Pecan Husbandry:
Challenges and
Opportunities

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ALTERNATE BEARING OF PECAN

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This workshop has been structured to provide a forum for the presentation of new knowledge, the interpretation of both old and new knowledge, and for speculation or extrapolation of what everything means. Since speculation is a cornerstone to the advancement of science, I have elected to take advantage of this opportunity to theorize concerning alternate bearing, a major horticultural problem. That is found to some degree in essentially all producing orchards.

The nature of pecan to alternately produce nut crops is a major problem for most people associated with the cultivation or marketing of pecans. It causes economic problems for growers and suppresses domestic and foreign markets. The problem is genetically based and affects both production and quality (i.e., yield).

Growers and scientists alike have been only partially successful in their efforts to reduce the deleterious impact of alternate bearing on the pecan industry. This is partially due to approach, which can be summed up by the words of a great American philosopher:

"For every thousand that chops away at the leaves of evil [or a problem] there is only one that strikes at the root," (H.D. Thoreau).

While extensive efforts have been made to eliminate alternate bearing, such efforts have traditionally focused on "chopping away at the leaves" and have not been able to effectively "strike at the root". Cultural inputs such as water, pruning, spacial arrangement, nutrient elements and pest control have "chopped off a lot of leaves" and have subsequently gone a long way in reducing the severity of the problem. However, most such inputs are expensive and have helped to create a crisis situation that has resulted in growers being caught in a severe "cost-price squeeze". The economic stresses of alternate bearing can likely be reduced as growers and scientists alike acquire a better understanding of the nature, or "root", of the problem.

This report is presented with the purpose of providing a conceptual tool, or working hypothesis, for growers and scientists in their efforts to reduce the economic impact of the alternate bearing problem and to provide a functional understanding of the problem to the nonhorticulturist (who make up the bulk of the pecan scientists in the U.S.). It should assist in efforts to moderate the impact of alternate bearing on the pecan industry by helping to reveal the "root" and to identify strategies to attach at or near to the root. I have elected to exclude an exhaustive literature review since the objective is to propose a functional concept rather than to provide a critical evaluation or reformulation of existing research results.

Since theories are typically modified as knowledge is acquired, the following concepts on alternate bearing are no exceptions. The reader is reminded that, within the realm of nature, it is impossible to absolutely prove anything [Our lack of absolute knowledge (or lack of knowledge that we have absolute knowledge if ever we were satisfied that we had absolute knowledge) regarding the true nature of the space-time continuum and its interaction with the multidimensional matrix of matter, energy and fundamental forces obviously precludes absolute proof and only allows proofs within limits defined by logic or apparent reality]. As scientists, we make objective observations of natural phenomenon, apply deductive and inductive reasoning to these observations and then formulate a theory that explains the phenomena. The theory is then verified by testing its predictions. These predictions, or hypotheses, are then objectively tested to see if they can be disproven (since a hypothesis can not be proven). A theory is therefore subject to continual revision as more information is acquired. The theory presented in this discussion on alternate bearing should be expected to be altered and/or refined, and subsequently better explain reality, as more information becomes available. Even though it obviously possesses a degree of error, most of the observed phenomena associated with alternate bearing are reconciled. Thus, the theory can function as a conceptual tool which would allow growers and scientists alike to strike closer to, or perhaps in the vicinity of, the root of the alternate bearing problem.

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Background
There are several concepts that require a degree of understanding before alternate bearing can begin to be understood. These are the concepts of 'Definition', 'Nature', and 'Compartmentalization'.

Definition. An understanding of alternate bearing begins with the recognition of the symptoms of the problem. For purposes of this discussion, alternate bearing is defined as the alternation of nut yield (encompassing both quantitative and qualitative factors) from one crop year to the next. The intensity, or magnitude, can vary from year-to-year, with cultivar, with environmental stresses, etc. It can be mathematically described (or approximated) in many different ways using quantities such as 'B', 'I', 'R', 'K', 'K²' and 'E' which identify and emphasize specific characteristics of alternate bearing (Pierce and Dobereck-Urbanc 1967).

Alternate bearing is often confused with 'biennial' or 'irregular bearing' (Monselise and Goldschmidt 1982). Alternate bearing is, in fact, a general term referring to qualitative and/or quantitative alterations in yield. Within this context 'biennial', 'triennial', 'quadennial', 'irregular' are all special types of alternate bearing. Absolute 'irregular bearing' means that there must be a yield pattern devoid of symmetry, or is totally random (Mish 1986); for example, production from year to year, or for a set of years, to another set of years is without any degree of cycling or periodicity. Since absolutes regarding phenotypic expression within the biological world are rare, alternate bearing should therefore be expected to take on a degree of irregularity; or rather, 'irregular bearing' can exhibit a weak 'alternate bearing' pattern (yield alternating from one year to the next).

Pecan trees exhibit a strong tendency to bear 'irregularly'; however, the term is generally not as precise a descriptor as is 'alternate bearing' because the perceived irregularity has in fact a regularity, which is usually evident only over long time periods (e.g., 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15 year cycles). Under these circumstances of 'triennial', 'quadennial', etc., cycles, the 'irregular' terminology is obviously inaccurate.

The term 'alternate', 'biennial', and 'irregular' bearing are all appropriate for describing fruit production in pecan trees or orchards under certain circumstances; however in general, 'biennial bearing' possesses the greatest degree of accuracy for describing production cycles at the shoot, limb, tree and orchard levels, however a better terminology would be 'periodic bearing' because pecan produces on cycles of different periods. 'Irregular bearing' is best utilized in reference to apparent irregular variations within the various bearing cycles.

'Biennial bearing' is a special case of 'alternate bearing'. Production patterns at state, regional, and multiple-regional levels can usually be characterized as 'biennial bearing' because there is usually a two-year cycle evident in the long-term yield history (Wood et al. 1991, Gemoets et al. 1976). For example, seedling nut production in Oklahoma exhibits a strong 2-year cycle. Such a pattern would fit the definition of 'biennial bearing', as a specific type of 'alternate bearing'. U.S. production of both cultivar and seedling class pecans possesses a 'biennial' tendency because there is a statistically significant 2-year-cycle, however the cycle is blurred, having a degree of irregularity due to complex interactions (Wood et al. 1991; unpublished observations).

Alternate bearing is a phenomena existing at several levels. It exists at the shoot level (Level I) as a purely biological property, limb (Level II) and tree (Level III) levels it exists as an interaction of biological and statistical properties. At the orchard (Level IV), regional (Level V), and multi-regional (Level VI) it exists as an averaged statistical or mathematical echo of the biological units. 'Biennial bearing' is the most pronounced type of alternate bearing at Levels I-IV, but is less pronounced at Levels V or VI; additionally, its intensity diminishes as level increases. Variability in production at the regional and national levels (multi-regional) usually can be termed 'cyclic bearing' since a statistical symmetry (or periodicity) of various periods does exist (Wood et al. 1991, Geomets et al. 1976).

It is common for growers, and sometime for scientists also, to classify pecan groves or orchards as 'non-alternate bearing' if the planting produces a relatively stable overall yield of nut crops. This characterization is partially true; however it is deceptive, and if misunderstood it can cost growers money. What is commonly not comprehended by some growers is the fact that, within such plantings, each individual tree is on a unique bearing pattern. An orchard comprised of individual trees on non-synchronous cycles produces relatively stable nut yields from year to year; however, the variability in nut quality (hence lower income) is high (Sparks

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Therefore, alternate bearing trees, within an otherwise stable yielding orchard, cause substantial revenue losses due to excessive variability in factors that affect nut quality. This loss in quality also translates into marketing related problems for the pecan industry.

**Nature.** Alternate bearing is a natural expression of most forest and fruit tree species, especially those producing medium to large fruits which ripen in late summer or early autumn (Monselise and Goldschmidt 1982). Trees of such species inherently bear on cycles ranging from 2-15 years. This reproductive trait is probably an adaptive advantage for long-lived trees in the wild insomuch that it likely increases the probability of a tree producing offspring that survive predation (inconsistent masting generally acts to suppress populations of seed consuming animals). Hence, annually bearing trees are probably at a selective disadvantage in the natural habitat. Even though it is an advantage in the wild, alternate bearing is distinctly undesirable in agriculture. Pecan is a relatively new crop with the majority of significant cultivars originating either as selections from wild trees or as selections only a couple of generations removed from the wild (Wood et al. 1990). There has not yet been enough biological domestication to result in cultivars that bear annually with only minor fluctuation in yield (an interaction between production and quality traits). The artificial selection pressures exerted by the USDA-ARS pecan breeding program is anticipated to eventually provide stable-yielding cultivars; meanwhile, the problem is best addressed by avoiding the cultivation of cultivars possessing a propensity for moderate to major oscillations in yield and to implementing cultural and pest management practices which moderate this phenomenon.

**Compartmentalization.** Pecan trees appear to naturally exhibit the characteristic of 'compartmentalization' (Figure 1) so typical of forest trees. Young trees are generally comprised of but a single compartmental unit. This means that organic molecules move more or less freely among all sectors of the tree's organs. As a tree grows, the degree of compartmentalization within the tree increases insomuch that certain major limbs and roots become closely affiliated physiologically with each other. These units appear to be largely nonexistent as far as the transport of nutrient elements and water is concerned, however they appear to be distinct realities for the transport of organic assimilates. The number of units and degree of compartmentalization (or autonomy) increase with tree size (personal observation). The relationship is probably more closely associated with tree size than tree age. Large trees, such as 60+ year-old-trees, are usually comprised of several (3-12+) distinct compartments. The result is that such trees are in actuality a composite organism made up of several physiologically distinct and quasi-autonomous entities which largely (from the standpoint of alternate bearing) behave as physiologically independent units. Again, physiological compartmentalization is minimal in small trees and becomes increasingly entrenched as trees enlarge. This compartmentalization results in the alternate bearing phenomena being expressed within these units; hence, small trees do not exhibit multiple alternate bearing units (i.e. major branches) whereas large trees are comprised of several alternate bearing units. These units may bear alternately 'in phase' or 'out of phase'. Major environmental stresses (such as winter cold, spring freezes, summer drought, cloudy growing season, severe disease or insect pressure, etc.) act to synchronize the compartmental units of large trees (and trees within orchards and orchards within regions), and therefore results in all major limbs of the entire tree being 'in-phase'. However, it is common for large trees to have one or more major limbs that are 'out of phase' with the rest of the tree (i.e. one or two limbs are 'on' while the rest of the tree is 'off', or vice versa).

**General Alternate Bearing Mechanism**

The impact of assimilate reserves on flowering or fruit-set appears to be mediated within the compartmental unit via alterations in endogenous growth regulating chemicals and/or growth regulating receptors. Endogenous plant growth regulating substances (such as hormones) appear to be associated with the perception and regulation of carbohydrate use; however, it is carbohydrates that are the basic regulators. Subjective and objective observations provide evidence that there is a critical amount, or level, of assimilate reserves that must be available before a floral meristem can develop to produce a ripe nut (Wood 1989, Worley 1979a, 1979b, Smith et al. 1986, Smith and Waugh 1938, Malstrom and McMeans 1982). This level varies with tree development (or age) and is closely associated with the interaction between 'sink and source' (generally the ratio of fruit number to leaf area) tissues (Sparks and Brack 1972). Factors which promote the accumulation of photo-assimilates have a strong tendency to also reduce the severity of
alternations in production and quality; hence a photoassimilate and their derivatives appear to play a key regulating role.

The following is a theory that I believe generally accounts for alternate bearing behavior in pecan. While it is not particularly novel, it does for the first time provide a formal statement of the general mechanism.

The phenotypic expression of alternate bearing (periodic alternations in flowering and/or nut-set) is regulated at the physiological level by the genetic and environmental factors influencing the quantitative and qualitative characteristics of assimilate reserves within a physiologically autonomous compartmental unit during each of two distinct regulatory phases of flower and fruit development - these being the 'Assimilate Reserve' and 'Assimilate Production' phases.

The primary assimilate factors are carbohydrates (most likely sugars and starch); however, several other storage biochemicals undoubtedly contribute to the regulation of critical developmental processes. Production periodicity is regulated primarily by the availability of photoassimilates during each of two critical physiological phases within a physiologically distinct compartmental unit. These phases are described as follows: The primary phase is the 'Assimilate Reserve Phase' (ARP) and occurs in late winter to early spring and regulates the expression and development of floral meristems (Figure 2). The availability of storage photoassimilates (especially starch) during this period determines the short-term fate of developing flowers (Wood 1989, Worley 1979b, Smith and Waugh 1938). A second critical period is termed the 'Assimilation Production Phase' (APP), and occurs at the time of kernel or cotyledon development and therefore largely regulates nut quality (Figure 3). The driving force behind the availability of photoassimilates is the relationship between kernel strength (a function of nut number and volume) and source strength (a function of leaf number, area, and physiological status) (Wood 1988). The interaction of this source-sink relationship with environmental stresses also influences the availability and utilization of assimilates, developmental processes and biochemical and physiological processes (Wood et al. 1987; Dutcher et al. 1985). The ARP and APP states encompass action thresholds which are continuous within a rather broad quantitative range of assimilate availability. Periodic alterations in nut yield is therefore regulated by imbalances in the supply and demand of photoassimilates within a compartmental unit during the critical developmental phases of 'flowering' and 'cotyledon development'.

Assimilate Reserve Phase (ARP). Within the context of the above described 'ARP' concept, if levels of dormant season assimilate reserves are below the threshold required for the initiation of flower development in early spring (during the ARP), then male and/or female flowering will be reduced. The critical storage assimilate appears to be starch found in roots (Wood 1989, Smith and Waugh 1938). Such levels correlated well with production when studied for several years in the field environment. While correlation can only be interpreted as circumstantial evidence, previous research has indirectly indicated that levels of dormant season starch play a critical role in regulating nut yield. It is hypothesized that starch (and probably other carbohydrates and amino acids) levels must exceed a particular minimum level (this level would likely vary with pecan cultivar and with growing environment) before the physiological processes regulating the development of staminate flowers (catkins and pollen) are fully manifested. This level is not sensed directly by the floral meristem but is done indirectly via physiological interactions associated with the level of sugars (and maybe other carbohydrates and nitrogenous substances) available for metabolic processes.

The common observance of trees exhibiting no visible pistillate flowers, but a substantial level of staminate flowers, is interpreted as evidence that staminate flower development naturally takes priority over pistillate (female) flowers; therefore the development threshold is lower for staminate flowers. This provides an adaptive advantage in the wild inasmuch that a source of pollen is usually available for out-crossing with others of the species. This is further substantiated by the observed absence of wild trees producing pistillate but no staminate flowers. As the level of available dormant season assimilate reserves increases, then the numbers of staminate flowers developing the following spring also increase to a maximum. This 'maximum' obviously defines the upper limit of the action threshold. The action threshold is therefore broad and is clinal in nature. It is not a 'black and white', or 'all or nothing' response, but is rather a 'black and white' with 'infinite shades of grey' in between. The response of the compartmental units is therefore not generally an 'all or nothing' reaction. The individual floral meristems within the compartmental unit are the basic response units. There is substantial
variability among meristems in regard to the 'availability of' and their 'sensitivity to' mobilized assimilates. This 'maximum' is achieved after surpassing the level necessary to trigger the visible development of female flowers; hence trees can be found with heavy catkin crops but moderate crops of pistillate flowers. Since there appears to be an absence of observations of trees exhibiting heavy female flower crops with light to moderate catkin crops, the upper limit of the response curves for staminate and pistillate flowers must be such that the maximum pistillate flower crop is dependent upon a higher level of assimilate reserves than do staminate flowers. The nature of these two response curves is currently unknown. For example, are they linear or curvilinear, and what is the nature of their slopes?

As growers know all too well, the presence of a good crop of female flowers does not necessarily mean a good nut crop. Flowers may abort for a variety of reasons (Sparks 1986). Some abort due to external stress (cold, wind, drought, insects, disease, etc.) whereas others abort due to internal stress (such as selfing, nonpollenation, incompatible pollen parent, or due to insufficient assimilate reserves). Abortion of staminate flowers due to insufficient assimilate reserves is a common reason for crop failures in pecan. This mechanism is associated with an assimilate threshold that is only a little higher than the threshold required for the production of pistillate flowers. If dormant season assimilate reserves are sufficiently high, then trees will enter the summer with a heavy crop of developing fruit and likely produce a good nut-set.

Assimilate Production Phase (APP). This mechanism becomes operative in early summer and acts to regulate further nut development and ripening. This phase largely influences nut size, the degree of kernel filling, and possibly a portion of the fruit abortion associated with the 3rd drop. The driving factor during this period appears to be the "source to sink" relationship. If this ratio is below a certain action threshold, then nuts will fail to fill and will subsequently produce pops (Sparks 1974). However, it should be recognized that the production of pops is sometimes due more to disease factors (especially pecan anthracnose) than to alternate bearing processes. Similarly, if the ratio is too high, then kernel filling is again poor because of excessive partitioning of assimilates to prolific second-cycle vegetative growth. Under this situation the sink strength of the kernel is not enough to successfully compete with excessive new shoot growth (Wood 1988). This mechanism is pronounced on especially vigorous trees possessing a high leaf to fruit ratio and is therefore most commonly exhibited by young trees.

As a tree ages physiologically, the average number of nuts set per flower cluster generally diminishes. This is largely due to a shift in the source:sink ratio. This means that if a grafted tree is only marginally able to fill its nuts when young (8-12 years-old), then the clone will be a progressively stronger alternate bearer as it ages and will subsequently produce poorly filled kernels.

A grower's challenge is largely two-fold. First, he or she should manage an orchard so as to stabilize orchard productivity and nut quality at a moderately high level. Secondly, production from individual trees should also be at a moderate to high level from year to year. Both objectives are interrelated insomuch that good cultural and pest management practices reduce the degree of alternate bearing.

A second regulatory level obviously encompasses either hormone-like factors or the receptors of these factors; however, little or no objective information is available (that has been derived from pecan) regarding their roles. Extrapolations from other crops (such as apple and pears) suggests that these hormone-like factors are the primary regulators of alternate bearing. They could also exert similar roles in pecan, however preliminary observations have not provided convincing evidence for this. For example, biweekly removal of fruit from major limbs throughout the growing season (June - Oct.) resulted in no differences in return bloom the following year. Also, the biweekly application of GA$_3$ or GA$_{4,7}$ to major limbs did not influence return bloom. This suggests to the author that the hormone mechanism theorized in apple may not be operating in pecan. Alternatively, these preliminary studies on pecan might have given different results if whole trees were defruited or sprayed with gibberellins. These possibilities certainly need to be investigated.

Management Strategies

Alternate bearing at the orchard level is commonly observed when tree yield cycles have been synchronized by an environmental factor. Stress factors such as drought, winter cold, spring freezes, severe diseases, sooty mold, severe black or yellow aphids (or any arthropod that substantially reduces leaf area, and/or leaf
efficiency, and/or leaf retention or increases fruit drop), excessive wind or hail, zinc or other elemental deficiencies, etc. act to directly or indirectly reduce assimilate reserves and leads to an imbalance in the "source:sink" ratio. This disruption echoes in the form of a pronounced undulation in orchard production for several seasons into the future (Sparks 1974).

The ability of orchards to recover from severe alternate bearing cycles relates to the scion cultivars, or genetic types, being cultivated (and also to the rootstock). Some cultivars are able to recover (Desirable, Stuart, Sumner) much sooner than others (Success, Moore). Such cultivars are generally those with less fruiting stress because the number of 'set' nuts per cluster is lower. Yield cycling patterns of cultivars which set more than about 2-3 average size nuts (about 50/lb) per fruiting cluster are especially sensitive to environmental stresses and respond by exhibiting a substantial degree of alternate bearing (frequently approximating biennial bearing). Such cultivars are difficult to manage for stable production and quality, even in the most desirable environments. A few examples of these overbearing cultivars include Success, Moore, Mohawk, Chickasaw, Shoshoni, Cherokee, Mahan, Cheyenne, and Van Deman. Cultivars which naturally abort, or thin their flowers to physiologically manageable levels, exhibit bearing patterns that are much less responsive to environmental stresses. These cultivars are therefore more likely to be of greater economic value (such as 'Desirable', 'Sumner' and 'Stuart').

In addition to selecting the right cultivar, the cultural practices that are most likely to act to moderate alternate bearing by individual trees are: 1) maintaining good tree nutrition (especially, N, P, K, and Zn); 2) establishing trees on deep and well-drained soils; 3) providing the tree with sufficient water (requiring supplemental irrigation); 4) maintaining minimal loss of assimilate production by leaves or a loss of developing fruit as a result of disease, mite, or insect pests; 5) thinning of excessive fruit loads (will probably involve the utilization of a mechanical shaker); and 6) configuring orchards to maximize sunlight utilization during the autumn (late August - mid October).

The primary step in reducing the significance of the alternate bearing problem is to utilize the best available scion and rootstock materials. While the rootstocks ability to absorb nutrients, to accumulate assimilates and to mobilize assimilates is of obvious importance, little is known concerning which genotypes are most suitable. Preferred scion cultivars are those which self-thin their fruit sufficiently to neutralize the impact of stress factors on next year's flower development. Growers should be careful, for the time being, about planting cultivars that are both precocious and prolific since these are likely to overproduce by the time the tree is 12 to 15-years-old, resulting in severe alternate bearing problems and the orchard being lost as a productive unit. Breeding efforts will likely be able to eventually separate these two characteristics. Major scion traits that impact alternate bearing are 1) size of fruit cluster; 2) size of fruit; 3) degree and timing of self thinning; 4) tree architecture; 5) photosynthetic efficiency; 6) ability to store and mobilize assimilates; 7) disease and pest resistance; 8) and length of leaf retention. These factors should be taken into consideration in efforts to develop new scion cultivars.

The fact that border trees of orchards are more productive than interior trees should help the orchard manager recognize that sunlight is also a major factor influencing alternate bearing. Its impact has probably been underestimated and merits intense investigation. The quantitative and qualitative aspects of solar irradiation obviously play a major role in tree productivity; however, a dearth of studies on light related problems has resulted in a failure to provide accurate guidelines for pecan. Studies by both Hunter (1963) and Wood and Joyner (1990) have indicated that a deficiency of sunlight during the kernel filling phase results with poor yield. This is especially significant insomuch that yield is the ultimate indicator of alternate bearing. Recent research has shown that, for all practical purposes, a pecan tree cannot get too much sunlight (independent unpublished observations by both Wood and Anderson). Since there is currently no objectively based model available to determine pecan orchard configuration (spacing and tree shape), much work needs to be done in this area. Sunlight interception is especially important to orchards growing in the southeastern U.S. because of the natural abundance of "frontal" and "convectional" clouds during the growing season. These clouds block about 30-40% of the possible sunlight from reaching the orchards (Wood and Joyner 1990). Trees should therefore be managed to make the best use of available sunlight. One major consideration is orchard crowding. Trees should be pruned or thinned so as to minimize unnecessary shading; however, the optimum degree is unknown and will be difficult to determine.
Work in other crops has revealed that there is generally better sunlight interception if the crop is grown with rows extending "North-South" rather that "East-West" (Westwood 1988). This 'may' or 'may not' be true for pecan. It is possible that an E-W orientation will be best for pecan because sunlight interception needs to be greatest in the 'APP' phase, which is operative in late summer and early fall. N-S or E-W row orientation obviously requires that within row spacings be smaller than between row spacings. This may not be wise in pecan since the species has little ability to tolerate the shade conditions that would likely be experienced within rows (Wood and Payne 1991). This suggests that a square, quincunx or hexagonal spacing might be better than a rectangular spacing, especially if light utilization is to be optimized within the context of over-shading. Additionally the "latitude" at which a crop is grown impacts the optimal orchard spacing due to the change in the sun's position in the sky. The importance of the North-South row effect generally increases as latitude increases. Or rather, the farther North pecan is cultivated, the more the impact of non 'North-South' rows on reducing sunlight utilization during midseason. Also, the distance between rows should be greater in the North than in the South due to 'cross-row' shading. This is due to changes in solar altitude with latitude.

A big unknown in pecan cultivation relates to that of optimal spacial arrangement. Trees currently are planted at a variety of spacings and orientations with only indirect information being used to justify such decisions. For example, 'between' and 'within' row spacings ranging from 30 to 60+ feet are typically utilized in commercial orchards. If pecan trees are planted on a square, should trees be oriented N-S or be shifted 45° to a NE-SW orientation? While these are but a few of the questions that need to be resolved if alternate bearing is to be minimized, it should be clear that obviously crowded orchards (those exhibiting death of lower limbs) mean that the alternate bearing effect will become increasingly pronounced as the tree ages.

Another unknown relates to just how much shading should be tolerated before an orchard is thinned? Opinions vary from about 50% shade (at solar noon on June 22nd) to about 80% shade. Unfortunately, there appears to be no objectively derived data that answers this question for pecan. The answer is probably dependent upon canopy shape and latitude; hence, varying with orchard location and cultivar. The derivation of this answer will not likely be soloed via total objectively because of

the time required to test the hypothesis would be impractical under the contemporary research environment.

The above brief discussion of alternate bearing will help those involved in pecan husbandry to better deal with this important biological problem. In the short-term, the best strategy for the orchard manager appears to be that of incorporating cultural and pest management practices which keep trees growing vigorously (but this can be over-done), especially when they begin chronologically age (10+ years-old). This helps to keep the leaf area to fruit ratio in balance, therefore producing relatively consistent crops of good quality. This task becomes increasingly formidable as the tree matures because of an ever increasing respiratory load and increasing number of fruiting points. The alternate bearing effect is far from being eliminated; however, the perceptive orchard manager should be able to minimize its impact by keeping in mind the nature of the problem. The "root" of the alternate bearing problem obviously lies in the genetic makeup of the scions and the rootstock. The interaction of these genotypes with the environment and with each other is the manifestation of the basic factors. Until the genetics can be altered, the most direct alternate approaches would appear to focus on regulating overproduction. This is likely most easily obtainable by mechanical thinning and the avoidance of cultivars with excessively large nuts (>45/lb) and to avoid clusters with several nuts set per cluster (>3/cluster). These strategies may simply be more "chopping", but at least the chopping is on the "trunk" rather than on the "leaves".

LITERATURE CITED


COMPARTMENTALIZATION OF ORGANIC MOLECULES

<CA. 10-YRS-OLD
(1 UNIT)

CA. 12 TO 20-YRS-OLD
(2-3 UNITS)

>CA. 30-YRS-OLD
(4-MANY UNITS)

Figure 1. Changes in compartmentalization of pecan trees as they become larger.
FLOWERS
(% OF POTENTIAL)

Staminate

IV

III

IV

V

VI

VII

Pistillate

DORMANT SEASON ASSIMILATE RESERVES

FLOWERING RESPONSE

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<th>Pistillate</th>
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Figure 2. Characterization of the 'Assimilate Reserve Phase' of alternate bearing.
"ASSIMILATE PRODUCTION PHASE"

**YIELD (% OF POTENTIAL)**

![Graph showing yield in percentage of potential over very low to very high source to sink ratio phases.]

**SOURCE TO SINK RATIO**

**YIELD RESPONSE**

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Figure 3. Characterization of the 'Assimilate Production Phase' of alternate bearing.