

44th ANNUAL WESTERN

PECAN GROWERS

ASSOCIATION

CONFERENCE
PROCEEDINGS



MARCH 7-9, 2010

HOTEL ENCANTO de LAS CRUCES
LAS CRUCES, NEW MEXICO

44th Annual

**WESTERN PECAN
GROWERS ASSOCIATION
Conference Proceedings**

**March 7-9, 2010
Hotel Encanto De Las Cruces
Las Cruces, New Mexico**

The Annual
Western Pecan Growers Association
Conference

WPGA Pecan Show

Pecan Food Fantasy

And

Pecan Trade and Equipment Show

sponsored jointly by

New Mexico State University
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in cooperation with
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Aphid Control with Imidacloprid: Issues in 2009

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Systemic insecticides containing the active ingredient imidacloprid are widely used in western pecan producing for controlling blackmargined pecan aphid (BMA), *Monellia caryella* (Fitch) in pecan. Imidacloprid is applied either to the foliage, chiseled in the soil, or applied through sprinkler or drip irrigation systems. Within the last two years, soil applications of imidacloprid have resulted in unsatisfactory BMA control in several Arizona and New Mexico flood and sprinkler irrigated orchards. Concurrent to initial observations of reduced efficacy associated with soil applications of imidacloprid were changes in insecticide formulations, marketing and use of "generic" formulations, and a change in cultural practices that result in an increase of organic matter in orchard surface soils. All aforementioned events have the potential to result in changes in the performance of soil applied systemic insecticides. Research was conducted over a two year period to determine if poor control of BMA following soil applications of imidacloprid were a result of BMA increased tolerance to imidacloprid or a result of other factors. Results for the first year of research involving imidacloprid uptake were presented at this conference last year. Research conducted during 2009, combined with previous research has determined the following regarding imidacloprid use in western pecans:

1. Imidacloprid uptake following soil applications may be slowed by higher amounts of soil organic matter and clay, which may result in lower concentrations of insecticide in the tree.
2. Imidacloprid is evenly distributed throughout the tree canopy, regardless of soil placement although overall insecticide concentrations may vary with placement.
3. Imidacloprid formulation concentration (2 lbs active ingredient per gallon, 4 lbs active ingredient per gallon) does not influence insecticide concentrations in the tree following soil applications.
4. The rate of imidacloprid applied to the soil (active ingredient per acre) not only influences residual of the insecticide in the tree, but also the concentration in the tree with higher rates of active ingredient resulting in higher titer concentrations in the tree.
5. Maximum concentrations of imidacloprid in pecan sap was measure following applications to one side of the tree only at approximately four feet from the trunk.
6. Foliar applications of insecticides containing imidacloprid continue to control BMA in most orchards.

Field observations combined with laboratory results generally indicate that BMA populations in western pecans are becoming increasingly tolerant to the insecticide imidacloprid following soil applications. Foliar imidacloprid applications remain efficacious due to the higher concentrations of imidacloprid that contact BMA compared to soil applications.

Resistant management strategies directed at preserving imidacloprid and the neonicotinoid class of insecticides (imidacloprid is identified as a neonicotinoid class insecticide) for use in western pecans is discussed. Additionally, alternative insecticide chemistries and their use will be presented. The current registration status of the recently registered insecticide "Movento" will be presented.

Stink Bug/Leaf-Footed Bug Management: Scouting and Control

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There are literally hundreds of insects that feed on all parts and locations of a pecan tree, everything from the roots to the shoots and buds are subject to attack. Some of these insects are rarely observed, some are just nuisance pests while others can and do cause serious economic losses. For those insects that feed on the fruit (nuts) I have recorded 18 species, with 11 belonging to the group of kernel feeding true bugs which comprises the true stink bugs (pentatomidae) and the leaf-footed bugs (Coreidae).

Pest Species

Species of true bugs that have been recorded feeding on pecans includes: southern green stink bug, *Nezara viridula*; green sting bug, *Acrosternum hilare*; brown stink bug, *Euschistus servus*; dusky stink bug, *E. tristigma*; concheula stink bug, *Chlorochroa ligata* – Leaf-footed bugs: *Leptoglossus phyllopus*; *L. oppositus*; *L. zonatus*; *Acanthocephala declivis*; *A. femorata* and *A. terminalis*.

These phytophagous or plant feeding stink bugs do not reproduce on pecan but rather pecan acts as a late season food source for adults. However, leaf-footed bugs will feed and reproduce on pecan throughout the season

Management obstacles

There are several factors that make this group of insects so difficult to control or manage. First, this group can feed on pecan up to the day of harvest, which includes feeding through the shell after shuck split which allows for late season damage. Next there are no established economic thresholds to guide producers in making management decisions. Third, these insects can be present through out the canopy which makes scouting difficult and last, there are pre-harvest interval restrictions on insecticides.

I feel that any producer that is having problems with this group will have to become a detective to some degree. Producers need to know who is causing the problem, is it a single species or a combination of species. Producers will also have to figure out where these insects are coming from, are they growing their own within the orchard or they moving in from alternate host crops. Although these insects can be in the orchard throughout the growing season, populations tend to increase during the late season as other host plants begin to die out and row crops are harvested.

Types of damage

Most producers are familiar with the black kernel spots which result from feeding after dough formation. Another type of damage that producers might not be aware of or rarely observe is a condition called “black pit”. This is when feeding occurs during the water stage and nutlets abort. This type of damage is characterized by the inside of the pecan, including the water during dark brown..

A third type of loss is that in addition to producers not getting paid for damaged kernels, producers have sprayed, harvested and handled those pecans and the tree has expended the energy to fill out the kernels. This hidden loss could be reflected on the potential for the following year’s crop.

Alternate host plants

As a group, stink bugs and leaffooted bugs feed on a very wide range of host plants including numerous weeds, row crops and vegetables (McPherson and McPherson). In understanding the dynamic movement of stink bugs and leaffooted bugs during the season, alternate host plants need to be identified. In the south central and central portions of Texas it is common to find high populations of the leaffooted bug *L. phyllopus* on thistle during the spring and on *Gaura parviflora* during the summer. You will also find the brown sink bug, *E. servus* on *G. parviflora* and Golden Crownbeard, *Verbensia encelioides* and it is well known that row crops such as soybeans and sorghum can generate high populations of stink bugs and leaffooted bugs. In the western states (NM, AZ) the Concheula stink bug is common on mesquite and *L. zonatus* can be a pest of pomegranate while the green stink bug, *A. hilare* has been reported from chokecherry, firethorn and Arizona dewberry (Jones) in addition to agricultural crops. In different geographical areas across the pecan belt there will be a different complex of alternate host plants and these plants need to be identified.

Management options

Management of this group is based primarily on the use of insecticides; however, there are practices producers can use that could help reduce the use of insecticides. The first step, as with any pest problem in any crop has to be sanitation and in this case means managing host weeds with in the orchard.

By understanding the dynamic movement of stink bugs/leaffooted bugs between host plants during the season and understanding when an orchard is at risk from immigrating adults, producers will improve their chances of detecting damaging populations.

Immigrating adults often colonize the outside tree rows so treatment of border rows can help. Another possible management tool is the planting of trap crops, or alternate host plants around the orchard to draw stink bugs/leaffooted bugs away from the primary crop (pecan) during August – October. These small planting can then be treated as needed with a limited amount of

insecticide. Where *Euschistus* species (brown and dusky) are the primary species, there is an aggregation pheromone that is commercial available that can be used in conjunction with traps to monitor the movement or placed in trap crop plots to enhance the attractiveness.

When it comes to insecticides, tests have shown that the pyrethroid class of compounds is more efficacious than the organophosphates or carbamates. It has also known that the brown stink bug, *E. servus* is harder to control than other species.

Field tests of several products during 2007 against *L. phyllopus*, *N. viridula* and *E. servus* showed good to fair results with Endigo ZC (lambda-cyhalothrin + thiamethoxam) against *E. servus* and good control of the other species. In 2009, bifenthrin (Brigade WSB) tested against *E. servus* and provided excellent control through 7 days.

In summary, management of kernel feeding stink bugs and leaffooted bugs will take some understanding of host plants, seasonal movement and insecticide selection to reduce economic losses.

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Pecan Root-Knot Nematode Update

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The pecan root-knot nematode (PRKN = *Meloidogyne partityla*) was first identified in 1986 from severely damaged South African pecan orchards that had been established using rootstock imported from Texas and Oklahoma in the 1920's. Ten years later, this nematode was confirmed from five orchards in Texas – and shortly thereafter from a mature orchard in Doña Ana County, NM. Since then, the pathogen has been confirmed from additional orchards in Arizona, Georgia, Florida and Oklahoma. The PRKN is unusual because, unlike the more common root-knot nematodes, this parasite has a very limited host range and can only reproduce on trees in the pecan family (Juglandaceae = pecan, walnut, hickory). The nematode spends nearly all of its life inside pecan roots, where it transforms root cells into specialized feeding sites and induces external knots or root galls. Both of these processes interfere with the ability of roots to absorb and transport water and nutrients in the tree. The feeding sites also act as nutrient sinks, causing the tree to redirect photosynthetic products away from new shoot growth and developing nuts to feed the nematode parasite. High rates of PRKN reproduction can occur in sandy soils, resulting in canopy die-back and decline of infected trees.

The narrow host range of PRKN and absence of native pecan, walnut or hickory in areas where orchards have been established in the Southwest should help restrict establishment and spread of the parasite. With this in mind, funds were secured from USDA APHIS, the NM Agricultural Experiment Station, and NM Department of Agriculture to conduct a survey of orchards in the seven major pecan-producing counties in NM to determine the current level of PRKN infestation. Preliminary results presented at the 41st Annual Western Pecan Conference in 2007 reported root-knot nematodes in 305 of 5,939 acres surveyed (5.1% of the sampled acreage; 10 orchards), with species identification yet to be determined. Subsequent DNA analyses and re-sampling of infested orchards confirmed the presence of PRKN in seven of the 10 orchards (Table 1), representing 3.2% (189 acres) of the surveyed acreage in NM. The remaining three orchards were infested with southern RKN, northern RKN, and an unknown species infecting bermudagrass.

Table 1. Root-knot nematodes (*Meloidogyne* species) recovered from New Mexico pecan orchards, winter 2005/2006.

County	Orchards infested	Acreage infested	<i>Meloidogyne</i> species
Doña Ana	2	35	<i>M. partityla</i> (pecan RKN)
Chaves	5	155	<i>M. partityla</i> (pecan RKN)
Doña Ana	1	15	<i>M. incognita</i> (southern RKN)
Doña Ana	1	71	--species undetermined--
Lea	1	30	<i>M. hapla</i> (northern RKN)

One of the biggest challenges to reducing dissemination of PRKN comes from the difficulty in differentiating this nematode from other, ubiquitous and less damaging root-knot nematodes found throughout pecan-producing areas. The two most common processes – morphological and enzymatic identification – are only possible if mature female nematodes are present, but the soil samples collected from potentially-infested orchards or nursery stock contain only recently hatched juveniles and are not suitable for such tests. A few years ago our lab modified DNA analysis procedures to provide a third means of identification. Recently, Mr. Rio Stamler compared DNA from PRKN populations from all infested pecan-producing states, and used information from these comparisons to develop a much simplified “yes/no” reaction to assist practitioners in determining when PRKN is present. During the process of developing this procedure, he also observed that PRKN populations from New Mexico and Oklahoma were similar, as were populations from Georgia and Arizona, while populations from Texas differed from both groups. No biological or pathological differences are known to exist as a result of these limited genetic variations.

A Possible Novel Black Aphid Control Approach Using Plant Growth Regulators

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The black pecan aphid, *Melanocallis caryaefoliae* (Davis) (Hemiptera: Aphididae), elicits localized chlorotic injury to pecan foliage in order to feed, thereby accelerating leaf senescence and defoliation. The action of certain plant growth regulators (i.e., forchlorfenuron, gibberellic acid and aviglycine) to prevent the black pecan aphid from triggering pecan leaf chlorosis and senescence-like processes was evaluated. Treatments were applied to orchard foliage and used in laboratory leaf disc bioassays to assess possible reduction of aphid-elicited chlorosis and concomitant effects upon aphid mortality and development.

Foliage pretreated in the orchard with the combination treatment of “forchlorfenuron + gibberellic acid,” prior to being challenged with aphids, resulted in much less aphid-elicited chlorosis than did control or aviglycine-treated leaf discs. No plant growth regulator affected aphid mortality; however, development time was increased by “forchlorfenuron + gibberellic acid” in 2006 and by the combination treatment of “aviglycine + gibberellic acid” on one date in 2007.

Field trials confirm that application of certain plant growth regulators to pecan can mitigate chlorotic injury associated with black pecan aphid feeding. Results from laboratory and field research trials will be presented.

In conclusion, certain plant growth regulators possess the potential for usage on pecan to protect foliar canopies from the black pecan aphid via changes in the susceptibility of the host leaf to senescence-like factors being introduced by feeding black pecan aphids.

Confirmation and Management of Glyphosate-Resistant Palmer Amaranth in New Mexico

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In the year 2007, a population of Palmer amaranth was reported to have survived several applications of glyphosate (Roundup) in a pecan orchard in Doña Ana County in New Mexico. This has raised concerns over the management of Palmer amaranth and future use of glyphosate for control of this weed, not only in pecan orchards but also in other common crops of New Mexico, especially cotton since more than 95% of cotton varieties in the region are glyphosate-resistant (Roundup-Ready) varieties. Subsequent diagnostic tests at New Mexico State University confirmed resistance to glyphosate in that Palmer amaranth population. To understand the level of resistance in that population, dose response curves were developed by applying glyphosate at increasing rates to the seedlings of the resistant population. The results of those dose response experiments identified 7-fold resistance to glyphosate in the resistant population compared to a susceptible population.

Management

We have conducted greenhouse tests on the efficacy of alternative herbicides in order to determine whether they remain efficient at controlling the glyphosate-resistant Palmer amaranth population. Post-emergence application of flumioxazin (Chateau), oxyfluorfen (Goal), carfentrazone-ethyl (Aim), imazethapyr (Pursuit), primisulfuron (Beacon), pyrithiobac-sodium (Staple), imazamox (Raptor), prosulfuron (Peak), dicamba (Banvel), 2,4-D (Hardball), glufosinate (Rely), and atrazine (Aatrex) indicated that the glyphosate resistant Palmer amaranth population was not resistant to those herbicides. Furthermore, Pre-emergence application of trifluralin (Treflan), and *S*-metolachlor (Dual) provided at least 95% control of both resistant and susceptible populations. These data also show that the mechanism conferring resistance to glyphosate is likely to be glyphosate specific and will not change the response to other herbicide groups.

Proliferation of herbicide resistant biotypes of Palmer amaranth in New Mexico is a serious concern, and unless effective herbicide resistant management strategies are utilized (e.g., use of alternative herbicides) this proliferation is inevitable. In fact, recently a new population of Palmer amaranth has been reported to have survived several application of glyphosate in an orchard 10 miles south of the first reported location. Research is underway to determine the level of resistance in the new population.

Salinity Management for Southwestern Pecan Orchards

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Managing salts in Southwestern pecan orchards can be a major challenge for growers due to limited soil permeability and/or low-quality irrigation water. However, effective, long-term salt management is essential for maintaining productivity of pecan orchards. The challenge is to effectively manage soil salinity and sodium (Na) in a cost-effective manner, using appropriate combinations of irrigation management, soil management, and soil amendments. Irrigation water and fertilizers contain salts that are continually added to the soil. Poor soil drainage due to the presence of compacted layers, heavy clay texture, or sodium problems may prevent downward movement of water and salts, leading to salt build-up. Adequate soil drainage is absolutely essential for effective management of soil salinity and so the risk of soil salinity formation is always greater in fine-textured (heavy) soils than in coarse-textured soils.

Excess soil salinity has the effect of reducing plant-available water, reducing growth rate, nut size, and yield. For pecans, the maximum soil EC_e (salinity measured in a saturated paste) causing no growth reduction is approximately 2 dS/m (equivalent to 1280 ppm). A soil salinity level of 3.5 dS/m (2200 ppm) can reduce growth by approximately 25%. Branch die-back can occur at soil salinity levels of 5 dS/m (3200 ppm), and trees may die when soil salinity reaches or exceeds 6 dS/m (3800 ppm). Salt-affected pecans typically have leaf burning or marginal necrosis. These symptoms may appear on older or younger leaves, but may be difficult to distinguish from Na or B toxicity.

The key to controlling soil salinity is adequate soil drainage which allows salts to be leached below the root zone. ***There are no amendments that can directly control soil salinity.*** Ultimately, irrigation water salinity will help to determine the soil salinity. As a rule of thumb, the EC of the soil is at least 1.5 times higher than the EC of the irrigation water, except in very sandy soils. The most effective means of controlling soil salinity at tolerable levels is to leach excess water and salts below the root zone. The leaching requirement is the percent of water applied to the crop (beyond the crop's water requirement) that must leach below the root zone to maintain soil salinity at a desired level. The greater the irrigation water salinity, the greater the leaching requirement, thus it is critical to know the salinity of orchard irrigation water.

Where high sodium levels restrict soil drainage, irrigation water can be treated with amendments, or amendments can be added directly to calcareous soils. Sulfuric acid or gypsum can be injected into irrigation water, or they can be applied directly to the soil. If restrictive layers exist in the soil, tillage may be needed. Often, a combination of tillage and amendment application

will be most effective for eliminating infiltration problems and allowing salts to leach from the rooting zone.

Practice prevention! Salt and sodium problems are easier to prevent than to correct.

Compaction Management in Pecan Orchards

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One characteristic of modern management of Pecan orchards is the large amounts of mechanical inputs used for nut production. This is typical of many farming systems in the US that need to advance technologically and increase their overall efficiency of resource utilization in order to keep up with rising costs of production. For the most part, mechanization provides great benefits to farmers; undoubtedly mechanization makes possible intensive and extensive exploitation of natural resources therefore machinery use plays a key role in the management of Pecan orchards. But it is also important to understand that machinery operating inside the orchards may have a significant negative impacts in soil quality if the use of mechanical power is done at less-than favorable soil conditions (i.e. as soil too wet). There is ample scientific evidence indicating that soil compaction is present in the soil profile of typical orchards with negative consequences in orchard productivity. One area of management greatly impacted by high levels of soil hardening is irrigation management because soil compaction reduces water infiltration rates. In addition, mobility rates of nutrients and air in the soil profile can be greatly reduced with negative implications to the development of microorganisms that are responsible for important biochemical processes in the soil. The above suggests that machinery management is an important area of pecan management that we should use to our advantage in reaching higher levels of efficiency , but it is also an area that we need to pay attention to given the risks of negative impact to soil quality.

Current studies in soil compaction of agricultural land make use of the ASABE cone penetrometer standard. This method is based on measuring the resistance to penetration of a steel probe of conical shape. Figure 1 shows the differences that can be found in orchards of the same soil type and irrigation scheme, but with different frequency of deep tillage and soil floor management. New research efforts at the University of Arizona are aiming at developing methods to allow growers to make an assessment of soil compaction in their orchards. A first objective is to determine what range of values in soil strength becomes a threshold that can be identified as a compaction problem. This line of research will continue into testing and evaluating the effectiveness of methods used for compaction amelioration such as deep tillage and orchard floor management.

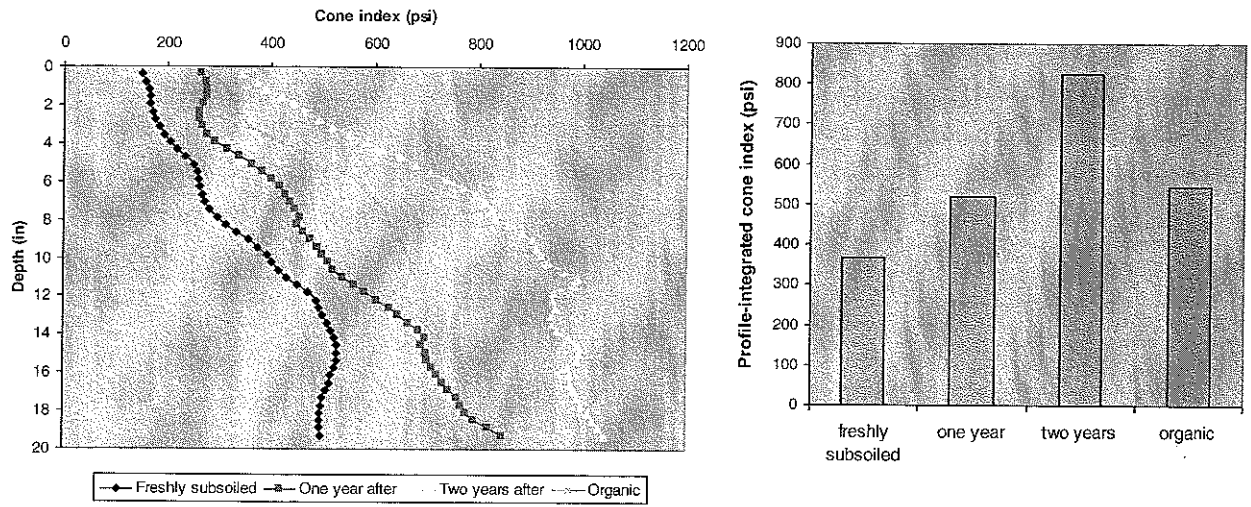


Figure 1. Comparison of soil strength levels according to time of last deep tillage operation and management type. Figure in the left shows profile detail and figure on the right shows profile-integrated amounts.

Practical Implications of a Changing Climate for Western Pecan Industry

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There is a general consensus among climate scientists that temperatures will increase over the next century due to the accumulation of greenhouse gases (GHG) in the atmosphere. Recent efforts to evaluate the impact of GHGs using regional climate models indicate temperatures in western North American will increase 1-3°C (1.8-5.4°F) over the next 30 years and 3-5°C (5.4-9.0°F) by 2100 (Christensen et al., 2007). While such changes might seem small in the Desert Southwest (DSW) where annual temperature extremes vary by 50°C (90°F) or more, such changes would greatly impact pecan production in the DSW. Perhaps the best way to visual the general impacts of the projected warming is to realize that temperatures in Arizona and New Mexico change about 2.2°C (4.0°F) per 1000' of elevation change. Warming projected for the next 30-50 years would therefore be equivalent to reducing the elevation of an existing orchard by ~1000'. Lower elevation orchards are exposed to longer growing seasons, higher summer temperatures, greater water demands and milder winters with less severe cold and fewer chilling hours.

Growing seasons lengthen about 8 days for each 1°F of warming in Arizona. If this trend can be extrapolated to the projected warmer future climate, growing seasons would lengthen by approximately one month by mid-century (2050). While pecans are reasonably tolerant of high temperatures, warmer late summer temperatures could lead to increasing problems with sticktights and vivipary, particularly in low elevation production areas (< 2000') and especially if future water supplies restrict the ability of growers to properly irrigate pecans.

Higher rates of water use are almost sure to develop in a warmer climate with a longer growing season. Pecan water use was found to increase 7.6" for each 1000' reduction in elevation in a recent Arizona analysis (Brown, 2009). Seventy-five percent of the increased water use at lower elevations was due to the longer growing season; just 25% was due to higher evaporative demand resulting from warmer temperatures. Water may in fact become the most limiting issue in this warmer future climate if projections for drier DSW winters come to fruition. Global precipitation is projected to increase as the climate warms, but the winters in the DSW are forecast to be drier due to a more northerly displacement of the storm track (jet stream) in winter. Production areas dependent on surface water could be seriously impacted if warming temperatures increase irrigation water requirements and lessen water supplies.

A warmer future climate may also generate other changes in production practices and/or tree performance. Provided the warming climate exhibits a similar level of seasonal temperature variability, one can expect milder winters and less extreme cold. Harvesting operations may be delayed or made more difficult if the dates of killing frosts (28°F) and defoliation frosts (23-25°F) are delayed, or fail to materialize in some years. Milder winters would also lessen chill accumulation which may impact the timing and variability of budbreak. Older literature suggests the winter chilling requirement for pecans is about 750 hours with temperatures below 45°F. Chill hour accumulation decreases ~100 hours for each 1°F of warming in the pecan growing areas of Arizona. A warming of 4°F in Arizona by 2050 would lower chill accumulation below the 750 hour total for elevations below 3000'. Sparks (1993) has found that budbreak in humid regions can be predicted by monitoring chill accumulation in December and January, and heat unit accumulation after 1 February. While this model has not been adequately evaluated in the DSW, it would project earlier (~7 days) and more variable budbreak (2-3 times greater variation) if the climate warmed by 4°F. Earlier budbreak and a warmer growing season would also accelerate nut maturity by 7-10 days (Sparks, 1989), forcing nuts to mature during late summer when high temperatures and monsoon humidity can increase problems with vivipary (Call et al., 2006).

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The Effect Of Deficit Irrigation On Yield, Quality, and Return Bloom During Three Different Growth Stages In Pecan

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The objective of this experiment was to determine at what stage (if any) during the growing season mature pecan trees can undergo a water deficit while minimizing negative influences on harvest quantity and quality.

This experiment used thirty-two mature trees in a flood-irrigated 'Western' pecan orchard in Doña Ana County, New Mexico. The experiment began in April 2008 and will finish in May 2010; 2008 was an "Off" year and 2009 was an "On" year for the experimental orchard. In this study there were three deficit irrigation treatment groups and a control group, which was fully-irrigated according to the Mesilla Valley Pecan Growers' Irrigation Scheduling Monitor ("the Pecanigator").

The experimental groups were:

- 1) Early Season Deficit - two nonconsecutive irrigations skipped during the period from May to mid-July, which corresponds to pollination and fertilization to the first indication of the water stage.
- 2) Mid-season Deficit - two nonconsecutive irrigations skipped during the period from mid-July through August, which corresponds to the water stage.
- 3) Late Season Deficit - two nonconsecutive irrigations skipped during the period from September to late October, which corresponds to kernel filling.

Tree and soil water status were measured to document the differences in water stress between the treatments. Before and after each irrigation, stomatal conductance was measured with a leaf porometer, and midday stem water potential was measured with a pressure chamber. Soil moisture was monitored with Watermark sensors at 1 ft and 3 ft depth between each pair of experimental trees.

Harvest quantities were weighed for each experimental tree in December 2008 and 2009. Nut samples were taken from each tree to determine nuts per lb, percent kernel, and percentage of sticktights and 'pops'. During March 2009, random shoots that were fruiting and non-fruiting the previous year were tagged so that the new shoots and female flowers could be counted on each shoot in May.

While our study did not show significant difference in the 2008 and 2009 combined yields between any of the treatments, in spring 2009 the early season deficit treatment did appear to negatively affect return bloom on shoots that had been non-fruiting in 2008. Additionally, the late season deficit treatment seemed to have more sticktights than the other treatments. However, no treatment differences were apparent in regard to “pops” or percent kernel in 2008. There may have been a lack of differences between treatments due to the “Off” status of 2008 in regard to yield. At this time, the 2009 nut quality has not been fully analyzed.

Our study was intended to illuminate some of the responses of pecan trees to water deficits at specific times of the growing season and assess the potential for regulated deficit irrigation strategies in ‘Western’ pecans, as has proved beneficial for other crops (eg. grapes, prunes, and pistachios). Regulated deficit irrigation provides a technique for intentionally subjecting a crop to water stress at particular growth stages to reduce irrigation water use while minimizing negative effects on crop yield and quality. Our study covers two growing seasons and is nearly finished, but at this time more research is needed to establish the potential for regulated deficit irrigation in ‘Western’ pecans.

Phenology of Pecan Fruit and Implications for Nutritional Management

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Producing pecans profitably and consistently requires meeting the nutritional needs of the tree with an efficient and sustainable fertilizer program. To minimize wasted resources and potential soil and groundwater contamination, only nutrients that are at risk of deficiency should be applied. Orchard managers can get economic returns from fertilizer by proper application timing and understanding nutrient demand in the tree and cycling in the orchard. A fertilizer program for a pecan orchard must meet two objectives: 1) supply all nutrients to grow and sustain every tree, and 2) prevent nutritional depletion by the developing seed crop.

Major and minor essential elements are used by pecan trees for growth and crop production. Sufficiency tables for those elements have been developed from research in various states over time from correlation of yields to mid-summer (July) leaf nutrient levels. The current recommended sufficiency tables for Texas and New Mexico are shown in Table 1. High pH, calcareous soils typify the western irrigated pecan-growing region, and such soils limit root uptake of certain minor essential elements. Preferred method of nutrient delivery (foliar versus soil-applied) is also noted in Table 1.

Phenology is the chronological order of biological events. Pecan tree phenology is predictable, advanced or delayed by temperature, and influenced by cultivar (Herrera, 1988) and rootstock (Grauke and Pratt, 1992). Pecan is adapted to the climate of North America by being deciduous, so the phenomenon of dormancy during the winter months compresses pecan growth and fruit phenology into approximately 270 days. The beginning and ending markers for the trees' growing season are from bud swell to leaf senescence. The seed crop phenology begins with anthesis of male and female flowers, and ends at shuck dehiscence. Included in pecan phenology is the initiation of buds that either generate new shoots and leaves in the current season (CS) or generate leaves, shoots and flowers in the succeeding season (SS).

Twenty important biological events are charted in half-month (15 day) intervals in Table 2. The event spanning the most time is vegetative leaf expansion and shoot growth, which is characterized by intermittent flushes of variable duration. Split applications of fertilizer to meter out N availability and limit losses from rainfall/irrigation leaching is recommended to support this event. Reduction of N in late summer is also advised to coincide with the cessation of vegetative growth and to reduce risk of winter injury, especially to young, non-bearing trees.

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Table 1. Sufficiency levels for pecan nutrients and preferred method of application

Element	Dry Wt. Concentration	Dry Wt. Concentration	Fertilizer application for calcareous soils
	Texas	New Mexico	
N-Nitrogen	2.5 to 4.0%	2.5-3.9%	Soil, Foliar
P-Phosphorus	0.15 to 0.30	0.12-0.30	Soil
K-Potassium	0.75 to 1.25	0.75-1.25	Soil, Foliar
Ca-Calcium	0.70 to 3.00	0.70-1.50	Soil
Mg-Magnesium	0.30 to 0.60	0.30-0.60	Soil, Foliar
Fe-Iron	50 to 300 ppm	50-300 ppm	Foliar
Mn-Manganese	40 to 300	100-800	Foliar
Zn-Zinc	80 to 500	50-100	Foliar
B-Boron	20 to 45	20-45	Foliar
Cu-Copper	10 to 30	10-30	Foliar

Table 2. Approximate times of important biological events in pecan phenology

Event	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Budbreak & Leafburst				■								
Leaf expansion & Shoot Elongation				■	■	■	■	■	■			
Catkin anthesis				■	■	■						
Pistillate flower anthesis				■	■	■						
Pistil fertilization (pollination)				■	■	■						
Nutlet expansion % ovule differentiation						■	■	■				
Ovule elongation						■	■	■				
Water stage						■	■	■				
Full ovule elongation						■	■	■				
Early shell hardening							■	■				
Half shell hardening							■	■				
Cotyledon thickening (Gel Stage)								■	■			
Full shell hardening								■	■			
Dough stage; kernel filling								■	■			
Separation of shuck & shell								■	■			
Shuck Split								■	■			
Leaf abscission										■	■	
Catkin differentiation & initiation					■	■	■	■	■			
Pistillate Flower induction					■	■	■	■	■			
Pistillate Flower Initiation	■	■	■									

2009 USDA-ARS Pecan Cultivar Release: 'Mandan'

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'Mandan' is a new pecan [*Carya illinoensis* (Wangenh.) K. Koch] cultivar released by the U. S. Department of Agriculture (USDA), Agricultural Research Service (ARS). 'Mandan' was released because of its high nut quality, high yield potential, early nut maturity, scab disease (*Fusicladium effusum* G. Winter) resistance, excellent tree strength, and late budbreak. 'Mandan' should be adapted to all pecan growing areas of the world. Pecans from this cultivar can be sold in-shell or shelled to produce a large proportion of halves and large pieces.

Origin

USDA conducts the only national pecan breeding program. Crosses are made at Brownwood and College Station, Texas (Grauke and Thompson, 1996; Thompson and Grauke, 1991; Thompson and Young, 1985). Seedling clones are established on their own roots or budded to pollarded trees for the initial 10-year testing phase at College Station. Superior clones then enter NPACTS (National Pecan Advanced Clone Testing System), where they are tested across the U.S. pecan belt in cooperation with state researchers and private growers. After several years, the best clones are given Native American tribe names and released to nurseries for propagation to sell to growers. USDA cultivars are never patented, and after release, growers can propagate the new cultivar as much as desired.

The 'Mandan' are a Native American tribe, and one of the seven tribes that make up the Great Sioux Nation (Hodge, 1975). They speak Lakota, one of the three major dialects of the Sioux

language. They are the westernmost of the three Sioux groups that occupy land in both North and South Dakota. Today they are found mostly in the five reservations of western South Dakota.

'Mandan', tested as selection 1985-1-2, is a progeny from a 1985 cross between the 'BW-1' and 'Osage' cultivars made by T. E. Thompson at Brownwood, Texas (Fig. 1). 'BW-1' originated as an open-pollinated seedling at Brownwood, Texas of unknown parentage. 'Osage' is a USDA cultivar released in 1989, from a 'Major' X 'Evers' cross (Thompson et al. 1991).

'Major' is an old native from the Green River, Henderson County, Kentucky (Thompson and Young, 1985). 'Major' is scab resistant and has early nut-maturity. It was long considered the best of the northern cultivars, but now has been largely replaced by newer superior USDA/state cultivars. It is also the female parent of two other USDA cultivars: 'Kanza' and 'Lakota'. It has been a main source of early nut maturity and scab resistance for the USDA Pecan Breeding Program.

'Evers' was a seedling tree purchased from J. A. Evans Nursery, Arlington, Texas by W. T. Evers and grown on his farm in Denton County, Texas. It was introduced about 1950. The early maturing nuts are small, and the tree is very prolific, but scab susceptible. 'Evers' is a pollen parent for 'Cherokee', 'Chickasaw', 'Shoshoni', and 'Osage' to which it conferred precocity and prolificacy.

Description

The 'Mandan' seedling was initially grown and evaluated at Brownwood, Texas. On the basis of preliminary performance, extensive testing was started in 1996. Yield data indicate that 'Mandan' has adequate precocity, similar to 'Pawnee'. In an eleven year NPACTS test at Brownwood, Texas (Table 1), 'Mandan' produced about 152 pounds of nuts per tree, compared to 160 for 'Pawnee', and 146 for 'Desirable'. A flood in 2004 removed a large portion of the crop that was on the ground, destroying yield data for this year. When considering total pounds of kernel per tree over the life of the test, both 'Mandan' and 'Pawnee' produced about 92 pounds per tree, compared to 75 for 'Desirable'. In this same test, nuts per cluster was 2.3 for 'Mandan', compared to 3.3 for 'Pawnee' and 2.7 for 'Wichita'. The alternate bearing tendency of 'Mandan' tentatively appears less than 'Pawnee' and 'Desirable'. As with most cultivars, fruit thinning in mid-summer may be needed in some years.

Average nut size (nuts per pound) is about 51 for 'Mandan' and 'Pawnee', compared to 48 for 'Desirable', and 58 for 'Wichita' (Table 2). The nut is oblong elliptic, with an obtuse apex and rounded base (Fig. 2). Nuts shell out with 59-65% kernel. Kernels are cream to golden in color, with medium, non-trapping dorsal grooves and rounded dorsal ridge.

'Mandan' has proven to be a consistent producer of high quality nuts that mature and are ready to harvest 2-4 days before the early-maturing 'Pawnee' cultivar. Time of spring budbreak is very late (later than 'Pawnee') (Table 3), contributing to its adaptation to northern sites. 'Mandan' is protandrous, with early to mid-season pollen shed and mid-season to late pistil receptivity (similar to 'Pawnee') (Fig. 3). 'Mandan' should be a good pollenizer for, and well pollenized by 'Kanza', 'Wichita', and 'Lakota'. Trees are compact columnar in growth habit, with strong branch angles. This should allow them to escape shading longer than more spreading trees such as 'Desirable', at any tree spacing. Tentative data shows that 'Mandan' is very resistant to scab disease (Table 4), with medium susceptibility to yellow and black aphids.

Availability

'Mandan' was released Feb. 13, 2009. It is not patented and can be grafted and budded as much as desired by anyone. Graftwood was supplied to nurserymen in the spring of 2009. The USDA does not have any trees for distribution. Genetic material of this release will be deposited in the National Plant Germplasm System where it will be available for research purposes, including development and commercialization of new cultivars. It is requested that appropriate recognition be made if this germplasm contributes to the development of a new cultivar.

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Table 1. National Pecan Advanced Clone Testing System (NPACTS) data from an eight replicate test at Brownwood, Texas comparing the yield of nuts (pounds per tree) of the ‘Mandan’ pecan to other cultivars. Trees were spaced 30 X 35 feet, and were grafted in April, 1996. A flood destroyed yield data in 2004.

Cultivar	Yield (lbs./tree)									
	1999	2000	2001	2002	2003	2004	2005	2006	2007	Total
Mandan	1.01	1.39	11.65	14.81	6.41	Flood	42.64	26.69	47.04	151.64
Pawnee	1.66	0.82	14.12	24.43	4.22	Flood	31.32	24.59	59.23	160.39
Desirable	0.11	0.39	6.95	9.93	22.64	Flood	39.23	11.33	54.97	145.55
Wichita	1.43	1.82	27.95	24.98	9.86	Flood	53.85	6.29	0	126.18

Table 2. National Pecan Advanced Clone Testing System (NPACTS) nut quality data from a replicated test at Brownwood, Texas comparing the ‘Mandan’ pecan to other cultivars.

Cultivar	Percent Kernel 1999-2007	Nuts Per Pound 1999-2007	70% Shuck Split	Kernel Color
			Date 2005-2007	(1=lightest) 1999-2007
Mandan	60.4	50.8	Sept. 16	2.9
Pawnee	57.6	51.6	Sept. 20	2.7
Desirable	51.6	47.8	Oct. 21	2.9
Wichita	57.7	58.3	Oct. 24	3.0

Table 3. National Pecan Advanced Clone Testing System (NPACTS) budbreak ratings from a replicated test at Brownwood, Texas made April 2, 2003 and April 1, 2009, comparing the ‘Mandan’ pecan to other cultivars (1 = dormant, 2 = bud swell, and 3 = inner scale split, 4=leaf burst, 5=leaf expansion).

Cultivar	2003 Rating	2009 Rating
Navaho	4.3 a	5.0 a
Wichita	3.5 b	3.3 b
Desirable	2.9 c	3.4 b
Pawnee	2.9 c	3.3 b
Mandan	2.1 d	3.1 b

Means based on rating of eight trees. Means followed by the same letter cannot be separated at the 0.05 level

Table 4. Scab ratings for four pecan clones growing near at Brownwood, Texas. Ratings recorded in 2004, 2005, and 2007 using the Hunter-Roberts (Hunter and Roberts 1978) 1 to 5 scale (1 = no scab and 5 = >50% coverage with scab lesions).

Cultivar	Leaf scab rating	Nut scab rating
Mandan	1.6	1.4
Pawnee	1.9	1.9
Desirable	1.9	2.0
Wichita	4.0	4.5

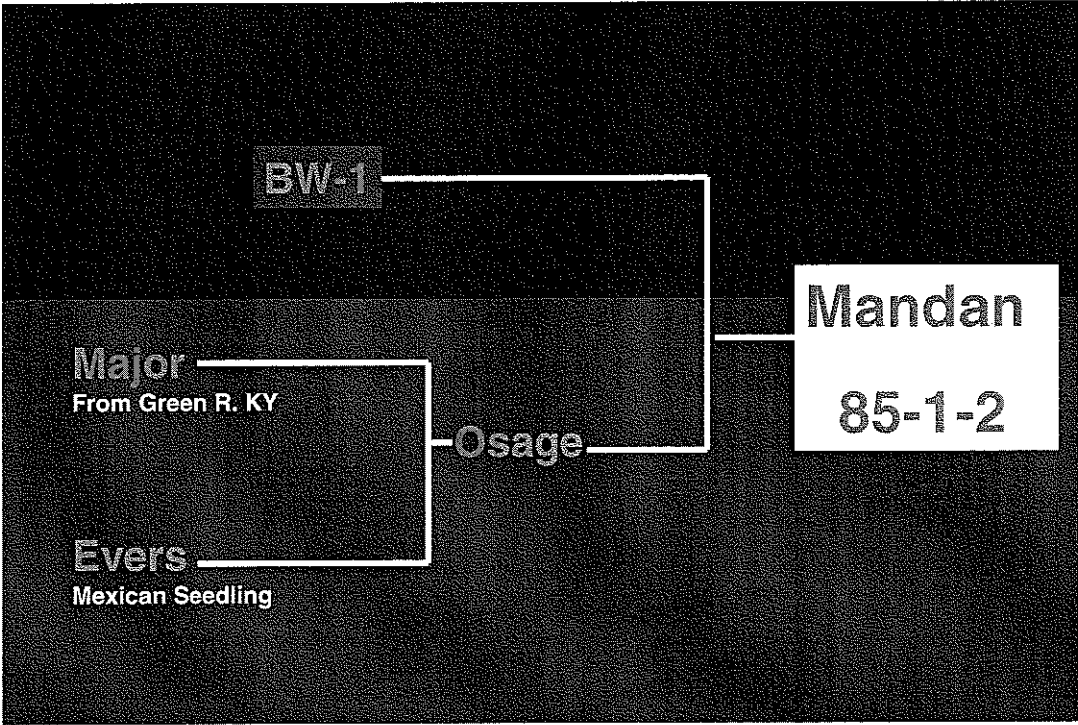


Fig. 1. Pedigree of the ‘Mandan’ pecan.

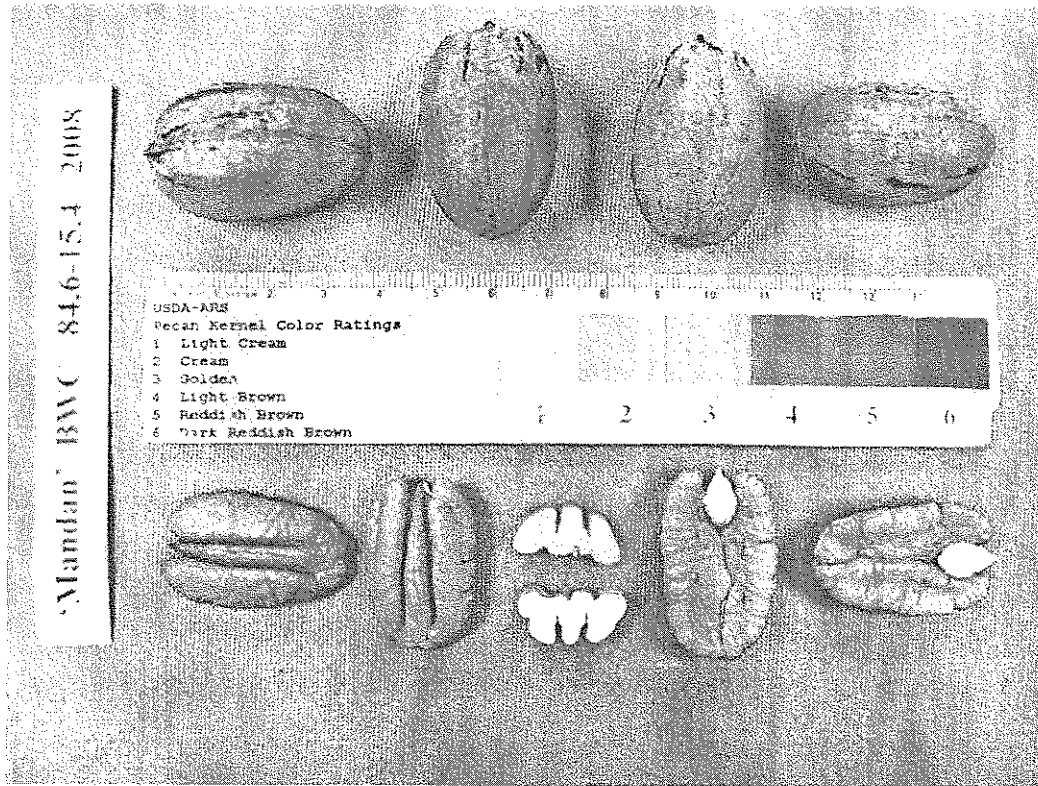


Fig. 2. Nuts and kernels of the 'Mandan' pecan.

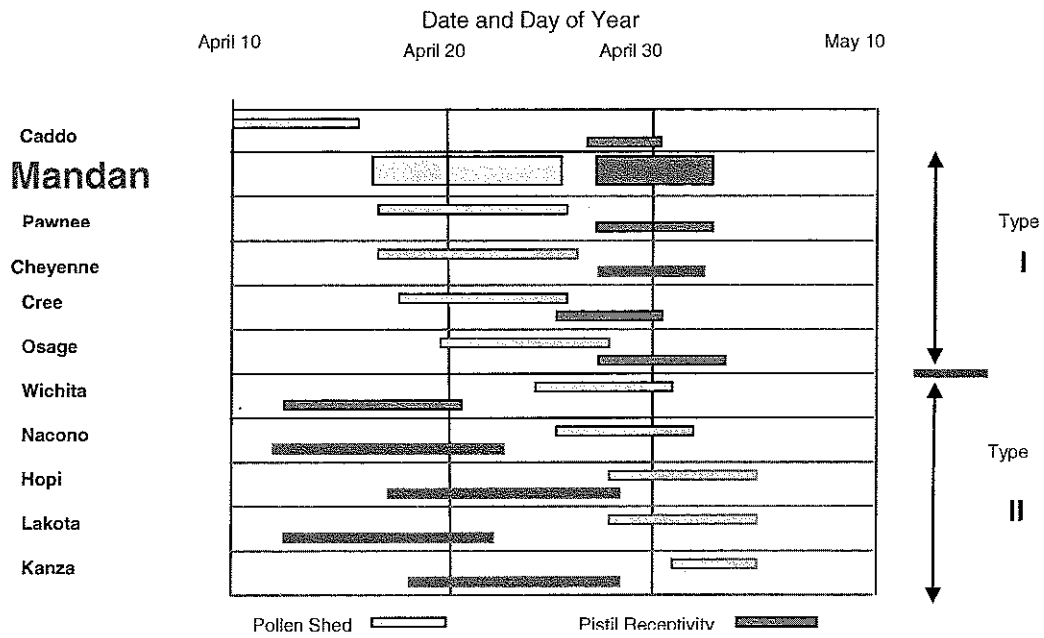


Fig. 3. Pollen shed and pistil receptivity for the 'Mandan' pecan and check cultivars at College Station, Tex. in 2007.

Estimating the \$ Value of a Pecan Tree

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The value of a pecan tree that had reached full production and later needs to be replaced because of its lost by physical or chemical damage has to be estimated by itemizing each one of the costs incurred in planting back the tree, training the tree and including the economic losses by lack or low nut production until the tree reaches again its full production capacity.

It is estimated that the **direct costs** of replacing the tree and training it until it reaches its full production will be in a range of **\$1,750.00 to \$2,000.00** . That its **nut production losses** until it reaches again full production that will take 8-9 years is estimated that will be from **\$ 650.00 to \$750.00** and **overhead or administrative costs will be \$ 100.00** until tree is in full production, adding all these components brings the value of a mature pecan tree to a value range from \$2,500 to \$2,850.00. All cost estimates were based on an average nut production per acre of 3,000 pounds, with a selling price of \$ 3.25 per point pound and an average 55% kernel.

Good Agricultural Practices for Pecans

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Over the last several years, agriculture has faced many challenges. Among these has been increased scrutiny resulting from various foodborne illnesses in multiple crops. Fortunately, the pecan industry has been spared the brunt of this abuse so far. Each year, there are approximately 76 million cases of food-borne illnesses, resulting in over 5000 deaths. The annual economic losses from bacterial contamination may be as much as 10-83 billion dollars. While many in the pecan industry feel that food safety and the prevention of contamination are problems that only shellers and processors should be concerned with, growers have a large role to play in making pecans safe for everyone.

Our understanding of the origins and persistence of microbes in the agricultural environment and food contamination has changed considerably over the last few years. Good agricultural practices are a set of *recommendations* that can help improve the quality and safety of the crops grown, minimizing the risk of crop contamination on the farm.

Bacteria such as *Salmonella* and *E. coli* O157:H7 are the most common culprits of foodborne illness associated with crop contamination. Pecans, while not immune to contamination, have some intrinsic barriers to microbial organisms, including shells and husks. The internal surface of dry, intact kernels from nuts with intact shells are also virtually sterile. However, hull or shell splitting can occur before, during, or after harvest. Varieties vary greatly in shell thickness, so some are more prone to cracking during the harvest process than others. Birds, insects, or other animals may also damage the shell. During wetting or drying, shells may crack. Additional protection is present in pecans in the form of the pecan nut packing tissue inside the shell, which has been shown to be toxic to *Salmonella*, providing some protection from initial contamination (Beuchat and Heaton, 1974).

Because bacteria can be found in animal waste products, therefore, the responsible use of manure as a fertilizer source has been a focus of on-farm contamination prevention. However, there are other factors to consider besides the use of manure in the orchard. These include the site, water source, worker health and hygiene, sanitary facilities, field sanitation, shelling/cleaning facilities, transportation, and traceback.

If the orchard site was “virgin” ground prior to its development as an orchard, the potential pathogen level is generally considered low. If for example, the land was previously used for a confined animal feeding operation, the risk could be higher. If the land was reclaimed for

agricultural use by application of animal waste or municipal biosolids, the risk could also be greater. Adjacent land uses may also be important. Potential pathogens may be airborne in dust, domestic animals may stray into the orchard, there may be pathogen-contaminated runoff from adjacent animal operations.

Water sources should be considered as possible sources of foodborne pathogens. This consideration should include water used for irrigation, mixing pesticides and other foliar-applied products, equipment sanitation, product sanitation, and cooling operations.

Surface waters may contain animal fecal matter and wells can become contaminated with bacteria. *E. coli* O157:H7 is viewed primarily as a water-borne pathogen.

Salmonella, *Giardia* and *Cyclospora* outbreaks on produce are primarily caused by contaminated water. Growers should try to use potable (drinking) water for pesticide sprays. When potable water is not available, test water quality and keep records.

Wild animals as well as domestic animals have been identified as a source of pathogens in some disease outbreaks. There may be no practical way to manage for wild animals in an orchard situation, but we need to be aware that they can present a risk.

Indeed, the most significant source of foodborne pathogens on the farm may be animal wastes, particularly manures, that have been added to improve soil texture as well as for nutrients. The “quality” of these amendments varies widely and, while our concern is primarily food safety, animal manure-based soil amendments are not currently regulated for food safety but nutrient content. Properly treated manure or biosolids can be an effective and safe fertilizer if the proper precautions are in place. Use treatments to reduce pathogens in manure and other organic materials. Treatments may be active (e.g., composting) or passive (e.g., aging).

Application of poultry litter to pecan orchards within 1-2 months of harvest carries a greater potential for pathogenic contamination of nuts than do early season applications. Certified USDA organic farming regulations prohibit the application of fresh manure for use on edible crops. These regulations also state that the last application of manure should be applied and incorporated into soils no less than 120 days before harvest for crops whose edible portions come into contact with the soil.

Poultry litter applied to pecan orchards is rarely incorporated, therefore, applications should be made no less than 180 days before harvest. The use of mature litter, applied prior to mid-May should be considered as a viable method of reducing the risk of contamination and would also avoid unfavorable perceptions by the public of “unhealthy” conditions in pecan orchards.

The management of cattle herds beneath pecan trees has a rich history in the U.S. However, in this age of accountability such a practice becomes increasingly risky and special precautions must be taken to ensure the safety of pecans that reach the consumer.

Research has shown that *E. coli* levels may increase from 4% to 23% following grazing. In addition, Salmonella contamination on pecans increased to 36% with grazing under wet conditions (Marcus and Amling, 1976). For this reason, the grazing of cattle in pecan orchards is highly discouraged. However, if a grower chooses to graze cattle in the orchard, those cattle should be removed no later than 180 days prior to pecan harvest.

There is little human contact with pecans prior to and during harvest in commercial operations as a result of the mechanized nature of the cultivation and harvesting processes. However, employees and field workers should be encouraged to practice good hygiene and must be provided with adequate sanitary facilities to insure that human waste does not enter the orchard.

Many of the potential sources of food-borne pathogens would increase the population numbers on the orchard floor. In addition to nut contamination on the orchard floor following shaking, pathogens may be “aerosolized” by various orchard activities including pest scouting, cultivation, spraying, and harvest and be deposited on the pecans. Granted, the likelihood of some of these events occurring may be small, but growers need to be aware of the risks involved. It is important to consider that perception plays a large role in consumer acceptance of your product, whether the perception is justified or not. Thus, it is important to consider all the activities in an orchard that could potentially contribute to pathogen contamination of pecans.

Proper field sanitation should include cleaning of harvest equipment, containers, and bins prior to use. In cleaning and shelling plants, nuts should be sorted and culled properly, good hygiene should be enforced, and equipment should be cleaned and sanitized. Wash waters should have detectable levels of free chlorine and all animals should be excluded from the facility.

Good hygienic and sanitation practices should be used when loading, unloading, and inspecting pecans as well. Inspect transportation vehicles for cleanliness, odors, and obvious dirt and debris before loading. Avoid leaving harvested crop in the sun and maintain proper temperatures throughout the transportation process. Pecans should be loaded with care in order to minimize cracking.

The availability of orchard operation records is essential and helpful when it comes to food safety. Although there are many common elements, each farming operation is unique. Specific documentation for each orchard block is optimal for minimizing risk. Ultimately, the product must be traceable from the farm through the accumulator, sheller, distributor, transporter, and retailer. The grower’s responsibility is to keep good records and know from which orchards individual lots were harvested from and to whom they are sold. Documentation should include the source of the product, the date of harvest, farm identification, and a record of who handled the product.

Food safety and product quality are of the utmost importance to the pecan industry. As all food products are placed under more intense scrutiny, the value of preventative steps to minimize the risk of the possibility of contamination cannot be overemphasized. Contamination could potentially arise from a variety of sources in the field, as well as in the shelling plant. Therefore, contamination management programs should not begin and end with the grower, sheller or handler. Unsanitary harvesting and transportation equipment, improper fertilizer use, and bacteria from the hands of workers are simply a few of the potential contamination sources that could occur on the production side of the pecan industry. Current technologies cannot eliminate all potential food safety hazards; however, by utilizing good agricultural practices growers can also minimize the risk of infection.

The market for pecans is growing worldwide. Protection of pecans as a product is an industry-wide effort. This helps our industry from top to bottom. Pecan producers want to provide buyers with the confidence that they are receiving the highest quality pecans, and that every precaution has been taken to reduce the presence of harmful microorganisms or chemicals. Good agricultural practices assure food processors, consumers, and government regulators worldwide that our industry is diligent in its commitment to offer the safest, highest quality pecans available.

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The National Pecan Sheller's Association Marketing Program

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For more than 10 years, the National Pecan Sheller's Association (NPSA) has sponsored medical research which shows pecans may help people live healthier lives. NPSA's goal is to expand the market and increase the demand for pecans among health-conscious consumers. Today NPSA is preparing to promote findings from a new study, published in a major medical journal, which suggests eating pecans may provide neurological protection. Specifically, data from the study conducted at the University of Massachusetts suggests pecans may help improve the quality of life for people suffering from Lou Gehrig's Disease. This study is the latest in a line of medical research which has changed the public perception of pecans.

**44th ANNUAL WESTERN PECAN GROWERS ASSOCIATION
CONFERENCE SPEAKERS**

March 7-9, 2010

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