J. Trop. Agric. and Fd. Sc. 41(1)(2013): 149–157

Population abundance of whitefly, *Bemisia tabaci* (Genn.), on chilli and other vegetable crops under glasshouse conditions

(Kelimpahan populasi lalat putih, *Bemisia tabaci* (Genn.), pada cili dan sayur-sayuran lain di bawah rumah kaca)

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Keywords: *Bemisia tabaci, Capsicum annuum*, host plant preference

Abstract

Whitefly (WF), *Bemisia tabaci* (Genn), is one of the most damaging pests for several vegetables in Malaysia which affects plant vigour, transmits geminiviruses and reduces crop quality. This study estimated the population abundance of *B. tabaci* on chilli, *Capsicum annuum* MC 11 alone, MC 11 planted with brinjal, *Solanum melongena* MT e1, tomato, *Lycopersicum* esculentum MT 1 or okra, *Abelmoschus esculentus* MK BE1 and MC 11 planted with a combination of all the other crops under glasshouse conditions. WF adults, egg and nymph samples were obtained every 4 days from the underside of the leaf (abaxial) on the upper, middle and lower strata of the plant for one month. The total mean numbers of WF adults, eggs and nymphs were significantly higher (p <0.05) on chilli in the monoculture experiment than on chilli in multiple crops experiment with okra, tomato and brinjal. Results also showed that the population of WF adults and eggs were significantly higher in the upper stratum than in the middle and lower plant strata. Interestingly, the number of nymphs was higher in the middle stratum than in the other strata in all treatments. This phenomenon indicated that mixed crops can lower pest populations and indirectly reduce virus disease incidence.

Introduction

Chilli (*Capsicum annuum*) is one of the new species in the New World origin which is cultivated throughout South-East Asia, with the pungent forms having the greatest distribution and importance (Siemonsma and Piluek 1994). The Food and Agriculture Organization reported that Asia produced 18,055,581 metric tonnes of chillies from 1,154,310 ha of land in 2010 (FAO 2010). Reports issued by the Ministry of Agriculture Malaysia (2011) indicated that production and areas planted with chillies in Malaysia in 2011 were 35,339 metric tonnes and 2,993 ha respectively.

Chilli cultivation is a risky venture. It is beset with many problems and constraints including those caused by pests and diseases. Among the pests that inflict a heavy toll on chilli production is the whitefly (WF), *Bemisia tabaci*. Reliable estimates of the economic impact of the *B. tabaci* species on agriculture systems are not easy to predict due to the extensive

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areas affected, the number of crops and ornamentals involved and different monetary systems used (Ellsworth 1999). *Bemisia tabaci* is also described as an ecumenical insect and a main pest in cropping systems in many tropical and subtropical areas (Oliveira et al. 2001). The pest damages the crops by direct and indirect feeding. Direct feeding involves activities such as sucking the cell sap in the leaves which strip the plant of vital nutrients, thus decreasing the productivity and health of the plant. The second is known as indirect damage in which the pest produced a sticky secretion known as honeydew, which supports the growth of sooty moulds (Lopez and Cock 1986). In addition, the WF also transmits plant pathogenic viruses and acts as an efficient vector of numerous geminiviruses (Chu and Henneberry 1998).

Currently, over 100 begomoviruses are known to be transmitted by at least two biotypes of the WF, to more than 20 different cultivated species of socioeconomic importance. Some of the main crops affected by whitefly-transmitted geminiviruses are the common bean, mung bean, black gram, lima bean, soybean, cowpea, tomato, potato, eggplant, pepper, chilli peppers, melon, watermelon, squash, okra, cassava, cotton and papaya (Muniyapa 1980; Brown 1994).

Bemisia tabaci was first reported as a pest of tobacco in Greece in 1889, but since 1990, it has been considered as a serious pest of cotton in North India (Singh et al. 1990). It became one of the important limiting factors for successful growing of cotton in Punjab. The result of reduced seed cotton yield, contamination with honeydew, sooty mould and transmission of begomoviruses such as cotton leaf curl virus (CLCuV) causing cotton leaf curl disease (Vikas and Dhaliwal 2009) and the economic damages of seed-cotton yield in Punjab (Singh et al. 1994) were estimated to range between 10.6 and 92.2%. In 1991 and 1992, losses of seed-cotton yield caused by *B. tabaci* in Arizona, California, Texas and Florida were estimated at about US200 and 500 million dollars respectively (Ellsworth 1999).

The whitefly was recorded as a pest for the first time in Malaysia in 1935 on soybean and okra in the lowlands of Malaya (Corbett 1935). Syed et al. (2000) later reported that *B. tabaci* was present in most parts of Peninsular Malaysia on vegetables such as angled loofah, brinjal, cucumber, french bean, long bean and okra. *Bemisia tabaci* is considered as polyphaguous for a wide variety of commercial and non-commercial plant species. Furthermore, the preference of the WF for the economic plants varies from one plant to another. Toscano et al. (2002) observed that the WF preferred *Lycopersicon esculentum* than the other types of tomato based on the density of adults and eggs numbers found on the plants. The structures of the plant (sizes, shapes and surfaces of leaves) have important impacts on herbivorous insects (McLellan 2005). Thus, the objective of this study was to investigate the response of *B. tabaci* populations on chilli (*C. annuum*) alone and chilli planted with several vegetables such as brinjal (*S. melongena*), tomato (*L. esculentum*) and okra (*A. esculentus*).

Materials and methods

The experiment was conducted in a glasshouse at the Malaysian Agriculture Research and Development Institute (MARDI) in Serdang, Selangor, from February to July 2010. The experiments were conducted in screen cages measuring 1.5 m × 3.0 m × 2.0 m and kept at 30 – 36 °C with 60 – 80% RH. Adult WFs used in the study were reared on tobacco plants for one month (before use in the experiments) inside screen cages measuring 0.5 m × 1.20 m × 1.2 m. The seeds of chilli (*C. annuum*, MC 11), brinjal (*S. melongena*, MT e1), tomato (*L. esculentum*, MT 1), and okra (*A. esculentus*, MK BE1) were obtained from MARDI Station Jalan Kebun, Klang. Seeds were planted in pots with soil mixtures at a ratio of 2:1:1 for clay, sand

and natural fertilizer. After planting, the seedlings were grown in separate insect-proof cages and when the plants reached 3 to 5 leaf stages, they were transferred to the experimental cages.

Monoculture chilli experiment

A total of 32 chilli plants were used in this experiment and arranged in a completely randomized design (CRD) with 3 replicates. Each replicate had 4 rows of chilli spaced 10 cm within and 20 cm between rows with 400 WF adults released into it (Toscano et al. 2002). After one day infestation, adult WF density was randomly counted daily on 3 plants per replicate on the underside of the leaf (abaxial) from the upper, middle and lower strata of the plants for one month (Naranjo and Flint 1995). Sampling of WF eggs and nymphs were performed every 4 days in 1 cm^2 disk using a stamp that was placed between the central and left lateral leaf veins (3 sampling per leaf). Sampling was made on the abaxial surface of 3 leaves per plant from each stratum for one month. The eggs and nymphs were observed under a stereoscopic microscope at 40X magnification and their numbers were recorded.

Chilli plus another crop experiment

The chilli was planted either with tomato, brinjal or okra. For each combination, a total of 32 plants (16 plants per species) were arranged alternately following CRD with 3 replicates per treatment. Each replicate consisted of 4 rows of plants spaced 10 cm apart within and 20 cm between rows. Then, a total of 400 WF adults were released into each replicate. Similar to the previous experiment, the sampling of WF eggs and nymphs was performed every 4 days for one month following the method of Naranjo and Ellsworth (2005) on 1 cm^2 disk on the abaxial surface of 3 leaves per plant stratum.

Chilli plus multiple crops experiment

The chili was planted with multiple crops such as brinjal, tomato and okra as treatments (8 plants per species) with 3 replicates. A total of 400 WF adults were released per replicate. The experiment was arranged in a CRD and data collected were similar to the previous procedure.

Data Analysis

One-way ANOVA was used to analyze the numbers of WF eggs, nymphs and adults among plant strata and between the strata of each treatment and those with the multiple crops experiment. Means were separated using Tukey's test at $p < 0.05$. Two-way ANOVA was conducted to determine the differences among means of a number of WF adults, nymphs and eggs among plant strata and different host plants. The *t*-test was also used for chilli plus one crop experiment. All of the above comparisons were done using Minitab Statistical Package Program (Minitab version 15).

Results and discussions

Abundance of WF populations on monoculture chilli

The results of the monoculture experiment showed significant differences ($p < 0.05$) in the mean numbers of WF adults, eggs and nymphs among the strata of the chilli plant. The mean numbers of adults (4.733 ± 0.176) and eggs (3.093 ± 0.361) were significantly higher on the upper stratum compared with the other strata (*Table 1*). The mean numbers of nymphs were also significantly higher on both the upper (1.741 ± 0.260) and middle (2.389 ± 0.420) strata than on the lower stratum (0.444 ± 0.123) of the plant. These results indicated that the WF preferred to lay eggs on the younger leaves on the upper plant stratum. This preference for apical leaves is probably due to the better nutritional quality of smaller and younger leaves than the bigger and older leaves at the lower stratum (Coudriet et al. 1986). These results were in accordance with studies conducted by Khan et al. (2011), Mansour, Mohamad Roff, Saad et al. (2012) and Leite et al. (2006) who reported that the density of WF adults and eggs were

Table 1. Mean (± SE) numbers of adults, eggs and nymphs of *B. tabaci* on different chilli strata in the monoculture experiment

Stage	Lower	Middle	Upper
Adults	0.160 ± 0.019c	1.499 ± 0.089b	4.733 ± 0.176a
Eggs	0.148 ± 0.055b	0.815 ± 0.154b	3.093 ± 0.361a
Nymphs	0.444 ± 0.123b	2.389 ± 0.420a	1.741 ± 0.260a

Means in row with same letter are not significantly different at *p* <0.05 (Tukey's test)

significantly higher on the upper stratum of several host plants. The high number of nymphs at the middle stratum was not surprising considering that these leaves were at the upper strata at the time of egg laying. Additionally, the result is probably due to the immobility of nymphs while the plant continues to grow. Mohd. Rasdi et al. (2009) also observed a higher density of WF nymphs at the middle stratum than at the other strata of the brinjal plant.

Abundance *of WF populations on chilli planted with another plant*

The data presented in *Figure 1a, b* and *c* shows that the total mean numbers of the various life stages of WF on chilli were lower when planted with another plant. The mean number of WF adults was significantly higher in brinjal (t, 1335 = 23.29, p <0.05), okra (t, 1248 = – 27.34, p <0.05) and tomato (t, 1527 = 20.87, p <0.05) than in chilli (*Figure 1a*). Similarly, the mean number of WF eggs was significantly higher in brinjal (t, 168 = 8.09, p <0.05), okra (t, 200 = –8.84, p <0.05) and tomato (t, 203 = 8.16, p <0.05) than in chilli (*Figure 1c*). The same results were obtained for the mean number of WF nymphs, which was significantly higher in brinjal (t, 253 = 3.26, p <0.05), tomato (t, 273 = – 3.71, p <0.05) and okra (t, 294 = 3.26, p <0.05) than in chilli (*Figure 1b*). The results showed that the chilli plant was a non-preference for the oviposition of *B. tabaci* when grown with tomato, brinjal or okra. This preference was not detected when chilli was planted alone, probably because of the better adaptation of *B. tabaci* to non-preferential hosts in

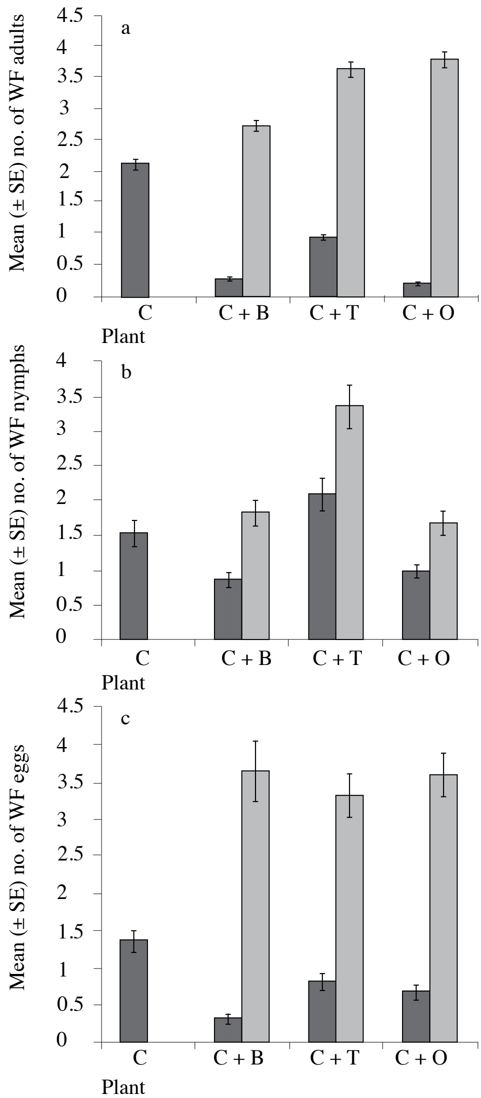

Figure 1. Mean (± SE) number of WF adults (1a), eggs (1b) and nymphs (1c) on chilli (C) planted alone and on C with brinjal (C+B), C with tomato (C+T) or C with okra (C+O)

a monoculture situation. This preference may be related to plant species and plant morphological characters such as the shape of the leaves where these structures have an important impact on herbivorous insects. These results were in agreement with Gold et al. (1989) who found that the population of whitefly, *Trialeurodes variabilis,* was lower on Cassava when intercropped with cowpea, compared with monoculture cassava. Muqit et al. (2008) also suggested that intercropping of cucumber with tomato could increase the yield of tomato by delaying the incidence of tomato yellow leaf curl virus (TYLCV) which is transmitted by *B. tabaci*.

Abundance of WF populations on chilli planted with multiple crops

When the plants were all grown together, the results showed significant differences (p <0.05) in the mean numbers of WF adults, which was higher among brinjal, okra and tomato but lower on chilli (*Table 2*). In contrast, the mean numbers of eggs and nymphs had no significant differences among okra and tomato. The mean numbers of eggs and nymphs were significantly higher on brinjal than on the other plants (*Table 2*).

The data presented in *Table 3* (two-way ANOVA) showed a significant interaction (F = 34.19, df = 6, 636, p <0.05) between the number of eggs per plant strata and host plant. The mean numbers of eggs were significantly different among plant strata (F = 201.7, df = 2, 636, p <0.05) and among host plants (F = 95.54, df = 3, 636, p <0.05). There were significant interactions between plant strata and host plant (F = 166.9, df = 6, 4848, p <0.05) which influenced the mean number of WF adults per plant. The mean numbers of WF adults were significantly different among plant strata (F = 1092.7, df = 2, 4848, p <0.05) and among host plants (F = 633.8, df = 3, 4848, p <0.05). In addition, the interaction among plant strata and host plant also had significant influence

Table 2. Total of mean (± SE) number of adults, eggs and nymphs of *B. tabaci* in multiple crops experiment

Stages	Okra	Tomato	Brinjal	Chilli
Adults	3.250 ± 0.093b	2.249 ± 0.078c	4.978 ± 0.161a	0.054 ± 0.007d
Eggs	1.531 ± 0.164b	1.099 ± 0.138bc	3.877 ± 0.369a	0.352 ± 0.066c
Nymphs	1.957 ± 0.181b	1.457 ± 0.144b	2.988 ± 0.247a	0.543 ± 0.070c

Means in rows with same letters are not significantly different at p <0.05 (Tukey's test)

Table 3. Two-way ANOVA results for mean numbers of adults, eggs and nymphs of *B. tabaci* on chilli planted with multiple crops

WF stages	Source	df	SS	F- value	P-value
Adults	Strata	2	17701.7	1092.7	0.000
	Plant	3	15400.9	633.8	0.000
	Strata X plant	6	8113.1	166.9	0.000
	Error	4848	39265.4		
Eggs	Strata	2	121583.7	201.7	0.000
	Plant	3	1124.9	95.5	0.000
	Strata X plant	6	805.2	34.1	0.000
	Error	636	2496.2		
Nymphs	Strata	2	356.3	42.1	0.000
	Plant	3	504.8	39.8	0.000
	Strata X plant	6	83.5	3.29	0.003
	Error	636	2689.2		

Table 4. Mean (± SE) number of adults, eggs and nymphs of *B. tabaci* on chilli strata when planted with multiple vegetable crops

Stages	Strata	Chilli	Tomato	Brinjal	Okra
Adults	Upper	0.135 ± 0.019c	4.190 ± 0.152b	9.244 ± 0.310a	6.126 ± 0.216ab
	Middle	0.022 ± 8.099c	2.309 ± 0.109b	5.299 ± 0.196a	3.262 ± 0.135ab
	Lower	0.004 ± 3.478b	0.249 ± 0.029a	0.390 ± 0.036a	0.363 ± 0.036a
Eggs	Upper	0.888 ± 0.168c	2.593 ± 0.297b	8.352 ± 0.698a	3.481 ± 0.316b
	Middle	0.148 ± 0.061c	0.630 ± 0.996bc	3.074 ± 0.325a	1.019 ± 0.172b
	Lower	0.018 ± 0.018c	0.074 ± 0.035ac	0.204 ± 0.071ab	0.093±0.039abc
Nymphs	Upper	0.388 ± 0.085c	0.796 ± 0.138bc	2.926 ± 0.364a	1.407 ± 0.212b
	Middle	0.888 ± 0.162c	2.611 ± 0.322b	4.333 ± 0.526a	3.241 ± 0.401ab
	Lower	0.351 ± 0.092b	0.963 ± 0.173ab	1.704 ± 0.289a	1.222 ± 0.212a

Means in rows with same letters are not significantly different at $p < 0.05$ (Tukey's test)

($F = 3.29$, df = 6, 636, $p < 0.05$) on the abundance of WF nymphs per plant. The mean number of WF nymphs per plant was ($F = 39.8$, df = 3, 636, $p < 0.05$) significantly different among plants, ($F = 42.14$, df = 2, 636, $p < 0.05$) and among plant strata.

In general, WF has shown the same behaviour for all experiments, where the mean number of adults was high on the upper stratum for all tested crops, with the highest density in brinjal (9.244 ± 0.310) and the lowest density in chilli (0.135 ± 0.019) (*Table 4*). Similarly, the highest mean number of eggs was noticed on the upper stratum of brinjal (8.352 ± 0.698) and the lowest on the upper stratum of chilli (0.888 ± 0.168). It is somehow predictable that as the number of adults of WF was found to be higher at the upper stratum, the number of eggs at the upper stratum was also higher. Therefore, the preference of WF to the appropriate host plant was reflected in the numbers of adults and eggs found on the plants. However, the highest mean number of nymphs was found on the middle stratum for all crops. The highest density of WF nymphs was noted on the middle stratum of brinjal (4.333 ± 0.526) and lowest on the middle stratum of chilli (0.888 ± 0.162), as listed in *Table 4*. These results could be attributed to species and morphological characters of the plant, such as plant age, the shape of the leaf and the presence of trichomes (Dalin et al. 2008; Mansour et al. 2012). These results were in agreement with Bezerra et al. (2004), who found that tomato, *L. esculentum,* was highly infested with WF when grown individually, compared with when it was grown with weeds, *Acanthospermum hispidum, Amaranthus deflexus, Datura stramonium* and *Euphorbia heterophylla*.

In a study on preference of WF to four varieties of melons, *Cucumis melo* L., Liu (2003) reported that the WF preferred the melon variety PRIMO when it was planted with other varieties such as HYMARK, TAM and TAMSun × gl. In another study, Legaspi et al. (2006) found that the proportions of whitefly eggs and nymphs were highest on cotton, followed by collards, cowpea and tomato, and lowest on hibiscus. This phenomenon may be due to the structure found on the leaves such as trichomes. Butler and Henneberry (1984) as well as Butler et al. (1991) concluded that high density of *B. tabaci* adults was related to high leaf trichome density on cotton (*Gossypium hirsutum* L.) cultivars compared with smooth leaf (with few trichomes) cultivars. Similarly, *B. tabaci* adult females were also found to feed and lay eggs preferentially on soybean which has more trichomes covering the leaves than the garden bean (*P. vulgaris* L.), which has less trichomes (Mansaray and Sundufu

2009; McAuslane 1996). They also reported a positive correlation between hairiness and oviposition of *B. tabaci* on soybean and tomato plants. Earlier reports suggested that this could happen because WF females prefer laying their eggs at the insertion base of trichomes (Berlinger 1986). This behaviour or strategy can protect their eggs from predators and parasitoids (Li et al. 1987; Heinz and Zalom 1995). Butter and Vir (1989) also reported that pubescence leaves in tomato genotypes provided a more suitable microclimate for oviposition by *B. tabaci* females.

Conclusion

Bemisia tabaci is a polyphagous insect which tends to colonize the suitable or better host when several host plants are available. Therefore, this study has shown that the presence of other plants planted with chilli has shifted the adult WF preference to the other plants, especially brinjal and okra, and that the adult WF stayed away from the chilli plant. The same results were shown for eggs and nymphs. These results suggested that chilli should be intercropped with these plants to reduce WF infestation. Another important factor is the nutritional profile, which was not evaluated in this study. Thus, a chemical analysis should be performed to study the effect of the nutritional profile on the behaviour of whiteflies.

Acknowledgement

This study was funded by UKM grant No. 05-01-02-SF1019, 02--0102-SF0601, Research University Grant (OUP): OUP-2012-043, OUP-2013-043 and MARDI grant No. P21003002300001. The authors deeply appreciate Mr Mohd Hanifah Yahya, Ms Salvana Hamid and Ms Siti Sakinah Abdullah for their valuable help. They also thank the staff of MARDI Station Serdang for providing the research facilities and the Ministry of Higher Education in Libya for granting a doctoral scholarship to the senior author.

References

Berlinger, M.J. (1986). Host plant resistance to *Bemisia tabaci*. *Agric. Ecosystems Environ.* 17: 69 – 82

Bezerra, M.A., De Oliveira, M.V. and Vasconcelos, S.D. (2004). Does the presence of weeds affect *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae) infestation on tomato plants in a semi-arid agro-ecosystem? *Neotropical Entomology* 33(6): 769 – 775

Brown, J.K. (1994). Current status of *Bemisia tabaci* as a plant pest and virus vector agroecosystems worldwide. *FAO Plant Protection Bulletin* 42: 3 – 32

Butler, G.D. Jr. and Henneberry, T.J. (1984). *Bemisia tabaci* effect cotton leaf pubescence on abundance. *Southwest. Entomol.* 9: 91 – 94

Butler, G.D. Jr., Wilson, F.D. and Fisher, G. (1991). Cotton leaf trichome and populations of *Empoasca lybica* and *Bemisia tabaci*. *Crop Protection* 10: 461 – 464

Butter, N.S. and Vir, B.K. (1989). Morphological basis of resistance in cotton to the whitefly *Bemisia tabaci*. *Phytoparasitica* 17: 251 – 261

Chu, C.C. and Henneberry, T.J. (1998). Arthropod management: Development of a new whitefly trap. *Journal of Cotton Science* 2: 104 – 109

Corbett, G.H. (1935). Malaysian Aleurodidae. *Journal of the Federated Malay States Museums* 17: 722 – 825

Coudriet, D.L., Meyerdrik, D.E., Prabhaker, N. and Kishaba, A.N. (1986). Bionomic of sweetpotato whitefly (Homoptera: Aleyrodidae) on weed hosts in Imperial Valley, California. *Environmental Entomology* 15: 1179 – 1183

Dalin, P., Agren, J., Bjorkman, C., Huttunen, P. and Karkkainen, K. (2008). Leaf trichome formation and plant resistance to herbivory. In: *Induced plant resistance to herbivory*. (Schaller, A., ed.), p. 89 – 105. Springer, Netherlands

Ellsworth, P.C. (1999). Whitefly management in Arizona cotton status and needs. *Proc. Beltwide Cotton Conferences*, p. 41 – 44. Memphis: National Cotton Council

Gold, C.S., Altieri, M.A. and Bellotti, A.C. (1989). The effects of intercropping and mixed varieties of predators and parasitoids of cassava whiteflies (Hemiptera: Aleyrodidae) in Colombia. *Bulletin of Entomological Research* 79(1): 115 – 121

FAO (2010). *Yearbook Production*. Rome: FAO Statistics Division

Heinz, K.M. and Zalom, F.G. (1995). Variation in trichome-based resistance to *Bemisia* *argentifolii* (Homoptera: Aleyrodidae) oviposition on tomato. *Journal of Economic Entomology* 88: 1494 – 1502

Khan, M.R., Ghani, I.A., Ghaffar, A. and Tamkeen, A. (2011). Host plant selection and oviposition behaviour of whitefly *Bemisia tabaci* (Gennadius) in a mono and simulated polyculture crop habitat. *African Journal of Biotechnology* 10(8): 1467 – 1472

Legaspi, J.C., Simmons, A.M. and Legaspi, Jr., B.C. (2006). Prey preference by *Delphastus catalinae* (coleoptera: coccinellidae) on *Bemisia argentifolii* (homoptera: aleyrodidae): Effects of plant species and prey stages. *Florida Entomologist* 89(2): 218 – 221

Leite, G.L.D., Marcelo, P., Raul, N., CarvalhoGuedes, C. and Carlos, E. (2006). Factors affecting the attack rate of *Bemisia tabaci* on cucumber. *Pesq.agropec.bras, Brasilia* 41(8): 1241 – 1245

Li, Z.H., Lammes, F., van Lenteren, J.C., Huisman, P.W.T., van Vianen, A. and De Ponti, O.M.B. (1987). The parasite host relationship between *Encarsia formosa* (Hymenoptera: Aphelinidae) and *Trialeurodes vaporariorum* (Homoptera: Aleyrodidae). XXV. Influence of leaf structure on the searching activity of *Encarsia formosa*. *Journal of Applied Entomology* 104: 297 – 304

Liu, T.X. (2003). Response of four melon varieties of silverleaf whitefly (Homoptera: Aleyrodidae) under laboratory and field conditions. *Subtropical Plant Science* 55: 27 – 31

Lopez-Avila, A., and Cock, M.J.W. (1986). *Bemisia tabaci*: A literature survey on the cotton whitefly with an annotated bibliography. In: *Economic damage*. (Cock, M.J.W., ed.), p. 51 – 61. C.A.B. International Institute of Biological Control, Ascot, U.K.

Mansaray, A. and Sundufu, A.J. (2009). Oviposition, development and survivorship of the sweetpotato whitefly *Bemisia tabaci* on soybean, *Glycine max*, and the garden bean, *Phaseolus vulgaris*. *Journal of Insect Science* 9: 1 – 6

Mansour, S.A.A., Mohamad Roff, M.N., Mohd. Hanifah., Y., Abuzid, I. and Idris, A.G. (2012). Effects of plant growth on the population of whitefly, *Bemisia tabaci,* under glasshouse conditions. *American-Eurasian Journal of Sustainable Agriculture* 6(4): 299 – 303

Mansour, S.A.A., Mohamad Roff, M.N., Saad, K.A., Abuzid, I. and Idris, A.G. (2012). Responses of whitefly, *Bemisia tabaci* (Genn.) (Homoptera: Aleyrodidae) population on tomato, *Lycopersicon esculentum,* mixed with other crops under glasshouse conditions. *APCBEE Procedia* 4: 48 – 52

McAuslane, H.J. (1996). Influence of leaf pubescence on ovipositional preference of *Bemisia argentifolii* (Homoptera, Aleyrodidae) on soybean. *Environmental Entomology* 25(4): 834 – 841

McLellan, T. (2005). Correlated evolution of leaf shape and trichomes in *Begonia dregei* (Begonliaceae). *American Journal of Botany* 92(10): 1616 – 1623

Mohd Rasdi, Z., Fauziah, I., Fairuz, K., Mohd Saiful, M.S., Md Jamaludin, B., Che Salmah, M.R. and Kamaruzaman, J. (2009). Population ecology of whitefly, *Bemisia tabaci*, (Homoptera: Aleyrodidae) on brinjal. *Journal of Agricultural Science* 1(1): 27 – 32

Muniyapa, V. (1980). Whiteflies. In: *Vectors of Plant Pathogens*. (Harris, K.F. and Maramorosch, K., eds.), p. 39 – 85. New York: Academic Press

Muqit, A., Akanda, A.M. and Alam, M.Z. (2008). Efficacy of three trap crops against whitefly to manage tomato yellow leaf curl virus. *Bangladesh Journal of Agricultural Research* 33(3): 515 – 517

Naranjo, S.E. and Ellsworth, P.C. (2005). Mortality dynamics and population regulation in *Bemisia tabaci*. *Entomologia Experimentalis et Applicata* 116: 93 – 108

Naranjo, S.E. and Flint, H.M. (1995). Spatial distribution of adult *Bemisia tabaci* (Homoptera: Aleyrodidae) in cotton and development and validation of fixed-precision sampling plans for estimating population density. *Environmental Entomology* 24: 94 – 128

Oliveira, M.R.V., Henneberry, T.J. and Anderson, P. (2001). History, current status and collaborative research projects for *Bemisia tabaci*. *Crop Protection* 20(9): 709 – 723

Siemonsma, J.S. and Piluek, K. (1994). *Vegetables*. Bogor: Plant Resources of South-East Asia

Singh, J., Singh, D., Sohi, A.S., Brar, D.S., Kapoor, S.K. and Russel, D. (1990). Management of resistant insect pests of cotton in North India: An analysis. *Proc. ICAC* - CCRI, p. 131 – 142. Regional Consultation Insecticide Resistance Management in Cotton, June 29 – July 1, Multan, Pakistan

Singh, J., Sohi, A.S., Mann, H.S. and Kapur, S.P. (1994). Studies on whitefly *Bemisia tabaci* (Genn.) transmitted Cotton Leaf Curl Disease in Punjab. *J. Insect Sci*. 7: 194 – 198

Syed, A.R., Sivapragasam, A., Loke, W.H. and Mohd.Roff, M.N. (2000). Whiteflies infesting vegetables in Malaysia. *Proc. of the Plant Resource Management Seminar*. p. 38 – 43

Toscano, L.C., Boica, A.L. and Maruyama, W.I. (2002). Nonpreference of whitefly for oviposition in tomato genotypes. *Scientia Agricola* 59(4): 677 – 681

Vikas, J. and Dhaliwal, G.S. (2009). Elucidating resistance in cotton genotypes to whitefly, *Bemisia tabaci*, by population build up studies. *Phytoparasitica* 137 – 145

Abstrak

Lalat putih (WF), *Bemisia tabaci* (Genn), merupakan serangga yang paling merosakkan untuk beberapa sayur-sayuran di Malaysia, yang memberi kesan kepada pertumbuhan tanaman, pemindahan geminivirus, serta mengurangkan kualiti tanaman. Kajian ini menganggarkan kelimpahan populasi *B. tabaci* pada cili, *Capsicum annuum* MC 11 sahaja, MC 11 ditanam dengan terung, *Solanum melongena* MT e1, tomato, *Lycopersicum esculentum* MT 1, atau bendi, *Abelmoschus esculentus* MKB E1 dan MC 11 ditanam campuran dengan MT el + MT 1 + MKB E1 di bawah keadaan rumah kaca. Sampel WF dewasa, telur dan nimfa diperoleh setiap 4 hari dari bahagian bawah daun (abaxial) pada strata atas, tengah dan bawah pokok selama satu bulan. Jumlah purata WF dewasa, telur dan nimfa adalah lebih tinggi (p <0.05) pada cili dalam eksperimen yang ditanam secara solo berbanding pada cili dalam eksperimen dengan tanaman campuran seperti bendi, tomato dan terung. Keputusan juga menunjukkan bahawa populasi WF dewasa dan telur adalah lebih tinggi pada strata pokok atas berbanding dengan tengah dan bawah. Menariknya, bilangan nimfa adalah lebih tinggi dalam strata tengah berbanding dengan strata lain dalam semua rawatan. Fenomena ini menunjukkan bahawa tanaman campuran dapat mengurangkan populasi perosak dan secara tidak langsung dapat mengurangkan kejadian serangan penyakit virus.

Accepted for publication on 1 April 2013