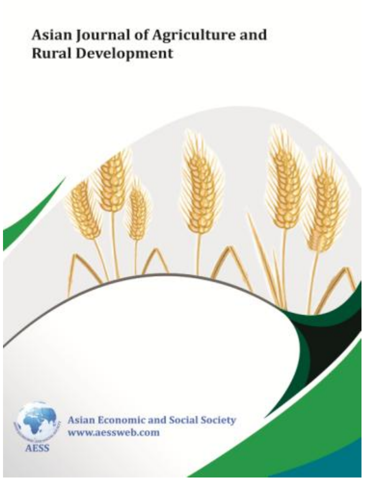
Publisher: Asian Economic and Social Society
ISSN (P): 2304-1455, ISSN (E): 2224-4433
Volume 2 No. 3 September 2012.



Field Evaluation of Some Insecticides on Whitefly (Trialeurodes vaporariorum) and Predator (Macrolophus caliginosus) on Brinjal and Tomato Plants

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Citation: Mohd Rasdi, Z., Che Salmah, M. R., Abu Hassan, A., Hamady. D., Hamaseh A. and Fauziah Ismail (2012) "Field Evaluation of Some Insecticides on Whitefly (Trialeurodes vaporariorum) and Predator **(**Macrolophus caliginosus) on Brinjal and Tomato Plants", Asian Journal of Agriculture and Rural Development, Vol. 2, No. 3, pp. 302-311.

Acknowledgements: We were grateful to the Head of MARDI station in the Cameron Highlands for providing the experimental sites and other facilities used in this experiment. This project was supported by the Ministry of Higher Education, Malaysia. Thanks to anonymous referees.

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Abstract

The effect treatments with the recommended application rates of avermectin, buprofezin, white oil, lambda-cyhalothrin and cyromazine on Trialeurodes vaporariorum Westwood (Aleyrodidae: Homoptera) was evaluated. Pesticides were applied against larvae infesting brinjal (Solanum melongena L.) and tomato (Lycopersicon esculentum Mill) plants in a natural environment of the Cameron Highlands, Pahang, Malaysia. We also examined whether these pesticides affect the whitefly predator, Macrolophus caliginosus Wagner (Heteroptera: Miridae). Tested pesticides significantly reduced the larval populations of the whitefly and affect throughout the survey period. Similar effects were observed on the predator except for the white oil. Avermectin was the most effective insecticide against the population of T. vaporariorum. However, it was highly toxic to the predator, M. caliginosus. Considering relatively low mammalian toxicity of buprofezin and white oil, these two insecticides were more suitable for controlling whiteflies, particularly during fruiting period. Proper selection of effective pesticides against the pest, but less harmful to natural enemies and also good timing of their applications are essential in formulating an Integrated Pest Management (IPM) programme for whiteflies.

Keywords: Brinjal, insecticides, Macrolophus caliginosus, tomato, Trialeurodes vaporariorum

Introduction

Brinjal (Solanum melongena L.) and tomato (Lycopersicon esculentum Mill) are considered as important commercial crops planted in the Cameron Highlands, the most productive upland vegetable production area in the state of Pahang, in Peninsular Malaysia. Both of these fruit vegetables are grown in the open fields as well as under protected rain shelters. The most destructive pest infesting these crops is a highland whitefly, Trialeurodes vaporariorum Westwood (Homoptera: Aleyrodidae) (Syed Abdul Rahman et al. 2000, Mohd Rasdi et al. 2009) that sucks the sap of plant leaves, stems, buds and flowers (Mohd Rasdi 2005). Insecticides have been substantially used to control this pest in Malaysia (Syed Abdul Rahman et al. 2000) and other parts of the world, particularly in the United States during the past decade (Perring et al. 1993, Ellsworth 1999). In the desert growing areas of Arizona and southern California, control of whitefly relies solely on chemical control. At these places, warm and dry climates and overlapping availability of multiple crop hosts throughout the year caused the population to be very high (Palumbo et al. 1999). Consequently, the whitefly Bemisia tabaci Gennadius (Homoptera: Aleyrodidae) has developed resistance to numerous conventional insecticides throughout the world (Dittrich & Ernst 1990, Denholm et al. 1996) leaving fewer effective insecticides to control the pest in the market (Li et al. 2001). Meanwhile several species of natural enemies have been reported to reduce the population of whiteflies in the fields (Alomar & Albajes 1996, Albajes & Alomar 1999). Unfortunately, in the advent of insecticides usage, the roles of natural enemies in whitefly control are undermined and they are killed together with the pest during insecticide applications. In Malaysia, suppression of whitefly population is very much dependent on chemical applications (Syed Abdul Rahman et al. 2000). Several types of insecticides which are very effective against whiteflies have been developed and available in the market (Horowitz & Ishaaya 1996). In this study efficacies of few selected insecticides on larval whitefly, T. vaporariorum infesting brinjal and tomato were investigated. Their toxicities against predator, Macrolophus caliginosus Wagner (Heteroptera: Miridae) were also evaluated.

Material and Methods

Study area

This study was conducted at Malaysian Agricultural Research and Development Institute (MARDI) Station, in the Cameron Highlands, Pahang, Malaysia. This station was located at an altitude of approximately 1400 meter above sea level, with an average temperature of 22±2ºC and relative humidity of 90±5%. Insecticide trials were carried out in a protected rain shelter from February to August 2003.

Plant materials

The seeds of ‘Super Naga’ F1 hybrid brinjal and Gin Yuen Bao variety of tomato were sown in seedling trays consisting of 104 small holes, filled with compost. After two weeks, the seedlings were transferred into white polybags (30×30 cm), filled with a mixture of cocoa peat and burnt rice husk at a ratio of 1:1. Polybags were arranged in rows under a rain shelter, of which water and nutrients were supplied through a drip irrigation system. Both plants were fertilized regularly with mixed fertilizers (calcium nitrate-900g/46%; potassium nitrate-152g/7.87%; potassium chloride-320g/16.57%; magnesium sulphate-500g/25.89%; phosphoric acid-13.6g/0.7%; ferum EDTA-41.6g/2.15%; zinc sulphate-0.1g/0.05%; cuprum sulphate-0.1g/0.05%; boric acid-1.4g/0.072%; ammonium molibadate-0.4g/0.02%; manganese sulphate-2g/0.103%) at doses recommended by the MARDI. To ensure an optimum plant growth, nutrient concentration was measured using a TD Scan4 and pH of the water was estimated by a Portable pHScan1. The plants were supported by plastic ropes tied across the structure of the rain shelter when they grew to 45 cm high or had four to five branches. Brinjal and tomato started to flowering at 4 to 6 weeks after transplanting. Side branches were pruned twice monthly to maintain a single trunk for better growth and high fruit production.

Experimental layout

Tomato and brinjal plants were watered and fertilized using a drip irrigation system that was constructed perpendicular to one end of the experimental planting beds. To minimise the variations in nutrients uptake by plants in each bed, the experiments were laid out using a randomised complete block design (RCBD). For both brinjal and tomato plants, two parallel rows of seedlings (in polybags), spaced 45 cm within rows and 100 cm between rows, were placed on a raised planting bed of 18 m long and 1 m wide. The bed was covered with black plastic mulches. Each bed was divided longitudinally into 6 plots of 10 seedlings (from 2 rows), separated by a plant from each row between plots to minimize effects of insecticide drift and movements of whiteflies to other plots. Five types of insecticides, one insecticide in each plot, were used in the experiments. The sixth plot was untreated control plot. Each planting bed represented one experimental block and four planting beds were prepared to provide four replications of each crop tested.

Insecticide application

Insecticides selected for these experiments were those commonly used by the farmers in the Cameron Highlands and readily available in the market (Myint, 1997). Five insecticides namely avermectin (Agrimec, 2% w/w, 9ml/9L), white oil (Albarol, 25ml/9L), buprofezin (Applaud, 9g/9L), lambda-cyhalothrin (Karate, 2.8%w/w, 9ml/9L) and cyromazine (Trigard, 8.9%w/w, 24ml/9L) were applied at manufacturer's recommended rates on clear days, from 0900 am to 1000 am. A nine-litre knapsack sprayer (Hatsuda Industrial Co.) was used to spray (spray pressure rate at 1.0 to 2.0 bar; deflector nozzle type= rated about 1.2 l/min at 1 bar) (Jones, 2006) the insecticide with fine quality spray and uniformly to the plants throughout the experiments. The first round of insecticides application was carried out 4 weeks after transplanting (WAT), when infestation of whiteflies reached the Economic Threshold Level of 20 larvae per leaf. This population level was recommended by MARDI and accepted in the Cameron Highlands growing area. Following that, the insecticides were regularly applied at weekly intervals until the end of cropping period of about two and a half months. Ten grams of fungicide (mancozeb 80% w/w) were mixed with all insecticides to prevent fungal infestation (powdery mildew) that commonly infested tomato and brinjal plants in this area. Since whitefly larvae preferred the undersides of brinjal and tomato leaves, all leaf surfaces were thoroughly sprayed to ensure uniform distribution of pesticides.

Sampling of T. vaporariorum and M. caliginosus on brinjal and tomato plants

A pre-treatment sampling of larval T. vaporariorum was carried out from 0900 am to 1200 noon, three days prior to the first application of tested insecticides. Following insecticide applications at 4 WAT, whitefly and its predators were sampled 3 days before the next insecticide treatments. According to Gomez and Gomez (1984), leaves at the middle stratum of the plant (10 leaves from the top) were the most suitable plant parts to estimate populations of whitefly and its predator. For both host plants, three leaves of similar sizes were randomly selected from each plot to sample whitefly and its predator. Sampling of the predator, M. caliginosus was conducted simultaneously on both crops. Each leaf was carefully and slowly inserted into a plastic bag (20×30 cm) and cut at its petiole. The opening of the bag was closed by holding it tightly and the predators on the leaves were immobilized with CO_2 (supplied by Malaysia Oxygen Sdn Bhd,) released for approximately 20-30 s into the bag at a flow rate of 20 psi. Then the leaf was shaken vigorously to dislodge the predators to the bottom of the plastic bags. The plastic bag was slowly pulled down until the leaf was outside of the bag and immediately fastened to prevent the escape of the predators when the effect of CO_2 has worn out. The leaf was kept in a new bag. Collection of the predators and whiteflies were done in three replicates per plot. The leaves with whiteflies and their predators were taken to the laboratory and examined under a stereo microscope (Olympus-SZX7). The numbers of whitefly larvae and their predators were counted and recorded. A total of 12 leaves per treatment (3 leaves×4 replicates) were thoroughly examined for whitefly larvae on every sampling occasion for each of the crop. Similarly 12 samples were collected for the whitefly predators in each treatment.

Data analysis

To evaluate the effect of the insecticides against the whitefly, the numbers of larvae were counted 72 hours after insecticide applications. Differences in abundance of whitefly larvae among the treatments were analysed using the Two-Way Analysis of Variance (Sokal & Rohlf 1969) and significant means were differentiated by the Duncan Multiple Mean Comparison using the SPSS, (2004) version 14.

Results

Abundance of T. vaporariorum in various treatments on brinjal

Overall, all insecticides significantly reduced the population of T. vaporariorum larvae for the entire sampling period (F = 9.891; df = 5,167; P < 0.05) compared to the untreated plot. Among the insecticides, avermectin was the most effective, reducing the population of whitefly below ETL from 5 week after transplanting (WAT) to 8.33/leaf at 10 WAT. Buprofezin was fairly effective as it decreased the pest population to ETL from 6 WAT to 9 WAT (Table 1). It was not effective at 4 and 5 WATs because as an insect growth regulator (IGRs). Buprofezin did not kill adult whiteflies at the time of the treatment (Bogran & Heinz 2000). Those adults continued to reproduce hence high numbers of larvae were recorded at those times. White oil (horticultural oils) reduced the population of T. vaporariorum larvae to 15/leaf at 9 WAT. In lambda-cyhalothrin and cyromazine treated plots, the population levels of T. vaporariorum larvae were maintained at above 20 larvae/leaf and increased to >250 larvae/leaf at the end of the study. The abundance of whitefly fluctuated erratically in lambda-cyhalothrin treated plot and increased tremendously to a very high level (274.67 ± 316.86) at 10 WAT, indicating this insecticide is completely ineffective against whitefly. A decrease in total number of T. vaporariorum larvae was observed at 5 WAT in cyromazine treated plot (22.67 ± 10.12) but the population increased continuously until 10 WAT (268.67 ±1 87.21). In the untreated plot, whitefly population increased superfluously (490.00 ± 148.44) at 10 WAT (Table 1), causing development of sooty mould on the surfaces of leaves.

Table 1: Mean number of larval whitefly, T. vaporariorum on brinjal leaves treated with different insecticides

WAT*	Treatment					
	Untreated	Buprofezin	Avermectin	Lambda-cyhalothrin	Cyromazine	White oil
Pre-monitoring	19.50ab	24.25ab	15.50ab	7.750ab	38.25bc	21.25ab
4 WAT	59.92±50.28a	127.33±59.65b	46.00±39.80a	82.00±82.64ab	85.33±99.81ab	49.67±32.68a
5 WAT	68.33±79.12a	33.67±30.12ab	14.67±17.40b	23.00±15.37b	22.67±10.12b	23.00±16.81b
6 WAT	97.67±54.49a	16.67±11.51b	12.67±10.30b	56.33±76.80ab	56.67±53.15ab	37.67±9.19b
7 WAT	142.67±211.85a	11.67±14.0b	17.33±3.39b	24.33±34.40b	53.67±62.30ab	61.33±11.12ab
8 WAT	121.33±68.61a	19.67±16.62bc	2.67±8.02b	64.00±51.24ac	81.33±117.05a	31.67±17.59b
9 WAT	400.67±459.35a	11.33±18.83bc	8.33±5.31bd	149.00±187.79acd	111.33±109.0bd	15.00±13.15bd
10WAT	490.00±148.44a	31.00±37.11b	8.33±2.10b	274.67±316.86c	268.67±187.2c	28.00±17.07b
Mean± S.E.**	197.24±56.89a	35.90±13.95bc	15.71±4.89c	96.19±31.54ab	97.10±28.42ab	35.19±22.59bc

Means in the row with the same letters are not significantly different at P = 0.05 based on Duncan Multiple Range Test (DMRT).
* Week after Transplanting; ** Standard Error of Mean

Abundance of M.caliginosus in various treatment plots of brinjal

At pre-treatment sampling, no significant difference was observed in the mean number of predators among the different plots (F = 1.067; df = 5,23; P > 0.05). After the treatment, all insecticides significantly reduced the population of M. caliginosus except white oil (F = 10.535; df = 5,147; P < 0.05). Avermectin caused a significant decrease in population of predators compared to that untreated plot at 6, 7, 8 and 9 WAT (F = 4.050; df = 5,23; P < 0.05) (F = 9.857; df = 5,23; P < 0.01) and (F = 10.345; df = 5,23; P < 0.01), respectively (Table 2). During the study, predators' abundance was found to be the highest in the untreated plot (40.00 ± 1.43), followed by white oil (37.00 ± 1.21), buprofezin (26.00 ± 0.87), lambda-cyhalothrin (24.00 ± 0.78), cyromazine (16.00 ± 0.78), and avermectin (1.00 ± 0.14) treated plots.

Table 2: Mean number of M. caliginosus per leaf after insecticide applications on brinjal

WAT*	Treatment					
	Untreated	**Buprofezin**	**Avermectin**	**Lambda-cyhalothrin**	**Cyromazine**	**White oil**
pre-monitoring	0.50a	0.50a	0.25a	0.50a	0.25a	0.75a
4 WAT	1.00±0.41a	0.75±0.48a	0.00a	1.00±0.58a	0.25±0.25a	0.75±0.25a
5 WAT	1.00±0.58a	0.25±0.25a	0.25±0.25a	0.75±0.48a	0.25±0.25a	1.25±0.48a
6 WAT	0.75±0.25ab	1.00±0.41a	0.00c	0.25±0.25bc	0.00c	0.50±0.29abc
7 WAT	1.25±0.25a	0.75±0.25ab	0.00bc	0.50±0.29b	0.75±0.25ab	1.25±0.25a
8 WAT	2.50±0.29a	1.25±0.25b	0.00c	1.25±0.25b	1.25±0.25b	2.00±0.41ab
9 WAT	3.00±0.41a	2.00±0.41ab	0.00e	1.5±0.25cd	1.25±0.25c	2.75±0.48ab
Mean ± S.E.**	1.43±0.36a	0.93±0.22ab	0.04±0.04c	0.86±0.20ab	0.57±0.19b	1.32±0.30a

Means in the row with the same letters are not significantly different at P= 0.05 based on Duncan Multiple Range Test (DMRT).
* Week after Transplanting; ****** Standard Error of Mean

Abundance of T. vaporariorum in various treatment plots of tomato

The pre-treatment sampling indicated that population of whitefly was high, above the ETL in all treatment plots. There was no significance difference in their densities (mean numbers (F = 0.672; df = 5,23; P > 0.05) before the treatments but significantly different among treatments after chemical applications during the whole sampling period (F = 6.389; df = 5,167; P < 0.01). The number of whitefly larvae sharply decreased in all treatments (including control plot) after insecticides application at 4 WAT (Table 3). However, no significant difference was observed between plots treated with white oil and avermectin and the untreated plot at 4 WAT (F = 1.764; df = 5,23; P > 0.05) and at 5 WAT (F = 1.687; df = 5,23; P > 0.05) which possibly related to low effectiveness of the insecticides on whiteflies.

Generally, population of larval whitefly was not significantly different among the treated plots at 6 WAT (F = 5.442; df = 5,23; P < 0.05), 7 WAT (F = 4.904; df = 5,23; P < 0.05), 8 WAT (F = 6.406; df = 5,23; P < 0.05), 9 WAT (F = 7.630; df = 5,23; P < 0.05) and 10 WAT (F = 6.314; df = 5,23; P < 0.05). The effect of insecticides on larval whitefly on tomato at 9 and 10 WAT were similar to that recorded on brinjal on the same sampling occasion, although whitefly abundance was 9 times lower in untreated tomatoes compared to untreated brinjal. The population of whitefly was significantly lower (P<0.05) in all chemical treated plots compared to the control plot at 6 WAT, but only populations in buprofezin and avermectin were lower at 7 WAT. At 8 WAT, no significant difference was observed among buprofezin, avermectin, white oil and the control plot (Table 3). Evidently, buprofezin and avermectin were effective in reducing the whitefly population to below the ETL. At the end of the growing period, population density of whitefly larvae decreased when the predators' population increased.

Table 3: Mean number of larval whitefly, T. vaporariorum on tomato leaves treated with different insecticides

WAT*	Treatment					
	Untreated	**Buprofezin**	**Avermectin**	**Lambda-cyhalothrin**	**Cyromazine**	**White oil**
Pre-monitoring	81.25a	32.00a	88.50a	62.00a	101.25a	91.75a
4 WAT	31.00±7.35abc	20.25±2.59bc	37.00±7.35abc	25.75±11.52bc	46.00±4.18ad	30.25±2.83abc
5 WAT	20.25±6.02ab	11.00±3.02ac	21.75±9.45ab	32.00±3.89bd	23.00±3.29ab	17.50±2.99ab
6 WAT	42.00±2.35a	12.00±2.86b	18.75±1.93b	21.75±4.55b	19.25±2.75b	21.50±8.26b
7 WAT	25.00±5.52a	4.75±1.75bc	7.50±1.55bcd	25.75±6.32a	18.00±2.80ad	14.25±3.11acd
8 WAT	5.25±0.85a	3.50±0.96a	6.00±1.83a	17.50±3.30b	20.00±5.23b	8.50±1.26a
9 WAT	17.25±3.44a	3.75±1.31b	5.00±1.08b	14.50±3.77a	20.00±3.24a	5.25±0.63b
10WAT	10.75±1.11ab	4.25±0.75ad	1.50±0.65d	10.50±2.02ab	17.00±4.81bc	4.50±1.26ad
Mean± S.E.**	21.64±4.68a	8.50±2.37b	13.93±4.77ab	21.11±2.81ab	23.32±3.85a	14.54±3.54ab

Means in the row with the same letters are not significantly different at P= 0.05 based on Duncan Multiple Range Test (DMRT).
* Week after Transplanting ; **Standard Error of Mean

Abundance of M. caliginosus in various treatment plots of tomato

Significant difference in mean number of predator among the treatment plots were observed during the whole sampling period (F = 11.372; df = 5,143; P < 0.01). Initially, the population of M. caliginosus was higher, then decreasing trends in its population were recorded in avermectin, lambda cyhalothrin and cyromazine plots. Immediately after treatments in other plots, abundance of M. caliginosus increased tremendously in the untreated plot to its highest peak at 5 WAT (5.50 ± 1.32), then decreased gradually until the end of growing season (Table 4). Avermectin suppressed the predator's population considerably (P < 0.05) until the end of the sampling period. In buprofezin treated plot, M. caliginosus population fluctuated slightly but maintained at satisfactory levels (compared to the control plot) until the end of the growing season. Lambda-cyhalothrin reduced predators' population significantly compared to the control plot at 6 WAT (F = 3.886; df = 5,23; < 0.05) and 9 WAT (F = 6.807; df = 5,23; P < 0.05). Cyromazine significantly suppressed the population of M. caliginosus at 5 WAT (F = 6.547; df = 5,23; P < 0.05), 6 WAT (F = 3.886; df = 5,23; P < 0.05), 7 WAT (F = 3.233; df = 5,23; P < 0.05), 8 WAT (F = 3.395; df = 5,23; P < 0.01) and 9 WAT (F = 6.807; df = 5,23; P < 0.05). Apart from its toxicity towards the predator, Cyromazine was previously found ineffective against whitefly infesting both brinjal and tomato (Syed Abdul Rahman et. al. 2000). White oil was rather harmless to Macrolophus caliginosus.

Table 4: Mean number of M. caliginosus after insecticides application on tomato

WAT*	Treatment					
	Untreated	**Buprofezin**	**Avermectin**	**Lambda-cyhalothrin**	**Cyromazine**	**White oil**
pre-monitoring	2.25a	2.75a	4.00a	2.25a	2.00a	5.75a
4 WAT	3.75±1.25a	2.00±1.00a	1.50±0.50a	2.00±0.41a	2.75±1.11a	3.50±1.32a
5 WAT	5.50±1.32a	3.50±0.65ad	0.50±0.29b	3.50±0.87ad	0.75±0.25bc	3.25±0.48d
6 WAT	4.25±1.03a	2.75±1.44b	0.00c	0.75±0.25bc	1.75±0.48b	1.50±0.29bc

7 WAT	2.00±0.41a	3.00±0.71ab	0.00d	1.75±0.85ac	1.25±0.48cd	2.50±0.65ac
8 WAT	2.25±0.75a	2.25±0.48a	0.25±0.25b	1.25±0.75ab	0.25±0.25b	2.25±0.48a
9 WAT	2.00±0.41a	1.75±0.48a	0.00b	0.50±0.29bc	0.25±0.25b	1.25±0.25a
Mean ± S.E.**	3.29±0.59a	2.54±0.27ab	0.38±0.24c	1.63±0.44ab	1.17±0.40bc	2.38±0.37ab

Means in the row with the same letters are not significantly different at P= 0.05 based on Duncan Multiple Range Test (DMRT), * Week after Transplanting ; ****** Standard Error of Mean

Discussion

Population of T. vaporariorum was found to be very much higher (9 times higher) on brinjal than on tomato but its predator, M. caliginosus preferred the smoothness of tomato leaf better than the hairy brinjal leaf as a platform to attack the whiteflies. Its population was 2.3 times more abundant on tomato plants compared to on brinjal plants. The result of this study also indicated that whitefly is more important as a pest for brinjal than for tomato. Low population of M. caliginosus on brinjal further contributed to the seriousness of whitefly attack on this crop. In tomatoes however, lower whitefly population with a relatively high predatory activities (population ratio pest:predator = 6:1) alleviated the effect of whitefly infestation, keeping its population just slightly above the ETL (20 insects/leaf) in the untreated plot. Mohd Rasdi (2005) reported that daily predation rate of M. caliginosus ranged from 5.3 to 6.3 whitefly larvae. At the population ratio recorded on tomatoes, whitefly infestation may not require chemical control interventions at all. Albajes and Alomar (1999) reported that an IPM program based on the conservation of mirid predators has significantly reduced population of whitefly in the fields and greenhouses. Using biological control agents can reduce the toxic effect of insecticides in the plants as well as in the environment.

At the initial stage of both experiments (brinjal and tomato), all the insecticides did not significantly decrease population of whitefly compared to the control plot. Different developmental stages of whiteflies had different degree of tolerance to insecticides. The eggs and pupae were less susceptible to the insecticides as they were protected by their egg shells and cocoons respectively (Sparks et al. 2002). Therefore, a single application of insecticide only killed the susceptible stages during the time of application. More tolerant stages and escaped individuals (adults) continued to grow and reproduce thus added to the high numbers of larvae after the first treatment. The results of this study showed that insecticides such as avermectin, buprofezin, and white oil required weekly application during a 30- 40 day period (four to six rounds of application), a duration for the completion of a whitefly's life cycle. However, application of insecticides at alternate week and utilization of the lowest effective dosage also reduced or delayed pesticide resistance development on the whitefly population (Palumbo et al. 2001, Drees 2000). Application of buprofezin and white oil that have relatively low mammalian toxicity, particularly during the fruiting period can help to reduce pesticide residue problems in the freshly harvested yields.

Among the insecticides used in this study, avermectin was found to be the most effective against the whitefly on both brinjal and tomato. However, this chemical was highly toxic to whitefly predator, M. caliginosus. Avermectin with its systematic properties has a good effectiveness, especially to the underside of the leaves where whiteflies mostly develop. A growth regulator, buprofezin affects specifically on immature developmental stages of whitefly resulting in nymphal mortality during ecdysis (Yasui et al. 1987). De Cock et al. (1990) reported that buprofezin caused mortality of B. tabaci nymphs through its vapour (vapour pressure, 9.4×10^{-6} mm Hg). It acted through inhalation by nymphs, and through direct contact as well as adsorption by the integument of the pests. Although buprofezin has no direct effect on longevity and oviposition of whitefly adult, it may reduce the fecundity and egg hatchability of females exposed to treated leaves (Ishaaya et al. 1988). In this study, bufrofezin showed relatively high effectiveness on the whitefly larvae after the avermectin although its effectiveness was only started at 6 WAT. White oil was detrimental to whiteflies on tomato but not on brinjal. Different morphological characteristics of tomato and brinjal leaves possibly influenced the effectiveness of this oil. White oil makes inconvenient places for adult whiteflies to oviposit. This oil is a contact insecticide, causing suffocation and desiccation to the nymph and adult. This chemical can be considered as a good alternative to control whiteflies as it is relatively safe to the natural enemies (Bogran & Heinz 2000). White oil has relatively low mammalian toxicity and can be used during the fruiting period which can help to reduce pesticide residue problems in the harvested yield.

The effectiveness of insecticides against whitefly in this study could be influenced by some factors other than efficacy of experimental insecticides. Firstly, during fruiting period, brinjal fruits were harvested at a fortnight interval. The plants were disturbed and some movements of whiteflies from treated to untreated plots or displacement of individual whitefly (especially adults) in the field could be expected. Secondly, the spraying coverage of insecticides on brinjal plants in the field is probably less uniform than in the full netted greenhouse due to the effect of wind. However, this factor can be considered negligible in this study. The honeydew deposited on the brinjal fruits makes them sticky, causing fungal growth and subsequently developed sooty mould on the leaves. The mould affects the dispersion of the insecticides as well as photosynthesis and transpiration processes of the plants (Berlinger 1986). In this study, M. caliginosus colonised naturally in the experimental plots. According to Alomar et al. (2002), natural colonisation of this predator occurs during the growing season and mixed population are commonly found in the crop. M. caliginosus is currently produced and marketed commercially in Europe for controlling of the greenhouse whitefly, T. vaporariorum Westwood, and the sweet potato whitefly, Bemisia tabaci Gennadius in tomato (Lenfant & Schoen 2000). A mirid bug management programme has been developed for an integrated pest management in tomato crops with the objective of keeping population density of predator high enough to maintain the greenhouse whitefly (T. vaporariorum) and other pest populations below than the economic threshold (Alomar & Albajes 1996, Albajes & Alomar 1999). Smith et al. (1997) proposed that for a successful biological control, it is important that predator population must be present earlier in the field and established when the pest population is at low density. However, in many cases when the population of whitefly increases immediately, the predator would not be effective in controlling the whitefly.

As conclusions, avermectin is the most effective insecticide to reduce population of larval whitefly on brinjal and tomato plants. However, it was toxic to whitefly predator, M. caliginosus. Meanwhile, buprofezin and white oil decreased the population of whitefly quite satisfactorily especially on tomatoes with only slight reduction in density of predators in the field. Combination of potential insecticide with biological agents such as M. caliginosus helps to control this pest. Selection of insecticides that is less harmful to the natural enemies, appropriate insecticide rotation and timing of application should be taken into account in formulating an Integrated Pest Management (IPM) against whiteflies.

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