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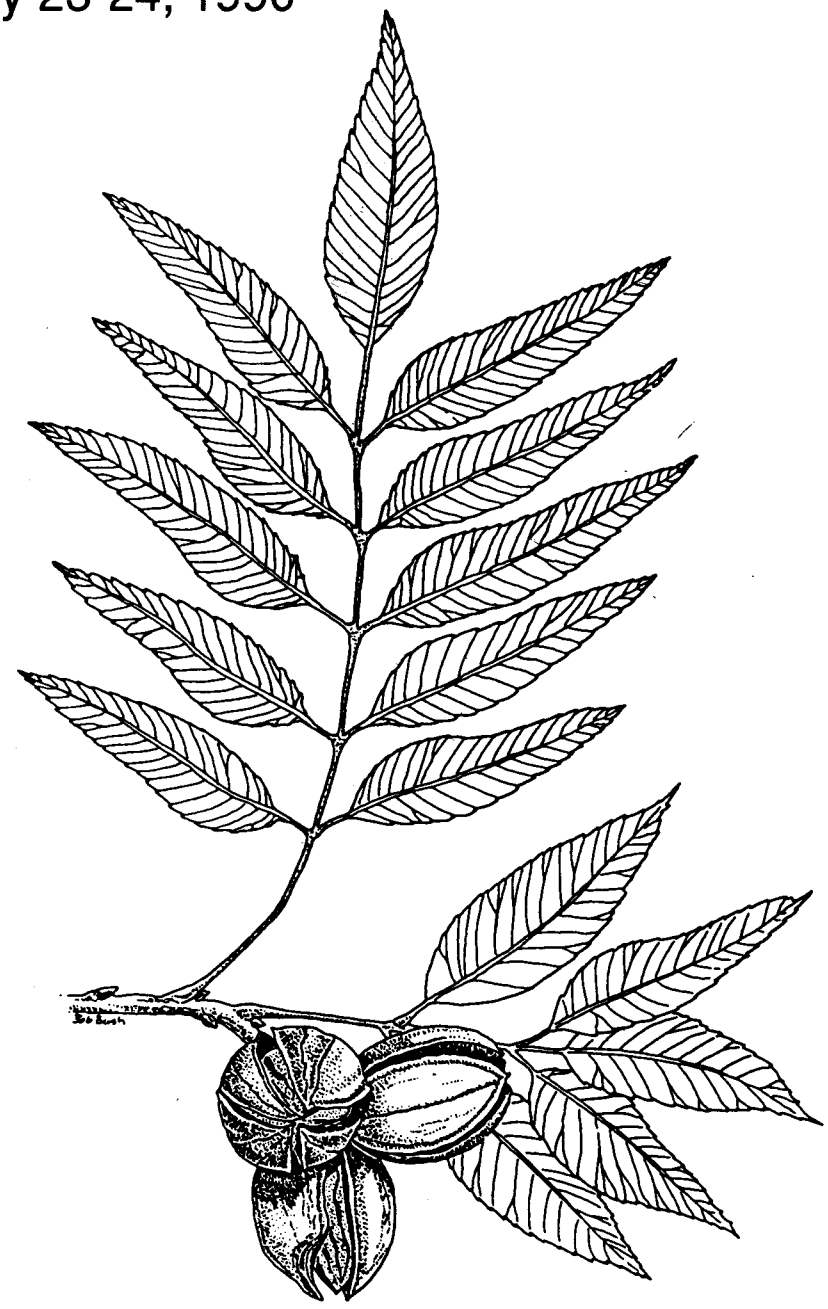

ALTERNATIVE CONTROLS FOR PECAN INSECTS

W. Louis Tedders[1]

The culture of pecans offers an excellent opportunity to demonstrate control of aphids and other pests by a number of alternatives to synthetic chemical sprays. However, it is unlikely that growers can produce pecans consistently and profitably without occasional, strategic use of some pesticides. Acceptance of alternative measures by growers may be difficult but likely will be necessary in pecan culture.

The purpose of this presentation is to describe current research on alternative controls, to introduce several new and/or controversial ideas, and to stimulate discussion of the potential of alternatives for pecan pest control. The concepts presented are not necessarily the opinions of and should not be taken as recommendations by, the USDA-ARS.

Alternative controls for pecan insects will be categorized as chemical, cultural, physical, and biological. These categories are rarely clear-cut, and usually have some overlap and impact on each other. The use of these alternatives by growers will include the integration of various combinations or parts of each. Some of the alternatives may be impractical for use by growers. The development of effective alternatives will prove to be a long and difficult process.

Chemical Alternatives

Broad spectrum pesticides have been beneficial as control agents in past years and the total abandonment of these chemicals is unlikely if not unwise. However, the days of indiscriminate use of broad spectrum pesticides seems to be drawing near. Perhaps reducing the use of chemical pesticides is for the best because the total chemical philosophy creates about as many problems as it solves.

Certain broad spectrum pesticides should still have value, when and if natural controls fail, when parasites of beneficial species must be reduced in numbers because of being overly abundant, when additional information reveals the need for growers to revamp control measures, or when the need arises for other unforeseen reasons. For example, a broad spectrum pesticide application to the orchard floor for control of certain pests may not have the same effect as its application to the tree canopy. This usage has not been fully explored. Perhaps pesticides can be used in this manner that are not permitted for use in the tree canopy.

A need exists for the chemical industry to develop a new arsenal of selective pesticides having minor or moderate effect on non-target species. During development, consideration should be given to the effect on beneficial, as well as pest species. Unfortunately, the costs for developing such chemicals will be great and the probability of rapid success is remote unless standards set by the Environmental Protection Agency and the Food and Drug Administration are relaxed.

Information available about the effects of currently recommended pesticides on the complex of beneficial species on pecans, with the exception of work by Mizell and Schiffhauer (1990), is scant. This type information is vital for development of effective alternatives. Although an excellent guideline based upon existing knowledge (Ellis et al. 1984) is available, improved guidelines will be needed for determining the least harmful pesticides for use during a given situation, for improved pest and beneficial insect sampling techniques, and for determining economic numbers of pests to minimize the use of pesticides. The points of diminishing returns to growers relative to incurred damage by pests when compared with the costs for sprays is the poorest studied area in pecan culture. Also, this information will likely be the most difficult to develop and to convey to growers.

Needs for other important chemical alternatives include the development of semiochemicals such as sex pheromones, kairomones, anti-feeding compounds, baits, repellants, growth inhibitors, sex sterilants, and juvenile hormones, to name a few.

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[1]Research Entomologist, USDA-ARS, Southeastern Fruit & Tree Nut Research Laboratory, Byron, GA 31008

One notable advancement in this area in the recent characterization of the sex pheromone for hickory shuckworm, *Cydia caryana* (Fitch) by M.T. Smith (1985) and the subsequent development of a commercial product for sampling the presence of male shuckworm moths. This work will lead to a considerable reduction in insecticides applied for this pest.

Other important Lepidoptera on pecan that probably have female sex pheromones include pecan bud moth, *Gretchena bolliana* (Slingerland), pecan nut casebearer, *Acrobasis nuxvorella* Neunzig, pecan leaf casebearer, *Acrobasis juglandis* (LeBaron), fall webworm, *Hyphantria cunea* (Drury), and walnut caterpillar, *Datana integerrima* Grote and Robinson. Sex pheromones for each of these could and should be characterized as soon as possible. With the current knowledge of the subject and availability of modern technology, this task should not be very difficult. Characterization of a sex pheromone for the coleopteran pecan weevil, *Curculio caryae* (Horn), may be difficult since several researchers have tried and failed.

Honeydew produced by aphids is a major food source for many insects and its presence may be necessary for attracting and retaining large numbers of many beneficial species. If the chemical attractant in honeydew can be characterized, then this alone may open the door for manipulation of many beneficial species.

Presently there are no baits recommended for use in pecans for control of red imported fire ants, *Solenopsis invicta* Buren. Used properly, baits are very effective. Several baits for fire ants have been developed, including fenoxycarb (Logic), abamectin (Affirm), and hydramethylnon (Amdro), but none have been labeled for pecan culture. Imported fire ants were recently shown to be major predators of certain beneficial species (Tedders 1990) and their their management is necessary for the development of alternative measures.

Cultural Alternatives

Cultural practices used in the pecan orchard that may have an impact on the presence of insect pests include maintaining (1) cover crops to serve as alternate host plants for beneficial species, (2) proper sanitation measures to reduce sites for overwintering larvae, (3) the orchard perimeter to control migrating pests, and (4) proper soil moisture and orchard humidity to provide suitable environments for sporulation of beneficial fungi. Integration of these practices into orchard management may reduce the need of chemical controls.

Cover crops. Most commercial pecan orchards are frequently mowed and routinely sprayed with both herbicides and pesticides. As a result, plants and animals in the orchard ecosystem are reduced by both numbers and diversity. Under these conditions of essentially a monoculture of trees, insect pests with resistance to sprays will increase rapidly because competition by other species and other natural controls are absent. The situation presently exits with aphids, mites, and leaf miners on pecans. Theoretically, the monoculture effect can be reduced by planting within or around the orchard, ground cover crops, perennial shrubs, and various annual plants which serve as sources for alternate supplies of food and refuge for beneficial species. Foods there include insect prey, honeydew, extrafloral and floral nectary secretions, and pollen. The preservation and enhancement of selected weed species can have similar effects.

Several winter cover crops (Tedders 1983), summer cover crops (Bugg and Dutcher 1988), and crape myrtle shrub (Mizell and Schiffhauer 1987) have been investigated for this purpose. Promising winter covers include vetch, clover, and alfalfa spp., Austrian winter peas, and English peas. Summer covers include joint vetch, *Sesbania* sp., cowpea, *Sorghum* sp., and buckwheat. Of these plants hairy vetch, *Vicia villosa* Roth, common vetch *Vicia sativa* L., crimson clover, *Trifolium incarnatum* L., *Sesbania exaltata* (Rafinesque-Schmaltz), and crape myrtle, *Lagerstroemia indica* L. seem to be the most promising.

Planting hairy vetch as a cover crop to provide a niche for the development and reproduction of ladybeetles, including *Hippodamia convergens* (Guerin-Meneville) and *Coccinella septempunctata* L. is an example of a cultural alternative to chemicals for controlling aphids. When aphid prey on vetch are depleted, the beetles migrate into pecan tree, and there consume, aphids, mites, and other pests. It is likely that over time these beetles move back and forth between trees and ground cover. In some instances nectar and pollen of certain plants may also help attract and retain beneficials within the orchard vicinity during the absence of prey on pecan trees. Also, cover crops of legumes are capable of supplying at least part of the nitrogen requirements of pecans (White et al. 1981). Alfalfa, crimson clover and other cover crops hold

promise for producing hay or forage, seed, and nectar for honey bees, all of which could supplement the grower's income. Winter cover crops improve the water and oxygen permeability of soil and the remaining mulch reduces soil erosion and preserves soil moisture. Cover crops and mulch also improve the orchard environment for many non insect arthropod and vertebrate predators. In addition to cultivated crops, a number of natural weed species including *Erigeron canadensis* L. and *Solidago* spp. are promising as food and refuge sources for beneficial spp.

Orchard Sanitation. Sanitation is a technique that has been badly neglected by pecan researchers and growers. Studies conducted during the 1940's indicated that hickory shuckworm infestations were reduced 50% by plowing into the soil, shucks infested with overwintering larvae (Monzette 1941). Presently plowing and tilling pecan orchards is not practiced by most growers. However, most pecan shucks in mechanically harvested orchards are passed through machinery during nut harvest operations and then returned to the orchard floor. The development of harvest equipment to destroy infested shucks should not be difficult. Conversely, equipment could be developed to collect infested shucks, which also contain parasitized shuckworms. These could provide a source for thousands of parasites including Tachinidae, Ichneumonidae and Braconidae. The shucks could be stored in cages to allow emergence of the parasites during the time period that is slightly different from that of shuckworm moths. Collected parasites could be released back into the orchard and the remaining shuckworms could then be destroyed.

With decreased use of insecticides, pecan growers will likely see an increase in the number of insect species that attack limbs branches and twigs of pecan trees. These pests include longhorned borers (Cerambycidae), metallic woodborers (Buprestidae), false powderpost beetles (Bostrichidae), and engraver or bark beetles (Scolytidae). Many of these species complete their life cycle within dead or weakened limbs that remain in trees and within branches and twigs that have fallen to the ground. Dead and weakened limbs should be pruned from the trees and branches and twigs should be gathered. Both should then be removed from the orchard and burned or otherwise destroyed. As these insects generally attack weakened and stressed trees, the best preventative measure is to keep the trees in a vigorous and healthy condition through the use of an adequate fertilizer and irrigation program.

Orchard Perimeter. Many insect pests, especially those attacking weakened limbs and a number of weevil species, breed in nearby hardwood stands and then move into adjacent orchards for feeding. Steps should be taken to remove the outside sources of these pests. Good examples are the migration of the pecan curculio, *Conotrachelus hicoriae* (Schoof) and *Conotrachelus schoofi* Papp from wild hickory stands and from fence rows. These usually attack the shoots and fruits of border trees of orchards most severely.

Other pest species that migrate into pecan orchards include stink bugs (Pentatomidae) and leaffooted bugs (Coreidae) which move from matured vegetable and field crops as well as from weed fields to alternate host plants in late summer. Pecan fruits are alternate hosts for many of these pests and thus receive significant damage each year. Here again, fruits in border trees usually receive the most damage. Preferred host plants for stink bugs and leaffooted bugs can be planted adjacent to pecan orchards to attract migrating bugs and to arrest future movement. There the arrested bugs can be killed with pesticides to prevent their future movement into pecans. The alternative use of "trap crops" has been studied for bug control on other agricultural crops and needs investigation for use with pecans. Blacklight traps placed around the periphery of orchards may be used to survey for their presence and may reduce their damage.

Irrigation

Irrigation is known to enhance the production of pecans but it has not been studied for the effect on pecan pests. For example, irrigating to raise the moisture level of orchard soil may increase the incidence of introduced or natural diseases of pests. Many important entomopathogens germinate and sporulate only in the presence of high humidity. Frequently after several days of extended rain and cloudiness, many species of dead insects having heavy sporulation of *Beauveria bassiana* (Balsomo) Vuillemin can be found within the mulch and litter on the orchard floor and beneath bark on the trees. Considerable background research has been done with the entomopathogens *B. bassiana* and *Metarhizium anisopliae* (Metschnikoff) Sorokin against pecan weevils (Tedders 1985). Results indicated that these fungi could effectively control weevils under the proper conditions. The factor apparently limiting the usefulness and effectiveness of these fungi is adequate moisture to insure timely sporulation and spore germination.

One hypothetical use of these fungi is to infect pest insects such as alfalfa weevil, *Hypera postica* (Gyllenhal) on vetch or alfalfa cover crops growing in the orchards. Sporulating cadavers of these weevils could then serve to raise the inoculum level in the orchard for alternative control measures of pecan weevils.

Irrigation may also be use to disseminate entomophagous nematodes including *Neoaplectana carpocapsae* Weiser (Tedders et al. 1973) and *Heterorhabditis heliothidis* (Nyczepir 1989). Both species attack pecan weevil larvae and are being investigated at this time. A moist environment associated with irrigation likely would enhance their survival and effectiveness.

Physical Alternatives

Physical methods are generally considered to be engineered devices such as traps and barriers. These instruments are usually constructed to utilize heat, light, sound, or air for repelling, trapping or killing pests. Blacklight traps are a good example and have been used to suppress hickory shuckworm populations in pecan orchards (Tedders et al. 1972) but the expense required for large numbers of blacklight traps, wiring, and energy may not be cost effective for large producers. Also examining trap collections for small or delicate insects is difficult. However, blacklight traps may be useful for control purposes for growers with small orchards or homeowners with only a few trees. Blacklight traps of various designs are now available through many department and hardware stores. Blacklight traps can be effectively used as survey tools by large growers to detect a number of important pecan pests including fall webworm, walnut caterpillar, may beetles (Scarabaeidae), stink bugs, leaffooted bugs, and longhorned beetles. Although difficult to use as control devices, blacklight traps are very good tools for surveying for pecan nut casebearer, fall webworm and pecan leaf casebearer. Until pheromone traps are developed for some of these species, blacklight traps may be the best detection method that is available. With reduced usage of broad spectrum pesticides, some of the above listed pests will likely return to prominence and growers will need detection devices.

Barriers also may have a place as physical alternatives to chemical sprays in control of pests. Research is needed on the effects of various barriers around tree trunks for capturing, killing, or preventing the migration of pecan weevil adults up tree trunks. While trunk barriers alone may not provide a high degree of weevil control, this technique could significantly lessen their attacks.

Research is also required to develop physical barriers on the soil beneath trees to prevent entry of weevil larvae and the emergence of weevil adults. Soil coverings of diatomaceous earth, fiberglass, or inexpensive screen beneath trees may serve as barriers against weevil larvae and adults. Pecan weevils have long been considered one of the most difficult pest problems for growers and they are a major stop-gap in the development of a good alternative control program for aphids. Developing an effective alternative method for control of pecan weevil will demand a long-term research effort because of the 2 and 3 year life cycle of this pest.

Also studies are needed on the use of barriers to prevent ant species from moving into pecan trees. Red imported fire ants were demonstrated recently to move into pecan trees and forage on the eggs, larvae, and pupae of the green lacewing, *Chrysoperla rufilabris* (Burmeister) and the puparia of the syrphid, *Allograpta obliqua* (Say) (Tedders et al. 1990). Lacewings and syrphids are important natural enemies of the aphids on pecans. This behavior by fire ants results in the increase of pecan aphids. Aphids in turn produce large amounts of honeydew. Fire ants collect honeydew which also is a major part of their food supply. Barriers to prevent the foraging on pecans by red imported fire ants would provide logical alternatives for their management. Barriers on fruit trees against various ant species are commonly used in other parts of the world and especially in South Africa (Samways and Tate 1984).

Presently we are studying the effects of light on the development of sexual forms of pecan aphids. Hopefully we will find that interruption or alteration of the scotoperiod will interfere with the normal development of sexual forms during September and October. Sexuals of female aphids lay eggs, which are overwintering forms. If egg production can be prevented then cold weather in November should kill the remaining asexuals, providing control during the following spring.

BIOLOGICAL ALTERNATIVES

The production and development of beneficial species on cover crops has already been discussed. The use of cover crops may be enhanced by liberating commercially available beneficial

species such as ladybeetles (*H. convergens*), lacewings (*Chrysoperla* spp.), and parasitic wasps (*Trichogramma* spp.) within the orchard to insure a timely start and to supplement the naturally occurring population of these species.

Paper wasps (Polistes spp.) are important predators of various insect pests especially foliar feeding caterpillars, and their habitat is easily improved in orchards. Wasps can be increased in numbers by stationing small wooden boxes with open bottoms throughout the orchard. The boxes can be attached to wooden poles or to tree trunks. Wasps build their nests in the boxes without further encouragement.

While imported fire ants may create aphid and scale insect problems (Tedders et al. 1990), they are very efficient predators known to attack many insects including pecan weevil larvae (Dutcher and Sheppard 1981). With the present availability of fire ants in most southeastern pecan orchards, these predators may be manipulated for use against weevils, shuckworms, certain leafminers and possibly other pests. Barriers designed to prevent fire ant movement into trees would be a means of manipulating the behavior of this potential pest for control of a number of insects on the orchard floor.

Certain species of insectivorous birds including bluebirds and swallows may be increased within or near orchards by providing nesting boxes and water (Tedders 1985). Other bird possibilities include domesticated fowl such as chickens, turkeys, and Guinea fowl as predators of pecan weevils. However, the use of large numbers of domesticated fowl may cause bacterial contamination of nuts from fecal matter.

Significant research has been devoted to the release and establishment of exotic beneficial insects, especially ladybeetles for pecan aphid control. Species evaluated to date include *Harmonia axyridis* Pallas from Japan, *Harmonia conformis* (Boisduval) from Australia, *Propylea japonica* (Thunberg) from South Korea, *Calvia quatuordecimguttata* L. from Japan, *Hippodamia variegata* (Goeze) (as *Adonia variegata*) from the USSR and *Coccinella septempunctata* L. from New Jersey (European origin). Only the latter species became established and provides minimal control of aphids on pecans (Tedders and Angalet 1981). As of 1989, APHIS/USDA recovered *C. septempunctata* from most states east of the Rocky Mountains and they released the species in Idaho, Nevada, California, Arizona, Utah, and Washington during 1989.

Trioxys pallidus (Haliday), a parasite of the walnut aphid, *Chromaphis juglandicola* (Kaltenbach), and *Trioxys complanatus* Quilis, a parasite of the spotted alfalfa aphid, *Therioaphis maculata* (Buckton) from California were released at Byron, Georgia several years ago as parasites of the blackmargined aphid, *Monellia caryella* (Fitch), the yellow pecan aphid, *Monelliopsis pecanis* Bissell, and the black pecan aphid, *Melanocallis caryaefoliae* (Davis) (Tedders 1977). Thereafter a new species, *Trioxys monelliopsis* Stary and Marsh, became established at the release site. It is likely that *T. monelliopsis* is a biotype of one of the original releases since it was found only at Byron, GA for many years. It is also possible that it is a hybrid resulting from a cross between *T. pallidus* or *T. complanatus* with a local species. *T. monelliopsis* fluctuates in numbers each year and provides minimal control of aphids on pecans.

The aphid parasite *Aphelinus perpallidus* Gahan occurs in fairly large numbers throughout the pecan growing region. This species is very tolerant of many insecticides (Mizell and Schiffhauer 1990) and is a prime candidate for manipulation and enhancement in the field.

Pecan aphids and the pecan leaf scorch mite, *Eotetranchus hicoriae* (McGregor), represent a major threat to pecan growers. Both are insecticide-induced species that are normally held in check by natural controls. Aphid numbers should decrease if applications of broad spectrum insecticides can be reduced and fire ants are controlled. Aphids and mites have high reproductive rates and rapid life cycles which enhance their genetic selection, resulting in tolerance or resistance to frequently used insecticides. Their greatest numbers occur naturally during the same time period as pecan weevils. To further complicate the aphid-mite dilemma, carbaryl, the only insecticide that effectively controls pecan weevils, is a broad spectrum pesticide. Aphids and mites are resistant to carbaryl and serious outbreaks usually occur after its use (Dutcher and Payne 1983). The migration of new beneficial species into a carbaryl treated orchard is of little consequence since these are unable to consume more aphids or mites than are being produced. Also, carbaryl residues may continue to kill immigrant beneficials for a number of days. Aphid and mite numbers eventually diminish as a result of crowding, competition for food, the urge to migrate, and the conditioning or death of tree foliage. Developing an alternative control for

pecan weevils is imperative to designing alternative control for aphids, mites and other pecan pests during the latter part of the growing season. This problem is among the most needed research for the culture of pecans.

The preceding information represents only a minute part of the potential for alternative measures for the pecan culture. There are literally hundreds of other possibilities, limited only by the imagination of pecan researchers and the number of people available to do the work.

In closing, one of the greatest threats to the development of workable alternatives for pecans is that of overzealous opportunists in the commercial alternative control business. Nothing will shatter the confidence of growers more quickly than the sale of systems of organisms that have little or no chance of working. There already is evidence that this may be happening. On the other hand, most commercial alternative control businesses have the best interests of the pecan industry at heart and most of these people are supportive, cooperative, and helpful.

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