

Population abundance and spatial distribution of *Aphis gossypii* Glover (Homoptera: Aphididae) and coccinellids on chilli (*Capsicum annuum* L.)

[Kelimpahan populasi dan sebaran spatial *Aphis gossypii* Glover (Homoptera: Aphididae) dan kumbang kura-kura pada cili (*Capsicum annuum* L.)]

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Key words: abundance, spatial distribution, *Aphis gossypii*, coccinellid, chilli

Abstract

The population abundance and spatial distribution of the aphids, *Aphis gossypii* Glover (Homoptera: Aphididae) and its predator coccinellids (adult) on chilli var. MC 11 (*Capsicum annuum* L.) were studied at MARDI Station Jalan Kebun, Klang, Selangor from February to July 2003. The mean number of aphids and adult coccinellids per plant at each sampling date were significantly different between the plant strata (lower, middle and upper) and sampling dates ($p < 0.0001$). The number of aphids per stratum was significantly ($p < 0.05$) higher in the lower stratum than in the middle and upper strata. However, the number of adult coccinellids was significantly higher ($p < 0.05$) in the middle and upper strata than in the lower stratum.

Populations of aphid and adult coccinellids were highest at 56 DAT, which differed significantly ($p < 0.05$) from the rest of the sampling dates. The number of aphids per plant at each sampling date was found positive and significant correlation ($r = 0.98$, $p = 0.0001$) with the number of adult coccinellids per plant per sampling date. The spatial distribution of aphids was aggregated (ID ranged from 48.57 to 1962.30 > 1) at all sampling dates throughout the entire cropping period. Similarly, the spatial distribution of adult coccinellids was aggregated (ID ranged from 2.69 to 11.82 > 1). The possible reasons of the abundance and distribution of aphids and adult coccinellids within chilli plants are discussed.

Introduction

The study on population dynamics of aphids has long been of interest to scientists and crop producers because of the destruction that aphids cause in agricultural crops (Mondor and Roitberg 2000). The polyphagous cosmopolitan aphid, *Aphis gossypii* Glover (Homoptera: Aphididae), not only remove nutrients from phloem of

the plants, but is also capable of transmitting plant viruses (Blackman and Eastop 1984). In Malaysia, the most damaging virus diseases of chilli are cucumber mosaic virus (CMV) and chilli veinal mottle virus (CVMV) transmitted by *A. gossypii* (Mohamad Roff and Ong 1992; Hussein and Abdul Samad 1993).

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Predaceous coccinellids have been widely used in biological control of insect pests especially aphids (Hodek 1973; Dixon 1989; Obrycki and Kring 1998). It has been reported that coccinellids can be a good candidate for biological control of aphids (Loklande and Mohan 1990). In the chilli ecosystem, coccinellids are found to be the most predominant species and are responsible in reducing the populations of *A. gossypii* (Salim and Hussein 1994). However, accurate assessment and estimation of field population densities of predaceous coccinellids are essential in ecology-based pest management programmes to verify its role (Hasan and Rashid 1997; Vuong et al. 2001).

Population of a pest and/or its predator may be distributed in clump, random and/or uniform pattern (Southwood 1978). In ecology, it is often difficult to study the movement of individual animal directly, because it is small in size and numerous in population. Ecologists studied the spatial pattern of individuals of a particular species to infer the underlying behaviour rules that govern their movement (Greig-Smith 1952; Taylor 1986).

Spatial distribution pattern of a pest and its predator is essential information needed in order to analyse their relationships (Hassell and May 1974). Such spatial patterns will be the result of variables directly measurable in space, like prey availability or crop characteristic. However, whether or not the spatial patterns on a certain date can be explained, there is often a need to study the change in such patterns over time, to develop an efficient sampling methodology and also essential for effective pest management.

The objectives of the study were to better understand the population abundance of *A. gossypii* and its predator coccinellid, and their spatial distribution on chilli crop. It is believed that with this information, we would be able to develop a sustainable biological control programme of *A. gossypii* and hence virus diseases on chilli. This

paper reports: 1) the population abundance of *A. gossypii* and adult coccinellids, 2) the relationship between the abundance of aphids and adult coccinellids, and 3) the spatial distribution of *A. gossypii* and adult coccinellids within chilli plot.

Materials and methods

The study was carried out at MARDI Station, Jalan Kebun, Selangor (latitude: 2° 59'N and longitude: 101° 31'E), from 25 February to 1 July 2003. The station is situated on a flat land with oligotrophic peat soil. The average pH of the soil ranges from 5.5–6.0.

Chilli variety, MC11 used in this study was produced by Seed Unit of MARDI. The variety has erect and open plant architecture characteristics (Idris and Mohamad Roff 2002). The leaves are alternate, simple and petiole up to 10 cm long, ovate in shape and the colour ranges from light to dark green. The height of the plant is 100–200 cm.

An experimental plot of 12 m x 12 m with four sub-plots as replication was prepared. Each replication had ten raised beds. The height and width of each bed were 0.6 m and 0.15 m, respectively. The beds were covered with black plastic mulch to control weed grown on the planting beds. Three empty beds (12 m long x 0.6 m wide x 0.15 m high) covered with black plastic mulch were maintained to separate each replication.

Chilli seeds were sown in the speedling trays and placed in an insect proof nursery structure. The seedlings were transplanted to the field 35 days after sowing (8–10 leaves) on 31 March 2004. A total of 200 plants were transplanted in 10 raised beds (20 plants/bed) per replication with spacing of 0.6 m within row and 1.0 m between rows. A compound fertiliser NPK Blue Special (12:12:17.2) was applied to the plots at the rate of 30 g/plant at monthly intervals for three consecutive months. No insecticide or acaricide was applied throughout the study period. Weeds grown between beds and

areas 2 m around the plots were removed by manual weeding.

Data collection was commenced on 5 May to 1 July 2003. About 30% of the total plants per replicate were selected randomly for sampling the aphids and adult coccinellids. Densities of aphids and adult coccinellids were determined at different levels of plant. Numbers of aphids and adult coccinellids were recorded in situ visually at three strata namely, lower third (lower stratum), middle third (middle stratum) and upper third (upper stratum) (Idris and Grafius 2001; Idris and Mohamad Roff 2002). Samplings were done between 0800–1100 h (generally insects are more active between this period) of the day at weekly interval. The same plants were used for sampling throughout the cropping period.

The data of aphids and adult coccinellids per stratum per plant at each observation date were pooled and transformed using $\sqrt{x+1}$ for normalisation before analysis. Mean data of aphids and adult coccinellids per plant strata per observation date were analysed separately by repeated measured ANOVA. The means were separated by Fisher's protected least significant difference (LSD, $p < 0.05$) to determine differences in density of aphids and adult coccinellids per plant per observation date, simple regression analysis was performed between mean number of aphids and mean number of adult coccinellids per plant per observation date. Data were analysed statistically using Minitab Statistical Package Program.

The term 'spatial distribution' is hereby defined as the distribution of aphids, *A. gossypii* and adult coccinellids within plot. One plot out of four (same plots used for determination of aphid and adult coccinellids populations) was selected for collection of data. A total of 60 plants (six plants per bed) were selected at random to determine the aphids and adult coccinellids distribution in each observation date. The number of aphids and adult coccinellids

were sampled on each plant following the procedure described above.

The model of Index of Dispersion, *ID*, often referred to as the coefficient of dispersion as described by Southwood (1978) was used to determine the spatial distribution of aphids and adult coccinellids within a plot. The *ID* indicates random pattern ($ID = 1$) when $s^2 = \bar{x}$, clumped ($ID > 1$) pattern when $s^2 > \bar{x}$, and uniform pattern ($ID < 1$) when $s^2 < \bar{x}$. The index of dispersion was calculated as described by Ludwig and Reynolds (1988) as follow:

$$ID = \frac{s^2}{\bar{x}}, \text{ where } ID = \text{Index of dispersion,}$$

s^2 = estimated variance of mean

\bar{x} = mean number of observed individual per plant per observation.

s^2 was calculated (Ludwig and Reynolds 1988) as follow:

$$s^2 = \frac{\sum x^2 - [(\sum x)^2 / N]}{N - 1}, \text{ where,}$$

x = number of aphids and adult coccinellids per sample unit

N = Number of samples taken per observation.

Results

The interaction between plant strata and sampling dates significantly influenced the mean number of aphids per chilli plant ($F = 2.32$, $df = 14 \text{ \& } 72$, $p = 0.011$). The mean number of aphids per plant between all plant strata was significantly different ($F = 32.88$, $df = 2 \text{ \& } 72$, $p = 0.0001$) (Figure 1A). The lower stratum had the highest mean number of aphid per plant and was significantly different ($p < 0.05$) than the middle and upper strata. The number of aphids per plant was also found to differ significantly ($F = 26.78$, $df = 7 \text{ \& } 72$, $p = 0.0001$) between the sampling dates (Figure 1B). Mean number of aphids per plant was highest at 56 DAT (146.68 ± 133.77) and lowest at 35 DAT (10.28 ± 2.44). The number of aphids was

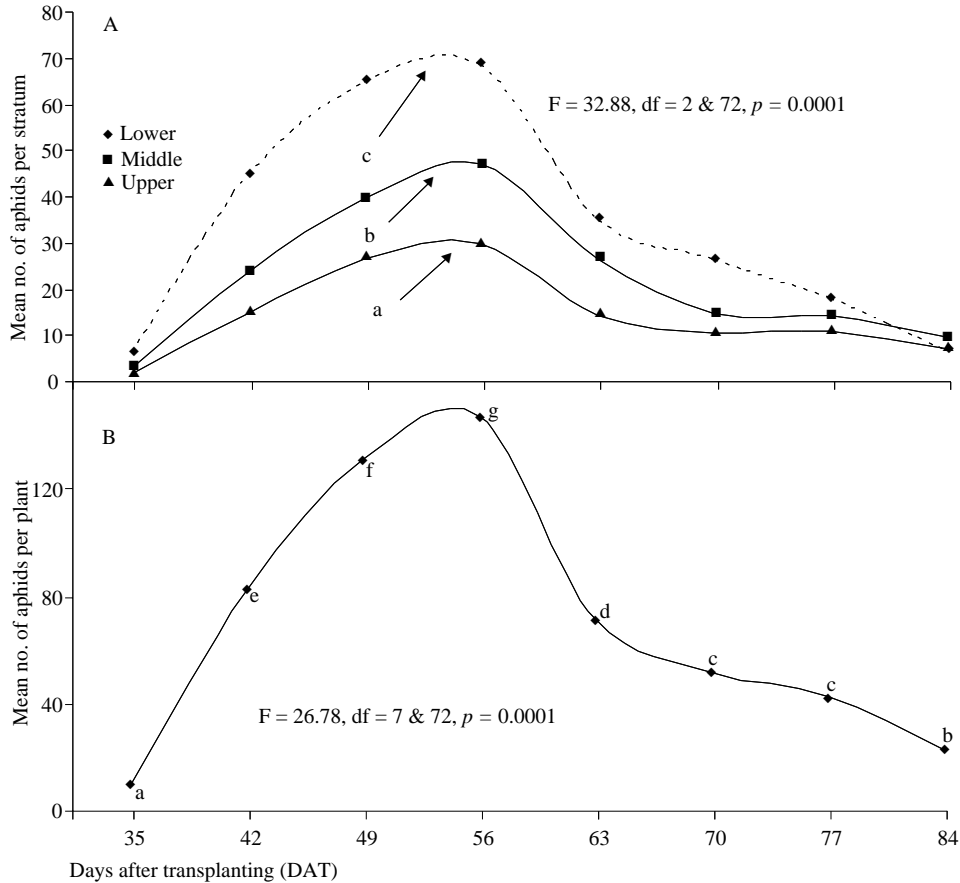


Figure 1. Mean number of aphids per stratum (A) and per plant (B) at different sampling dates. Means with different letters differed significantly (LSD, $p < 0.05$)

significantly different ($p < 0.05$) at 56 DAT from the rest of the sampling dates.

There was no significant interaction between plant strata and sampling dates in influencing the number of adult coccinellids per plant ($F = 1.17$, $df = 14 \text{ \& } 72$, $p = 0.316$). The mean number of adult coccinellids was significantly different between the plant strata ($F = 14.72$; $df = 2 \text{ \& } 72$, $P = 0.0001$) (Figure 2A) and the sampling dates ($F = 12.30$, $df = 7 \text{ \& } 72$, $p = 0.0001$) (Figure 2B). Mean number of adult coccinellids was highest in the middle stratum and lowest at the lower stratum (Figure 2A). However, there was no significant difference in the mean number of adult coccinellids at the middle and upper strata (Figure 2B). The mean number of

adult coccinellids per plant was highest at 56 DAT and was significantly different ($p < 0.05$) from the rest of the observation dates except at 49 DAT (Figure 2B). The number of adult coccinellids present per plant was positively correlated ($r = 0.978$, $F = 133.42$, $df = 1 \text{ \& } 6$, $p = 0.0001$) with the abundance of aphids in the entire cropping period (Figure 3).

The spatial distribution of *A. gossypii* and adult coccinellids within chilli plot were aggregated throughout the cropping period. The variance of mean of aphid at each sampling date was greater (644.99 to 435,886.73) than the mean number of aphids on the respective sampling dates, while, the *ID* value ranged from 48.57 to 1,962.30 ($ID > 1$) (Figure 4). The spatial distribution

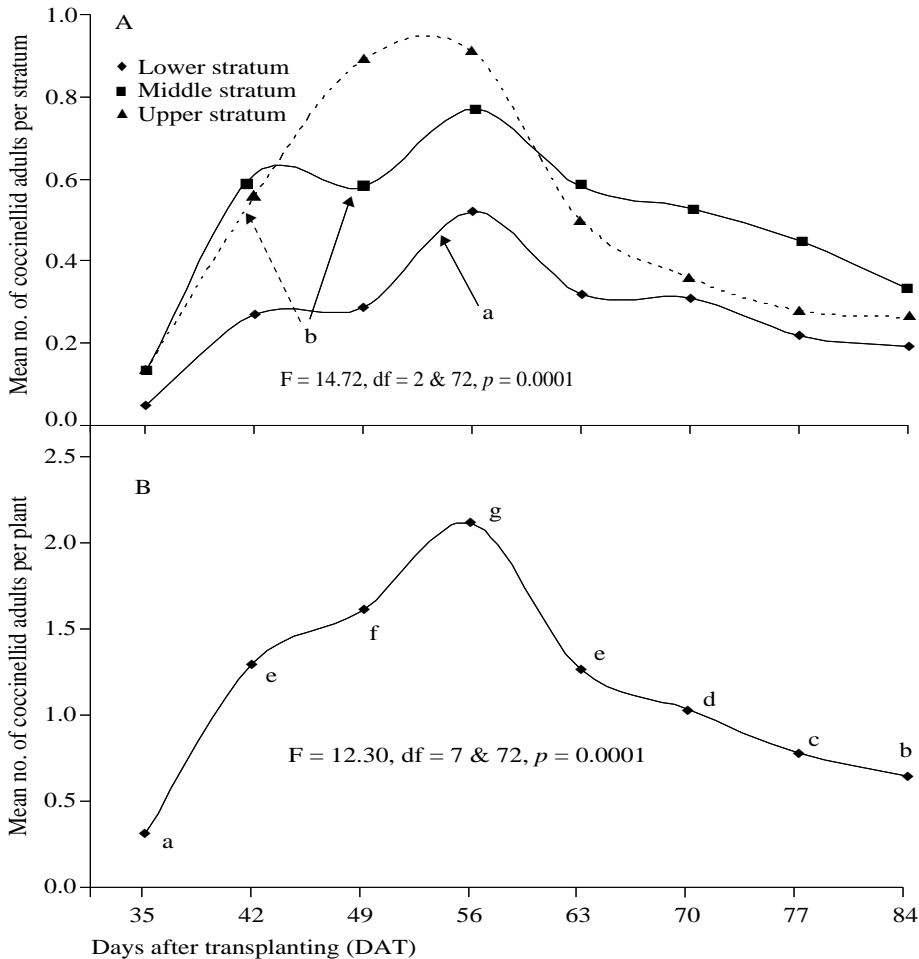


Figure 2. Mean number of adult coccinellids per stratum (A) and per plant (B) at different sampling dates. Means with different letters differed significantly (LSD, $p < 0.05$)

pattern of adult coccinellids was also aggregated across the chilli plots. The variance of mean for adult coccinellids per plant at each sampling date ranged from 1.17 to 16.36 ($>$ mean) while the *ID* ranged from 2.69 to 11.82 ($ID > 1$) (Figure 4).

Discussion

The density of aphid per stratum per plant was significantly higher at the lower stratum ($p < 0.05$) (Figure 1) than the other two strata throughout the cropping period except at 84 DAT, where the number of aphids at the middle stratum was higher than the other two strata (Figure 1A). This indicated that

aphids generally prefer the lower leaves and/or nodes of plant than leaves and/or nodes of middle and upper strata of the plant.

Similar result was also reported by Idris and Mohamad Roff (2002) who evaluated similar aspects on several chilli varieties namely Kulai, MC 4, MC 12, CB 1 and CB 3.

The green peach aphid (GPA), *Myzus persicae* (Sulzer) was reported to prefer the lower leaves of potato plant (Bradley 1952). It was also reported that the population of *A. gossypii* on cotton (*Gossypium hirsutum* L.) is significantly higher at the lower stratum than at the middle and upper strata (Deguine and Hau 2001).

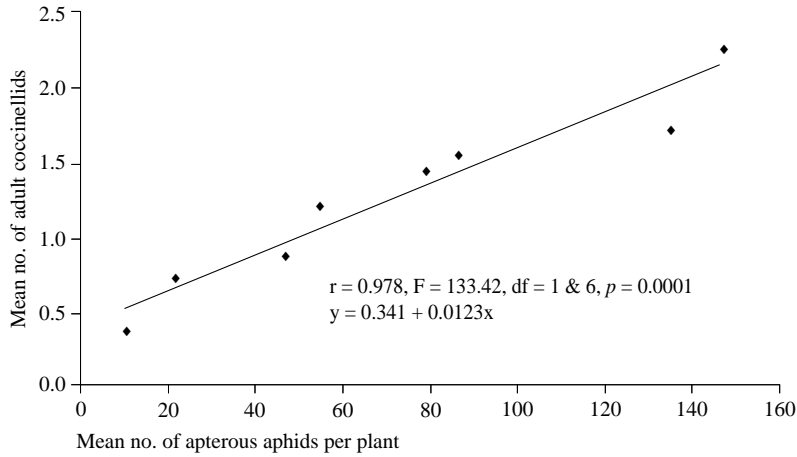


Figure 3. Effect of aphids population on adult coccinellids. Mean adult coccinellid per plant plotted against mean aphids per plant

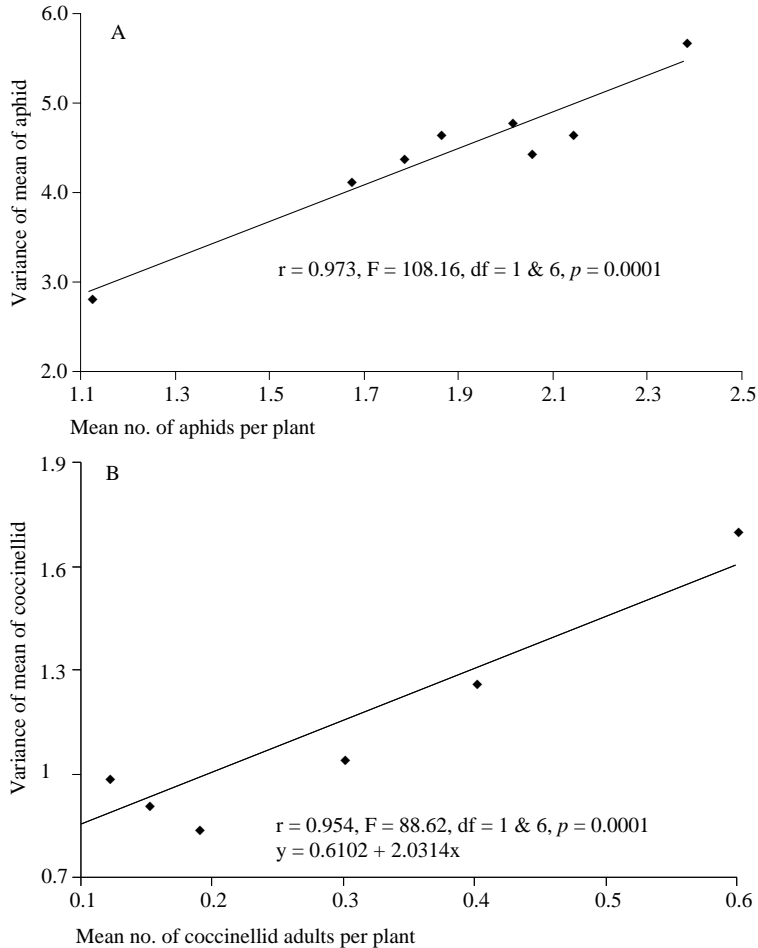


Figure 4. Highly aggregated aphid (A) and adult coccinellid (B) populations within chilli plot

Several factors might be responsible for such abundance of aphids at different levels of plant. Differences in leaf phenology along the vertical gradient (Jasson and Smilowitz 1985), nutrients (percentage of nitrogen and sugar) and percentage of leaf moisture at different levels of plant might influence the distribution of *A. gossypii* at different plant strata (Mattson 1980).

The percentage of moisture, nitrogen and sugar (glucose, fructose and sucrose) contents in the leaves (Slosser et al. 1992; Slosser et al. 1998; Slosser et al. 2004) have positive linear correlation with density of aphid at different levels of a plant. The moisture, nitrogen and sugar contents are significantly higher at lower level of the cotton plant than at the middle and upper levels (Slosser et al. 1992).

The presence of more glandular hairs on leaves at the middle and upper levels of plant might also be responsible for the greater number of aphids at the lower stratum. Abdallah et al. (2001) reported that infestation of *A. gossypii* on cotton cultivars is relatively low at the middle and upper strata than at lower stratum due to the presence of gland hairs that secrete phenols, which repel aphids.

Moreover, it is a general phenomenon that the lower part of a plant can give more protection to any insect colony from direct damage of rain and wind and even from natural enemies. Furthermore, natural enemies normally land more frequently on the upper and middle parts of the plant (Idris and Grafius 2001) which might also lead aphids to multiply in greater number at the lower level of the chilli plant. However, at 84 DAT, it was found that the number of aphids was relatively higher at the middle stratum than at the upper and lower strata. This situation might be due to the less number of leaves at the lower part of the plant as compared to other plant strata. Generally, in late cropping period more leaves at the lower strata will senesce and hence the aphids will move to the middle

stratum in search for food (Slosser, J.E., pers. comm. 2005).

Results showed that the number of aphids per plant was significantly different between sampling dates ($p < 0.05$) (Figure 1B). The highest and lowest numbers of aphids were recorded at 56 and 35 DAT (Figure 1B) respectively. The population of aphids increased from 35 to 56 DAT, but from 63 DAT to the end of the cropping period, the population declined gradually. Vuong et al. (2001) also reported that the populations of *M. persicae* and *A. gossypii* on watermelon are lowest in the early cropping period and highest in the middle of the cropping period. However, the population declined towards the end of the cropping period. The low number of aphids during the end of the cropping period suggests that the chilli plants became more resistant to aphid colonisation as the plants mature. Tylor (1955) reported that mature broad bean, *Vicia faba* L. and potatoes are more resistant to infestation of *A. fabae* and *M. persicae*, respectively.

Nutrient factors might have an influence on the abundance of aphid population. Jasson and Smilowitz (1985) and van Emden (1966) found that the lower leaf zones of plant contain higher amount of amino-nitrogen compounds than the middle and upper zones, which are favourable for aphid colonisation as aphids consume these compounds. Other factors that might have involved are the influence of natural enemies (Idris and Mohamad Roff 1999) and weather conditions (Minks and Harrewijn 1987).

Result indicated that the number of adult coccinellids was significantly higher ($p < 0.05$) at the middle and upper strata than at the lower stratum of the chilli plant (Figure 2A). This result is in disagreement with the 'Resource Concentration Hypotheses' proposed by Root (1973). Similar results were also reported by Idris and Mohamad Roff (2002). They reported that density of adult coccinellids is significantly higher at the middle and upper

strata than at the lower stratum of chilli varieties Kulai, MC 11 and MC 12. This suggests that other factors besides plant architecture might influence the distribution of adult coccinellids within the chilli plant. Musser and Shelton (2003) also reported that density of *Harmonia axyridis* on grain and sweet corn plants is significantly higher at the upper and middle strata of the plant than at the lower part.

Higher density of adult coccinellids at the middle and upper strata might be due to active landing of coccinellids. It was found that when yellow sticky traps were placed at different levels in plots with different chilli varieties, the number of adult coccinellids trapped was higher on yellow sticky traps that were placed at the canopy and below canopy levels (unpublished data). The number of adult coccinellids trapped was lowest on the yellow sticky traps placed at the bottom third level of the plant.

The population of adult coccinellids (Figures 2B and 3) per plant per sampling date on chilli crop was positively correlated with the abundance of aphid per plant per sampling date. Although the density of adult coccinellids (Figure 2A) within the plant strata was in disagreement with the 'Resource Concentration Hypotheses' (Root 1973), the abundance of adult coccinellids per plant per sampling date showed a strong positive correlation (Figure 3). This suggests that adult coccinellid population was influenced by the aphid population.

Similar result was also reported by Smith (1966) and Brown (2004) who observed that the population of predator, *Harmonia axyridis* is positively dependant on the abundance of spirea aphids, *Aphis spiraeicola* Patch, on apple. Furthermore, Grez and Prado (2000) also reported that the predatory coccinellids follows the abundance of *Brevicoryne brassicae* L. (Hemiptera: Aphididae) on *Brassica oleracea* L. They found that the abundance of predatory coccinellids is low, and gradually increases with the increase of aphid population at the mid-cropping period

and declines again in late cropping period, when the number of aphid is low.

Results showed that the spatial distribution of *A. gossypii* within the chilli plot was aggregated during the entire cropping period (Figure 4). It was reported that aphids spent most time feeding on plant sap (Rohdes et al. 1996) which ultimately resulted in greater number at their initial landing point. Another possible reason for the aggregated distribution of aphids within plot might be due to their immobility. According to Reilly and Sterling (1983), higher aggregation of aphid was due to their immobility resulting in a higher concentration in the same area.

Results of the study showed that the population of adult coccinellids at each sampling date was highly aggregated together with aphids (Figure 4). This result suggests that the distribution of adult coccinellids was influenced by the distribution of aphids as the predators may aggregate on patch of high prey densities (Root 1973). In the present study, the population of aphids within chilli plots was aggregated, which had influenced the coccinellid distribution. It was also observed that the adult coccinellids tended to aggregate on chilli plants where the density of aphid was high (unpublished data). Hassell (1978) reported that normally the predators would concentrate on the patch with high prey density.

Considering adult coccinellids synchrony with *A. gossypii* population abundance on chilli, it could be concluded that the coccinellids could be the most important predator of *A. gossypii*. Other natural enemies such as ants, syrphid flies, and lacewing are low in numbers (unpublished data) (Idris et al. 1999). Therefore, future study needs to be carried out to manipulate and maximise the role of coccinellid species on aphids and its behaviour on different chilli varieties. This information can be integrated into the existing management strategy for better control of aphids and the virus diseases.

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References

- Abdallah, Y.E.Y., Ibrahim, S.I., Abd-Elmoiem, E.M. and Youssef, L.A. (2001). Incidence of some piercing-sucking insects in relation to morphological leaf characters, some chemical and nutritional components of some cotton cultivars. *Annals of Agricultural Science (Cairo)* 46: 807–27
- Blackman, R.L. and Eastop, V.F. (1984). *Aphids on the World Crop: An Identification and Information Guide*. Chichester. New York: John Wiley and Sons
- Bradley, R.H.F. (1952). Methods of recording aphid (Homoptera: Aphididae) populations on potatoes and distribution of species on the plant. *Canadian Entomology* 84: 93–102
- Brown, M.W. (2004). Role of aphid predator guild in controlling spirea aphid populations on apple in West Virginia, USA. *Biological Control* 29: 189
- Deguine, J.P. and Hau, B. (2001). The influence of the plant on *Aphis gossypii*: Some results of research conducted in Cameroon. *Proc. Seminar of the project Improvement of the marketability of cotton produced in zones affected by stickiness*. (Gourlot, J.P. and Frydrych, R., ed.), 4–7 July 2001, p. 86–98. France: Lillie
- Dixon, A.F.G. (1989). An experimental study of the searching behaviour of the predatory coccinellid beetle *Adalia decempunctata* (L.). *Journal of Animal Ecology* 28: 259–81
- Greig-Smith, P. (1952). The use of a random and contiguous quadrates in the study of the structure of plant communities. *Annals of Botany* 16: 293–316
- Grez, A.A. and Prado, E. (2000). Effect of plant patch and surrounding vegetation on the dynamics of predatory coccinellids and their prey *Brevicoryne brassicae*. *Environmental Entomology* 29: 1244–50
- Hasan, S.T.S. and Rashid, M.M. (1997). Numerical and binomial optimal samplings of arthropods of wet paddy ecosystems in Malaysia. *J. Trop. Agric. and Fd. Sc.* 25: 55–63
- Hassell, M.P. (1978). *The dynamics of arthropods predators-prey systems*. New Jersey: Princeton University Press
- Hassell, M.P. and May, R.M. (1974). Aggregation of predators and insect parasites and its effect on stability. *Journal of Animal Ecology* 43: 567–94
- Hodek, I. (1973). *Biology of Coccinellidae*. Prague: Academic Press
- Hussein, M.Y. and Abdul Samad, N. (1993). Intercropping chilli with maize or brinjal to suppress populations of *Aphis gossypii* Glover and transmission of chilli viruses. *International Journal of Pest Management* 39: 216–22
- Idris, A.B. and Grafius, E. (2001). Effects of plant density on abundance of diamondback moth (Lepidoptera: Plutellidae) and *Diadegma insulare* (Cresson) (Hymenoptera: Ichneumonidae). *International Journal of Pest Management* 47: 103–7
- Idris, A.B. and Mohamad Roff, M.N. (1999). The population abundance of *Aphis gossypii* Glover and its predators on chilli (*Capsicum annum*) plants intercropped with other crops. *Journal of Plant Protection in the Tropics* 12: 45–54
- (2002). Vertical and temporal distribution of *Aphis gossypii* Glover and coccinellid population on different chilli (*Capsicum annum* L.) varieties. *Journal of Asia-Pacific Entomology* 5: 185–91
- Idris, A.B., Mohamad Roff, M.N. and Fatimah, S.G. (1999). Effect of intercropping and chilli varieties on the abundance of *Aphis gossypii* Glover predators. *Proceedings of the Symposium on Biological Control in the Tropics*. (Loke W.H., Sastroutomo S.S., Caunter, I.G. et al., ed.) March 1999, p. 113–7. Serdang: CAB International, South East Asia Regional Centre
- Jasson, R.K. and Smilowitz, Z. (1985). Influence of potato plant phenology on the population dynamics of green peach aphid, *Myzus persicae* (Homoptera: Aphididae). *Environmental Entomology* 14: 7–14
- Loklande, R.K. and Mohan, P. (1990). Study on biocontrol of aphid, *Aphis craccivora* Koch. by ladybird beetle, *Menochilus sexmaculatus* F. in chilli. *Advances in Plant Sciences* 3: 281–6

- Ludwig, J.A. and Reynolds, J.F. (1988). *Statistical Ecology: A Primer on Methods and Computing*. New York: John Wiley & Sons
- Mattson, W.J., Jr. (1980). Herbivory in relation to plant nitrogen content. *Annual Review of Ecology and Systematics* 11: 119–61
- Minks, A.K. and Harrewijn, P. (1987). *Aphids, their control: biology, natural enemies and control*, p. 171–310. Amsterdam, Oxford, New York, Tokyo: Elsevier
- Mohamad Roff, M.N. and Ong, C.A. (1992). Present status of virus diseases on chilli in Malaysia. *Teknologi Sayur-sayuran* 8: 7–13
- Mondor, E.B. and Roitberg, B.D. (2000). Individual behaviour and population dynamics: lessons from aphid parasitoids. *Entomologia Experimentalis et Applicata* 97: 75–81
- Musser, F.R. and Shelton, A.M. (2003). Factors altering the temporal and within-plant distribution of coccinellids in corn and their impact on potential intra-guild predation. *Environmental Entomology* 32: 575–83
- Obrycki, J.J. and Kring, T.J. (1998). Predaceous coccinellidae in biological control. *Annual Review of Entomology* 43: 295–321
- Reilly, J.J. and Sterling, W.L. (1983). Dispersion patterns of the red imported fire ant (Hymenoptera: Formicidae), aphids, and some predaceous insects in East Texas cotton fields. *Environmental Entomology* 12: 380–5
- Rohdes, J.D., Croghan, P.C. and Dixon, F.G. (1996). Uptake, excretion and respiration of sucrose and amino acids by the pea aphid *Acyrthosiphon pisum*. *Journal of Experimental Biology* 199: 1269–76
- Root, R.B. (1973). Organisation of a plant-arthropod association in simple and diverse habitats: the fauna of collards (*Brassica oleracea*). *Ecological Monograph* 43: 95–124
- Salim, J. and Hussein, M.Y. (1994). Population changes and distribution of *Aphis gossypii* on chilli. *Proceedings of the 4th International Conference on Plant Protection in the Tropics*, 28–31 March 1994, p. 381–2. Kuala Lumpur: Malaysian Plant protection Society
- Slosser, J.E., Parajulee, M.N., Hendrix, D.L., Henneberry, T.J. and Pinchak, W.E. (2004). Cotton aphid (Homoptera: Aphididae) abundance in relation to cotton leaf sugars. *Environmental Entomology* 33: 690–9
- Slosser, J.E., Pinchak, W.E. and Frank, W.A. (1992). Effect of planting date on cotton aphid (Homoptera: Aphididae) and bandedwinged whitefly (Homoptera: Aleyrodidae) populations in dryland cotton. *Southwestern Entomologist* 17: 89–100
- Slosser, J.E., Pinchak, W.E. and Rummel, D.R. (1998). Biotic and abiotic regulation of *Aphis gossypii* Glover (Homoptera: Aphididae) in West Texas dryland cotton. *Southwestern Entomologist* 23: 31–65
- Smith, R.F. (1966). Summing-up of the section V. In: *Ecology of Aphidophagous Insect*, (Hodek, I., ed.) p. 285–7. Pargue and The Hague: Academia
- Southwood, T.R.E. (1978). *Ecological Methods with Particular Reference to the Study of Insect Populations*. 2nd ed. London: Chapman & Hall
- Taylor, L.R. (1986). Synoptic dynamics, migration and the Rothamsted Insect Survey. *Journal of Animal Ecology* 55: 1–38
- Tylor, C.E. (1955). Growth of the potato plant and aphid colonisation. *Annals of Applied Biology* 43: 151–6
- van Emden, H.F. (1966). Studies on the relations of insect and host plant III. A comparison of the reproduction of *Brevicoryne brassicae* and *Myzus persicae* (Homoptera: Aphididae) on Brussels sprout plants supplied with different rates of nitrogen and potassium. *Journal of Entomologia Experimentalis et Applicata* 9: 444–60
- Vuong, P.T., Kim, J. and Song, Y. (2001). The seasonal occurrence of the two aphid species, *Myzus persicae* and *Aphis gossypii*, and their natural enemies on vegetable crops in Chinju, Korea. *Journal of Asia-Pacific Entomology* 4: 41–4

Abstrak

Kelimpahan populasi dan sebaran spatial afid, *Aphis gossypii* Glover (Homoptera: Aphididae) dan pemangsanya kumbang kura-kura (dewasa) pada cili var. MC 11 (*Capsicum annuum* L.) telah dikaji di Stesen MARDI Jalan Kebun, Klang, Selangor dari Februari hingga Julai 2003. Purata bilangan afid dan dewasa kumbang kura-kura sepokok pada setiap tarikh pensampelan didapati berbeza dengan signifikan antara strata pokok (bawah, tengah dan atas) dan tarikh pensampelan ($p < 0.0001$). Bilangan afid pada setiap strata adalah tinggi dengan signifikan pada strata bawah berbanding dengan strata tengah dan atas.

Walau bagaimanapun, bilangan dewasa kumbang kura-kura paling tinggi pada 56 HST dan berbeza dengan signifikan ($p < 0.05$) daripada tarikh pensampelan lain. Bilangan afid sepokok pada semua tarikh pensampelan mempunyai korelasi yang positif dan signifikan ($r = 0.98$, $p = 0.0001$) dengan bilangan dewasa kumbang kura-kura sepokok pada setiap tarikh pensampelan. Sebaran afid didapati beragregat (julat ID daripada 48.57 hingga 1962.30 >1) pada setiap tarikh pensampelan sepanjang tempoh penanaman. Begitu juga dengan sebaran spatial dewasa kumbang kura-kura didapati beragregat (julat ID daripada 2.69 hingga 11.82 >1). Kelimpahan dan sebaran spatial afid dan dewasa kumbang kura-kura pada tanaman cili dibincangkan.