CHAPTER TWO - SEASONAL ABUNDANCE AND DIVERSITY OF APHIDS IN JAMAICAN PEPPER AGROECOSYSTEM

Abstract

Seasonal abundance and diversity of aphids on pepper farms in St. Catherine, Jamaica were investigated throughout 1998 and 1999. Aphid flight activity was monitored weekly on five farms using water pan traps. Peak aphid flights and the greatest species diversity occurred during mid-September through mid-May, whereas few aphids and the lowest species diversity occurred from mid-May through mid-September. Over 30 species of aphids were collected including five known *tobacco etch potyvirus* vectors, *Aphis gossypii* Glover, *A. craccivora* Koch*, A. spiraecola* Patch*, Lipaphis erysimi* Hille Ris Lambers and *M. persicae* (Sulzer), and 12 new records for Jamaica, *Aphis amaranthi* Holman*, Brachycaudus helichrysi* (Kaltenbach)*,*Capitophorus hippophaes (Walker), Geopemphigus floccosus (Moreira), *Hysteroneura setariae* (Thomas)*, Lipaphis erysimi* Hille Ris Lambers, *Rhopalosiphum padi* (Linnaeus)*, Schizaphis graminum* (Rondani)*, Schizaphis rotundiventris* (Signoret), Trichosiphonaphis poligoni (van der Goot), *Uroleucon ambrosiae* complex (Thomas) and *Uroleucon pseudoambrosiae* (Olive). Commonly encountered aphid species were observed on weeds and crops within and near fields. Based on this information, implications for management of common pepper viruses and their aphid vectors in St. Catherine, Jamaica are discussed.

KEYWORDS: aphid abundance, TEV vector, Potyvirus, seasonal abundance, new records.

Introduction

Peppers in Jamaica are severely affected by mosaic diseases caused by aphid-transmitted viruses, particularly *tobacco etch potyvirus* (TEV) (Family: Potyviridae) (McGlashan *et al.* 1993, Myers 1996, Martin *et al.* 1998). Myers *et al*. (1998) found a known TEV vector, *Aphis gossypii* Glover (Laird and Dickson 1963), colonizing pepper and in pan traps on a pepper farm. Myers *et al* (1998) also reported that from a trapping period in Jamaica lasting from July to November 1997 aphid flights were greatest during September. Information on aphids of Jamaica is sparse and fragmented but the few available sources of literature indicate that 26 species of aphids are recorded from Jamaica (Frank and Bennet 1970, Smith and Cermali 1979, Murray 1985, Jayasingh 1996, Nafría *et al.* 1994). There has not been a comprehensive survey of the aphid species present in Jamaica or the seasonal activity of aphids in the pepper agroecosystems of Jamaica. Such knowledge is important in understanding the epidemiology of aphid-borne viruses of pepper and the development of appropriate management strategies.

There is very little information available about seasonal abundance of aphids in tropical regions. Seasonal activities of alate aphids are often monitored in temperate regions, where temperature plays a significant role in aphid dispersal. For example, Shaunak and Pitre (1971) found two major flight periods for aphids in Northeastern Mississippi. There was one peak flight between April and May and another between October and November when aphids moved from overwintering to summer hosts and vice versa. The timing of major flights often remains the same from year to year (Halbert *et al.* 1981, Eckel and Lampert 1996, DiFonzo *et al.* 1997) even though the species composition may change (Halbert *et al.* 1981, DiFonzo *et al.* 1997).

Crops and weeds in and around fields may affect the species diversity of aphids and are often potential sources of virus inocula (Bos 1981). DiFonzo *et al.* (1997) found several cultivated crops and volunteer plants in the Red River Valley of Minnesota and North Dakota, USA that influenced the species composition of aphids caught on potato farms in the same region. Anderson (1959) found 21 species of weeds as sources of viruses to which pepper was susceptible, growing near pepper fields in Florida.

The migratory habits of aphids make them important vectors of plant viruses. Peak aphid flights and the presence of known vectors are often associated with rapid spread of viruses in a particular area (Halbert *et al.* 1981, Shultz *et al.* 1985, DiFonzo *et al.* 1997). In some instances virus incidences have been correlated with high numbers of inefficient vectors when numbers of efficient vectors were low (Halbert *et al.* 1981, Shultz *et al*. 1985, DiFonzo *et al.* 1997). Knowledge of the seasonal flights of aphid vectors of TEV and *potato virus Y* (PVY) (Family: Potyviridae) will allow farmers to plan planting dates of pepper so less susceptible stages of their crops will be exposed to viruses brought in by these viruliferous vectors during heavy flight periods. Therefore, in this study we sought to identify seasonal patterns in aphid flight activity and the species diversity in a hot pepper growing area of St. Catherine parish, Jamaica, W.I. so that we may use these data to help develop new management practices.

Materials and methods

Aphid flight activity was monitored on five pepper farms (Figure 2.1) in St. Catherine parish, Jamaica from 13 February 1998 through 9 December 1999. On each farm, three water pan traps (Figure 2.2) were placed diagonally within a pepper plot 10 m apart. Each trap consisted of a green plastic flower saucer (Thermoplastic®, Jamaica; 22.9 cm in diameter) mounted on a wire frame. Saucers were painted with two shades of green (cobalt green HO56 and green gold HO86 acrylic paints, FINEST™, Grumbacher Inc., Bloomsbury, NJ) similar in shade to pepper leaves to give a mosaic pattern that might reduce selective attraction of aphid species to the traps.

Four holes, 0.7 cm in diameter, located 1 cm from the top of each saucer and covered with cloth (pore size $\leq$ 0.5 mm^2) allowed drainage of excess fluid due to rain or overhead irrigation. The height of the pan traps was adjusted to the level of the plant canopy. Saucers were filled with approximately 250 ml each of monoethylene glycol and water (1:1), (modified from Difonzo *et al.* 1997) which was collected and replenished weekly. Data on minimum and maximum temperatures were recorded from Farm 3 at the same time that aphids were collected.

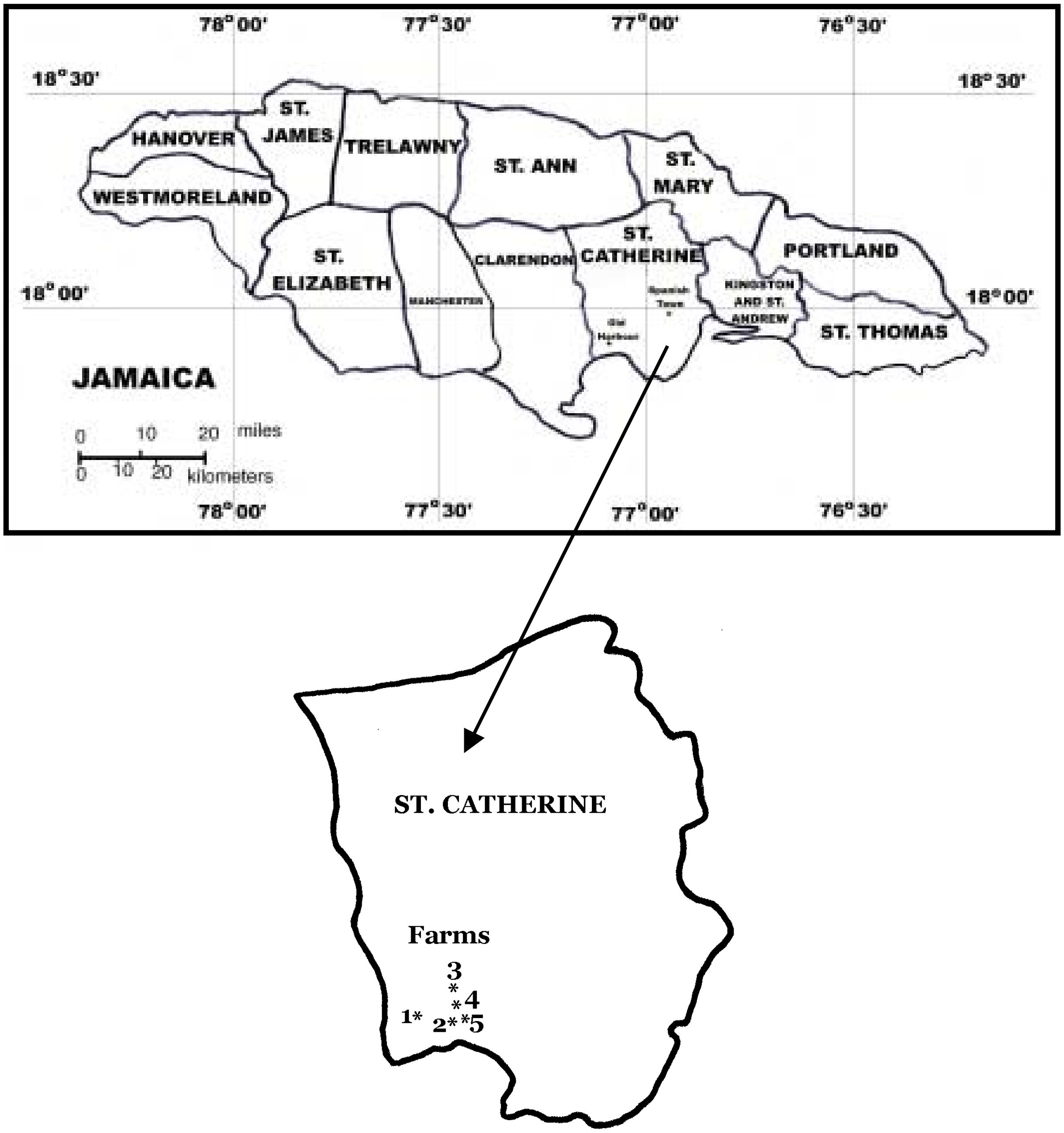

Figure 2.1. Location of farms used to study seasonal abundance and diversity of aphids in St. Catherine, Jamaica

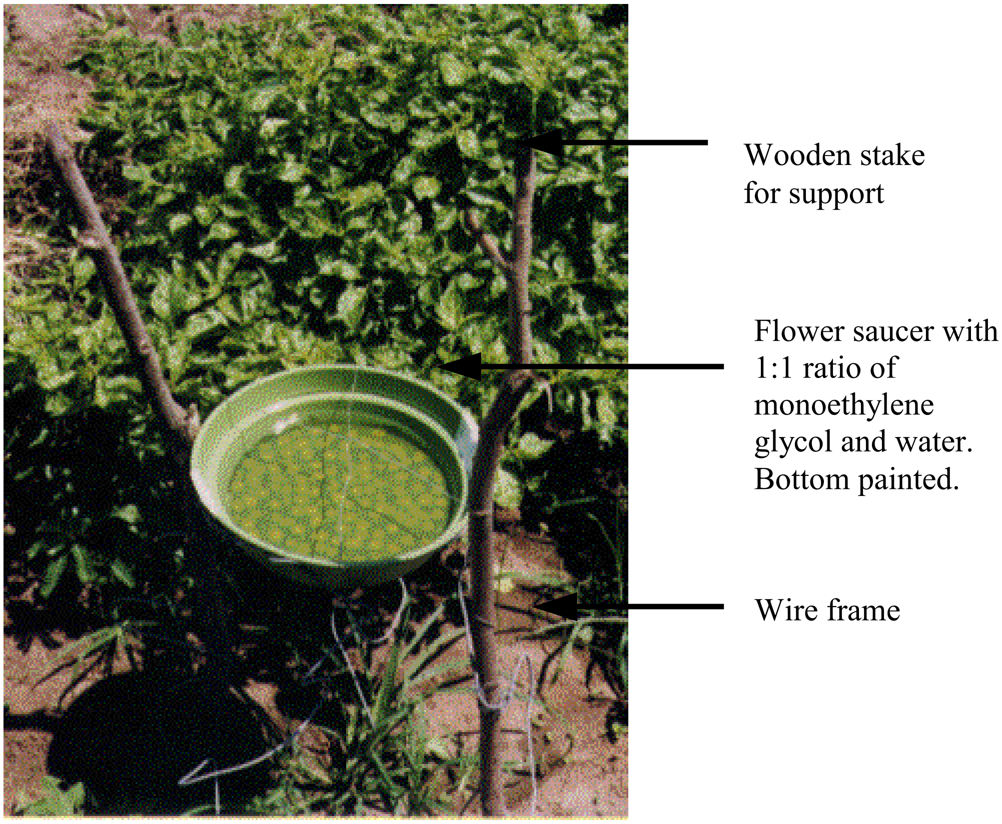

Figure 2.2. Pan trap used to monitor aphids during study of field spread of TEV in ‘Scotch Bonnet’ peppers at Bodles, St. Catherine, Jamaica, 26 June through 1 October 1998.

In the laboratory, aphids were removed from the collection fluid, counted and stored in 70% ethanol until identified to species. Most aphid species were identified by Dr. Susan Halbert[1] and few by Dr. David Voegtlin[2]. The remaining aphid species were identified by the senior author with the aid of museum specimens obtained from previously collected samples (identified by Dr. Halbert) and according to Smith *et al*. (1963) and Kono and Papp (1977).

The effects of location, time and their interactions on the abundance of aphids were determined using time series analysis of variance (MIXED DATA procedure, SAS Institute 1996). Data from two farms (Farms 2 and 5) were omitted from this analysis because they were not sampled continuously over the same period as the others. Analysis of variance was conducted to determine the effect of seasons on the number of aphids caught on all five farms (GLM procedure, SAS Institute 1997).

Results

Seasonal abundance of aphids

Aphid abundance varied significantly among locations ($F = 26.92$; $df = 1, 2$; $p < 0.0001$), over time ($F = 5.83$; $df = 1, 77$; $p < 0.0001$) and was highly affected by a location by time interaction ($F = 3.69$; $df = 1, 153$; $p < 0.0001$). Aphid flight activity was high from February through mid-May 1998 and mid-September 1998 through mid-May 1999. In contrast, flight activity was low from mid-May to August/mid-September 1998 and 1999 (Figure 2.3).

Mid-September to mid-May tended to be a cooler period of the year than mid-May to mid-September, with the most noticeable difference being in the minimum temperatures between these two periods (Table 2.1). Temperature appeared to have been a primary factor affecting

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[2] Center for Biodiversity, Illinois Natural History Survey, Champaign, Illinois.

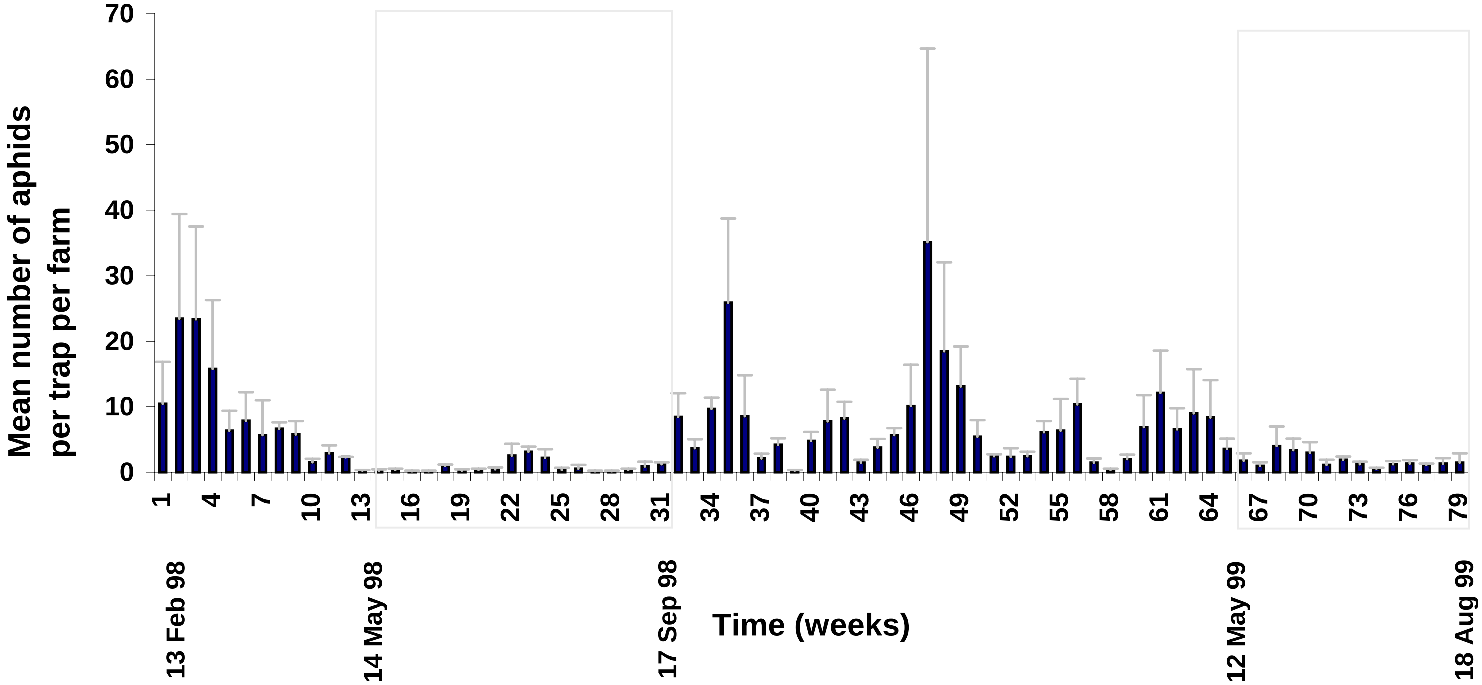

Figure 2.3. Mean ± SE number of aphids collected in pan traps each week on pepper farms in St. Catherine, Jamaica, W.I. during 13 February through 18 August 1999.

Table 2.1. Weekly minimum and maximum temperatures (^oC) for Bushy Park St. Catherine, Jamaica, during 13 February 1998 through 18 August 1999

Temperature (^oC)	High aphid flight activity		Low aphid flight activity	
	February to mid-May 1998	mid-September 1998 through mid-May 1999	mid-May 1998 to mid September 1998	mid May 1999 to August 1999
Minimum	range = 17.0 – 21.0 mean = 18.9	range = 14.5 – 21.5 mean = 18.3	range = 16.5 – 22.0 mean = 20.7	range = 19.5 – 21.0 mean = 20.1
Maximum	range = 30.5 – 33.0 mean = 32.2	range = 28.5 – 35.0 mean = 30.0	range = 31.5 – 35.0 mean = 32.9	range = 31.0 – 33.5 mean = 32.3

Table 2.2. Mean (± SE) number of aphids captured during periods of high and low flight activities on five pepper farms in St. Catherine, Jamaica, W.I. during 13 February 1998 through 18 August 1999

Farm	High flight activity mid-September to mid-May (number of aphids per trap per week)	Low flight activity mid-May to August/mid-September (number of aphids per trap per week)
1	1.98 ± 0.278 a	0.48 ± 0.052 b
2	1.57 ± 0.258 a	0.76 ± 0.251 a
3	10.45 ± 1.325 a	1.65 ± 0.367 b
4	12.20 ± 2.562 a	1.40 ± 0.405 b
5	3.35± 0.504 a	1.21± 0.113 b

Means within the same row followed by identical letters are not significantly different (Student's t-test, $p > 0.05$)

seasonal flights of aphids. For example, in the second week of March 1999 (week 56), the maximum temperature rose to 35 ^{o}C after remaining below 30 ^{o}C for over a month and the mean number of aphids per trap fell from 10 to $\leq$ 2 for three consecutive weeks although the maximum temperature fell below 30 ^{o}C again. Both warm and cool seasons had frequent rainfall.

When seasonal abundance of aphids during periods of high and low activity was compared among locations, activity was significantly higher ($F = 35.34$; df = 1, 38; $p < 0.0001$) from mid-September through mid-May on all farms, except Farm 2 (Table 2.2). Mean numbers of aphids captured per trap from mid-September through mid-May were 4, 2, 6, 9 and 3 times greater than the numbers captured from mid-May through August/mid-September on Farms 1-5, respectively (Table 2.2).

Seasonal variation of aphid species

Over 30 aphid species were collected from pan traps in St. Catherine, 12 of which were new records for Jamaica (Table 2.3). At least two incompletely identified aphids, one belonging to the genus *Mizini* and the other belonging to the tribe Fordini, are also new records for Jamaica. At least 15 different aphid species were collected from traps on Farms 1 and 5, and >20 species on Farms 3 and 4. The number of aphid species could not be ascertained for Farm 2. Species richness tended to be greatest when aphid flight activity was highest (Table 2.3).

From February to September 1998, 1,240 aphids were collected from the traps. Seventy-seven percent of these were collected from February through April, while only 1% was collected from June through August. *Myzus persicae* (Sulzer) accounted for 26% of all aphids caught, *Uroleucon ambrosiae* complex for 20% and *Tetraneura nigriabdominalis* (Boyer de Fonscolombe) for 3%. Most of the remaining 51% of aphids were *Aphis* spp., which were not separated quantitatively among species. Of the 2,546 aphids collected from October 1998 through August 1999, 87% of these were captured from October 1998 through April 1999, 6% during May 1999 and only 7% during June to August 1999.

Table 2.3. Seasonal diversity of aphid species collected on five pepper farms in St. Catherine, Jamaica, W.I. and total number of each aphid species collected on four of these farms from October 1998 through 9 December 1999. Shaded months indicate low aphid flight activity and correspond with the hottest time of the year.

Aphid	Feb/ Mar-98	Apr-98	May-98	Jun-98	Jul-98	Aug-98	Sep-98	Oct-98	Nov-98	Dec-98	Jan-99	Feb-99	Mar-99	Apr-99	May-99	Jun-99	Jul-99	Aug-99	Sep-99	Oct-99	Nov-99	Dec-99
Aphis amaranthi Holman*	•	•	•			•		3	0	3	25	18	28	84	26	20	2	0	0	1	1	2
Aphis coreopsidis (?) Thomas								1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Aphis craccivora Koch[◊]		•			•		•	4	3	18	7	19	12	3	6	1	1	1	1	2	2	3
Aphis gossypii Glover[◊]	•	•			•	•	•	428	130	122	52	47	44	87	32	40	12	6	28	16	4	3
Aphis nerii Boyer de Fonscolombe		•			•		•	1	4	8	3	13	17	7	0	3	2	0	2	1	0	0
Aphis spiraecola Patch[◊]		•			•		•	8	3	19	13	10	34	22	43	2	2	3	1	0	0	0
Aphis sp./unknown	•	•						2	0	0	2	1	1	2	6	2	0	0	0	2	0	0
Brachycaudus helichrysi (Kaltenbach)*		•						0	0	1	6	1	3	2	2	0	0	0	0	0	0	0
Capitophorus hippophaes (Walker) *							•	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0
Fordini (tribe) *								0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Geopemphigus floccosus (Linnaeus) *								0	0	1	1	1	1	1	1	0	0	0	0	0	0	0
Hysteroneura setariae (Thomas) *	•		•					2	1	0	1	1	1	0	2	0	0	0	0	0	0	0
Lipaphis erysimi Hille Ris Lambers*[◊]								0	0	3	13	10	11	2	1	0	0	0	0	0	0	0
Macrosiphum sp.		•		•	•			0	0	1	0	1	0	0	0	0	0	0	0	0	0	0
Melanaphis sacchari (Zehntner)								4	2	1	1	1	0	1	0	3	0	0	0	1	0	0

*New record for Jamaica; [◊]Known vector of TEV (Eckel and Lampert 1993)

Table 2.3 Cont'd

Aphid	Feb/ Mar-98	Apr-98	May-98	Jun-98	Jul-98	Aug-98	Sep-98	Oct-98	Nov-98	Dec-98	Jan-99	Feb-99	Mar-99	Apr-99	May-99	Jun-99	Jul-99	Aug-99	Sep-99	Oct-99	Nov-99	Dec-99
Mizini sp. ? *								0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Myzus persicae (Sulzer) ◊	·	·					·	0	0	0	1	2	2	1	1	0	0	0	0	0	0	0
Myzus sp.								0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Pentalonia nigronervosa Coquerel		·						0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Rhopalosiphum maidis *(Fitch)*		·				·		4	2	1	0	0	0	0	0	1	1	0	0	0	0	0
Rhopalosiphum padi (Linnaeus) *								0	0	0	0	0	0	1	0	0	0	0	1	0	0	0
Rhopalosiphum rufiabdominalis (Sasaki)								0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
Schizaphis graminum (Rondani) *							·	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
Schizaphis rotundiventris (Signoret)*	·		·					3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sipha flava *(Forbes)*	·	·	·	·	·		·	3	2	3	2	8	6	3	1	2	0	0	0	0	0	0
Tetraneura nigriabdominalis *(Sasaki)*								4	4	6	8	9	10	17	25	19	14	0	0	0	0	0
Toxoptera aurantiae (Boyer de Fonscolombe)								1	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Toxoptera citricida (Kirkaldy)								0	0	2	1	2	6	9	2	2	1	0	2	0	1	0
Trichosiphonaphis poligoni (van der Goot) *	·	·						0	0	1	0	0	0	0	0	0	0	0	0	4	0	0
Uroleucon ambrosiae (Thomas)* complex								0	0	68	517	11	16	94	16	20	5	4	0	1	1	0
Uroleucon pseudoambrosiae (Olive)*								0	0	0	0	1	0	0	0	0	0	0	0	0	0	0

* New records for Jamaica; ◊Known vector of TEV (Eckel and Lampert 1993)

Five known TEV vectors, *A. gossypii* (Laird and Dickson 1963), *A. craccivora* Koch (Herold 1970), *A. spiraecola* Patch (Laird and Dickson 1963), *Lipaphis erysimi* Hille Ris Lambers (Eckel and Lampert 1993) and *M. persicae* (Laird and Dickson 1963), accounted for 50% of all the aphids caught during October 1998 to August 1999. *A. gossypii* was the most abundant vector species accounting for 39% of all aphids collected. *U. ambrosiae* complex, *A. amaranthi* and *T. nigriabdominalis* comprised 42% while the remaining aphid species (>20) only represented 8% of the total aphid catch from October 1998 through August 1999. *U. ambrosiae* complex alone accounted for 30% of all aphids collected. The TEV vectors predominated during October 1998 while the three common aphids, not known to be vectors, accounted for most of the aphids trapped during January 1999 (Figure 2.4). Both groups of aphids made up the greater portion of aphids captured during April 1999.

Variations among farms

Increased aphid flights occurred at slightly different times on each farm. There was one main increase in aphid flight on Farm 1 during the week of 25 November to 2 December. The mean (± SE) catch per trap was 13 ± 1 aphids and *A. gossypii* was the most abundant aphid species then. Farm three had two major aphid flight periods during the week of 7-14 October when the mean number of aphids per trap was 37 ± 2, and during 22 December 1998 through 20 January 1999 when the mean number of aphids caught per trap each week ranged from 22 ± 5 to 94 ± 37. These two periods of increased flights were due, respectively, to *A. gossypii* and *U. ambrosiae* complex. Two smaller increases in aphid flights occurred during the first week of March 1998 (mean = 19 ± 4) and in the month of April 1999 (means = 17 ± 1 to 25 ± 8). Both increases resulted from high numbers of *U. ambrosiae* complex, *A. gossypii* and *A. amaranthi*. On Farm 4 the greatest aphid flight activity was during February to March 1998 (mean = 23 ± 2 to 55 ± 19) and the weeks of 7-21 October 1998 (means = 21 ± 10 and 41 ± 8). These increases were related to heavy flights by *M. persicae* and *A. gossypii*, respectively. In January 1999, we started monitoring aphid flights on Farm 5. The highest aphid flight activity on this farm was observed during 3-10 March 1999, when the mean number of aphids caught per trap was 12 ± 1 and *A. gossypii* and *A. nerii* accounted for most of the aphids captured.

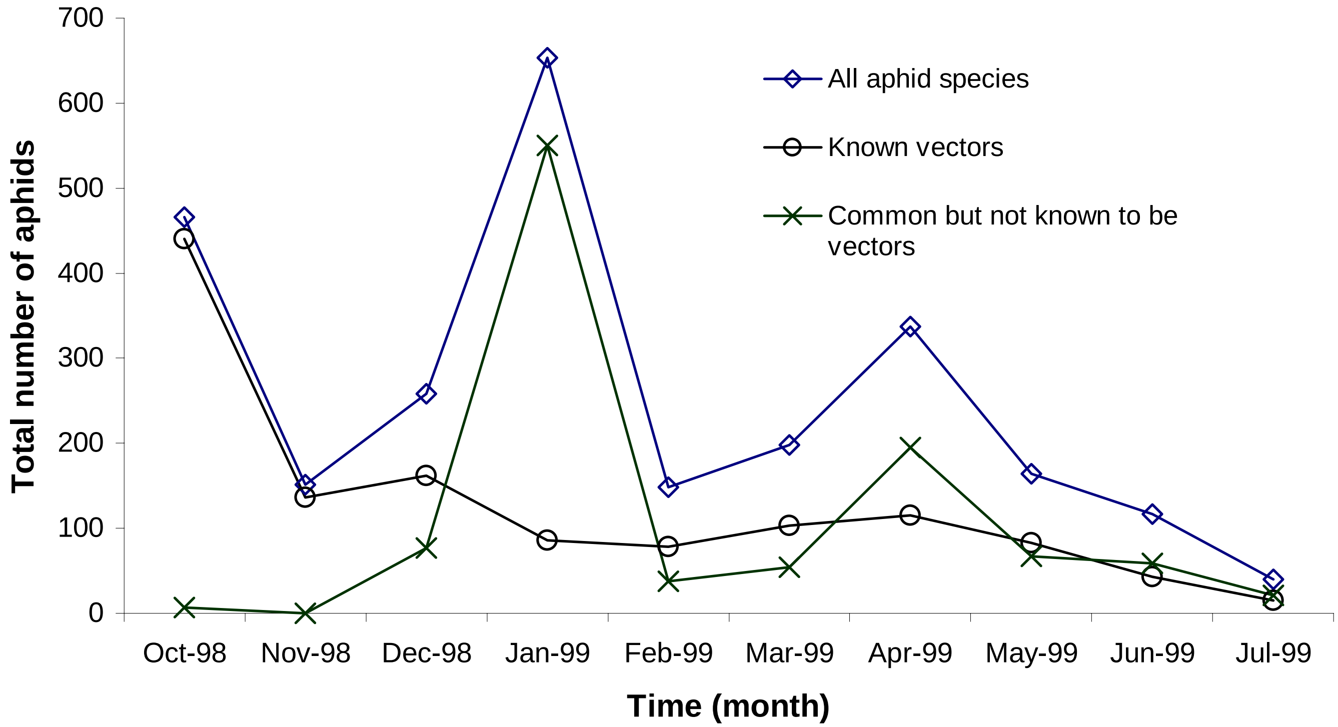

Figure 2.4. Total number of aphids, total number of known TEV vectors, and total number of common aphid species with unknown TEV vector status collected in pan traps each week on pepper farms in St. Catherine, Jamaica, W.I. during October 1998 through August 1999.

Discussion

Temperature appeared to have been an important factor affecting seasonal flights of aphids. The greatest number of aphids and variety of aphid species in St. Catherine, Jamaica were associated with the cool season (mid-September to mid-May) although differences in temperature between the cool and hot seasons are not as great as in temperate regions. In the tropics, aphids are known to be most active during the cooler periods of the year (Pandey *et al.* 1986, Kandoria *et al*. 1989, Rohilla *et al.* 1996). Pandey *et al.* (1986) reported that alate forms of *L. erysimi* are most abundant during late October to early November when they colonize *Brassica sp.* in Uttar Pradesh, India. These colonies attain maximum populations in early January after which the poulations decline (Pandey *et al.* 1986). In Haryana, India, *L. erysimi* populations grow best at average temperatures of about 14 ^{o}C and relative humidities of 65% and decline at temperatures above 35 ^{o}C and relative humidities of < 60% (Rohilla *et al.* 1996). Kandoria *et al*. (1989) reported that whereas *A. gossypii* may be found throughout the entire year in the Punjab, India, its populations were greatest during September to mid-May but declined thereafter when temperatures increased to $\geq$ 40 ^{o}C.

Aphids are known to be most active during dusk and dawn in tropical regions (Eastop 1977) and Schultz *et al*. (1985) reported that *R. maidis* showed greater activities during dusk and dawn in soybean fields in Illinois. Therefore, aphids might be most affected by minimum temperatures at crepuscular times of day when they are most active.

Photoperiod is another possible factor influencing the flight activity of aphids. Mid-September to mid-May is the period of year when there are short day-lengths and long night-lengths. The reverse is true for the period mid-May through mid-September. During mid-September to mid-May when the day-lengths are short, aphids would have longer periods of low temperatures suitable for flight activities from dusk to dawn. This could be effective in fostering greater flight activities although differences between maximum and minimum temperatures in the tropics are not as great as in temperate regions and photoperiod length differences might only be about an hour in the tropics.

Unlike in the temperate regions photoperiod has little or no direct effect in the development of morphs of aphids in the tropics (Rajagopal and Kareem 1983, Singh *et al.* 1990, Kuo 1999, Kuo *et al.* 1999). Photoperiod had little effect in the induction of alatae formation in a *M. persicae* clone from India (Rajagopal and Kareem 1983) and only indirect effect in a clone from Taiwan (Kuo *et al.* 1999). Kuo (1999) reported that photoperiod did not induce alatae formation in a clone of *L. erysimi* from Taiwan while Singh *et al* (1990) thought photoperiod might have some minor infuence on the formation of alatae of this species in India. Rajagopal and Kareem (1983), Singh *et al.* (1990), Kuo 1999 and Kuo *et al.* (1999) all found that the most important factors influencing alatae formation were temperature and overcrowding.

Known TEV vectors were most prevalent around October when many farmers transplant pepper so their crop will coincide with the winter export market. Farmers might need to consider rescheduling their planting date or implement strict management practices to delay and/or reduce TEV infections as the young pepper plants are at high risk during this time. Less mature plants are more severely affected by infections of the same virus than more mature plants (Agrios and Walker 1985, Avilla *et al*. 1997).

Ten of the 12 new aphid species are not new to the Caribbean. *A. amaranthi* was reported in Cuba from as early as 1968 (Smith and Cermali 1979). *C. hippophaes* and *U. pseudoambrosiae* are also found in Cuba. *B. helichrysi*, *G. floccosus, H. setariae, L. erysimi, R. padi, S graminum* and *U. ambrosiae* are found in Cuba and Puerto Rico (Smith and Cermali 1979). *Schizaphis rotundiventris* (Signoret) and *Trichosiphonaphis poligoni* (van der Goot) appear to be new records for the Caribbean.

Variations in the number of aphids collected from the farms appeared to be influenced by differences in farm management practices, as well as by the diversity of crops grown on the farms. Several crops were grown concurrently on Farms 3 and 4 while the other farms had fewer crops in larger plots. A large number of *M. persicae* was collected during February and March

1998 when it was also observed colonizing *Brassica oleracea* L. growing adjacent to pepper on Farm 4. *U. ambrosiae* was observed on the weed, *Parthenium hysterophorus* L. (Asteraceae), which was common on all farms. *A. gossypii* was often observed colonizing pepper and is known (Smith *et al*. 1963) to colonize a wide range of host plants found on and near pepper fields. *A. amaranthi* colonizes *Amaranthus* spp. (Smith and Cremeli 1979) and *T. nigriabdominalis* colonizes the roots of grasses (Smith *et al*. 1963) which form part of the weed community on all farms year round. Amaranths are grown commercially on Farms 3 and 4 and were common weeds on all farms throughout the year.

All farms had heavy weed pressures during some period of the study. Farms 3 and 4 had the heaviest weed pressure, lasting throughout most of the investigation. The other farms tended to become weedy during rainy periods. Weed species (Fournet and Hammerton 1991) common to all farms included, *Amaranthus* spp. (Amaranthaceae), *P. hysterophorus*, *Cleome viscosa* L. (Capardiaceae), *Commelina elegans* (HBK) (Commelinaceae), *Chamaesyce* spp. and *Phyllantus amarus* (Euphorbiaceae), *Cyperus rotundus* L. (Cyperaceae), *Cenchrus echinatus* L. and *Sorghum halepense* (L.) Pers. (Poaceae).

U. ambrosiae is not known to be a vector of TEV but it was more abundant during December through April than during other times of the year. Farmers in St. Catherine, Jamaica, grow pepper throughout the year, so if this aphid is a vector of TEV it could prove to be a serious threat to pepper. *A. gossypii, A. amaranthi* and *T. nigriabdominalis* are present throughout the year, even when aphid flights are low. If *A. amaranthi* and *T. nigriabdominalis* are TEV vectors, then they too will pose constant threats to pepper.

References

Anderson, C. W. 1959. A study of field sources and spread of five viruses of peppers in central Florida. Phytopathology 49:97-101.

Agrios, G.N., and M.E. Walker. 1985. Effect of cucumber mosaic virus inoculation at successive weekly intervals on growth and yield of pepper (*Capsicum annuum*) plants. Plant Dis. 69:52-55.

Avilla, C., J.L. Collar, M. Duque, and A. Fereres. 1997. Yield of bell pepper (*Capsicum annuum*) inoculated with CMV and/or PVY at different time intervals. J. Plant Dis. Protect. 104:1-8.

Bos, L. 1981. Wild plants in the ecology of virus diseases. Pp 1-33 In: K. M Maramorosch and K. F. Harris. (Eds.) Plant Diseases and Vectors: ecology and epidemiology. New York, Academic press.

Difonzo, C. D., D.W. Ragsdale, E.B. Radcliffe, N.C. Gumestad, and G.A. Secor. 1997. Seasonal abundance of aphid vectors of potato virus Y in the Red River Valley of Minnesota and North Dakota. J. Econ. Entomol. 90: 824-831.

Eastop, V.F. 1977. Worldwide importance of aphids as virus vectors. pp. 4-61. In: K.F. Harris and K. Maramorosch. (Eds.) Aphids as Virus Vectors. Academic Press Inc.

Eckel, R.V.W., and E.P. Lampert. 1993. Spatial and temporal analysis of tobacco etch virus distribution and its relationship to aphid (Homoptera: Aphididae) vectors in flue-cured tobacco J. Econ. Entomol. 86:1534-1545.

Eckel, R.V.W., and E.P. Lampert. 1996. Relative attractiveness of tobacco etch virus-infected flue-cured tobacco to aphids (Homoptera: Aphididae). J. Econ. Entomol. 89:1017-1027.

Fournet, J., and J.L. Hammerton. 1991. Weeds of the Lesser Antilles. Institut National de la Recherche Agronomique, Paris. 214 p.

Frank, J.H., and F.D. Bennet. 1970. List of sugar cane arthropods of Jamaica. Sugar Research Department, Mandeville, Jamaica, W.I. Technical Bulletin 1/70.

Halbert, S.E., M.I. Irwin, and R.M. Goodman. 1981. Alate aphid (Homoptera: Aphididae) species and their relative importance as field vectors of soybean mosaic virus. Ann. Appl. Biol. 97:1-9.

Herold, F. 1970. Tobacco etch virus in Venezuela. Plant Dis. Rep. 54:344.

Irwin, M.E. 1980. Sampling aphids in soybean fields. Pp. 13-33. In: M. Kogan and D.C. Herzog. (Eds.) Sampling Methods in Soybean Entomology. Springer, Berlin Heidelberg New York.

Jayasingh, D. 1996. Catalogue of insect pests of crops in Jamaica. Prepared for the Ministry of Agriculture, Kingston, Jamaica. 46p.

Kandoria, J.L., R. Jamwal, and S. Gurdip. 1989. Seasonal activity and host range of *Aphis gossypii* Glover in the Punjab. J. Insect Sci. 2:68-70.

Kono, T., and C.S. Papp. 1977. Handbook of Agricultural Pests: aphids, thrips, mites, snails, and slugs. State of California Department of Food and Agriculture, Division of Plant Industry Laboratory Services - Entomology, California.

Kuo, M.H. 1999. Effects of temperature, photoperiod, and crowding treatment on alate formation in the turnip aphid, *Lipaphis erysimi* (Kalt.). Plant protec. Bull. Tapei. 1999. 41:255-264.

Kuo, M.H., Y.C. Liu, and Y.Y. Ma. 1999. Effects of temperature, photoperiod, and crowding treatment on alate formation in the green peach aphid, *Myzus persicae* (Sulzer). Chinese J. Entomol. 1999. 19:1-18.

Laird, E.F. Jr., and R.C. Dickson. 1963. Tobacco etch virus and potato virus Y in pepper, their host plants and insect vectors in Southern California. Phytopathology 53:48-52.

Martin, R., L. Myers, S. McDonald, and F.W. Ravlin. 1998. Seasonal incidence of hot pepper pests in major hot pepper (*Capsicum* spp.) producing areas in Jamaica. Proceedings of the Third IPM CRSP Symposium. 15-18 May 1998, Blacksburg Virginia, USA. pp. 111-118.

McGlashan, D.H., J.E. Polston, and D.N. Maynard. 1993. A survey of viruses affecting Jamaican 'Scotch Bonnet' pepper *Capsicum chinense* (Jacq.). Proc. International Soc. Trop. Agric. 37:25-30.

Murray, R.C. 1985. Some common pests of agricultural crops, including ornamentals, in Jamaica. Plant Protection Division, Ministry of Agriculture, Jamaica. 15 p.

Myers, L.R.S. 1996. The etiology of viruses affecting pepper (*Capsicum* spp.) in Jamaica. Masters Thesis, University of the West Indies, 142 p.

Myers, L., R. Martin, and S. McDonald. 1998. The effect of tobacco etch virus on the growth and yield of two pepper *Capsicum chinense* varieties. In: Proceedings of the joint JSAS/ 34th Annual conference of the CFCS, Montego Bay, Jamaica, July 12 - 18, 1998.

Nafría, J.M.N., M.A. Delfino, and M.P.M. Durante. 1994. La afidofauna de la Argentina su conocimiento en 1992. Universidad de León. 235 p.

Pandey, K.P., A. Kumar, and C.P.M. Tripathi. 1986. Population ecology of *Lipaphis erysimi* Kalt. on *Brassica capmestris*. Bull. Instit. Zool., Academia Sinica 25:125-128.

Rajagopal, S., and A.A. Kareem. 1983. Studies on certain factors affecting alatae production in green peach aphid, *Aphis persicae* Sulzer. Pranikee. 4:17-22.

Rohilla, H.R., Havir Singh, T.P. Yadava, and H. Singh. 1996. Seasonal abundance of aphid pests on rapeseed-mustard crops in Haryana. Ann. Agri. Bio. Res. 1:75-78.

SAS Institute (1996). SAS/STAT User's Guide, Release 6.12 ed. SAS Institute, Cary, NC.

Shaunak, K.K., and H.N. Pitre. 1971. Seasonal alate collections in yellow pan traps in Northeastern Mississippi: possible relationship to maize dwarf mosaic virus. J. Econ. Entomol. 64:1105-1109.

Shultz, G.A., M.E. Irwin, and R.M. Goodman. 1985. Relationship of aphid (Homoptera: Aphididae) landing rates to the field spread of soybean mosaic virus. J. Econ. Entomol. 78:143-147.

Singh, H., Z. Singh, and T.P. Yadava. Influence of abiotic factors on alate production in mustard aphid, *Lipaphis erysimi* (Kaltenbach). J. Aphidol. 4:71-74.

Smith, C.F., L.F. Martorell, and M.E. Pérez Escolar. Aphidae of Puerto Rico. University of Puerto Rico Agricultural Experiment Station. Technical Paper 37, September 1963. 121p.

Smith, C.F., and M.M. Cermeli. 1979. An annotated list of Aphididae (Homoptera) of the Caribbean Islands and South and Central America. North Carolina Agricultural Research Service. Technical Bulletin No. 259. 131 p.