Production and Marketing Report

Biological Control of Pecan Insects in New Mexico

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The pecan aphid complex, pecan nut casebearer, and hickory shuckworm are insect pests that can decrease pecan *[Carya illinoinensis* (Wangenh.) C. Koch] nut yield and quality. Several biological techniques can be used to control these potentially damaging pests.

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Pecan aphid complex

In the Mesilla Valley, pecan trees are attacked by three species of aphids, These include 1) yellow pecan aphid *[Moneliopsis pecanis* (Bissel)], 2) black-margined aphid *[Monellia caryaefolia* (Fitch)], and 3) black pecan aphid *[Melanocallis caryaefolia* (Davis)]. Yellow-and black-margined aphids comprise the yellow aphid complex. These phytophagus species are major pests in other states also. According to Estes (1981), in Alabama, these aphids are second in importance only to the pecan scab disease caused by *Fusicladium effusum* (G. Wint; Moniliacen). In Georgia, they are ranked second behind the pecan weevil *Curculio caryae* (Horn) (Tedders, 1983).

Life history. The life history of each species of the pecan aphid complex is similar. The aphids overwinter as eggs laid in crevasses of the tree bark. Eggs hatch in the spring and the young nymphs feed on developing leaf tissue. Yellow aphids usually feed on the abaxial leaf surface, and black aphids feed on both sides of the leaf. In about 2 to 3 weeks, nymphs develop into winged females that reproduce parthenogenetically during the summer. Winged males and wingless females are produced in the fall. Subsequent mating and oviposition occurs as winter approaches (Davidson and Lyon, 1987; English and Huddleston, 1985; Estes, 1981).

Damage. The yellow aphid complex exhibits a bimodal seasonal abundance pattern in Arizona, Alabama, Georgia, and South Carolina (Liao et al., 1984), Spring and fall population peaks also occur in New Mexico (English and Huddleston, 1785). Liao et al. (1984) identified a mid- and late-season population fluctuation in central Texas pecan orchards As they feed, the aphids deplete leaves of photosynthates and excrete copious amounts of honeydew, Honeydew is a substrate for sooty mold development on leaves that further reduces the photosynthetic capacity of the tree (Davidson and Lyon, 1987; Tedders et al., 1982), The black pecan aphid is notably damaging in the late summer, injecting a toxin as it feeds. The toxin damages leaf tissue, causing chlorotic spots that become necrotic, sometimes causing leaflets to abscise prematurely (Bissel, 1928; English and Huddleston, 1985; Tedders et al., 1982, Wood et al., 1987).

In research by Tedders and Wood (1985), early season feeding by the yellow aphid complex had significantly and adversely affected the growth, energy reserves, and productivity of mature 'Stuart' pecan trees. They found a reduction in fruit size and quality, nut yield, leaf area, quantity of leaf chlorophyll, and shoot starch content due to aphid feeding, Another study on the effects of feeding by the yellow aphid complex and black aphids on pecan seedlings indicated reductions in root and main stem dry weights and reductions in the chlorophyll content of foliage. The yellow aphid and black-margined aphid reduced root dry weight by 41% or more The black aphid reduced root dry weight 29%. Feeding by the three aphids resulted in a decrease in main stem length of 34% to 38%. The yellow aphid arrested foliage growth at 68% of the potential leaf area. The black pecan aphid caused the greatest loss of total carbohydrates (40%) (Tedders et al., 1982). In energy consumption studies, black-margined aphids consumed over eight times more energy than yellow aphids and seven times more energy than black aphids (Wood et al., 1987). One study documented the economic damage of the black pecan aphid. In Georgia pecans, Moznette (1934) found that, when black pecan aphids were controlled during the growing season in 1932 by nicotine sulfate 3-(1-methyl-2-pyrrolidyl) pyridine sulfate, the average percentage of shoots blooming in 1933 was 22.9 compared to 1.6 in an untreated control plot. Also, the shoots that set nuts in 1933 averaged 18.9% ,while the percent nut set in the untreated control was 1.5. Aphid-induced defoliation was cited as the causative factor for this lower fruit production. These studies indicate that each of the three aphids is detrimental to the pecan, and caution should be exercised in labeling one aphid more damaging than the others (Tedders et al., 1982).

The yellow and black pecan aphids are serious induced pecan pests (Tedders, 1983), Aphid populations may culminate after pesticide applications for the control of other pests such as the pecan nut casebearer. Calendar sprays for the yellow aphid complex in the spring may necessitate subsequent sprays later in the season to control induced secondary pests,

Economic threshold. The economic threshold is the point at which action must be taken to prevent economic loss (Metcalf and Luckman, 1982). This threshold varies from region to region. In Georgia, Alabama, and Texas, treatment is recommended when populations of yellow aphids exceed 10 to 20 per compound leaf, and the action level for black pecan aphids is one to three aphids per leaf (Davidson and Lyon, 1987; Edelson and Estes, 1981; Harris, 1983). In the Mesilla Valley, efforts to implement a biological control program for pecan pests are underway via conservation, enhancement, and augmentation of beneficial arthropods. Economic thresholds have been set arbitrarily at 38 per compound leaf for the yellow aphid complex and at 12 per compound leaf for black pecan aphids. Care should be taken in evaluating aphid populations, because aphids clump within trees, on certain varieties, within fields, and among fields, Insecticide efficacy can be increased by spraying half rates of relatively noninvasive compounds, i.e., those that do not kill the beneficial complex and by spot treatments.

Biological control. The pecan aphid complex became uncontrollable at Stahmann Farms (Dons Ana County, N.M.) in 1986 because of severe resistance after heavy insecticide applications for 30 years, These applications typically culminated in six treatments per year, A four-element biological control program (Ellington, 1991) greatly reduced the density of the aphid complex, Briefly, the program involved the following,

- Terminating insecticide use to permit buitd-up of native beneficial arthropods.
- Mass release of aphid predators (lacewings and lady beetles).
- inoculative release of the exotic parasitoid *(Trioxys pallidus* (Haliday).
- Using groundcover to improve beneficial insect habitat.

Stahmann (1991) essentially eliminated insecticide use in 3 years, built up and established a complex of beneficial insects in the orchard, and allowed native vegetation to grow under the orchard canopy as a shelter for insects. Cost for aphid control decreased to $0.71/acre from over $270.00/acre in previous years, Yields increased, quality remained consistent, and control costs and aphid density decreased from 1987 to 1990. A single black-aphid outbreak in 1992 suggests the need for a black-aphid biological control factor that can be used when black aphids occasionally break out.

The biological control program that eliminated insecticides at the Stahmann Farm may have been generally successful for one or a combination of reasons,

- Aphid damage may have been more cosmetic than yield-reducing,
- The elimination of insecticides may have preserved the beneficial complex already present,
- The use of groundcovers, there lease of an exotic parasitoid, and the augmentative release of indigenous predators may have reduced aphid populations below their economic threshold,

Although there is documented evidence in the literature to suggest that the pecan aphid complex can cause economic yield and quality loss in pecans, it is presently not known why high populations of pecan aphids did not cause an overall yield or quality reduction at Stahmann Farms over a period of years after ending insecticide use. Some possible explanations include the following.

- Aphid feeding experiments in the Southeast were sometimes carried out on small trees that may not have had the resilience of mature trees.
- Secondary agronomic factors (i.e., fertilizer, irrigation, tree spacing, cover crops, soil type, and variety) may have contributed to reduced tree resilience.
- Environmental conditions may have been different (New Mexico vs. southeastern region). Cloud cover and water stress appear to be particularly important factors,
- Tree resistance may have been decreased by additional phytophagous insects or diseases.

Presently, it is felt that proper agronomic practices may greatly enhance the ability of pecan trees to resist aphids. Fertilizer and irrigation should be optimal. Some varieties are susceptible and should be watched closely. Tree spacing is very important, because shading can limit photosynthesis. Twenty-four trees per acre (60 × 60 ft) may be optimal for large trees. Even though conditions in New Mexico may be more optimal than in the southeastern region, dieback and tree loss can occur under very high black-aphid pressure.

Lady beetles

Traditionally, convergent lady beetles *(Hippodamia convergens* Guerin Meneville) have been collected in mountainous areas in the western region and released in agricultural cropping systems for aphid control (including pecans). Convergent lady beetles have two shortcomings: they cannot be reared artificially and they often migrate outside the fields where they are released.

Last year, *Harmonia axyridis* Pall as was imported from Georgia (previously imported from China or Japan) for release in the Mesilla Valley. *Harmonia axyridis* appears to be relatively host-nonspecific, and it does not migrate out of fields after release. *Harmonia axyridis* was inoculatively released at several locations in the Mesilla Valley, and research was initiated to optimize laboratory rearing. Since then, an artificial diet has been developed in the laboratory (El-Salam, 1994) that consists of dehydrated chicken liver, sucrose, yeast, egg yolk, casein, and peptone in dry powder. In laboratory studies, all life stages of *H. axyridis* fed the artificial diet completed development in a time comparable to those fed a natural prey food source (yellow pecan aphids or pink bollworm eggs); however, oviposition rate was half that of *H. axyridis*- fed insects. The development of an artificial diet will allow year-round production of *H. axyridis* for research and commercial use,

Spiders

Spiders form a large part of the beneficial complex in agroecosystems; however, not all spiders are equally beneficial, and some, because they eat predatory or parasitic insects, pollinators, or other spiders, may be detrimental to the biological control of insect pests. It is likely that certain spiders feed on the pecan aphid complex at different times of the year and that, among these, based on 2 years' bark sampling, *Aysha, Metaphidippus, Pseudicius,* and *Chiracanthium* are major genera. *Aysha* could be especially important because it overwinters as immature instars under bark. These spiders and small ballooning spiders in late winter and early spring may affect aphids and their eggs, *Aysha* and *Chitacanthiun* are known to recognize and eat some insect eggs. (Richman et al., 1989, 1983) Spiders should be sampled further in pecan orchards to determine the major species present and their actual prey.

Hickory shuckworm and pecan nut casebearer

The pecan nut casebearer(PNC) *[Acrobasidis nuxvorella* (Fitch)] and hickory shuckworm (HSW)

[*Cydia caryana* (Neunzig)] were found in El Paso, Chaparral, and Mesilla Valleys at low levels in 1989 and 1990. Intensive spraying for these species could inhibit biological control of the aphid complex. Long-term pecan insect control should consist of cultural and biological control of all the major phytophagus insect species found in pecans.

Hickory shuck worm life history. Full-grown larvae overwinter in dropped nuts and pupate within the shuck in early spring. The moths emerge in the spring and oviposit on foliage and small nuts, where the developing larvae mine and feed on the interior of the immature nuts, causing them to drop. After the nuts harden, the larvae tunnel in the green shucks, distort kernel development, and stain the shells. There may be four to five generations annually.

Pecan nut casebearer life history. The casebearer overwinters as small larvae in a hibernaculum at the base of dormant pecan buds. The larvae tunnel into the buds in May and early June The larger larvae attack the newly formed nut by tunneling into the stem end where they web together the infested nuts. A single larva may destroy all the nuts in a cluster. The mature larvae are about 1/2 inch long, with olive to reddish-green bodies and dark brown heads. They pupate in nuts or under bark scales, The second-generation adults emerge in late June and July, feeding on shuck surfaces and leaves causing less damage, There may be three or four generations per year.

Presently, there is no proven way to control PNC biologically; however, several researchable alternatives do exist.

- Inoculative release of exotic egg and larval parasitoids from Georgia and Texas and management of a groundcover habitat for their survival.
- Sprays of new formulations of the bacterial insecticide, *Bacillus thuringiensis* var. *kurstaki,* and insecticidal soap for controlling PNC larvae.
- Development and release of synthetic pheromones to suppress PNC mating.

Parasitoids

The natural habitat of the wild pecan in North America is alluvial soil adjacent to rivers in the southeastern states and Mexico (Harris, 1983). Unlike many introduced horticultural crops, the pecan pests and beneficial complex consist almost entirely of species that have evolved with the pecan,

Twenty-six species of primary native egg and larval parasitoids were reared from PNC in Texas (Nickels et al., 1950). Average percentage parasitization of larvae in overwintering hibernacula, shoots and first-, second-, and third-generation larvae from 1929 to 1934 was 45%. Gunasena and Harris (1988) found that PNC larvae and pupae of the first summer generation were parasitized in Texas by at least 24 species belonging to 10 families in 2 orders. *Goniozus columbianus* (Ashmead), *Tetrasticus sp.,* and *Eupelmus limneriae* (Howard) were new species, Total observed parasitism of first-summer-generation PNC by all parasites collectively ranged from 13.6% to 47.1% in 1983 and 1984. A characteristic of these systems appears to be lack of a dominant parasitoid. The complex is made up largely of nonhost-specific hymenopterous larval parasitoids. The host range may vary from 1 to 79. Effective parasitism results from low levels of parasitism by many parasitoids.

Pecan nut casebearers often may not be an economic problem in Georgia because first-generation larvae can be heavily parasitized and early season zinc treatments (April to May) often have included an insecticide in the southeastern region (W.L.Tedders, personal communication). Because many PNC parasitoids are nonhost-specific, arboreal species in New Mexico may experience more PNC damage than Georgia. It also maybe difficult to achieve good, natural PNC control in the Mesilla Valley because of a lack of alternative arboreal host species. However, if hyperparasites are eliminated and nonsprayed fields are chosen for release, native parasitoids from Georgia and Texas may establish and provide good PNC control. Habitat management may prove to be essential to establish exotic parasitoids. In an attempt to control PNC and HSW biologically, the following parasitoids were imported from the W, L. Tedders (Southwestern Fruit Tree Nut Laboratory, Agricultural Research Service, Bryan, Ga.): *Calliephialtes grapholithae(Cress.), Phaneratoma fasciata* (Prov), *Lixophaga mediocris* (Aldrich), *Macrocentrus instabilis* (Muse beck), and *Agathis acrobasidis* (Cushman).

In addition, exotic pink bollworm parasitoids of HSW or PNC were also released. These include *Goniozus pakmanus* (Gordh), *G. legneri* (Gordh), *G. nigrifemur* (Wolcott), and *Trichogrammatoidea bactrae* (Pinto).

There needs to be a concerted effort to release additional parasitoids and monitor establishment and parasitization rates of released species.

Bacillus thuringiensis and insecticidal soap

Bacillus thuringiensis has been labeled for pecan nut casebearer control, Compared to conventional insecticides, *B. thuringiensis* and insecticidal soaps usually give poor control; however, new formulations of *B. thuringiensis* and insecticidal soaps may kill enough pecan nut casebearers to allow inoculative parasitoid populations to increase to sufficiently high levels to control populations.

A significant reduction of PNC populations were obtained in El Paso, Texas in 1990, with high--pressure ground sprayers, using Dipel ES and Dipel 2X plus molasses. Two disadvantages of using *B. thuringiensis* are 1) timing must be precise and 2) *B. thuringiensis* is known to kill some parasitic Hymenopteran (Croft, 1990).

Pheromones

Pheromones have been developed for HSW and PNC and presently are being used in the Mesilla Valley to monitor the spread of HSW and PNC. in the future, pheromones maybe used for control, because pheromones are compatible with biological and cultural control.

Orchard groundcover arthropod evaluation

Orchard groundcover management varies throughout the Mesilla Valley. Some growers prefer to have clean, weed-free floors, while others maintain a natural groundcover. This mayor may not determine the effectiveness of beneficial insects.

The success of a biological control program may be affected by the choice of groundcover. Diversity may not lead automatically to stability (Risch et al., 1983). According to van Emden and Williams (1974), diversity may be defined as a richness of species or structure, This may include such factors as the number of plant species present, plant morphology, height, and time of flowering. There may be associated changes in the microclimate, development of alternate food sources, and shelter for oviposition. Stability often is defined as a fluctuation around an equilibrium level overtime (Murdock, 1975; Risch et al., 1983; van Emden and Williams, 1974).

To establish a biological control agent, the various life-stage requirements of that agent must be met. Habitat selection is one of the first priorities of a predator or parasitoid (Hassel and Southwood, 1978; Huffaker and Messenger, 1976). A structurally and spatially complex environment may be more appealing to a natural enemy than a monoculture (Altieri and Letourneau, 1982; Metcalf and Luckman, 1982). Also, insect species diversity tends to increase as the number of ecological niches increases (Metcalf and Luckman, 1982; Vandermeer, 1981); however, the indiscriminate addition of plants or animals, solely for the purpose of increasing diversity, may lead to destabilization of the system(Murdock, 1975; Risch et al., 1983; van Emden and Williams, 1974). Bugg et al. (1991)demonstrated that, in pecan orchards cover cropped with rye *(Secale cereale* L.) and hairy vetch [*Vicia rillosa* (Roth)], the mean density of aphidophagus coccinellids was 6 times greater than in unmowed resident vegetation and 87 times greater than in mowed grasses and weeds.

At the Fabian Garcia Horticulture Science Farm, New Mexico State Univ., research has been conducted for 2 years on different leguminous and nonleguminous groundcovers to evaluate shade tolerance, plant height, flowering-period (nectar source), and attractiveness to beneficial insects

Year 1 consisted of planting and evaluating crown vetch, rape, wild mustard, indigo, brome, field pea, strawberry clover, common vetch, aslike clover, buckwheat, coffee weed, white sweet clover, red millet, white clover, joint vetch, crimson clover, and two varieties of alfalfa.

Year 2 determined selection of the most promising ground covers for planting in replicated plots, These consisted of seven groundcovers, replicated three times, planted on 25 × 25-ft plots under mature pecan trees. Rape, brome, alfalfa, and white clover proved to be the best candidates for pecan orchard groundcovers, These groundcovers maintained a reservoir of beneficial insects, tolerated shady conditions, and provided a nectar source for parasitoids. The perennial nature of alfalfa and white clovers provided regrowth in subsequent years, and the annual brome proved to have good reseeding potential.

Weekly compound aphid leaf counts were compared to weekly ground cover vacuum samples. The mean number of yellow pecan aphids peaked in early June and black pecan aphids peaked in late August, The mean number of beneficial arthropods from vacuum samples peaked in early to mid-June as expected. Although there were abundant beneficial arthropods in the groundcover at the time pecan aphids were increasing, actual effectiveness was unpredictable.

There is a need to test potential plant cover further and to document arthropod density and diversity, soil compaction, and water penetration under various management practices.

Advantages of cover crops may include the following.

- Provide refugia for beneficial or innocuous insects.
- Provide better water penetration.
- Reduce the need for fertilizer (nitrogen-fixing plants).
- Provide nectar and pollen sources for beneficial insects.
- Reduce soil compaction.
- Reduce insecticide and herbicide use.
- Provide a food source for host insects.

Conclusions

Early indications suggest that pecans in New Mexico may be able to tolerate higher aphid densities than in the southeastern region, A combination of cultural and biological control techniques may reduce the level of PNC, HSW, and aphids to the point at which insecticides may be required only infrequently.

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