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Effects of Chilli Plant Architecture on the Population Abundance of *Aphis gossypii* Glover, its Coccinellid Predator and Relationship with Virus Disease Incidence on Chilli (*Capsicum annum*)

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Abstract: The population abundance of the aphid, *Aphis gossypii* Glover and its coccinellid predator as well as the relationship between aphid population abundance and virus disease incidence on five varieties of chilli with different forms of plant architecture was determined. Chilli varieties with short and prostrate plant architecture (MC-12) had higher population of aphids and coccinellids than the chilli varieties with tall and erect plant architecture (Kulai and MC-11), suggesting that the chilli variety with prostrate plant architecture harboured higher aphid population. The number of alate aphids trapped per week was generally higher in early than in the middle and late seasons. The accumulative percentage of virus disease incidence was significantly ($P < 0.05$) different among chilli varieties. The accumulative percentage of virus disease incidence was also significantly correlated ($r = 0.86$, $P < 0.05$) with days after transplanting and types of chilli varieties but not with the total number of apterous aphids. However, percentage of virus disease incidence was inversely correlated ($r = 0.69$, $P = 0.02$) with the number of alate aphids collected per week. Light intensity and air temperature had significant correlation with number of apterous aphids and coccinellid populations in chilli varieties with erect plant architecture only. However, there were no correlations in the number of apterous aphids and coccinellids in relation to rainfall and evaporation rate. The effects of infestation by *A. gossypii* and incidence of virus diseases on chilli varieties with different plant architecture and recommendation on the types of chilli to be used as cultural control are also discussed.

Key words: Chilli variety, *Capsicum annuum*, *Aphis gossypii*, coccinellid, cultural control

Introduction

The genus *Capsicum* contains about 20-35 species, all of which are New World in origin. Some of the wild species occur naturally in undisturbed vegetation. Only five species namely, *C. annuum*, *C. baccatum*, *C. chinense*, *C. frutescens* and *C. pubescens* are widely cultivated and used by man (Smith, 1957).

In Malaysia, only two domesticated species of *Capsicum* are cultivated viz., *C. annuum* and *C. frutescens* (Leong *et al.*, 1985). Between the two species, *C. annuum*, which include red chilli (*C. annuum* cv. group Acuminatum) and bell pepper (*C. annuum* cv. group Grossum) are grown commercially. The species *C. frutescens* which includes bird chilli is grown sporadically in small plots by farmers. At present, the cultivars or varieties of *C. annuum* cv. group Acuminatum popularly planted by farmers are Langkap, Kulai, MC 11, MC 12, Tanjung Minyak and Cili Puteh. Varieties like Chilli Bangi 1 (CB 1), CB 2, CB 3 and CB 4 developed by the University Kebangsaan Malaysia is gaining acceptance by farmers.

Although the area cultivated for chilli showed a declining trend since 1994, the crop is still considered as an important fruit vegetable in Malaysia (DOA, 1998 – personal communication) mainly because of its high nutritional and economic value. There are several reasons that can explain the fall in production of chilli. Among these the land is becoming more scare and expensive, particularly close to urban areas and problems of pests and diseases. The problems caused by pests and diseases on chilli have become more serious recently especially those caused by viruses. The disease has escalated with the opening of commercial chilli farms where chilli is planted as a monocrop and the practice of calendar pesticide spraying by farmers.

At present, chilli varieties resistant or tolerant to viruses are still not available in Malaysia. As such, other available control measures developed for the control of virus diseases in Malaysia are the use of reflective plastic mulch (Mohamad Roff & Ong, 1992), intercropping chilli with maize (Idris *et al.*, 1999; Idris & Mohamad Roff, 1999) and spraying of insecticide against vectors (Ng & Mohamad Roff, 1992).

The use of intercropping in managing virus disease of chilli was also found effective, however, its limitation in commercial farm is that it hinders mechanization (Mohamad Roff & Ho, 1991). Therefore, the only possible way is the use of superior chilli varieties into the existing management practice where insecticide and reflective plastic mulch are used. But at present, none of the chilli varieties grown in Malaysia are resistant/ tolerant to viruses or their vectors. Nevertheless, identification of chilli cultivars with plant architecture that can reduce the colonization of virus vectors will also help to save the industry by reducing loss due to virus disease. This can be achieved by integrating the variety component with other components such as insecticide spraying and use of reflective plastic mulch.

The objective of our study was to identify the chilli varieties with different plant architecture that can reduce the colonization of the aphid, *A. gossypii*, and virus diseases, and enhance the population of coccinellid predators. Results of this study will open the avenue for development of a more refined management package against virus diseases on chilli in Malaysia.

Materials and Methods

Study Site: Study was conducted at MARDI (Malaysian Agriculture Research and Development Institute) Research Station Jalan Kebun, Klang, Selangor from 2 April to 24 July 1998. The station is situated on a peat land area.

Source of chilli varieties: Six chilli varieties namely, Kulai, MC 4, MC 11, MC 12, Chilli Bangi 1 (CB 1) and CB 3 were used in the study. The variety Kulai and MC 11 had characteristics of erect and open plant architecture, while MC-12 had prostrate characteristic which is short and spread laterally. MC 4, CB 1 and CB 3 had compact plant architecture.

Experimental layout: Chilli seeds were sown in a nursery house covered with net to avoid insect infestation. Thirty days after sowing, the seedlings were then transplanted to a field. There were six treatments (chilli varieties) arranged in a randomized complete block design with three replications. Ten chilli plants were planted per bed (6.0 m long x 0.5 m high x 1.0 m wide; five bed per treatment) with a spacing of 60 cm within plants and 1.0 m between rows (two rows per bed). A compound fertilizer NPK Blue Special® (12:12:17.2) was applied at 30 g/plant in four split applications at monthly interval. No insecticide was applied throughout the entire cropping season. A circular yellow pan trap (30 cm in diameter and 10 cm in depth) half filled with water and detergent (0.01 ml soap/l water) was placed in middle of the plot to trap the alate aphids. Traps were supported with four wooden stakes and adjusted to the level of chilli canopy from time to time. The water was changed every alternate day.

Data collection and analysis: The data collection began from 14 May (26 days after transplanting, DAT) and continued until harvesting (24 July, 96 DAT). Five chilli plants were selected randomly in each treatment per replicate for the determination of apterous aphids and coccinellid populations. The alate aphids trapped were counted at 0800 h daily until 24 July 1998.

Incidences of virus disease were recorded weekly by inspecting the symptoms visually on every plant from 33 to 96 DAT. These incidences were calculated as percentage by dividing the total number of chilli plants infected at the time of sampling in a treatment/replicate with the total number of plants in a treatment/replicate and multiplied by 100.

One-way ANOVA was used to analyze the total number of apterous aphids per plant per season, coccinellids per plant per season, alate aphid per week per season and percentage virus disease incidence per treatment. Multiple regression analysis was used to analyze the relationship between accumulative percentage of virus disease incidence and ages of chilli (week after transplanting, WAT), chilli varieties plant architecture and total number of apterous aphids per plant. The relationship between percentage of virus disease incidence and number of alate aphid caught per week was analyzed using simple regression analysis. All data were run on a statistical program of 'SuperAnova®' (Abacus Concept, 1991). A multiple correlation analysis was performed to study the influence of abiotic factors on the total number of apterous aphids per plant.

Results

The total number of apterous aphid ($F = 5.18$, df = 5 & 120, $P = 0.001$) and coccinellids ($F = 3.65$, df = 9 & 120, $P = 0.005$) per plant were found to be significantly different among the treatments (Fig. 1 A and B). The population of apterous aphids per plant was significantly higher on MC 12 than on MC 4, MC 11, Kulai and CB 3 ($P < 0.05$) (Fig. 1A). Similarly, the total number of coccinellids per plant was also significantly ($P < 0.05$) higher on MC 12 than on other varieties. Conversely, the variety MC 11 had the lowest number of cocccinellids per plant. Although there was no significant difference in number of coccinellids per plant observed between MC 4, CB 1, CB 3, MC 11 and Kulai, their population followed similar pattern as in the number of apterous aphids per plant (Fig. 1B).

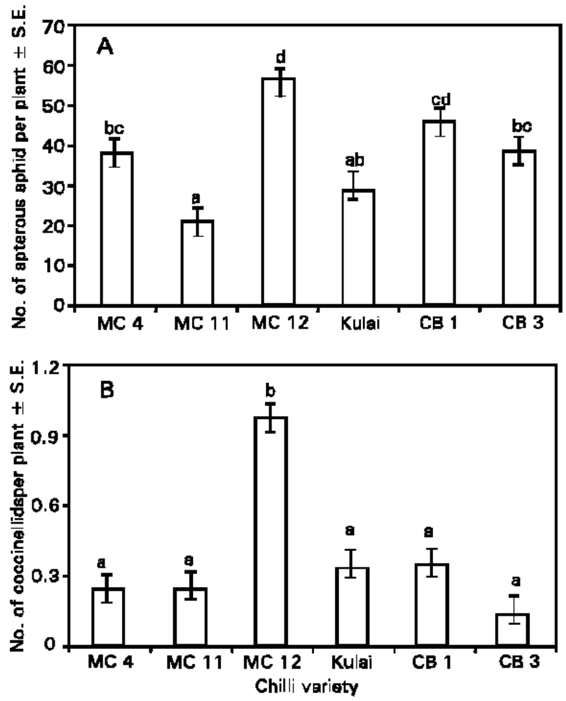

Fig. 1: Total numbers of Apterous *A. gossypii* (A) and coccinellids (B) per plant on different chilli varieties.

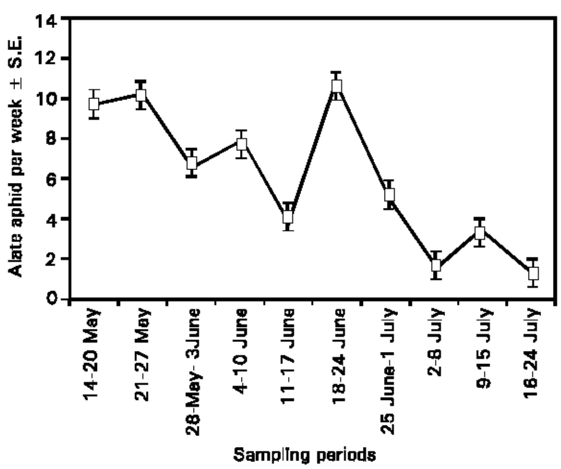

Fig. 2: Mean number of alatae aphid per week caught using yellow pan trap. Note: 14-20 May is 26-33 days after transplanting (DAT) or the 3rd week after transplanting (3 WAT).

Generally, the mean number of alate aphids trapped per week was found to be significantly different among sampling periods ($F = 7.89$, df = 9 & 40, $P = 0.001$) (Fig. 2). The numbers of alate aphids trapped between 30 - 44 DAT (in May) and 65 -72 DAT (18 – 24 June) were significantly higher than in other sampling days (Fisher's Protected LSD, $P < 0.05$). The results also showed that high number of alate aphids were trapped between May and June but low in July.

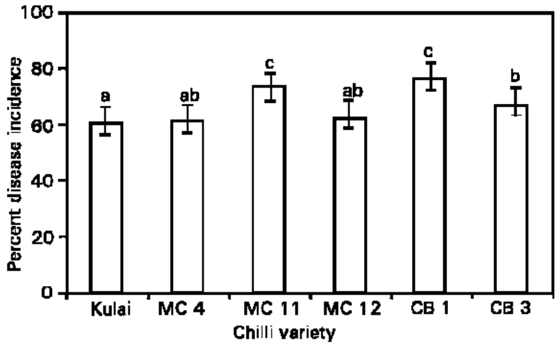

Fig. 3: Accumulative percentage of virus disease incidence per season on different chilli variety.

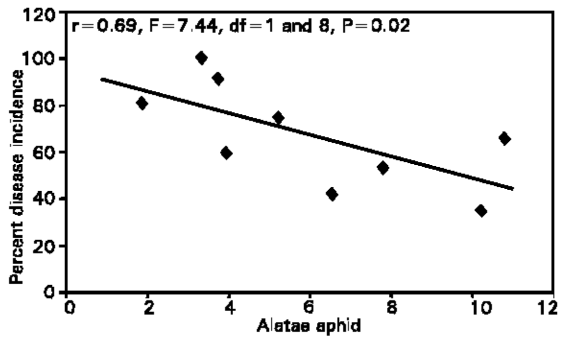

Fig. 4: Relationship between accumulative of percent virus disease incidence and the total number of alatae *Aphis gossypii* caught per season.

Table 1: Multiple correlation analysis for the percent virus diseases incidence in relation to days after transplanting (DAT or plant ages), chilli varieties and numbers of aphid.

Factor	F	df	P
Days after transplanting	30.44	9, 45	0.000
Chilli variety	12.56	5, 45	0.006
Numbers of apterous aphids[a]	0.30	1, 45	0.590
r = 0.86			

[a], not significant even after elimination regression analysis

Table 2: Correlation statistics for total number of apterous *A. gossypii* sampled weekly starting from 20[th] May to 24[th] July 1999 in relation to abiotic factors.

Variety	Factors	r^2	df	F	P
Kulai		0.43	4, 5	0.95	0.500
CB 1	Multiple correlation statistics	0.35	4, 5	0.69	0.620
CB 3	(light, rainfall, temperature,	0.40	4, 5	0.86	0.540
MC 4	and evaporation	0.37	4, 5	0.74	0.600
MC 11		0.55	4, 5	3.85	0.080
MC 12		0.57	4, 5	1.67	0.290
MC 11	Single correlation statistics[1,2]				
Light		0.46	1, 8	7.04	0.029
Temperature		0.57	1, 8	10.97	0.016
Rainfall		0.05	1, 8	0.04	0.830
Evaporation		0.004	1, 8	0.04	0.847

[1] After stepwise elimination regression
[2] None of the abiotic factors significantly correlated with the total number of apterous *A. gossypii* collected on other chilli varieties.

There was a significant difference in the accumulative percentage of virus disease incidence among the chilli varieties tested (F = 10.03, df = 5 & 40, P = 0.0001). The accumulative percentage of virus disease incidence was significantly higher on MC 11 and CB 1 than on other chilli varieties (Fig. 3). Analysis of multiple correlation showed that percentage virus disease incidence was strongly correlated (r = 0.86, P < 0.05) with the age of chilli varieties and chilli varieties (types of plant architecture) but not the number of apterous aphids per plant (Table 1). Results also showed that the accumulative percentage of virus disease incidence was inversely correlated with the mean number of alate aphids trapped per week (r = 0.69, F = 7.44, df = 1 & 7, P = 0.019) (Fig. 4).

Analysis of multiple correlation indicated that the total number of apterous aphids per plant was not significantly correlated with all the abiotic factors (P > 0.05) (Table 2). However, results of stepwise elimination correlation analysis showed that light intensity (r = 0.46, F = 7.04, df = 1 & 8, P = 0.029) and air temperature (r = 0.57, F = 10.97, df = 1 & 8, P = 0.016) were significantly correlated with the total number of apterous aphids per plant on variety MC 11 but not other varieties. Similarly result was obtained between the total number of coccinellids per plant of all varieties and abiotic factors (r = 0.62, F = 13.52, df = 1 & 8, P = 0.006) except for MC-11 where the number of apterous aphids was only significantly correlated with light (Table 3).

Table 3: Correlation statistics for total number of coccinelids sampled per week starting from 20[th] May to 24[th] July 1999 in relation to abiotic factors.

Variety	Factors	r^2	df	F	P
Kulai		0.48	4, 5	1.16	0.420
CB 1	Multiple correlation statistics	0.32	4, 5	0.61	0.676
CB 3	(light, rainfall, temperature,	0.17	4, 5	0.26	0.890
MC 4	and evaporation	0.69	4, 5	2.83	0.141
MC 11		0.69	4, 5	2.91	0.135
MC 12		0.47	4, 5	1.11	0.444
MC 11	Single correlation statistics[1,2]				
Light		0.62	1, 8	13.52	0.006
Temperature		0.29	1, 8	3.30	0.105
Rainfall		0.02	1, 8	0.198	0.667
Evaporation		0.02	1, 8	0.20	0.664

[1] After stepwise elimination regression
[2] None of the abiotic factors significantly correlated with the total number of apterous *A. gossypii* collected on other chilli varieties.

Discussion

Results of our study showed that chilli varieties with different plant architecture had different effects on the population abundance of apterous aphids. The populations of apterous aphids were high on chilli variety with prostrate plant architecture (MC-12) followed by compact and erect plant architectures (MC 4, MC 11, Kulai, CB 1 & 3) (Fig. 1 A & B). This indicates that the population of the apterous aphids is greatly affected by the geometrical and topological characteristics of chilli plant. The more open varieties of brussels sprout plants were reported to have high number of *Brevicoryne brassicae* (L.) than close foliage varieties brussels sprout plants (Brenkey & Carlson, 1944). Other factors such as secondary metabolites and nutrients content may also influence the number of aphids per plant (Van Emden & Bashford, 1976; Bach & Tabashnik, 1990). This is shown by the relatively higher number of apterous aphid on CB-1 than on CB-3, MC-4, MC-11 and Kulai. Low number of apterous aphid on MC-11 and Kulai may not be surprising as both varieties have similar plant architecture (tall and erect). This type of plant architecture may have exposed aphids to more adverse effects of abiotic factors (direct sunlight and rainfall) (Harris & Maramorosch, 1977) as well as predation (Van Emden, 1966; Lowe, 1973) as compared to other varieties.

Similarly, the number of coccinellids also follows the pattern of apterous aphids population according to the type of plant architecture. Plant with prostrate architecture had higher number of preys (aphids) and its predators (coccinellids) (Fig. 1 A & B). This indicates that our results tend to agree with that of resource concentration hypothesis proposed by Root (1973). Our results also indicate that differences in plant architecture seemed to have no negative effect on the functional response of coccinellid towards their preys. The coccinellids may be able to adjust their searching behaviour in response to differences in prey density in different plant architectures (Timberlake, 1993; Bell, 1991).

Aphid polymorphism is an adaptation enabling aphids to exploit different host plants as these become nutritionally suitable (McNeill & Southwood, 1978). Several researchers have suggested that a decrease in the nutritional value of the host plant may indirectly promote alate production (Way & Cammel, 1970). For this reason, aphid emigration may be, in part, a response to a physiological change, such as diminishing nutritional value, in the host plant as the season progress (Kennedy & Fosbrooke, 1973; Jansson & Smilowitz, 1985). If this is true, then it explained the reason why in general the number of alate aphids in our study declined towards the end of the season except during the third week of June (i.e., between 30 - 44 DAT and 65 -72 DAT) (Fig. 2). Similar phenomenon, however, was observed in green peach aphid populations, *Myzus persicae*, infesting only certain varieties of potato plants (Jasson & Smilowitz, 1985). The attractiveness of plants to flying aphids is generally enhanced if their background provides a contrast (Smith, 1976). This condition is similar to the earlier stage of chilli growing period and that explained why aphids trapped were highest in an early season (Fig. 2). Higher numbers of alate aphids trapped between 30 - 44 DAT and 65 -72 DAT indicating a high rate of emigration during mid-season as compared with the early and late season. Our results showed that CB 1 (short and compact plant architecture) had a high percentage of virus disease incidences and haboured high population of apterous aphids per plant (Fig. 1A and 3). The variety MC 11 (erect plant architecture) which haboured low population of apterous aphids per plant had high percentage of virus disease incidence. Whilst, variety MC 12 (short and prostrate architecture) that had the highest number of aphids per plant had significantly ($P < 0.05$) lower percentage of disease incidence than that of CB 1 and MC 11. This indicates that higher number of aphids per chilli plant does not necessarily result in higher percentage of disease incidence. The presence of aphid individuals (per plant) that is viruliferous is necessary for infection to occur (Harris & Maramorosch, 1977). The varieties of Kulai and CB 3 seemed to be less susceptible to virus disease infection than that of MC 11 and CB 1, respectively, even though they have similar plant architectures. This is probably one of the reasons that many chilli growers preferred planting Kulai or CB 3 varieties. Results showed that the accumulative percentage of virus disease incidence was positively correlated with DAT and chilli varieties but not the number of apterous aphids (Table 1). This indicates that the accumulative percentage of disease incidence increases with plant age (Harris & Maramorosch, 1977; Kift *et al.*, 1996). Although the number of apterous aphids per plant was high in prostrate and compact plant architecture (Fig. 1A), it had no significant influence on the increase of virus disease incidence in the field (Table 1). This may be due to different tolerance levels of the chilli varieties towards virus infection. For example, the variety Kulai and MC-11 had low number of aphids per plant but they had as high disease incidence as in MC-12 (Fig. 1A and 3). The accumulative percent of virus disease incidence was inversely correlated with the total number of alate aphids trapped per week (Fig. 4). This indicates that the occurrence of high percentage of virus disease incidence was not necessarily attributed to the large number of alate aphids trapped. This is true as both apterous and alate stages are equally capable of transmitting the viruses (Ribbands, 1965; Broadbent, 1965). Other factors such as the tolerance level of chilli variety to virus infection, mobility of aphids within plot and environmental factors may be involved (Ribbands, 1965; Harris & Maramorosch, 1977; Walter & Dixon, 1984).

Welling and Dixon (1987) reported that weather factors can influence the movement of aphids within canopy and an aphid outbreak. However, our results showed that the abiotic factors (light, rainfall, temperatures and evaporation) had no influence on the number of apterous aphids per plant irrespective of plant varieties except for MC 11 (Table 2). The ranges of light intensity, evaporation, temperatures and rainfall recorded throughout the experimental period were 4. 8 – 7.8 lux, 2.5–8.2 mm, 27.8–30.8 °C and 0–9.0 mm, respectively. These ranges may not be the limitation factors for apterous aphid development and reproduction. For example, the temperatures recorded in this study were well below the thermal death-points of most of the aphid species (Broadbent & Hollings, 1951). Since both MC 11 and Kulai have similar plant architecture (tall, erect and open) the difference in their response to light and temperatures may be due to physiological differences (Barnes *et al.*, 1976), and this explains, why there was less apterous aphids recorded on MC 11 than on Kulai varieties. Similar result was obtained between the total number of coccinellids per plant and the abiotic factors (Table 3), indicating that these predators have co-evolved to similar conditions adapted by their prey.

Planting varieties tolerance to virus disease is important in enhancing the impact of insect predators and parasitoids on aphid populations (Jacobson & Cropt, 1998). Results of our study indicate that the variety Kulai supports less aphid populations, more tolerance to virus disease infection and had no negative impact on its predators (coccinellids) as compared to other varieties. Differential in plant architecture among chilli varieties had a larger influence on the abundance of apterous aphid populations but not on the percentage of virus disease incidence. The physiological variation in genetic traits of the chilli varieties may be the limiting factor for disease development (Harris & Maramorosch, 1977) and that further study in these aspects is necessary. The aphid population and virus disease incidences could be managed to a certain extent by interplanting chilli with maize or other suitable crops rather than just planting chilli in monoculture system (Idris & Mohamad Roff, 1999; Hussein & Abdul Samad, 1993). An approach of field setting, which includes a weedy field margin, should also be tested as it could disrupt the alate aphid landing on chilli (Banks, 2000).

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