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PROJECT No. US-228-80

Natural Arthropod Defense Mechanisms of Deciduous Trees, Adaptable for Use in Agriculture

M.K. Harris, F. Mansour

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Natural Arthropod Defense Mechanisms of Deciduous Trees Adaptable for Use in Agriculture

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ABSTRACT

Investigations on the blackmargined pecan aphid, Monnelliella caryella (Homoptera: Aphidae), on the pecan Carya illinoensis (Juglandaceae) were conducted in the US (Texas) and Israel. The population dynamics of the aphid were studied in the US in managed and unmanaged pecan trees, emphasizing the role of the physiology of the pecan host and the natural enemies of the aphid in the risk of epidemics of the pest and the susceptibility of the host to the aphid following an induced epidemic of the aphid. Studies were also conducted on rearing Aphelinus perpallidus, a primary parasite of M. caryella, and introducing it to Israel. Results show that M. caryella can reach epidemic levels on managed and unmanaged pecans throughout the growing season when placed on foliage protected from aphid predators and parasites. Such epidemics caused little or no defoliation, was followed by a disappearance of the aphids and aphids could not be reestablished on the affected foliage. Aphid fecundity and gravidity was higher when soluble N in the host was higher, but aphid numbers varied widely from treatment to treatment and season to season. Aphid predators, particularly chrysopids, but also coccinellids and hunting spiders were found to be chiefly responsible for maintaining low aphid densities in the field. A. perpallidus was reared successfully on M. caryella and several thousand parasitized mummies were carried to Israel for inoculation work. No introduced parasites have been recovered at this time. These studies indicate that M. caryella is usually under satisfactory natural biological control, primarily from predators, in the US and pecans fertilized with N support aphids that are more gravid and fecund. Management practices that maintain predators and optimize the use of N fertilizer are recommended to reduce the risk of epidemics. Delaying pesticide treatments until pecan pests exceed previously established action levels will contribute to the former.

Research Achievements^{1/}

The primary objective of this study was the development of an integrated pest management (IPM) program for the blackmargined pecan aphid Monellia caryella in the US and Israel. The management approaches used at the time this study began were predominantly the prophylactic use of chemicals whenever aphids were observed, in the case of foliar treatments, and whenever they were anticipated in the case of systemic treatment. The pecan pest complex is quite different in the US compared to Israel with the former possessing more than 100 frugivorous and phytophagous species while the latter is primarily restricted to M. caryella as the chief pest. Therefore, IPM of the aphid in the US required considering additional pests as well.

Studies were conducted on M. caryella population dynamics and biocontrol in relation to pecan phenology, pecan physiology (particularly soluble Nitrogen), and pecan ecology to attempt to determine when the pecan was most susceptible to attack and why. The publication referenced in the text document the following statements and should be referred to for precise methodology and details.

M. caryella was examined in the US by sampling natural field populations on orchard trees, native trees (wild trees that had been cleared of competing trees and brush) and on wild trees in mixed species tree stands; and, cage studies were also conducted throughout the season to determine the ability of the aphid to grow and reproduce in a protected environment on the various kinds of pecans. Natural field populations of M. caryella were found to vary widely among treatments and locations with wild pecan trees always supporting few if any aphids. Initially these differences were largely attributed to the physiological state of the host, however, the closed cage studies clearly demonstrated this was not entirely true. M. caryella

^{1/}Three copies of all papers and manuscripts referred to in the text have been previously sent.

placed in cages enclosing 10 compound leaves would increase to epidemic levels within a 3 week period, regardless of the physiological, phenological or ecological condition of the host (Liao and Harris 1985). Furthermore, the incipient epidemics were invariably prevented if the cage was opened at one end to allow access by natural enemies (Liao et. al. 1984, 1985). A close inspection of the intrinsic rate of natural increase of the aphid showed that these factors were highest in April/May and decreased until late July (Liao and Harris 1985, Liao et al 1984, 1985). This meant that epidemics took a little longer to materialize as the season progressed. Aphid gravidity and fecundity examined in natural populations also show this trend with fertilized pecans producing more gravid and fecund aphids for a longer period than those left unfertilized (Liao and Harris, submitted manuscript). Aphids left in closed cages typically reached their highest populations in the 4th week and then died out causing less than 10% defoliation (Liao et al 1984), despite the fact that copious amounts of honeydew were produced indicating substantial levels of carbohydrates had been removed from the infested leaves. Comparison studies of a related species, Monelliopsis nigropunctata, resulted in 80 + % defoliation by contrast (Liao 1984 Ph.D. Dissertation)). The reintroduction of M. caryella on caged foliage that had previously supported an epidemic did not result in another epidemic indicating that the foliage was unsuitable or at least unattractive to the aphid. We concluded from these studies that M. caryella could increase to epidemic levels throughout the season regardless of pecan condition and that following an epidemic the aphid would not reoccur in large numbers on the same foliage.

The studies of natural enemies of M. caryella indicate very strongly that they are the key element in maintaining this aphid at low levels, and, that it is the predator component of the natural enemy complex that is the most important feature as opposed to the parasites emphasized by others previously (Liao et al

1984, 1985). Paired cage tests were conducted where M. caryella adults were introduced into both cages and ca. 12 days later as the population in each cage was rapidly increasing, one was opened to allow natural enemies access; aphids always declined in the opened cage and predators were routinely noted inside, while the epidemic and subsequent natural demise of the population was observed in the closed cage. Another study examined the results of introducing a second or third instar lady beetle or chrysopid larva into a cage enclosing 10 compound pecan leaves infested by an increasing population of several hundred aphids. Within a few days after introduction, aphids were eliminated from the cage indicating that a density of 1 predator/10 leaves was sufficient to prevent an increasing aphid population from reaching epidemic levels. The investigations of natural enemies indicated that Chrysoperla (species probably rufilabris) (Neuroptera: Chrysopidae) was responding to increasing aphid populations by laying more eggs in the vicinity and that hunting spiders were an important biological control component in this system, while the parasite Aphelinus perpallidus was never observed adversely affecting an increasing aphid population and was rarely ever found except for a brief period following an epidemic (Liao et al 1984, 1985). Natural enemies were present in the field in the greatest diversity and numbers beginning in April/May and decreased until August and then rebounded slightly (Liao et al 1985); this mirrored the capacity of the aphid to increase as discussed earlier. A major predator of pecan aphid during mid-summer was Chrysoperla rufilabris and investigations were undertaken to determine the feasibility of mass rearing this neuropteran for use in a biocontrol program. Good results have been obtained and techniques have been developed to produce 10,000 + first instar larvae/week using appropriate temperatures, photoperiods and diets (Elkarmi 1986, M.S. Thesis). Pilot field trials using this predator have been frustrated by the imported fire ant, Solenopsis invicta,

which infests the test orchard and itself attacks C. rufilabris when they are released onto or adjacent to tree trunks. One study using a small string controlled balloon to release C. rufilabris from over the pecan trees was inconclusive when aphid populations did not increase as expected in the untreated trees. We concluded from this work that natural enemies of M. caryella, especially predators (emphasizing C. rufilabris and hunting spiders in mid-summer) were key factors maintaining aphid populations at low levels and that reduction, or if possible, elimination of practices that interfered with predators would contribute more than anything else to aphid management.

Another component of this project was the laboratory rearing of the US M. caryella parasite, Aphelinus perpallidus, and making shipments to Israel to establish it there. Shipments were made six times during 1982-85 (Table 1, note p. 16). Many problems in shipment and establishment of these parasites were encountered during this study. Laboratory rearing of A. perpallidus in Israel resulted in low levels of parasitism and low levels of emergence (Tables 2-6). No A. perpallidus have been recovered from any of the release sites in Israel at this time (Table 5). In light of the natural enemy studies and the minimal impact of this parasite in the US on the aphid, this might not be such a lamentable matter, but how the parasite might operate in the Israeli system has yet to be seen.

During May 1984, Trioxys pallidus was found parasitizing the blackmargined pecan aphid at the New Ya'ar Experiment Station in Israel (Table 6). This is a new record for this well known parasite of walnut aphid, Chromaphis juglandicola, to be recovered from a pecan aphid in the field. A hyperparasite was also found in 1984 (Table 7). No parasitism was found in 1985 despite increased sample sizes and examination of more locations. This outcome is an enigma.

Intensive studies were conducted in the US on the status of nitrogen in pecan

foliage obtained from managed improved pecans, seedling pecans, native pecans and wild pecans at various times through the growing season. Nitrogen was examined as total N, insoluble/soluble N and in some studies as amino N to determine what the N status was during the season in these circumstances. Comparison studies were also made of blackmargined aphids and their responses to these circumstances in appropriate tests. These studies show the following; total nitrogen is at its highest levels early in the spring shortly after budbreak and declines from then until late July when it again increases slightly; this pattern was mirrored by soluble nitrogen but the latter was less distinct (Journet and Harris, in manuscript -- Note, all citations were submitted previously). The patterns of amino acids were less distinctive than soluble N through the season and significant amounts of soluble N were not accounted for in the amino form (Journet, Holman and Harris, in manuscript). The highest N levels usually occurred in the most intensively managed trees, managed improved and seedling pecans, as compared to native and wild pecans, and these levels were typically sustained longer, although the low levels of N observed in late July tended to be comparable in all treatments. The relationship of pecan host physiology to the population dynamics of the blackmargined pecan aphid was not clear cut (Journet et al, Journet and Harris, Liao et al 1984a, 1984b, Liao and Harris 1985), under most field conditions. Blackmargined pecan aphid gravidity and fecundity tended to correspond to soluble N with high nitrogen in the pecan resulting in higher aphid fecundity (Liao and Harris, submitted manuscript). The best correlation between increased aphid numbers and higher levels of soluble N occurred when aphid populations found 10-20 days after soluble N was measured were compared (Journet, Harris Liao and Storey). This indicates that about 2 aphid generations were required to exhibit a response to soluble N change in the host. This is a subtle comparison and given the wide range of aphid abundances among

treatments and seasons and the lack of direct correspondence between aphid populations and soluble N, we concluded that although soluble N appears to have a minor affect on aphid density, the principal factors regulating pre-epidemic aphid populations were predators (Liao et al 1985).

Literature Cited

- Elkarmi, Lina A. 1986. Laboratory rearing of Chrysoperla rufilabris (Burmeister) (Neuroptera:Chrysopidae) a predator of pecan insects. M.S. Thesis. Entomology, Texas A&M University, College Station, Texas 77843. 43 pp.
- Journet, A.R.P. and M.K. Harris. Nitrogen in the leaf tissue of pecan: seasonal and site variation (in manuscript).
- Journet, A.R.P. and M.K. Harris. Response of the blackmargined aphid to variation in foliage quality of the pecan. (in manuscript).
- Journet, A.R.P. and M.K. Harris. Population dynamics of pecan aphids in relation to foliar nitrogen quality and management regimes of the pecan. (in manuscript).
- Journet, A.R.P. and M.K. Harris, H-t. Liao and J.B. Storey. The role of soluble protein nitrogen in the population dynamics of the blackmargined aphid on pecan (in manuscript).
- Journet, A.R.P., G.M. Holman and M.K. Harris. Amino acids in the ethanol soluble extract of pecan leaf tissue: seasonal and site variation (in manuscript).
- Liao, H-t. and M.K. Harris. 1986. Potential fecundity of the blackmargined pecan aphid. Tex. Agric. Exp. Sta. Progress Report. (in review).
- Liao, H-t. and M.K. Harris. 1985. Population growth of the blackmargined aphid on pecan in the field. Agric. Ecosystem Environ. 12:253-61.
- Liao, H.T., M.K. Harris, F.E. Gilstrap, D.A. Dean, C.W. Agnew, G.J. Michels and F. Mansour. 1984. Natural enemies and other factors affecting seasonal abundance of the blackmargined aphid on pecan. Southw. Entomol. 9:404-20.
- Liao, H.-T., M.K. Harris, F.E. Gilstrap and F. Mansour. 1985. Impact of Natural Enemies on the blackmargined pecan aphid, Monellia caryella (Homoptera: Aphidae). Environ. Entomol. 14:122-6.

Evaluation of Findings vs. Funded Proposal

The goals established in the funded proposal and the results reported above complement each other well. However, heavy emphasis was made in the beginning on the role of the physiology of the pecan host in how that influenced the population dynamics of the blackmargined aphid. This view has changed during the course of these experiments so that the role of predators appears to be the driving factor influencing the ability of the aphid to reach epidemic numbers with host physiology exerting a detectable but less dramatic effect than originally expected. The most important blackmargined pecan aphid predator amenable to manipulation in the laboratory and field was Chrysoperla rufilabris and techniques were developed to mass rear this predator for further studies. This research avenue was not anticipated in the beginning and provides new abilities and insights into better managing the blackmargined pecan aphid. Rearing of the native parasite Aphelinus perpallidus was successful in the US, but inability to establish it through numerous shipments to Israel prevented this aspect of the study from contributing to management of the aphid in Israel.

Results of Cooperation

A better understanding of the relationship between the blackmargined pecan aphid and pecan in Israel and the US has emerged from these studies. The intensive management system in Israel using two and three times the levels of supplemental nitrogen result in greater levels of soluble nitrogen during the growing season and, based on the US studies, this provides an environment that allows the aphid to build up more rapidly than in the US over a longer period in the field. The routine use of broad spectrum systemic pesticides for aphid control in Israel reduces predator numbers because prey of all kinds are affected by the systemic pesticides. This makes aphid management doubly difficult when the systemic wears off or if it is not used at a particular location. The experience of the Israeli cooperator in biological control and particularly with hunting spiders ensured that this aspect of the study was properly emphasized and the range of treatments in the US compared to the intensive Israeli management system provided a wide spectrum in which to examine aphid/pecan interactions not otherwise available. Finally, new research contacts with other entomologists, plant pathologists and plant breeders were initiated by both project leaders that enhance their abilities to conduct research on pecan as well as other crops. Several initiatives to conduct other research were a direct result of this project as one example of this aspect of the interaction.

Benefits to Agriculture

This study provided a much more rounded view of blackmargined pecan aphid/pecan interaction than had been previously available, particularly in regard to soluble nitrogen and natural enemies as they affected population dynamics of the aphid. This information provides the basis for aphid management programs that preserve natural enemies of the aphids and optimize fertilizer useage. Given a better understanding of why epidemics of blackmargined pecan aphid occur, research has been directed toward developing and maintaining higher populations of aphid natural enemies in the field and, in the US, toward reducing pesticide treatments for other pests that disrupt natural enemies. Each foliar treatment of pesticide in the US costs \$20-30/acre and 2-6 treatments each year are sometimes made just for pecan aphids. The primary management approach in Israel has been systemic pesticides at a cost of \$100/hectare or more. Translation of this new knowledge into economic benefits for the producer is presently easier in the US by encouraging an overall reduction in pesticide usage by elimination of unnecessary treatments and greater tolerance for low populations of aphids that maintain natural enemies. Implementation of this approach has been underway in the US as a result of this work and where adopted, savings of \$25 to over \$100/acre have resulted. The prophylactic nature of systemic pesticide use in the US and Israel is more difficult to modify and the full impact of this work will not occur there until aphid resistance makes adoption of a more integrated approach to pecan pest management necessary; or, reliance on systemic pesticides is reduced to a more "as needed" approach such as may be possible through the so called "chemigation" techniques where use of a systemic insecticide is limited to small amounts applied through the irrigation system when aphid action levels, as determined by weekly monitoring, are exceeded.

Inventions

No inventions or patents have resulted from this work.

Appendix

The three copies of papers and manuscripts have been submitted separately with this final report and this section was considered too lengthy for general distribution. They are also available on request.

Table 1: Shipments and Emergence of A. perpalidus Adults
From M.caryella Mummies Imported From El Paso, Texas

No.	Dept. Date.	Receiving Date	Total No. Mummies	No. Alive	Emerged Dead	Date
1.	Sept. 9, 1982	Sept. 12	722	45 62 33 8 8	160 62 23 19 14	Sept. 12 " 13 " 15 " 16 " 18
			Total	157	276	
			Percentage	22%	38%	
2.	Oct. 14, 1982.	Nov. 11	654	2	130	Nov. 8
			Total	2	130	
			Percentage	0.3%	19.9%	
3.	Aug. 6, 1983.	Aug 8	979	92 112	35 60	Aug. 8 Aug. 9 - 30
	(Carried Personally)	Total		204	95	
		Percentage		20.8%	9.7%	
4.	Oct. 20.1983	Oct. 26	423	43 67 10	11 50 8	Oct. 27 " 28 " 28 - 30
			Total	120	69	
			Percentage	28.4%	16.3%	
5.	June 1984.	June 8	277	14 3	56 30	June 8 " 8 - 20
			Total	17	86	
			Percentage	6.1%	31.0%	
6.	May 13, 1985.	May 30	397	6	111	May 30
			Total	6	111	
			Percentage	1.5%	27.95%	

TABLE 2: EMERGENCE OF A. PERPALIDUS ADULTS FROM M. CARYELLA
MUMMIES REARED IN CAGES IN ACCLIMATIZED ROOM
(25 - 27 °C; 60 ± 5% RH)

Collection Date	Total Mummies	No. Emerged	Percentage Emergence	Days after Collection
April 6	91	5	5.5%	5
		12	13.2	7
		9	9.9	9
		12	13.2	11
		4	4.4	13
		6	6.6	14
Total	91	48	52.8	14
Sept. 11	75	2	2.6	6
		9	12.0	7
		9	12.0	8
		21	28.0	11
		2	2.7	14
Total	75	43	57.3	14
Sept. 12	29	1	3.4	6
		3	10.3	7
		2	6.9	8
		4	13.8	9
		8	27.6	10
		2	6.9	13
Total	29	20	68.9	13
Sept. 18	18	2	11.1	8
		2	11.1	9
		7	38.8	11
		0	0.0	13
		0	0.0	15
Total	18	11	61.0	15
Sept 20	22	1	4.5	7
		5	22.7	9
		5	22.7	11
		2	9.1	13
		1	4.5	15
Total	22	14	63.5	15

TABLE 2: (cont.)

Collection Date	Total Mummies	No Emerged	Percentage Emergence	Days after Collection
Sept. 30	20	2	10.0	7
		7	35.0	8
		2	10.0	10
		1	5.0	11
		1	5.0	14
Total	20	13	65.0	14

Table 3: Rearing of A. perpallidus on Caged Pecan Seedlings
Highly Infested with M. caryella (800 - 1,300)

Cage	Release of Parasites		Collection of Mummies	
	Date of Release	Parasites Released	Date	Mummies Collected
1.	March 23	20	April 6	91
	24	10	13	29
	30	9	15	2
	Total	39		122
2.	April 11	5	April 26	0
	13	12	May 1	0
	15	9	6	0
	18	12	9	0
	19	4	13	0
	20	6		
	Total	48		0
3.	April 4	6	April 15	16
	6	16	20	05
	8	16	26	19
			May 1	0
	Total	38		40
4.	April 22	17	May 6	11
	25	10	9	14
	29	4	11	8
	May 3	7	13	7
	4	2	15	5
			17	2
			20	9
	Total	40		56
5.	May 6	2	May 23	23
	8	1	25	12
	11	3	27	9
	13	3	30	6
	20	5	June 3	3
	23	6		
	Total	20		53

Table 3: (cont.)

Cage	Release of Parasites		Collection of Mummies	
	<u>Date of Release</u>	<u>Numbers of A.P. released</u>	<u>Date</u>	<u>Mummies Collected</u>
6.	May 25	8	June 3	4
	27	8	5	17
	29	5	7	13
	June 3	18	10	15
			12	4
			15	5
Total		<u>39</u>		<u>58</u>
		<u>224</u>		<u>329</u>

Table 4: Parasitism of M. caryella Population by
A. perpalidus in the Laboratory, 1982.

Date	Cage	<u>A. perpalidus</u> <u>Released</u>	10 days after release			
			Total Aphid	Total Mummies	Percentage Parasitism	
March	13	1	50	1294	83	6.4
	23	2	39	1463	92	6.2
April	3	3	49	1321	39	2.9
	10	4	16	947	52	5.5
154			5025	266	$\bar{x} = 5.29$	
Jan.	30	1	50	836	41	4.9
Feb.	4	2	45	1370	67	4.8
	7	3	38	493	15	3.0
	11	4	31	911	44	4.8
164			3610	167	$\bar{x} = 4.6$	

Table 5:

Release and Establishment of the Imported Parasite A. perpalidus in Unsprayed Pecan Trees in Israel.

Release of <u>A. perpalidus</u>					Investigation for establishment (data from 60 leaves)			
Location	Year	Date	No.	Parasite	Date	No.	<u>M. caryella</u>	No. Mummified aphids
Beve Ya'ar	1982	Sept.	19	7	Oct. 3, 1983	1609	0	
		Oct.	6	20		Oct.17	1770	0
		Oct.	10	31		Nov. 1	1468	0
		Oct.	17	37		Nov.15	320	0
		Nov.	10	24				
		Nov.	11	32				
Total			151		5167			
	1983	Aug.	21	17	Aug.24,1983	42	0	
		Sept.	16	42		Sept.14	63	0
		Sept.	19	37		Sept.30	44	0
		Sept.	28	75		Oct. 12	65	0
		Oct.	5	24		Oct. 28	45	0
		Oct.	10	18		Nov. 9	3	0
Total			213		262			
Beve	1982	Sept.	15	77	Sept. 6,1982	241	0	
		Sept.	22	58		Oct. 6	178	0
		Sept.	29	64		Oct. 20	107	0
Total			199		526			
	1983	May	16	71	May 30,1983	115	0	
			23	83		June 13	131	0
			30	95		June 27	63	0
		June	6	87		June 4	21	0
Total			336		330			

Table 6: Number of aphids and evidence of parasitism from 60 leaf samples of M. caryella populations at five different sites in Israel - Neve Ya'ar, Nahalal, Geva, Acre and Hulla 1982, 1983, 1984, 1985.^{1/}

Location/Year	Month						
	May	June	July	August	September	October	November
Combined all Sites 1982 & 1983 Total Aphids	1500	1000	1000	1000	1500	1000	0
1982 & 1983 Total Parasitism	0	0	0	0	0	0	0
1984 Neve Ya'ar Aphids	696	159	32	201	5836	129	0
Parasites	22	16	9	7	16	4	0
Nahalal Aphids	---	1155	151	46	72	67	0
Parasites	---	72	182	128	73	55	3
Geva Aphids	---	408	---	312	88	52	0
Parasites	---	19	---	74	3	2	0
1985 ^{2/} Neve Ya'ar							
Nahalal							
Geva							
S de Eliahu							

^{1/} Samples typically consisted of 3 or 4 replications ca. of 60 leaves.

^{2/} No parasitism was found at any of these locations in 1985 despite examination of 5220 leaves infested with 6998 aphids during April to November at these locations.

Table 7: Emergence of Hyperparasite (Aphidencyztus Sp.) from Trioxys pallidus Mummies Collected from Monellia caryella Populations, 1984.

Location	Total Mummies	No. Hyperparasites	Percentage Hyperparasites
Neve Ya'ar	55	0	0
Nahalal	512	5	0.98
Geva	79	1	1.27