Effect of different host plants on population development of the sweetpotato whitefly (*Bemisia tabaci* Genn., Homoptera: Aleyrodidae)

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ملخص

أجريت تجارب في البيوت الزجاجية لدراسة تأثير عوائل نباتية مختلفة على تطور تعداد حشرة ذباب البطاطا الحلوة البيضاء.

لقد أكملت الحشرة دورة حياتها على نباتات الفاصوليا في ٣٠٫٢ يوما، بينما تراوحت فترة دورة الحياة على نفس درجات الحرارة والرطوبة ما بين ٢٢٫٣ – ٢٣٫٥ يوما على نباتات الخيار والباذنجان والكوسا والبندورة. كما أن فترة بقاء الحشرات الكاملة حية كانت أطول (١ – ٢٩ يوماً) على نباتات البندورة والباذنجان منها على نباتات الكوسا (٢ – ٢٣ يوما) والفاصوليا (٣ – ٢٠ يوما) والخيار (٢ – ١٩ يوم). وكانت نسبة الاناث الى الذكور في الحشرات الكاملة اعلى ما يمكن على نباتات الباذنجان (١٫٦٣ : ١)، تلاها وبشكل متناقص النسبة على نباتات الكوسا (١٫٥٥ : ١) والفاصوليا (١٫٤٦ : ١) والخيار (١٫١٣ : ١) والبندورة (١٫٠٧ : ١).

لقد وضعت الاناث المخصبة أعلى عدد من البيض على نباتات البندورة (٧٫٨٢ بيضة/ سم^{٢}) تلاها وبشكل متناقص الاعداد التي وضعت من البيض على كل نباتات الكوسا (٢٫٦١) والباذنجان (٠٫٩٤) والفاصوليا (٠٫٧٧) والخيار (٠٫٧٢). الا أن نسبة الموت في الاطوار غير الكاملة كانت أقل ما يمكن على نباتات الباذنجان (١٢٫٠٨) والخيار (٢٥٫٥٧ ٪) والكوسا (٢٧٫٣٥ ٪) وعليه فان الكثافة العددية للحشرة كانت أعلى ما يمكن على نباتات البندورة (٣٣٫٨٦ حشرة/ سم^{٢}) ومن ثم على نباتات الكوسا (٨٫٦٤)، وكانت متوسطة على نباتات الباذنجان (٤٫١٢) والفاصوليا (٣٫٩٨)، بينما كانت أقل ما يمكن على نباتات الخيار (٢٫٥٢).

في ضوء النتائج المتحصل عليها تم تقدير اعداد الحشرة لثلاثة اجيال متتالية على العوائل النباتية المختبرة. وبناء على ذلك فقد اقترح نظام زراعة جديد يمكن من خلاله مقاومة ذبابة البطاطا الحلوة البيضاء والحد من انتشار مرض اصفرار والتفاف اوراق البندورة الفيروسي.

Abstract

Greenhouse experiments were conducted to study the effect of different host plants on population development of the sweetpotato whitefly, *Bemisia tabaci* Genn.

Whiteflies reared on common bean plants completed development in 30.2 days, whereas those reared at the same temperature and relative humidity (22-23 C^0, 57-61 %RH) on cucumber, eggplant, squash and tomato plants required 22.3-23.5 days. Female whiteflies lived for a longer time (1-29 days) on tomatoes and eggplants than on squash plants (2-23

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days), beans (3-20 days) or cucumbers (2-19 days). Sex-ratio (♀ :♂) in adult whiteflies was the highest for those reared on eggplants (1.63:1), followed in descending order by squash plants (1.55:1), beans (1.46:1), cucumbers (1.13:1) and tomatoes (1.07:1).

Gravid female whiteflies laid the highest number of eggs on tomatoes (8.72 eggs/cm^2), followed in descending order by squash (2.61), eggplant (0.94), bean (0.77) and cucumber plants (0.72). However, mortality in the immature stages was the lowest on eggplants (12.08%), followed in ascending order by tomatoes (16.27%), beans (23.44%), cucumbers (25.57%) and squash plants (27.35%). Thus, whitefly population density was highest on tomatoes (33.86 inividuals/cm^2), followed by squash plants (8.64). It was intermediate on eggplants (4.12) and beans (3.98) and lowest on cucumbers (2.52).

In view of the aforementioned results, population build-up of whiteflies was estimated for three generations on the different tested host plants. Accordingly, a cropping pattern for controlling whiteflies and reducing the incidence of virus dieases transmitted by them was suggested for the Jordan Valley.

Introduction

Approximately 70% or 20,000 hectares of the total arable area of the Jordan Valley (JV) is planted to vegetable crops annually. Three fourths of this vegetable area grows tomatoes, cucumbers, squashes, eggplants and common beans (Anon, 1980). These crops are attacked throughout the year by the sweetpotato whitefly[1], *Bemisia tabaci* Genn., (Sharaf and Allawi, 1980), the vector of tomato yellow leaf curl virus (TYLCV) (Makkouk, 1978) and cucumber vein yellowing virus (CVYV) (Qusus and Al-Musa, 1983). These viruses are major problems to tomato and cucurbits crops, often causing yield reductions ranging from 50 to 100% (Al-Musa. 1982; Cohen and Nitzany, 1960).

The population density of *B. tabaci* is higher and the incidence of the diseases is greater in the fall/winter growing season than in the spring/summer season (Sharaf, 1981; Al-Musa, 1982), a situation attributed mainly to changes in weather conditions (Sharaf, 1981). In addition, cropping pattern might have a significant role in the wide fluctuations of whitefly populations within and/or between the two growing seasons and, consequently, in the extent of viral infections. In the JV, eggplants remain for two consecutive years in the same area. Beans, squashes, tomatoes and cucumbers are planted in overlapping sequence of time and in adjacent areas during the fall/winter season, whereas the same crops occupy the cultivated vegetable area at the same time during the spring/summer season.

The objectives of this study were to evaluate the effect of different host plants on population development for the sweetpotato whitefly, and to investigate the effect of the cropping pattern adopted by Jordanian farmers on whitefly multiplication.

Material and methods

Insect rearing

Adult whiteflies were collected from infested plants in the JV. They were reared on *Lantana camara* L. shrubs raised in insect-proof cages at the greenhouse of the Faculty of Agriculture, University of Jordan, Amman, Jordan, to establish a culture for further infestation procedures.

Host-plants

Five host plants commonly cultivated in the JV were chosen for this study: the common bean (***Phaseolus vulgaris*** L.), cucumber (*Cucumis sativa* L. var. Special), eggplant (*Solanum melongena* L. var. Black Beauty), squash (*Cucurbita pepo* L. var Tala), and tomato (*Lycopersicon esculentum* Mill. var. Claudia RAF). Seeds of those plants were sown on June 7,1982 in plastic pots (12.5 cm in diam). A mixture of peatmoss and sand (2:1) was used as a potting medium. Seedlings were raised in insect-proof cages at the greenhouse of the Faculty of Agriculture. They were thinned to one seedling per pot before infestation. Irrigation was done when needed.

Infestation

Seedlings of each plant were infested with whiteflies as described by Wardlow et al. when they reached the 2-leaf stage (1972). They were exposed to heavy infestations of whitefly cultured on *L. camara* to allow oviposition for 24 hrs, then adults were removed by blowing. Thereafter, seedlings were kept in insect-proof cages at the greenhouse.

Assessment

At the time of infestation, plant length and leaf area were measured. Measuring the leaf area was accomplished by using an areameter apparatus "Model 3100". Also, the time elapsed between sowing and infestation dates for each host plant was recorded. This was done to establish variations in growth characteristics and speed of development between the five selected host plants.

Duration and number of each stage of whitefly development were determined in order to estimate the length of its life cycle and to calculate population density (whitefly/cm^2) on each host plant. Dead and alive individuals in life stages on each host plant were daily observed at 2 pm. The mortality percentage was assessed. A random sample (68-121) of newly emerged adult whiteflies on each host plant was taken. Adult whiteflies were sexed and the sex-ratio was determined. Also, adult longevity was determined by confining a host plant in a small plastic cage under

prevailing greenhouse conditions (22-23^{0}C, 57-61% RH) until all emerged adults died. Longevity range and mean in days were recorded. The population size on each host plant was calculated as follows:

Population size (F_1) = Total Leaf area × 2 (2 Leaves of each plant were only infested) × population density.

Population development up to the third generation (F_2 and F_3) was calculated as follows:

$$F_2 (F_3) = [(F_1 (F_2) - (F_1 (F_2) \times \% \text{ Mortality})] \times \% \text{ adult females} \times \text{egg density} \times \text{leaf area} \times 2$$

Weather records

Temperatures and relative humidities were recorded simultaneously throughout the experiments periodically by thermohygrographs in the test cages. Mean temperature and relative humidity for each experiment on each host plant was calculated by averaging daily maximums and minimums.

Statistical analysis

A completely randomized design was used for the experiments. Three plants representing three replicates were used for each stage, with a total of 15 plants (5 stages ×3replicates). Another three plants were used in each experiment to follow the development of the different stages of whitefly.

Data were statistically analysed using the analysis of variance. Means separation was performed using Fisher's least significant difference at 95% level of confidence. Also, horticultral data were statistically analysed using the standard deviation from the mean.

Results

1 . Effect of host plant on population development of whitefly

The duration of the life cycle of *B. tabaci* was significantly longer on beans than on the other four hosts (Table 1). However, bean and cucumber plants sustained significantly lower population densities of whiteflies than squash and tomato plants. The highest population density was on tomatoes, while it was intermediate on eggplants (Table 2).

Although there were no significant differences in the overall average whitefly mortality on the different host plants, larval mortality was significantly higher on cucumbers than on eggplants. It was also higher on cucumbers than on squashes,

beans and tomatoes, but the differences were not significant. In particular, the first larval instar mortality was significantly higher on cucumbers than on the other four hosts (Table 3). Also, there were no significant differences in the adult longevity on the different hosts (Table 4).

Almost equal proportions of females and males were found in the adult populations of whiteflies reared on tomatoes and cucumbers. However, beans, squashes and eggplants supported higher ratios of adult females than males (Table 4).

2 . *Growth Characteristics of Host Plants*

Squash plants reached the 2-leaf stage in the shortest time (17 days), attained the highest length (35.86 cm), and had the largest leaf area (88.58 cm^2). This was followed by beans. Cucumber plants ranked third in developmental period and plant length. However, cucumber leaves were smaller in size than those of eggplant. Tomato plants were fourth in developmental period and plant length; their leaves were the smallest in size. Eggplants ranked fifth in developmental period and in length (Tables 5).

Table 1. Life Cycle Duration of Immature ***Bemisia tabaci*** on Tested Hosted Host Plants. (Temperature: 22-23 C^0; Relative humidity: 57-61%).

Host plant	Mean[1,2] duration of the different immature stages in days						Average duratio of the immature stages in days.
	Egg	Larval instars 1st	2nd	3rd	Larva	Pupa	
Bean	9.5 c	4.5 b	3.7 c	5.0 b	13.2 c	7.5 b	30.2 b
Cucumber	7.5 a	2.7 a	2.3 ab	3.0 a	8.0 a	7.0 b	22.5 a
Eggplant	8.5 b	2.8 a	2.0 a	3.0 a	7.8 a	6.0 ab	22.3 a
Squash	7.5 a	2.3 a	2.8 abc	4.5 b	9.5 b	6.5 b	23.5 a
Tomato	7.5 a	3.0 a	2.8 abc	4.1 ab	9.9 b	5.0 a	22.4 a
LSD	0.96	1.36	1.03	1.37	1.25	1.62	2.20

1 - Mean of three replicates.

2 - Figures with the same letter in each column are not significantly different at the 5% level of probability using Fisher's Least Significant Difference Test.

Table 2. Population Density of Immature *Bemisia tabaci* during its Life Cycle Period on Tested Host Plants.

	Average[1,2] number of whitefly individuals per cm^2							Overall
	Egg	Larval instars 1st	2nd	3rd	Larva	Pupa	Pupal case	average whitefly density
Bean	0.77 a	0.77 a	1.57 a	0.58 a	2.92 a	0.22 a	0.07 a	3.98 a
Cucumber	0.72 a	0.65 a	0.30 a	0.32 a	1.27 a	0.12 aa	0.41 a	2.52 a
Eggplant	0.94 a	0.90 a	0.56 a	1.20 a	2.66 a	0.65 a	0.66 ab	4.12 ab
Squash	2.61 b	2.51 b	0.57 a	1.18 a	4.26 a	0.95 a	1.18 bc	8.64 b
Tomato	8.72 c	8.03 c	8.20 b	4.25 b	20.48 b	3.26 b	1.41 c	33.86 c
LSD	1.63	1.60	1.51	1.32	3.14	1.21	0.72	5.61

1 - Mean of three replicates.
2 - Figures with the same letter in each column are not significantly different at the 5% level of probability using Fisher's Least Significant Difference Test.

Table 3. Mortality (%) in the Immature Stages of *Bemisia tabaci* on Tested Host Plants.

Host plant	Avg.[1, 2] % mortalityin individual whiteflies at different Laveal instars						Overall average mortality in %
	Egg	1st	2nd	3rd	Larva	Pupa	
Bean	1.64 a	1.85 a	49.76 c	64.16 ab	31.51 ab	26.92 a	23.44 a
Cucumber	12.57 a	36.42 b	37.52 bc	33.41 b	35.76 b	27.63 a	25.54 a
Eggplant	4.12 a	10.48 a	15.75 ab	7.36 a	10.01 a	36.15 a	12.08 a
Squash	3.20 a	3.96 a	55.81 a	66.75 c	33.00 ab	39.17 a	27.35 a
Tomato	8.91 a	9.46 a	17.62 ab	22.72 ab	15.55 ab	36.45 a	16.27 a
LSD	12.57	13.70	22.45	17.97	23.95	15.44	15.94

1 - Mean of three replicates.
2 - Figures with the same letter in each column are not significantly different at the 5% level of probability using Fisher's Least Significant Difference Test.

Table 4. Adult Longevity and Sex-ratio of *Bemisia tabaci* on Tested Host Plants.

Host plant	Longevity mean[1, 2] in days		Longevity average in days		Sex-ratio
	Female	Male	Female	Male	Female: Male
Bean	12.04 a	9.06 a	3-20	4-13	1.46: 1
Cucumber	9.13 a	8.22 a	2-19	2-14	1.13: 1
Eggplant	13.96 a	8.25 a	1-29	1-18	1.63: 1
Squash	12.14 a	7.77 a	2-23	2.14	1.55: 1
Tomato	12.82 a	8.17 a	1-29	1-19	1.07: 1
LSD	5.35	4.19			

1 - Mean of three replicates.
2 - Figures with the same letter in each column are not significantly different at the 5% level of probability using Fisher's Least Significant Difference Test.
Longevity mean[1, 2]
in days

Table 5. Some Horticultural Data of Tested Host Plants of ***Bemisia tabaci*** at the Second Leaf-stage.

Host plant	Developmental period in days	Average[1] plant length in cm	Average[2] leaf area in cm[2]
Bean	22	34.70 ± 4.06	75.70 ± 21.46
Cucumber	31	26.63 ± 3.96	44.74 ± 16.13
Eggplant	56	9.65 ± 1.55	48.25 ± 14.09
Squash	17	35.86 ± 2.62	88.58 ± 17.71
Tomato	42	14.68 ± 1.69	14.13 ± 6.08

1 - Average of 15 plants.
2 - Average of 30 leaves.

3 . Population Development of Whiteflies

The estimated populations of *B. tabaci* in three successive generations on different host plants infested at the 2-leaf stage are presented in Table 6. By the first generation, squash supported the highest population of whiteflies (1530.66 individuals), followed in descending order by tomato, bean, and eggplant. The lowest population (225.49) was estimated on cucumber plants. Populations increased in

proportion to the population size (F_1) on the different host plants by the second and third generations. They attained very high numbers in the third generation, especially on squash, tomatoes and beans. Whitefly populations developed slowly on cucumber plants *(F_2/F_1) = 25.42; F_3/F_1 = 646.46),* moderately on eggplants and beans *(F_2/F_1 = 49.43 and 52.66; F_3/F_1 = 2443.35 and 2772.95* for eggplants and beans, repectively), and rapidly on tomatoes and squashes *(F_2/F_1 = 106.65 and 204.07; F_3/F_1 = 11 375.17 and 41 646.64* for tomatoes and squashes, respectively) (Table 6).

Table 6. Estimated Population of of ***Bemisia tabaci*** in Three Successive Generations on Certain Host Plants Infested at the Second-leaf stage (22-23 C^0, 57-61% RH).

Host plant	F_1	F^2	F_2/F_1	F_3	F_3/F_1
Bean	602.57	31730.75	52.66	1670901.20	2772.95
Cucumber	225.49	5733.04	25.42	145771.28	646.46
Eggplant	397.58	19652.42	49.43	971427.63	2443.35
Squash	397.58	19652.42	49.43	971427.63	2443.35
Tomato	956.88	102055.42	106.65	10884721.00	11375.17

Discussion

The rate of increase of *B. tabaci* is not only affected by weather conditions (mainly temperature and relative humidity), but also by the host plant and other environmental factor. Host plant affects survival, longevity, reproduction, and rate of development.

Growth and development of *B. tabaci* are greatly affected by the nutritional value of the host plant. *B. tabaci* reared on common beans completed development in 30.2 days, whereas those reared at the same temperature and relative humidity (22-23^{0}C, 75-61% RH) on cucumber, eggplant, squash and tomato plants required 22.3-23.5 days (Table 1). This difference in the duration of the life cycle of whiteflies on the different host plants was mainly due to prolonged duration of egg and larval stages on beans. Leaves of bean plants might contain toxic materials which retarded larval growth and development. Similar results indicated that the duration of the life cycle of *B. tabaci* is longer on urdbean and soybean plants than on sweetpotato and potato plants (Nene, 1972; Azab et al., 1971; El-Helaly et al., 1971).

Among the more important factors that affect population density of whiteflies are the longevity of the adult females, the sex-ratio, the egglaying capacity and the mortality in the immature stages. Adult female whiteflies lived for longer time on tomatoes and eggplants than squashes, beans and cucumbers. Also, the highest sex-

ratio was found on eggplants, followed in descending order by squashes, beans, cucumbers and tomatoes (Table 4). Adult longevity and sex-ratio are food-dependent if whiteflies are reared on different host plants under the same conditions. Differences in adult longevity on cotton and *L. camara* were reported by Gameel (1979) and Azab et al. (1971).

The number of whitefly eggs laid per cm^2 was higher on tomato plants than on squashes, and it was higher on squashes than on eggplants, beans and cucumbers (Table 2). Differences in the number of eggs laid on leaves of urd-and soybeans, sweetpotatoes, *L. camara* shrubs, and eggplants were reported by various workers (Nene, 1972; El-Helaly et al., 1971; Azab et al., 1971; Avidov, 1956). Chemical nature, texture, and microclimatic conditions of the leaves of the host plant are probably responsible for preferential behavior of egg-laying in *B. tabaci* (Gupta, 1973). This behavior might be also greatly affected by the type of hairs present on the lower surface of the leaves of different host plants, as well as by the density of the hair cover (Ohnesorge et al., 1980). Hairiness and chemical constituents of the leaves might also be responsible for the different mortalities in the larval stage of whiteflies reared on various host plants under the same conditions.

The highest population density found in whiteflies reared on tomatoes, followed in descending order by squashes, eggplants, beans and cucumbers agree with findings of Herakly and El-Ezz (1970). They indicated that whitefly infestation is heaviest on eggplants followed by tomatoes, and it is lower on broad beans.

O'Reilly (1974) studied the effect of plant species and tomato varieties on adult infestation rates, oviposition and the development cycle of the greenhouse whitefly, *Trialeurodes vaporarirum* Westw. He found significant differences in all factors examined for the ten plant species used in the experiment. The differences in susceptibility of the plant species tested indicate the presence of factors in some plants which make them less attractive for development and feeding by adults. Van Boztel et al., (1978), van de Merendonk and van Lenteren (1978) and Woets and van Lenteren (1979) found differences between eggplant, cucumber, tomato and sweet pepper: experiments where greenhouse whiteflies were allowed to choose one of the four host plant species showed that after a certain time, differences in the number of whiteflies were observed on each host plant species. This eventual choice, although not made before landing (Verschoor-van der Poel and van Lenteren, 1978) had an influence on rate and success of development. On plants with more whiteflies, the total number of eggs laid per female, the oviposition frequency and the life span of the females were greater, the development period was shorter and mortality was lower (all differences significant). The conclusion by van Lenteren et al. (1977) that "a good host plant for one aspect means a good host plant for all other asspects" is not supported by data of recent research done by van Sas et al. (1978) on the quality of three other host plant species (gherkin, melon and gerbera) for the greenhouse whitefly. Our findings on the quality of beans, cucumbers, eg-

gplants, squashes and tomatoes for the sweetpotato whitefly disagree also with the conclusion made by van Lenteren et al. (1977).

The quality effect of the different tested host plants on the population build-up of *B. tabaci* is illustrated theoretically for three successive generations (Table 6). This should be, however, taken with ultimate care, since the number of whiteflies used for the initial infestation of the different host plants was not fixed, the number of eggs laid per female in the time allowed was not representative of its fecundity; the distribution of the eggs on the leaves was assumed to be even, and the leafareawas assumed to represent the available area each plant offers for infestation. Nevertheless, it gives an idea about a cropping pattern which could be adopted in the JV to reduce whitefly populations and, consequently, to delay incidence of virus diseases. Accordingly, the traditionally used cropping pattern in which squash, tomato, bean, and cucumber are grown in overlapping periods and in adjacent areas to each other and to the perennial eggplant could be changed as follows:

i. Planting cucumber one month earlier than tomato, squash or bean.
ii. Separating tomato, squash, bean, and eggplant fields with cucumber fields; and
iii. Removing eggplant from fields annually.

This is a suggested cropping pattern for reducing the total population of whiteflies. Such cropping patterns were also recommended by other workers for controlling whiteflies on cotton and tobacco (Shaw, 1979; Monsef and Kashkooli, 1978; Habibi, 1975).

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