plant (tomato) shared in common by the two viruses was thus chosen as the virus source plant and as the test plant.

Results and Discussion

The "A" indigenous whitefly population was observed more than hundred years ago and was essentially associated with more rural areas. Monitoring of whitefly populations on the basis of some thermal and growth parameters revealed a mixture of different biotypes on various host plants and locations (Tables 1 and 2).

Populations on the same host plant species at different situations showed varied values for thermal and growth characteristics. On the other hand, each population showed its own biological characteristics on the tested host plant species (Tables 1 and 2).

Data in Table 3 clearly indicate the presence of three different whitefly biotypes, one of them has a very strong biological and ecological character-istics with lower values for development thermal threshold (8.3-8.75^{0}C), higher values for upper temperature (38-41^{0}C) and higher values for population growth parameters than the "A" biotype of *B. tabaci* whereas, the second one ranked nearly in between with variable values for biological characteristics. The new biotype reached about 64% of the total samples, indicating a rapid shift from the original population to another new one (Table 3).

In whitefly, variation in host plant preference, life cycle and even disease-transmission capacity can be expressed between populations in different locations and hosts.

Whitefly-host plant associations:

Host range and preference:

Data in Table 4 revealed that whitefly populations when given a choice showed a clear oviposition and feeding preference. Because whiteflies develop from egg to adult on a single plant, species used by these populations is mediated by their respective oviposition preference. The new biotype has a considerably wider host range than the indigenous one, allowing it to colonize a large number of agricultural and weedy plants. Similar results were recorded by Byrne and Miller, 1990 and Perring et al, 1992. The mechanism that allows homopterous insects to exploit a wide array of plant is not well understood.

Mechanisms can however, be divided into behavioral and physiological adaptations (Via, 1986). Concerning behavioral adaptations, oviposition preference is of primary importance. Physiological adaptation is only important if behavioral allows an insect to develop on the host in question.

The importance of oviposition preference is intensified for insects, such as whiteflies, having juveniles that develop from egg to adult on a single plant. The present data clearly indicate that some whitefly populations have large host range, relative to *B. tabaci*. This had led us to examine the mechanisms that may be responsible for this difference in host range.

The ability to develop on a multitude of host plants would certainly benefit an insect when resources are available within and among seasons (vegetable crops). Additionally, this ability might allow these biotypes to escape from natural enemies that are associated with a particular host plant. The host plant preference pattern of whiteflies correlates well with host plant suitability for adult insects utilizing that plant for food and/or oviposition.

Feeding host preference:

Based on number of adult whitefly per leaf in a habituation studies, the following preference ranking was obtained: cotton> tomato, squash> cucumber> melon> eggplant> capiscum> potato (Table 4).

Oviposition site preference:

Oviposition preference, based on mean number of immatures per leaf showed a completely different ranking as follows: squash> cucumber> cotton> melon> tomato> eggplant> potato> capiscum. Meanwhile, biotype "B" showed higher preference levels as compared to "A" biotype on the same host plant species. The new biotype also, was found to be colonized on some new host plants (lettuce and coli) (Table 5).

B. tabaci populations generally have relatively wide host range with apparent specialization (Burban et al, 1992), however dramatic differences in prefer-ence for a host based upon relative growth measurement may be indicative of a recent or transient change in population when typically characterized by having a wide host range and suggests that habituation does not occur.

Host plant suitability (no-choice study):

Host plant suitability is defined as the aspects of the host that affect the preference of immatures or adults utilizing that plant as food or for oviposi-tion (Singer, 1986). Since generations of the tested populations of whitefly overlap, the development and growth rates of a population can be used as parameters for host suitability (Caswell and Hans, 1980). Thus, tomato, cucumber, melon and squash showed higher suitability rates as whitefly ("A" and "B") hosts. On the same time, data indicate a considerably wider host range with higher suitability rates for the new biotype, allowing it to colonize a larger number of agricultural plants including lettuce and coli. It is possible that the hosts to which *B. tabaci* populations have been most recently exposed (lettuce and coli) are those upon which developmental and growth rates are relatively most favorable.

Preference-performance study:

Greater host preference correlates with a greater number of whiteflies where-as, higher rates of individual development and population growth parameters (finite rate of increase and population doubling time) also reflected a higher degree of suitability for the tested host plants. Data presented in Table 5 indicate the relationship between preference and performance of whiteflies and their host plants. Whitefly "A" showed higher preference rates to certain host plants including clover and cotton but with poor host suitability as indicated in lower values of developmental rates and growth parameters. On the other hand, some hosts showed poorer performance but with high suitability rates for the pest achieving higher rates for development and population growth characteristics (potato and eggplant). Some host plant species (tomato) showed high preference and suitability rates and others (capiscum) were of lower preference and suitability rates.

The same pattern of response was observed for the whitefly "B". Moreover, all pest individuals on squash, cucumber, lettuce and coli were of "B" biotype while they were of "A" biotype on melon cultivated in reclaimed lands of an isolated desert.

Epidemiological studies:

Capabilities of whiteflies as virus vector:

Whitefly-borne diseases are of major importance in tropical and subtropical agriculture. Among the factors associated with the epidemiological cycles are: vector population spread and behaviour and host plant susceptibility. Recognition of the factors involved to efficiently control the disease by attacking the cycle at its weakest point is important. This point may differ with the insect-virus-vector combination.

In virus transmission studies, both "A" and "B" biotypes were successful vectors of the two geminiviruses of tomato, leaf curl virus (LCV) and yellow leaf mosaic virus (YLMV), but "B" biotype showed higher efficiencies as virus vector (Table 6). High transmission efficiencies were positively correlated with an increase of inoculative adults and/or feeding duration.

Association between B. tabaci population dynamics and distribution and spread of virus:

Because the biological characteristics (host range) and phytotoxic disorders associated with the "B" biotype of *B. tabaci* have not been observed until quite recently, either an exotic insect has been introduced or genetic changes have occurred in the local population. If the latter is the case, the data pre-sented here may be taken as evidence in favor of the argument that the genetic change has occurred probably to the whitefly populations in certain areas where they are subjected to high pressure of pesticides in the regular pest control programs.

In most of the cases a connection was found between the vector's population and the spread of the virus. Therefore, reduction of *B. tabaci* population before whiteflies migrate from the breeding hosts may consequently reduce virus spread. In many cases, cultivated crops of high preference as sites of oviposition such as cucurbits, cotton and tomato are these breeding hosts.

The obtained results suggest the presence of "B" biotype of whitefly as an important virus vector with a wider host range, broader temperature range and high rates of individual development and population growth. In short, further taxonomic work must be field oriented, involving studies on the living insects both as immatures and as adults, in addition to utilizing of morphological, biochemical and genetic characteristics.

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Table 1. Thermal and growth parameters for whitefly populations on various hosts and locations (1994).

Host/ Location		t_o	t_u	T_c	r_m	F	DT
	1	8.55	39.5	0.33	0.182	1.990	3.81
	2	8.26	39.9	0.32	0.193	1.212	3.59
Tomato	3	8.60	38.3	0.33	0.185	1.203	3.75
	4	10.20	32.0	0.24	0.098	1.103	7.10
	1	10.70	36.0	0.50	0.094	1.098	7.37
	2	8.60	40.2	0.33	0.192	1.121	3.61
Potato	3	9.00	38.5	0.28	0.151	1.163	4.59
	4	8.66	39.9	0.36	0.193	1.213	3.59
	1	9.60	34.0	0.29	0.123	1.300	5.63
	2	9.20	33.5	0.29	0.116	1.123	5.97
Melon	3	9.50	32.0	0.26	0.112	1.118	6.19
	4	10.50	32.5	0.24	0.098	1.100	7.10
	5	9.10	36.5	0.25	0.130	1.139	5.30
	1	8.50	38.3	0.34	0.186	1.204	3.73
	2	8.60	38.5	0.33	0.194	1.214	3.57
Cucumber	3	10.60	31.5	0.23	0.097	1.100	7.1
	4	8.75	39.0	0.32	0.175	1.191	3.96
	1	8.60	39.2	0.33	0.188	1.207	3.69
Clover	2	10.40	32.0	0.24	0.091	1.095	7.62
	3	8.50	40.1	0.34	0.186	1.204	3.73

t_o = lower thermal threshold
t_u = Upper thermal threshold
T_c = Thermolability coefficient
r_m = Intrinsic rate of natural increase
F = Finite rate of increase
DT = Population doubling time

Table 2. Thermal and growth parameters for whitefly populations on various hosts and locations (1994).

Host/ Location		t_o	t_u	T_c	r_m	F	DT
	1	8.70	40.2	0.33	0.18	1.20	3.77
	2	8.66	39.5	0.33	0.19	1.21	3.63
Cotton	3	8.75	39.6	0.32	0.18	1.20	3.85
	4	8.55	40.1	0.33	0.19	1.21	3.65
	5	9.00	36.5	0.25	0.16	1.18	4.20
	6	10.50	31.5	0.22	0.09	1.10	7.45
	1	8.70	40.2	0.32	0.18	1.20	3.77
Eggplant	2	10.20	32.6	0.23	0.09	1.10	7.21
	1	8.55	39.7	0.33	0.19	1.21	3.65
Capiscum	2	8.50	40.0	0.34	0.18	1.20	3.79
	3	10.60	33.2	0.22	0.09	1.10	7.40
	1	8.60	39.6	0.33	0.19	1.21	3.65
	2	8.45	39.8	0.34	0.19	1.21	3.57
Squash	3	8.33	40.2	0.33	0.20	1.22	3.48
	4	10.40	32.0	0.22	0.10	1.10	7.07
	1	8.50	38.5	0.33	0.19	1.21	3.67
Lettuce	2	8.60	39.0	0.33	0.18	1.20	3.83
	1	8.40	40.1	0.34	0.20	1.22	3.55
Coli	2	9.30	39.8	0.28	0.16	1.18	4.22

Table 3. Whitefly populations classified on the basis of thermal statistics and growth parameters.

Popula- tions	t_o	t_u	T_c	r_m	F	DT	%
1	8.3-8.8	38-41	0.32-0.34	0.18-0.20	1.19-1.22	3.6-4.0	64
2	9-10	34-38	0.26-0.29	1.1-1.6	1.12-1.18	4.2-6.2	19.4
3	10-10.7	31-34	0.25-0.29	0.09-0.10	1.09-1.10	7.1-7.6	16.6

Table 4. Mean number of adult and immature whiteflies (A&B) per 2.5 cm leaf on various host plants in multi-choice situation.

Host plant	WF	Avg No. of adults	Avg No. immature
Tomato	A	31.50	8.25
	B	74.50	23.20
Potato	A	11.75	4.50
	B	20.50	9.00
Melo	A	15.40	11.50
	B	51.30	96.50
Clover	A	22.50	16.66
	B	73.50	28.25
Cotton	A	37.50	32.30
	B	77.60	56.00
Eggplant	A	15.40	71.60
Cucumber	B	23.50	11.50
Capiscum	A	17.50	5.50
	B	27.60	9.00
Squash	B	71.50	125.7
Lettuce	B	80.50	106.5
Coli	B	79.66	108.3

Table 5. Preference-performance (host suitability) of whiteflies on various host plants in Middle Egypt.

Host plant	WF	Avg. No. of WF	Rate of develop.	Finite rate	Double time
Tomato	A	19.9	0.048	1.1	7.07
	B	48.8	0.056	1.2	3.59
Potato	A	8.1	0.046	1.1	7.37
	B	14.8	0.055	1.21	3.59
Melon	A	13.5	0.047	1.11	6.18
Cucumber	B	78.9	0.057	1.21	3.57
Clover	A	19.6	0.048	1.09	7.62
	B	65.9	0.056	1.21	3.68
Cotton	A	34.9	0.047	1.10	7.50
	B	66.8	0.057	1.20	3.80
Eggplant	A	11.5	0.048	1.10	7.20
	B	17.5	0.058	1.20	3.80
Capiscum	A	11.5	0.049	1.10	7.40
	B	18.3	0.055	1.21	3.60
Squash	B	98.6	0.056	1.22	3.50
Lettuce	B	93.5	0.056	1.21	3.70
Coli	B	94.0	0.058	1.22	3.60

Table 6. Relative percent transmission efficiencies of whiteflies (A&B) of TLC and YLC on tomato.

		% transmission					
-		Duration					
-		24 hr		48 hr		72 hr	
Virus	No. WF	A	B	A	B	A	B
	2	1	11	2	19	6	37
V I	15	3	29	9	42	11	75
	10	6	52	16	83	26	91
	2	3	15	4	25	7	32
V II	5	6	30	10	51	15	78
	10	11	66	18	90	25	95
0	0	0	1	0	2	2	3