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Godfrey H. Kagezi
University of Illinois

David J. Voegtlin
Illinois Natural History Survey

Richard A. Weinzierl
University of Illinois

THE APHIDS (HOMOPTERA: APHIDIDAE) ASSOCIATED WITH BELL PEPPERS AND SURROUNDING VEGETATION IN SOUTHERN ILLINOIS

Godfrey H. Kagezi[1,2], David J. Voegtlin[3], and Richard A. Weinzierl[4]

ABSTRACT

Outbreaks of cucumber mosaic virus (CMV) disease, caused by an aphid-transmitted pathogen, greatly reduced yields of bell pepper in southern Illinois in the mid–1990s. To provide the basis for further studies of the roles of individual aphid species in virus transmission, we surveyed aphid flights in and around pepper fields in 1996 and 1997 by using suction traps, interception nets, landing traps, sweep nets, and hand-picking. We collected 78 species of aphids, 15 of which have been reported to transmit CMV to peppers. The most abundant species taken from suction traps and interception nets in combination were *Lipaphis erysimi*, *Rhopalosiphum padi*, *Rhopalosiphum maidis*, *Schizaphis graminum*, and *Aphis craccivora*. All of these species are known to transmit CMV to peppers, but the phenology of *R. maidis* in Illinois suggests it is not the vector that brings CMV to pepper fields to initiate disease outbreaks. *Brachycaudus helichrysi* was relatively abundant in 1996 in May and June when a CMV outbreak may have been initiated; it was absent in 1997, and CMV infections were rare that season. Two species, *Carolinaia carolinensis* and *Myzus hemerocallis* were recorded for the first time in Illinois.

In the mid 1990's, outbreaks of cucumber mosaic virus (CMV) increased in prevalence and severity in commercial fields of bell peppers in southern Illinois, causing near total crop losses in some fields in 1995 and 1996 (Kagezi 1998). CMV is transmitted in a nonpersistent manner by over 60 species of aphids, 23 of which are known to act as vectors in peppers (Kennedy et al. 1962, Raccah et al. 1985, Katis 1989, Basky and Raccah 1990). It infects over 800 species of plants in 85 plant families (Palukaitis et al. 1992). Although outbreaks of CMV in southern Illinois appear to result from field transmission of the virus by aphids (not from infected seed or the use of infected transplants), the identities of the aphid vectors and the alternate hosts of the strain of CMV involved in pepper infections in this region are unknown. Viruses that are transmitted in a nonpersistent manner may be moved short distances by the local movements and feeding probes of resi-

[1]Department of Natural Resources and Environmental Sciences, University of Illinois.

[2]Current address: International Institute of Tropical Agriculture, P.O. Box 7878 Kampala, Uganda.

[3]Center for Biodiversity, Illinois Natural History Survey, 607 East Peabody Drive, Champaign, IL 61820.

[4]Department of Crop Sciences, University of Illinois, 1102 South Goodwin Avenue, Urbana, IL 61801.

dent aphid species (Irwin and Ruesink 1986) or transported over long distances by migrating aphids (Zeyen and Berger 1990). As a result, local or distant flora may serve as sources of CMV.

In monitoring aphid flights in and around crop fields, researchers have used suction traps to capture aphids flying just above the crop canopy (Taylor and Palmer 1972, Plumb 1976, Raccah 1983, Raccah et al. 1985), colored pan or landing traps to detect species landing in the crop (Irwin 1980, Raccah 1983, Halbert and Pike 1985, Raccah et al. 1985, Schultz et al. 1985, Gray and Lambert 1986, Halbert et al. 1986, Boiteau 1990), vertical interception nets (Irwin 1980, Halbert et al. 1981, 1986), and more direct collecting techniques such as hand-picking and sweep-netting (Blackman and Eastop 1984). To determine the species composition and seasonality of the aphids associated with peppers in southern Illinois and thereby provide the basis for further examination of their roles as virus vectors, we used multiple collection methods to sample the aphid fauna in and around pepper fields in Johnson and Union counties in 1996 and 1997. The results of our aphid survey efforts are reported herein. Studies of disease epidemiology and the vector roles of certain species are yet to be completed and will be published separately.

MATERIALS AND METHODS

To characterize aphid flights into and around pepper fields, aphids were collected by use of suction traps and interception nets in and adjacent to pepper fields near Belnap in Johnson County, Illinois, in 1996 and 1997. In 1997, landing traps, sweep nets, and hand-picking were also used at the field site near Belnap. In addition, interception nets, landing traps, sweep nets, and hand-picking were used in 1997 to make collections at an additional pepper field near Anna in Union County, Illinois. All field sites were located in the area where CMV outbreaks had been severe. This region of Illinois is known as the Coastal Plain Division and is characterized by major bottomland areas along the Cache, Ohio and Mississippi Rivers and areas of low hills capped by Cretaceous and Tertiary sand, gravel and clay. The bottomlands are the northernmost extension of the Gulf Coastal Plain Province of North America, and bald cypress-tupelo gum swamps and associated plant species grow in these areas. Much of the bottomland farm ground is seasonally flooded and remains uncultivated for extended periods in the spring. These uncultivated fields become covered with a variety of weed species that are hosts to many of the known vectors of CMV. Early spring composits, crucifers, cool season grasses and sedges are abundant in these fields. Conventional cropping of soybeans and corn in this region has not been economical, and tracts of land can be found in a variety of successional stages, returning to the oak-hickory-gum dominated riparian forest. The mix of weedy fields, old field successions, and extant riparian forest provides a great diversity of hosts for aphids. This area also is characterized by a relatively mild climate that often is suitable for vector species capable of surviving milder winters as colonies on host plants.

Two suction traps (Fig. 1) were used, one in the middle of a 30-ha bell pepper field and the second 5–10 meters outside the west edge of the same field. These traps, operated on 12-volt batteries, used fans rated at 9.3 m^3 (100 ft^3) per minute. The intake for the traps was 1–1.25 m above the ground and about 0.5 m above the crop canopy at maturity. Aphids were collected in jars containing a 1:1 polyethylene glycol: water mixture and were later isolated from other insects under a dissecting microscope, mounted on slides,

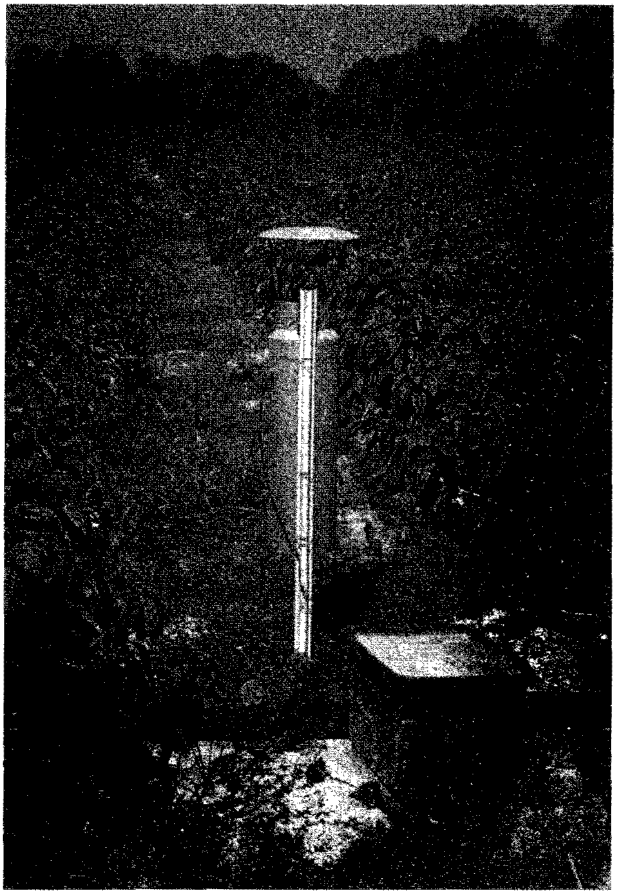


Figure 1. Battery-powered suction trap used to monitor aphid flights in and adjacent to bell pepper fields in southern Illinois, 1996–1997.

and identified. Suction traps were operated continuously during daylight hours from 13 May to 2 September 1996 and from 15 May to 10 October 1997. Collection jars were exchanged two to three times weekly.

Two stationary vertical interception nets similar to those described by Halbert et al. (1981) and consisting of 24 × 20-mesh netting, 1.07 m high and up to 10 m long (BioQuip, Gardena, CA), were suspended between steel posts in the interior of and along the upwind edge of pepper fields. Nets were suspended perpendicularly to the wind at the time of collections; they were repositioned and re-oriented when wind direction changed. The bottom of the nets rested on the soil surface. Collections from nets usually spanned two days during each sampling period. During the two days, a morning (0600 to 1000 h), a mid-day (1000 to 1500 h), and a late-day (1500 to 2000 h) collection were made. Alate aphids landing on interception nets were collected using fine brushes and immediately caged individually on virus-free pepper seedlings to assess their roles in virus transmission, then removed after 3 to 12 h and preserved in 70% ethanol for identification. Interception nets were operated during four periods in May and June and one period each in July, August and September of 1996, and weekly from May to August in 1997.

In 1997, aphids were sampled by means of landing traps to determine which species might be settling in pepper fields. Traps were made of plastic sandwich boxes (approximately 12 × 12 cm), each with a green ceramic tile (Irwin 1980) covering the bottom. They were filled with water and mounted at canopy level and used on the same sampling dates as interception nets (in 1997 only). Four to 10 traps were used per field, and aphids were collected from the traps using a fine brush each evening of operation. In addition, aphids were collected directly from herbaceous and woody plants in the borders and woods surrounding pepper fields during the 1997 season. Aphids were taken from plants using a fine brush or by sweeping the vegetation with a net, used in inoculation experiments on virus-free pepper seedlings, and then preserved for identification (as described above for aphids collected from interception nets).

Trapped aphids were sorted into morphospecies categories by the senior author, who also made slide mounts of representative morphs to verify the homogeneity of each category. All mounted aphids were identified by David Voegtlin. Voucher specimens were deposited in the collection of the Illinois Natural History Survey, Champaign, Illinois.

For analysis, counts from suction traps were pooled for each sampling period. To illustrate the seasonal occurrence of key species, aphid counts for each sampling period were graphed (Figs. 2–7), and bars representing relative densities were placed at the median date for each sampling period. Where aphids were collected from interception nets for 2 or 3 days in succession, total counts for the period were graphed at the first or median date, respectively.

RESULTS AND DISCUSSION

More than 2,400 individual aphids representing more than 78 species were collected from interception nets and suction traps during the two years of study (Table 1). Four additional species were collected only from surrounding vegetation. Of the aphid species we collected, 15 have been reported to transmit CMV to peppers under field conditions (Raccah et al. 1985, Basky and Raccah 1990).

Aphid flights into pepper fields (as measured by interception nets and suction traps) were much lighter in 1997 than in 1996. In order of abundance, *Lipaphis erysimi* (Kaltenbach), *Rhopalosiphum padi* (L.), *Rhopalosiphum maidis* (Fitch), *Schizaphis graminum* (Rondani), and *Aphis craccivora* (Koch) (all reported as vectors of CMV) were collected in greatest numbers from the suction traps and interception nets in combination. A total of 1,675 individuals of these species were taken by these two methods; this total represented approximately 68 percent of all the specimens taken by the suction traps and interception nets. Seasonal patterns of occurrence of these species plus *Brachycaudus helichrysi* (Kaltenbach) are illustrated in Figures 2–7.

To date, inoculation trials using field-collected aphids have not identified the aphid species most important in transmitting CMV to peppers in southern Illinois. In the absence of such findings, the flight phenology of common and suspect species may provide clues for further investigations. The seasonal capture data we obtained for five of six such species (Figs. 2–5 and Fig.

7) indicate patterns of occurrence that include abundance in May and June. This timing would allow them to have been important vectors of CMV, given the timing of disease outbreaks in early July of 1996 and previous years.

Most abundant species. *Lipaphis erysimi*, which reached peak numbers in late May (Fig. 1), can overwinter as eggs on *Brassica* spp., although Hottes and Frison (1931) note that all their collections contained only viviparous adults. Most collections of this species in Illinois have been made on cultivated species of *Brassica*, however, its host range includes many native species of Brassicaceae that might serve as overwintering hosts.

Rhopalosiphum padi (Fig. 3) is a species that can survive milder winters on winter wheat. Studies of this species (Voegtlin and Halbert 1998) show that clones collected in Illinois are incapable of producing sexuales. The presence of winged individuals in early spring is thus either the product of surviving overwintering colonies or the result of immigration. The extensive host range of *R. padi* is comprised primarily of grasses. This aphid is a common component of trap catches over agricultural fields in Illinois in the spring, and our peak captures of this species in late September (Fig. 3) are also typical in Illinois, as emerging winter wheat is infested with winged adults. The source of these winged adults is not known but is likely to the north where cereals and other grasses are still growing.

Schizaphis graminum (Fig. 4) can also be found on winter wheat well into the winter, and in mild winters colonies survive on this crop. We observed an early spring peak and movement into pepper fields well into the summer. This species is known to lay eggs on *Poa praetensis* and may, as *R. padi* does, move north as each growing season progresses. More commonly known as the greenbug, *S. graminum* is comprised of many biotypes and is one of the major pests of sorghum in the southern and central United States. Its host range is large and comprised mainly of grasses.

Aphis craccivora is somewhat of a mystery in Illinois. Hottes and Frison (1931) did not collect this species, and it has been uncommon in extensive trapping efforts in corn and soybean fields in northern and central Illinois. It was relatively abundant, however, in both suction trap and interception net catches in this study (Fig. 5). It is polyphagous, with a marked preference for plants in the family Fabaceae. Blackman and Eastop (1984) state that this species is primarily anholocyclic throughout its range and that sexuales are uncommon. In this manner it is similar to *R. padi* and *S. graminum* in either overwintering as colonies or immigrating each season.

It seems unlikely that *Rhopalosiphum maidis* plays an important role in introducing CMV to pepper fields, because it is virtually absent during May and June (Fig. 6) when initial virus transmission appears to have occurred in 1996 (and in previous years). Instead it became common only in July and August. Hence, it is possible that *R. maidis* may contribute to within field transmission that occurs throughout the summer. The delay in the appearance of *R. maidis* is due to its inability to reproduce sexually in North America and its failure to overwinter successfully on cereals, even in mild winters. To reach Illinois, it must migrate from milder southern regions each year. The timing illustrated in Fig. 6 is very typical of the phenology of *R. maidis* in other areas of Illinois as well.

Brachycaudus helichrysi, another species not found by Hottes and Frison (1931), is also a known vector of CMV. Primary hosts are *Prunus* spp. and secondary hosts are most often in the Asteraceae (e.g. *Achillea, Chrysanthemum, Matricaria, Senecio, Erigeron*, and *Ageratum*) and Boraginaceae. Only two specimens were collected in 1997, though it was abundant in May 1996 (Fig. 7). Because many more *B. helichrysi* were captured on interception nets in 1996 (when CMV became prevalent) than in 1997, its role as a possible

Table 1. Aphid species collected in or adjacent to pepper fields in southern Illinois using suction traps (S), interception nets (I), sweep nets (N), landing traps (L), or hand-picked by brush (H) from plants, 1996 and 1997.

Aphid species	Collected by	Total from *suction traps* 1996	Total from *suction traps* 1997	Total from *interception nets* 1996	Total from *interception nets* 1997
Acyrthosiphon lactucae (Passerini)	S,I	2	2	5	1
Acyrthosiphon kondoi (Shinji)	S		1		
Acyrthosiphon pisum (Harris)	S, I, N	6	6	33	25
Acyrthosiphon sp.	I			45	
Anoecia corni (Fabricius)	H				
Anoecia cornicola (Walsh)	S, I		1	10	3
Anoecia oenotherae (Wilson)	I				3
Aphis coreopsidis (Thomas)	S, I		1	7	
**Aphis craccivora* (Koch)	S, I	3	25	43	4
**Aphis fabae* subsp. *solanella* Theobald	S, I, H	1		9	10
Aphis folsomii (Davis)	S	1	2		
**Aphis gossypii* (Glover)	S, I	2	7	16	
Aphis helianthi (Monell)	I			10	
Aphis illinoisensis (Shimer)	S		1		
Aphis maidiradicis (Forbes)	I, N				14
**Aphis nasturtii* (Kaltenbach)	I, H				2
**Aphis nerii* (Boyer de Fonscolombe)	S, I, N, L	5	2		1
Aphis pomi (DeGeer)	I				1
Aphis rubifolii (Thomas)	I				3
Aphis spiraecola (Patch)	S, I		2		7
Aphis thaspii (Oestlund)	S		1		
Aulacorthum solani (Kaltenbach)	I				1
**Brachycaudus helichrysi* (Kaltenbach)	I			36	2
Capitophorus hippophaes (Walker)	S, I		1	3	3
Carolinaia carolinensis (Smith)	I			13	
Chaitophorus minutus (Tissot)	S		1		
Chaitophorus niger (Oestlund)	I				2
Chaitophorus populicola (Thomas)	S, I	3	2	4	2
Chaitophorus pusillus (Hottes & Frison)	I				2
Chaitophorus viminicola (Hille R. Lambers)	S, I		1	1	
Drepanaphis acerifolii (Thomas)	S	3	1		
Dysaphis sp.	I			1	
Eriosoma sp.	S, I	5		11	
Geoica squamosa (Hart)	I				2
Glabromyzus rhois (Monell)	I, L				4
**Hayhurstia atriplicis* (Linnaeus)	I			2	
Hyadaphis foeniculi (Passerini)	S		1		
Hyalopterus pruni (Geoffrey)	S, I	45	10	7	
Hysteroneura setariae (Thomas)	I			2	
Iziphya flabella complex (Sanborn)	S		2		
Iziphya sp.	S, I	3		14	
**Lipaphis erysimi* (Kaltenbach)	S, I, N	30	38	372	95
Macrosiphoniella topuskae (Hottes & Frison)	I				1
**Macrosiphum euphorbiae* (Thomas)	S, I	5	2	9	*12*
Microparsus singularis (Hottes & Frison)	S, I		1		*5*
Myzocallis discolor (Monell)	I			1	

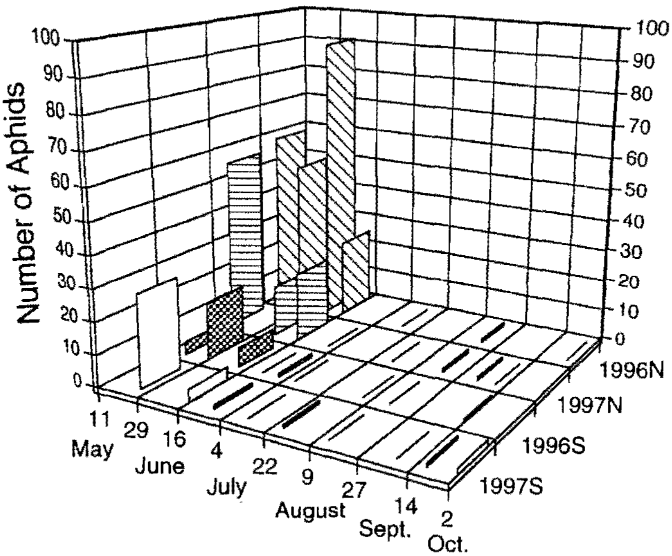
Table 1. (Continued)

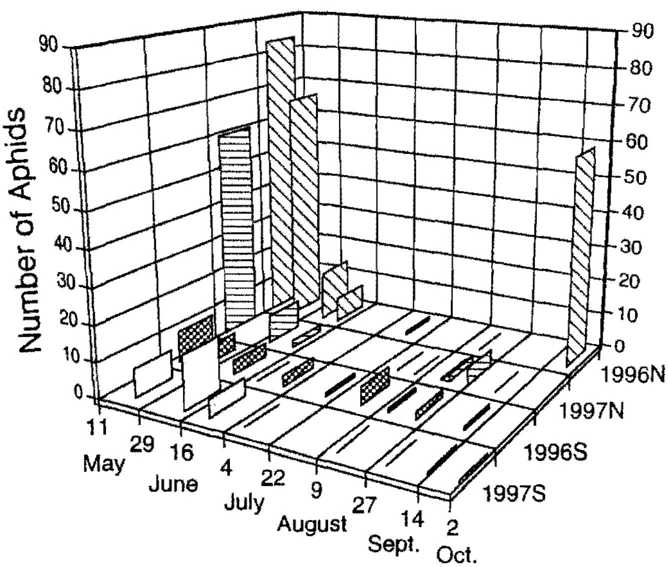
Aphid species	Collected by	Total from *suction traps* 1996	Total from *suction traps* 1997	Total from *interception nets* 1996	Total from *interception nets* 1997
Myzus certus (Walker)	I			2	
Myzus hemerocallis (Takahashi)	I				2
**Myzus persicae* (Sulzer)	S, I	3	1	5	2
Nearctaphis bakeri (Cowen)	I, N			6	3
Nearctaphis crataegifoliae (Fitch)	I			1	
Pemphigus populitransversus (Riley)	S, I	2	7	13	2
Pemphigus sp.	I, H			14	
Pleotrichophorus sp.	I			9	
Prociphilus erigeronensis (Thomas)	I				5
Prociphilus fraxinifolii (Riley)	S		6		
Rhodobium porosum (Sanderson)	I			18	
Rhopalomyzus poae (Gillette)	I, L				3
Rhopalosiphoninus latysiphon (Davidson)	S		1		
Rhopalosiphoninus staphyleae (Koch)	I				2
Rhopalosiphum insertum (Walker)	S		1		
**Rhopalosiphum maidis* (Fitch)	S, I, N, L	233	49	88	77
**Rhopalosiphum padi* (Linnaeus)	S, I, N	33	30	377	80
Rhopalosiphum rufiabdominalis (Sasaki)	S, I	2	1	34	3
**Schizaphis graminum* (Rondani)	S, I	17	12	57	12
Schizaphis sp.	I				12
Sipha flava(Forbes)	I			2	1
**Sitobion avenae* (Fabricus)	S, I, N	3	2	11	4
Tetraneura akinire (Sasiki)	I			13	13
Tetraneura nigriabdominalis (Sasiki)	S, I	3	3	8	
**Therioaphis trifolii* (Monell)	S, I	1	4	37	3
Tinocallis caryaefolie (Davis)	I			1	
Uroleucon ambrosiae (Thomas)	H				
Uroleucon (Lambersius) sp.	I			10	
Uroleucon (Lambersius) gravicorne	I			1	1
Uroleucon (Uromelan) sp.	I			2	
Uroleucon chrysanthemi (Oestlund)	I				4
Uroleucon eupatoricolens (Patch)	N				
Uroleucon nigrotuberculatum (Olive)	I			3	2
Uroleucon reynoldense (Olive)	I			8	

*Potential vectors of CMV in peppers, as reported by Raccah et al. (1985) and Basky and Raccah (1990).

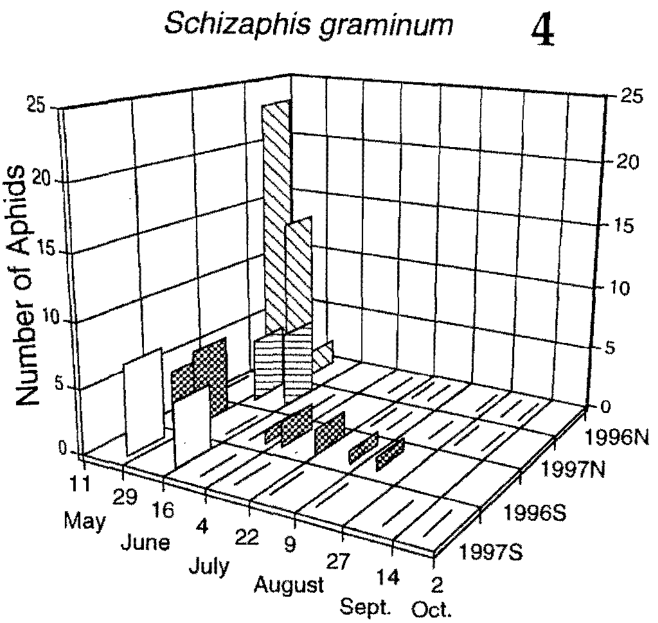
vector of CMV may be especially worthy of further investigation. This species was not captured in suction traps, even in May 1996 when it was abundant on interception nets. This is particularly surprising because the height of the suction trap intake was approximately equal to the height of the top of the interception nets. There are no obvious reasons for the difference in captures between these trapping methods.

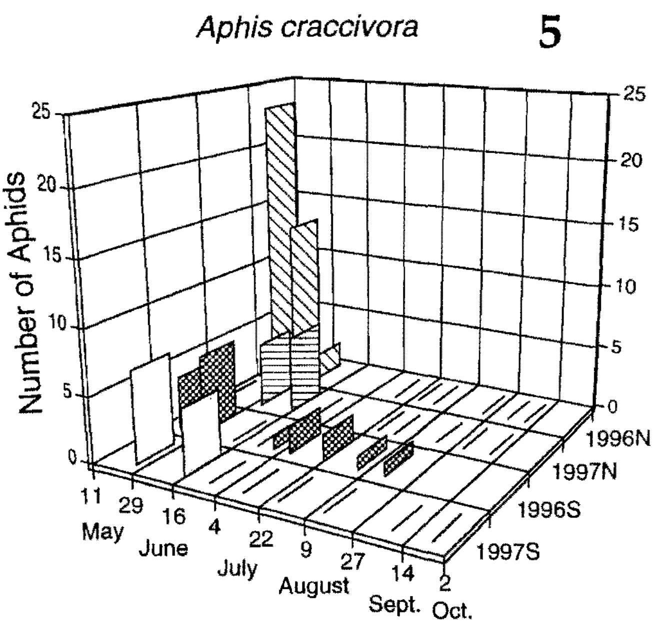
Other potential vectors collected in lesser numbers. *Aphis fabae* subsp. *solanella* Theobald was collected from nightshade, *Solanum nigrum*, and curly dock, *Rumex crispus*, in weedy areas adjacent to pepper fields. *Aphis fabae* is a known vector of CMV, but it is not known if this subspecies





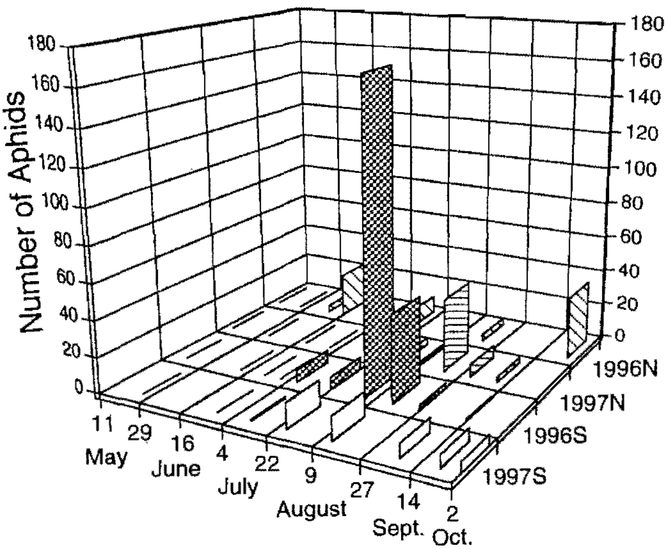
Figures 2 and 3. Seasonal abundance of *Lipaphis erysimi* (Kaltenbach) and *Rhopalosiphum padi* (L.) in suction trap (S) samples and interception net collections (N) in southern Illinois, 1996–1997. See text for details on sample collections and calculations of totals.



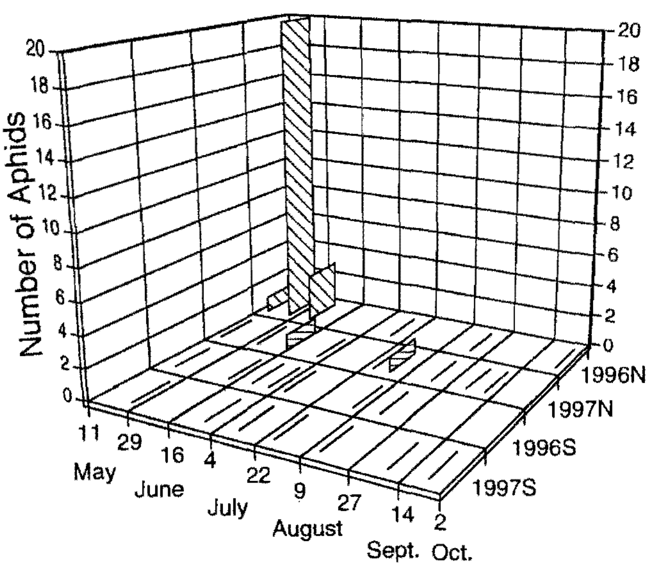


Figures 4 and 5. Seasonal abundance of *Schizaphis graminum* (Rondani) and *Aphis craccivora* (Koch) in suction trap (S) samples and interception net collections (N) in southern Illinois, 1996–1997. See text for details on sample collections and calculations of totals.

Rhopalosiphum maidis **6**



Brachycaudus helichrysi **7**



Figures 6 and 7. Seasonal abundance of *Rhopalosiphus maidis* (Fitch) and *Brachycaudus helichrysi* (Kaltenbach) in suction trap (S) samples and interception net collections (N) in southern Illinois, 1996–1997. See text for details on sample collections and calculations of totals.

has been tested and implicated in the transmission of CMV. In Illinois, *Aphis fabae* (Scopoli) uses *Euonymus* and *Viburnum* as primary hosts and migrates to a wide range of secondary hosts in the spring.

Aphis nasturtii (Kaltenbach) was collected from horseweed, *Erigeron canadensis*. This is a third species not recorded by Hottes and Frison and also not recorded in earlier epidemiological studies in soybeans and corn in central and northern Illinois. Stroyan (1984) suggests that this is probably a species complex and that American populations have a broader host range than the European species. Patch (1938) lists a broad host range for *A. nasturtii* (as *Aphis abbreviata* Patch), including plants from 28 different families. Most common among these are genera in the Asteraceae.

Aphis nerii (Boyer de Fonscolombe), commonly known as the milkweed-Oleander aphid, is found mainly on plants in the families Asclepiadaceae and Apocyanaceae. It also occasionally colonizes plants in other families, including Euphorbiaceae, Asteraceae, and Convolvulaceae (Blackman and Eastop 1984). It is unlikely that *Aphis nerii* overwinters in southern Illinois because none of its preferred hosts are available. It is rarely found in Illinois before mid-summer and does not form sexuales. In the fall, colonies of viviparous females continue to feed on hosts until they are killed by frost.

Acyrthosiphon pisum (Harris) and *Therioaphis trifolii* (Monell) feed on a wide range of plants in the family Fabaceae. The most likely host plants for both species in southern Illinois are alfalfa and sweet clover.

Only three vector species, *Aphis gossypii* (Glover), *Myzus persicae* (Sulzer), and *Macrosiphum euphorbiae* (Thomas), are known to colonize pepper plants (Blackman and Eastop 1984). None of these was seen colonizing peppers or collected in any abundance in traps, and their biology in the area is not known. It is possible that they can survive holocyclicly, but most specimens of these three species were collected in mid to late summer, suggesting that they are not the product of populations that overwinter either as colonies or eggs.

Sitobion avenae (Fabr.) is another species that can survive milder winters in colonies on winter wheat in Illinois. It has a wide host range of grasses and several other monocotyledons (Blackman and Eastop 1984). Most of our specimens were collected in early spring.

Other species and notes. The other species collected in this survey (as recorded in Table 1) consist of a mix of native and exotic aphids, some of which have been collected before in the region but never reported as present in Illinois. Two such species are *Carolinaia carolinensis* (Smith) and *Myzus hemerocallis* (Takahashi), both captured on interception nets. *Carolinaia carolinensis* is described from specimens taken on poison ivy, *Rhus radicans*, and Smith (1980) suspects that it alternates to plants in the family Cyperaceae. Blackman and Eastop (1984) reported that *M. hemerocallis* attacks basal parts of young leaves of daylily, *Hemerocallis* spp., but there are no host records for this species in Illinois.

Though landing traps have proven useful in other epidemiological studies, only three species, *A. nerii*, *Glabromyzus rhois* (Monell), and *R. maidis*, were caught in them in pepper fields. It is possible that the color of the tiles used in these traps did not match closely enough the background color of pepper foliage. If the reflected light from these tile traps matches closely that of the surrounding crop, it can be assumed that the aphids landing in the trap will also be landing on the crop. Continued use of these traps will depend on identification of a tile that matches pepper foliage.

Although 15 species collected in this survey have been implicated in the transmission of CMV to peppers in other regions, it is possible that other species are responsible for carrying and transmitting this virus in the southern Illinois pepper production area. Nonetheless, even though our inoculation studies did not allow us to identify the key vector species (one or more) involved in CMV outbreaks, we suspect that the vectors are among the species we collected. Movement of the virus may be accomplished by multiple species, with the transfer of the virus from local weed hosts to peppers effected by different species than those that effect the within-field movement of the virus.

As noted earlier, the region in Illinois where this work was done is a large flood plain with extensive riparian areas along the Cache River. The diversity of plants in these riparian areas and abundance of uncultivated flood plain fields provide abundant host plants for native and non-native aphid species. Future work will focus on the biology (local host plants, overwintering hosts, and flight phenology) of the known vector species discussed above and such native aphids as *Uroleucon ambrosiae* (Thomas), an aphid commonly collected in the vicinity of the pepper fields from thistle, *Cirsium discolor*.

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