Host Plant Selection and Suitability to *Bemisia tabaci* (Gennadius) on Different Vegetable Crops Planted in Fall and Spring Growing Seasons in the Central Jordan Valley.

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DEDICATED TO MY PARENTS

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List of Contents

List of Figures

ABSTRACT

Host Plant Seleciton and Suitability to *Bemisia tabaci* (Gennadius) on Different Vegetable Crops Planted in Fall and Spring Growing Seasons in the Central Jordan Valley

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A field study was conducted at the University Agricultural Research Station (UARS) in the Central Jordan Valley (CJV), from September 27, 1995 to June 7, 1996, to determine the plant selection and suitability of six vegetable crops to the sweetpotato whitefly, ***Bemisia tabaci*** (Gennadius) in the two growing seasons. Tomato, cucumber, summer, squash, beans, eggplant, and sweetpepper were planted in five planting dates in an area of 3735 m^2 using 3 × 6 factorial arrangement within a radnomized complete block design (RCBD), starting on September 27, 1995 at about monthly intervals. Host selection was and suitability determined by counting eggs and immature whiteflies per leaf section (1.5 cm) in diametere respectively, at weekly intervals in the five planting dates.

Cucumber crop was the most selected host plant for ***B. tabaci***, followed in descending order by squash, tomato, bean eggplant, and sweet pepper.

Also, cucumber ranked first as the most suitable host plant, since the percentage reduction in whitefly populaiton was the least, followed by tomato, bean, squash, eggplant and sweet pepper.

Consequently, the most appropriate cropping pattern based on the frequency of host plants for whitefly selection and suitability can be as follows: sweetpepper < eggplant= bean< tomato< squash = cucumber.

INTRODUCTION

Vegetable crops are the most important cultivated plants in the Jordan valley (JV). They constitute 42% of the total area (230098.8 du.). These 42% are mostly planted with tomato, cucumber, summer, squash, beans, eggplant, and sweetpepper (Statistical Year Book, 1995). Vegetables are usually grown in fall and spring seasons at different planting dates (Sudah and Mustafa, 1977).

Sweetpotat whitefly ***Bemisia tabaci*** (Homoptera: Aleyrodidae) rank among the most noxious insects attacking field vegetables crops around the world (Mound and Halsey, 1978). In Jordan, the whitefly was reported attacking the six vegetable crops throughout the year (Sharaf, and Allawi, 1980). Immature stages as well as adults, feed on the phloem sap of the plant, and cause damage by excretions of honeydew which provides a suitable medium for growth of sooty mould fungus (***Chladosporium sp.***) (Avidov and Harpaz, 1969; Gameel, 1969; Nene, 1972; Stwal, 1976).
This fungus inteferes with photosynthesis and render fruits unmarketable Furthermore, whiteflies can act as vector for many virus diseases. In Jordan, ***B. tabaci*** transmittes tomato yellow leaf curl virus (TYLCV) (Makkouk, 1978) and cucumber vein yellowing virus (CVYV) (Al-Musa, 1982). These viruses are a major problem on tomatoes and cucurbits, often causing yield reductions ranging from 50-100% (Al-Musa, 1982).

The need for chemical control of ***B. tabaci*** is strongly debated at the present time. Chemical control is difficult and expensive, and may lead to decimination of natural enemies (Eveleens, 1983). The development or improvement of non-chemical control methods for whitefly requires a thorough understandig of the interactions between insects and their host plants, as well as the relations between whiteflies and their natural enemies (Gerling, 1990).

This study deals with the interactions between *B. tabaci* and some vegetable crops grown in the Jordan Valley. The objectives of this study were:

1. to determine the best planting date during each of the fall and spring growing seasons.
2. to investigate whitefly host selection on the six vegetable crops planted at various planting dates in each of the two growing seasons.
3. to investigate the suitability of the six vegetable crops for ***B. tabaci*** development, and
4. to recommend the most appropriate cropping pattern in the two growing seasons.

II. LITERATURE REVIEW:

Whiteflies are small phytophagous insects, with peircing sucking mouth parts. They belong to the order Homoptera, family Aleyrodidae. Homoptera also includes, aphids, coccids, scales, and psyllids.

II.1. Origin and Distribution of *B. tabaci*

The sweetpotato whitefly, ***B. tabaci***, is one of the 1200 species described (Mound and Halsey, 1978). It is found in tropical and subtropical areas, in Asia, Africa, Australia and Pasific Islands, North America, Central and West Indies of South America (Common. Inst. Ent., 1971). Recently, it was found in the greenhouses of Europe (Gerling, 1990).

II.2. Life Stages of *B. tabaci*

B. tabaci, has six life stages: eggs; crawler (1st nymphal instar); two sessile instars (2nd and 3rd nymphal instars); what so called "pupa" (4th nymphal instar); and adults (Gerling, 1990). These stages have been described in detail by many authers (Avidov and Harpaz, 1969; Hill, 1969; Batta, 1984).

II.3. Host Plants of *B. tabaci*

B. tabaci is a polyphagous insect. It has been recorded from over 360 plant species belonging to 64 plant families (Mound and Halsey, 1978). In Jordan, it was found feeding on 39 plant species belonging to 13 different families (Sharaf and Allawi, 1980).

II.4. Damage of *B. tabaci*

Whiteflies are minute insects, and may be extremely injurious. They are efficient vectors of plant viruses (Al-Musa, 1982). They feed on the plant sap, and when present in sufficient numbers cause leaf drop and prohibit the maturity of the fruits. Whiteflies also produce sticky honeydew which soil and damage crops, serves as a substrate for development of black sooty fungus that grows and prohibits normal respiration of leaves. Losses resulting from the various types of injury, mainly replacement of damaged plants and control of insects, amount to millions of dollars (Gerling, 1990).

II.5. Effect of Temeprature and Host Plant on Some Biological Aspects of *B. tabaci*

Time necessary for the different stages of ***B. tabaci*** to develop is temperature dependent, but at constant temperature, developmental time varies depending on host-plants involved (Gerling, 1990).

II.5.1 Life Cycle

The period elapsed between egg deposition and adult emergence is considered the duration of the life cycle. The life cycle of ***B. Tabaci***, on sweetpotato ranges from 14-75 days depending on the prevailing temperature throughout the year (Azab ***et al.***, 1971).

II.5.2 Longivity of Adults:

The longivity of ***B. tobaci*** adults is prologed during winter season and reduced during the summer season (Nene, 1972; Batta, 1984). Longivity of adults varied from 2-17 days for males and from 8-60 days for females on sweetpotato according to the prevailing temperatures in the different seasons of the year (Azab *et al.*, 1971).

II.6.1.1 Selection of Feeding and Oviposition Sites:

The relationship between selection of oviposition sites and growth, survival and reproduction of offsprings is a central element in the evolution of host association between herbivorous insects and plants (Singer, 1986; Thompson, 1988). For many insect species, the selection of an oviposition substrate is a critical phase in their life. Since nymphal instars of ***B. tabaci*** are completely sessile, except for the limited disperal of the crawler, oviposition site selection by female whiteflies has a profound effect on their fitness. As most whiteflies feed and oviposit on the same leaves, feeding and oviposition site selection go hand in hand (Gerling, 1990)

In variable environments, whiteflies may encounter several plant species that differ in suitability for the phytophage. Host suitability vary significantly among individuals of a given plant species, and among parts of agiven plant. Thus, whiteflies should select those plant parts that are most suitable for feeding and oviposition. (Gerling, 1990). The selection process consists of different phases (Hassel and Southwood, 1978), mediated by visual (Prokopy and Owens, 1983), Olfactory (Visser, 1986, 1988), and gustatory stimuli (Stadler, 1986).

II.6.1.2 Selection of Host-Plant Species Before Landing:

Colour is the only factor in host-plant responsible for selection by whiteflies from a distance (Mound, 1962; Woets and Van lenteren, 1976; Van lenteren and Woets, 1977; El-Helaly ***et al.***, 1981ab). They are attracted most strongly to yellow/ green colour followed in decreasing order by yellow, red, Orange/red, dark green and purple (Husain and Trehan, 1940).

II.6.1.3 Selection of Host-Plant Species After Landing:

There are no studies explicity addressing selection behavior of *B. tabaci* on the plant or in choice situaitons with plants of different species. The behaviour that follows after a host plant has been selected for feeding was described in detail by Pollard (1955), who made the morphological study of the pentration behaviour of *B. tabaci* on cotton. He recorded that stomata can be used to enter the leaf, that the stylets usually follow an intercellular path through the paranchyma, plasmolysis of parenchyma cell adjacent to the stylets rarely occur. Stylets often end in phloem tissue. The path way of the stylet is almost completely intercellular before the phloem is reached, which occurs no sooner than half an hour after the start of pentration. Therefore, rejection of a host plant, which occurs within minutes, can not be based on probing of the phloem. Selection of suitable feeding site occurs during probing of the apoplast in the mesophyll layer shortly after the onset of pentration. Whitefly can detect wether it is a suitable host plant only after landing and internal probing (Van lenteren and Woets, 1977; Van Sas *et al.*, 1978; Verschoor, *et al.*, 1978).

Rejection of a host plant occurs after probing for a few minutes (Noldus *et al.*, 1986ab; Van Vianen *et al.*, 1988a). Host-plant descrimination seems to be based on internal chemical or physical plant properties. Once on a plant, visual stimuli probably determine the place where a whitefly will start probing. Whiteflies often land on the upper surface of the leaf and starts walking toward the underside (Shaded), and start probing immediately. This is response to light intensity, because when the leaf underside is exposed to strong light, whiteflies stop feeding and move to the unlighted upper surface and resume feeding there (Coombe, 1982).

The behaviour of whiteflies is strongly influenced by host-plant species (Van der Kamp and Van lenteren, 1981; Noldus, *et al.*, 1986). On some host plants (eggplant, cucumber), they do not move about on the plant after their initial probes, and stay on some leaf for several days. However, on other plants (tomato, and especially sweetpepper) they frequently change position between probes and often leave the plant within a few hours (Van. Sas *et al.*, 1978; Verschoor *et al.*, 1978). In experiments where whiteflies were released into a cage with four different host plants. (Eggplant, Cucumber, Tomato, and Sweetpepper), a consistent change was observed within 24 hours after the first landing. The number of individuals on eggplant and cucumber always increased, and on tomato and sweetpepper always decreased (Verschoor -van der Poel, 1978).

II.6.1.4 Selection of Feeding and Ovipostion Sites Within a Plant:

Once a leaf is selected, female whitefly use the same leaf for ovipostion and feeding. The circular egg patterns which are often found on relatively smooth leaves are the result of concurrent feeding and oviposition, whereby the female rotates around the point where her stylets is inserted into the leaf. However, leaf selection by adult females is governed by many factors (Gerling, 1990). The most important factors are:

a. Leaf age:

Leaf age is a major factor influencing ***B. tabaci*** densities within a plant. ***B. tabaci*** females perfer young leaves for oviposition (Khalifa and El-Khidir, 1964; Avidov and Harpaz, 1969; Gameel, 1977; Ohnesorge *et al.*, 1980). Vertical distribution patterns have been described for ***B. tabaci*** on tomato, eggplant, and cotton (Ohnesorge *et al.*, 1980; Von Arx, *et al.*, 1984). Eggs are laid predominantly on the underside of leaves and, on hairy plant species, ***B. tabaci*** refrains from ovipositing on very young leaves (Mound, 1965). Naive females stay longer on young leaves than on old ones. On old leaves they move and probe more frequently, spend less time probing and feeding and depart sooner (Gerling, 1990).

b. Intensity of light reflection

Oviposition occurs only on young leaves and the first egg is usually laid before pholem feeding during probing. Because development to adulthood takes 3-4 weeks, adult whitefly emerge from the middle part of the plant. Newely emerged whiteflies move upward and reach to the top of the plant within about 3-days (Noldus ***et al.***, 1985, 1986). Whiteflies might be attracted to the top of the plant because of a higher intensity of light relfection or transmittance (MacDowall, 1972; Vaishampayan ***et al.***, 1975).

c. Chemical Constituent

Within plant leaf, selection is probably affected by chemical differences between the leaves (Noldus ***et al.***, 1986ab), measured during probing of the apoplast in the mesophyll layer (Gerling, 1990).Morphological properties, such as the length of epidermal cell boundaries at which pentration takes place and the density of phloem veins don't influence host selection (Van der kamp and Van lenteren, 1981; Van Vianen, ***et al.***, 1988a).

d. Leaf Hairiness

Leaf hairiness clearly influence host-plant selection by whiteflies. Direct effect can be two fold: hairs provide a physical barrier (Duffy, 1986) as well as favourable microclimate (Willmer, 1986) for phytophages. ***B.***

tabaci does not oviposite on very hairy leaves of cotton (Mound, 1965). Moderate hairiness seems to be preferable. ***B. tabaci*** numbers were lower on smooth and okra-type leaves, because of the openess of plant canopy resulting in more light and wind, higher temperature and lower humidity(Butler *et al.*, 1988).

II.6.2 Host Plant Suitability

Host suitability is defind as the various aspects of a host plant that affect the performance of immature or adult insects utilizing that plant as food (Singer, 1986). Since most whitefly species have overlapping generations, the growth rate of populations can be used as a parameter for host suitability (Caswell and Hastings, 1980). Differences in growing seasons may lead to different growth of plants and thus differences in host plant suitability (Gerling, 1990).

II.6.2.1 Variation Between Plant Species and Cultivars

a. Development time:

Whitefly lower threshold for development is 8°C and the upper threshold is almost 35°C (Hulspas-Jordana and Van lenteren, 1989). Development of *B. tabaci* can generally be ranked as short on Cucumber, intermediate on eggplant, long on tomato and very long on beet (Courdriet *et al.*, 1985).

b. Mortality of Immatures:

The only comprehensive life table for ***B. tabaci*** is the one on cotton published by (Horowits *et al.*, 1984) who concluded that mortality of ***B. tabaci*** due to climatic conditions, is highest during the crawler and young nymphal instars. Host plant suitability measured as pre-adult mortality, shows the same trend for *Trialeurodes vaporariorum* (Westwood). However, eggplant and cucumber are far more suitable hosts than tomato, which in turn is a better host than sweetpepper (Coudriet ***et al.***, 1985).

*C. **Fecundity:***

The preoviposition period of ***B. tabaci*** in the field ranges from 1-8 days at temperatures above 20°C (Butler ***et al.***, 1986) and at lower temperatures can be much longer. Most mating occurs during the first day after emergence (Khalifa and El-Khidir, 1964; Azab ***et al.***, 1971).

Fecundity of *T. vaporariorum* is highly variable and is influenced by species, cultivar, and physiological state of the host plant. It is constant from 18-27 °C but decreases at lower and higher temperatures, the values of fecundity measured on several host-plant species yielded the following ranking: cucumber> bean > tomato > sweet pupper (Gerling, 1990).

Fecundity of ***B. tabaci*** on cotton, varies between 20-350 eggs depending on cultivars, prior experience to pesticide, and experimental conditions. However, the oviposition rate of ***T. vaporariorum*** is age-dependent, gradually increasing during the first days, and reaching a plateau that is maintained until shortly before the female dies. Daily ovipositon rate for several host-plant species at temperatures between 12-35°C yield the following ranking: cucumber > bean > tomato> sweetpepper (Gerling, 1990). Maximum oviposition of ***B. tabaci*** occurs within the first week of adult life (Gameel, 1974). Oviposition rates for ***B. tabaci*** on cotton average 10 eggs/day/female at temperatures between 25-30 °C (Gerling ***et al.***, 1986).

d. Sex Ratio:

The sex ratio (female:male) of ***B. tabaci*** is usually 1: 1 on cotton (Gameel, 1978). However, other studies indicate that sex ratio is sufficiently variable to preclude generalization (Butler ***et al.***, 1986; Gerling ***et al.***, 1986).

e. Longevity:

Females live much longer than males (Van Boxtel, 1980). There is a positive correlation between temperature and longevity at temperature between 5 and 15 C°. Above 15 °C there is a strong negative correlation. For ***T. vaporariorum*** longevity values from several host plant species yield the following ranking: cucumber> bean > tomato > sweetpepper (Gerling, 1990).

Longevity of ***B. tabaci*** adults is 10-15 days in the field during summer (temperature in high twenties) and 30-60 day in winter (temperature around 15 °C) (Gerling ***et al.***, 1986).

II.6.2.2 Preferance-Performance Relationships Between Plant Species and Cultivars

The more a plant species is prefered, the greater the total number of eggs laid per female, the higher the oviposition rate, the higher the longivity of females, the shorter the developmental time from egg to adult, and the lower the mortality of individuals of all stages (Van Boxtel ***et al.***, 1978; Van der Merendonk and Van lenteren, 1978; Van Sas ***et al.*** 1978; Verschoor-Van der Poel and Van lenteren, 1978).

The variability of experimental procedures, plant cultivars, and whitefly strains make it difficult to generalize about host-plant suitability. Also, expressing host-plant preference by ***T. vaporariorum*** as the number of whiteflies present on a plant in a choice situation, yielded the following ranking: Cucumber > Tomato> Sweetpepper. Clearly preference of *T. vaporariorum* for a host plant reflects it's suitability for the whitefly. Not only do plant cultivars differ in their suitability for whiteflies, but whiteflies from different localities also show variation in performance on the same cultivar (Gerling, 1990).

II.6.2.3 Preference-Performance Relationships within Host Plants:

Young leaves may provide the best compromise between optimal development of immatures and nutritional quality for adult (Gerling, 1990). Suitability of the young leaves depend on several factors:

a. **Physical factors:** include, trichomes (Duffy, 1986); presence of glandular hairs (Gentile, 1968); thickness of the cuticle (Walker, 1985, 1987); distance between the leaf cuticle and vascular tissue (Van der kamp and Van lenteren, 1981); plant protection against adverse climatic conditions (Willmer, 1986).

b. **Chemical factors:** include, probing deterrents (Walker, 1987, 1988); water content (Noldus *et al.*, 1986); sugar and nitrogen content (Noldus *et al.*, 1986ab); pH value (Husain *et al.*, 1936; Berlinger *et al.*, 1983).

c. **Biotic factors:** include, durability of plant leaves to allow total development from egg to adult; degree of hairiness (Gerling, 1990).

III. MATERIALS AND METHODS

II.1. Layout of the Experiment:

The research was conducted at the University Agricultural Research Station (UARS) in the Central Jordan Valley (CJV). Six vegetable crops of the following cultivars: Tomato (Faredah), ***Lycopersicon esculentum (Mill)***; Cucumber (Biet-Alfa), ***Cucumis sativus*** L.; Squash (Anita), ***Cucurbita pepo*** L.; Beans (Broncho), ***Phaseolus vulgaris*** L.; Sweetpepper (Sunar), ***Caspicum annuum*** L.; Eggplant (Klasic), ***Solanum melongena*** L., were used to study their suitability to sweetpotato whitefly (Fig. 1) infestation throughout the life cycle of this insect, in five planting dates in two growing seasons. The studying period lasted from September 27, 1995 to June 7, 1996.

Seedlings of the six vegetable crops were raised in the nursary in due time for perminant planting in the assigned land at the UARS. Transplanting was accomplished in seedling trays filled with a mixture of Peatmoss and Barlite (2:1/ size unit), respectively. Seeds of each crop were inserted at (1-3 cm) deep in the holes of the trays and kept under the plastic cover until germinaiton occured. To keep seedlings away from the reach of adult whiteflies, the whole set of trays were kept in insect-proof wooden cages covered with muslin until they were taken for perminant planting in the field. During this period, seedlings were irrigated as needed.

The three solanaceous crops (Tomato; Eggplant; and sweetpepper) were transplanted earlier than the other three crops (Cucumber; Squash; and Beans), because they needed longer time to germinate and be ready for transporting to the field.

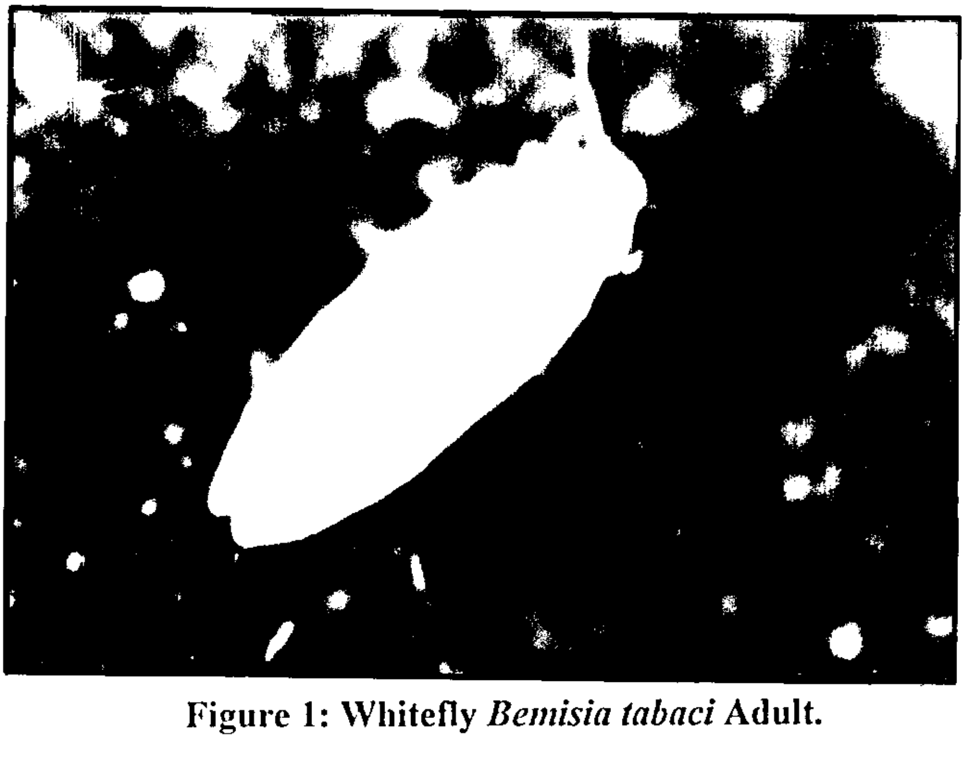


Figure 1: Whitefly *Bemisia tabaci* Adult.

The time elapsed from seeding to transplanting lasted 30-40 days for the first three crops, while it lasted 10-14 days for the other three crops, depending on the prevailed environmental conditions (Temperature and relative humidity). The different crops were monitored carefully during their presence in the nursary to obtain healthy and noninfested seedlings.

During the production of seedlings in each growing season, the field was prepared using 3×6 factorial arrangment within randomized complete block design (RCBD) (Fig. 2). A total area of (3735 m²) was divided into three blocks representing three replicates; each block was further divided into three columns, and each column included six treatments. Each treatment represented one of the following vegetable crops (tomato; cucumber; squash; beans; sweetpepper; and eggplant), and one of the five planting dates (27/9/1995; 5/11/95; 7/12/95; 30/3/1996; and 26/4/96). The distance between columns was two meteres and between treatments it was one metere. In addition, the whole experiment was surrounded by two meteres as border. The width of the three blocks was 83 m and their length was 45 m. The total area of the three blocks was (83 × 45 = 3750 m²). A total of 54 treatments (3×6×3) were cariedout in the first (Fall) growing season, where as 36 treatments (3 ×6×2) were conducted during the second (Spring) growing season. Each treatment consisted of 36 seedlings of each of the six crops, planted in three rows each 7 m long at 50 cm between plants and one metere between rows(Fig. 3).

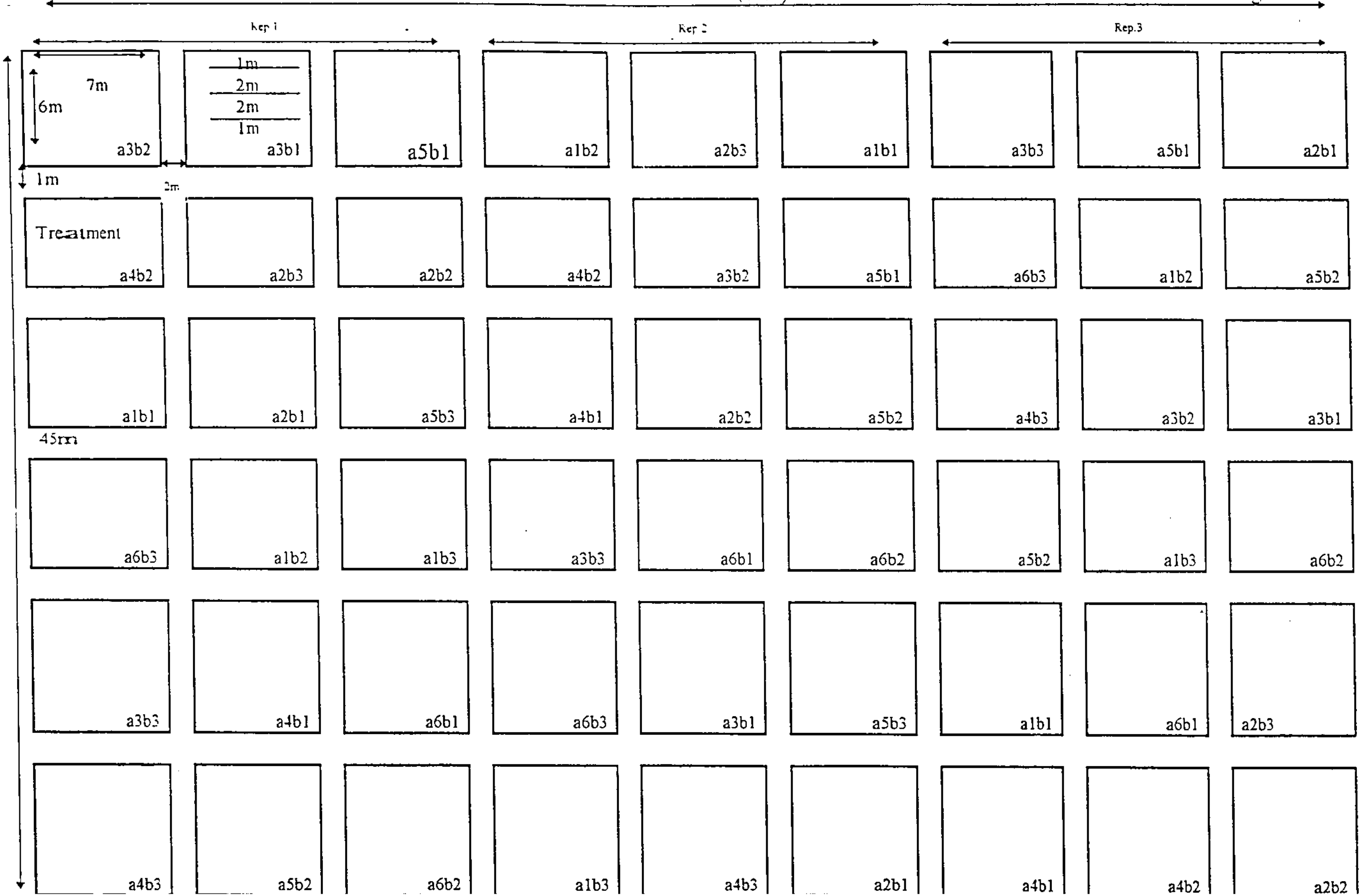
Preparing of land was achieved by ploughing, hoeing and dividing the land in stripes (rows) of 7 meteres long and 1 metere wide, then installing drip irrigation and covering the stripes tightly with black plastic mulch of 50 µ thick. The drip irrigation system was also used for applying fertilizers. Before making the seedling holes in the mulch, the planting areas were

Factorial Arrangement within RCBD. Total Area: 3750 m

⇒ Randomized

a: Vegetabel crop

b: Planting date



fumigated using methylbromide at the rate of one can 680 ml per row ($7\times1=7m^2$) or three pakages per treatment (three rows) ($7\times1\times3=21m^2$). Two days post fumigation, the plastic mulch was removed and the stripes were left uncovered for three days. Thereafter, the stripes were recovered with the plastic mulch and seedling holes were made.

After the seedling of each of the six crops reached the three-leaflet stage, they were transplanted in the field randomly as predetermined in the layout of the experiment (Fig. 3). The necessary agricultural practices needed were carried out to assure healthy growth of the vegetable crops involved. The same planting procedure was carried out in each of the five planting dates.

III.2. Agricultural Practices:

III.2.1 Irrigation

Drip irrigation was used in this experiment. Vegetable crops tested were irrigated every 2-3 days on average for several hours, depending on the physical conditions, mainly temperature, except for the rainy days where less or no irrigation was needed.

III.2.2 Fertilizer Application

During the first two weeks after transplanting, no fertilizers were added. After that, fertilizers were added to provide the essential nutrients to the crops begining with fertilizers with high nitrogen content to inhance vegetative growth such as Urea (8 kg/ 54 treatments), compound fertilizers containing N, P, K ratios of 19: 6: 6 and trace elements, respectively.

Then different ratios of N, P, K were provided to enssure healthy growth of the plants such as 12: 48: 12 or 20: 20: 20 at the rate of (3.4 kg/54 treatmens). The fertilizers were used every 1-2 weeks depending on the physiological status of the plants.

Fig. 3: Different Vegetable Crops Planted at Different Planting Dates in One Column.

III.1.2.3 Pesticide Usage:

No insecticides were used, but at seedling stage drenching using "Lanate" was applied at the rate of 20 grams/ 30 litters of water, as spot treatment, to control cut worms. Fungicides were also used, as spot treatment. "Afugan" was used to control powdery mildew at the rate of 8-12cm³/20 litters water. Drenching using "Tachigaren" was also used at the rate of 20-40 cm³/20 litters water to control soil-born pathogens, mainly Fusarium sp. "Herbikill" at the rate of 20 gms/20 litters of water, was used as a herbicide to control the weeds in the field especially ***Chenopodium album*** and ***Malva sylvestris***. Knap-sac sprayer was used for application of the different pesticides.

III.3. Monitoring Whiteflies

The first readings of adults and immatures were taken two weeks after palnting date for all crops.

III.3. Adult Counting

a. Counting devise:

Whitefly adult readings were taken at weekly intervals, to determine host-plant selection using a wooden box, according to the method described by Ahmad and Harwood (1973) (Fig. 4). The box was made of wood (1×1× 1 m³), covered from all sides, except for the lower one, with black plastic mulch, so as the box could be installed over th plant. On one side of the box, an opening of 15×20 cm was prepared in a way allowing transparent movable glass slide to the placed (Fig. 5). The glass slide was covered with lubricate material (like, grease) to catch the whitefly attracted to light going through it. Also, a small opening in the upper side of the box was left, so as a long stick could be inserted to shake the plant parts within it.

Figure 4: The Wooden Cage Used For Counting *B. tabaci* Adults

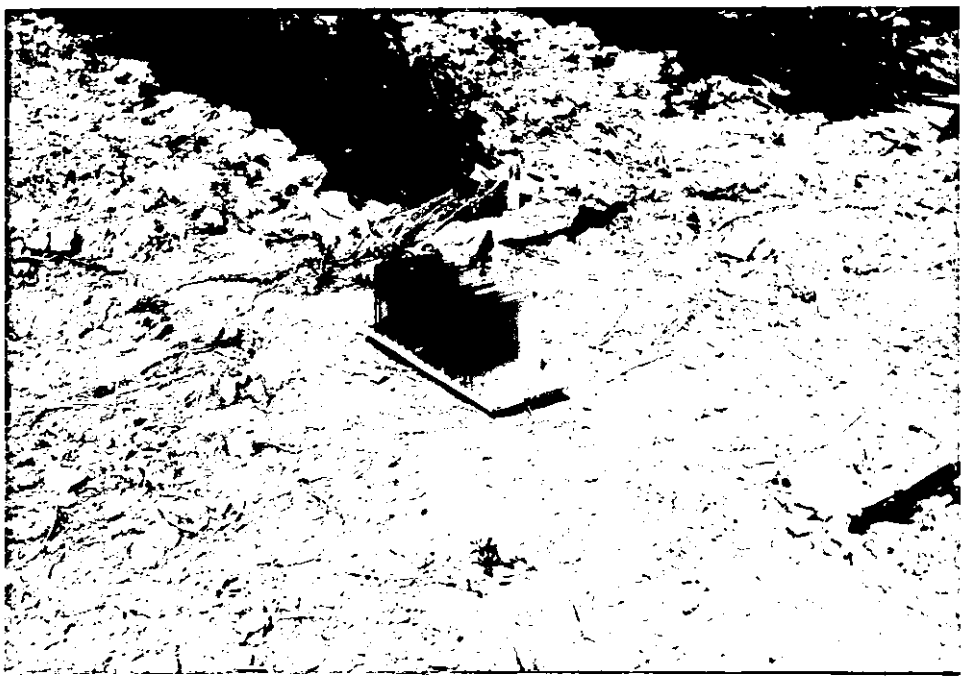


Figure 5: Smeared Glass Slides Used For Capturing *B. tabaci* Adults.

b. Counting Procedure

After the transparent slide is covered with the lubricant material, it was placed in it's position in the lateral opening of the box. The box was then placed for three minutes over one plant choosen randomly per each crop and replicate of each treatment. The plant was shaken by a long wooden stick to force the adult whiteflies to fly towards the transparent slide. Adult whiteflies were captured by the grease covering the slide. Smeared slide was changed and capturing process was repeated for each reading. 54 slides were used for each weekly counting (Fig. 6). After counting, used slides were cleaned to be ready for use in the following counting.

Counting was performed by using a white clean piece of paper divided into 80 squares (squre area = 2 cm^2). The paper was placed under the transparent slide (Fig. 6), for easier and more accurate counting. The total adult numbers of each replicate were recorded, and the mean number of adults per each treatment was computed.

III.3.2 Immatures Counting.

a. Counting device

The different immature stages of ***B. tabaci*** were counted at weekly intervals, to determine host-plant selection and suitability on leaf sections, each of 1.5cm in diametere. The area of each section was 1.76cm^2. The sections were taken randomly from the upper, middle and lower leaves of the plants. For each crop, 9 sections were taken, 3 from each replicate. Sections were taken from the leaves by using a sharp tool made of a hollow metal tube (Fig. 7).

b. Counting Procedure

Immature whiteflies (eggs; 2nd nympal instar; and pupae) were counted using a stereo-binocular microscope (30X)(Fig. 8). Counting was recorded and the mean numbers of immature stages per each treatment were computed.

III.4. Meterological Data

Meterological data were collected from the Meterological Station of the UARS, about (1km) south of the experimental site.

III.5. Statistical Analysis

Data were anlayzed statistically by using F-test for significance,; to accept either, the original hypothesis, that there is no significant differences among the tested treatments, or the alternative hypothesis, that there is at least one treatment significantly different. Taking into consideration that both crop and planting date factors are fixed. Then, if F-test showed significance, means are seperated using Least Significant Difference (LSD) test. The standard error (mean ± SE) of each treatment was calculated to show the best sequence of planting of the six vegetable crops tested.

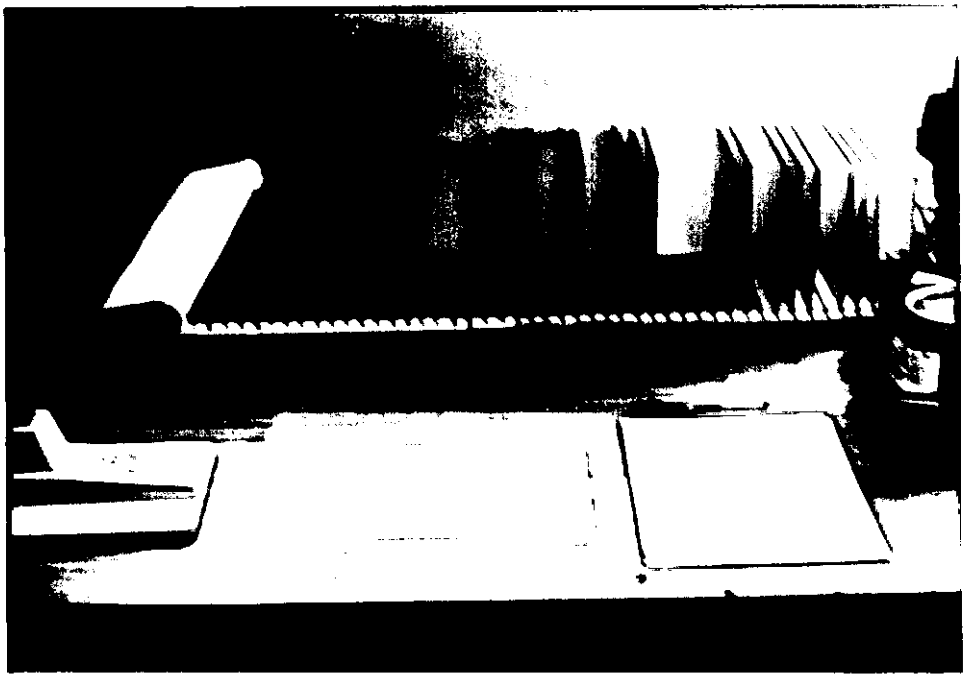


Figure 6: Counting Device of *B. tabaci* Adults

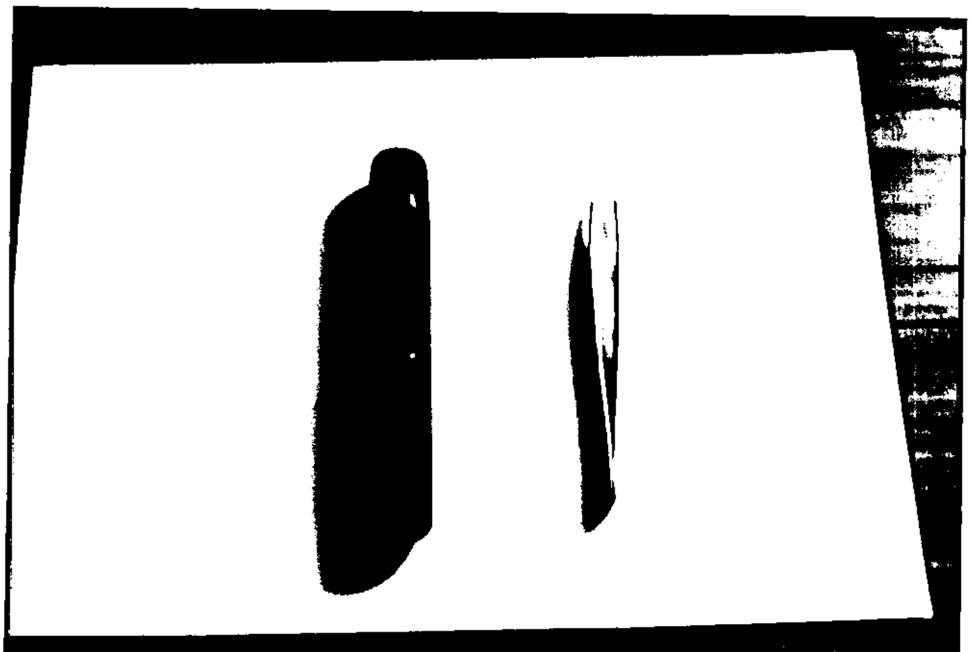


Figure 7: Celendrical Sharp Tube for Taking Leaf Sections

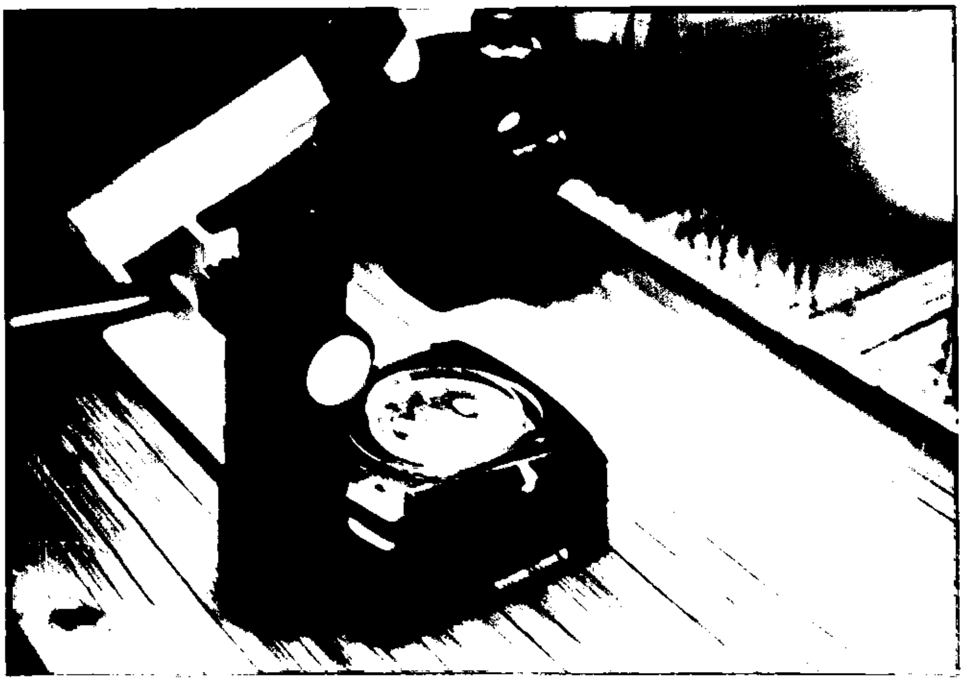


Figure 8: Counting Device For *B. tabaci* Immatures Using Stereo-Binocular Microscope.

IV. RESULTS

IV.1. Effect of Planting Dates on the Mean Numbers of Different Stages of *Bemisia tabaci.*

The effect of planting dates on the mean numbers of the different stages of ***B. tabaci*** (eggs, 2nd nymphal instars, pupae, and adults) fed on six vegetable crops is presented in (Table 1).

Mean numbers of eggs varied significantly in the five planting dates. The highest numbers of eggs ($\bar{X}$=24.94/week) were laid during the first platning date, whereas the lowest numbers ($\bar{X}$=2.94/week) were laid during the third planting date. Moderate numbers of eggs ($\bar{X}$=14.88-15.61 /week) were laid during the second and fourth planting dates, and low numbers ($\bar{X}$=8.16/week) were laid during the fifth planting date (Table 1).

The average numbers of ***B. tabaci*** second nymphal instars varied also within the five planting dates The highest numbers of second nymphal instars (X=6.00/week) were recorded in the first planting date, followed by moderate numbers ($\bar{X}$=3.77-4.83/week) in the fifth and fourth planting dates. The lowest numbers ($\bar{X}$=1.61-2.72/week) were recorded during the second and third planting dates (Table. 1).

There were significant differences betweent the average numbers of pupae in the first planting date ($\bar{X}$=5.33/week) and the average numbers of pupae in the other four planting dates. Also, the average numbers of pupae in the fourth planting date ($\bar{X}$=1.61/week) varied significantly from those in the other three planting dates ($\bar{X}$=0.00-0.61/week) (Table 1).

As development of whiteflies proceeds, the average numbers of ***B. tabaci*** adults will consequently have the same trend as that of the pupae. The highest numbers of adults ($\bar{X}$=157.11 /week) were recorded in the first planting date, followed by numbers of adults ($\bar{X}$=56.22/week) in the fourth planting date. Average numbers of adults varied significantly in both

Table.1: Mean Numbers of the Different Stages of ***Bemisia tabaci*** on Six Different Vegetable Crops in Five Different Planting Dates in Fall and Spring Growing Seasons (1995/1996) in Central Jordan Valley.

Growing Season	Planting Date Number	Duration of Planting Dates in Weeks	Mean[1,2,3] Number of *B. tabaci* Stages.			
			Egg	Second nymphal instur	Pupa	Adult
First (Fall) Growing Season	I	27/9/95-28/1/96 18 weeks	24.94 a	6.00 a	5.33 a	157.11 a
	II	5/11/95-31/3/96 22 weeks	15.61 b	1.61 c	0.22 c	33.66 c
	III	7/12/95-25/5/96 25 weeks	2.94 d	2.72 cb	0.00 c	19.50 c
Second (Spring) Growing Season	IV	30/3/96-7/6/96 11 weeks	14.88 b	4.83 ab	1.61 b	56.22 b
	V	26/4/96-7/6/96 7 weeks	8.16 c	3.77 abc	0.61 c	31.11 c

1)Mean calculation = Mean number of *B. tabaci* stages/3 Reps./6 crops/ week.

2) Mean of three replicates.

3) LSD Values for : egg = ± 4.42; 2nd Nymphal Instar = ± 2.28; pupa = ± 0.81; Adult = ± 17.47.

numbers were also recorded on sweetpepper. The average numbers of whitefly adults on these crops were: 103.06, 86.26, 76.06, 45.20, 36.66, and 9.86/week, respectively (Table. 2).

IV.3. Effect of Different Vegetable Crops and Different Planting Dates on *Bemisia tabaci*, Host selection

The effect of six vegetable crops planted in five planting dates during the fall and spring seasons in the central Jordan Valley (CTV), on whitefly host selection measured by the mean number of ***B. tabaci*** eggs deposited on each crop and in each planting date is presented in Table (3).

The average number of eggs deposited in the first planting date comencing on September 27, 1995 varied within the six vegetable crops. The highest number of eggs were deposited on cucumber ($\overline{X}$= 64.67/week), followed in descending order by beans ($\overline{X}$=27.33/week), tomato ($\overline{X}$=25.67/week), squash ($\overline{X}$ = 17.00 / week), eggplant ($\overline{X}$=13.33/week), and sweetpepper ($\overline{X}$=1.67 /week). (Table 3).

Whitefly-host selection changed in the second planting date starting on November 5, 1995. Squash and cucumber were highly selected by whitefly for egg deposition, followed by tomatoes and beans as they were moderately favourable for whitefly egg-laying. Eggplant was less favourable than the aforementioned four crops. However, no eggs were deposited on sweetpepper. The average number of ***B. tabaci*** eggs on the six vegetable crops were: 19.67; 16.00, 6.67; 5.33; 1.33; and 0.00/week, respectively (Table.3).

Host-selection by adult females of ***B. tabaci*** for egg deposition was more obvious in the third planting date than in the previous two planting dates as well as the other two successive planting dates. The average number of eggs deposited varied-significantly within the six vegetable crops, except for beans and eggplant. It was the highest on squash

Table 2: Effect of Six Different Vegetable Crops on the Mean Numbers Of ***Bemisia tabaci*** Stages in Five Different Planting Dates in Fall and Spring Growing Seasons (1995/1996) in Central Jordan Valley.

Vegetable crops	Mean[1,2,3] Numbers of *B. tabaci* Stages			
	Egg	2nd Nymphal Instar	Pupa	Adult
Tomato	11.00 c	3.60 cb	1.33 b	76.06 b
Cucumber	34.73 a	6.46 a	2.80 a	86.26 b
Squash	17.33 b	6.53 a	1.53 b	103.06 a
Bean	10.06 cd	4.26 ab	1.60 b	36.66 c
Sweetpepper	0.86 e	0.26 d	0.00 c	9.86 d
Eggplant	5.86 d	1.60 cd	2.06 ab	45.20 c

1)Mean calculation = Mean number of *B. tabaci* stages/3 reps./crop/5 palnting dates/week.
2) Mean of three replicates
3)LSD values for. egg = ± 4.8; second nymphal instar = ± 2.49; pupa = ± 0.89; adult = ± 19.14.

($\overline{X}$=9.67/week), followed in descending order by cucumber ($\overline{X}$=4.00/week), tomato ($\overline{X}$ = 2.00/week), beans ($\overline{X}$ = 1.00/week) and eggplant ($\overline{X}$=1.00/week). As in the second planting date, no eggs were deposited on sweetperpper (Table. 3).

Cucumber ranked first in the fourth planting date, as the number of eggs deposited on it was the highest ($\overline{X}$=33.67/week). Squash came second with an average number of eggs equals to (19.33/week). Tomato, beans and eggplant did not differe significantly in their selection by adult female of ***B. tabaci***. The average number of eggs deposited in each of the three crops ranged from (10.67 - 11.33/week). As in the previous three planting dates, sweetpepper was the least host selected for egg-laying ($\overline{X}$=1.33 /week) (Table .3).

In the fifth planting date, whitefly more or less selected it's hosts as in the fourth planting date. However, ***B. tabaci*** laid significantly higher number of eggs on tomato ($\overline{X}$=9.33/week) than on beans and eggplant ($\overline{X}$=3.00-3.67/week) (Table 3).

In all planting dates, cucumber was the most frequent host selected by ***B. tabaci*** females, followed in descending order by squash, tomato, beans, eggplant and sweetpepper. Sweetpepper was obviously the least host selected as ***B. tabaci*** deposited no eggs in the second and third planting dates and only very low numbers ($\overline{X}$=1.33-1.67/week) of eggs were laid in the other three planting dates.

The interacting effect of vegetable crops and planting dates on host selection was very obvious in the third planting dates, as host selection play an important role in the development of ***Bemisia tabaci*** population when the numbers are very low. Results on this interation are presented in (Table 4).

The mean number of different stages (egg, second nymphal instar, pupa, and adult) of ***B. tabaci*** in the third planting date (7/12/95-25/5/96)

Table 3: Mean Numbers of ***Bemisia tabaci*** Eggs on Six Different Vegetable Crops Planted in Five Different Planting Dates in the Fall and Spring Growing Seasons (1995/1996) in Cenral Jordan Valley.

Vegetable crop	Mean Number of *B. tabaci* Eggs [1,2]				
	Date I 27/95±SE	Date II 5/11/95 ±SE	DateIII 7/12/95 ±SE	Date IV 30/3/96 ±SE	Date V 26/4/96 ±SE
Tomato	25.67 ±4.18 b	6.67 ±0.88 b	2.00 ±0.00 c	11.33 ±0.88 c	9.33 ±0.66 c
Cucumber	64.67 ±1.66 a	16.00 ±3.21 a	4.00 ±0.00 b	33.67 ±6.49 a	55.33 ±9.67 a
Squash	17.00 ±5.86 cb	19.67 ±3.18 a	9.67 ±0.88 a	19.33 ±1.86 b	21.00 ±9.45 b
Beans	27.33 ±10.90 b	5.33 ±1.33 bc	1.00 ±0.00 d	13.00 ±2.08 c	3.67 ±0.33 d
Sweetpepper	1.67 ±0.33 c	0.00 ±0.00 e	0.00 ±0.00 e	1.33 ±0.33 d	1.33 ±0.33 e
Eggplant	13.33 ±1.76 cb	1.33 ±0.33 d	1.00 ±0.00 d	10.67 ±1.86 c	3.00 ±1.55 d

1) Mean calculation = Mean number of *B. tabaci* eggs/3 reps./crop/5 palnting dates/week.

2) Mean of three replicates.

was the highest in squash, followed in descending order by cucumber, tomato, eggplant, beans and sweetpepper. The mean number of different stages of *B. tabaci* in the third planting date yielded the following ranking: sweetpepper< beans < eggplant <tomato <cucumber <squash (Table. 4).

IV.4. Effect of Different Host Plants and First Planting date on *Bemisia tabaci,* Host Suitability

Host-suitability measured as % reduction in *B. tabaci* population affected by planting six vegetable crops at the begining of the fall growing season in the Central Jordan Valley (CJV) is presented in (Table 5).

The turn-over in *B. tabaci* populaiton was highly reduced on eggplant, followed in descending order by squash, beans, tomato and cucumber. The % reduction on these crops were 60, 25, 18, 17, and 16%, respectively (Table. 5).

Table 4: Effect of Six Different Vegetable Crops in the Third Planting Date on ***Bemisia tabaci*** Host Selection.

Development stage	Different Vegetable Crops Sequence [1,2,3)]					
Egg	Sweetpepper (0.00)	Bean (1.00)	Eggplant (1.00)	Tomato (2.00)	Cucumber (4.00)	Squash (9.67)
Second nymphal instar	Sweetpepper (0.00)	Bean (0.33)	Eggplant (0.67)	Tomato (1.00)	Cucumber (2.00)	Squash (12.33)
Pupa	Squash (0.00)	Eggplant (0.00)	Bean (0.00)	Sweet pepper (0.00)	Cucumber (0.00)	Tomato (0.00)
Adult	Sweet peeper (2.67)	Bean (11.00)	Bean (17.00)	Cucumber (17.33)	Tomato (24.00)	Squash (45.00)
Overall[(3)] Sequence	Sweetpepper	Bean	Eggplant	Tomato	Cucumber	Squash

1. The sequence is based on the mean number of different developmental stages of *B. tabaci*. From left (lowest mean number) to right (highest mean number).
2. Figures in brackets are average numbers of the different developmental stages.
3. Overall sequences is based on the frequency of host selection.

Table. 5: % Reduction in *Bemisia tabaci*, Populations on Different Vegetable Crops* in the First Planting Date (27/9/1995).**

Host	Eggplant	Squash	Beans	Tomato	Cucumber
%Reduction	60	25	18	17	16

* Pepper is not included, because of very low number of eggs deposited on it.

** First planting date was choosen for suitability assessment, because of high number of immature whiteflies were present in this planting date, as compared with the very low number of immatures, especially pupae, available in the other four planting dates.

V. DISCUSSION

Whitefly, ***Bemisia tabaci*** is subject to strong selective pressure for choosing plant species or parts of plants (host-selection) that are suitable for feeding and oviposition. Differences in growing seasons may lead to different growth of the plants and thus differences in host plant suitability (Gerling, 1990).

Late plating date in each of the two fall and spring growing seasons is favourable as the average numbers of ***B. tabaci*** different immature stages decreased with delaying planting date (Table. 1). These results are in agreement with the results are obtained by Sudah and Mustafa (1977). They found that tomatoes planted on November 15, harboured less whitefly popuulations than those planted on September 15, or on October 15.

Also, late planting coincided with a lower population of adult whiteflies (Sharaf, 1981). During the fall/winter season, the pupulaiton of immature whiteflies (individuals/leaf) reached a peak in November, and then declined steadily until they reached their lowest levels during the late winter months. However, in the spring/summer growing season, densities of immatures started at lower level than in the fall season, declinded in the following weeks, and remained at a moderate level until the end of the growing season (Sharaf, 1984).

This might be due to high initial infestation levels that developed on herbaceous plants during the summer months and reached outbreak status, then invaded the preferable hosts that are planted in September. However, in the second and third planting dates the climatic conditions became insuitable for ***B. tabaci*** immature development. Low temperatures and heavy rainfalls adversly affected whitefly populaitons during the cold winter months (Sharaf, et al., 1985).

In addition to the "Khamasin" winds (hot dry desert wind, loaded with sand particles) which prevailed during the spring, the hot dry weather in summer limited increase of whitefly populations (Sharaf, 1981).

Results indicated that the average number of ***B. tabci*** different development stages varied within the six vegetable crops in the different planting dates (Table. 2). Cucumber and squash were the most suitable crops and harboured the highest numbers of the different stages, followed by tomato which was moderately favourable, beans and eggplant were less favourable and sweetpepper was the least favourable crop. These results are in agreement with the results obtained by different investigators. Sharaf ***et al.*** (1985) found that cucumber, squash, eggplant, beans and tomato sustained the same trend as absolute numbers of whiteflies in descending order. Coudriet *et al.* (1985) found that development rate of ***B. tabaci*** was high on cucumber, intermediate on squash and eggplant, and low on tomato. Van de Merendonk and lenteren (1978) found that the percentage pre-adult mortality of ***T. vaporariorum*** for the host plants (Cucumber, squash, bean, tomato, and sweetpepper) gave the following ranking: cucmber< squash< bean< tomato< sweetpepper. Gerling (1990) found that fecundity of ***T. vaporarionum*** on different host plants was in the following order: Cucumber> Squash> Bean> Tomato> Sweetpepper. Variation in the selection and host suitability of different vegetables tested migh be due to morphological and chemical differences (Sharaf ***et al.***, 1985).

Results indicated that cucumber was the most frequent host plant selected by ***B. tabaci*** females, followed in descending order by squash, tomato, bean, and eggplant. Sweetpepper was the least frequent crop selected (Table. 3). These results are in general agreement with Verschoor van der Poel (1978) who found that ***T. vaporariorum*** released into a cage with four different host plants (eggplant, cucumber, tomato and sweetpepper) selected randomly an increasing number of whiteflies on cucumber and eggplant and a decreasing number of whiteflies on tomato and sweetpepper within twenty four hours after landing. Also, Gerling (1990) found that the oviposition rate of *T. vaporariorum* at temperatures ranging from 12 to 35 °C on different host plants (cucumber, tomato, squash, beans, and sweetpepper) yielded the following ranking: cucumber> squash> bean > tomato> sweetpepper. Differences in random selection and preferential behaviour of egg-laying of ***B. tabaci*** might be due to chemical nature, texture, and microclimate conditions of the leaves of the host plants, (Gupta, 1973).

Overall sequence of vegetable crops tested in the third planting date based on favourability for ***B. tabaci*** development (Table. 4), ranked from highest to lowest as follows: squash> cucumber> tomato> eggplant> bean> sweetpepper. Sharaf *et al.* (1985) found that the duration of the life cycle of ***B. tabaci*** was significantly longer on beans that on cucumber, squash, tomato, and eggplant. Also, Sharaf (1981) found that ***B. tabaci*** adults seek shelter between the large and dense leaves of squash in rainy and windy days. These results support generally this study findings.

Percentage reduction in ***B. tabaci*** populaitons on the tested crops in the first planting date was in the following sequence: eggplant> squash> bean> tomato> cucumber (Table 5). Mound (1965) found that ***B. tabaci*** does not oviposit on the very hairy and hairy cotton varaieties; however, moderate hairiness seems to be preferable. Also trichomes on the leaf surface can hamper feeding and ovipositon by serving as barrier or releasing sticky exudents that trap insects (Duffy, 1986).

Chemical contents and pH values of vegetable leaves have been also reported as factors affecting ***B.tabaci*** host suitability (Husain ***et al.*** 1936; Joyce, 1958; Berlinger ***et al.***, 1983). In addition, interspecific competition between ***B. tabaci*** and different species of eriophyid, tarsomid and tetranychid mites affected to a great extent host suitability for ***B. tabaci*** development (Sharaf, 1984). All these morphological, chemical and ecological factors interact in the differentiation between hosts for their suitability for *B. tabaci* development.

VI. CONCLUSIONS

The following Conclusions could be derived from this study:

1. Late planting of vegetables, especially in the first growing season, is favourable as average number of different immature stages of ***B. tabaci*** decreased with delaying planting.
2. Cucumber was the most favourable host plant of ***B. tabaci*** development and sweetpepper was the least in the five planting dates. Other vegetable crops were intermediate in their suitability for whiteflies.
3. The overall cropping pattern of the six vegetable crops tested, based on host selection ranked as follows: Squash> Cucumber> tomato> eggplent> bean> sweetpepper.
4. The overall croping pattern of the six vegetable crops tested, based on host suitability ranked as follows: Cucumber> tomato> bean> squash> eggplant> sweetpepper.
5. The overall cropping pattern of the six vegetabel crops tested, based on host selection and suitability can be ranked as follows: Sweetpepper< bean=eggplant< tomato< squash=cucumber.

VII. RECOMMENDATIONS

According to the results obtained in this study, the following recommendations could be presented:

1. Delaying planting in general is recommended as whitefly population are decreased.

2. During the fall growing season, the sequence of planting sweetpepper, followed by eggplant or beans, tomato, squash or cucumber is also recommedned as whitefly population will be continuously reduced since host selection and suitability showd the same sequence.

These recommendations should be taken with care by the farmers because the economic aspects of growing these vegetables in such a sequence needs further investigation.

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الملخص

اختيار وملاءمة محاصيل خضار مختلفة لنمو وانتشار الذبابة البيضاء (*Bemisia tabaci*) في موسمي الزراعة التشريني والربيعي في غور الاردن الاوسط

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المشرف

الاستاذ الدكتور نعيم شرف

اجريت دراسة حقلية في محطة البحوث الزراعية في غور الاردن الاوسط خلال الفترة الواقعة مابين نهاية ايلول من عام ١٩٩٥ وحتى بداية شهر حزيران من عام ١٩٩٦، لدراسة اختيار وملاءمة ستة محاصيل خضرية لحشرة الذبابة البيضاء (*Bemisia tabaci*) في موسمي الزراعة التشريني والربيعي. تمت زراعة محاصيل: البندورة، الخيار، الكوسا، الفاصوليا، الباذنجان، والفلفل الحلو، في خمسة مواعيد زراعة على مساحة مقدارها ٣٧٣٥م٢ باستعمال الترتيب الفكتوري ٣ × ٦ داخل تصميم المربعات العشوائية الكاملة (RCBD)، ابتداء من ٢٧ ايلول ١٩٩٥ بفاصل حوالي الشهر مابين مواعيد الزراعة المختلفة.

لقد تم تحديد عاملي اختيار الحشرة للعائل وملاءمة العائل للحشرة بواسطة تعداد بيض الحشرة والاطوار غير الناضجة على مقطع (نصف قطره = ١,٥سم) على فترات اسبوعية في مواعيد الزراعة الخمسة.

دلت الدراسة على أن محصول الخيار كان الاكثر اختياراً من قبل حشرة الذبابة البيضاء (*Bemisia tabaci*) يتبعه وبشكل متناقص محصول الكوسا، ثم البندورة، ثم الفاصوليا، ثم الباذنجان من ثم الفلفل الحلو.

كذلك فقد كان ترتيب محصول الخيار، الأول من حيث ملاءمته للحشرة لاحتوائه على اقل نسبة موت للاطوار غير الناضجة، يتبعه وبشكل متناقص محصول البندورة، ثم الفاوصوليا ثم الكوسا، ثم الباذنجان ومن ثم الفلفل الحلو.

وبناء على ماسبق، فان النتائج تشير الى ان التتابع الامثل للمحاصيل الخضرية المستعملة في التجربة بالاستناد الى تكرار هذه المحاصيل في الترتيب المستند الى اختيار الحشرة للعائل والترتيب المستند الى ملاءمة العائل للحشرة، يكون على النحو التالي: الفلفل الحلو< الباذنجان= الفاصوليا < البندورة < الكوسا= الخيار.