Field Resistance to Yellow Aphids in Pecan

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ABSTRACT. Putative resistance to the blackmargined aphid (*Monellia caryella* Fitch) in 'Pawnee' pecan [*Carya illinoensis* (Wangenh.) K. Koch] was first noted in greenhouse tests by rating cultivars for relative amounts of honeydew on adaxial leaf surfaces. This resistance was confirmed in two field tests monitored from mid-June to mid-October. 'Pawnee' supported significantly lower aphid populations during every rating period when relatively large numbers of these insects were present. 'Navaho' also showed resistance, with 'Desirable' having intermediate resistance and 'Stuart' being very susceptible. Insect populations were also monitored on the four quadrants of each tree, with quadrant effect being significant in only one test. This test had the highest populations on the western quadrant and lowest populations on the eastern quadrant. In determining individual clone resistance, it is recommended that the general orchard aphid infestation level be determined so that only two or three well-timed clonal ratings are needed. We also recommend that all sides of the tree be monitored.

The blackmargined aphid (*Monellia caryella* (Fitch)) and the yellow pecan aphid (*Monelliopsis pecanis* Bissell) make up what is commonly referred to as the yellow aphid complex on pecan (*Carya illinoensis*). These are the most common foliar feeding aphids on pecan (Tedders, 1978), and are considered by many to limit production. Huge quantities of carbohydrate are extracted, and photosynthetic rates are reduced in damaged leaf tissue (Wood and Tedders, 1986; Wood et al., 1987). Of the two species, the population buildup of the blackmargined aphid can be rapid, since it has the shortest development, prereproductive, and generation time as well as the highest fecundity rate. This gives it the highest intrinsic and finite rates of increase (Kaakeh and Dutcher, 1992). This insect may produce up to 32 parthenogenetic generations in a single season (Tedders, 1978). Compared to the yellow pecan aphid, it has been estimated that each blackmargined aphid does somewhere between five times (Bumroongsook and Harris, 1992) and eight times (Wood and Tedders, 1985) as much damage since they require more energy for rapid growth, respiration, and excretory products. A secondary effect of yellow aphid infestation is the growth of black sooty mold on the adaxial leaf surface. This material intercepts radiation and limits photosynthesis.

Loss of pes-

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ticide efficacy is common in the chemical control of the blackmargined aphid and has created a dilemma for growers and entomologists (Dutcher and Htay, 1985). Host plant resistance may be a viable alternative to reduce damage.

'Pawnee' was released by the U.S. Dept. of Agriculture (USDA) in 1984 (Thompson and Hunter, 1985). In 1988, the senior author noted what seemed to be useful levels of resistance to this aphid in 'Pawnee' in replicated greenhouse experiments. Field tests followed in 1990, which are reported here.

Materials and Methods

The first data taken on aphid resistance were recorded on an 11-replicate test of single-tree plots in the greenhouse at Brownwood, Texas, on 20 May 1988. Aphid honeydew ratings (1 to 10 with 1 = none and 10 = heavy honeydew accumulation on adaxial leaf surfaces) were recorded on the four cultivars in this test—'Pawnee', 'Choctaw', 'Cheyenne', and 'Desirable'. An overall rating of

Table 1. Pecan clones tested in NPACTS-A and NPACTS-B at College Station, Texas.

Clone	NPACTS-A		Clone	NPACTS-B	
	Female parent	Male parent		Female parent	Male parent
72-10-42	Riverside	Apache	74-04-11	Chickasaw	Cheyenne
73-01-10	Western	57-07-22 ^z	74-05-55	Cheyenne	Sioux
73-01-15	Western	57-07-22	74-05-60	Cheyenne	Sioux
73-05-24	Riverside	Apache	74-06-16	Cheyenne	Wichita
74-01-12	48-13-311 ^y	Wichita	75-01-75	Wichita	49-23-16 ^x
74-04-03	Chickasaw	Cheyenne	75-05-06	Cheyenne	Sioux
Desirable	Success	Jewett	75-05-32	Cheyenne	Sioux
Navaho	48-13-311	Wichita	76-01-64	Chickasaw	Desirable
Pawnee	Mohawk	SHG ^w	76-02-96	Wichita	Cape Fear
Stuart	AL Seedling		76-04-44	Shoshoni	Cape Fear
			76-07-15	Cherokee	Choctaw
			76-07-41	Cherokee	Choctaw
			77-36-909	Wichita	Western
			Desirable	Success	Jewett
			Pawnee	Mohawk	SHG
			Stuart	AL Seedling	

^zSelection 57-7-22 has the parentage 'Mahan' x 'Brake'.

^ySelection 48-13-311 has the parentage 'Moore' x 'Schley'.

^xSelection 49-23-16 has the parentage 'Brake' x 'Sioux'.

^wStarking Hardy Giant.

Table 2. Day of year and calendar date (month and day) of aphid data collection in 1990 at College Station, Texas.

Collection no.	NPACTS-A		NPACTS-B	
	Day of year	Calendar date	Day of year	Calendar date
1	165	14 June	169	18 June
2	180	29 June	183	2 July
3	194	13 July		
4	208	27 July	211	30 July
5	222	10 Aug.	225	13 Aug.
6	236	24 Aug.	239	27 Aug.
7	255	12 Sept.	256	13 Sept.
8	274	1 Oct.	275	2 Oct.
9	288	15 Oct.	289	16 Oct.

each tree was made. Individual leaves were not rated. Further testing under field conditions was planned, based on these ratings.

Data were taken on two established National Pecan Advanced Clone Testing System (NPACTS) orchards (NPACTS-A and NPACTS-B) at College Station, Texas. NPACTS is the testing system for elite clones produced in the USDA's pecan breeding program. These performance tests were begun in 1983 when bare-root 'Apache' rootstocks, grown from open-pollinated seed, were planted in a Westwood silt loam soil, 0% to 1% slope (fine-silty, mixed, thermic Fluventic Ustochrepts). Trees were spaced 10.7 m each way, with 87.8 trees/ha. Single tree plots with six blocks in NPACTS-A and five blocks in NPACTS-B were grafted in April 1986. There were 10 clones under test in NPACTS-A and 16 clones in NPACTS-B (Table 1). General orchard care for this locale was followed. The trees received no insecticidal spray in 1990.

Blackmargined aphid populations were monitored nine times in NPACTS-A and eight times in NPACTS-B. The third sampling date was missed in NPACTS-B, but the other rating dates are comparable to NPACTS-A, with data being recorded in NPACTS-B 1 to 3 d after NPACTS-A (Table 2). Alate adult aphids on leaflets 4 and 5 (numbered from the distal portion of each leaf) were counted on four leaves in each quadrant (north, east, south, and west) of the trees. Only alate adults were counted since these numbers reflect total aphid populations (Flores, 1981) and since wing structure is the best criteria to separate species. Yellow aphids have peaked or gabled wings, while blackmargined aphids hold their wings flat in the same plane as the leaf. Mature leaves growing in full sun were sampled from the middle portion of the current season's growth. Counts for a given test were completed the same day. All statistical tests were performed on the average number of insects on these four-leaf samples. Thus, the number of aphids reported are always the mean number of alate adult

blackmargined aphids on two leaflets of a single leaf.

SAS's general linear model procedures (SAS Institute Inc., Cary, N.C.) was used to determine the influence of clones and other factors upon aphid populations. Duncan's multiple range tests were used to separate means after individual date analyses.

Results and Discussion

The aphid honeydew ratings in the greenhouse indicated that genetic differences in host plant resistance to this insect existed among cultivars ('Pawnee' 1.3, 'Choctaw' 6.5, 'Cheyenne' 6.7, and 'Desirable' 8.2). 'Pawnee' had significantly less honeydew than the other three cultivars. 'Cheyenne' has the reputation of being especially susceptible, and this susceptibility is sometimes ascribed to its dwarfish limb growth and the resultant thick foliage, which may allow aphid populations to build up faster. 'Choctaw' and 'Desirable' have been considered less susceptible. At the time of this test, 'Pawnee' was a new cultivar (Thompson and Hunter, 1985). Based on the greenhouse study, it was determined that further tests to investigate possible resistance in 'Pawnee' were warranted.

The overall analysis of variance tests (Table 3) showed highly significant clone and rating date effects in both NPACTS tests. The block effect was significant in NPACTS-A but not in NPACTS-B. The reason for this is not apparent. The blocks (tree rows) in both tests run northwest to southeast and the two tests are separated by only ≈ 100 m. The quadrant effect was significant in NPACTS-B but not in NPACTS-A. Temporal effects on aphid populations were dramatic in both tests. The aphid infestation levels differed for the two tests, with an overall mean count of ≈ 0.3 in NPACTS-A (Table 4) and ≈ 0.5 for NPACTS-B (Table 5). The reason for this disparity was unclear.

Table 3. Summary of analysis of variance for two aphid resistance studies at College Station, Texas in 1990.

Aphids (no.)	NPACTS-A			NPACTS-B		
	df	Type III SS	Probability ^a	df	Type III SS	Probability
Block	5	2.22	0.02	4	2.45	0.22
Clone	9	17.52	0.00	15	92.67	0.00
Quadrant	3	0.46	0.44	3	10.77	0.00
Quadrant $\times$ clone	27	4.78	0.41	45	20.17	0.39
Date	8	172.71	0.00	7	576.00	0.00
Quadrant $\times$ date	24	21.25	0.00	21	45.60	0.00
Clone $\times$ date	72	35.42	0.00	105	218.24	0.00
Quadrant $\times$ clone $\times$ date	216	30.83	0.95	315	150.60	0.09
Error	1687	288.16		1754	750.23	

^aProbability of a greater F value for differences due to chance alone.

Table 4. Average number of blackmargined aphids per leaf (on leaflets 4 and 5) on each clone for different sampling dates in NPACTS-A at College Station, Texas., in 1990. Heading format is sampling number with day of year in parenthesis. Means in the same column not followed by a common letter are statistically different according to Duncan's multiple range test (0.05 probability).

Clone	1(165)	2(180)	3(194)	4(208)	5(222)	6(236)	7(255)	8(274)	9(288)	Mean
Pawnee	0.03 c	0.14 b	0.21 d	0.19 c	0.546 c	0.103 a	0.00	0.16 abc	0.00	0.15 f
Desirable	0.19 abc	0.22 b	0.54 cd	0.24 abc	1.06 ab	0.06 ab	0.02	0.13 abcd	0.03	0.28 cd
Navaho	0.07 bc	0.11 b	0.39 d	0.24 abc	0.72 bc	0.00 b	0.04	0.05 cd	0.01	0.18 ef
Stuart	0.26 ab	0.50 a	1.41 a	0.46 ab	0.62 bc	0.10 a	0.01	0.03 d	0.00	0.38 ab
72-10-42	0.17 abc	0.17 b	0.53 cd	0.29 abc	1.06 ab	0.02 ab	0.01	0.05 cd	0.01	0.26 de
73-01-10	0.13 abc	0.16 b	0.54 cd	0.30 abc	0.96 abc	0.06 ab	0.02	0.06 bcd	0.01	0.25 de
73-01-15	0.27 ab	0.51 a	0.84 bc	0.49 a	1.00 ab	0.10 a	0.07	0.23 a	0.04	0.40 ab
73-05-24	0.26 ab	0.64 a	1.08 ab	0.49 a	1.36 a	0.04 ab	0.02	0.17 ab	0.00	0.45 a
74-01-12	0.08 bc	0.16 b	0.53 cd	0.22 bc	0.66 bc	0.04 ab	0.00	0.05 cd	0.00	0.19 ef
74-04-03	0.34 a	0.45 a	0.57 cd	0.44 abc	1.05 ab	0.01 b	0.04	0.22 a	0.01	0.35 bc
Means	0.18	0.30	0.66	0.33	0.90	0.06	0.02	0.16	0.01	0.29
Probability ²	0.02	0.00	0.00	0.03	0.00	0.02	0.13	0.00	0.11	0.00

²Probability of a greater F value for clonal differences due to chance alone.

The 10 clones tested in NPACTS-A showed varying levels of resistance when the overall mean for all nine rating periods are considered (Table 4). 'Pawnee' supported the lowest population, and was significantly more resistant than 'Desirable' and 'Stuart'. It was not significantly different from the recently released 'Navaho' (Thompson et al., 1995) or 74-1-12 (a full sib of 'Navaho'). It is interesting that these two sib clones are so similar in resistance. Trying to predict resistance of the other clones based on parentage was less encouraging. Pecan is highly heterozygous, with some sibs differing greatly in genetic characteristics. 'Stuart' was highly susceptible and could not be statistically separated from the most susceptible clones (73-1-15, 73-5-24, and 74-4-3).

NPACTS-B clonal results were similar to those of NPACTS-A. The mean overall aphid counts showed 'Pawnee' to be significantly more resistant than 'Stuart' but not 'Desirable' (Table 5). This latter cultivar was intermediate for actual aphid counts between the same cultivars in NPACTS-A. Also, 'Desirable' showed more susceptibility in the greenhouse test than expected. The aphid population dynamics are shown for five clones in each field test in Fig. 1. The rating dates for the two tests are similar, except that date three is missing in NPACTS-B. Comparing peak aphid populations for the two tests, there are three peaks in NPACTS-A and only two were detected in NPACTS-B. Popula-

tions developed more quickly in NPACTS-B, and to a much higher level. These results are consistent with those of Bumroongsook and Harris (1992), who found that the blackmargined aphid typically increases and declines during a 4-week period following inoculation, leaving foliage substantially intact. That is, the foliage is not substantially damaged as far as ability to support infestation by the yellow or black aphid species at a later date. Each NPACTS test showed a slight population rebound on the next-to-last date during the first part of October. Other studies generally have shown that the yellow aphid complex has two population peaks during each growing season—an early peak (April and June) and a late peak (late August to November) (Kaakeh and Dutcher, 1994).

Aphid populations on 'Pawnee' built up slower than on some other clones. In NPACTS-A, a significant population was not reached until 10 Aug., and in NPACTS-B only a single small peak was evident on 30 July. Therefore, 'Pawnee' showed consistent resistance throughout the season in both tests. The other clones showing some resistance ('Navaho' and 74-1-12 in NPACTS-A and 75-1-75, 76-1-64, and 77-36-909 in NPACTS-B) had never been tested for this trait before. 'Navaho', released by the USDA in 1994, is an especially high-yielding cultivar for the southwestern United States. Resistance in 'Navaho', as well as that in

Table 5. Average number of blackmargined aphids per leaf (on leaflets 4 and 5) on each clone for different sampling dates in NPACTS-B at College Station, Texas., in 1990. Heading format is sampling number with day of year in parenthesis. Means in the same column not followed by a common letter are statistically different according to Duncan's multiple range test (0.05 probability).

Clone	1(169)	2(183)	4(211)	5(225)	6(239)	7(256)	8(275)	9(289)	Mean
Pawnee	0.31 de	0.31 g	0.62 cdef	0.29 cd	0.04 bc	0.04	0.02 e	0.00 b	0.21 h
Desirable	0.45 cde	0.97 efg	0.72 bcdef	0.45 bcd	0.04 bc	0.05	0.14 cde	0.00 b	0.35 fgh
Stuart	0.94 abc	2.07 bcd	0.46 ef	0.39 cd	0.04 bc	0.00	0.20 cde	0.01 b	0.51 cde
74-04-011	0.56 cde	3.08 a	1.17 bc	0.17 d	0.03 bc	0.02	0.17 cde	0.02 b	0.65 c
74-05-055	1.37 a	1.94 bcd	0.62 cdef	0.70 ab	0.02 c	0.03	0.28 bcd	0.00 b	0.62 cd
74-05-060	1.21 ab	1.56 bcde	1.27 b	0.44 bcd	0.10 b	0.10	0.23 cde	0.04 b	0.62 cd
74-06-016	0.52 cde	2.22 bc	0.55 def	0.30 cd	0.01 c	0.04	0.16 cde	0.01 b	0.48 def
75-01-075	0.45 cde	0.74 efg	0.71 bcdef	0.32 cd	0.02 bc	0.00	0.07 de	0.02 b	0.29 gh
75-05-006	0.85 abcd	2.26 b	1.84 a	0.79 a	0.07 bc	0.07	0.57 a	0.09 a	0.82 b
75-05-032	0.49 cde	1.11 efg	1.01 bcde	0.46 bcd	0.02 bc	0.01	0.31 bc	0.04 b	0.43 efg
76-01-064	0.25 e	0.72 efg	0.66 cdef	0.55 abc	0.02 bc	0.05	0.30 bc	0.00 b	0.32 gh
76-02-096	0.79 bcde	1.02 efg	0.72 bcdef	0.36 cd	0.02 bc	0.04	0.19 cde	0.00 b	0.39 efg
76-04-044	0.47 cde	1.42 cdef	0.64 cdef	0.31 cd	0.03 bc	0.03	0.20 cde	0.02 b	0.39 efg
76-07-015	0.94 abc	3.67 a	2.14 a	0.70 ab	0.19 a	0.11	0.45 ab	0.00 b	1.02 a
76-07-041	0.99 abc	1.39 def	1.11 bcd	0.41 bcd	0.05 bc	0.05	0.21 cde	0.00 b	0.53 cde
77-36-909	0.27 e	0.70 fg	0.41 f	0.20 d	0.05 bc	0.03	0.12 cde	0.02 b	0.22 h
Mean	0.67	1.57	0.91	0.43	0.05	0.04	0.23	0.02	0.49
Probability ²	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00

²Probability of a greater F value for clonal differences due to chance alone.

Fig. 1. Average number of blackmargined aphids per leaf (on leaflets 4 and 5) on 'Pawnee' and check clones at College Station, Texas, in 1990 (A = NPACTS-A and B = NPACTS-B).

'Pawnee', should prove valuable in commercial production. The other clones with resistance may have utility in our breeding program to increase blackmargined aphid resistance.

These results are largely consistent with the resistance data obtained in the lab and orchard in 1992 by Kaakeh and Dutcher

(1994). Three species of aphids attacking pecan were studied, including the blackmargined aphid studied here. Orchard trees were sprayed for aphid control on 20 Aug. and 1 Sept. Aphid counts were made 6 July and 9 Oct. of that year. 'Pawnee', followed by 'Cape Fear', was the least preferred by the three species, as demonstrated by orchard infestation levels and high number of probes per feeding period and long nonprobing durations in lab tests. 'Pawnee' showed consistent low populations in all categories studied.

Although the mean black-margined aphid populations across all dates for the quadrants in NPACTS-A are not significant, individual reading dates did show some significant differences between quadrants (Table 6). On 14 June, populations were significantly higher on the western quadrant and lowest on the eastern quadrant, which remained low for the second rating period. In NPACTS-B, the same directional effects were obvious with faster population build up on the west (Table 7). Rating periods 1, 4, 5, and 8 showed significant differences for both tests; however, no consistent additional directional effects were obvious (Fig. 2).

Directional effects across the orchard containing both tests were not obvious. Each block consisted of a single row in NPACTS-A and of two rows in NPACTS-B. NPACTS-B is situated north of NPACTS-A. Block effect was significant in only the first

test. Although aphid populations across all dates were highest on the northern block, no consistent gradient effect in population levels existed across the entire test.

These quadrant and directional effects are largely in agreement with those shown in a study by Polles and Mullinix (1977). They found that there was no overall quadrant effect, although they state that directional preferences changed during the season. Gentry et al. (1975) found no significant differences between quadrants, although there was a trend toward higher populations on the

Table 6. Mean blackmargined aphids per leaf (on leaflets 4 and 5) per quadrant and date in 1990 at College Station, Texas, in NPACTS-A. Heading format is sampling number with day of year in parenthesis. Means in the same column not followed by a common letter are statistically different according to Duncan's multiple range test (0.05 probability).

Quadrant	1(165)	2(180)	3(194)	4(208)	5(222)	6(236)	7(255)	8(274)	9(288)	Mean
North	0.16 ab	0.30 a	0.55 bc	0.45 a	1.07 a	0.06	0.02	0.07 bc	0.01	0.30
East	0.11 b	0.15 b	0.75ab	0.30 a	1.01 ab	0.03	0.01	0.19 a	0.01	0.28
South	0.17 ab	0.42 a	0.95 a	0.16 b	0.75 c	0.05	0.03	0.14 ab	0.00	0.30
West	0.27 a	0.33 a	0.39 c	0.42 a	0.76 bc	0.08	0.03	0.06 c	0.02	0.26
Means	0.18	0.30	0.66	0.33	0.90	0.06	0.02	0.12	0.01	0.29
Probability ^z	0.05	0.00	0.00	0.00	0.01	0.22	0.73	0.00	0.36	0.45

^zProbability of a greater F value for quadrant differences due to chance alone.

Table 7. Mean blackmargined aphids per leaf (on leaflets 4 and 5) per quadrant and date in 1990 at College Station, Texas in NPACTS-B. Heading format is sampling number with day of year in parenthesis. Means in the same column not followed by a common letter are statistically different according to Duncan's multiple range test (0.05 probability).

Quadrant	1(169)	2(183)	4(211)	5(225)	6(239)	7(256)	8(275)	9(289)	Mean
North	0.68 b	1.51	0.94 b	0.61 a	0.02	0.02 b	0.20 b	0.02 ab	0.50 b
East	0.35 c	1.59	0.62 c	0.41 b	0.06	0.02 b	0.21 b	0.01 b	0.41 c
South	0.43 c	1.65	0.82 bc	0.36 b	0.05	0.08 a	0.32 a	0.00 b	0.46 bc
West	1.23 a	1.53	1.26 a	0.36 b	0.05	0.04 b	0.20 b	0.03 a	0.58 a
Means	0.67	1.57	0.91	0.43	0.05	0.04	0.23	0.02	0.49
Probability ^c	0.00	0.86	0.00	0.00	0.09	0.00	0.03	0.02	0.00

^cProbability of a greater F value for quadrant differences due to chance alone.

northern and southern quadrants early and late in the season.

These data all support the conclusion that 'Pawnee' and 'Navaho' contain a significant, and probably economically valuable, level of host plant resistance to the blackmargined aphid. Since these cultivars are not immune, this resistance should be most valuable when used in conjunction with other recommended

methods of aphid population management. These methods include predator enhancement and insecticide management to maintain a balance of predator-prey insect populations in the orchard.

As far as a minimal rating regime to determine clonal resistance, perhaps the best system is to monitor general aphid populations in the orchard and time detailed ratings to coincide with high aphid populations. Perhaps by doing this, resistance could be adequately determined by taking only two or three well-timed readings. In the field tests reported here, we were especially concerned that aphid

populations would peak on different clones at different times. In other words, a clone might appear to be resistant on one date, but support an abnormally large population at a later date. This danger does not appear to be as great as expected. Population peaks seem to flow together for the entire orchard and not according to levels of host plant resistance in the individual clones.

Concerning which area of tree to monitor to quantify the level of genetic host plant resistance, it is recommended that population counts be made on all quadrants of every tree to obtain the best index of resistance. There also seems to be at least some value in rating trees for relative amounts of honeydew, even under greenhouse conditions, since these data eventually led to the identification of aphid resistance in 'Pawnee' and 'Navaho' pecan. Obviously, greenhouse honeydew ratings are not as good as field population counts.

Literature Cited

- Bumroongsook, S. and M.K. Harris. 1992. Distribution, conditioning, and interspecific effects of blackmargined aphids and yellow pecan aphids (Homoptera: Aphididae) on pecan. *J. Econ. Entomol.* 85:187-191.
- Dutcher, J.D. and T. Hay. 1985. Resurgence and insecticide resistance problems in pecan aphid management, p. 17-29. In: W. W. Neel, W.L. Tedders, and J.D. Dutcher (eds.). *Aphids and phylloxeras of pecan*. Univ. Ga. Agr. Expt. Sta. Spec. Publ. 38.
- Flores, R.J.F. 1981. A comparison of

Fig. 2. Average number of blackmargined aphids per leaf (on leaflets 4 and 5) on different quadrants at College Station, Texas, in 1990 (A = NPACTS-A and B = NPACTS-B).

- field population dynamics in relation to developmental time and fecundity under laboratory conditions of the foliage aphid species complex on pecan. PhD diss., Texas A&M Univ., College Station.
- Gentry, C.R., H.L. Malstrom, and J.L. Blythe. 1975. Sampling populations of yellow pecan aphids in relation to tree variety, height, quadrant, and season. *Pecan S.* 2:24–25.
- Kaakeh, W. and J.D. Dutcher. 1992. Estimation of life parameters of *Monelliopsis pecanis* (Homoptera: Aphididae) on single pecan leaflets. *Environ. Entomol.* 21:632–639.
- Kaakeh, W. and J.D. Dutcher. 1994. Probing behavior and density of *Monelliopsis pecanis*, *Monellia caryella*, and *Melanocallis caryaefoliae* (Homoptera: Aphididae) on pecan cultivars. *J. Econ. Entomol.* 87:951–956.
- Polles, S.G. and B. Mullinix. 1977. Distribution of yellow pecan aphids within pecan trees. *Environ. Entomol.* 6:429–434.
- Tedders, W.L. 1978. Important biological and morphological characteristics of foliar feeding aphids of pecan. USDA Tech. Bul. 1579.
- Thompson, T.E. and R.E. Hunter. 1985. 'Pawnee' pecan. *HortScience* 20:776.
- Thompson, T.E., L.J. Grauke, and J.B. Storey. 1995. 'Navaho' pecan. *HortScience* 30:156–157.
- Wood, B.W. and W.L. Tedders. 1985. Estimate of energy drain by three pecan aphid species and their influence on leaf net photosynthesis, p. 45–50. In: W.W. Neel, W.L. Tedders, and J.D. Dutcher (eds.). *Aphids and phylloxeras of pecan*. Univ. Ga. Agr. Expt. Sta. Spec. Publ. 38.
- Wood, B.W. and W.L. Tedders. 1986. Reduced net photosynthesis of leaves from mature pecan trees by three species of pecan aphids. *J. Entomol. Sci.* 21:355–360.
- Wood, B.W., W.L. Tedders, and J.D. Dutcher. 1987. Energy drain by three pecan aphid species (Homoptera: Aphididae) and their influence on in-shell pecan production. *Environ. Entomol.* 16:1045–1056.