LABORATORY BIOASSAY AND FIELD CONTROL STUDIES ON *BEMISIA TABACI* (HOMOPTERA: ALEYRODIDAE) IN EGYPT

KHALAFALLA, E.M.E., SAMIRA H. METRI AND A. M. A. NASSEF

Plant Protection Research Institute, ARC, Giza, Egypt.

(Manuscript received 2 April 2006)

Abstract

The pesticides Furathiocarb (Deltanet), Pirimiphos-methyl (Actellic), Tedifol (Kelthane "Dicofol"+Tedion), insect growth regulator (IGR) Buprofezin (Applaud), fungus Biofly (*Beauvaria bassiana*), mineral oils KZ and Schocrona, liquid detergents Nastabon and Oki and natural vegetative oil were evaluated for their efficacy for control of *Bemisia tabaci* (Genn.) (Homoptera: Aleyrodidae) under laboratory and field conditions. Laboratory bioassay tests on adults showed highest toxicity effect resulted from Buprofezin, followed by the vegetative oil, Pirimiphos-methyl, and KZ, then Furathiocarb, Tedifol, and Schocrona. Pirimiphos-methyl, vegetative oil, and KZ were the most effective compounds on eggs, Furathiocarb, Schocrona, and Nastabon were less effective. Furathiocarb showed the highest toxicity on larvae followed by Schocrona and the vegetative oil whereas Buprofezin and detergents had low toxicity. Pupae were considerably less susceptible to the tested toxicants except Furathiocarb. IGRs had no direct toxicity. Apart from detergents, pesticides or their alternatives showed considerable latent effect with the highest effectiveness with Buprofesin. Furathiocarb was potentiated by the natural vegetative oil, detergent, and strongly by the mineral oils. Pronounced potentiation was observed when mixing Tedifol with mineral oils, natural vegetative oil, and detergents. The biocontrol agent greatly reduced egg hatching, pupation, and adult emergence. Field experiments indicated that apart from Pirimiphos-methyl, Furathiocarb or Tedifol were poorly effective against adults or immature stages infesting cotton or squash. The IGR (Buprofezin) had faint efficacy against adults, but considerable effect was noticed against immature stages on cotton and squash. Mineral or vegetative oils gave satisfactory reduction against adults or immature stages. Although oils had no residual toxicity, they suppressed the insect for two weeks. For soap, good control were obtained against larvae and pupae but moderate efficacy of detergents was obtained against eggs. Mixing alternatives with Furathiocarb greatly improved the efficacy of this compound against adults or immature stages.

INTRODUCTION

The whitefly *Bemisia tabaci* (Complex) (Gennadius) (Homoptera: Aleyrodidae) is considered as one of the most serious pests attacking plants. It damages crops by extracting large quantities of phloem sap causing more than 50% yield losses. The excreted honeydew serves as medium for sooty mold fungi (*Capnodium* spp.) which reduce the crop quality. Few species serve as vectors of economic viral plant pathogens.

In Egypt, it is well known as a key pest on field and vegetable crops especially tomatoes and squash in traditional and protected plantations. Investigators attributed the increase of whitefly in the last few years to changes in ecosystem such as intensification and diversification of the cropping system, the use of broad spectrum and persistent chemicals that suppressed the natural enemies and the resistant to many groups of pesticides due to their extensive applications. Hence, applying alternatives of traditional pesticides is urgently needed (Azab *et al.*, 1971, Coudiret *et al.*, 1985, El-Bessomy *et al.*, 1996, El-Khawalka *et al.*, 1996, Puri *et al.*, 1991, and Radwan *et al.*, 1985).

The aim of this work is to evaluate the bioefficacy of certain conventional pesticides and their alternatives for controlling the whitefly *B. tabaci* under laboratory and field conditions.

MATERIALS AND METHODS

Sensitive race of *B. tabaci* was reared on sweet potato in pots as described by Azab *et al.* (1971). Stock culture was initiated by exposing potted sweet potato plants to adults of *B. tabaci* for 12 hours. Newly deposited eggs (0-1 day old) were kept under laboratory conditions (27$\pm$1 °C, 65$\pm$5% R.H. and photoperiod 16 L:8 D) until appropriate stages were ready for bioassay tests.

1. **The tested pesticides were** Furathiocarb (Deltanet) 40% EC, Pirimiphos-methyl (Actellic) 50% EC, Tedifol 24.5% EC (Kelthane "Dicofol"18.5%+Tedion 6%) applied at the rates of 0.5, 1.5, and 1 L/feddan. The insect growth regulators (IGR) were Buprofezin (Applaud) 25% S.I. applied at the rate of 0.8 L/feddan. The biocontrol agent was Biofly (*Beauvaria bassiana* 3x10^2 conidia/ml. applied at the rate of 0.4 l/feddan. The mineral oils KZ oil 95% EC, Schocrona 95% applied at the rate of 2 l/feddan. The liquid detergents Nastabon and Oki applied at the rate of 2 l/feddan. The natural vegetative oil was isolated from seeds of black cumin *Nigella sativum.* The seed powder was soaked in distilled petroleum ether at 40-60 °C for 3 days. The mixture was agitated for 6 hr using mechanical shaker. The extract was filtered, dried over a hydrous sodium sulfate and the solvent was evaporated under pressure using a rotary evaporator.

2. **Toxicity tests against adults:** The toxicity of pesticides, alternatives or their mixture (1 pesticides: 10 alternatives) were prepared using tap water. Triton X-100 was added to natural oil as an emulsifier. The bioassay technique described by El-Helaly *et al.* (1976) was adapted with minor modifications. Adults were exposed to

treated leaf discs of sweet potato plants (2-3 cm diameter) dipped in each concentration for 10 second. After drying discs were introduced into test-kit vials (5x2-3 cm). Twenty adults were introduced into each vial and each treatments was replicated 3 times. Kits were maintained at 27$\pm$1 °C, 65$\pm$5% R.H. and photoperiod of 11.5 hours. After 24 hr, mortality counts (dead or moribund) were recorded. Obtained data were corrected by Abbott formula (Abbott, 1925). LCP-lines were drawn and statistically analyzed according to Litchfield and Wilcoxon (1949). Toxicity index was calculated according to Sun equation (Sun, 1950) as follows:

$$\text{Toxicity index} = \frac{LC_{50} \text{ of the most toxic compound}}{LC_{50} \text{ of the candidate compound}}$$

3. For pesticides/alternative mixtures, potentiation ratio was calculated according to Metcalf equation (Metcalf, 1967) as follows:

$$\text{Potentiation ratio} = \frac{LC_{50} \text{ of the pesticide alone}}{LC_{50} \text{ of the pesticide in the mixture}}$$

4. Toxicity tests against immature stages: Leaves attached to plants carrying the deposited eggs (2-3 days old) were sprayed with the tested concentrations using hand sprayer till run-off. Each treatment was replicated 4 times. After 7 days, un-hatched eggs or crawlers that died during hatching were counted. LCP-lines were drawn and LC50 values were calculated (LC50: the concentrations that inhibited hatching of 50% of the treated eggs).

Leaves carrying larvae (12 days old) and pupae (16 days old) were sprayed with different tested concentrations. Number of treated individuals varied within the tested concentrations and their replicates because of the oviposition differences. After 48 hr, mortality counts were recorded. Larvae and pupae that were dry and detached from the leaf when probed were considered dead. Mortality percentages were calculated and corrected by Abbott formula (1925). LCP-lines were drawn and statistically analyzed according to Litchfield and Wilcoxon (1949).

5. The toxicity as latent effect: Leaves (attached to sweet potato plants) and carrying the oviposited eggs were sprayed with the tested toxicants at concentrations equal to their LC50`s. Development of stages starting with eggs was observed daily till ceasation of adult emergence in the untreated check. Hatchability percentage, pupal case, and adult emergence after 7, 12, and 21 days, respectively were determined.

6. The entomopathogenic effect of the fungus *Beauvaria bassiana* : The entomopathogenic effect of *B. bassiana* was tested against *B. tabaci* under laboratory conditions. Eggs were sprayed with fungus suspension at concentration of 3x104 conidia/ml which equal to the concentration in the field. The developmental stages were examined for any abnormalities or fungal infection compared with untreated check.

7. Calculation for susceptibility factor: To predict the possibility of applying toxicants (tested in the laboratory) effectively in the field, the susceptibility factor was calculated as the formula adopted by Khalafalla and Abo-Sholoa (1993) as follows:

$$\text{Susceptibility factor} = \frac{LC_{90} \text{ of the tested toxicant from LCP line (ppm)}}{\text{Field recommended concentration (ppm)}}$$

Field recommended concentration based on that dose/feddan diluted to 400 L as final volume of spray. The toxicant expected to be effective under field conditions are those having values less or equal to 0.5 only.

8. Field experiments: The efficacy of pesticides, alternatives or their mixture, and microbial insecticide (Biofly) was evaluated under field conditions on squash and cotton plants at Sakha Agric. Res. Station, Kafr El-Sheikh. The cultivated cotton area (var., Giza 75) was divided into plots, each of 1/100 feddan. Another cultivated squash area (var., Eskandarani) was divided into plots, each of 10 m^2. A complete randomized block design was adopted. Mature plants in late season were sprayed with pesticides, alternatives or their combinations. Pesticides were mixed with alternatives at half dose of each. Doses per feddan were each completed to 400 liters of water as a final volume of spraying liquid. In case of vegetative oil, Triton X100 was added to the diluting water at 0.075% to ensure a good emulsification. A knapsack sprayer (20 liters) was used. Four replicates (i.e., 4 plots) were set for each treatment. Four plots were left untreated as check control. Samples of cotton (20 leaves) and squash (5 leaves) were randomly chosen from each replicate 2, 3, 5, 7, and 14 days after application, and the number of insects were visibly counted in the field at 6-9 AM. The same samples were carefully taken to the laboratory in cloth bags to count the number of living immature stages using a binocular-microscope. Initial kill after 48 hrs and percentage reduction of infestation were estimated according to Henderson and Tilton (1955) as follow:

% reduction of infestation = 100 [1- (B x A*) / (A x B*)]

Where, A: number of individuals in the treatment before spraying.

B: number of individuals in the treatment after spraying.

A*: number of individuals in check before spraying.

B*: number of individuals in check after spraying.

Bio-insecticide (Biofly) was tested on squash plants in separate cultivated area. It was divided into 4 plots, each of 2 karats. The entomopathogenic fungus (*B.*

bassiana) was sprayed at dose of 0.4 L/Feddan diluted to 400 L water as a final volume. Percentage initial kill and percentage reduction were estimated as described above.

For all treatments, vegetative growth was examined during the season for any phytotoxicity or morphological changes compared with the untreated check.

RESULTS AND DISCUSSION

A. Laboratory Bioassay Tests:

1. **Toxicity to adults:** Data presented in Table (1) indicated that the highest toxicity effect was resulted from the IGR (Buprofezin) treatment, followed by the vegetative oil, pesticide (Pirimiphos-methyl), and the mineral oil (KZ) showing LC_{50} value of 76, 80, 84, and 170 ppm, respectively. Furathiocarb, Tedifol, and Schocrona resulted in moderate toxicity effect (220, 260, and 360 ppm, respectively). However, Confidence limits of LC_{50} values showed great interference between them. Detergents showed weak toxicity as LC_{50} values for Nastabon and Oki were 800 and 2200 ppm, respectively.

The superiority of vegetative oil as toxicant against *B. tabaci* (LC_{50} = 80 ppm) was previously confirmed by El-Khawalka *et al.*, 1996.

Table 1. The toxicity of the tested pesticides and their alternatives on adults of *Bemisia tabaci* under laboratory conditions

Compound	LC_{50} ppm	Confidence limits	Slope	Toxicity index *	LC_{90} ppm	Confidence limits
Furathiocarb	220	145.7-332	2.5	34.5	750	500-1125
Pirimiphos-methyl	84	46.9-165.5	1.5	90.5	620	246.3-1109
Tedifol	260	176.9-382.2	2.6	29.2	820	561.6-1197
Buprofezin	76	25.25-228.2	0.92	100	1900	633.3-57.0
KZ oil	170	85-340	1.5	44.7	1250	625-2500
Schocrona	360	264.7-489.6	3.3	21.1	880	647-1196.8
Vegetative oil	80	48.2-132.8	2.0	95.0	370	224.2-610.5
Nastabon	800	330.6-636	1.15	9.5	1100	458.3-2540
Oki	2200	973-4972	1.2	3.5	3000	1363-6600

$$\text{* Toxicity index} = \frac{LC_{50} \text{ of the most toxic compound}}{LC_{50} \text{ of the candidate compound}} \times 100$$

2. **Toxicity to eggs:** Table (2) showed that toxicants could be categorized into 2 groups according to LC_{50} (concentrations required to inhibit hatching of 50% of eggs). The most effective compounds on *B. tabaci* eggs include Pirimiphos-methyl, vegetative oil, and mineral oil (KZ) which show LC_{50}'s of 180, 250, and 265 ppm, respectively. The less effective compounds include Furathiocarb, Schocrona, and Nastabon which show LC_{50}'s of 300, 500, and 500 ppm, respectively. Tedifol, Buprofezin, and Oki were inferior in this respect showing LC_{50}'s of 620, 800, and 900 ppm, respectively. The comparative high ovicidal action exhibited by vegetative and mineral oils could be attributed to its unique mode of action. Mineral and plant oils are considered physical poisons that interfere with insect respiration. Thus, oils making thin films surrounding to eggs might prevent egg respiration leading to the good ovicidal action (Coudiret *et al.*, 1985).

Table 2. The ovicidal toxicity of the tested pesticides and their alternatives on eggs of *Bemisia tabaci* after 7 days of treatments under laboratory conditions

Compound	LC_{50} ppm	Confidence limits	Slope	Toxicity index *	LC_{90} ppm	Confidence limits
Furathiocarb	300	250-360	1.4	60	2500	2083-3000
Pirimiphos-methyl	180	156.5-207	1.75	100	1000	869.5-1150
Tedifol	620	522.3-732.9	1.2	29	7000	5932-8260
Buprofezin	800	689.6-928	1.4	22.5	7000	6034-8120
KZ oil	265	240.9-291.5	5.2	67.9	500	454.4-550
Schocrona	500	276.2-304.5	2.8	36	1550	861-2790
Vegetative oil	250	227.3-275	2.8	72	700	642.2-763
Nastabon	500	416.6-600	2.8	36	1550	1291.6-1860
Oki	900	825.6-981	2.6	20	2900	2661-3161

$$\text{* Toxicity index} = \frac{LC_{50} \text{ of the most toxic compound}}{LC_{50} \text{ of the candidate compound}} \times 100$$

3. **Toxicity to immature stages (larvae and pupal case):** The toxicity of the tested pesticides or their alternatives on immature stages of *B. tabaci* (larvae and pupal case) were presented in Table (3). Data on larvae indicated that Furathiocarb exhibited the highest toxicity followed by the mineral oil (Schocrona) and vegetative oil (LC_{50}'s gave 60, 80, and 110 ppm, respectively). Low toxicity was resulted by the IGR, Buprofezin (310 ppm), while very weak toxicity was displayed by the detergents (1100 ppm).

Pupal case were considerably less susceptible to the tested toxicants(LC50s > 600 ppm) except Furathiocarb (270 ppm). The weak toxicity of IGR (Buprofezin) could be due to the recording of data 48 hours after treatment. Generally, IGRs have no direct toxicity but had latent lethal disturbance in development, reproduction or other vital functions as the chitin-deficient endocuticle disrupts and insect became unable to moult. In this respect, Ishaaya *et al.* (1988) found that Buprofezin had no direct effect on adults of *B. tabaci* or oviposition but strongly inhibited 50% of egg hatch and suppressed more than 95% of the progeny formation up to 26 days after treatment.

Table 3. The toxicity of the tested pesticides and their alternatives on immature stages of *Bemisia tabaci* (larvae and pupae) under laboratory conditions

Compound	LC_{50} ppm	Confidence limits	Slope	Toxicity index *	LC_{90} ppm	Confidence limits
Larvae						
Furathiocarb	60	31.5-114	1.6	100	370	147.7-703
Pirimiphos-methyl	160	106.6-240	2.3	37.5	650	433.3-975
Tedifol	160	80-320	1.4	37.5	1300	650-2600
Buprofezin	310	206.6-456	2.6	19.3	950	633-1425
KZ oil	230	194.2-322	2.7	26	760	593.2-826
Schocrona	80	53.3-152	1.5	75	620	413.3-930
Vegetative oil	110	68.7-176	1.9	54.5	500	312.5-750
Nastabon	1100	733-1650	2.2	5.5	4300	2867-6450
Oki	1100	647-1850	1.8	5.5	5900	3470-10030
Pupae						
Furathiocarb	270	180-450	2.3	100	1000	667-1500
Pirimiphos-methyl	650	500-845	3.5	4.5	1500	1154-1950
Tedifol	600	1230-2080	3.1	16.8	4300	3308-5590
Buprofezin	600	500-720	5.6	45	1000	833.3-1200
KZ oil	840	560-1260	2.5	32.1	2300	1533-3450
Schocrona	840	646-1092	3.1	32.1	2300	1769.2-2990
Vegetative oil	1450	1907-2320	2.1	18.5	5800	3648-9222
Nastabon	1900	1462-2470	3.3	14.2	4800	3692-6240
Oki	1400	1166-1680	3.9	19.3	3100	2883-3720

$$\text{* Toxicity index} = \frac{LC_{50} \text{ of the most toxic compound}}{LC_{50} \text{ of the candidate compound}} \times 100$$

4. Latent toxicity effect on egg hatching, pupation and adult emergence:

Table (4) showed the latent effect produced from treated eggs of *B. tabaci* with LC_{50}'s of the tested pesticides or their alternatives. Apart from detergents, pesticides or their alternatives showed considerable latent effect where pupation and adult emergence were greatly reduced. The highest effect was observed with the IGR (Buprofezin). No adult emergence was noted 21 days after treatment compared with 89.7% adult emergence in untreated check. Radwan *et al.* (1985) found that IGR`s remarkably inhibited and delayed maturation and adult eclosion of *B. tabaci* and the effect was dose-dependent.

Table 4. Latent effect produced from treating eggs of *Bemisia tabaci* with LC_{50} of tested pesticides and their alternatives under laboratory conditions

Compound	Initial no. of eggs	Hatching of eggs (after 7 days)		Pupation (after 12 days)		Adult emergence (after 7 days)	
		No.	Hatchability (%)	No.	Pupation (%)	No.	Emergence * (%)
Furathiocarb	140	73	52.1	18	12.8	9	6.4
Pirimiphos-methyl	133	53	39.8	45	33.8	38	28.5
Tedifol	370	190	51.5	86	23.2	83	22.4
Buprofezin	275	119	43.3	35	12.7	0	0
KZ oil	155	80	51.6	22	14.2	17	10.96
Schocrona	227	146	64.3	35	15.4	4	1.76
Vegetative oil	100	63	63	18	18	10	10
Nastabon	150	123	82	105	70	95	63.3
Oki	80	80	100	68	85	62	77
Control	245	233	95.1	225	91.8	220	89.7

*Based on the Initial no. of eggs.

It could be concluded that based on the laboratory results, the tested IGR (Buprofesin), mineral and natural vegetative oils were promising materials in protecting plants against adults or immature stages of the whitefly *B. tabaci*. The detergents tested were of lower toxicity in this respect. Puri *et al.* (1991) found that 3 days after treatment, vegetative oils were superior to a washing powder (detergents) in their insecticidal efficacy against *B. tabaci*.

5. Joint action of pesticides and their alternatives:

Table (5) showed that none of the tested alternatives (mineral, natural vegetative oils, or detergents) showed potentiation action to Pirimiphos-methyl or Buprofesin against adults of *B. tabaci*. It was obvious that Furathiocarb was potentiated by the natural vegetative oil, detergent, and strongly by mineral oil (potentiation ratios: 1.15, 1.22, and 3.33, respectively). Pronounced potentiation was observer when mixing Tedifol with mineral oil, natural vegetative oils, and detergent (potentiation ratios: 4.33, 8.66, and 4.06, respectively).

In this respect, Ishaaya *et al.* (1986) stated that petroleum oil might increase the uptake of toxicant by the insect or reduce its evaporation, dissipation or both. In some insects, petroleum oil inhibits respiration and in that turn may synergize the toxicity of pesticides that act on the nervous system.

Table 5. The toxicity of the tested pesticides alone or mixed with certain alternatives at ratio 1: 10 and the synergistic action of some alternatives on the toxicity of pesticides against adults of *Bemisia tabaci* under laboratory conditions

Pesticide or alternative compound	LC_{50} in ppm	Confidence limits	Slope	LC_{90} in ppm	Confidence limits	Potentiation ratio at LC_{50}
Furathiocarb (Fura)	220	145.7-332	2.5	750	500-1125	-
Fura.+KZ oil	66	21.9-198.6	0.92	1800	600-2400	3.33
Fura.+Vegetative oil	190	119.5-302.1	2.17	750	474.6-1158	1.15
Fura.+Nastabon	860	298.6-2476.8	0.96	19000	6785-53200	0.26
Fura.+Oki	180	63.16-513	0.96	3900	1392.8-10920	1.22
Pirimiphos-methyl (Pir-me)	84	46.9-165.5	1.5	620	346.3-1109.8	-
Pir-me. + KZ oil	270	110.2-661.5	1.12	2800	1166.6-6720	0.31
Pir-me. +Vegetative oil	125	83.9-186.3	2.5	400	285-560	0.67
Pir-me. + Nastabon	350	236.5-518	2.5	1200	857.2-1680	0.24
Pir-me. + Oki	400	242-660	1.6	1300	812.5-2080	0.21
Tedifol	260	176.9-382.2	2.6	820	561.6-1197.2	-
Tedifol+ KZ oil	60	19.9-180.5	0.89	1800	600-5400	4.33
Tedifol+Vegetative oil	30	9.5-94.8	0.88	900	290.3-2790	8.66
Tedifol+ Nastabon	170	68.8-419.9	1.12	2500	1041.6-6000	1.53
Tedifol+ Oki	64	29.3-139.5	1.3	650	299.5-1410.5	4.06
Buprofesin	76	25.25-228.2	0.92	1900	633.3-5700	-
Buprofesin+KZ oil	250	127.6-490	1.4	1800	947.3-3420	0.30
Buprofesin+Vegetative oil	100	85.5-117	0.6	160	137.9-185.6	0.76
Buprofesin+Nastabon	340	236.1-489.6	2.8	1000	714.3-1400	0.22
Buprofesin+Oki	470	283.1-780.2	0.2	21000	13125-33600	0.16

6. The entomopathogenic effect of *Beauvaria bassiana* against *Bemisia tabaci*:

Results in Table (6) indicated that *B. bassiana* greatly affected the developmental stages of *B. tabaci*. Egg hatching, pupation, and adult emergence were greatly reduced particularly when eggs of 1-2 days old were used. Out of 80 eggs as initial treated number, only 5% pupal case (morphologically infected and dead) was obtained. The produced infected pupal case failed to develop to adults. For sign of infection, eggs did not become infected but pupae or adults infected filled with a white mycelium which occasionally covered the insect entirely. The entomopathogenic fungus *B. bassiana* was frequently found to reduce *B. tabaci* stages in different experiments (El-Bessomy *et al.*, 1996). The infect conidia of the fungus may penetrate the insect cuticle from a combination of mechanical pressure by germ tube and enzymatic degradation of the cuticle.

Table 6. The entomopathogenic effect of *Beauvaria bassiana* against *Bemisia tabaci* under laboratory conditions

Treatment	Concentration Conidia/ml	Initial no. of eggs	% Hatchability * (after 7 days)	% Pupation* (after 12 days)		% Adult emergence* (after 7 days)	
				H	I	H	I
Entomopathogenic fungus *B. bassiana*	3x104	73	52.1	18	12.8	9	6.4
	3x104	53	39.8	45	33.8	38	28.5
Untreated check	---	190	51.5	86	23.2	83	22.4
	---	233	95.1	225	91.8	220	89.7

*: Based on the Initial no. of eggs, H: Healthy, I: Infected

B. Field Experiments:

1. Insecticidal activity of single toxicants:

Results in Tables (7) and (8) showed that the tested materials varied in their efficacy depending on the examined stage (adults or immature stages), type of attacked plants (cotton or squash), and mainly the type of toxicant. Data indicated that apart from Pirimiphos-methyl, pesticides (Furathiocarb or Tedifol) were poorly effective against adults or immature stages infesting cotton or squash. Pirimiphos-methyl was relatively effective against adults on cotton and squash (initial kill: 92 and 86%, and average of reduction: 69.6 and 72.5%, respectively). However, Pirimiphos-methyl was of poor efficacy against immature stages (larvae and pupae).

The IGR (Buprofezin) had faint efficacy against adults especially on cotton plants. However, considerable effect was noticed against immature stages on cotton and squash (initial kill: 75 and 11%, and average of reduction: 84.2 and 90%, respectively). It was clear that the average of reduction through the experimental period was higher than initial kill.

Mineral or vegetative oils gave satisfactory results and kept *B. tabaci* under control throughout the experimental period as adults or immature stages were considerably reduced. The percentage initial kill for adults ranged 63.3-83.3% and 75-82%, while the average percentage reduction ranged 67.5-68.3% and 66-69.5% on cotton and squash, respectively. As for pupae and larvae, the effect was better, showing percentage initial kill ranged 72.5-89% and 82-91%, while the average percentage reduction ranged 67.3-96.5% and 62.5-81% on cotton and squash, respectively.

Table 7. Efficacy of pesticides and their alternatives against adults of *Bemisia tabaci* on cotton and squash plants under field conditions.

Compound	Application rate (L/Fed)	Average no./leaf/ treatment	% initial kill 48 hr after applica-tion	% Reduction after application / days				Aver-age of % reduc-tion
				3	5	7	14	
on cotton								
Furathiocarb	0.4	10	0.0 g	0	18.5	0	0	4.6 c
Pirimiphos-methyl	1.5	21.5	92 a	71.8	67.6	67.2	71.8	69.6 a
Tedifol	1.0	26	37.7 de	60.6	54.5	78.6	71	66.3 a
Buprofezin	0.8	8.5	0.0 g	0	0	26	0	6.5 c
KZ oil	2.0	25	83.3 ab	69	68.6	52.2	82.9	68.3 a
Schocrona	2.0	20	63.3 c	86.7	76.8	64.5	85.5	78.4 a
Vegetative oil	2.0	18.5	77.5 bc	77.6	85.6	62.8	39.2	66.3 a
Nastabon	2.0	16.5	29.3 e	0	11.7	10.2	0	5.4 c
Oki	2.0	22	46.9 d	33.8	68.4	3.7	11.7	29.4 b
Untreated check	--	18.5	--	0	0	0	0	0
on squash								
Furathiocarb	0.4	25	13.4 d	--	--	49.6	0	24.8 f
Pirimiphos-methyl	1.5	37.5	86 a	--	--	88	57	72.5 b
Tedifol	1.0	15	0 e	--	--	0	62	31 f
Buprofezin	0.8	39.75	46 c	--	--	69	68	69 bc
KZ oil	2.0	30	75 b	--	--	84	48	66 cd
Schocrona	2.0	51.6	82 a	--	--	83	33	58 de
Vegetative oil	2.0	53.75	82 a	--	--	57	82	70 bc
Nastabon	2.0	56.29	37 c	--	--	53	38	45.5 e
Oki	2.0	41.25	48 c	--	--	50	68	58 de
Untreated check	---	53.75	0	--	--	0	0	0

In the same column, means followed by the same letter are not significantly different according to Duncan (1955).

Although oils had no residual toxicity, they suppressed the number of insect under control for two weeks. This might be attribued to their effect on adult and immature stages leading to suppression of the population and reducing progeny formation. The pronounced ovicidial action of these oils was also observed. The pesticide action of mineral oils against the adult or immature stages were currently reported by Ishaaya *et al.* (1986).

For soap, weak activity against the adult *B. tabaci* was observed showing percentage initial kill ranged 29.3-46.9% and 37-48%, while the average percentage reduction ranged 5.4-29% and 45.5-57.5% on cotton and squash, respectively.

Table 8. Efficacy of pesticides and their alternatives against immature stages (larvae and pupae) of *Bemisia tabaci* on cotton and on squash and against eggs on squash plants under field conditions.

Compound	Application rate (L/Fed)	Average no./leaf/ treatment	% initial kill 48 hr after application	% Reduction after application at days				%Average of reduction
				3	5	7	14	
Against immature stages on cotton								
Furathiocarb	0.4	7.5	30 cd	0	26	30	0	14 e
Pirimiphos-methyl	1.5	4	61.3 b	50	40	42.6	32.5	41.3 d
Tedifol	1.0	7	14.3 d	28.6	100	14.3	0	35.8 d
Buprofezin	0.8	9	75 b	100	76.9	100	60	84.2 b
KZ oil	2.0	8.25	89 a	94.2	99	87.8	98.6	94.9 a
Schocrona	2.0	7	72.5 b	80.5	91.8	0	96.9	67.3 c
Vegetative oil	2.0	6	80 a	88.2	100	99	99	96.5 a
Nastabon	2.0	2	75 ab	76.5	95	100	95	91.6 a
Oki	2.0	4	66.8 b	41.2	99	50	99	72.3 c
Untreated check	--	9	0	0	0	0	0	0
Against immature stages on squash								
Furathiocarb	0.4	37.5	79 b	--	--	39	65	52 a
Pirimiphos-methyl	1.5	20	0 e	--	--	0	0	0 e
Tedifol	1.0	25	14 d	--	--	9	0	4.5 d
Buprofesin	0.8	45	11 d	--	--	100	80	90 a
KZ oil	2.0	50	88 a	--	--	87	75	81 b
Schocrona	2.0	40	82 ab	--	--	70	55	63 c
Vegetative oil	2.0	40	91 a	--	--	93	65	79 b
Nastabon	2.0	20	66 c	--	--	78	71	74.5 b
Oki	2.0	25	72 b	--	--	61	58	59.5 c
Untreated check	--	23.5	0	--	--	0	0	0
Against eggs on squash								
Furathiocarb	0.4	15	73.9 b	--	--	97	56	77 ab
Pirimiphos-methyl	1.5	10	99 a	--	--	100	55	78 ab
Tedifol	1.0	10	50 d	--	--	60	75	68 ab
Buprofezin	0.8	10	60 c	--	--	100	40	70 ab
KZ oil	2.0	7.5	88 b	--	--	100	60	80 a
Schocrona	2.0	6.25	61 c	--	--	84	92	88 a
Vegetative oil	2.0	12.5	99 a	--	--	60	100	80 a
Nastabon	2.0	7.5	66 a	--	--	87	76	81.5 a
Oki	2.0	10	54 c	--	--	99	20	59.5 b
Untreated check	--	15	0	--	--	0	0	0

In the same column, means followed by the same letter are not significantly different according to Duncan (1955).

However, good results were obtained against larvae and pupae where percentage initial kill ranged 66.8-75% and 66-72%, while the average percentage reduction ranged 72.3-91.6% and 59.5-74% on cotton and squash, respectively. A moderate efficacy of detergents against eggs was also observed, this was not in parallel to results obtained in the laboratory that showed 82 and 100% hatchability caused by Nastabon and Oki, respectively. The variation may be due to uneven coverage of spray on plant parts during application.

2. Efficacy of pesticides / alternative mixtures against *Bemisia tabaci*:

Results recorded in Tables (9) and (10) revealed that mixing alternatives with Furathiocarb greatly improved the efficacy of this compound against adults or

Table 9. Efficacy of pesticides alone and combined with certain alternatives (mixed at half dose of each) against adults of *Bemisia tabaci* on squash plants under field conditions.

Pesticide or alternative compound	Average no. of adult/leaf/ treatment	% initial kill 48 hr after application	% Reduction after application at days				Aver-age of % reduction
			3	5	7	14	
Furathiocarb (Fura)	25	13.4 e	--	--	49.6	0	24.8 eg
Fura.+KZ oil	40	81.6 b	--	--	97.6	94.3	95.9 a
Fura.+Vegetative oil	36.75	77.9 b	--	--	79.5	69.2	74.4 bc
Fura.+Nastabon	27	95.8 a	--	--	90.2	77.8	84 ab
Fura.+Oki	72.5	76.6 b	--	--	68	88.3	78.2 abc
Pirimiphos-methyl (Pir-me)	37.5	86 ab	--	--	88	57	72.5 bd
Pir-me. + KZ oil	30	33.4 d	--	--	77.9	19.8	48.9 de
Pir-me. +Vegetative oil	45	3.7 f	--	--	0	87.4	43.7 de
Pir-me. + Nastabon	25	35.9d	--	--	11.4	15.1	13.3 g
Pir-me. + Oki	31	0 g	--	--	12.4	49.8	31.1 ef
Tedifol	15	0 g	--	--	0	100	50 ce
Tedifol+ KZ oil	26.25	60.5 c	--	--	64	89.2	76.6 ac
Tedifol+Vegetative oil	25	0 g	--	--	0	0	0 h
Tedifol+ Nastabon	20	24.6 de	--	--	80	36.3	58.2 cd
Tedifol+ Oki	15	37.1d	--	--	27.7	39.6	33.7 e
Control	53.75	0	0	0	0	0	0

Table 10. Efficacy of pesticides alone and combined with certain alternatives (mixed at half dose of each) against immature stages of *Bemisia tabaci* on squash plants under field conditions.

Pesticide or alternative compound	Average no. of adult/leaf/ treatment		% initial kill 48 hr after application		% Reduction after application / days				Average of % reduction	
					7		14			
	Egg	Pupal case	Egg	Pupal case	Egg	Pupal case	Egg	Pupal case	Egg	Pupal case
Furathiocarb (Fura)	15	37.3	73.9 b	79 b	97	39	56	65	76.5 cd	52 d
Fura.+KZ oil	25	41.9	62 b	26.7 f	89	100	100	98	94.6 ab	99 a
Fura.+Vegetative oil	10	53	100 a	8.5 h	63	66	83	82	72.5 cd	74.1 b
Fura.+Nastabon	23	33	100 a	0 i	100	86	97	79	98.5 a	82.5 b
Fura.+Oki	7.5	53	100 a	61 c	93	82	100	100	96.4 ab	90.9 ab
Pirimiphos-methyl (Pir-	10	20	99 a	0 i	100	0	55	0	77.5 cd	0 g
me)	7.5	22.5	99 a	39.4 e	0	75	0	58	0 g	66.5
Pir-me. + KZ oil	19	32	99 a	46.7 d	98	30	100	56	99 a	bc
Pir-me. +Vegetative oil	10	10	0 f	0 i	93	0	40	0	66.4 de	42.7 e
Pir-me. + Nastabon	7.5	10	8.1 e	99 a	88	0	92	0	89.8 ab	0 g
Pir-me. + Oki										0 g
Tedifol	10	25	99 a	14 g	60	9	75	0	67.5 de	4.5 f
Tedifol+ KZ oil	10	10	31 d	99 a	100	0	10	0	55 e	0 g
Tedifol+Vegetative oil	15	75	54 c	0 i	90	0	90	0	90 ab	0 g
Tedifol+ Nastabon	56	10	99 a	99 a	100	0	40	0	70 cd	0 g
Tedifol+ Oki	10	7.5	99 a	99 a	64	100	100	0	82.2 bc	50 d
Control	15	23.5	0	0	0	0	0	0	0	0

immature stages *B. tabaci*. The effect was more noticeable for adults (for mixture, percentage initial kill ranged 76.6-95.8% and the average percentage reduction ranged 74.4-95.9%) compared with Furathiocarb alone (percentage initial kill 13.4% and the average percentage reduction 24.8%). Mixtures of Pirimiphos-methyl or Tedifol with alternatives failed to achieve a good control against adults or immature stages. It was found that the efficacy of pesticides / oil mixtures (compared with single pesticides) against *B. tabaci* varied considerably depending on the mixing ratio, type of oil and/or pesticides used (Ishaaya *et al.,* 1986). On the other hand, mixing IGR`s with pesticides was often of advantageous effect against *B. tabaci*.

3. Efficacy of the entomopathogenic fungus *Beauvaria bassiana* (Biofly) against *Bemisia tabaci*:

Results recorded in Table (11) showed that bio-control agent *B. tabaci* was of low efficacy against *B. tabaci* and failed to produce satisfactory suppression of the population throughout the tested period, where average percentage reduction was 36.6 and 48% for eggs and adults, respectively. These results were not in harmony with those of laboratory that showed a considerable entomopathogenic effect against *B. tabaci*. The reduction of efficacy of the fungus under field conditions might be due to climatic conditions. High humidity for number of nights per week was critical for reliable pest control, therefore, fungi cannot be depended on for field use.

For all treatments, examination during the season showed that no phytotoxicity appeared as leaves injuries or morphological changes or abnormalities could be noticed on the vegetative growth of all treated plants compared with those of untreated check.

Table 11. Efficacy of the entomopathogenic fungus *Beauvaria bassiana* (Biofly) against *Bemisia tabaci* on squash plants under field conditions.

Treatment	application rate (L/400 L. w/fed)	Average No./ inch²/ leaf	Average No./ leaf/ treatment	% Reduction after application / days			Average of % reduction
				2	7	14	
Eggs							
Entomopathogenic fungus *B. bassiana*	0.4	50		54	28	28	36.6
Untreated check	--	60		0	0	0	0
Adults							
Entomopathogenic fungus *B. bassiana*	0.4		27	20	55	71	48
Untreated check	--		21.5	0	0	0	0
Immature stages (larvae and pupal case)							
Entomopathogenic fungus *B. bassiana*	0.4		10	0	0	0	0
Untreated check	--		20	0	0	0	0

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دراسات التقييم الحيوي معمليا والمكافحة الحقلية لذبابة القطن والطماطم البيضاء *Bemisia tabaci* في مصر

السيد محمد السيد خلف الله ، سميرة حنين متري،
علي محمود علي ناصف

معهد بحوث وقاية النباتات– مركز البحوث الزراعية – الدقي – الجيزة– مصر.

تم تقييم إجراءالتقييم الحيوي لبعض مبيدات الآفات {فيوراثيوكارب (دلتانيت) والبريميفوس ميثايل (أكتيلك) والتيديفول (كلثين "ديكوفول"+ تيديون)} ومنظمات النمو الحشرية (IGR) {بوبروفيزين (أبلود)} والبيوفلاى (فطر *Beauvaria bassiana*) والزيوت المعدنية (كزد وشيكرونا) والمنظفات الصناعية (نستابون وأوكاي) والزيوت النباتية الطبيعية في مكافحة الذبابة البيضاء تحت الظروف المعملية والحقلية.

أظهرت نتائج التجارب المعملية السمية العالية للبوبروفيزين علي الحشرات الكاملة، يليه الزيوت النباتية والبريميفوس ميثايل وكزد، ثم فيوراثيوكارب والتيديفول وشيكرونا. أظهر البريميفوس ميثايل والزيوت النباتية وكزد فعالية كبيرة علي البيض، أما فيوراثيوكارب وشيكرونا والنستابون فكانت أقل فعالية. أظهر فيوراثيوكارب سمية شديدة لليرقات يليه شيكرونا والزيوت النباتية. كانت العذارى أقل في حساسيتها من اليرقات للمركبات المستخدمة ما عدا فيوراثيوكارب. لم يكن لمنظمات النمو الحشرية أي سمية مباشرة. وبخلاف المنظفات الصناعية، فإن المبيدات وبدائلها أظهرت تأثير باقي بلغ أقصاه مع مركب بوبروفيزين. أمكن تقوية فيوراثيوكارب مع الزيوت النباتية والمنظفات الصناعية وبدرجة كبيرة مع الزيوت المعدنية. أمكن تقوية التيديفول بدرجة ملحوظة عند خلطه مع الزيوت المعدنية والمنظفات الصناعية والزيوت النباتية. أثرت المعاملة بالفطر الممرض بدرجة كبيرة علي نمو الأطوار المختلفة.

أظهرت التجارب الحقلية أنه ما عد البريميفوس ميثايل، فإن فيوراثيوكارب أو التيديفول كانا ضعيفا الفعالية ضد الحشرات الكاملة أو الأطوار غير الكاملة علي نباتات القطن والكوسة. كان لمنظمات النمو الحشرية بوبروفيزين فعالية غير واضحة ضد الحشرات الكاملة، إلا أنه كان هناك تأثير ملحوظ ضد الأطوار غير الكاملة علي القطن والكوسة. أدت المعاملة بالزيوت المعدنية أو الزيوت النباتية إلي تقليل الإصابة بدرجة جيدة ضد الحشرات الكاملة أو الأطوار غير الكاملة. وعلي الرغم من أن الزيوت ليس لها متبقيات سامة، فإنها أدت إلي تثبيط الحشرة لمدة أسبوعين. أما المنظفات الصناعية فكان تأثيرها جيدا ضد اليرقات ومرحلة العذراء، وكان التأثير متوسطا ضد البيض. حسّن خلط البدائل مع فيوراثيوكارب كثيرا من فعاليتها ضد الحشرات الكاملة أو الأطوار غير الكاملة.