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NUMERICAL RESPONSE AND DENSITY-DEPENDENT RELATIONSHIP OF *MENOCHILUS SEXMACULATUS* AGAINST *APHIS GOSSYPII*

(RESPON NUMERIK DAN HUBUNGAN KEPADATAN SALING TERGANTUNG MENOCHILUS SEXMACULATUS *TERHADAP* APHIS GOSSYPII*)*

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INTISARI

Kutu daun Aphis gossypii *Glover merupakan vektor penting penyakit virus CVMV (Chilli veinal mottle virus) pada tanaman cabai. Di Malaysia kehilangan hasil karena penyakit ini dapat mencapai 60% dan diketahui bahwa kumbang buas* Menochilus sexmaculatus *Fabricius merupakan pemangsa afis yang dominan pada ekosistem cabai. Hasil penelitian membuktikan bahwa kumbang buas ini menunjukkan respon numerikal yang kuat terhadap mangsanya,* A. gossypii. *Populasi* M. sexmaculatus *{Y dalam log (Y+1)} sangat ditentukan oleh populasi* A. gossypii *{X dalam log (X+1)}. Model respon langsung numerikal adalah Y = - 0,1148 + 0.3046X dengan r^2 = 0.81 dan P<0.001, sedangkan model respon numerikal tiga hari setelah pengamatan afis adalah Y = - 0, 1076 + 0.2962X dengan r^2 = 0.75 dan P<0.001. Kumbang buas ini juga menunjukkan kemampuannya untuk menstabilisasi populasi* A. gossypii *yang ditandai oleh arah berlawanan jarum jam dari bentuk siklik hubungan kepadatan saling tergantung di antara mereka.*

Kata kunci: Pemangsa, Menochilus sexmaculatus, Aphis gossypii, *respon numerikal*

ABSTRACT

The leaf aphid *Aphis gossypii* Glover is an important vector of virus disease CVMV (Chilli veinal mottle virus) on chillies. In Malaysia the disease could cause the yield loss up to 60% and the predaceous coccinellid *Menochilus sexmaculatus* Fabricius was observed a dominant predator in the chilli's ecosystem. The studies had revealed that the coccinellid exhibited a strong numerical response to its prey, *A. gossypii*. The predator population {Y in log(Y+1)} was determined strongly by the aphid population {X in log(X+1)}. The immediate numerical response model was Y = - 0,1148 + 0.3046X with r^2 = 0.81 and P<0.001, while the 3-day delayed numerical response model was Y = - 0, 1076 + 0.2962X with r^2 = 0.75 and P<0.001. The coccinellid showed its power to stabilise *A. gossypii* population as indicated by the anti-clockwise direction of cyclic form of their delayed density-dependent relationship.

Key words: Predator, *Menochilus sexmaculatus*, *Aphis gossypii*, numerical response.

INTRODUCTION

Aphids are among the most damaging insect pests of vegetable crops. They cause economic crop loss by directly sucking sap from the plants and indirectly transmitting plant viruses. An aphid species, *Aphis gossypii* Glover (Homoptera: Aphididae) (hereafter referred to as AG), is a vector of more than 50 plant viruses (Blackman and Eastop, 1989). AG efficiently transmits non-persistent chilli veinal mottle virus (CVMV) (Ong *et al*., 1978; Lee *et al*., 1994) in the nursery and in the field. CVMV is among the most important constraints of chilli production in Malaysia (Syed and Loke, 1995) and was known to significantly reduce the chilli yield. The yield reduction may reach 60% if plants were infected at the early stage of growth (Ong *et al*., 1980).

The viral disease of crop plants may be controlled indirectly by controlling the vector. Under natural situation the vector populations are normally controlled by the natural enemies especially by polyphagous predators such as the ladybird beetle. The important role of the ladybird beetle as predators of aphids is well known since the mid-19th century (Whitcomb, 1981). Among the ladybird beetles *Menochilus sexmaculatus* Fabricius (Coleoptera: Coccinellidae) (hereafter referred to as MS) is the most common predator of aphids in the vegetable and food crops in Malaysia.

MS is commonly present in many agroecosystems in Malaysia. It has been reported as a good candidate for biological control of aphids (Parker et al., 1976; Zailani, 1984; Saha, 1987; Gupta and Yadava, 1989; Lokhande and Mohan, 1990; Hussein, 1991; Maisin et al., 1994). Agarwala and Ghosh (1988) grouped MS into the true aphidophagous Coccinellidae, where they fully or partially depend on aphid for development and reproduction. In the chilli ecosystem in Malaysia, MS is the predominant species (Maisin et al., 1994) and is found to be responsible in controlling populations of AG (Salim and Hussein, 1994). However, the MS-AG predator-prey relationship and MS performance in controlling AG have never been previously studied in depth.

Density-dependent relationship between the predator and prey is desirable performance of a good predator. In nature, prey number rarely remains static. Abundance of the prey in the field could attract the predators to remain on the plants. The predator's response to a change in prey density was originally formulated by Solomon (1949) in two major ways. They are the 'functional response' (changes in the number of prey eaten by a predator at different prey densities) and the 'numerical response' (changes in the predator density at different prey densities).

The characteristics of these two responses will indicate the effectiveness of a predator in regulating its prey numbers. The number of prey actually eaten depends on the product of the functional and numerical responses (Luff, 1983). Hassell (1966) stressed that a weak functional response may be insufficient to result in a density-dependent mortality, for which there must be an increase in the proportion of prey taken by a predator as prey density increases. Likewise, a weak numerical response may not produce a delayed density-dependency.

Before appraising the ability of a particular predator in controlling its prey numbers, numerical response of the predator should be understood (Frazer, 1988). The characteristics of MS's response to the AG density are not fully understood. As such, the objectives of the studies were to analyse the numerical response of the predator to its prey density and their density-dependence.

MATERIALS AND METHODS

The studies were conducted in a chilli plot in the Experimental Field II at Universiti Pertanian Malaysia. The chillies were planted in two stages, namely December 1993 and July 1994. In the first planting, the chilli plot was bordered by weeds, while in the second planting long bean was planted as a border crop. The daily temperature, humidity and rainfall varied from 22.2 to 35.1 °C, 41.8 to 90.3% and 0 to 479.8 mm, respectively. Field reservoirs of MS were established by planting long bean as border crops around the chilli plot (30 x 20 m). The long beans, planted 25 days prior to transplanting of chilli seedlings, were intended to be a trap crop for *Aphis craccivora* Koch., the prey of MS.

A total of 720 chilli seedlings var. Kulai (35 days old) were transplanted in the plot at a spacing of 100 cm between rows and 60 cm within row. Standard cultural practices were employed in growing the crops and no insecticide was applied. The plants were individually supported by a wooden stake to prevent damage from strong wind.

Reservoirs of AG were established on three aphid-infested chilli seedlings planted in each of the four borders of the chilli plot. The chilli plants inside the plot were naturally colonised by AG and MS. Other predators namely syrphids, chrysopids, coccinellids and spiders found in the chilli crops were hand-picked and removed. Other insect pest such as leaf feeders (*Spodoptera litura* F.) were also eliminated in a similar manner.

The number of AG and MS per plant (75 - 100 sample plants) was recorded *in situ* every three days beginning at one day after transplanting (DAT) and ending at 67 DAT. The densities of MS were plotted against density of AG to show the delayed density-dependent relationship and numerical response of the predator. Moran's curve was also performed to show time-lag relationship (Hughes, 1963; Hodek *et al.* 1972; Hussein, 1982). Linear regression was employed to determine immediate and time-lag numerical response (Wright and Laing, 1980). The raw data contained some zero values and standard errors were very high. The variance tended to proportional with the mean, hence, to ensure the normality of the data, the data were transformed into $\log_{10}(x+1)$ prior to the linear regression analysis.

RESULTS

The changing numbers of AG and MS in both planting seasons (December 1993 and July 1994) are shown in Figure 1. In the planting season of December 1993 (Figure 1, A) the maximum prey density was less than 25 aphids per plant as compared to 170 aphids/plant in the July 1994 planting season (Figure 1, B). The introduction of MS in 21 days after aphid colonisation (Figure 1.A) might not be sufficient to retain the predator in the chilli crop as indicated by very low predator counts, less than one per plant. The numerical response and density-dependent relationship were not clearly observed. The linear regression analysis [$Y = 0.00036 - 0.00492X$, $P>0.05$, where X is $\log_{10}$ (aphid density + 1) and Y is $\log_{10}$ (predator density + 1)] shows a non significant regression coefficient. The analysis indicated that in the planting season of December 1993, the MS did not exhibit numerical response.

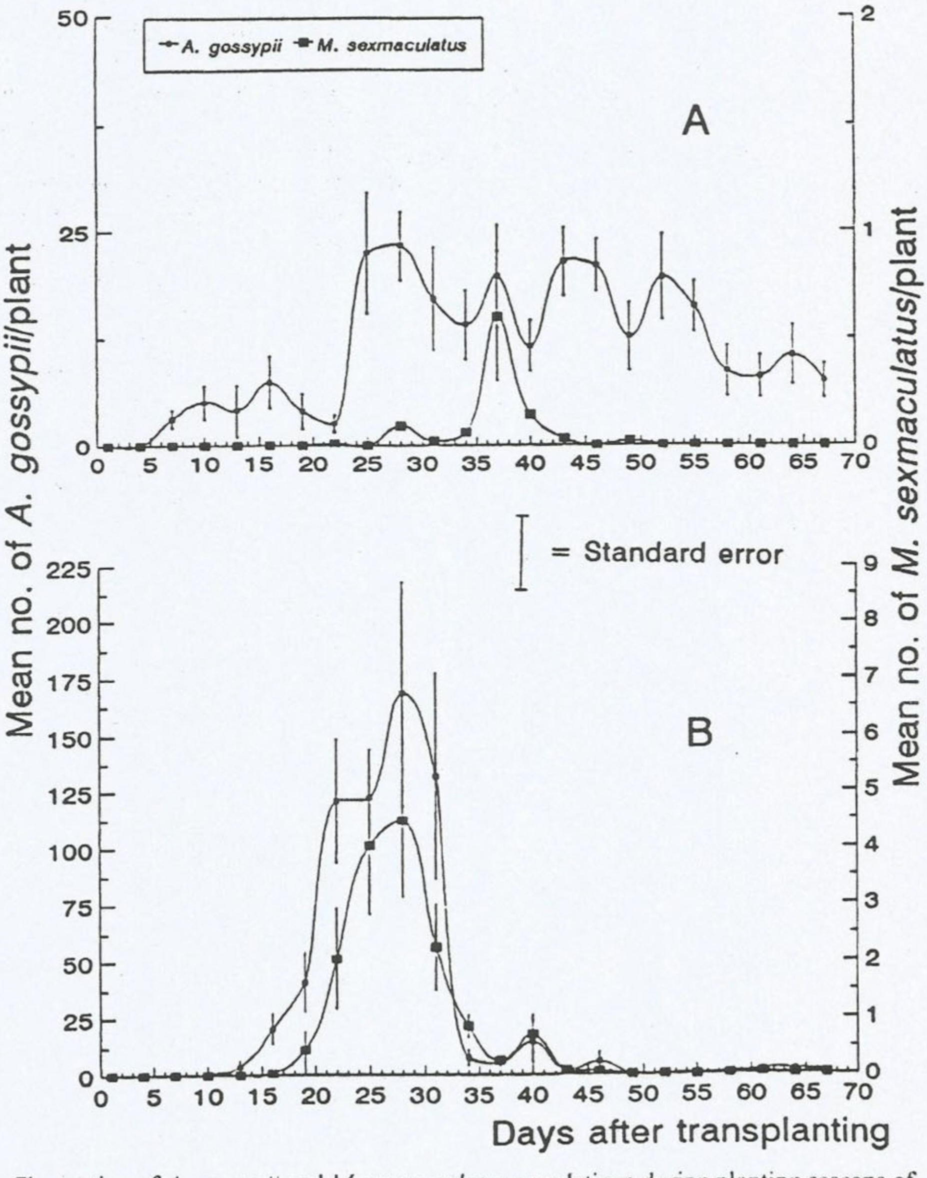

Figure 1. Fluctuation of *A. gossypii* and *M. sexmaculatus* populations during planting seasons of December 1993 (A) and July 1994 (B)

Different results were obtained in the second planting whereby long bean was planted bordering the chilli plot. Abundance of *A. craccivora* was sufficient to retain MS on the long bean plants. Figure 1 (B) shows that the predator numbers rise and fall with the prey. This cyclic pattern in the prey and predator numbers suggests that the predator is regulating the prey abundance. A Moran's curve was plotted to indicate a time-lag relationship in the predator-prey oscillation (anticlockwise) such as shown in Figure 2. The curve presents the evidence for a delayed-density dependence mechanism in operation between MS and AG populations.

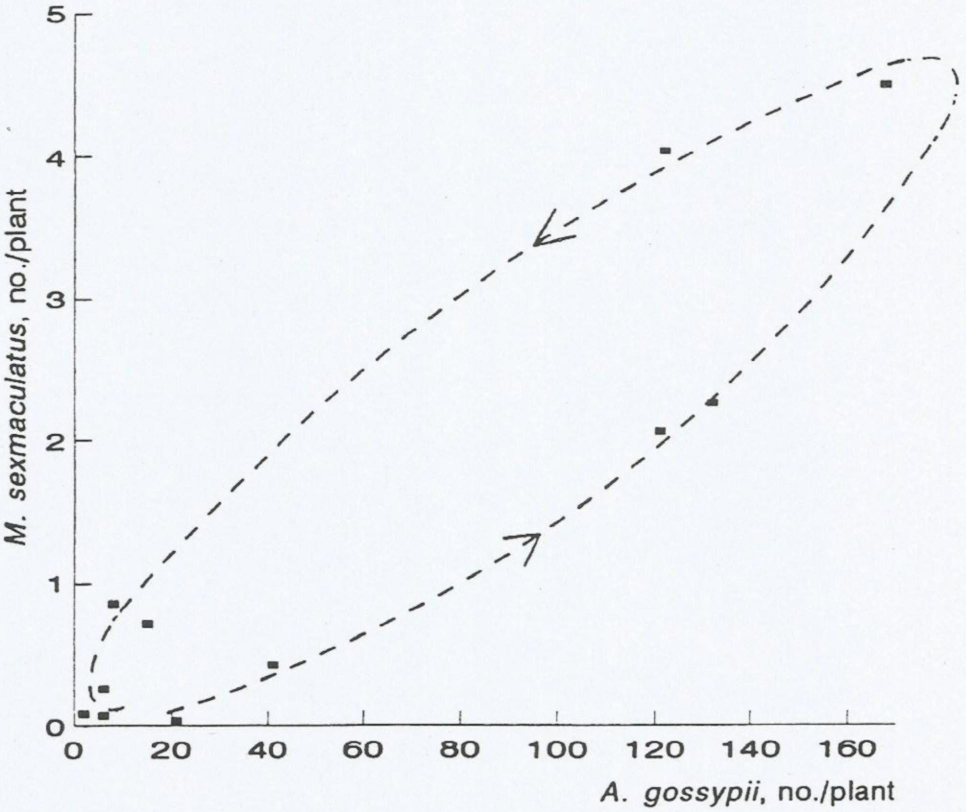

Figure 2. The time-lag relationship between the density of *A. gossypii* and the density of *M. sexmaculatus* in the second planting season of July 1994. The points along the curve represent the dates when the samples were taken. Direction of arrows indicate sequence of dates.

A strong numerical response of immediate and 3-day delayed response by MS was also observed in the second planting (Figure 3). The linear regression for the immediate response was $Y = -0.1148 + 0.3046X$; $r = 0.90$, $r^2 = 0.81$, $P < 0.001$ and for the delayed response was $Y = -0.1076 + 0.2962X$; $r = 0.87$, $r^2 = 0.75$, $P < 0.001$. As a rule of thumb, Guilford and Fruchter (1973) categorised the coefficient of correlation of $r = 0.71$ to 0.90 as a strong relationship. The r values observed in this study for both immediate and delayed numerical response were 0.90 and 0.87 which belongs to this category. The r^2 (coefficient of determination) values reveals that the MS densities were dependent upon the AG densities as much as 81% for the immediate response and 75% for the delayed response.

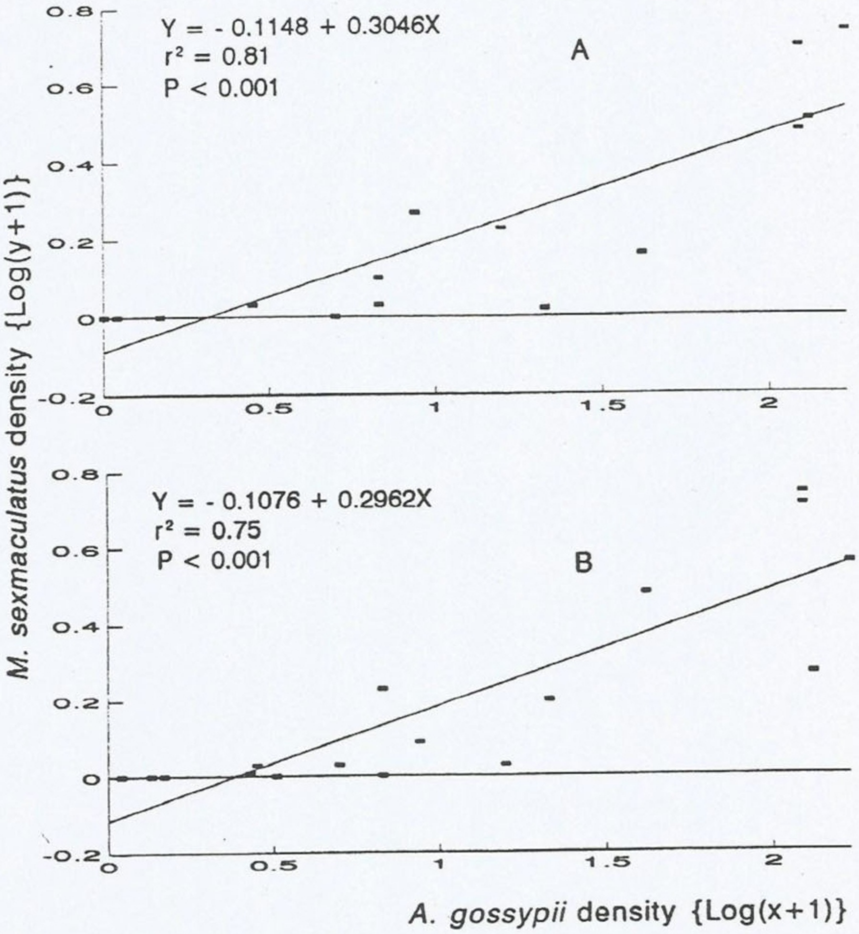

Figure 3. Linear regression analyses on the numerical response of *M. sexmaculatus* against *A. gossypii* showing the two types: immediate response (A) and 3-day delayed response (B).

DISCUSSION

In the chilli field, AG population is suppressed by MS. The predator population increased its response to increasing AG density as a result of its aggregation or reproduction. High MS population was observed following high numbers of MS larvae to eventually suppress AG populations. Tamaki *et al.* (1974) confirmed that predator capability of predators in controlling their prey is a product of the predator numbers and their voracity, which is termed as a predator power. A strong numerical response and high capability of MS in suppressing AG populations was successfully demonstrated in the 1994 field studies. Very low AG density and poor synchronisation might have contributed to the weak numerical response observed in 1993 studies. In the 1993 study MS synchronisation period was 3 weeks after AG colonisation. In the 1994 study the synchronisation period was shortened to 7 days by providing alternate prey (*A. craccivora*) on the long bean.

In the field, MS was capable stabilising the AG populations as indicated by their delayed density-dependent relationship. Hughes (1963) produced a typical Moran's curve while working a predatory syrphid larvae preying on *Brevicoryne brassicae*.

A strong numerical response was observed when MS responded to increasing AG density as indicated by the steep slopes of the linear regressions and significant ($P<0.05$) positive coefficient of correlation. A strong numerical response values correspond to those reported by Wright and Laing (1980), who studied a coccinellid preying on *Rhopalosiphum maidis* (Fitch.).

CONCLUSION

The studies had revealed that the larvae and the adults of MS preying on AG exhibited a strong numerical response. The MS showed its power to stabilise AG populations as indicated by the anti-clockwise direction of their delayed density-dependent relationship.

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LITERATURE CITED

Agarwala, B. K. and A. K. Ghosh (1988) "Prey Records of Aphidophagous Coccinellidae in India." *Tropical Pest Management* 34(1): 1-14.

Blackman, R. L. and V. F. Eastop (1989) *Aphids on the World's Crops: An Identification Guide*. New York: John Wiley & Sons.

Frazer, B. D. (1988) "Predators." In A. K. Minks and P. Harrewijn (eds.) *Aphids: Their Biology, Natural Enemies and Control*. Vol. B. New York: Elsevier Science Publishers pp. 217-230.

Guilford, J. P. and B. Fruchter (1973) *Fundamental Statistics in Psychology and Education*. 5th ed. New York: McGraw Hill.

Gupta, B. M. and C. P. S. Yadava (1989) "Role of Coccinellid Predators in Regulating the Aphid *Myzus persicae* (Sulzer) Population on Cumin in Field." *Indian Journal of Entomology* 51(1): 24-28.

Hassell, M. P. (1966) "Evaluation of Parasite or Predator Responses." *Journal of Animal Ecology* 35: 65-75.

Hodek, I., K. S. Hagen and H. F. van Emden (1972) "Methods for Studying Effectiveness of Natural Enemies." In H. F. van Emden (ed.) *Aphid Technology, with Special Reference to the Study of Aphids in the Field*. London: Academic Press pp. 147-188.

Hughes, R. D. (1963) "Population dynamics of the Cabbage Aphid, *Brevicoryne brassicae* (L.)." *Journal of Animal Ecology* 32: 393-424.

Hussein, M. Y. (1982) *The Effect of Natural Enemies of* Myzus persicae *Sulzer upon its Population Trends in Potato Crops in South Australia*. Ph.D. Dissertation, University of Adelaide.

Hussein, M. Y. (1991) "*Menochilus sexmaculatus* Fabr. (Coleoptera: Coccinel-lidae): It's Biology, Prey Requirement and Artificial Diets." *Journal of Plant Protection in the Tropics* 8(3): 153-160.

Lee, K. M., N. A. Samad, M. Y. Hussein and I. Sulaiman (1994) "Behaviour of *Aphis gossypii* Glov. in Transmitting Chilli Veinal Mottle Virus." *In* Proceedings of the 4th International Conference on Plant Protection in the Tropics, 28-31 March 1994. Kuala Lumpur: Malaysian Plant Protection Society pp. 240-241.

Lokhande, R. K. and P. Mohan (1990) "Study on Biocontrol of Aphid, *Aphis craccivora* Koch. by Ladybird Beetle, *Menochilus sexmaculatus* F. in Chillies." *Advances in Plant Sciences* 3(2): 281-286.

Luff, M. L. (1983) "The Potential of Predators for Pest Control." *Agriculture, Ecosystems and Environment* 10: 159-181.

Maisin, N., S. T. S. Hassan, M. Y. Hussein and A. S. Sajap (1994) "Within-plant Distribution Pattern of Predators on Chilli Plant." *In* Proceedings of the 4th International Conference on Plant Protection in the Tropics, 28-31 March 1994. Kuala Lumpur: Malaysian Plant Protection Society pp. 59-61.

Ong, C.A., G. Varghese and W. P. Thing (1980) "The Effect of Chilli Veinal Mottle Virus on Yield of Chilli (*Capsicum annuum* L.)." *Mardi Research Bulletin* 7(1): 74-78.

Ong, C.A., W. P. Thing and G. Varghese (1978) "Role of Aphid Vectors in the Spread of Chilli Veinal Mottle Virus." *In* Proceedings of the Plant Protection Conference, 22-25 March 1978. Kuala Lumpur: Malaysian Plant Protection Society pp. 53-60.

Parker, B. L., Ng S. Ming, T. S. Peng and G. Singh (1976) "The Effect of Malathion on Fecundity, Longevity and Geotropism of *Menochilus sexmaculatus*." *Environmental Entomology* 5(3): 495-501.

Saha, J. J. L. (1987) "Studies on the Fecundity, Hatchability, Mortality and Longevity of *Menochilus sexmaculatus* Fabr. (Coleoptera: Coccinellidae)." *Journal of Aphidology* 1: 1-2,47-50.

Salim , J. and M. Y. Hussein (1994) "Population Changes and Distribution of *Aphis gossypii* on Chilli." *In* Proceedings of the 4th International Conference on Plant Protection in the Tropics, 28-31 March 1994. Kuala Lumpur: Malaysian Plant Protection Society pp.: 381-382.

Solomon, M. E. (1949) "The Natural Control of Animal Populations." *Journal of Animal Ecology* 18: 1-35.

Syed, A. R. and W. H. Loke (1995) "Development and Challenges in Pest Mana-gement of Vegeta-bles." *In* Proceedings of the Seminar on Develop-ment and Challenges in Pest Management in Ma-laysia, 28 March 1995. Kuala Lumpur: Malaysian Plant Protection Society pp. 43-56.

Tamaki, G., J. U. McGuire and J. E. Turner (1974) "Predator Power and Efficacy: A Model to Evaluate Their Impact." *Environmental Entomology* 3: 625-630.

Whitcomb, W. H. (1981). "The Use of Predators in Insect Control." In D. Pimentel (ed.) and A. A. Hanson (ed. in-chief) *CRC Handbook of Pest Management in Agriculture*. Vol. II. Florida: CRC Press, Inc. pp. 105-123.

Wright, E. J. and J. E. Laing (1980) "Numerical Response of Coccinellids to Aphids in Corn in Southern Ontario." *Canadian Entomologist* 112(10): 977-988.

Zailani, M. M. R. (1984) *A Study on the Biology of* Menochilus sexmaculatus *(Fabr.) (Coleoptera: Coccinellidae), a Predator of* Aphis craccivora *(Koch) (Homoptera: Aphididae).* B. Agric. Sc. Project Paper, Universiti Pertanian Malaysia.