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Vertical and Temporal Distribution of *Aphis gossypii* Glover and Coccinellid Populations on Different Chilli (*Capsicum annuum*) Varieties

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Abstract The vertical and temporal distribution of an aphid, *Aphis gossypii* Glover, and the coccinellid populations on six chilli varieties were studied. The total number of apterous aphid per plant stratum was significantly different among plant strata of a particular variety (treatment) as well as among the treatments. Generally, the total number of aphids was significantly greater in the lower stratum than in the middle and upper strata. However, the varieties with erect and open plant architecture (Kulai and MC 11) had significantly less number of apterous aphids at all strata as compared to varieties with compact or prostrate plant architectures. There was a significant difference in the total number of coccinellids per plant strata among the treatments but not within a treatment. The distribution of apterous aphid populations varied significantly among sampling periods and treatments. The temporal distribution of coccinellids showed a similar trend as that of apterous aphids. The total number of alate aphids caught per week was significantly different among the sampling periods. However, its population was significantly greater during the early season and gradually declined as the season progressed except during June 18 to 24. The importance of recording the most observed coccinellids species, which limit the aphid populations at each particular plant stratum per variety, and the conditions that favor natural enemies are also discussed.

Key words *Aphis gossypii*, Coccinellids, vertical distribution, temporal distribution

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Introduction

Chilli (*Capsicum annuum*) is one of the most important vegetable crops grown in Malaysia. However, its production is often influenced by viral diseases transmitted by an aphid, *Aphis gossypii* Glover (Mohamad Roff and Ong, 1992; Mohamad Roff and Shahran, 1989). Most farmers in Malaysia use cultural methods, pesticides and resistant or tolerant varieties to keep aphids from infesting their chilli plants as well as spreading disease (Mohamad Roff and Ong, 1991a and 1991b). The use of silver plastic mulch as a cultural control of aphids is widely used by farmers. However, its effectiveness as a ground cover to reduce aphid landing declines with plant age as chilli leaves overshadow the plastic mulch.

Although pesticides have proved very effective at protecting crops against aphids, the level of control achieved with aphicides is not sufficient enough to prevent the spread of viral diseases especially of non-persistent viruses (Mohamd Roff and Idris, 1999). Breeding for resistant or tolerant plants can provide a much cheaper alternative without detrimental side-effects such as that of the aphicides (Horber, 1972; Metcalf, 1972). Plant resistance or tolerance to aphids may be due to a failure of aphids to alight (Kennedy *et al*., 1961), the presence of hairs and other epidermal characters restricting aphid movement (Gibson, 1974), the failure of aphids to settle, feed or breed (Watson and Plumb, 1972), and substances that lower alate aphid production (Lees, 1966; Gallun, 1972). These could determine the abundance of aphids and viral disease incidence on any plant (Harris and Maramorosch, 1977).

There has been no record or study on the effect of chilli plant architecture on spatial (vertical) and temporal distribution of aphids and their predators as well as on viral disease incidence on chilli plants. Jansson and Smilowitz (1985) reported that the vertical distribution of the green peach aphid, *Myzus persicae* (Sulzer), on the commercial cultivars of potato plants was not uniform and changed during the growing season. Myint *et al*. (1999) also found that there was a significant difference in the spatial (canopy stratum) and temporal abundance of agromyzids leaf miners and their parasitoids on sugar peas, *Pisum sativum saccharatum*.

This study was conducted to test the hypotheses that the vertical and temporal distribution of *A. gossypii* and its coccinellids predator populations are different among chilli varieties. Information obtained from this will be incorporated into an IPM program formulated for chilli growers in order to control aphids and viral diseases of the crop.

Materials and Methods

Study site

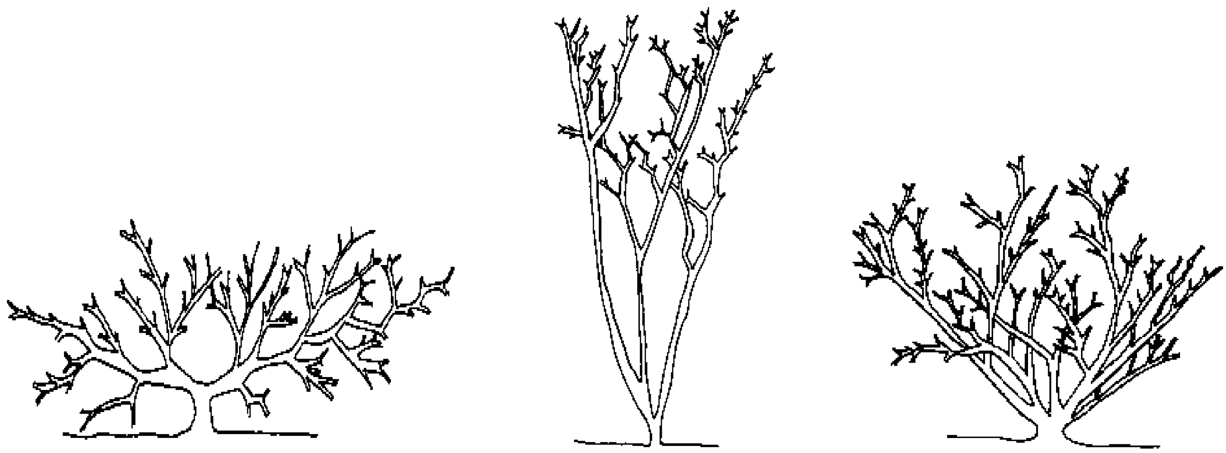
This study was conducted at MARDI (Malaysian Agriculture Research and Development Institute) Research Station Jalan Kebun, Klang, Selangor from 2 April to 24 July 1998. The station is situated on a peat land area.

Source of chilli

Six chilli varieties, Kulai, MC 4, MC 11, MC 12, Chilli Bangi 1 (CB 1) and CB 3 were used in the study. The variety Kulai was purchased from Nine Top Seed Company at Batu Arang, Selangor. MC 4, MC 11 and MC 12 varieties were obtained from Dr. Melor Rejab of MARDI Research Station Jalan Kebun, Klang while CB 1 and CB 3 varieties were purchased from the Universiti Kebangsaan Malaysia, Bangi, Selangor. The varieties Kulai and MC 11 are characterized by erect and open plant architecture while MC 12 variety is prostrate, meaning it is short and spread laterally (Fig. 1). MC 4, CB 1 and CB 3 varieties have compact plant architecture. Generally all the chilli varieties have similar leaf shape. The leaves are alternate, simple, petiole up to 10 cm long, ovate in shape and light to dark green in colour. The only difference is in the architecture and height of the plant. The height of MC 11 and Kulai is between 100-200 cm; MC 4, CB 1 and CB 3 is in the range of 60-70 cm while MC 12 is between 40-50 cm.

Experimental layout

Chilli seeds were sowed in a nursery house covered with net to avoid insect infestation. Thirty days after sowing, the seedlings were transplanted to a field. There were six treatments (chilli varieties) arranged in a randomized complete block design with three replications. Each replicate in a treatment had 25 chilli plants, planted on five beds (6.0 m long x 0.5 m high x 1.0 m wide). On each bed, 5 chilli plants were planted with a spacing of 60 cm within plants and 1.0 m between rows. A compound fertilizer NPK Blue Special® (12:12:17.2) was applied at 30 g/plant in four split applications at monthly intervals. No insecticide was applied throughout the entire cropping season. Weeds were controlled manually every week from first week after transplanting to the end of data collection period. A circular yellow pan (30 cm in diameter and 10 cm in depth) half-filled with water and detergent (0.01 ml soap/l water) was placed in the middle of the plot to trap alate aphids. Traps



MC 12 Kulai and MC 11 MC 4, CB 1 and CB 3

Fig. 1. Schematic representation of plant architecture of six different chilli varieties used in the study.

were supported with four wooden stakes and adjusted to the level of chilli canopy from time to time. The water was changed every other day.

Data Collection and Analysis

Data collection commenced on 14 May (30 days after transplanting, DAT) and continued until harvest time (24 July, 100 DAT). Five chilli plants per replicate were selected randomly. From each plant, the numbers of apterous aphids and coccinellids (adult and larvae) present per plant stratum (each plant was subdivided into three different strata namely upper, middle and lower) were recorded. Counting for alate apids was done at 0800 h daily.

Two-way analysis of variance (2-way ANOVA) was used to analyze the data on apterous aphids and coccinellids while data on alate aphid was analyzed using one-way ANOVA. All data were run on a statistical program of 'SuperAnova®' (Abacus Concept, 1991).

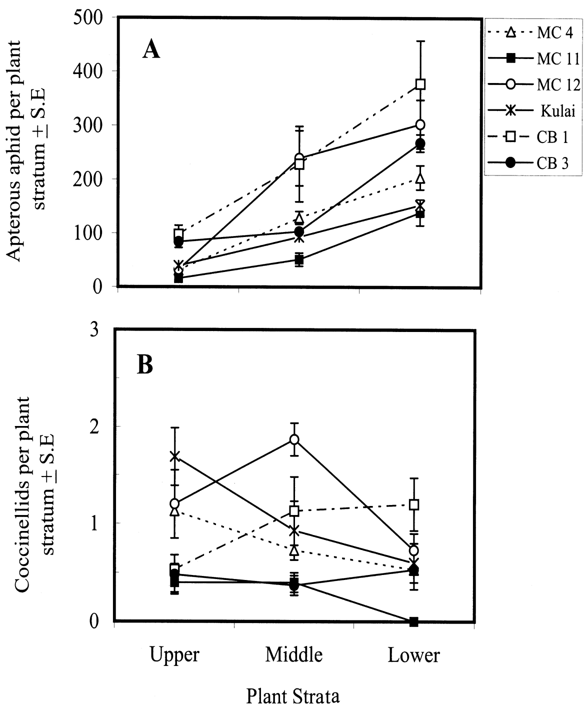


Fig. 2. Total number (mean ± S.E) of apterous aphids (A) and coccinellids (B) at different plant stratum of six chilli varieties.

Results and Discussion

Vertical Distribution

Apterous aphid The total number of apterous aphids was significantly different among plant strata (F= 24.72; df=2, 36; P=0.0001) and chilli varieties (F=5.18; df=5, 36; P=0.0011) (Fig. 2 A). However, the interaction between plant strata and chilli varieties was not significant (F=0.09; df=10, 36; P=0.53) and it had no influence on the total number of aphid populations on chilli plants.

The total number of apterous aphids was greater at the lower than at the upper strata of all chilli varieties irrespective of plant architectures. This indicates that apterous aphids preferred the lower leaves than the upper leaves. The green peach aphid (GPA), *Myzus persicae* (Sulzer), was also reported to prefer the lower leaves of the potato plant (Bradley, 1952). Differences in leaf phenology (i.e., leaf senescence) along the vertical gradient of chilli plants may have influenced the distribution of apterous *A. gossypii* as it did for GPA on potato plants (Jansson and Smilowitz, 1985). The lower leaf zones of plants colonized by the aphids had a higher content of amino-nitrogen compounds than the higher leaf zones (Jasson and Smilowitz, 1985; van Emden, 1966).

The distribution of aphid populations per plant stratum among chilli varieties of similar plant architecture was not uniform. For example, the varieties CB 1, CB 3 and MC 4 had similar compact plant architecture but not the number of aphids in most strata (Fig. 2A). Similarly, the total number of aphids on MC 4 was not significantly different (P>0.05) with that of Kulai (erect and open plant architecture) in all strata. The difference in the number of aphids at the middle and lower strata of CB 1 and CB 3 was significant (P<0.05) but not at the upper stratum. The variety CB 1 had the greatest number of aphids, irrespective of plant strata, as compared with other chilli varieties (Fig. 2A). This suggests that plant architectures and phenology were not the only factor which influenced the number of aphids per plant stratum. Other factors that may have been involved are the differences in tolerance to aphids among chilli varieties as well as the influences of aphids natural enemies (Idris *et al.*, 1999; Idris and Mohamad Roff, 1999).

In general, the varieties MC 11 and Kulai with erect and open plant architecture had a significantly (P<0.05) fewer number of aphids as compared to MC 12 in all plant strata. The open plant architecture of MC 11 and Kulai as opposed to MC 12 (prostrate) may have provided less protection to aphids from predators, to the heat of the sun, to gusty wind and to heavy rainfall that promoted drowning (Idris and Grafius, 1998; Dunn and Kempton, 1971).

Coccinellids There was a significant difference in the total number of coccinellids per plant stratum among the varieties (*F*=3.02; df=10, 36; *P*=0.023), but not within a variety (*F*=1.25; df=5, 36; *P*=0.29) (Fig. 2B). The interaction between plant strata and chilli varieties had no significant influence on the number of coccinellids per plant (*F*=0.09; df=10, 36, *P*=0.53).

In contrast to the distribution of aphid populations (Fig. 2A), the distribution of coccinellid populations among plant strata per chilli variety was somewhat random. These predators were not really aggregated at the lower plant stratum where their preys were abundant. For example, the predators were in greater numbers in the upper and middle plant strata of Kulai and MC 12, respectively, than in the lower plant stratum. These results cannot be explained by the resources concentration hypotheses proposed by Root (1973), which refers to the differential abundance of insect populations between plants.

As with the aphids, the distribution of coccinellid populations was significantly influenced ($P<0.05$) by the plant architectures of the different chilli varieties. The varieties Kulai, MC 12 and MC 4 had greater numbers of coccinellids in the upper stratum than in the upper stratum of other varieties (Fig. 2B). With respect to the middle stratum, MC 12 had the greatest, while CB 3 and MC 11 had the least number of coccinellids. In the lower stratum, however, CB 1 and MC 11 had the greatest and least numbers of coccinellids, respectively. It was noted that coccinellids preferred to stay in the upper stratum and lower stratum of Kulai and MC 11, respectively, although both varieties are of the erect and open plant architecture (Fig. 1A). This indicates that differences in the variety characters, other than plant architecture, may have influenced the distribution of coccinellids within the plant canopy. However, high number of coccinellids in the middle stratum of MC 12 was probably due to its prostrate characteristic (short and spread laterally) that gave better protection to aphids from sunlight and the impact of heavy rainfall. This result also indirectly disagrees with the resources concentration hypotheses proposed by Root (1973). This is because there was a relatively greater abundance of apterous aphids but not of the coccinellids at the lower leaf zone or stratum.

Temporal Distribution

Apterous aphids There was a significant interaction between sampling periods and chilli varieties (*F*=2.35; df=45, 120; *P*=0.0001) that influenced the total number of aphids sampled per chilli plant per week. This indicates that the abundance of apterous *A. gossypii* population varied with chilli varieties and phenology. The total number of apterous aphids per plant on CB 1 and CB 3 were significantly greater between 37 DAT and 62 DAT (27 May-24 June) ($P<0.05$) (Fig. 3A). Whilst on MC 4, MC 12 and Kulai aphid numbers were greater during 37 DAT until the second week of June (55 DAT) than during other sampling periods ($P<0.05$) (Fig. 3A and B). This suggests that in general, aphid populations were larger during the early than during the late season, irrespective of chilli varieties. A similar trend was reported for GPA populations on various potato cultivars (Tylor, 1955). He attributed the differences in the development of GPA infestations to the variation among cultivars in the time at which leaves senesced.

The low number of apterous aphids during the late season suggests that the chilli plants became more resistant to aphid as the plants matured. The matured

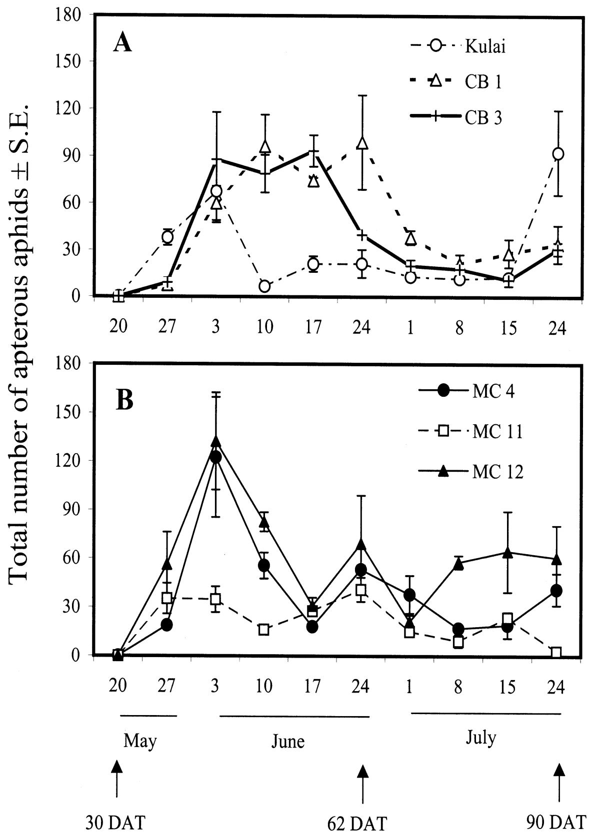


Fig. 3. Total mean number of the apterous aphid, *Aphis gossypii*, on different chilli varieties (A=MC 4, 11 & 12; B=Kulai, CB 1 & 3) at different sampling periods (DAT=days after transplanting) in 1999.

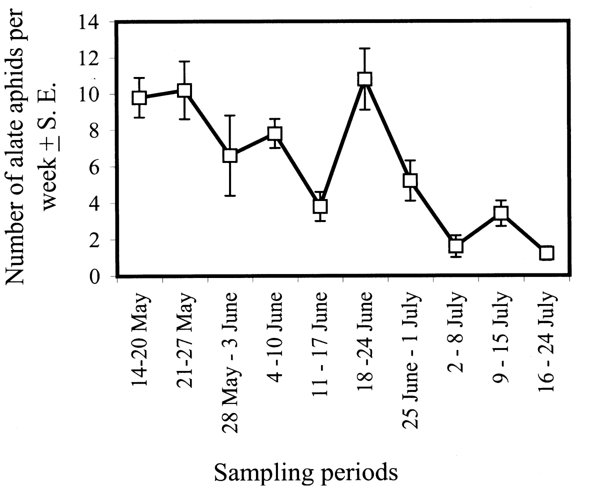


Fig. 4. Mean number of alate aphids per week caught using yellow pan trap. Note: 14 - 20 May is 26 - 33 days after transplanting (DAT) or the 3rd week after transplanting (3 WAT).

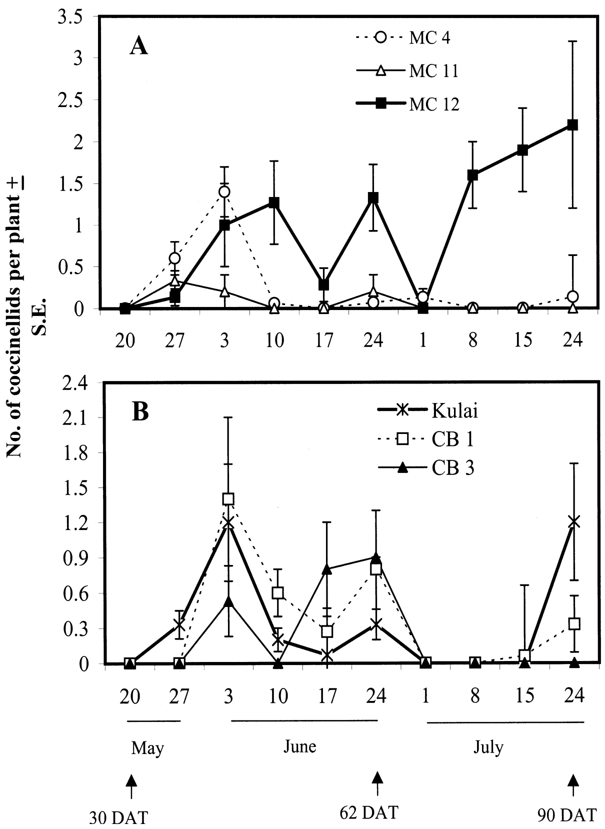


Fig. 5. Total number of coccinellids on different chilli varieties (A; MC 4, MC 11 and MC 12; B, Kulai, CB 1 and CB 3) per sampling period (DAT=days after transplanting) in 1999.

Vicia faba and potatoes were reported to be more resistant to infestation of the *Aphis fabae* and *Myzus persicae*, respectively (Tylor, 1955). Interestingly, a greater number of aphids were recorded on MC 12 and Kulai in July samplings (late season). This may be due to the random emigration of alate aphids to plots having these varieties, Kulai and MC 12 but not to plots of other varieties. The variety MC 11 had the least number of aphids per plant throughout the season even though it has similar plant architecture as Kulai. This suggests that MC 11 was not the preferred host of the aphids as compared to other varieties, particularly CB 1 and CB 3.

Alate aphids The total number of alate aphids trapped per week was found to be significantly different among sampling periods (weeks) (F=7.89; df=9, 40; P=0.001). Generally, greater number of aphids was trapped during early season. This numbers declined afterwards except in mid-June (Fig. 4). The numbers of alate aphids trapped were significantly larger during May and the 3rd week of June (61-68 DAT) than in other sampling periods (Fisher's Protected LSD, P<0.05).

Aphid polymorphism is an adaptation enabling aphids to exploit different host plants as these become nutritionally suitable (McNeill and Southwood, 1978). Several researchers have suggested that a decrease in the nutritional value of the host plant may indirectly promote alate production (Way and 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 and Fosbrooke, 1973; Jasson and Smilowitz, 1985). If this is true, then it explain the reason why in general the number of alate aphids in our study declined toward the end of the season except during the third week of June. A similar phenomenon was observed in GPA populations infesting potato plants (Jasson and 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 the chilli-growing period and this explains why the highest number of aphids was trapped during the early season (Fig. 4). A greater number of alate aphids were trapped during June 18 to 24 (61-68 DAT), indicating a high rate of emigration during the mid-season as compared with the early and late seasons. Because the background contrast was almost zero during this period, the emigration of alate aphids may be related to abiotic factors especially light (Barnes *et al.*, 1976; Broadbent and Hollings, 1951).

Coccinellids The total number of coccinellids trapped per week was significantly different among sampling periods (F=3.65; df=9, 120; P=0.005) and chilli varieties (F=7.80; df=5, 120; P=0.001). Unlike with the apterous aphids, the total number of coccinellids was not significantly influenced (F=1.39; df=45, 120; P=0.081) by the interaction between sampling periods and varieties (Fig. 5 A & B). However, the distribution pattern of coccinellids throughout the season was somewhat similar with that of the aphids (Fig. 3 and 5). This is tends to agree with the resources concentration hypotheses proposed by Root (1973). Except for MC 11, most varieties harbored high number of coccinellids in June (middle of cropping season). In July, however, the number of coccinellids was significantly higher on MC 12 or Kulai (last sampling week) than on other varieties.

Conclusion

Planting resistant and/or tolerant varieties is one of the best cultural methods for controlling viral diseases incidence. Our results suggest that the varieties with erect and open plant architecture (MC 11 and Kulai) were more tolerant to aphid infestation than the other varieties. As such, these varieties may be the better choice for commercial planting as they harbored low number of aphids particularly during the early growing stage of chilli, which is the most susceptible stage to virus infection. In addition, they seem to favor the presence of coccinellids and probably other natural enemies of *A. gossypii*. Although there were more aphids on Kulai than on other varieties during the late season, their presence might not have influenced disease spreading, as the plants were already matured and more tolerant to disease infection.

Further study is needed to look into which varieties are more susceptible to alate aphid infestation because of the insects' importance in viral disease spreading. There may be a possibility to develop an economic threshold level based on the number of alate aphid per plant for certain varieties or cultivars. It is also important to record the species of coccinellids most observed in a particular plant stratum. This is because the aphid seemed to aggregate more at the middle and lower plant strata than at the upper stratum. By doing so we might be able to have an idea on the coccinellids species that actually feed on more aphids in the field. Subsequently, a mass rearing of that particular coccinellids species could be done for field release. This will indirectly enhance the effectiveness of an integrated management of *A. gossypii* in a chilli cropping system.

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