Pest Management Strategic Plan

for

Pecans

in the

Southeastern U.S.

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PEST MANAGEMENT NEEDS IN SOUTHEASTERN PECANS

BACKGROUND

Pecan production in the Southeastern U.S. encompasses ca. 265,000 acres, 54% of the national total. Georgia and Texas contain ca. 60% of the national acreage. However, it must be noted that only the eastern part of Texas is considered as part of the Southeast region.

From 1993 - 1998, the Southeast region produced ca. 63% of the nations crop.

Pecans are a perennial crop, requiring at least 20 years to recoup establishment costs in the Southeast. Trees will produce for more than 75 years. Most commercial orchards are planted to improved varieties.

CRITICAL ISSUES

Key Pests

The primary disease pest of pecans is pecan scab, caused by the fungus *Cladosporium caryigenum.* The fungus attacks leaves, stems and developing fruit, and is active throughout the growing season. Left unchecked, scab can cause near total crop loss.

Pecan nut casebearer (PCNB), pecan weevil (PW), and hickory shuckworm (HSW) are the key pests of the nuts. Key pests of foliage include black pecan aphid (BPA), black-margined aphid, and yellow pecan aphid (YA).

More sporadic, but sometimes serious, pests include pecan scorch mite, stem phylloxera, stink bugs, and nut curculio.

The most difficult weed pest for pecan growers is mistletoe. Because no herbicides are labeled for mistletoe control, pruning is the only remedy available to pecan growers. Orchard floor management includes the use of broad spectrum herbicides, mowing, and shading of the orchard floor. Left unchecked, the variety of annual and perennial weeds growing under the trees can reduce tree growth and yield by 50% or more from competition for water and nutrients. Harvest efficiency is also compromised if the orchard floor weeds are not managed.

Key Pest Management Issues

Current management practices for scab control consist of fungicide sprays, either on a 10-14 day schedule or based on a predictive model, AU-Pecan, that is weather-based. Sprays begin at bud break and continue through the season until the nuts have reached mature size.

The biggest obstacle to good scab control is spray coverage. Even the best sprayer, skillfully operated under ideal conditions, cannot always provide complete coverage of all the foliage of large tall trees.

Because scab control is preventive (none of the available fungicides can eliminate the fungus once infection has begun), the disease control program often drives other aspects of pest management in the pecan crop. Sprayer availability and time limitations can lead to the necessity to compromise on ideal timing of treatments for insect pests, since insect pests can be controlled after damage has begun. Tank mixing of insecticides with fungicides is a routine practice.

Management of pecan weevil requires application of insecticides, generally either carbaryl (Sevin) or one of the pyrethroids, at 10 - 14 day (Sevin) or 5 - 7 day (pyrethroids) intervals. Carbaryl is a carbamate insecticide, and the future of that class of chemicals is in doubt. Pyrethroid insecticides have a tendency to induce outbreaks of mites and aphids if used too early or too often.

Aphid control relies largely on foliar applications of insecticides, with a small (<10%) proportion of the total acreage treated with systemics, either Temik or Admire. Foliar insecticides include older materials such as the organo-phosphate (OP) insecticides dimethoate and chlorpyrifos (Lorsban), a variety of pyrethroids, and newer, more selective materials such as imidacloprid (Provado), and pymetrozine (Fulfill).

As with disease control, the biggest obstacle to good aphid control seems to be spray coverage. Even with the systemic action of Provado, Centric and Fulfill, complete coverage is still essential. Large trees and improperly set-up and operated spray equipment invariably lead to poor control.

Pecan nut casebearer and hickory shuckworm, two lepidopterous pests, are more sporadic and localized problems than pecan weevil and the aphid complex, but they cause significant damage and losses every year. Timing of insecticide applications is critical for these multi-voltine pests. Pheromone traps, coupled with scouting for first signs of damage, are very effective at detecting PNCB moth flights. These traps allow growers to apply insecticides in a timely fashion and minimize damage. Traps (both pheromone and light traps) are available for HSW, but they are much less effective and therefore, less useful. Currently, the best method of detecting HSW is scouting for signs of damage to nuts that drop from the trees in mid-season.

Both PNCB and HSW can be controlled effectively with available insecticides including OP's, pyrethroids, and newer more selective materials such as methoxyfenozide (Intrepid). Another insect growth regulator, diflubenzuron (Dimilin) has recently been registered as well. As with aphid control, application of OP's and pyrethroids at mid-season is discouraged because of the potential for inducing aphid and mite outbreaks.

While mistletoe is the only weed pest that affects pecan trees directly, no herbicides are labeled and effective for mistletoe control. Most weed management is aimed at a variety of woody and herbaceous plants that grow on the orchard floor, competing with the trees for water and nutrients. The vast majority of managed orchards employ some sort of total weed control in a strip along the rows of trees coupled with mowing of the row middles to facilitate harvest and

other orchard operations. The bare-ground strip is usually maintained with broad-spectrum herbicides, both pre- and post emergence; tilling of the strip is used only occasionally because of effects on the root system of the trees.

Southeastern Pecan Pest Overview
Insect & Mite Pests

Pecan Weevil (PW), pecan nut casebearer (PCNB) and hickory shuckworm (HSW) are the key pests attacking the nuts. All can cause serious loss of yield, PCNB by attacking developing nuts early in the season and PW by attacking in late season, after the nuts have reached mature size. Hickory shuckworm attacks developing nuts in mid-season and again in late season, after the nuts have reached mature size. Although none is present in every area of the southeastern production region, these pests are widespread and considered serious pests in all states.

Current IPM Programs for PW include trapping of emerging adults in July and August, and spraying with carbaryl (Sevin) or Fury at 10 - 14 day intervals (Sevin) or 5 -7 day (Fury) intervals if soil conditions are good for weevil emergence.
Current management systems for PCNB include pheromone traps to monitor moth flights and time insecticide applications, scouting programs to confirm presence of larvae in the orchard, and a variety of insecticides that are very effective at controlling the pest. Most commonly used insecticides include chlorpyrifos (Lorsban), zeta-cypermethrin (Fury), and tebufenozide (Confirm), an insect growth regulator (IGR).

Attack by HSW in mid-season causes nuts to drop from the tree. After nuts reach mature size, affected nuts do not drop but feeding by developing larvae affects kernel development and causes the shuck to stick, resulting in reduced quality and losses at the shelling plant. Both mid - and late-season HSW population are controlled by insecticide sprays (Lorsban primarily, also Fury and Intrepid) in June and August.

More sporadic but sometimes serious nut pests include nut curculio (NC), and a complex of stink bugs. Stink bugs are primarily late-season pests, migrating into the orchard from surrounding crops and woodlands, and attacking the nuts even after shell hardening. Their mobility makes spray timing difficult. Attack by NC causes nuts to drop in mid season. Control is difficult because the weevils move into orchards from surrounding woodlands and usually are not detected until nuts begin to drop, at which time much of the damage may already be done. Insecticide sprays (Lorsban, Fury) will control NC and reduce damage if detected early.

The aphid complex, including yellow pecan aphid (YPA), black margined aphid (BMA), and black pecan aphid (BPA) are the most widespread and serious of the foliage-attacking pests. Of these, BPA is the most damaging. The main damage from YPA and BMA is caused by the build-up of sooty mold on the honeydew they excrete, which blocks photosynthesis and reduces tree vigor and productivity. Damage from BPA feeding is direct, with chlorotic spotting produced at the feeding site and leaf drop resulting from the feeding of only a few individuals per leaflet. Extensive defoliation can result from BPA outbreaks. This usually occurs in late

season and reduces the tree's ability to store carbohydrates for the following season, reducing yield in the next crop year.

Current IPM programs for aphid control rely on insecticide applications triggered by regular scouting of the orchards. Primary insecticides include organic-phosphates (OP's) Lorsban and dimethoate, the neonicotinyls, imidacloprid (Provado) and thiamethoxan (Centric) and the pyrethroid (Fury). The carbamate Temik (aldicarb) is applied to the soil as a systemic on a small percentage of the acreage, as is another formulation of imidacloprid (Admire).

Pecan leaf scorch mite (PLSM) is a sporadic but sometimes serious foliar pest that can cause extensive defoliation in late season if populations reach outbreak levels. Hot, dry weather favors mite buildup, and populations may flare following applications of certain insecticides, most notably Sevin and pyrethroids. Mites can be controlled effectively with the miticides dicofol (Kelthane) or fenbutatin-oxide (Vendex).

Diseases

Scab is the primary foliar disease of pecan, and the fungus will also attack nuts and twigs. Effective control can be achieved with a variety of fungicides and combinations of fungicides, but application must begin at bud-break and continue at 10-14 day intervals until the nuts reach mature size and there are no juvenile leaves, usually in late August. Reduction in the frequency of fungicide sprays can be realized by use of a weather-based predictive model, AU-Pecan, available over the internet.

Other diseases of pecan are sporadic, though they sometimes require treatment to prevent significant loss of yield or quality. These treatments are used mostly when scab programs are complete, after shell hardening, since the fungicides used in scab management also provide control for other diseases.

Weeds

With no effective alternatives available, pecan growers control mistletoe by pruning. Not only is this operation dangerous to farm workers, the pruning is often severe enough to reduce yields for more than one season. The process of hand-pruning affected limbs, and collecting and disposing of the debris, is very labor intensive and expensive.

Orchard floor management usually involves application of both pre-emergence and post-emergence herbicides to maintain a bare-ground strip along the tree row. Generally, two or three herbicide applications per year are required. Row middles are managed by mowing in most cases, although reduced rates of herbicides are used by some growers.

OUTLINE OF PLAN

Pest-by-Pest Profiles. *Pest status, damage and biology, along with current and potential control options, are outlined in the pest-by-pest profiles that follow, with particular attention to currently used organophosphate and carbamate insecticides and B1-B2 carcinogens. Also noted are other control options, chemical and non-chemical, new, non-registered pesticide chemistries in development, and a "TO DO" list of research, regulatory and educational needs.*

Insects and Mites

1) Pecan Nut Casebearer (PNCB)

- PCNB is the key nut pest throughout the region.
- Overwintering generation larvae feed on bud scales and cause minimal damage. Moths of this generation lay eggs on small nutlets, and larvae may destroy several nutlets or an entire cluster. Eggs of the second generation, in mid-summer, are laid on mid-sized nuts. These larvae typically damage only one nut each, and so are less important overall.

Current Management Options

- Pheromone traps are effective tools for detecting moth flight, and allow growers to focus scouting efforts and optimize insecticide timing.
- Well-timed insecticide applications, aimed at the first (spring) generation larvae, are very effective at reducing or eliminating losses from PNCB. Older organophosphate materials such as chlorpyrifos are effective; as are several pyrethroids, but these materials tend to lead to outbreaks of aphids and mites. Newer insect growth regulators (IGRs) now available include tebufenozide (Confirm), methoxyfenozide (Intrepid), and diflubenzuron (Dimilin). These materials are very effective and have little impact on the beneficial insect complex that helps suppress aphid and mite populations.

Research Needs

- The relationship between pheromone trap catches and subsequent damage levels is not clear.
- The complex of natural enemies attacking PNCB eggs and larvae is not well known. It seems likely that this complex is the reason that trap catches do not always correlate well with damage, and more research is needed to characterize the benefits a grower can expect from the presence of various beneficials in the orchard. This information could be used to interpret scouting reports and make better decisions on the need for and timing of insecticide applications.

2) Pecan Weevil (PW)

- Key pest throughout the region, although not present in all orchards in any area.
- Potential "export issue", in that western areas (including Mexico) do not have this pest and do not want it.
- The weevil has a 1- , 2-, or 3- year life cycle. Most complete development in two years. Adults emerge in late summer, about the time nuts are maturing and fly or crawl into the tree canopy. Adult feeding causes younger nuts to drop. More mature nuts remain on the tree, but are ruined and cause quality losses at the shelling plant after harvest. Once maturing nuts reach the ½ shell hardened stage, females begin laying eggs in the nuts. Developing larvae feed on the kernel, destroying it, and emerge to drop to the ground. They dig in the soil and pupate, emerging as adults 1, 2, or 3 years later.

Current Management Options

- Adult weevil emergence can be monitored effectively using Tedders-type silhouette traps or circle-type traps on the trees. Emergence coincides with periods of adequate soil moisture and extended dry weather reduces or prevents weevils from digging out of the ground.
- Adults can be controlled by application of carbaryl (Sevin), a carbamate, and by several pyrethroid insecticides including Fury, Mustang, and Ammo. Sprays must be re-applied every 10-14 days (Sevin) or 5-7 days (pyrethroids) as long as weevils continue emerging, or until the shucks split, a period of 6 - 8 weeks.
- All of the currently available weevil insecticides have a strong tendency to produce outbreaks of aphids and scorch mites, requiring additional insecticide / miticide applications.

Research Needs

- More research is needed on the potential of nematodes and microbial products for control of larvae and/or adult weevils in the soil.
- Research is needed on potential of targeted sprays applied to the tree trunk. This could particularly benefit small growers, homeowners, and those orchards where insecticidal drift onto adjacent property is important.
- More information on basic biology and behavior could lead to better timing and placement of insecticides.

Regulatory Needs

- Loss of Sevin would be a serious blow and would lead to an increase in pest status of aphids and mites.

3) Hickory Shuckworm (HSW)

- Key nut pest throughout the region, but severity of problem varies widely within the region.
- Moths begin laying eggs on nuts in June with 3 - 4 generations in most of the region. The problem becomes worse with each successive generation as the population builds. Before shell hardening, larvae tunnel into the nuts, causing them to drop. After the shells harden, larvae tunnel in the shucks and prevent kernels from developing properly. Injured portions of the shuck stick to the shell, interfering with processing.

Current Management Options

- Both pheromone and blacklight traps are available to monitor moth flight, but neither type has yet proven efficient at detecting activity or preventing damage.
- Damaged nuts often have a whitish stain around the entrance hole which scouts can easily recognize.
- Organophosphates chlorpyrifos and imidan are effective, as is carbaryl (Sevin), a carbamate. Pyrethroids are also effective. Spinosad (Spintor), a newer bacteria-based product, is effective but more expensive than other products. IGRs are very effective. Late season populations are controlled by weevil sprays if used. Otherwise, infested orchards require two treatments, 10 -14 days apart in late summer to prevent damage.

Research Needs

- Better monitoring tools are needed to improve detection and timing of insecticides. Methods for improving use of known pheromone must be developed.
- There is potential for improving biological control, but more information is needed on the natural enemy complex in pecan orchards.

4) Black Pecan Aphid (BPA)

- Key foliage pest throughout the region.
- Aphids sometimes overwinter in bark crevices. Wingless females known as stem mothers hatch in early spring, and move out to the opening buds and feed until fully grown. As adults, they give birth without mating to living young, which are also all female. Under some conditions and in some generations, winged females are produced that can fly to different trees. Reproduction is very fast, and in warm weather BPA populations can double in less than three days. Feeding of BPA causes necrotic spots on pecan leaflets, and 8 - 10 feeding spots will cause a leaflet to drop. Complete defoliation is possible under heavy pressure. Populations usually peak in late summer or early fall, but damage can occur at any time.

Current Management Options

- Organophosphate insecticides chlorpyrifos, dimethoate, and phosmet (Imidan) are effective foliar sprays. Pyrethroids are less effective.

- Systemic insecticides aldicarb (Temik) and imidacloprid (Admire) are available, but treatment is expensive.
- Newer nicotinyls include imidacloprid (Provado) and thiamethoxam (Centric). These provide systemic activity as foliar sprays.
- Pyrproxifen (Fulfill) is a selective insecticide with a unique mode of action that disrupts feeding of aphids and related insects, but has little effect on beneficial insects.
- Most applications against BPA are tank mixes of more than one of these insecticides, with a foliar systemic (Provado, Centric, or Fulfill) plus either an organophosphate, pyrethroid, or a surfactant such as Kinetic.

Research Needs

- Research into manipulation of natural enemies, including impact of newer insecticides on beneficial insects and mites.
- Development of microbial products for aphid control.
- Reduction of fungicide sprays to increase impact of entomopathogenic fungi.
- Monitoring of resistance developing to organophosphate and nicotinyl insecticides.
- Impact of fertility and irrigation on aphid tolerance by trees.

Regulatory Concerns

- Loss of organophosphate insecticides will make resistance management difficult.

5) Black-Margined Aphid and Yellow Pecan Aphid (YA)

- Key pest throughout the region.
- The two species have similar biology and behavior, and impact is essentially the same.
- Primary damage is due to sooty mold growing on the sugary liquid the aphids excrete. This sooty mold can cover the leaf surface, interfering with photosynthesis. Heavy infestations can contribute directly to tree stress, especially in late season.

Current Management Options

- Yellow aphids are controlled by sprays aimed primarily at BPA, including systemic application of aldicarb or imidacloprid.
- Treatments for YA only are almost always one of the nicotinyls (imidacloprid or thiamethioxam) or pyrproxifen.

Research Needs

- Research into manipulation of natural enemies, including impact of newer insecticides on beneficial insects and mites.
- Development of microbial products for aphid control.
- Reduction of fungicide sprays to increase impact of entomopathogenic fungi.
- Monitoring of resistance developing to organophosphate and nicotinyl insecticides.

- Impact of fertility and irrigation on aphid tolerance by trees.

6) Pecan Leaf Scorch Mite (PLSM)

- A sporadic and sometimes severe pest throughout the region. Problems tend to be worse in drier years.
- Mites overwinter on the trees, emerging in spring and moving to new leaves. Populations build throughout the year, and usually do not reach treatable levels in most orchards. Defoliating outbreaks can occur, usually in late season.

Current Management Options

- Four materials are currently registered for mite control in pecans. Two, dicofol and fenbutatin, are more than 40 years old and currently undergoing EPA review. Another, hexythiazox, is primarily an ovicide and is not used alone. The only recent registration is for bifenazate (Acramite), but it is priced for use on vegetables and, at around $60/acre, is too expensive for most pecan growers.

Research Needs

- Microbial materials may hold some promise for mite control.
- Predatory mites have shown promise for bio-control, but more research is needed.

Regulatory Concerns

- Review of one of the most commonly used materials, dicofol, will almost certainly lead to reduced rates and extended re-entry intervals, making effective use problematic.
- There are many effective miticides that are not currently labeled in pecan. The IR-4 program should consider this problem.

7) Nut Curculio (NC)

- Occasional pest throughout the region, but occurrence is scattered.
- Control is difficult, because the damage is often done and the larvae is inside the nut before NC is detected in an orchard.
- Nut curculio attacks immature nuts from late June through August, with most damage done by mid-July. Adult females puncture nuts and lay a single egg inside. The larvae consume the developing kernel, causing the nut to drop. The larvae continue feeding in the nut on the ground, and then leaves the nut to pupate in the soil.

Current Management Options

- Detection of punctures and/or larvae in dropped nuts is the only indication of NC infestation.
- Only adults can be targeted by current insecticides, as the larvae are protected inside the nut. Chlorpyrifos is the most commonly used insecticide, but several pyrethroids are also effective. Use of pyrethroids in mid-season is strongly discouraged, due to the tendency of such applications to aggravate aphid and mite problems.

Research Needs

- There is an acute need for better tools to monitor NC activity in an orchard.
- Microbial materials and nematodes have potential for controlling the larvae in the soil or adults as they emerge, but more research is needed

8) Stinkbug Complex

Includes Southern Green Stinkbug (*Nezara viridula*), Brown Stinkbug (*Euscristus servus*), *Euschistus tristigmus*, Green Stinkbug (*Acrosternum hilare*), *Leptoglossus phyllopus*, and others

- Stinkbugs attacking pecan include several species in the heteropteran families Pentatomidae and Coreidae.
- Stinkbugs may be present in pecan orchards throughout the year, but adults are highly mobile. Their presence may be transitory. They do not normally reproduce on the trees, although they may use herbaceous weeds on the orchard floor.
- Feeding on immature nuts causes them to drop. Feeding on mature nuts causes spots on the kernel which cannot be detected until shelling. The bugs can feed through hardened shells, even after harvest.

Current Management Options

- Stinkbugs are effectively controlled by application of pyrethroid insecticides.

Research Needs

- Basic research into the biology and behavior of stinkbugs is needed, especially involving seasonal movement from other crops.
- There is potential to develop a trap-crop system to detect and control migratory adults.

9) Spittlebug

- Spittlebugs are common in pecan orchards throughout the summer, with populations higher in wetter years. This pest is an enigma, as no firm thresholds have been established and well managed orchards can tolerate extremely high numbers with little apparent damage.

- Spittlebugs overwinter as eggs in slits in stems. Nymphs appear soon after nut set and move onto the new growth and new nut clusters.

Current Management Options

- Spittlebugs have most often been controlled with chlorpyrifos, but the newer nicotinyls are extremely effective and have little impact on beneficials.

Research Needs

- Research is needed to determine treatment thresholds.

10) Foliage-Feeding Caterpillars

- This encompasses many species of caterpillars that commonly feed on pecan including walnut caterpillar, *Datana integerima*; Fall webworm, *Hyphantria cunea*; Pecan cigar casebearer, *Coleophora laticornella*; Pecan catocala, *Catocala obtuse* or *C. viduata*; and Pecan budmoth, *Gretchina bolliana*.
- Serious damage from caterpillar feeding on foliage is rare, although virtually all orchards have some level of infestation from one or more of these every year.

Current Management Options

- All caterpillars are effectively controlled by any of the organophosphate, carbamate, or pyrethroid insecticides used for other pests. Spinosad (Spintor) is very effective and somewhat less disruptive of beneficials, but more expensive. The IGRs tebufenozide and methoxyfenozide are effective and affect virtually nothing except caterpillars.

Research Needs

- More rain-fast formulations of *Bacillus thurengiensis* products would make this "organic" option viable for commercial use.

11) Phylloxera

Includes "leaf" phyllexorans, *Phylloxera notabilis,* and *P. russelae*, and "stem" phylloxera, *P. devastatrix*

- Infestations of phylloxerans are scattered and generally isolated across the region.
- Leaf phylloxera generally causes minor damage.
- Stem phylloxera can be devastating, as the name implies.
- Overwintering eggs hatch as the buds break in spring, and young phylloxera move out and begin feeding at new leaves or terminals. A gall soon forms that envelopes the

insect. Stem phylloxera galls replace nut clusters, and heavy infestations can eliminate production and reduce growth of new shoots.

Current Management Options

- Phylloxerans can be controlled with chlorpyrifos, pyrethroids, or nicotinyl insecticides. Timing is critical to prevent loss of yield, but application of an insecticide at bud-break is usually effective.

Research Needs

- Effect of systemic insecticides, applied for aphid control in one season, on phylloxera success the next is unknown

12) Asian Ambrosia Beetle

- While these minute beetles may infest small branches in the canopy of large trees, the main problem is in young trees in the first 2 - 3 years after planting, and in nurseries.
- Female beetles usually bore into the heartwood of small (<2" diameter) stems and branches, although occasionally large trees are attacked under conditions of extreme stress. If the beetles are contaminated with disease-causing fungal spores, death can follow attack by even one or two beetles. If no disease is introduced, multiple attacks can cause loss of vigor and eventual death of young trees.

Current Management Options

- Barrier sprays with permethrin or bifenthrin provide protection for 4 - 6 weeks.

Research Needs

- Better monitoring tools will allow improved prediction of attack and more timely insecticide application.
- Research is needed on biology and behavior of the beetle, especially the factors attracting females to particular trees.

Pecan Weed Management

Weeds compete with pecan trees for water and nutrients. Allowing weeds to go uncontrolled during establishment and subsequent formative years of orchard can result in reduced growth and productivity, especially in the early life of an orchard. Pecans are harvested directly from the orchard floor therefore minimum vegetation or plant residue is necessary for maximum harvest efficiency. In order to obtain adequate control growers' use pre-emergence herbicides to prevent weed emergence. A weed control program solely dependent upon post-emergence herbicides is undesirable because increased plant residue interferes with harvest. In extreme cases, orchard floor conditions can reduce harvest efficiency by 50% or more.

The orchard floor management program of choice consists of a managed weed-free strip (12-15 ft wide) in the tree row. Herbicides, both pre and post-emergence are used to control weeds in the weed-free strip. Between the tree rows managed vegetation provides a drive alley to facilitate equipment movement through the orchard during wet weather. In addition this vegetation strip prevents erosion. Mowing and reduced rates of post-emergence herbicides are used to manage this vegetation.

Other means for managing the orchard floor include tillage and allowing perennial grasses growing on the entire orchard floor. Tillage is an undesirable means for managing vegetation. It is destructive to fine tree roots, which make up a large portion of tree root surface area responsible for water and nutrient uptake. In addition tillage can spread crown gall, a disease common to pecan trees. Tillage equipment operated close to tree trunks can cause serious injury to bark. Numerous tillage operations throughout the year would be required to maintain the desired level of control making this practice costly and time consuming. Planting the entire orchard floor in a perennial crop that is managed by mowing is not recommended. This practice requires mowing equipment to be operated close to tree trunks which can be injurious to tree bark. Furthermore, from a competitive standpoint, research has shown this practice for orchard floor management is no more effective than doing nothing at all. Trees growth is very poor and pecan yields are reduced.

The standard weed management program for pecans in the Southeastern United States consists of a spring pre- and post-emergence herbicide spray in March or April. The March or April application controls escaped winter annual weeds and provides residual control of summer annual weed species. During the summer escaped annual weeds and perennial weeds, like bermudagrass, yellow and purple nutsedge, are controlled with post-emergence herbicides. Usually one and no more than two post-emergence herbicide applications are made. Some growers use reduced rates of glyphosate to suppress vegetation in the middle or drive alley. This practice reduces the need for mowing. In the late summer or fall a pre- and post-emergence herbicide is applied to control emerging winter annual weeds through harvest to maximize harvest efficiency.

Mistletoe is an increasing problem in pecan production. Mistletoe is a parasitic weed that attaches to limbs. Infested limbs produce little or no yield, reducing the overall productivity of the tree and orchard.

Critical Weed Management Needs

1. Identification of new pre-emergence herbicide alternatives to simazine and diuron. Such alternatives need to have favorable environmental profiles, provide broad-spectrum, long, term residual control.
2. Woody perennial plants are difficult to control. There is a need for an alternative to glyphosate for controlling undesirable woody perennial plants. Trees can become sensitive to glyphosate applied in late summer and fall. Application time is specific for individual species requiring increased management in orchards where 2 or more perennial weed species are a problem.
3. Mistletoe is a parasitic weed that can cause significant yield loss. Control depends on physical removal of infected tree limbs. Limb removal reduces tree productivity.

General Conclusions

1. Pre-emergence herbicides, primarily simazine and diuron, are critical for effective weed management in pecan orchards. Research has shown that ground cover management practices including pre-emergence and post-emergence herbicides maximizes tree growth, yield, and profitability. Pre-emergence herbicides prevent weed seed germination over time, minimizing trips through the orchard. The long growing season, and climatic conditions like rainfall and humidity is ideal for weed growth thus creating some the most competitive crop/weed interaction in the United States. Such conditions would require numerous trips throughout spring, summer, and fall should growers have to depend solely on post-emergence herbicides alone.
2. Weed competition is most significant in the formative years of a pecan orchard. Largely due to minimum shading of the orchard floor. Young orchards have very little canopy effect, thus minimizing the competitive advantage shade offers in mature pecan orchards. It is critical that weed competition be minimize in the formative years of the pecan orchard so early growth and productivity may be maximized. Early tree growth influences pecan productivity in the early life of the orchard. Early orchard productivity is critical to growers trying to recover costs associated with the long-term investment of pecan production.
3. Harvest efficiency can be greatly impacted by orchard floor management. Nuts are harvested directly from the orchard floor and weeds can physically interfere with the harvest. Nuts get caught in weeds or weed remains. Those nuts are unable to be harvested and are a significant loss to the grower. Such losses can easily exceed 30 % in orchards where the orchard floor is poorly managed or control failure occurs.

Weed Pests of Pecan

Summer Annual Weeds

Common summer annual weeds include common lambsquarters, large crabgrass, fall panicum, Southern sandbur, Texas panicum, tropic croton, Florida pusley, pigweeds (*Amaranthus* species), entireleaf morningglory, pitted morningglory, smallflower morningglory, tall morningglory, prickly sida, and spreading dayflower

Herbicides Currently Recommended

Diruon (Karmex)

Oryzalin (Surflan)
Pendimethalin (Prowl; Non-bearing Only)
Simazine (Princep)
Norflurazon (Solicam)
Paraquat (Gramoxone Max, Boa)
Glyphosate (Roundup UltraMax, Generic Formulations)
2,4-D amine
Halosulfuron (Sempra; registration limited to certain states)

Notes

Herbicides applied as a directed spray in the herbicide strip.
Includes both pre- and post-emergence herbicides.
Applied from March to April

Summer Annual and Perennial Weed Control

Warm season perennial grasses, summer annual weeds, and yellow and purple nutsedge. Common warm season perennial grass weeds include bermudagrass, johnsongrass, and bahiagrass. Common annual weeds include those previously mentioned.

Notes

Herbicides applied as directed spray in herbicide strip.
These herbicides provide post-emergence control.
Perennial weeds may require multiple applications.
Summer applications (May, June, July, and August)
Applied if needed

Herbicides Currently Recommended

Glyphosate (Roundup UltraMax, Various Generic Formulations)
Paraquat (Boa, Gramoxone Max)
Fluazifop (Fusilade DX)
Sethoxydim (Poast)
Halosulfuron (Sempra)

Winter Annual Weeds

Common winter annual weeds include annual ryegrass, common chickweed, common mallow, cutleaf eveningprimrose, horseweed, mousear chickweed, Virginia pepperweed, Venice mallow, and wild radish

Notes

Applied specifically for harvest efficiency.
Fall, pre-harvest application

Currently recommended Herbicides

Simazine (Princep, Various Generic Formulations)

Norflurazon (Solicam)
Glyphosate (Roundup UltraMax, Various Generic Formulations)
Paraquat (Boa, Gramoxone Max)
2,4-D amine (Various Generic Formulations)

Non-Chemical Options

Tillage

Tillage is not a viable option in pecans. Tillage destroys perennial groundcover necessary for minimizing erosion and prevents equipment movement through orchard during wet weather. Tillage is destructive to fine tree roots, which are a large portion of tree root surface area responsible for water and nutrient up take. Another negative of tillage is it spreads crown gall disease through the orchard.

Flame Cultivation

The utilization of open flame to kill weeds once that have emerged is being re-visited as an alternative to herbicides. The primary concern with this weed control method is the risk associated with flammable materials on the orchard floor. Such materials include leaves, pecan shucks, twigs, dead weeds, and grass clippings.

Unregistered Chemicals

Flumioxazin (Chateau)
Sulfentrazone (Spartan)
Thiazapyr (Visor)
Fluroxypyr (Starane)

Strategies for Future Control

Registration of new herbicides
Utilization of split rate technology

Research

Screen herbicides for potential alternatives for simazine and diuron.
Determine if split rate technology will provide equivalent weed control at reduced rates.

Mistletoe

Mistletoe is a parasitic weed the grows in the tree tops, attached to limbs. Limbs infected with mistletoe will have greatly reduced nut production beyond area of attachment. Severely infested trees can have yields reduced by 90 % or more.

Chemical Controls

None

Non-Chemical

Removal of infected limbs with chainsaw

Notes

Removal is very expensive and dangerous to individual working in the tree.

Strategies for Future Control

Herbicide registration
Biological control options

Regulatory

Allow registration of herbicide for use in tree limbs

Research

Screen herbicides for mistletoe efficacy and crop tolerance.
Investigate the opportunity for biological controls.

Educational Needs

Weed control manuals.
Increase presence of weed control information in production guides.

Pecan Diseases

1) Pecan scab - primary disease

- **Scab is the major disease problem on pecan in the southeastern US.**
- Caused by fungus, *Fusicladosporium effusum* (= *Cladosporium caryigenum*)
- Primary infection results in lesions on developing foliage, stems, and fruits; all green, expanding tissues are susceptible to infection by the fungus
- Conidia produced in lesions provide inoculum for secondary infections
- Infection of foliage can result in premature defoliation, but primary economic impact results from infections of the nut shuck that cause premature nut drop and reduced nut size.
- losses can approach 100% in wet years and 50-70% in localized areas in dry years, but losses are usually much less than this because growers spend $275 per hectare to control this disease (based on 2004 costs)

Current Management Strategies

Sterol-inhibitors (DMIs)

propiconazole (Propimax and Orbit)
fenbuconazole (Enable)

- The DMIs provide good control, especially early in the season for leaf scab
- Moderate risk of fungicide resistance, and populations with reduced sensitivity have been found, but to date have not been linked with reduced control.
- Number of applications limited, recommended to tank mix or alternate with chemically unrelated fungicides
- Most widely used fungicides for scab control

Strobilurins (QoIs)

azoxystrobin (Abound)
- effective, but limited use due to high cost
kresoxim-methyl (Sovran)
- effective, but not used much due to high cost
pyraclostrobin (Headline)
- new on the market in 2003

- The strobilurins are very effective for scab control, both on leaves and nuts.
- High risk of fungicide resistance, but resistance in scab pathogen not reported
- Number of applications limited, alternate with chemically unrelated fungicides

Benzimidazoles

thiophanate-methyl (Topsin-M)
- only fair control of scab, not recommended as a stand-alone management tool

- high risk of fungicide resistance, resistance to benzimidazoles (benomyl) documented in early 1970s

EBDCs (ethylenebisdithiocarbamates)

ziram (Ziram)
- only fair scab control, not recommended if heavy disease pressure
- low risk of fungicide resistance
- B2 carcinogen, under EPA review, future availability uncertain

Other:

fentin hydroxide (Super Tin, AgriTin)
- excellent nut scab control
- low risk of fungicide resistance
- good partner material for resistance management
- number of applications limited
- has been one of the most widely used fungicides for scab control for past 40 years
- worker exposure concerns, has been under review by EPA, future availability uncertain

dodine (Elast)
- excellent scab control
- moderate risk of fungicide resistance
- good partner material for DMI resistance management

Pre-packaged or tank-mix fungicide combinations

propiconazole/fentin hydroxide (sold as Orbit/Super Tin Co-pack)
trifloxystrobin/propiconazole (sold as Stratego)
fenbuconazole/fentin hydroxide (sold as Enable/Agri Tin Co-pack)
fenbuconazole/dodine
propiconazole/azoxystrobin (sold as Quilt)

- these combinations provide excellent scab control and are also effective for fungicide resistance management

Alternative Management Options

Scab-resistant cultivars
- costly to convert orchard to new cultivar
- lack of commercially available scab-resistant cultivars with desirable horticultural/market characteristics
- the scab pathogen is known to adapt and overcome host resistance over time
- Thinning and improved air circulation
- helps reduce epidemics but losses can still be severe.

Unregistered Fungicides

tebuconazole (Folicur) - DMI

- excellent scab control(?)
- not labeled for use on pecan

Pest Management Aids

AU-PECAN

- weather-based disease advisory system, useful in timing fungicide applications for scab control

Strategies for Future Control ("To-Do" list for scab)

Regulatory Needs

- expedite registration of new fungicides and other control tactics as they become available
- develop and implement a program that will allow researchers to test new chemistries on up to 250 acres prior to full registration
- encourage regulatory procedures to maintain diversity of chemical disease control options for resistance management to maximize long-term disease control

Research Needs

- influence of cultural practices (nutrition, pruning, hedging) on scab (and other diseases)
- effectiveness of fungicide resistance management strategies on pecan
- reduced inputs for scab management
- genetic variability in scab and develop resistant varieties to scab (assessment of genotypes as resources for breeders)
- molecular characterization of scab resistance
- effect of genotype diversity (host mixtures) by row on reduction of scab (disease management)
- evaluation of new fungicides on minor crops like pecan
- improved fungicide application technology for disease management (reduce inputs)

Education/Training Needs

- development of a regional IPM website for pecan management as a tool to deliver technology transfer to growers
- increase extension funding for technology transfer
- integrated orchard management carry considerable management costs.

Growers need orchard consultants to successfully implement increasingly complex pest management options. The economics of pest management must be re-examined in light of its non-farm benefits to society in order to sustain a badly needed cadre of pest management consultants. Integrated Orchard Management is a key element of both worker safety and environmental stewardship.

2) Downy spot

- secondary disease problem, occurs sporadically in the southeastern US, but is common in central Texas
- caused by fungus, *Mycosphaerella caryigena*

- causes a foliar leaf spot
- can be a problem in some years or locations on more scab-resistant cultivars or in unsprayed orchards
- can cause significant reduction in photosynthesis, premature defoliation, reduced nut quality
- is generally not a problem in orchards where fungicides are applied for scab control

Current Management Strategies

Sterol-inhibitors (DMIs)

propiconazole (Propimax)
fenbuconazole (Enable)

- The DMIs provide excellent disease control
- Most effective when applied early in the season (prepollination)
- Moderate risk of fungicide resistance, but resistance in downy spot pathogen not reported
- Number of applications limited, recommended to tank mix or alternate with chemically unrelated fungicides
- Most widely used fungicides for downy spot control

Benzimidazoles

thiophanate-methyl (Topsin-M)
- good control of downy spot, but not recommended as a stand-alone management tool due to potential resistance problems
- high risk of fungicide resistance, but resistance in downy spot fungus not reported

Other:

fentin hydroxide (Super Tin, AgriTin)
- good downy spot control
- low risk of fungicide resistance
- good partner material for resistance management
- number of applications limited
- worker exposure risk, has been under review by EPA, future availability uncertain

dodine (Syllit)
- good downy spot control
- moderate risk of fungicide resistance
- good partner material for DMI resistance management

Pre-packaged or tank-mix fungicide combinations

propiconazole/fentin hydroxide (sold as Orbit/Super Tin Co-pack)
fenbuconazole/fentin hydroxide (sold as Enable/Agri Tin Co-pack)

- these combinations provide excellent downy spot control and are also effective for fungicide resistance management

Alternative Management Options

- none known
- efficacy of fenbuconazole/dodine tank mix is unknown, but presumed good
- efficacy of currently registered strobilurins (azoxystrobin, kresoxim-methyl, pyraclostrobin), ziram, and strobilurin mixtures (Stratego) on downy spot is unknown

Strategies for Future Control ("To-Do" list for downy spot)

Research Needs

- influence of cultural practices (nutrition, pruning, hedging) on disease
- evaluation of currently registered strobilurin fungicides for downy spot control
- management of downy spot, in the absence of scab control or on scab resistant varieties
- timing of fungicide applications for most effective disease control, relative to availability of initial inoculum and host susceptibility
- evaluation of scab-resistant pecan cultivars for resistance to this and other secondary diseases

Regulatory:

- expedite registration of new fungicides and other control tactics as they become available
- develop and implement a program that will allow researchers to test new chemistries on up to 250 acres prior to full registration
- encourage regulatory procedures to maintain diversity of chemical disease control options for resistance management to maximize long-term disease control

Education/Training

- development of a regional IPM website for pecan management as a tool to deliver technology transfer to growers
- increase extension funding for technology transfer
- integrated orchard management carry considerable management costs

Growers need orchard consultants to successfully implement increasingly complex pest management options. The economics of pest management must be re-examined in light of its non-farm benefits to society in order to sustain a badly needed cadre of pest management consultants. Integrated Orchard Management is a key element of both worker safety and environmental stewardship.

3) Zonate leaf spot

- secondary disease problem
- caused by fungus, *Grovesinia pyramidalis* (anamorph = *Cristulariella moricola*)
- causes a foliar leaf spot
- can cause significant premature defoliation, especially in wet years

Current Management Strategies

Sterol-inhibitors (DMIs)

propiconazole (Propimax)
- excellent control of zonate leaf spot

fenbuconazole (Enable)
- good control of zonate leaf spot

- Moderate risk of fungicide resistance, but resistance in pathogen not reported
- Number of applications limited, recommended to tank mix or alternate with chemically unrelated fungicides

Benzimidazoles

thiophanate-methyl (Topsin-M)
- good control of zonate leaf spot, but not recommended as a stand-alone management tool due to potential resistance concerns
- high risk of fungicide resistance, but resistance not reported in this pathogen

Other:

fentin hydroxide (Super Tin, AgriTin)
- only fair control of zonate leaf spot
- worker exposure risk, has been under review by EPA, future availability uncertain

dodine (Syllit)
- only fair control of zonate leaf spot

Pre-packaged or tank-mix fungicide combinations

propiconazole/fentin hydroxide (sold as Orbit/Super Tin Co-pack)
fenbuconazole/fentin hydroxide (sold as Enable/Agri Tin Co-pack)

- these combinations provide good control of zonate leaf spot and also have some effectiveness for fungicide resistance management

Alternative Management Options

- none known
- efficacy of currently registered strobilurins (azoxystrobin, kresoxim-methyl, pyraclostrobin) and strobilurin mixtures (Stratego) on downy spot is unknown
- efficacy of fenbuconazole/dodine tank mix is unknown

Strategies for Future Control ("To-Do" list for zonate leaf spot)

Research Needs

- influence of cultural practices (nutrition, pruning, hedging) on disease development
- evaluation of currently registered strobilurin fungicides and fungicide mixtures for downy spot control

- management of zonate leaf spot, in the absence of scab control or on scab resistant varieties
- evaluation of scab-resistant pecan cultivars for resistance to this and other secondary diseases

Regulatory:
- expedite registration of new fungicides and other control tactics as they become available
- develop and implement a program that will allow researchers to test new chemistries on up to 250 acres prior to full registration
- encourage regulatory procedures to maintain diversity of chemical disease control options for resistance management to maximize long-term disease control

Education/Training
- development of a regional IPM website for pecan management as a tool to deliver technology transfer to growers
- increase extension funding for technology transfer
- integrated orchard management carry considerable management costs.

Growers need orchard consultants to successfully implement increasingly complex pest management options. The economics of pest management must be re-examined in light of its non-farm benefits to society in order to sustain a badly needed cadre of pest management consultants. Integrated Orchard Management is a key element of both worker safety and environmental stewardship.

4) Powdery mildew
- secondary disease
- the fungal species *Phyllactinia guttata* and *Microsphaera penicillata* have been reported to cause powdery mildew on pecan
- occurs primarily on nut shucks
- a severe outbreak in the early stages of fruit development can reduce kernel weight by reducing overall fruit size by 20%
- most susceptible cultivars are Curtis, Desirable, Farley, Moore, Pabst, Wichita, and Woodard

Current Management Strategies

Benzimidazoles

thiophanate-methyl (Topsin-M)
- good control of powdery mildew

Sterol-inhibitors (DMIs)

propoconazole (Propimax)
- very good control of powdery mildew

fenbuconazole (Enable)
- very good control of powdery mildew

- Moderate risk of fungicide resistance, but resistance in pathogen not reported.
- Number of applications limited, recommended to tank mix or alternate with chemically unrelated fungicides

Other

sulfur
- fair control of powdery mildew

Alternative Management Options
- none available

Strategies for Future Control ("To-Do" list for powdery mildew)

Research Needs
- need more quantitative info on economic impact of powdery mildew and yield loss
- management options for powdery mildew
- evaluation of scab-resistant pecan cultivars for resistance to this and other secondary diseases

Regulatory:
- expedite registration of new fungicides and other control tactics as they become available
- develop and implement a program that will allow researchers to test new chemistries on up to 250 acres prior to full registration
- encourage regulatory procedures to maintain diversity of chemical disease control options for resistance management to maximize long-term disease control

Education/Training
- development of a regional IPM website for pecan management as a tool to deliver technology transfer to growers
- increase extension funding for technology transfer
- integrated orchard management carry considerable management costs.

Growers need orchard consultants to successfully implement increasingly complex pest management options. The economics of pest management must be re-examined in light of its non-farm benefits to society in order to sustain a badly needed cadre of pest management consultants. Integrated Orchard Management is a key element of both worker safety and environmental stewardship.

5) Phytophthora shuck and kernel rot
- secondary disease
- caused by Oomycete, *Phytophthora cactorum*

- can be a problem in some locations, especially in wet years

Current Management Strategies

Sterol-inhibitors (DMIs)
propiconazole (Propimax)
fenbuconazole (Enable)

- DMIs provide poor control of Phytophthora shuck and kernel rot

Other:
fentin hydroxide (Super Tin, AgriTin)
- good control of Phytophthora shuck and kernel rot
- low risk of fungicide resistance
- number of applications limited
- high mammalian toxicity, has been under review by EPA, future availability uncertain

Copper fungicides (Kocide)
- good disease control

Alternative Management Options
- none available

Strategies for Future Control ("To-Do" list for Phytophthora shuck and kernel rot)

Research Needs
- management options for Phytophthora shuck and kernel rot
- need data on efficacy of currently registered strobilurins (azoxystrobin, kresoxim-methyl, pyraclostrobin), strobilurin mixtures (Stratego), DMI/fentin hydroxide mixtures, ziram, dodine, and dodine/fenbuconazole mixtures on Phytophthora shuck and kernel rot
- need more quantitative info on economic impact of Phytophthora shuck and kernel rot and yield loss
- evaluation of scab-resistant pecan cultivars for resistance to this other secondary diseases

Regulatory:
- expedite registration of new fungicides and other control tactics as they become available
- develop and implement a program that will allow researchers to test new chemistries on up to 250 acres prior to full registration
- encourage regulatory procedures to maintain diversity of chemical disease control options for resistance management to maximize long-term disease control

Education/Training
- development of a regional IPM website for pecan management as a tool to deliver technology transfer to growers

- increase extension funding for technology transfer
- integrated orchard management carry considerable management costs.

Growers need orchard consultants to successfully implement increasingly complex pest management options. The economics of pest management must be re-examined in light of its non-farm benefits to society in order to sustain a badly needed cadre of pest management consultants. Integrated Orchard Management is a key element of both worker safety and environmental stewardship.

6) Anthracnose

- secondary disease
- caused by fungus, *Glomerella cingulata* (anamorph = *Colletotrichum gloeosporioides*)
- causes irregular lesions on leaves and dark, sunken lesions on nut shucks

Current Management Strategies

Sterol-inhibitors (DMIs)

propiconazole (Propimax)
fenbuconazole (Enable)

- The DMIs provide good control of anthracnose
- Moderate risk of fungicide resistance, but resistance in pathogen not reported

Benzimidazoles

thiophanate-methyl (Topsin-M)

- good control of anthracnose, but not recommended as a stand-alone management tool due to potential for resistance
- high risk of fungicide resistance, resistance in this pathogen not reported

EBDCs (ethylenebisdithiocarbamates)

ziram (Ziram)

- poor control of anthracnose, not recommended

Other:

fentin hydroxide (Super Tin, AgriTin)

- good control of anthracnose
- low risk of fungicide resistance
- good partner material for resistance management
- number of applications limited
- worker exposure risk, has been under review by EPA, future availability uncertain

Pre-packaged or tank-mix fungicide combinations

propiconazole/fentin hydroxide (sold as Orbit/Super Tin Co-pack)
fenbuconazole/fentin hydroxide (sold as Enable/Agri Tin Co-pack)

- these combinations provide good control of anthracnose and are also effective for fungicide resistance management

Alternative Management Options

Research Needs:
- management options for anthracnose
- need data on efficacy of currently registered strobilurins (azoxystrobin, kresoxim-methyl, pyraclostrobin), strobilurin mixtures (Stratego), DMI/fentin hydroxide mixtures, ziram, dodine, and dodine/fenbuconazole mixtures on anthracnose
- need more quantitative info on economic impact of anthracnose and yield loss
- evaluation of scab-resistant pecan cultivars for resistance to this and other secondary diseases

Regulatory:
- expedite registration of new fungicides and other control tactics as they become available
- develop and implement a program that will allow researchers to test new chemistries on up to 250 acres prior to full registration
- encourage regulatory procedures to maintain diversity of chemical disease control options for resistance management to maximize long-term disease control

Education/Training
- development of a regional IPM website for pecan management as a tool to deliver technology transfer to growers
- increase extension funding for technology transfer
- integrated orchard management carry considerable management costs.

Growers need orchard consultants to successfully implement increasingly complex pest management options. The economics of pest management must be re-examined in light of its non-farm benefits to society in order to sustain a badly needed cadre of pest management consultants. Integrated Orchard Management is a key element of both worker safety and environmental stewardship.

7) Nematodes
- secondary disease
- pecan roots can be damaged by dagger, ring, root-knot, and lesion nematodes
- nematodes associated with pecan roots include *Helicotylenchus, Meloidogyne, Mesocriconema, Paratylenchus, Pratylenchus, Radopholus, Trichodorus, Tylenchorhynchus,* and *Xiphinema*

Current Management Strategies
- perception is that damage by nematodes is not economically significant and does not justify management action

Telone II

- pre-plant fumigation treatment
- very expensive, difficult to justify economically, rarely used

aldicarb (Temik)
- in certain situations, particularly in sandy soils, application of aldicarb (Temik) provides fair control of nematodes

Alternative Management Options
- no post-plant nematicides are available for use on pecan

Strategies for Future Control ("To-Do" list for nematodes)

Research Needs:
- effects of nematodes on pecan growth and production
- management options for nematodes
- evaluation of pecan cultivars for resistance to nematodes

Regulatory:
- expedite registration of new nematicides and other control tactics as they become available

Education/Training
- development of a regional IPM website for pecan management as a tool to deliver technology transfer to growers
- increase extension funding for technology transfer
- integrated orchard management carry considerable management costs.

Growers need orchard consultants to successfully implement increasingly complex pest management options. The economics of pest management must be re-examined in light of its non-farm benefits to society in order to sustain a badly needed cadre of pest management consultants. Integrated Orchard Management is a key element of both worker safety and environmental stewardship.

8) Sooty mold
- secondary disease
- caused by several unidentified species of fungi
- sooty mold fungi do not actually infect the leaves, but grow exclusively on leaf surfaces, feeding on aphid honeydew
- shading effect can reduce photosynthesis
- Significant effects on yield or quality have not been conclusively demonstrated

Current Management Strategies
- can be managed most effectively by keeping aphid populations low
- all of the fungicides currently registered for use on pecan have poor activity against sooty mold

Alternative Management Options

- none available

Strategies for Future Control ("To-Do" list for sooty mold)

Research Needs

- quantitative effects of sooty mold on pecan yield and production
- etiology/taxonomy of sooty mold fungi on pecan
- influence of cultural practices (nutrition, pruning, hedging) on disease development
- management options for sooty mold

Education/Training

- development of a regional IPM website for pecan management as a tool to deliver technology transfer to growers
- increase extension funding for technology transfer
- integrated orchard management carry considerable management costs.

Growers need orchard consultants to successfully implement increasingly complex pest management options. The economics of pest management must be re-examined in light of its non-farm benefits to society in order to sustain a badly needed cadre of pest management consultants. Integrated Orchard Management is a key element of both worker safety and environmental stewardship.

9) Bacterial leaf scorch

- secondary disease
- caused by bacterium, *Xylella fastidiosa*
- pecan cultivar Cape Fear is particularly susceptible to this disease
- can reduce quantity and quality of pecan yield

Current Management Strategies

- remove infected trees (roguing)
- plant resistant cultivars, avoid planting cv. Cape Fear

Alternative Management Options

- none available

Strategies for Future Control ("To-Do" list for bacterial leaf scorch)

Research Needs

- management options for bacterial leaf scorch
- identify primary insect vectors of bacterial leaf scorch
- evaluation of pecan cultivars for resistance to this other secondary diseases

Regulatory:

- expedite registration of new bactericides and other control tactics as they become available

Education/Training

- development of a regional IPM website for pecan management as a tool to deliver technology transfer to growers
- increase extension funding for technology transfer
- integrated orchard management carry considerable management costs.

Growers need orchard consultants to successfully implement increasingly complex pest management options. The economics of pest management must be re-examined in light of its non-farm benefits to society in order to sustain a badly needed cadre of pest management consultants. Integrated Orchard Management is a key element of both worker safety and environmental stewardship.

10) Crown gall

- secondary disease
- caused by bacterium, *Agrobacterium tumefaciens*
- can weaken root system, making trees more susceptible to uprooting by wind
- pathogen can be spread from tree to tree by root/crown wounding by mowers and other equipment

Current Management Strategies

- crown gall occurs in many pecan orchards, but is not considered serious enough to warrant management action

Alternative Management Options

- none available

Strategies for Future Control ("To-Do" list for crown gall)

Research Needs

- economic impact of crown gall
- management options for crown gall
- efficacy of the registered biopesticide GallTrol (*Agrobacterium radiobacter*, strain K-84) as a pre-plant treatment for control of crown gall on pecan
- identification/development of resistant cultivars

Education/Training

- development of a regional IPM website for pecan management as a tool to deliver technology transfer to growers
- increase extension funding for technology transfer
- integrated orchard management carry considerable management costs.

Growers need orchard consultants to successfully implement increasingly complex pest management options. The economics of pest management must be re-examined in light of its non-farm benefits to society in order to sustain a badly needed cadre of pest

management consultants. Integrated Orchard Management is a key element of both worker safety and environmental stewardship.

Worker Exposure Risks in Pecans

PRE-PLANT ORCHARD ESTABLISHMENT

Pre-plant treatment of new pecan orchards by fumigants is not an issue, as virtually none of the new orchards are treated with fumigants. The pests controlled by these materials are not considered to be important enough, economically, to justify the cost.

PLANTING

Pecan trees are generally planted bare-root during the dormant season, or moved from crowded orchards to new orchards by tree spade, maintaining as large a root ball as possible. In neither case are the trees dipped or otherwise treated with pesticides as a standard procedure.

NON-BEARING ORCHARDS

Non -bearing orchards are treated for the same diseases and with the same fungicides as mature orchards. Because the trees are smaller, air movement and sunlight penetration are greater and conditions favoring disease development occur less often. With no nuts to protect, susceptibility to pecan scab is limited to the time when leaves are expanding. Late-season applications are not needed, and fewer applications are made in spring and early summer than in producing orchards. Fungicide applications to non-bearing orchards are made with air-blast sprayers pulled by closed cab tractors. Choice of fungicides is very much an individual decision, but lower cost materials (sterol inhibitors, fentin hydroxide, and the combination product, Stratego) are favored by most. Hand-gun applications are not used.

The primary insect threat to young trees is from borers (including Asian ambrosia beetle). Hand-gun application of chlorpyrifos or permethrin as a barrier spray on the trunk and scaffold limbs is common but not universal. One or two applications, in early spring and/or early summer, are made according to perceived need. Use of PPE specified on the label, i.e. gloves, safety glasses, long-sleeved shirt/coveralls, etc., minimizes exposure risks while using a hand-gun applicator.

Both black pecan aphid and yellow pecan aphid/black-margined pecan aphid complex can reach treatable populations in non-bearing orchards. Foliar sprays of systemic insecticides (primarily imidacloprid but also thiamethoxam) are used to control these pests. Except for very young (<4 yr.) trees, air blast sprayers are used for these applications.

For the first 2 - 3 years after planting, pecan bud moth is also a threat to newly established orchards. The hand-gun applied chlorpyrifos treatment aimed at borers will also control this pest.

Tree Training

While some tree training is done, the primary purpose is to eliminate weak branch angles and low limbs that would interfere with orchard management. This is a sporadic activity that is done in the dormant season when no pesticide applications are routine, and worker exposure is not an issue. During the first growing season, removal of buds and sprouts from the trunk is necessary to keep tree shape and encourage top growth. This is generally done by hand. Wearing of gloves would reduce exposure to any pesticide residue that might be on the trees.

Herbicide Application

Weed management for non-bearing orchards is primarily accomplished by mowing, but a weed-free area around each tree is maintained by herbicide application. This may be a spot around each small tree, or the same sort of strip down the row as is standard in producing orchards. The primary herbicides used are pre-emergent (diuron and simazine are most common, but others may also be used) with additional application of post-emergence herbicides to control escaped summer annual and perennial weeds. Care must be taken with very young trees, as post-emergence herbicides can damage the trees if applied to thin bark or allowed to drift on to foliage. Because only one or two applications are typically made, and few other orchard operations are necessary in non-bearing orchards, the risk of worker exposure is slight if label instructions are followed.

BEARING ORCHARD CULTURE & IPM

Dormant Season Pruning

Few dormant season pesticide applications are required, and those that are made, (herbicide applications in late winter - early spring) do not coincide with pruning operations. The risk of worker exposure to pesticides during dormant season activities is virtually nil.

Pesticide Loaders and Applicators

Application of fungicides, insecticides and miticides is done almost exclusively by air-blast sprayer, as no other equipment can deliver coverage to the entire canopy of the trees. Most growers use closed-cab tractors to pull the sprayers. Those applicators using open cab tractors, and all loaders, are urged to wear appropriate protective clothing (PPE) during operations. Growers make from a low of 5 - 6 to as many as 15 fungicide applications per season with a variety of fungicides. The number of insecticide / miticide applications varies widely from grower to grower and year to year. Tank mixing of fungicides with insecticides is routine. Again, the primary risk of exposure is to loaders and operators of open-cab tractors pulling air-blast sprayers.

Other orchard management activities that might offer some exposure risk, mowing and limb pickup, are easily scheduled to avoid bringing workers into contact with recently treated foliage. Most orchards have no low-hanging limbs in the row middles, as such limbs would be an impediment to tractor operations. Most of the crop is produced in the top of the canopy and trees are routinely pruned to allow easy operation of equipment in the orchard at little cost in production. Limb pick-up is done by hand, and wearing of boots and gloves is recommended to reduce any risk of pesticide exposure.

What little fruit-thinning there is, is done by mechanical tree shaker, and carries no real risk of additional worker exposure.

Weed Management

Weeds on the orchard floor are managed in two ways: mowing of row middles, either mechanical or chemical, and maintaining a weed-free strip down the row by herbicide application. Usually two and no more than three herbicide applications are made with a variety of herbicides. The risk of worker exposure is primarily to loaders and operators of open-cab tractors, and use of recommended PPE can virtually eliminate that risk.

Crop and IPM Monitoring

Crop & IPM Monitoring activities are normally carried out by the grower/manager or select employees. Following label recommendations for REI and PPE seems adequate to protect these workers from exposure.

HARVEST

Most harvest of larger orchards is done mechanically. Smaller orchards are sometimes harvested by hand, but labor costs have lead many smaller operations to contract for mechanical harvesting as well. Mature foliage and fruit are susceptible to few diseases and fungicide applications typically end as much as two months before harvest. Most insect pests continue to feed on mature foliage, but PHI requirements generally mean that no insecticides/miticides are applied after shuck-split, which occurs some weeks before harvest. No pesticides are applied directly to the nuts.

POST HARVEST

Once harvested, pecans are taken to a cleaning plant or an "accumulator." Because no pesticides are applied once the shuck opens, the only potential exposure is to any shucks that are included as a contaminant, and that source is as small as possible given current harvesting equipment because it costs the grower at the point of sale. Most handling at the cleaning and shelling operations is mechanical.

Table: Efficacy of pest management tools for control of pecan diseases. Rating scale: E = excellent; G = good; F=fair; P=poor; ?=more research needed; NU=not used; *=used but not necessarily a stand-alone management tool

Pest Management Tool	**Scab**	**Zonate leaf spot**	**Powdery mildew**	**Downy Spot**	**Anthracnose**	**Phytophthora shuck and kernel rot**	**Sooty mold**	**Nematodes**	**Bacterial leaf scorch**	**Crown gall**
Registered materials:										
Fentin hydroxide	E	F	F	G	G	G	P	NU	NU	NU
Dodine	E	F	F	G	?	?	P	NU	NU	NU
Propiconazole	G	E	G	E	G	P	P	NU	NU	NU
Fenbuconazole	G	G	G	E	G	P	P	NU	NU	NU
Stratego	E	?	E	?	?	?	P	NU	NU	NU
Kocide	NU	NU	NU	NU	NU	G	NU	NU	NU	NU
Sovran	E	?	?	?	?	?	P	NU	NU	NU
Azoxystrobin	E	?	G	?	?	?	P	NU	NU	NU
Thiophanate-methyl	F*	G*	G*	G*	G*	?	P	NU	NU	NU
Ziram	F	NU	NU	?	P	?	P	NU	NU	NU
Sulfur	NU	NU	F	NU	NU	NU	P	NU	NU	NU
Enable/Super Tin	E	G	G	E	G	?	P	NU	NU	NU
Orbit/Super Tin	E	G	G	E	G	?	P	NU	NU	NU
Temik	NU	NU	NU	NU	NU	NU	G	F	?	NU
Biopesticides										

Agrobacterium radiobacter, strain K-84 (GallTrol)	NU	NU	NU	NU	NU	NU	NU	NU	NU	?