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Pecan Food Fantasy

And

Pecan Trade and Equipment Show

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Introduction

Mechanical hedging has become a standard practice among Southwestern US pecan growers. Trees are typically hedged (pruned on the sides of the trees) and topped. This operation serves several purposes. It keeps the tree size manageable, eliminating the need for removing trees. It allows light to penetrate into the orchard, increasing nut production on lower branches. Hedging in the 'on' year reduces the amount of nut-bearing wood and therefore the fruit load, and is thought to increase 'on' year nut quality, increase 'off' year nut yield, and reduce alternate bearing.

Although mechanical hedging has been widely adopted, there are few studies evaluating the effects on crop production and quality. There is no standard method of hedging; each grower adopts their own methods.

Methods

At Green Valley Pecan Company, located in south-central Arizona, a four-year hedging cycle has been adopted. In this cycle, every fourth row is pruned every fourth year (i.e. each row is pruned once in four years). This program was adopted partly for reasons of practicality. The orchard covers almost 5,000 acres and it is not practical to prune more than one quarter of the orchard in any given year.

In 2009, we began monitoring pruned 'Wichita' and 'Western Schley' trees to evaluate the impact of hedging. The Western Schley trees were planted in 1969, and are now on 60 x 60 foot spacing. Wichita trees were planted in 1967 and are spaced 30 feet apart in rows that are 60 feet apart. Both blocks are flood irrigated.

Trees are side-hedged approximately 20 feet from the tree trunk, angled in at about a 5^o angle. Western Schley trees are topped at 50 to 60 feet at the peak, and angled at 45^o. Wichita trees are topped at 50 feet. Hedging and topping are done in the dormant season, usually in January or February. This practice was started in both orchard blocks prior to the 2006 growing season.

In 2009 and 2010 we collected nuts from individual rows in the Western Schley and Wichita blocks with a Flory self-propelled harvester. The nuts were transferred to a Thomas bank-out runner which was weighed empty, and again after collection of each row of nuts to obtain a per row harvest weight. A sample was collected from each row's harvest, and cleaned to remove sticks, rocks, and other trash. Nuts were graded to separate marketable nuts, stick-tights, and pregerminated nuts. All three categories were weighed. A sub-sample of good nuts was counted and weighed to measure nut size, and then shelled to determine percent marketable kernel.

In 2009, when our first data were collected, the trees had been in the 'every fourth row, every fourth year' hedging program for three years, so all the rows had been pruned once. In 2010, a different set of trees were measured because the hedging category is based on 'leaf since hedging' (for example, the 1st leaf since hedging would have been pruned during the previous dormant season). The individual rows in each block that were pruned at the same time were considered a hedging treatment. Pollinizer rows were not included.

Results

In-shell yield: Western Schley trees yields increased every year after hedging (Figure 1; Table 1). First leaf yields were 24%, 2nd leaf 50%, and 3rd leaf 80% of the yields from the 4th leaf. The Wichita trees, on the other hand, rebounded more quickly from hedging and topping, with the in-shell yields in the 1st leaf averaging 45%, and the 2rd and 3th leaf approximately 80% that of the 4th leaf (Figure 1; Table 2).

Kernel percentage: At the time of this writing, data were only available for 2009 and 2010. The kernel percentages of both varieties were highest in the 1st leaf, and declined thereafter (Tables 1 and 2). In Wichita, the kernel percentage was 63% in the 1st leaf, and decreased approximately 1% with each year following hedging, reaching 59% in the 4th leaf. Kernel percentage of Western Schley, on the other hand, was 58% in the 1st and 2nd leaf, and did not decline substantially until the 4th leaf after hedging when it dropped to 56%.

Nut size: The size of Wichita nuts decreased from approximately 7.2 g/nut in 1st, 2nd, and 3rd leaf after hedging to 6.5 g/nut in the 4th leaf (Table 2). Western Schley nuts also had a relatively constant size (from 5.9 to 6.1 g/nut) in the 1st through 3rd leaf, and declined to 5.4 g/nut in the 4th leaf (Table 1).

Stick-tights: The number of stick-tights generally increased with time since hedging (Tables 1 and 2). Wichita had 1.3% stick-tights in the 1st leaf, which increased to 2.8% in the 4th leaf after hedging. In Western Schley the percentage of stick-tights was 1.6% in the 1st and 2nd leaf, and increased to 2.3% in the 4th leaf after hedging.

Pre-germination: The amount of nuts showing pre-germination, or vivipary, varied but was not apparently related to time since hedging (Tables 1 and 2).

Alternate bearing: In 2002 to 2006 to (hedging was initiated prior to the 2006 season) Western Schley trees exhibited a relatively uniform pattern of alternate bearing, with even numbered years being 'off' years, and the odd ones 'on' years (Figure 2). From 2007 to 2010, the alternate bearing pattern appears to have been considerably depressed. Wichita had a less pronounced alternate bearing pattern prior to the start of the hedging program, partly because of low yields in 2005, which should have been an 'on' year (Figure 3). Nonetheless, alternate bearing appears to be reduced since initiation of hedging. It is important to remember that the 2009 growing season was the first in which all four rows of the four-year pattern had been hedged. More seasons of data are needed to fully evaluate the effect of hedging on alternate bearing.

Summary

In-shell yields were greatly depressed in the 1^{st} growing season after hedging in both varieties. However, Wichita yields rebounded rapidly and had largely recovered by the 2^{nd} leaf after hedging, although 4^{th} leaf yields were higher than 2^{nd} or 3^{rd} leaf yields. In contrast, Western Schley yields increased annually each year of the four years following hedging.

Several aspects of nut quality changed with time following hedging. Kernel percentage declined in both varieties, but Wichita began declining in the 2^{nd} leaf, in contrast with Western Schley, which did not begin declining until the 3^{rd} leaf. The overall decline was greater in Wichita (from 63.2 to 59.9%) than in Western Schley (57.6 to 55.7%). Average size of Wichita nuts began declining in the 2^{nd} leaf, whereas Western Schley did not show a decline in nut size until the 3^{rd} and 4^{th} leaf. The decline over four years was similar in Wichita (from 7.2 to 6.5 g/nut) to than in Western Schley (6.1 to 5.4 g/nut). The number of stick-tights in Wichita increased in the 3^{rd} and 4^{th} leaf, and in Western Schley in the 4^{th} leaf after hedging. Pre-germination was not consistently affected by hedging.

Alternate bearing in both Western and Wichita appears to be decreasing since hedging and topping were initiated; however, the history of the hedging program is not long enough to draw firm conclusions. Continued monitoring of yield and quality in these orchard blocks will provide a better understanding of the long-term effects of the four-year hedging program.

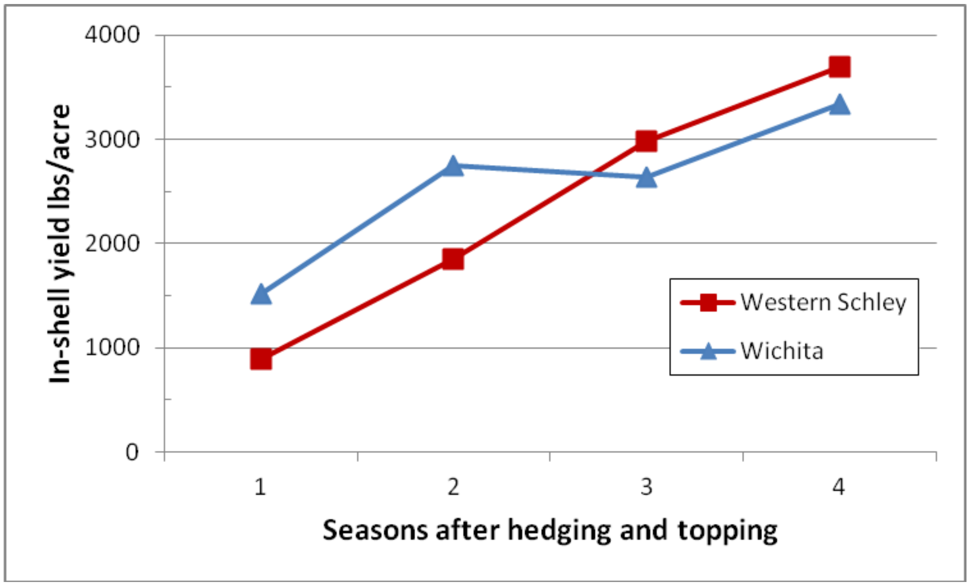

Figure 1. In-shell nut yields for Western Schley and Wichita pecans for four years following hedging and topping.

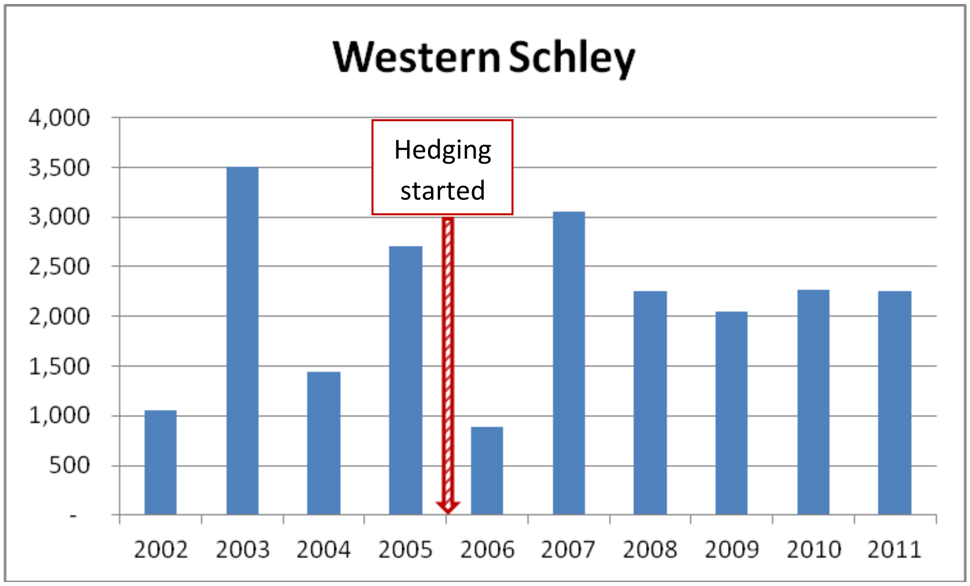

Figure 2. Annual Western Schley nut yield, 2002 - 2011.

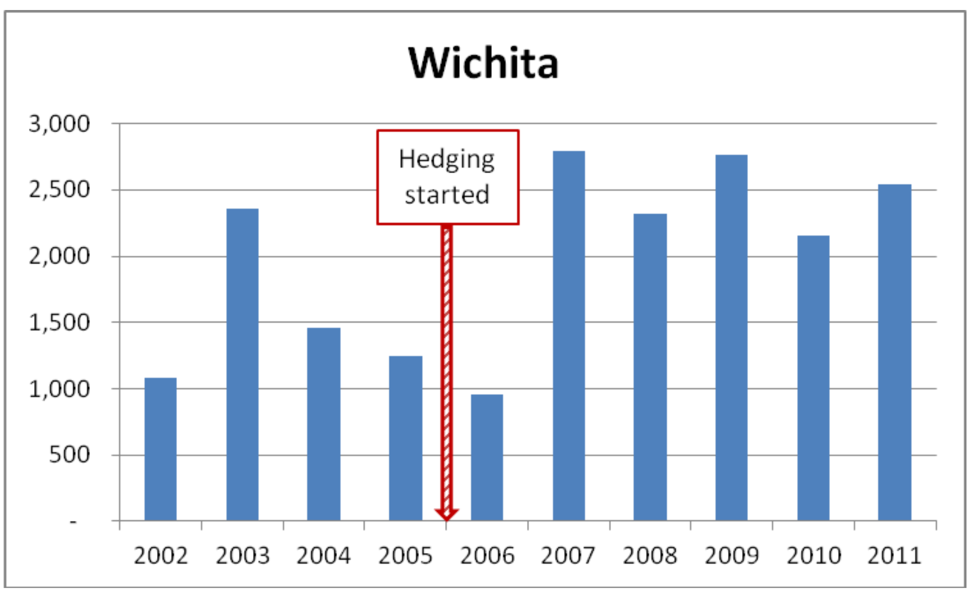

Figure 3. Annual Wichita nut yield, 2001 - 2011.

Table 1. Western Schley nut yield and quality.

	Year	Leaf after hedging			
		1	2	3	4
In-shell nuts (lbs/acre)	2009	1040	2512	3212	2860
	2010	774	1570	3238	4037
	2011	849	1474	2482	4191
	Average	888	1852	2977	3696
Nut weight (g/nut)	2009	5.6	5.3	5.8	5.4
	2010	6.6	6.4	6.6	5.7
	2011	6.1	5.6	5.3	4.9
	Average	6.1	5.8	5.9	5.4
% Kernel	2009	56.5	55.7	55.3	54.5
	2010	59.4	60.3	59.3	57.0
	2011	-	-	-	-
	Average	57.6	57.7	57.1	55.7
% Sticktights	2009	1.5	1.9	2.3	3.3
	2010	1.4	1.5	1.1	2.1
	2011	1.8	1.4	2.7	1.6
	Average	1.6	1.6	2.0	2.3
% Pre-germination	2009	4.5	7.5	2.4	4.7
	2010	0.3	0.0	0.0	0.2
	2011	4.3	2.3	2.9	5.3
	Average	3.0	3.3	1.8	3.4

Table 2. Wichita nut yield and quality.

	Year	Leaf after hedging			
		1	2	3	4
In-shell nuts (lbs/acre)	2009	1616	2954	3001	2702
	2010	1319	2777	2598	3582
	2011	1616	2508	2297	3732
	Average	1517	2746	2632	3339
Nut weight (g/nut)	2009	6.5	6.6	6.6	6.3
	2010	8.1	7.4	7.7	6.8
	2011	7.2	6.9	7.3	6.5
	Average	7.2	7.0	7.2	6.5
% Kernel	2009	62.8	60.5	60.5	60.0
	2010	63.6	63.0	62.1	59.6
	2011	-	-	-	-
	Average	63.2	61.8	61.2	59.9
% Sticktights	2009	0.6	1.7	1.4	4.5
	2010	2.9	2.0	5.9	3.0
	2011	0.4	1.1	0.7	1.1
	Average	1.3	1.6	2.7	2.8
% Pre-germination	2009	4.2	3.3	9.3	6.2
	2010	0.3	0.2	0.4	1.3
	2011	1.5	1.2	1.3	5.4
	Average	2.0	1.6	3.6	4.3

Impact of Hedge Pruning (New Mexico)

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Introduction

In the southwestern US, the need to the maximize nut production early in the life of orchards has driven growers to plant trees at higher densities than in the historic pecan-producing areas of the southeast. Early in their productive life, higher density pecan orchards (48 to 73 trees or more per acre) are indeed more productive on a per acre basis than low density orchards, but also become crowded more quickly. Pecan pistillate (female) flower formation, fruit set, and kernel growth are dependent on adequate canopy light exposure. Thus, as crowding advances in more densely planted orchards, overall yields begin to decline, alternate bearing intensity increases, and 'On' (high production) season nut quality declines. Furthermore, correcting micronutrient deficiencies and managing insect pests, where thorough spray coverage in tree canopies is critical, is problematical in crowding orchards.

In the late 1980's and early 1990's, many orchard managers thinned their orchards (i.e., decreased the number of trees within the orchards) to allow better light distribution in the orchard canopies. This strategy proved to be a temporary solution as canopy size continued to increase, and the magnification of alternate bearing and associated problems returned. Today the primary method for managing crowding in southwestern pecan orchards is mechanical hedge pruning. Although the benefits of hedge pruning are now well-documented for pecan (e.g., Lombardini, 2006; Wood and Stahmann, 2004; Wood, 1969), continued pruning research is needed to address the increasing number of circumstances that western pecan managers face, and to collect data over longer periods of time. Numerous mechanical pruning strategies have been used by western orchard managers. Elements of these strategies that can vary greatly among producers include: pruning interval (two, three, four, and five + years); number of rows included (every, alternate, or every third or fourth tree row); tree height and width; and pruning with respect to crop yield ('On' and 'Off' production years).

The objective of our study is to shed light on the question of mechanical pruning frequency especially with respect to total annual yield, alternate bearing, and nut quality. The initiation of four pruning cycles used in this study was after a reclamation pruning process that was conducted prior to a low production year. We define reclamation as the pruning of an orchard that had experienced significant magnification of alternate bearing for several years (not part of a maintenance pruning schedule). Although reclamation pruning conducted prior to a ‘Off’ season is not the preferred time, it is a common circumstance that western grower face. We recognize the limitations of this research in that that no single study can incorporate all pruning strategies currently used, nor answer the majority of the questions concerning different pruning strategies. Data presented in this study is preliminary and represents the first five years of a 10+ year study.

Materials & Methods

The experimental orchard was a mature ‘Western’ cultivar orchard with ‘Wichita’ pollinizers located in the Mesilla Valley near Las Cruces, NM (32° 14’N; 106° 47’W; elevation 3872 feet). Trees were planted 30’ by 30’ on a square pattern. The orchard had a history of severe alternate bearing.

In Winter 2005/2006, the entire orchard was hedge-pruned (sided and topped) in the NW-SE direction. After that initial pruning, trees were either left unpruned (unpruned control) or were subjected to one of three pruning frequency treatments (every year, every other year, or every three years). With each pruning, the east and west sides of each tree row were topped at a 45° angle from the vertical with a height at the apex of about 30 feet from the ground. Tree row sides in pruned plots were pruned during the appropriate pruning cycle to minimize overlap from adjacent tree rows.

The study was arranged as a randomized complete block design with four blocks and one replication per block. Each plot is approximately 5.5 acres and roughly square in shape. Harvest data was collected from one ‘Western’ tree row in the middle of each plot, and from the adjacent halves of the two neighboring ‘Western’ rows. This harvest strategy was used to minimize the effect of yield variability between individual trees by including more trees in the samples. Approximately 0.9 acres is harvested from each plot using commercial equipment. Pecans and field trash from each plot were weighed in field carts using four truck scales. An aliquot was removed from each cart to determine percent trash and to remove pecans for quality analysis.

Preliminary Results and Discussion

Inshell nut yield in the first three seasons of the study (2006-2008) was similar among all of the treatments (Fig. 1). Inshell nut yields in 2009 (an ‘On’ season) from the 1- and 3-year pruning cycles were less than 68% of that of the unpruned control. In contrast, in 2010 (an ‘Off’ season), inshell yields from the 1- and 3-year pruning cycles were 138 and 153% of that of the unpruned control, respectively. Although five seasons is too short a period to draw firm conclusions, it appears that by the fourth and fifth years of this study reductions in alternate bearing were beginning to emerge for trees pruned annually and on a three year cycle.

This same trend was not evident for the 2-year pruning cycle treatment, where inshell yields were 83% of the control in the 2009 'On' season and 80% of the control in the 2010 'Off' season (Fig. 1). The trees in the 2-year pruning cycle treatment may be responding to hedge pruning differently from trees subjected to 1- and 3-year hedge pruning cycles, in part, because pruning prior to 'Off' seasons in severely alternate bearing pecan orchards may further reduce 'Off' season yields. The first season of our study was an 'Off' season and, therefore, trees in the 2-year cycle were pruned only prior to 'Off' seasons (2006, 2008, and 2010). Trees in the 1- and 3-year pruning cycle treatments were pruned prior to both 'Off' and 'On' seasons. Unlike trees in our 2-year pruning cycle treatment, the 1- and 3- year pruning cycle trees could benefit from thinning of fruit wood that occurs when trees are pruned prior to an 'On' season. Unfortunately our experiment did not include a second 2-year hedge pruning treatment beginning a year later in which trees were only pruned prior to 'On' seasons. Yields associated with our 2-year pruning cycle may eventually increase as fruit wood develops and matures in the canopy interiors.

Cumulative inshell nut yields over the first five seasons of the study (2006-2010 growing seasons) were nearly 8000 lbs per acre for both the unpruned control and the trees hedge-pruned on a three year cycle (Fig. 2). More frequently hedge-pruned trees (every year and every two years) had lower cumulative yields than trees pruned every tree years or unpruned. The 2-year cycle treatment had the lowest five year cumulative yields with an average of 6806 lbs per acre.

Regardless of pruning treatment, pecan percent kernel was higher during 'Off' years when crop demand for carbohydrate and mineral resources was relatively low than in 'On' years when crop demand was higher (Fig. 3). By the last three seasons of the study, it appears that the pruning treatments have had positive effects on percent kernel in 'On' seasons, but not in 'Off' seasons. In the 2009 'On' season, average percent kernel was 56.3% for trees in the 1- and 3-year cycle treatments and 55.6% for trees in the 2-year cycle. The average percent kernel for unpruned control trees was only 53.7% in 2009. In the 2008 and 2010 'Off' seasons the average percent kernel was similar across all treatments and the control.

Alternate bearing research in pecan is probably best served by conducting longer-term studies over multiple pruning cycles. At this early point in our study, it seems that the benefits of mechanical hedge pruning with respect to annual nut production, alternate bearing intensity, and nut quality may have appeared in the fourth year of our study. At least in the relatively short term, the 3-year pruning cycle treatment may have afforded the greatest benefit with the least cost to the producer. It remains to be seen, however, whether this balance will carry through as this experiment progresses over time.

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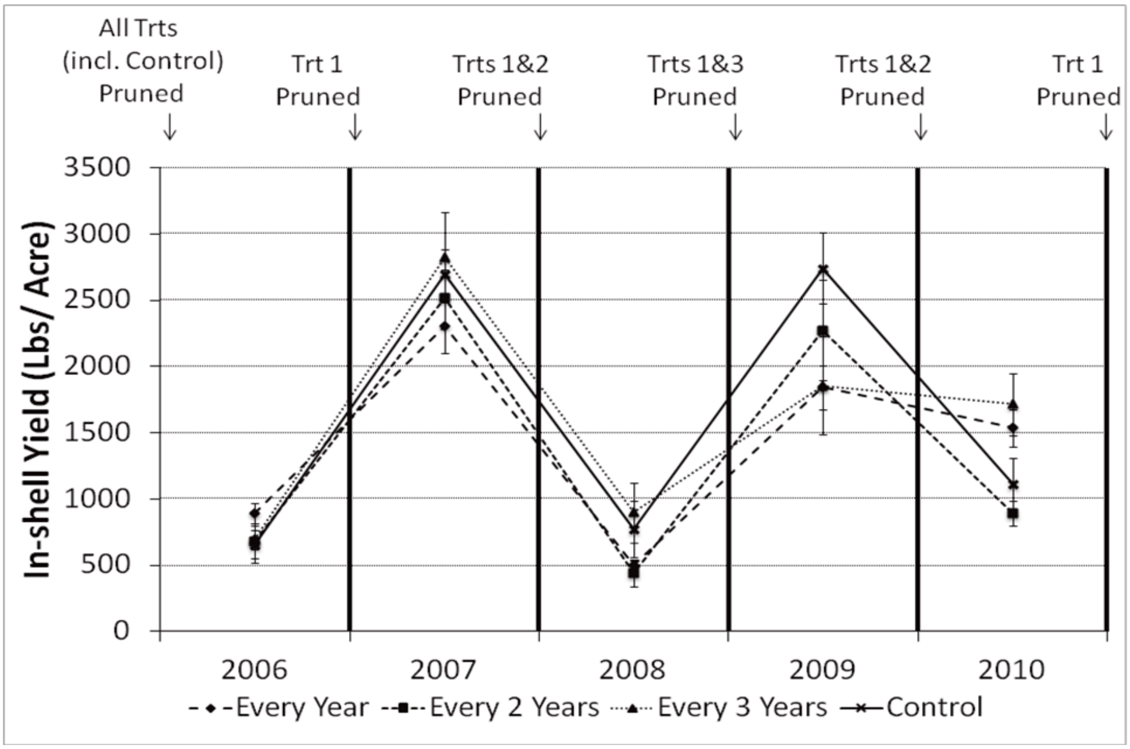

Figure 1. Inshell yield 2006-2010.

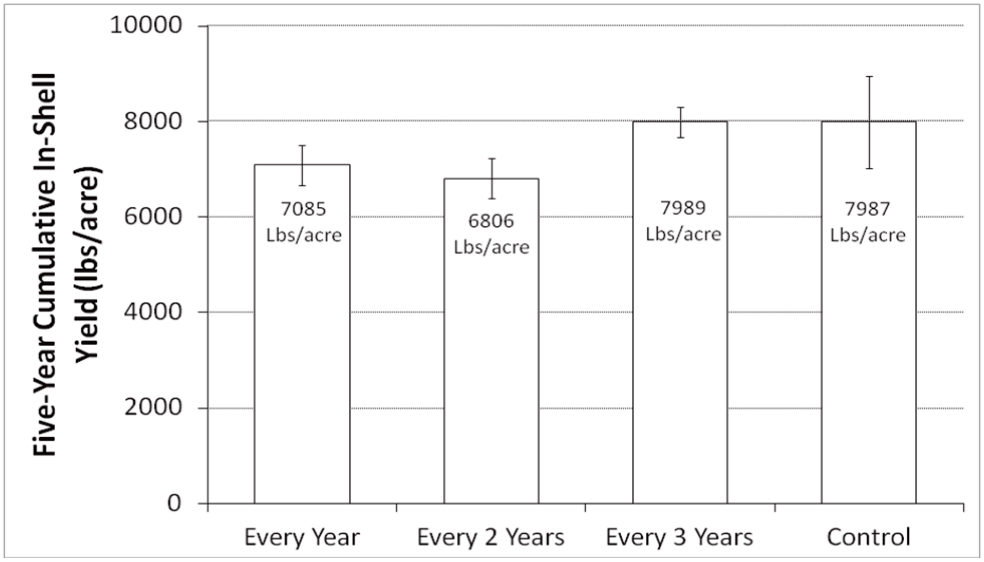

Figure 2. Cumulative inshell nut yield 2006-2010.

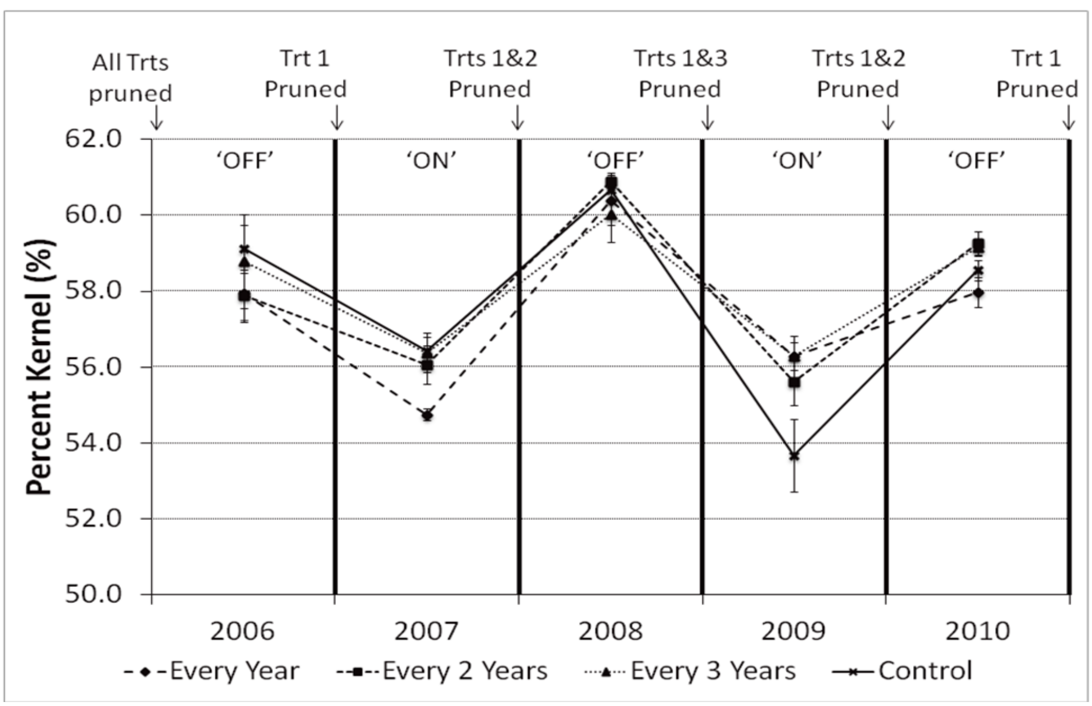

Figure 3. Percent kernel 2006-2010.

Smart Sprayer Technology for Orchard Spraying

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The Technology: Sensor-equipped Orchard Sprayers

Sensor-operated orchard sprayers, often called "target sensing" (TS) sprayers, use arrays of ultrasonic or optical detectors to sense trees and activate spray nozzles in vertical zones only when a target is present. While often considered a new technology, the technique was developed over 30 years ago and has been on the market for decades. The initial patents on the ultrasonic systems have expired, allowing any sprayer manufacturer to develop and use the technology. Sensors on the TS sprayers turn off the spray when between trees or in areas where trees are missing and turn off nozzles where trees are short or sparse. Early studies found an average savings of 28 - 34 % and 36 - 52 % for applications to in-season peaches and apples respectively, using TS sprayers. The studies found that spray volume savings were, as expected, dependent on crop characteristics; when used in orchards with younger, smaller trees or in mature orchards with high proportions of replanted trees, spray savings increased correspondingly.

In principle, TS sprayers maintain, on the target trees, spray deposition equivalent to the conventional sprayers while reducing wasted spray that would deposit on the non-target orchard floors and contribute unnecessarily to both pesticide waste and, potentially, to spray drift and runoff. Moreover, the reduction in applied pesticide would provide an economic return to the grower, providing an immediate return on the capital investment in the sprayer control system.

The Studies: Measuring the Performance of the Sprayers

A series of field experiments were conducted in California orchards in almonds, prunes (in two planting densities) and walnuts. Details of the studies and results have been published in an article in California Agriculture (2011. 65(2): 85-89) and summarized here. In the studies, the spray savings due to the target sensing technology, the reduction in spray deposition (waste) on the orchard floor and in once case, the reduction in the pesticide runoff were measured.

In every field experiment, use of the TS sprayer resulted in spray savings, i.e., less pesticide applied. Deposition on the trees was maintained at levels equivalent to the conventional spraying. The mature prune orchard, being more dense, similar to a uniform "wall" of foliage and having smaller gaps between trees, had the least spray savings, 15%. The mature almonds, being large trees but with larger gaps, especially between the lower portions of the trees, produced a 22% reduction in applied spray. Finally, the mature prunes, in a less dense planting and wide gaps between trees, resulted in a 40% reduction in applied spray. These results reinforced that savings from TS spraying are related to the orchard characteristics. Additionally, the TS systems allow the operator to adjust the sensitivity and "overspray" settings; different applicators may use different settings, resulting in more or less spray savings. Often there is a tendency to be conservative, by setting the sensitivity to overspray, to prevent underspraying portions of trees.

The ground deposition results revealed similar trends to the spray savings. In the denser prune orchard, the TS sprayer reduced ground deposition by 5% versus the conventional sprayer. For the more open prune and the almond orchards, the reduction was 41% and 71% respectively. When concentrations of pesticide were measured in the runoff water of the open prune orchard, the reduction from TS spraying was 41%, roughly equivalent to the reduction in ground deposition.

Economic Implications of the Technology: Savings and Payback Period

Spray application technology that reduces the amount of pesticide applied while maintaining the necessary levels of deposition on the trees provides a direct economic benefit to the grower. An additional benefit is improved productivity using TS sprayers. By reducing the application rate of the pesticide mix, each tank load covers a greater land area, effectively reducing the number of refills, ferry trips to the filling location and the resulting time spent spraying each orchard. This provides an additional economic return to the grower by increasing the acreage each sprayer can treat, thereby reducing labor and fuel costs.

A grower's decision to invest in a new technology is often cautious and based on projections of economic return. The economic return would come from two sources: reduction in pesticide use and the improved productivity of the equipment. Reduction in pesticide costs can be substantial. The UC Cooperative Extension publications (UC Davis, 2008) on costs to establish and produce orchard crops were used as a guide to estimate annual pesticide costs in common California orchard crops. For Sacramento Valley almonds, the annual cost of pest control sprays (material only for diseases and insects) was estimated at $233 per acre. Similarly, for San Joaquin almonds, the cost was estimated at $203. For Sacramento Valley prunes, the estimate was $149 and for San Joaquin peaches, the estimate was $283. These estimates are for material only and do not include variable costs for application (labor and fuel) expenses; these costs are estimated at $9.50 - $10.00 /acre for almonds and similar crops based on $2/gal Diesel fuel at the time of the study.

Based on the results of the field tests, assumptions of spray materials savings of 20% and operating cost savings of 10% (due to fewer refills and less ferry time leading to better equipment productivity) were made. This resulted in a $1 /acre operating cost savings and material cost savings of $47, $41, $30 and $57 per acre for Sacramento Valley almonds, San Joaquin almonds, Sacramento Valley prunes and San Joaquin peaches, respectively.

At the time of the study, the cost of a retrofit spray sensor and control system was approximately $15,000. A rule of thumb in the agricultural electronics industry is that a new product has a reasonable if the payback period is two years or less. Therefore, with the estimated purchase price and the estimated economic savings, a two-year payback period would be achieved for almond, prune and peach growers spraying total acreage of 160, 250 and 130 acres per year. For growers with larger areas, the payback period would be proportionally less.

Regulation of Flowering in Pecan

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Natural selection operating over evolutionary time has produced pecan as an economically important species that exhibits pronounced biennial-like alternations in seed production as a strategy for ensuring long-term reproductive success in the natural environment. This year-to-year variation in pistillate (female flowers) flowering, and subsequent crop-load, is termed alternate bearing (i.e., AB), and is generally considered by growers to be the most important biological problem affecting the U.S. pecan industry. While AB linked variation in pistillate flowering likely increases individual fitness in natural habitats, it is also a major impediment to greater horticultural domestication and profitability, and is the primary biology-based impediment to pecan horticultural enterprises. Excessive year-to-year variability in pistillate flowering limits tree and orchard profitability; thus, adversely affecting producers, processors and consumers via instabilities in nutmeat supply, quality and price. While the specific processes regulating AB in pecan remain ambiguous, the trait tightly links to floral initiation processes occurring within bud meristems within the tree's canopy.

Horticultural manipulation of pistillate flowering and mitigation of AB in commercial pecan orchards currently targets minimization of tree stress, with orchard management strategies directly or indirectly targeting key exogenous biotic and abiotic stressors. These include sunlight, nutrient elements, and water as essential resources; and pathogens, arthropods, and weeds as potentially harmful pests. Mechanical shaking of trees to remove excessive fruit, or mechanized hedge pruning to reduce tree size and crop load, act to reduce physiological stress relative to events occurring within the floral meristem located within each developing bud on current season shoots. Crop-load thinning (via shaker or hedger) prior to, or at the time of, inception of kernel (i.e., primarily cotyledon) filling of developing seeds also acts to moderate AB by increasing subsequent year pistillate flowering. This fruit/seed association implicates one or more seed-associated phloem mobile phytohormones in regulation of floral initiation (i.e., the production of meristems of clearly recognizable flower primordia, and includes all preceding reactions that are required if flowers are to be initiated).

Regulation of floral initiation within bud meristems in trees depends on processing of environmental and/or endogenous cues, with initiation in most large-seeded temperate woody perennial angiosperms being primarily controlled by endogenous cues consistent with processing via an autonomous flowering pathway involving phytohormones. Floral initiation in pecan is therefore likely to involve an autonomous flowering pathway as a key step in its floral initiation process. As with many other tree-fruit species, florally induced bud primordia on heavy crop-load trees (i.e., "on" year of alternate bearing cycle) are likely exposed to different phytohormonal environments than are primordia of induced buds on light crop-load trees (i.e., "off" year of alternate bearing cycle). This raises the possibility that timely application of phytohormones or bioregulators to tree canopies might alter the phytohormonal environment of primordia in such a way as to enable control of pistillate flowering by pecan farmers.

The efficacy and horticultural potential of bioregulators to control the "on" and "off" flowering phases of pecan trees has not been reported despite considerable circumstantial evidence that endogenous phytohormones are involved in floral initiation processes. A variety of natural and synthetic bioregulators are efficacious for control of floral initiation processes in several polycarpic perennial crops, and involve timely usage of floral promoters [generally ethephon and prohexadione-Ca (P-Ca); and naphthaleneacetic acid (NAA) or gibberellin A_4 (GA_4) in certain situations in "on" years to promote return flowering the following "off" year, and usage of floral inhibitors [gibberellic acids ($GA_{3, 4, 7}$); and auxin analogues (e.g., NAA), in certain cases] in "off" years to decrease subsequent year flowering. It is unknown whether these promoters and inhibitors similarly affect pecan flowering in "on" and "off" years.

Commercial pecan production enterprises need better horticultural tools for managing flowering and AB. Successful development and exploitation of such tools depends on acquiring better understanding of floral initiation processes operating in pecan. A recent study at USDA-ARS at Byron, Georgia, assessed certain promising bioregulators for activity and/or influence on pecan flowering and how their interactions influence pistillate (female) flower initiation. It found that several synthetic bioregulators possess potential as horticultural tools for controlling pistillate flowering and AB in pecan; and based on observed influence of bioregulators on flowering, identifies a "three-level-signaling" model explaining regulation of pistillate flower initiation in pecan trees.

This research found evidence supporting the theory that the 'autonomous floral pathway' dominates floral initiation process acting between floral induction (i.e., processes required for evocation), and vernalization (inductive process requiring low temperature) or evocation (processes required for irreversible commitment to initiate flower primordia) occurring prior to actual flower development (processes occurring from after evocation until anthesis). This work supports conclusions by others, working with different crops, that endogenous factors regulating at least one flowering phase includes gibberellins (GAs), auxin (IAA), ethylene, and cytokinins. These phytohormones collectively act and interact as a long-distance "level-two floral signals" to regulate flowering via chromatin modification after florigen (i.e., florigen as the "level-one floral signal") triggered chromatin modification that initiates floral induction physiology.

Additionally, sugar signaling also plays key roles in developmental processes, such as flowering, where complex interplay between phytohormones and sugars affect each other. In the case of pecan, it is clear that sugars are intimately involved in one or more processes controlling floral initiation, with their role being expressed in association with successful vernalization and subsequent floral evocation; however, sugars are not the sole factor driving pistillate flower initiation nor AB . Timely use of bioregulators show promise as providing a means of affecting key downstream floral initiation processes via effects on sugar-based chromatin modulation, such as that occurring during floral vernalization and evocation within the bud meristem.

Recent work provides evidence that GAs, auxins, ethylene, and cytokinin influence floral initiation in pecan; thus, at least one key process is largely controllable by the action and/or interaction of one or more molecular species of these phytohormones. It is therefore postulated that pecan's post-induction phase of pistillate flower initiation is largely regulated by the endogenous "cytokinin-gibberellin" environment to which young bud meristems are exposed during late spring and early summer prior to kernel filling. This cytokinin-gibberellin balance appears to be subject to modulation by ethylene and auxin exported from foliage and/or fruit, and/or influenced by tree and/or organ stress. The cytokinin-gibberellin balance likely affects chromatin related activities within bud meristematic cells, as well as downstream changes in floral initiation processes needed to prepare pistillate floral primordia for vernalization and evocation. When considered within the context of what is known in other crops it appears that pistillate flower initiation in pecan involves three distinct phases of chromatin modification before new flowers appear in early spring. The following is a proposed model explaining initiation of pistillate flowers in pecan:

> *Three sequential phases of chromatin modification control pistillate flower initiation, beginning with a) a foliage produced phloem translocated florigen acting as a first-level-signal to initiate phase-one chromatin modifying inductive processes in young bud primordia; b) then phase-two chromatin modification regulated by translocated phytohormones, from foliage and/or fruit, acting in the primordia environment during early post-induction as a "cytokinin-gibberellin ratio" based second-level-signal subject to modulation by auxin and ethylene, and c) an finally phase-three chromatin modification regulated by concentration of one or more non-structural carbohydrates (e.g. sucrose) acting in the primordia environment during vernalization as a third-level-signal enabling floral development in preparation for anthesis.*

This model identifies a testable theory possessing three distinct stages as potential candidates for horticultural intervention for controlling pistillate flowering. It also provides a basis for future research toward better understanding of flowering and alternate bearing processes, and subsequent development of horticultural tools and strategies enabling greater year-to-year stability in nutmeat yield and quality from trees and orchards of pecan and other woody perennial polycarpic species.

This research also clarifies why it is important that growers strive within the context of cost:benefit to maximize tree and canopy health for assimilation of energy providing elements such as carbon, sulfur, and phosphorus. Thus, carbon assimilation as carbohydrates (e.g., sugars and starch) plays a key role in the third phase of processes that enable the setting of flowers in early spring. It also explains why crop load thinning approaches such as timely mechanical shaking or hedging helps to ensure return flowering via regulation of phytohormone balances within floral meristems. It also gives direction as to how to regulate flowering via usage of currently produced or future bioregulators

A Peek at the Other Half of Your Orchard: The Roots

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Measurements of soil water contents and roots at different depths were carried out during 2009 and 2010 at two pecan orchards: a private orchard (Site 1) located 12.7 km northwest of Las Cruces, New Mexico (Latitude 32° 17′ 5.32″ N, Longitude 106° 50′ 3.85″ W at an altitude of 1185 m above sea level), and at the New Mexico State University Leyendecker Plant Science Research Center (PSRC) (Site 2), 14.5 km south of Las Cruces (Latitude 32° 11′ 56.66″ N, longitude 106° 44′ 30.50″ W at an altitude of 1174 m above sea level). Site 1 was 0.9 ha in size and consisted of 5 rows of 25–year–old 'Western Schley' pecan trees planted in a diamond pattern with 15 trees in each row (Deb et al., 2011a; b). Row spacing was 8 m and tree spacing in each row was 15 m. The size of Site 2 was 1 ha, which consisted of 7 rows of 30-year-old 'Western Schley' pecan trees planted in a rectangular pattern with 29 trees in each row, and row spacing and tree spacing in each row were 7 and 8 m, respectively. Average tree height, diameter at breast height and tree crown width were 12.8 ± 0.1 m, 1.2 ± 0.0 m, 10.3 ± 0.4 m at Site 1, and 10.9 ± 0.2 m, 0.7 ± 0.0 m, 7.1 ± 0.5 m at Site 2, respectively.

Three representative trees at each Sites (1 and 2) were chosen for the rootzone soil water monitoring. Tree canopy of each tree was divided into four quadrants, one of the quadrants was used to monitor diurnal soil water content under the canopy (approximately half way between trunk and the tree dripline) and outside the tree dripline along a transect at depths of 20, 40, 60 and 80 cm. Two quadrants under each tree were used for soil core sampling to determine root distribution and soil physical and hydraulic properties in 2009 and again in 2010, and Rhizotron tubes were installed to monitor roots nondestructively at the fourth quadrant.

Broadly, soil at both Sites is characterized as deep, nearly level, well–drained, and formed in alluvium on flood plains and stream terraces along the Rio Grande Valley. Soil at Site 1 is classified as the Brazito (loamy fine sand, mixed, thermic Typic Torripsammments)–Agua (coarse–loamy over sandy or sandy–skeletal, mixed, calcareous, thermic Typic Torrifluvents), while soil at Site 2 is the Harkey (coarse–silty, mixed, calcareous, thermic Typic Torrifluvents)–Glendale (fine–silty, mixed, calcareous, thermic typic Torrifluvents). The alluvium is modified by wind and Aeolin material. The typical surface layer for a Glendale soil is clay and the layers below are clay loam and very fine sand. The upper surface for a Harkey is loam and layers below very fine sand and silt loam. The climate of the experiential areas is classified as arid with average annual temperature and precipitation is 17.7°C and 29.7 cm, respectively (Gile et al. 1981).

Both orchards were flood–irrigated. The groundwater table fluctuated between 1.5 and 2.5 m below the soil surface and both Sites were irrigated with surface as well as groundwater. At each study Site, a total of 16 CS616 time domain reflectometry (TDR) sensors (Campbell Scientific, Inc., Logan, Utah) were installed horizontally at depths of 20, 40, 60 and 80 cm to continuously monitor diurnal volumetric soil water content under the canopy of three trees and outside the tree dripline. Soil properties were determined using standard methods (Deb et al., 2011b). Four soil cores, two near the middle of the canopy and two just inside the drip line, were collected up to 80 cm depth for each tree and Site. Soil cores were taken using soil sampling steel tube (1.22 m long and 11.4 cm in diameter) (Giddings Machine Company, Inc., Windsor, Colorado) modified to mount on the front of a Bobcat 753 (Bobcat Company, West Fargo, North Dakota). The soil cores were taken within a quadrant of each tree. Additionally, cores were collected from three outside the tree dripline spots. Each soil core was cut lengthwise into 10–cm incremental layer and soil core samples were stored in labeled Ziploc polyethylene bags at 4°C for up to 2 weeks before root separation (Böhm 1979). Soil samples were soaked for 4 min in water and then washed for 10 min through ***hydroelutriator*** to collect roots from the soil. However, for Site 2, core samples were dispersed chemically in a 7% sodium hexametaphosphate solution for 2–3 days to speed up the process of washing roots prior to the operation of ***hydroelutriator***. Soil was washed and roots were extracted from the soil volume by washing and separating them using a hydropneumatic elutriation system (Smucker et al. 1982). Roots were then manually separated from the ***hydroelutriator*** sieves and root samples were stored in 15% ethanol (cm^3 cm^{-3}) at 4°C until further analysis (Böhm 1979).

Analysis of the root length density (RLD; total length of roots in a given soil volume) was performed with the WinRHIZO version 2008a (Regent Instruments Inc., Quebec, Canada), an interactive scanner–based image analysis system that controls scanning, digitizing, and analysis of root samples. Images were acquired using EPSON V700 Photo Dual Lens System flatbed scanner (Epson America, Long Beach, CA) that optimized each scan, automatically selecting from two lenses for the desired scan resolution. All measurements were carried out at a resolution of 400 dpi (dots per inch), which is equivalent to a pixel length of 0.064 mm. Root subsamples were placed in the Plexiglas tray (20 by 25 cm) with a 2 to 4 mm deep layer of water to help untangle the roots and minimize root overlapping. Before measurements, several known masses of roots were placed on tray, tested, and analyzed to determine the adequate mass that could result in a minimum amount of root crossing over. The RLD (cm root cm^{-3} soil) was calculated from the root lengths and the volume of the soil core separately for each 10 cm layer at each Site.

According to USDA classification, soil texture at Site 1 was sandy loam above 40 cm depth and sand below it. The texture was silty clay loam up to 80 cm depth at Site 2. On accord with the soil texture, the K_s for Site 1 was generally higher and FC lower for Site 1 than Site 2. The TDR device measured the soil water content at various depths very well. Both destructive and nondestructive sampling techniques were successful in determining the roots at various depths. In general root length density (root length per unit volume of soil) decreased after 40 cm depth at Site 1. More roots were found in Site 2 at deeper depths. Spatial variability of roots was observed within and out-side the drip-line. The nondestructive measurements of roots during winter months from November to February showed live roots at 30-40 cm depth at both sites although no winter irrigation was applied at both site.

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The USDA Rural Energy for America Program (REAP)

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The Rural Energy for America Program offers three opportunities 1) renewable energy feasibility study grant for agricultural producers or small rural businesses to do a feasibility study for wind, solar, and other renewable; maximum grant is ¼ of the cost of the study up to $50,000; 2) grant and/or loan guarantee funding for small rural businesses and agricultural producers for purchase and installation of energy efficiency projects (changing out equipment or other items for those that are more efficiency; could include HVAC, insulation, windows, etc.) or renewable energy projects (purchase and installation of solar, wind, anaerobic digesters, other bioenergy, etc.). Grant is up to ¼ of the total eligible costs of the project; minimum for energy efficiency projects is $1,500 and maximum $250,000; minimum for renewable projects $2,500 and maximum of $500,000. The loan guarantee minimum is $5,000 and the maximum $25 million. A combination loan guarantee/grant is allowable; 3) energy audit and renewable energy development assistance or units of state, local, and tribal government or their instrumentalities; institutions of higher education; rural electric coops; and certain utilities to provide energy audits and/or renewable energy development assistance to rural small businesses and agricultural producers. This is a federal program, which is available in all States. Contact for program: Jesse Monfort Bopp, 505.761.4952; jesse.bopp@nm.usda.gov .

Solar Project funded by USDA Rural Energy for America Program (REAP)

Bruce Haley
Pecan Producer
Bonham Haley Mountain States Pecans
Roswell, NM

In Oct of 2010 I was introduced to the idea of Solar Energy. I had always had an interest but it never seemed feasible. This gentleman and done the research and determined that this was the right time and that there were several programs in place that now did make it feasible.

I grew up having a statement drilled into my head “that if something sounds too good to be true, then that is probably what it is” so the skeptic that I was, I took 5 months researching and sitting on the fence trying to determine which was the best way to fall off of it, either in favor or there is something I am missing.

In March, I heard that the USDA had a grant available that could pay up to 25% of the project cost of a Rural Energy Project. I contacted the office of Rural Dev. In Albq and not only did they confirm it was true but said they would help me put the application together.

Over the next 3 months this is the application that had to be put together and in June, 2011 I found I had been awarded all the funds the NM office had for my grant. And since I know that there are probably a few of you there wondering what goes into a grant application, what I would like to do is just go thru the details of putting one of these together. Ok, Maybe some other time.

We had contracted a contractor out of Arizona to build this for us and I called them and gave the “let’s get started”.

--- Here you can see the Galvanized pipe and aluminum mounting system. Slide 2

--Here are the first of More than 1500 solar panels going up

--and more. Slide 3 & 4

--Our framing system allows up to manually change the angles of the panels twice a year. Here illustrates the summer setting and the winter setting. Slide 5

-These are the solstice invertors. One of 3. The DC electricity from the panels comes in on the Left, is converted to AC and matched up the 60 hrz to match the utility before going out on the Right. Slide 6

--This is the irrigation well that this array is dedicated to. This is a 150HP motor and a 30 hp sprinkler booster motor. This is the larger of 2 well that we have on this 260 acre pecan orchard. This is also how we determined what size solar array to build. I wanted to be able to run this well from the panels during the day and put enough electricity back on the grid so then at night when the panels are down but the well still running, we are able to then use that credit gained in the day. This well runs 23 hrs a day, by morning we are theoretically starting at “0”. Slide 8 & 9

--These 2 meters, one on right is the production or REC meter which measures the total production of the array, and the one on the left is the Utility meter which is unique in that it runs both directions in reverse when electricity is going to the grid and forward when I am drawing from the grid. Slide 10

----here you can see the completed project of 1562 panels Manuf. by Schott in Albuquerque sitting on 3 acres of property. Slide 11

----This slide (12) shows the cost breakdown:

Project cost $1,500,000

We were awarded a grant from the USDA Rural Dev. Of $292,000

Also available is a DOE grant or Federal Tax Credit not to exceed 30% of the project cost, $451,000

NM has a personal Tax Credit of a maximum $9,000

Net Cost $751,000

----Slide 13 shows the return on investment:

We eliminated our pumping costs for this well which were up to 6,000 per month.

The excess electricity is sold back to the utility with a monthly settlement.

We locked in our energy costs for the life of the project, at least 30 years.

The Renewable energy credits (REC) are credits that the utility contracts for for a determined amount of time. We were able to get a contract for 20 years at an average of 17 cents per watt which amounts to an average check of $10,000 per month. Side 14

Slide 15 shows a web site on the internet open to the public where you can see the current production of my solar array. The URL is at the bottom.

Here in NM Our Lord has provided an abundant source of sunlight we as pecan growers are used to harvesting the sunlight with our pecan trees and now with solar panels we can harvest the sunlight to pump our water also.

‘Lipan’ Pecan

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C:\Publications\Lipan\LipanWPGA12.doc
Updated: 1-17-12
TET Pub. 305

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'Lipan' is a new pecan [*Carya illinoinensis* (Wangenh.) K. Koch] variety released by the U. S. Department of Agriculture (USDA), Agricultural Research Service (ARS). The Lipan are a Native American Apache tribe (Hodge, 1975). During various periods of the 18th and 19th centuries they roamed from the lower Rio Grande in New Mexico and Mexico eastward through Texas to the Gulf coast. The name has probably been employed to include other Apache groups of the southern plains, such as the Mescaleros and the Kiowa Apache.

‘Lipan’ was released because of its high nut quality, high yield potential, medium early nut maturity, and scab disease (*Fusicladium effusum* G. Winter) resistance. ‘Lipan’ should be adapted to all pecan growing areas of the world except the extreme northern production area of the U.S. Pecans from this variety 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 12-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 federal and 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 pecan varieties are not patented, and after release, growers can propagate the new varieties as much as desired.

‘Lipan’, tested as selection 1986-3-624, is a progeny from a cross between the ‘Cheyenne’ and ‘Pawnee’ varieties made by T. E. Thompson at Brownwood, Texas in 1986 (Fig. 1). ‘Cheyenne’ is a USDA variety released in 1970 and originated from a cross of the ‘Clark’ and ‘Odom’ varieties (Madden, 1969). ‘Clark’ is a native pecan from San Saba County, Texas. ‘Odom’ is a seedling from Ocean Springs (Newton County), Mississippi. It may be a seedling of the ‘Russell’ variety (Thompson and Young, 1985). ‘Pawnee’ is also a USDA variety released in 1984 (Thompson and Hunter, 1985). It is from the cross ‘Mohawk’ and ‘Starking Hardy Giant’. Mohawk is a USDA variety released in 1965 from a cross of the ‘Success’ and ‘Mahan’ varieties (Thompson and Young, 1985). ‘Success’ originated in 1903 in Jackson County, Mississippi, and ‘Mahan’ originated in Attala County, Mississippi. ‘Mahan is a parent of six of the 29 released USDA varieties, and ‘Success’ is a parent of four of these varieties. Starking Hardy Giant is a native variety from Carroll Co., northern Missouri.

Description

The ‘Lipan’ clone was initially grown and evaluated on its own roots at College Station, Texas. On the basis of preliminary performance, extensive testing was started in April, 1996 by grafting an NPACTS yield and performance test at Brownwood, Texas. This test had eight replications (single-tree), with a tree spacing of 30 X 35 ft.. Yield data indicate that ‘Lipan’ has adequate precocity, similar to ‘Pawnee’ (Table 1). ‘Lipan’ produced about 154 pounds of nuts per tree, compared to 160 for ‘Pawnee’, and 146 for ‘Desirable’. When considering total kernel produced per tree over the life of the test, ‘Lipan’ produced 84 pounds and ‘Pawnee’ produced about 92 pounds, compared to 75 for ‘Desirable’. Nuts per cluster was 2.5 for ‘Lipan’, 3.3 for ‘Pawnee’ and 2.2 for ‘Wichita’. The alternate bearing tendency of ‘Lipan’ appears less than ‘Pawnee’, ‘Desirable’ and ‘Wichita’ (Table 1). As with most varieties, fruit thinning of ‘Lipan’ in mid-summer may be needed in some years.

Average nuts per pound is about 44 for ‘Lipan’, compared to 51 for ‘Pawnee’, 47 for ‘Desirable’, and 58 for ‘Wichita’ (Table 2). Nuts shell out about 55 % kernel. Kernels are cream to golden in color (Fig. 2 and Table 2), with open, non-trapping dorsal grooves and a rounded dorsal ridge. The nut is elliptic with a slightly pointed apex and rounded base and is round in cross section. The shell suture is very strong, and should be very resistant to splitting if harvest is delayed.

‘Lipan’ has proven to be a consistent producer of high quality nuts that mature and are ready to harvest about two weeks after the early-maturing ‘Pawnee’ variety and about two weeks before ‘Desirable’ (about Oct. 4 at Brownwood) (Table 2). Time of spring budbreak is midseason (similar to ‘Pawnee’ and ‘Desirable’) (Table 3). ‘Lipan’ is protandrous, with early pollen shed and mid-season pistil receptivity, similar to ‘Creek’ and ‘Cheyenne’; and later than ‘Caddo’ (Fig. 3). ‘Lipan’ should be a good pollenizer for, and well pollenized by ‘Choctaw’, ‘Kanza’, and ‘Wichita’. Preliminary data shows that ‘Lipan’ is very resistant to scab disease (Table 4), and has medium susceptibility to yellow and black aphids.

Availability

‘Lipan’ was released on July 22, 2011. As stated above, ‘Lipan’ is not patented and can be grafted and budded as much as desired by anyone. Graftwood will be supplied to nurserymen in late winter of 2012. 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 varieties. It is requested that appropriate recognition be made if this germplasm contributes to the development of a new variety.

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Table 1. National Pecan Advanced Clone Testing System (NPACTS) data from Brownwood, Texas comparing the yield of nuts of the 'Lipan' pecan to other varieties. Rootstocks were planted 1983 through 1986, and trees were grafted from April 29, through June 30, 1996. A flood destroyed the yield in 2004.

	Yield ($Lb.\cdot tree^{-1}$)									
Variety	1999	2000	2001	2002	2003	2005	2006	2007	Total	ABI[z]
Lipan	0.42	0.29	15.14	12.40	14.62	19.66	23.37	67.61	153.51	0.49
Pawnee	1.66	0.82	14.12	24.43	4.22	31.32	24.59	59.23	160.39	0.59
Desirable	0.11	0.39	6.95	9.93	22.64	39.23	11.33	54.97	145.55	0.65
Wichita	1.43	1.82	27.95	24.98	9.86	53.85	6.29	0	126.18	0.66

[z]Alternate Bearing Index (Pearce and Dobersek-Urbanc,1967) which includes the year of 2004 of no yield for any variety.

Table 2. National Pecan Advanced Clone Testing System (NPACTS) data from Brownwood, Texas comparing nut and tree characteristics of 'Lipan' to other varieties. Average kernel content, average nut weight and average kernel color refer to the period between 1999 and 2007; average nut maturity refers to the period between 2005 and 2007.

Variety	Average kernel content (%)	Average nut weight (nuts per pound)	Average nut maturity[z]	Average kernel color[y]
Lipan	54.7	43.8	Oct. 4	2.6
Pawnee	57.6	51.3	Sept. 20	2.7
Desirable	51.6	47.5	Oct. 21	2.9
Wichita	57.7	57.9	Oct. 24	3.0

[z] Recorded at 70% shuck split date.
[y]1=lightest color.

Table 3. National Pecan Advanced Clone Testing System (NPACTS) data from Brownwood, Texas comparing the bud break date of 'Lipan' to other varieties.[z]

Variety	Budbreak, 2003	Budbreak, 2009
Lipan	2.7 c[y]	3.4 b[y]
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

[z]Ratings were made April 2, 2003 and April 1, 2009 (1 = dormant, 2 = bud swell, 3 = inner scale split, 4=leaf burst, and 5=leaf expansion).
[y]Means within columns followed by a common letter are not significantly different according to Duncan's multiple range test, 0.01 level.

Table 4. National Pecan Advanced Clone Testing System (NPACTS) data from Brownwood, Texas comparing the scab resistance of 'Lipan' to other varieties[z].

Variety	Leaf scab	Nut scab
Lipan	1.8	1.4
Pawnee	1.9	1.9
Desirable	1.9	2.0
Wichita	4.0	4.5

[z]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).

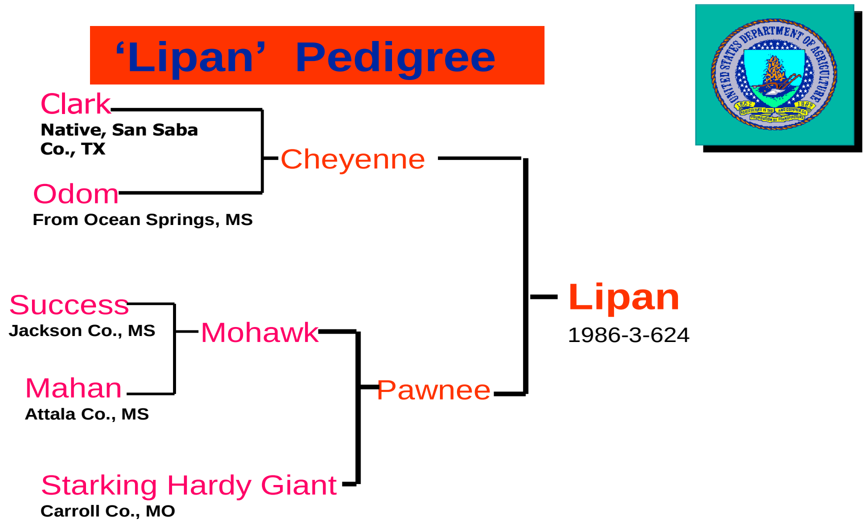

Fig. 1. Pedigree of the 'Lipan' pecan.

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

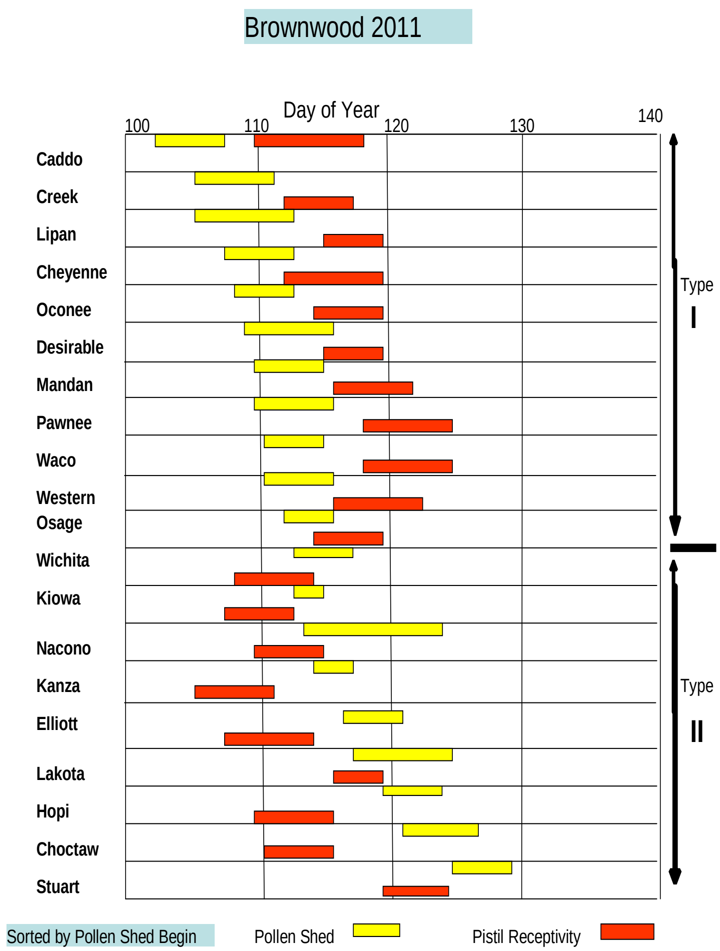

Fig. 3. Pollen shed and pistil receptivity for the 'Lipan' pecan and check varieties at Brownwood, Texas. in 2011. Type I = protandrous varieties; Type II = protogynous varieties.

Re-Evaluation of Potassium & Phosphorus Requirements

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Phosphorus (P) and potassium (K) are relatively immobile in the soil, making it difficult to correct shortages. Soil P can be thought of as existing in three pools – solution P, active P and fixed P. The solution P pool is small, usually only containing about 1 lb/acre of P. Most of the solution P is orthophosphate with a smaller quantity of organically bound P. Plants take up most of their P from the solution P. This P pool would be rapidly depleted if not continuously replenished from the active P pool.

The active pool is the solid phase that is readily released into the soil water, thus replenishing the solution P. The combination of solution P and active P makes up the available P for crop utilization, and may be from several pounds to hundreds of pounds per acre. The active P pool is composed of P attached to small soil particles, P bound with such elements as calcium, aluminum or iron that are relatively soluble, and P in organic compounds that are easily mineralized (broken down by microorganisms).

Phosphorus in the fixed pool consists of inorganic compounds that are very insoluble and organically bound P that resists mineralization by soil microorganisms. This P pool may remain in the soil for years without being available to the plants and has little impact on P availability.

Phosphorus fertilizers are initially quite soluble and available to plants. However, upon addition to the soil various reactions occur making the added P less soluble and consequently less available to the plants. The rates of the reactions are affected by soil pH, moisture content, temperature, and minerals present in the soil.

Applied P dissolves and begins movement in the soil solution where it encounters and reacts with other minerals in the soil and is adsorbed to small soil particles. Phosphate ions readily react with calcium, magnesium, aluminum and iron forming solid compounds. These newly formed compounds are relatively soluble (active P) and replenish solution P to meet the crop needs. However, insoluble forms develop with time contributing to the fixed P pool that is unavailable for plant utilization. The speed at which these unavailable forms develop is much faster if the soil pH is above 7.2 or below 5.6, but insoluble forms develop at all soil pH levels.

When fertilizer P is added to the soil the active P pool and fixed P pool increase. If too much of the fertilizer P is converted to the fixed P pool, there may be little effect on P availability to the plant. This explains why applied fertilizer P may not affect P availability and the lack of crop response even though analysis indicated that P was low.

Soil K is in three forms – unavailable, slowly available or fixed, and readily available or exchangeable. Unavailable K constitutes 90-98% of the total soil K. It is found in some minerals, such as micas and feldspars, that are weathered into clay particles on a geologic time scale. This weathering process is too slow to impact plant nutrition.

Slowly available K is trapped between layers of clay minerals and is frequently referred to as fixed. Although this form of K is plant available, its rate of release to readily available K is relatively slow and inadequate to meet plant need during a single growing season. The type and amount of clay in the soil determines how much K becomes slowly available when fertilizer K is applied and how fast the slowly available K will be released to the readily available K. Many pecan soils are high in clay content and clay types that tend to fix large amounts of K combined with a slow release rate.

Readily available K is dissolved in the soil water and held on the exchange sites of clay particles and organic matter. Plants absorb their K from the soil water, where it is replaced by the exchangeable K. Exchangeable K is gradually replaced by the slowly available K. If the exchangeable K is inadequate to replenish the solution K absorbed by the plant, a K shortage occurs. Unfortunately, many times when K fertilizer is applied as a broadcast application to the soil, large quantities of K are fixed in the slowly available form, resulting in little impact on the amount of readily available K.

Both P and K have been difficult to correct using conventional broadcast application. A solution to the problem might be to apply the fertilizer in a band rather than broadcast, using the same rate that would normally be broadcast. This might "overload" the soil system making the P or K available. Phosphorus or K could be applied in a band using a conventional "tractor pull" fertilizer wagon with ground drive for the fertilizer conveyor and pto driven spinners. The fertilizer spreader could be set for the normal application rate, say 200 lbs/acre of 18-46-0 and applied within the tree drip line in a band by engaging the ground drive, but leaving the spinners off (Figs 3 and 4). If the orchard is irrigated, applying the fertilizer within the wetted area should also increase availability. Phosphorus and K can be applied together if both are low since the factors affecting their availability are different.

An orchard with leaf P and K concentrations below the desired concentrations was utilized for a study to determine the response to banded P and K. Treatments were none, P, K or P+K applied beginning in the spring of 2009. All trees received the same amount of N by adjusting the total N received with urea. Banding 18-46-0 and 0-0-60 increased leaf P and K concentrations, indicating that both elements were plant available. Addition of P substantially increased the subsequent year's crop compared to the control (Fig. 5). Addition of both K and P to trees low in both elements resulted in a greater increase in return bloom than either K or P alone.

Results of this study and others have led to changes in Oklahoma's recommended minimum leaf K and leaf P concentrations. The new recommended minimum leaf K concentration for varieties is 1% and for native pecans 0.75%.

Banding works well for application of 18-46-0 or 0-0-60. However, banding would not be a good choice for application of urea. Banding urea would increase loss of N by volatilization, since urease would convert the urea to NH_3 faster than the soil system could convert this volatile gas to stable NH_4. The conversion of urea to NH_3 would be substantially slower if applied when the high temperatures were lower than 70^{o}C and the soil surface was dry. In those instances, low rates of urea may be banded successfully with P or K.

Fig. 1. Wagon type tractor pulled fertilizer spreader in action.

Fig. 2. Pattern of ground cover growth following a banded application of 18-46-0.

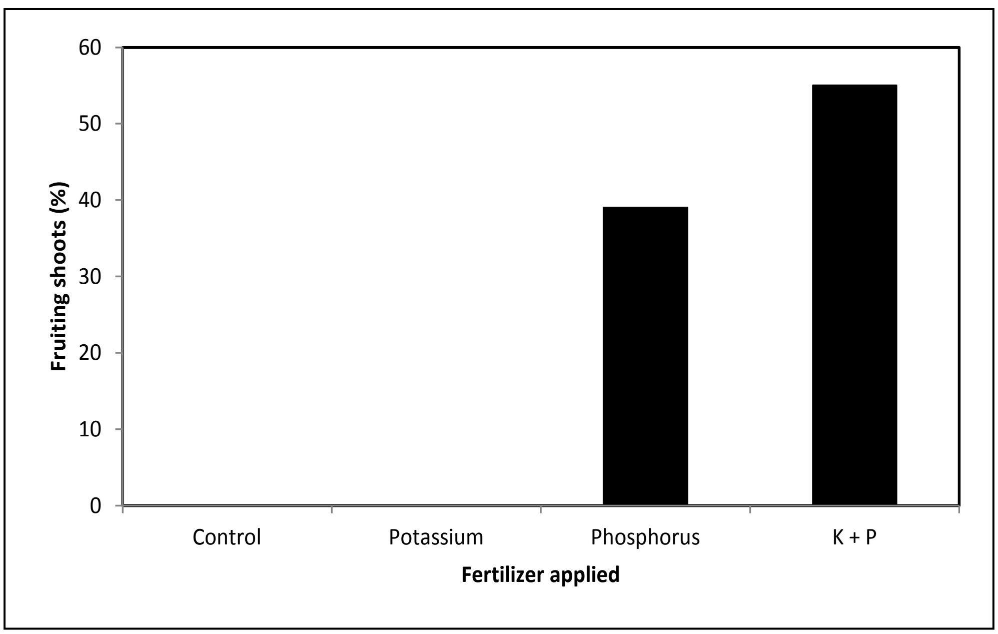

Fig. 3. Return bloom of previously fruit bearing shoots of 'Pawnee' pecan trees after two years of banded P and K applications. Leaf K of the control was 0.73% and K treated was 0.80%; leaf P was 0.09% and 0.14% for the control and P treated, respectively.

Weed Control and Resistance Management with Pre-emergence Herbicides in Pecan Orchards

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Alternative mechanism of actions herbicides have been previously shown to provide acceptable control of glyphosate-resistant Palmer amaranth populations from New Mexico. However, the major obstacle in employing alternative herbicides by the growers has been the possibility of increased weed management costs. The objectives of this study were to identify the efficacy and cost of alternative mechanisms of action herbicides for season-long weed management in pecan orchards. Field studies were conducted in 2010 and 2011 in Rincon New Mexico. The treatments include Chateau (6 oz/acre), Honcho (1 qt/acre), GoalTender (2.5 pt/acre), Prowl H_2O + Honcho (4 qt/acre + 1 qt/acre), Chateau + Prowl H_2O (6 oz/acre + 4 qt/acre), GoalTender + Prowl H_2O (2.5 pt/acre + 4 qt/acre), and untreated control. In 2010, Alion + Rely 280 (5 oz/acre + 56 oz/acre), Alion + Honcho (5 oz/acre + 1 qt/acre) were also included, however, in 2011, instead of treatments with Alion Surflan + GoalTender (4 qt/acre + 2.5 pt/acre), Surflan + Chateau (4 qt/acre + 6 oz/acre) were included in the experiments. The cost of each herbicide was obtained from local retail companies and the application cost ha^{-1} was obtained from several commercial applicators and was estimated at US. $17/acre. Herbicides were applied at their recommended field rates. In 2010, season-long weed control was achieved with on application of Chateau + Prowl H_2O, GoalTender + Prowl H_2O, Alion + Rely 280 and Alion + Honcho treatments. In 2011, season-long weed control was also achieved with on application of Chateau + Prowl H_2O, GoalTender + Prowl H_2O, Surflan + GoalTender, Surflan + Chateau treatments. However, additional applications of glyphosate (i.e., Honcho) were required to achieve acceptable season-long weed control with Chateau, Honcho, GoalTender, and Prowl H_2O + Honcho treastments. These results indicated that the pecuniary benefit of season-long weed management with glyphosate, in pecan orchards, was comparable to some of the tested alternative herbicides.

Real Stinkers in Pecan Production:
Stink Bugs, New & Old (plus Leaf-footed Plant Bugs)

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While some insects are chronic pests of pecan nuts, others show up occasionally, sometimes suddenly, and create economic damage not visible until the nut meats are extracted. Two widespread families of ''true bugs[1],'leaf-footed bugs and stink bugs ,have long been blamed for making sunken brown or black, foul-tasting spots on pecan kernels as a consequence of their feeding (Figs. 1-3). Herein, we will review the similarities and differences between the two bug families. The brown marmorated stink bug (BMSB, Figs. 8-10) is a relatively new invasive, exotic pest now entering Southwestern states and other parts of the US 'pecan belt.' Since pecan has been noted as one of numerous BMSB hosts, growers, crop consultants and others should add BMSB to their list of pests when scouting orchards. We will compare the adult stage of BMSB to some of the more common stink bugs likely to be found in our western orchards. This home invading, highly mobile, crop destroyer originally from east Asia has already developed a reputation in the Mid-Atlantic states as a serious pest of many fruit, berry, vegetable and field crops (Bernon et al. 2004, Holtz et al. 2010, Jentsch, 2011). While it is unknown how serious BMSB may be as a pecan pest in different parts of the US, producers and consultants should be aware of their management options for this pest since it could affect current IPM programs sooner or later.

[1] Order Hemiptera (true bugs); the Family Coreidae includes the leaf-footed plant bugs; the Family Pentatomidae includes the stink bugs.

*****

As an introduction to leaf-footed bugs and stink bugs, these insects share some common characteristics:

> Both have 'simple metamorphosis,' involving egg (Figs. 6, 9, 18) several nymphs (Figs. 7, 10), and adult stages (Figs. 4, 5, 8, 11-17).
>
> If handled or treated roughly, all nymphs and adults of both bugs "stink" in self-defense.

> Adult bugs have two pairs of wings. Each forewing has two different textures; half is opaque and the latter half is membranous (e.g. Fig. 4, 8). This feature is reflected in the name of the bugs' insect order Hemiptera---'half wings.'
>
> Adults of both bugs have a scutellum, a large triangular plate on the thorax easily visible from above (e.g. Figs. 4, 8).
>
> All nymph stages and adults have sucking mouthparts, restricting them to liquid or liquified diets. They can also inject digestive enzymes into their food sources through these mouthparts.

Leaf-footed bugs (LFBs) are aptly named for the flattened, leaf-like appearance of the tibiae on the hind legs (Figs. 4, 5). The most common genus pecan growers will see in orchards in the Southwest is *Leptoglossus.* The narrow-bodied adults are chocolate brown and approximately 5/8" to ¾" long. Much narrower than the thorax, the relatively small LFB head is almost triangular; the bulging compound eyes are at the base of the triangle but the head usually tapers to a sharp point beyond the antennal attachments. Most adults have a readily visible white zig-zag line across the forewings, just beyond the point of the scutellum. The nymphs are shaped like miniature, wingless adults, but are grayish-brown, sometimes with light-colored areas visible from above. The hind tibiae may not have recognizable flattened leaf shapes until the nymphs are nearly sub-adults. Females may lay a 'chain' of russet-colored, cylindrical eggs on twigs or bark in the orchard, or they may oviposit outside the orchard (Fig. 6). Winged adults may fly into or out of an orchard, exploring feeding and mating opportunities. Adults are quite wary and, when disturbed, take flight with a loud Zzzz-t sound. These occasional pests may feed on a variety of fruits as well as nuts, vegetables, seeds, weeds, and some agronomic crops. High populations can cause direct losses of buds, flowers, fruit (s.l) and seeds as well as 'cat-facing' on some fruit crops; internal quality problems of fruit and nut crops, such as discoloration, dry or hard flesh, and bad flavor are common.

As a family, the stink bugs usually are shield-shaped and shorter, broader and flatter than leaf-footed bugs (e.g. Fig. 8). Their antennae are 5-segmented, the scutellum and compound eyes are prominent and the head tapers to a broadly blunt end. (NOTE: These are NOT the same insects as the all black beetles that stand on their heads when disturbed or agitated. These beetles are members of the darkling beetle family, Tenebrionidae, and the genus *Eleodes*.). With the exception of *Bagrada hilaris*, a pest of Brassicaceae (mustard and cole crops), all stink bug species lay their barrel-shaped eggs on end in neat column-and-row arrays on foliage or bark (Figs. 9, 18). Eggs of some species are highly ornamented and identifiable to at least genus (Fig. 18). Eggs often change color as the embryos develop inside. Hatching usually occurs all at once in a given egg mass, with hatchlings remaining on the empty eggs for several days before dispersing. Predaceous species of stink bugs feed first on insect eggs and immatures. As the stink bug nymphs molt and grow larger, they graduate to larger prey. Stink bugs that feed on plants take sap meals intermittently as they explore their immediate environments. As with other common bugs, only the adults can fly and reproduce.

The stink bug that should be of greatest concern for pecan producers is one that is only now invading pecan-growing states---the brown marmorated stink bug (BMSB), *Halyomorpha halys* (Figs. 8-10). A well-known crop pest in east Asia, BMSB probably hitch-hiked undetected on cargo shipped to North America sometime in the 1990s. First identified in Pennsylvania in 1998, BMSB spread to other Mid-Atlantic states in the late 1990s-early 2000s where it soon developed a reputation as a serious, persistent crop pest and home invader probably for several reasons. In North America, BMSB likely has few or no effective natural enemies, having left them behind in Asia. BMSB has an extensive host range and is probably competitive with other insects. Living on stored body fat, adult BMSBs overwinter in protected areas, often in homes and other occupied spaces where effective insecticidal control is difficult, impossible or undesirable. It has a high reproductive potential and a short enough life cycle to permit more than one generation per year in warmer parts of the US. While the pest has one generation per year in Pennsylvania, in southern China, BMSB can complete up to five generations each year. Adult BMSBs are strong fliers, allowing dispersal into new habitats or re-entry into crop fields previously treated for these or other pests. Long distance dispersal of BMSB from Asia to North America and, more recently, across North America is probably facilitated by the bugs' habit of seeking shelter in cracks and crannies---which, at times during the year, may include cargoes, shipping crates, pallets, packing materials, trailers, vehicles and other components associated with transportation and commerce.

In pecans, the type and amount of damage caused by BMSB remain to be seen in different parts of the US. BMSB feeding may cause immature nuts to fall ('August drop') as well as brown or black spots on nut kernels; both can cause significant economic damage, not counting costs associated with applications of various protective or rescue treatments. It may be instructive to review figures recently published for BMSB damage in certain tree fruit crops in the Mid-Atlantic and Northeastern states. The U.S. Apple Association estimated BMSB cost Mid-Atlantic apple growers $37 million (18% of the crop) in 2010; Pennsylvania peach growers lost $15 million that year (Fears, 2010). Nielson and Hamilton (2009) documented an average of 25% fruit damage on New Jersey and Pennsylvania farms.

Pecan growers as well as anyone else across the country should watch for unusual stink bugs on their crops and anywhere else they draw attention. Both light and pheromone traps are being developed and field tested for detection of BMSB in many different habitats in the US, but the places of these tools in long-term pest management for pecans or other crops have not been determined; each of these methods has its pros and cons. They can supplement visual scouting, but not necessarily replace it.

Suspect BMSB should be collected in a zip-lock plastic bag or a small container with a secure lid for identification by your County Extension Agent or university Entomologist. Since none of the stink bugs can bite or sting and since none are considered risks for human health or safety, they can be collected safely by hand or net. While actual specimens are best for an accurate identification, digital photos must be IN FOCUS and ULTRA-CLOSE-UP (bug image nearly fills the frame) to be helpful for identifications.

Since BMSB is an imminent invader into pecan production areas of the country, it is worthwhile to compare some common stink bugs with this invasive species. Since relatives of New Mexico stink bugs occur in other parts of the country, tips on identification can be helpful to growers in other states. We will focus on identification of adult stink bugs here, since variations in colors and patterns are common and can be confusing among the nymphs of different stink bug species.

Comparison of Brown Marmorated Stink Bug with Native Stink Bugs

Adult BMSBs are 14 to 17 mm (½" to 2/3" long) and are mottled dark brown (Fig. 8). With much higher magnification, one can see that the upper surfaces of these bugs have tan exoskeletons barely visible because of the multitudes of dark brown dot-punctures; their undersides are pale tan with brown appendages. Probably the easiest feature to see (from above) is the alternating brown and off-white bands on the last two antennal segments. The exposed edge of the thorax has neither sharp points on the 'shoulders' nor fine 'teeth.' The exposed edges of the abdomen---beyond the folded wings---also have alternating dark and light brown checkerboard marks; however, some other common stink bugs also have this feature.

Of our native stink bugs, the genus most likely to be confused with BMSB is *Brochymena* (Fig. 11). These are sometimes called 'rough stink bugs.' Our New Mexico species are about the same size as BMSB and are mostly gray to dark gray, sometimes with brown tones. However, *Brochymena* spp. lack alternating light and dark antennal markings. With much higher magnification, *Brochymena* spp. also have distinct fine teeth on the edges of the thorax back of the head---which BMSB lack. Expect to see well camouflaged *Brochymena* on tree bark, shrubs and sides of buildings year 'round in New Mexico and elsewhere. Common but infrequently gregarious, *Brochymena* seems to be a harmless associate of pecan and many other trees and shrubs where the bugs likely feed on sap; some authors also report them as occasional predators of other insects.

Stink bugs of the genus *Chlorochroa* are primarily western in distribution. When numerous, they can damage a variety of crops including pecan nuts. Again, adults are about the same size as BMSB and lack both 'shoulder' spines and fine teeth along the edges of the exposed thorax. *Chlorochroa ligata* is commonly called the conchuela in the Southwest (Fig. 12). Conchuelas vary from dark green to very dark olive or charcoal gray when viewed from above. Many have a narrow orange or reddish-orange rim on their bodies. In 2010, the conchuela was the likely culprit in many New Mexico pecan orchards with black and brown withered spots on their pecan kernels. The pests were common on other nut, fruit and vegetable crops, annual ornamentals and weeds as well. Aggregations of nymphs demonstrated that these bugs reproduced in some pecan orchards, suggesting long term exposure of the nutlets to feeding damage.

Say's stink bug, *Chlorochroa sayi* (Fig. 13), and Uhler's stink bug, *Chlorochroa uhleri*, could be pecan nut pests, although most records indicate these basically green stink bugs feeds on small grains, various vegetables and certain ornamentals and weeds; host choices are likely to vary by season, year, host availability and feeding opportunities. The membranous portion of the forewing on both of these stink bugs may be smoky or nearly colorless; some may have a narrow white, yellowish or orange rim on the body while others lack this marking. Most adults will have minute white dots on the upper surfaces of their bodies and on the opaque parts of the forewings.

Brown stink bugs, *Euschistus* spp., are yellowish-brown, brown or grayish-brown and slightly smaller than BMSB (Figs. 14, 15). These bugs also lack the dark brown/off-white banding patterns on the ends of the antennae that are diagnostic for BMSB. The *Euschistus* thorax has broad, dull points on the 'shoulders.' Some adults will have prominent light and dark brown checkerboard patterns on the abdomen, around the edges of the folded wings, while others have faint markings or none. All common western *Euschistus* species lack the alternating white bands on the ends of their antennae that would be found on BMSB. Species common in the southern states occasionally are damaging to cotton, especially cotton bolls, and other field and vegetable crops. If they are found in pecan orchards, *Euschistus* stink bugs are probably feeding on various weeds on the orchard floor or perimeter.

The spined soldier bug, *Podisus maculiventris*, is another yellowish brown to brown or dark brown stink bug approximately the same size as BMSB (Figs. 16, 17). True to its common name, this predatory species has two sharp and obvious spines on its 'shoulders'. *Podisus* lacks the white bands on the antennae that distinguish BMSB. Unlike the other stink bugs described above, spined soldier bugs are predators of other insects, mainly caterpillars. Their sucking mouthparts are slightly thicker and appear to be attached farther forward on the head than those of plant-feeding stink bugs. Spined soldier bugs impale their prey with these mouthparts and inject salivary enzymes that digest the internal contents of their prey. The predators suck up fluids periodically before injecting more enzymes to further digestion.

Other stink bug genera also occur in New Mexico and elsewhere in North America, but they look even less like BMSB and are also less likely to be found in or near pecan orchards, especially in any numbers.

Control of Leaf-footed Bugs and Stink Bugs in Pecans

A variety of Insecticides with different active ingredients and modes of action are currently registered in New Mexico and probably most other states for stink bugs---in general---and leaf-footed bugs (Table 1). Many of these products have been registered on pecans for years and are either on hand already or readily available from local distributors, if needed. Producers NOT from New Mexico or unfamiliar with some of the products listed below can ask officials with their state departments of agriculture for specifics on registrations and research labels on-line before purchasing products. Whether BMSB becomes a key pest of pecan is not known; it took over a decade for BMSB to reach key pest status in the eastern US. Whether the available registered products will provide sufficient control of BMSB in pecans remains to be seen, also. Producers and consultants are reminded to READ ALL PESTICIDE LABELS before purchase, mixing and application. FOLLOW ALL LABEL DIRECTIONS for mixing, application and general safe use. Where several insecticide applications might be necessary for one pest, rotating treatments among different modes of action is advisable to slow the development of insecticide resistance.

Fig. 1-2.Pecan kernel damage, likely due to bug feeding. Both by Jerry A. Payne, USDA Agricultural Research Service, Bugwood.org

Fig. 3. Black spot on kernels, HC Ellis, Univ. Georgia,

Figs. 4, 5. *Leptoglossus clypealis*, Western leaf-footed bug, adult. Both by Whitney Cranshaw, Colorado State University, Bugwood.org

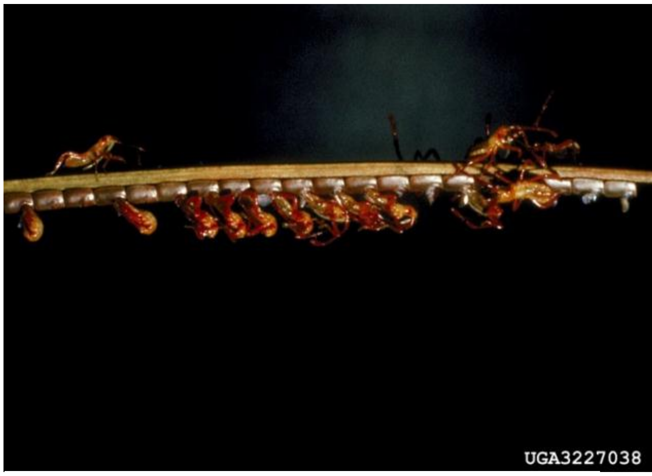

Fig. 6. *Leptoglossus* egg mass and hatchlings. Ronald F. Billings, TX Forest Service, Bugwood.org

Fig. 7. *Leptoglossus* nymph. Kristina Simms, Bugwood.org

Fig. 9. Egg mass of brown marmorated stink bug. Susan Ellis, Bugwood.org

Fig. 10. Brown marmorated stink bug nymph. Steven Valley, Oregon Department of Agriculture, Bugwood.org

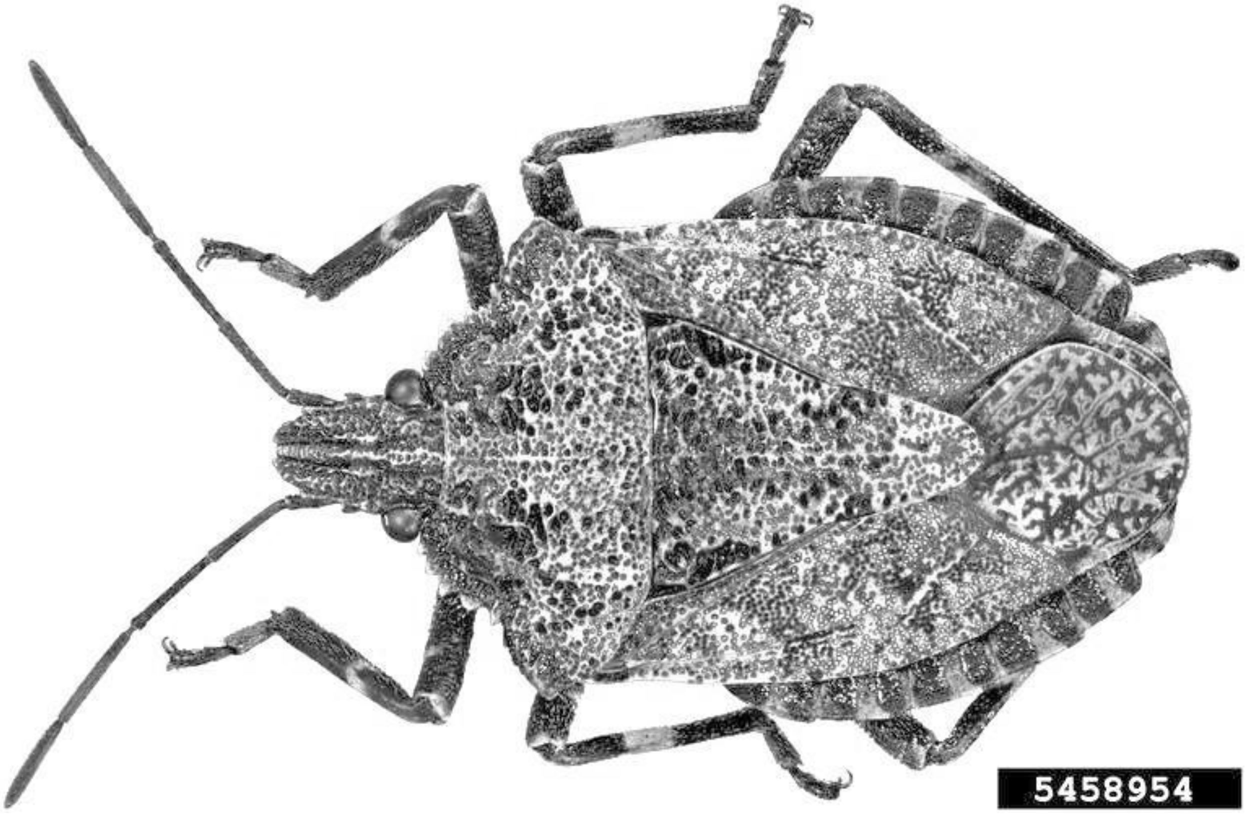

Fig. 12. *Chlorochroa ligata*,, the conchuela, adult. Whitney Cranshaw, Colorado State University, Bugwood.org

Fig. 13. *Chlorochroa sayi*, Say's stink bug adult. Frank Peairs, Colorado State University, Bugwood.org

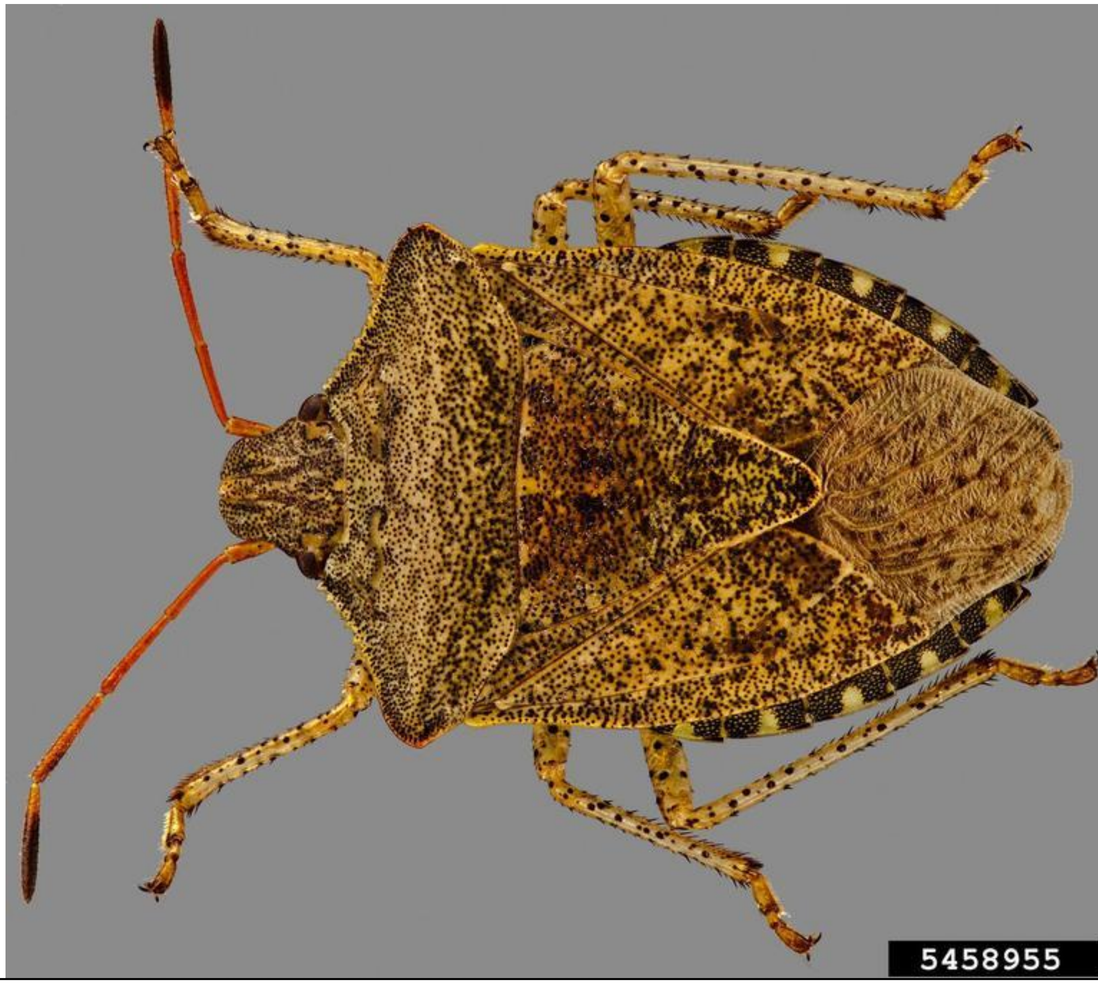

Fig. 14. *Euschistus conspersus*, a ‘brown stink bug. Steven Valley, Oregon Department of Agriculture, Bugwood.org

Fig. 15. *Euschistus* sp., a ‘brown stink bug.’ David Cappaert, Michigan State University, Bugwood.org

Fig. 16. *Podisus maculiventris*, spined soldier bug, a predatory stink bug with prey (tree hopper). Frank E French, Georgia Southern University, Bugwood.org

Fig. 17. *Podisus maculiventris,* spined soldier bug, a predatory stink bug with prey, fall armyworm. Frank Peairs, Colorado State University, Bugwood.org

Fig. 18. *Podisus maculiventris* eggs. John Ruberson, University of Georgia, Bugwood.org

Table 1. Examples of currently registered (2012) insecticides for commercial pecan producers dealing with leaf-footed bugs and stink bugs in New Mexico. **Active Ingredient**	**Mode of Action*(MOA)**	**Leaf-footed Bugs?**	**Stink Bugs?**	**Examples of Commercially Formulated Insecticides for Pecan with Target Pest(s) Listed on Label****
Acetamiprid	4A	X		Assail
Azadirachtin+	Un(known)	X		70% Neem Oil, Neemazad, Neemix, others
Bifenthrin	3A	X		Bifenture EC, Fanfare 2EC, Hero EW (with zeta-cypermethrin), Sniper, Steed
Carbaryl	1A	X		Drexel Carbaryl 4L, Sevin XLR Plus, Sevin 80 Solupak, others
Chlorantraniliprole	28	X		Besiege (with lambda-cyhalothrin), Voliam (with thiamethoxam)
Chlorpyrifos	1B	X		Drexel Chlorpyrifos 4E-AG, Lorsban Advanced, others
Clothianidin	4A	X		Arena 50 WDG, Belay, Clutch 50 WDG
Beta-cyfluthrin	3A	X		Baythroid XL
Cyfluthrin	3A	X		Leverage (with imidacloprid), Renounce, Tombstone
Gamma-cyhalothrin	x	X		Cobalt (with chlorantraniliprole), Declare

Domestic International Sales Corporations
Tax Incentives for Exporters

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US-based agriculture exporters are recognizing significant tax savings through Interest Charge Domestic International Sales Corporations, better known as “IC-DISCs.”

Exports play a tremendous role in and are an integral part of strong, progressive economies. Therefore, it’s understandable that U.S. Congresses and Administrations have been devising and revising tax laws to encourage exports. In fact, such legislation has been commonplace amongst competitive, foreign governments throughout modern history. In 1971, Congress enacted the Domestic International Sales Corporation (DISC) as a means for U.S. companies to remain competitive with their foreign rivals by deferring domestic taxes on export receipts until they are repatriated to DISC shareholders. In 1984, the DISC evolved into the “Interest Charge” DISC (IC-DISC), which imposes an annual interest charge to DISC shareholders for the deferral of U.S. taxes resulting from the DISC.

In 2003, the Jobs and Growth Tax Relief Reconciliation Act reduced all tax payers’ personal income tax rates and cut the tax rate on qualified dividends from the ordinary income tax rates to the lower long-term capital gains tax rates. As a result, **instead of just deferring taxable income, an IC-DISC was given the ability to permanently convert income that would normally be taxed at 35% to income that would be taxed at 15%.** Despite the enormous benefits available with IC-DISCs, unfortunately only a small percentage of the small to mediumsized, closely-held businesses that qualify for an IC-DISC actually make use of it. This is largely due to lack of awareness among companies and their advisors.

With more than 35 years of experience serving the agriculture industry, Dixon Hughes Goodman has successfully helped many exporters recognize significant tax benefits through ICDISCS. For more information regarding IC-DISCS, or to speak with an advisor regarding other accounting matters, contact Larry Evans, Tax Partner with Dixon Hughes Goodman, at 404.575.8950 or larry.evans@dhgllp.com.

About Dixon Hughes Goodman

With more than 1,700 people in 30 offices in 11 states and Washington, D.C., Dixon Hughes Goodman is the largest certified public accounting firm based in the Southern U.S. and the 14th largest in the nation. In addition to comprehensive accounting and advisory services, the firm focuses on eight major industries and serves clients in all 50 states. Visit www.dhgllp.com for more information.

Improving Competitiveness of US Pecans Based on Nutritional & Health-Promoting Components

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Introduction

The pecan [*Carya illinoinensis* (Wangenh.) K. Koch] is a monoecious, heterodichogamous, deciduous nut tree that is indigenous to the U.S. (*1*). This specialty crop is economically important to the U.S. as it accounts for > 80% of the world's production (*2*). Six states in 2010 comprised ~93% of the U.S. production and they were Georgia, New Mexico, Texas, Arizona, Oklahoma, and Louisiana. In 2010 the U.S. utilized production totaled 273 million pounds (in-shell) with an estimated market value of $675 million (*3*).

Pecan Clinical Studies

According to the heart disease and stroke statistics for 2012, cardiovascular disease (CVD) was responsible for 32.8% of all deaths nationwide in 2008 with heart disease remaining as the number one killer in the U.S. (*4*). Epidemiologic studies have demonstrated an inverse association between nut consumption and risk markers of coronary heart disease (CHD) (*5*,*6*). In relation to individuals who ate nuts < one time/wk, those who ate them one-four times/wk had a 25% reduced risk of dying from CHD; individuals who ate nuts ≥ five times/wk experienced a ~50% reduction in risk (*7*). The Food and Drug Administration (FDA) was eventually petitioned and approved a qualified health claim in July 2003 with the following statement: "*Scientific evidence suggests, but does not prove, that eating 1.5 ounces per day of some nuts, as part of a diet low in saturated fat and cholesterol, may reduce the risk of heart disease.*"

A number of mechanisms exist as to why nuts, such as pecans, impart favorable effects on our cardiovascular system; the most important one being the lipid-lowering in blood serum. Yet, the lipid effects of nut intake only explain in part the CHD risk reduction observed in prospective studies. Pecans are low in saturated fatty acids and rich in the monounsaturated fatty acids (MUFA), particularly oleic acid, which is known for its positive effects on blood lipids (*8*). In fact, the MUFA levels in pecans are similar to those of olive oil. The Scientific Advisory of the

American Heart Association reported that high MUFA diets tend to raise high-density lipoprotein (HDL) cholesterol and lower triacylglycerols (TAG) concentrations compared with low fat carbohydrate-rich, cholesterol-lowering diets; this has the benefit of reducing the process of atherosclerosis and hence the risk of CHD. Evidence further suggests that other components in pecans further reduce total cholesterol and low-density lipoprotein (LDL) cholesterol concentrations beyond the effects predicted by equations based solely on fatty acid profiles. Pecans are also rich in antioxidant vitamins, minerals, and numerous bioactives including flavonoids, stilbenes, and phytosterols that may have health benefits. Kris-Etherton *et al.* (*5*) pointed out that it is conceivable, though not proven, that many nutrients and bioactives in nuts, like pecans, may act synergistically to exert beneficial effects in the human body.

There have been five significant dietary studies about the effects of pecan consumption on serum (blood) lipid profiles. The first, a randomized control study from New Mexico State University compared the serum lipid profiles and dietary intakes of individuals with normal lipid levels (*i.e.*, normolipidemic) who consumed pecans and those who did not eat any nuts (*9*). The pecan treatment group consumed 68 g pecans per day for eight weeks plus "self-selected" diets, whereas the control group avoided pecans plus other nuts and also consumed "self-selected" diets. What is most interesting about this study, is that though there is variability in the dietary habits of food choices made and calories consumed on a daily basis, this approach represents perhaps a realistic appraisal of the impact of pecans set forth in the FDA qualified health claim for tree nuts. Total, LDL, HDL, and TAG levels were measured at the onset of the study to offer baseline data, again at week four and then finally at week eight. Results showed that LDL cholesterol was lowered in the pecan treatment group from 2.61 ± 0.49 mmol/L at baseline to 2.35 ± 0.49 at week four ($P < 0.05$) and to 2.46 ± 0.59 at week eight ($P < 0.05$). For the control group, LDL cholesterol levels increased from 2.74 ± 0.26 mmol/L at week zero to 3.03 ± 0.57 at week eight. In terms of total cholesterol and HDL cholesterols, the numbers for the pecan treatment group at week eight were significantly ($P < 0.05$) lower than in the control group (total cholesterol: 4.22 ± 0.83 vs 5.02 ± 0.54 mmol/L; HDL cholesterol: 1.37 ± 0.23 vs 1.47 ± 0.34 mmol/L). Additionally, dietary fat, MUFA, polyunsaturated fatty acids (PUFA), insoluble fiber, magnesium, and energy were significantly higher in the pecan treatment group than in the control group. Body mass indices and body weight were unchanged in both groups. Morgan and Clayshulte (*9*) concluded that pecans can be included in a healthful diet when energy intake and potential weight gain are addressed.

The clinical study from New Mexico State University might be the first published study to specifically examine the effects of pecan ingestion on blood cholesterol and TAG levels. Even though the study involved only 19 people, its findings are supportive of the FDA qualified health claim for nuts and heart disease prevention. A study from Loma Linda University published in 2001 confirmed and extended the findings put forward by Morgan and Clayshulte (*9*). The study by Rajaram *et al.* (*10*) incorporated strict dietary regiments to control nutrient intake in addition to pecan supplementation. This study examined the effects of pecan lipids as an alternative to the American Heart Association's Step I diet (*i.e.*, a diet recommended by the National Cholesterol Education Program to lower cholesterol). Although the Step I diet is deemed favorable due to its relatively high carbohydrate and low fat contents, it has the disadvantage of tending to lower HDL cholesterol and raise TAG levels in the blood serum: an undesirable characteristic. Rajaram *et al.* (*10*) designed a single-blind, randomized, controlled, crossover feeding study for 23 subjects to follow two diets each of four weeks: a Step I diet, and a pecan-enriched diet (72 g per day) which proportionately reduced all food items of the Step I diet by one fifth to provide a 20% isoenergetic replacement with pecan. Both diets improved lipid profiles of the subjects. The pecan-enriched diet decreased both total and LDL cholesterol concentrations by 0.32 mmol/L (*i.e.*, 6.7 and 10.4%, respectively) and TAG by 0.14 mmol/L (~ 11.1%) beyond the Step I diet, while increasing HDL cholesterol by 0.06 mmol/L. Furthermore, other serum lipoprotein markers decreased (a good thing!) as a result of pecan supplementation to the diet. The authors concluded that pecans, which are rich in MUFA, may be recommended as part of a prescribed cholesterol-lowering diet for patients or as part of the diet for healthy individuals. They also postulated that the unique non-fat component of pecans (*i.e.*, phytochemicals with noted antioxidant activity) may also play a role in favorably modifying the blood lipid profile and potentially other cardiovascular risk factors.

In 2011, Hudthagosol *et al.* (*11*) found that bioactive constitutes of pecans such as γ-tocopherol and the flavan-3-ol monomers (e.g., (-)-epicatechin and epigallocatechin gallate) demonstrated antioxidant properties *in vivo*. Postprandial changes in plasma ORAC values and in concentrations of tocopherols, catechins, oxidized LDL, and malondialdehyde were evident in response to pecan test meals of either whole pecans or blended pecans. Though few differences were noted in the results between the pecan forms, the study showed that the bioactives in pecans inhibit post-intake plasma lipid oxidation and counteract the prooxidant effect of high-fat meals on LDL cholesterol, increase antioxidant capacity of the plasma, and are bioavailable. The authors noted that this was the first study to their knowledge which evaluated the effects of pecan consumption on postprandial antioxidant biomarkers in humans.

The Nutrients and Bioactives of Pecans

The proximate compositions for both raw and dry roasted pecans are given in Table 1 (*12*). In addition to MUFA, emerging evidence indicates there are other bioactive molecules in nuts, such as pecans, that elicit cardioprotective effects. These include plant proteins, dietary fiber, micronutrients such as copper, zinc, and magnesium, plant sterols, and last but not least phytochemicals (*13*). Pecans are an excellent source of tocopherols, particularly *γ*-tocopherol (*14*). Emerging research suggests that *γ*-tocopherol does not get the respect it deserves as a nutrient. *γ*-Tocopherol may have unique functions in detoxifying nitrogen dioxide and other reactive nitrogen species (*15*). The phytochemicals in pecans account for a portion of the nut's observed antioxidant and radical-scavenging capacities. The antioxidant activity originates mostly from the phenolic constituents (*e.g.*, phenolic acids and tannins) and tocopherols. Early studies by Senter *et al.* (*16*) from the testa of Stuart pecan kernels revealed the presence of gallic, gentisic, vanillic, protocatechuic, *p*-hydroxybenzoic, and *p*-hydroxyphenylacetic acids, with coumaric and syringic acids present in trace amounts. Phenolic acid levels decreased markedly in the kernels during 12 weeks of accelerated storage. Strong correlations (r^2 = 0.95 to 0.97) were obtained between decreases in the hydroxybenzoic acid derivatives and declines in sensory quality of the kernels, thereby suggesting that these phenolic compounds may function antioxidatively and provide stability during storage. In a more recent study, Villarreal-Lozoya *et al.* (*17*) analyzed six pecan cultivars and found strong correlations in the kernels between total phenolic content and antioxidant activity. The total phenolic content ranged from 62 to 106 mg chlorogenic acid equivalents/g defatted kernel and was significantly affected by pecan cultivar. These findings as well as on-going nutrient and bioactive research in Dr. Pegg's lab confirm the presence and importance of proanthocyanidins in pecan kernels and their role as antioxidants.

In a report that screened common foods and vegetables across the U.S., pecan kernels were shown to have the highest antioxidant capacity and total extractable phenolic content within the nut group, and pecans ranked amongst the foods with the highest phenolic content (*18*). Our data on antioxidant activity of pecans concurs with this finding. Both oxygen radical absorbance capacity ($ORAC_{FL}$) and 2,2′-diphenyl-1-picryhydrazyl (DPPH) radical data on defatted kernels show marked radical-scavenging capacity and strong correlations between these antioxidant assays with total phenolics; mean $ORAC_{FL}$ values for the different pecan cultivars ranged from 373 to 817 µmol Trolox equivalents/g defatted meal. Finally, there is a growing body of evidence that polyphenols can facilitate circulatory function through increased production of the primary mediator of endothelial dilatation, viz. nitric oxide (*19*). Maintaining the functional capacity of the endothelial cells lining blood vessels is vital to vascular health. Improvements in endothelial vasodilator function have been reported with high nut consumption (*20*).

Conclusions

Pecan consumption can play a significant role in human nutrition and health on account of its high and special nutritional components. Marketers should take advantage of the FDA qualified health claim for nuts in tandem with the nutrient and bioactive contents found in present day pecan cultivars. The major challenge faced by marketers, however, is the education of the public on the bioactives (e.g., antioxidants) found in pecans. The nutritional attributes clearly indicate that pecans can serve as an important healthy food in the human diet and should be consumed every day. With respect to functional lipid characteristics of pecans, they are good sources of natural antioxidants (*e.g.*, *γ*-tocopherol) and bioactives, thus reflecting their nutraceutical potential in different food and specialty applications. Despite an increase in dietary fat content, pecan-enrichment as part of a healthy diet favorably affects plasma LDL and HDL cholesterol levels as well as lipoprotein profiles, major risk factors of CVD. A high MUFA-rich pecan diet is preferred to a low-fat control diet in decreasing plasma LDL cholesterol concentrations. The presence of essential minerals, vitamins, and amino acids, the high content of heart-healthy fats, and the presence of soluble dietary fiber, bioactives, and phytochemicals, including their antioxidant and radical-scavenging capacities, make the choice of pecan addition to healthy diets an important dietary consideration in assisting against the potential development of chronic disease states.

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Table 1.

Proximate composition (g/100g) of raw and dry roasted pecans.[a]

	Raw	**Dry roasted**
Water	3.52	1.12
Total Lipid	71.97	74.27
Protein	9.17	9.50
Ash	1.49	1.56
Carbohydrate, by difference	13.86	13.55

Fiber, Total Dietary	9.6	9.4

[a] USDA National Nutrient Database for Standard Reference, Release 24 (*12*).

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