PECAN ORCHARD SOIL MANAGEMENT PRACTICES AND THEIR EFFECTS ON TREE PERFORMANCE AND MECHANICAL HARVESTER EFFICIENCY

By

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Scope and Method of Study: Mechanical pecan harvesters were thought to require a sodded ground surface for efficient performance. However, competing vegetation may reduce availability of moisture and nutrients to the pecan trees. Permanent sods have been shown to appreciably inhibit tree growth and nut yield. Annual ryegrass, Lolium multiflorum Lam., has several attributes which make it appealing as a winter cover crop. One attribute is its ability to consistently return from volunteer seed. It was unknown what effect the timing and number of cultivations have on establishment of volunteer ryegrass seed. This study was undertaken to: (1) determine the effects of various soil management systems on tree performance; (2) measure the efficiency of a mechanical harvester operated on various orchard floor surfaces; (3) study the effects of timing and number of cultivations on tree performance and the ability of annual ryegrass to establish from volunteer seed; (4) measure the effects of soil management systems on soil compaction. Management system plots were established at the Oklahoma Pecan Research Station near Sparks, Oklahoma. Treatments included were: (a) year-round clean cultivation, (b) rye and vetch winter cover crop with summer cultivation, (c) tall fescue permanent sod, (d) annual ryegrass winter cover crop with summer cultivation, (e) volunteer native grass winter cover crop with summer cultivation, (f) Korean lespedeza, (g) fall planted perennial ryegrass, and (h) fall planted crimson clover.

Findings and Conclusions: Tall fescue permanent sod inhibited stem growth and resulted in less pecan leaf nitrogen. Multiple summer cultivations (four) increased yield. No differences could be determined in nut size or nut quality. Machine recovery of pecans was not significantly influenced by ground cover type except in one instance. Machine recovery of soil was significantly influenced by the degree of soil cloddiness and by the presence of vegetation. Early cultivation increased nut size and leaf nitrogen of trees in annual ryegrass. A second cultivation had no effect on tree performance. Only an early cultivation (June 1) resulted in significantly less dry weight of the annual ryegrass ground cover in November. Variability in soil texture prevented establishment of a relationship between soil management systems and soil compaction.

ADVISER'S APPROVAL Herman A. Hinrichs

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TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

INTRODUCTION

Factors to be considered in the evaluation of any orchard floor management system are: a) tree performance, usually thought of in terms of growth, yield, and fruit quality, b) interaction of the management system with disease development and insect populations, c) costs incurred through implementation of the management system including time, labor, and fuel, d) the potential for loss of topsoil through wind and water erosion, e) the long term effects of the soil management system on the soil structure, and f) the effects of the management system on other cultural operations such as spraying and harvesting.

There is probably no single best management system for all pecan growing regions. The most suitable soil management system for a high density irrigated pecan orchard in Arizona may not be compatible with a mature, widely spaced orchard in Louisiana.

In Oklahoma eighty-five percent of the pecan production comes from native groves which are typified by large, irregularly spaced trees growing near streams and rivers. Grazing of livestock in the grove is a common practice and bermudagrass and tall fescue sods are frequently used to provide summer pasture.

Annual ryegrass, *Lolium multiflorum* Lam., has been used successfully by at least one Oklahoma pecan grower as a winter cover crop (26). Its attributes include: a) a winter annual growth habit which precludes competition between it and the pecan trees during the summer months, b) provision of winter pasture, and c) the ability to return year after year from volunteer seed. It was not known what effects late and multiple cultivation have on the plant stands of annual ryegrass established from volunteer seed.

The objectives of this study were:

(a) to determine the effects of various soil management systems on tree performance,

(b) to measure the efficiency of a mechanical harvester operated on various orchard floor systems,

(c) to measure the effects of soil management systems on soil compaction, and

(d) to study the effects of timing and number of cultivations on tree performance and the ability of annual ryegrass to re-establish from volunteer seed.

CHAPTER II

REVIEW OF LITERATURE

Soil Management Practices

Several soil management practices and combinations of practices have been used in pecan orchards and groves. These are: 1) winter cover crops, both grazed and ungrazed, followed by summer cultivation to control weed growth, 2) winter cover crops followed by summer mowing, 3) winter cover crops followed by summer cover crops, 4) winter cover crops followed by a summer intercrop, 5) permanent sods, such as bermudagrass or tall fescue, 6) winter cover crops followed by summer mulching, and 7) chemical weed control in the tree rows with a mowed, permanent sod between rows (2,7,8,13,19,27,28,29,30,36,38,40,42,45,46, 47,48,54,63). Recommended winter cover crops are most often legumes, but also include some small grains and winter annual grasses. These recommended winter cover crops are rye, hairy vetch, crimson clover, Austrian winter peas, Monantha vetch, oats, smooth vetch, Hungarian vetch, annual ryegrass, rescuegrass, burr clover, and blue lupine (4, 5,6,7,8,15,20,30,32,35,41,42,44,45,46,54). Recommended summer cover crops include velvet beans, crotalaria, cowpeas, soybeans, beggar weed, and kudzu (3,4,7,15,35,41,44,60,62).

Sitton and coworkers (47) reported that trees in plots receiving summer cultivation had greater increases in trunk cross sectional area and yielded more pecans than did trees in plots in which weeds and grass were allowed to grow. They also reported that for orchards planted to a winter green manure crop, trees in areas disked early in the season, prior to foliation of the trees, yielded more pecans and larger pecans than did trees in areas where the cover crop was disked later, e.g. after appearance of pistillate flowers. No differences occurred in the degree of filling of the nuts between the two treatments.

Dodge and Alben (14) compared nut yields and increases in trunk cross sectional area for trees in a winter legume- cotton intercrop treatment, trees in a winter legume- summer cultivation treatment, and trees in a bermudagrass sod. Over a six year period trees in the winter legume- summer cultivation treatment averaged 848 kg nuts per ha while trees in the cotton intercrop treatment averaged 597 kg nuts per ha and trees in bermudagrass sod averaged only 200 kg nuts per ha. Growth measurements revealed the greatest increases in trunk cross sectional area occurred in the summer cultivation treatment and the smallest cross sectional area increases occurred in the bermudagrass sod treatment.

Hunter (30) reported that use of a blue lupine winter cover crop with summer cultivation was more productive than blue lupine as a winter cover crop with summer mowing. In one year of the four year study nuts from trees in the mowing treatment were higher in kernel percentage.

Grazing cattle on the orchard's winter cover crop can increase monetary income for the pecan grower (28). Woodard (63) showed that pecan yields are not reduced by grazing if fertilization is included in the orchard management system to replace nitrogen normally provided by legumes.

Hunter (31) reported that bermudagrass sod culture had no detrimental effect on nut yield for trees located on a Blakely clay loam even during a dry year (528 mm precipitation from Jan.1-Sept.30). Yields were compared with those from trees in a winter cover crop-summer cultivation treatment. The lack of difference was attributed to the high water holding capacity of the Blakely clay loam soil type.

Ware and Johnson (56,57) measured cumulative growth and yield over a nine year period for trees in an experiment consisting of fifteen different cultural treatments. Maximum growth occurred in the following treatments: a) straw mulch, b) clean cultivation plus 1.8 kg sodium nitrate per tree per year, and c) a winter legume cover crop turned under on April third. Minimum growth occurred on plots planted to a bermudagrass sod with no addition of fertilizers. Addition of 1.8 kg or 3.6 kg sodium nitrate per tree per year resulted in better growth than that of trees in bermudagrass sod without sodium nitrate. Growth of trees in bermudagrass sod with sodium nitrate was less than growth of trees in all other treatments except for trees located in an annual lespedeza sod. Maximum yield occurred on trees treated with straw mulch. Treatments with the next highest yields were: a) clean cultivation plus 1.8 kg sodium nitrate per tree per year, b) a winter cover crop of vetch, cut and left in place, and c) a rye winter cover crop turned under early. Minimum yields for the experiment occurred in bermudagrass sod without added sodium nitrate.

Gossard and Hammar (21,22) reported that over a five year period average yields from trees receiving summer cultivation were fifty percent greater than were average yields of trees in bermudagrass sod.

Yields were further increased by tripling the annual rate of potassium fertilization from 45 kg potassium per ha to 134 kg potassium per ha. Nuts from the cultivated treatment were generally larger than nuts from the sod treatment, especially during dry seasons.

Smith, Harris, and Hammar (49) compared performance of trees receiving a winter legume plus summer cultivation to that of trees receiving a winter legume plus a summer Dallis grass sod. Each cultural system received two different levels of nitrogen fertilization, 0 and 34 kg nitrogen per ha for the cultivated areas and 34 and 68 kg nitrogen per ha per year for the sodded areas. When Dallis grass was fertilized at the lower rate tree growth and nut yield were inferior to the cultivation treatments. When 68 kg per ha nitrogen was used Dallis grass sod had no effect on either growth or yield of the trees.

Worley and Harmon (64) were unable to discern any difference in growth or yield during a five year period between cultural treatments of a) coastal bermudagrass pasture, b) winter legume cover crop with summer cultivation, c) intercropping with a winter or spring vegetable, and d) a natural sod mowed at about 2.5 cm. All treatments received 448 kg of 10-10-10 fertilizer per ha each year.

It becomes apparent from the aforementioned work that any vegetation allowed to compete with pecan trees has the potential of reducing growth and yield. The effects of competition are more severe and more easily discerned when either water or mineral nutrients or both are in short supply. Also, young trees are more affected by competition than are older, better established trees.

Cultivation to control vegetation is expensive in terms of time, labor, and fuel. Kenworthy (34) reports that continuous clean cultivation can alter the soil structure and result in poor penetration of water and increased runoff.

According to Daniell (13), herbicides already cleared for use in pecans can provide better weed control than cultivation with no apparent harm to the trees.

Pecan Harvesting

Methods of harvesting pecans have changed throughout the years. The earliest procedure consisted of flailing the trees with a bamboo pole to knock the nuts to the ground and subsequent retreival from the ground by hand. Wight (61) reported in 1929 that pecans could be harvested faster if sheets were placed on the ground prior to dislodging the nuts. The sheets were then inverted, leaving the pecans in a windrow from which they were hand picked.

The first mechanical tree shakers employed a 15 to 23 meter wire cable attached to a rocker arm worked by a belt driven eccentric shaft and mounted on a tractor. One person was required to climb the tree to attach the cable to individual branches and another person was required to operate the tractor (7,24). Brison (9) reported in 1950 that an experimental pecan huller and separater could be used to remove unopened shucks and to separate pecans from leaves and twigs. Pecans could be dislodged onto sheets and dumped directly into the separater, eliminating the tedium of hand picking.

In the late 1940's an experimental machine for harvesting filberts was developed in Oregon. This mechanical harvester used suction to pick up nuts from the ground. The nuts were lifted into an airstream through four rectangular nozzles mounted on the front of the machine. A bar grid separater removed twigs and leaves while the filberts dropped out of the airstream, through an airlock and revolving dirt cleaner, and were conveyed to a sacking chute (39). A similar machine was developed in California for harvesting almonds (43).

By the early 1950's suction-type harvesters began appearing in the orchards of some of the larger pecan growers (10). One such machine was manufactured by the Circle V Nut Harvester Company of Fort Worth, Texas. Of two reports by pecan growers who owned early suction-type pecan harvesters, one is optimistic and the other is pessimistic. Callahan (11) reports that his harvester will pick up at least 2268 kg of pecans per day with no pecans left on the ground. Van Cise (55) reported that his Circle V Harvester required a tractor to push it, six men plus a tractor driver to operate it, used 57 l of gasoline and one l of oil per day, and harvested a daily maximum of only 1134 kg of pecans.

Many improvements have been made in pecan harvesting equipment since 1951. Cable-type shakers were replaced by boom-type shakers which require only one operator, and these in turn have largely been replaced by tractor mounted and larger truck mounted trunk shakers. Suction-type harvesters have been refined and other machines which employ reel mounted fingers to lift up the pecans have become widely available (17). In addition, sweepers are often used to windrow the pecans to be picked up by machine (59).

The introduction of the mechanical harvester to the pecan industry added a new dimension to the theories of soil management. The orchard floor should be smoothed prior to harvest for optimum efficiency (59).

Where annual cultivation is practiced, mechanical harvesting necessitates annual preharvest ground preparation. It has been suggested that some type of sod culture will provide the best conditions for mechanical harvesting (27). It is claimed that the equipment picks up too much dirt and too many clods on clean land (18). However, permanent sods constitute the least desirable soil management system in terms of tree performance.

Soil Compaction

Soil compaction can be described as the reduction of soil pore space due to the rearrangement of soil particles resulting from an applied force. The amount of compaction resulting from a given force is dependent on the structural arrangement of the soil particles, the particle size distribution, the clay mineral type, the degree of bonding between adjacent particles, and the moisture content of the soil (25).

Empirical measurements to determine the degree of compaction include a) various methods of determining the volume and dry weight of a soil sample (bulk density), b) conductivity of the soil to air, water, or nuclear radiation, and c) soil strength, both shear strength and compressive strength (16).

The forces responsible for changes in soil porosity can be grouped into mechanical, climatic, and biotic forces. The greatest source of mechanical compactive force is vehicular traffic. Pressures beneath tractor tires may exceed 3.5 kg per square cm. Tillage implements generally decrease bulk density but may also produce localized zones of increased bulk density (plow pans) (12). Climatic forces include rainfall, freezing and thawing cycles, and wetting and drying cycles. The kinetic energy of raindrops can effectively increase the bulk density of the upper 2.5 cm of a bare soil surface. Swelling and shrinking due to wetting and drying and freezing and thawing are influenced by the amount of clay, the type of clay mineral, and the orientation of clay platelets in the soil. These actions tend to decrease the bulk density of a compacted soil and to increase the bulk density of a loose aggregated soil until an equilibrium is reached. The macro and micro fauna in the soil may create localized compaction, but have the overall effect of increasing soil porosity. Plant roots likewise may create localized compaction, but after death and degradation of root tissues permeability is increased due to flow in root channels. Treading by animals during times of high soil moisture may profoundly increase soil bulk densities (37).

The effects of soil compaction on plant growth are indirect. A compressed layer at the surface may impede water penetration and increase runoff. A buried compressed layer can create a perched water table which may be beneficial or detrimental, depending on the depth of the layer and rainfall distribution patterns. A buried compressed layer may effectively inhibit plant roots from exploring the lower soil depths for water and nutrients (52). During compaction it is the largest pores which are decreased most in size (58). Compaction may reduce soil porosity enough to stop or limit gaseous transfer (23). Limited aeration may limit root growth (53), cause changes in the types and activities of microbial populations, and reduce nitrification (33).

CHAPTER III

METHODS AND MATERIALS

Cultural Treatments Experiment

Treatments

Plots 0.2 ha in size were established in the autumn of 1975 at the Oklahoma Pecan Research Station near Sparks, Oklahoma. Each plot received different soil management treatments. These are:

(a) rye, *Secale cereale* L., and hairy vetch, *Vicia villosa* Roth., in combination as a winter cover crop with summer cultivation,

(b) year-round clean cultivation,

(c) tall fescue, *Festuca arundinacea* Schreb. cv. 'Kentucky 31', sod established from seed and maintained by mowing.

(d) annual ryegrass, *Lolium multiflorum* Lam., established the first year from seed, cultivated in the summer after seed maturity, and allowed to reestablish each fall from volunteer seed,

(e) Korean lespedeza, *Lespedeza stipulacea* Maxim., originally established from seed, maintained by mowing, and allowed to reestablish each spring from volunteer seed, and

(f) summer cultivation with a winter cover crop of volunteer native grasses.

Treatments were arranged in a randomized complete block design with five single tree replicates. Each plot contains one 'Dodd', one 'Nugget', one 'Hayes', and two 'Patrick' cultivars. Analysis of variance and Duncan's new multiple range test were used for statistical analysis. Arcsin transformation of data was used where applicable (50).

During the springs of 1976 and 1977 each plot received 10-20-10 fertilizer at a rate of 336 kg per ha. During the growing season of 1977 each plot also received one application of NZN[1] at 14 l per ha and such applications of fungicides and insecticides as were necessary to control diseases and insects.

The rye and vetch plot was cultivated four times during 1977. The final cultivation was on September 1 to prepare the surface for seeding. Seeding was accomplished with a John Deere grain drill on September 2. The vetch seed was innoculated with rhizobium prior to being sown to ensure nitrogen fixation.

The year-round clean cultivation treatment received cultivation with a disk four times in 1977. The diskings occurred on April 1, April 28, June 1, and August 16.

The annual ryegrass treatment was cultivated on June 17 and August 16. After the August cultivation no extra measures were taken to prepare the soil surface.

Korean lespedeza, a summer annual, was mowed on May 10, June 1, and August 16.

In the spring of 1977 the majority of the plants in the native

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[1]Trademark for a liquid nitrogen-zinc formulation for foliar application manufactured by Allied Chemical Corporation, Houston, Texas.

grasses plot were rescue grass, *Bromus catharticus* Vahl., and little barleygrass, *Hordeum pusillum* Nutt. Annual bluegrass, *Poa annua* L., was also abundant. The native grass plot received cultivation on June 1 and August 16.

The tall fescue sod was mowed on June 1 and again on August 16.

In addition to the aforementioned cultural treatments one 0.2 ha plot was seeded to perennial ryegrass, *Lolium perenne* L., and another was seeded to crimson clover, *Trifolium incarnatum* cv. 'Dixie Reseeding', on September 29. The soil was first disked in two directions and dragged with a land leveler to smooth the surface. The perennial ryegrass was sown at a rate of 465 kg per ha. The crimson clover was sown at a rate of 150 kg per ha.

Tree Performance

On July 6 length of current season's growth at a height of 3 to 4 m was measured for 100 stems per tree in all of the cultural systems excluding the native grasses treatment, perennial ryegrass, and crimson clover.

Leaf samples were collected on June 21 according to the procedure described by Sparks (51). These were washed to remove traces of NZN, dried, ground to 20 mesh, and subsequently analyzed for nitrogen, phosphorus, potassium, calcium, magnesium, and zinc. Leaf samples collected September 22 were analyzed for nitrogen.

Nitrogen analysis was by the macro-Kjeldahl method (1).

One g dried tissue from each leaf sample was digested in 10 ml of a nitric-perchloric acid mixture (3 parts 70% HNO_3 and 1 part 72% $HClO_4$) using moderate heat. The resulting digestive fluids were filtered and diluted to 100 ml. Two ml 5% lanthanum chloride were added to 8 ml aliquots and these were analyzed for potassium, calcium, magnesium, and zinc using a Perkin-Elmer model 403 atomic absorption spectrophotometer.

To 5 ml aliquots of the dilutes digestive fluids were added 100 ml water, 5 ml 2% sodium molybdate, and 5 ml 2% hydrazine sulfate. These were heated to boiling, cooled, and compared against standards of known concentration of potassium dihydrogen phosphate using a Bausch and Lomb colorimeter.

During harvest yield was recorded and nut samples were collected for determination of nut size and nut quality in terms of kernel percentage.

Mechanical Harvesting

Harvest efficiency was measured on all cultural treatments using a Model 409 pecan harvester manufactured by the Lockwood Corporation of Gering, Nebraska. The Lockwood Model 406 employs stiff rubber fingers attached to a horizontal reel which spins opposite the direction of travel. The pecans are lifted onto a chain link conveyer through which they pass while much of the trash is blown away and is deposited behind the machine. The self-propelled harvester has two drive wheels in front and is steered by a single rear wheel. Hydraulic driven rotary sweepers located in front of each drive wheel are intended to sweep pecans out of the paths of the drive wheels and into the path of the pick-up fingers. The pecans are augered into a revolving holding drum which has a 159 kg capacity and slotted holes through which small pieces of soil and trash can pass.

Two rectangular harvest test areas 10.7 m long and the width of the harvester (1.85 m including rotary sweepers) were outlined under each tree. The areas pass under the trees' canopies and extend beyond the dripline.

The harvest procedure was begun by shaking the trees with a tractor mounted trunk shaker.[1] Next, the harvester was driven over a test area from east to west, perpendicular to the drill rows, and everything picked up was emptied from the holding drum into a sack which was marked and sealed. The harvester was then returned to the east end of the harvest test area and the area was mechanically harvested a second time. Once again, all materials recovered by the machine were placed in sacks. The final field procedure was to carefully hand pick the test area to recover any broken or unbroken pecans not recovered by the machine.

Materials recovered by machine were divided into five categories. These were broken pecans, unbroken pecans, soil, shucks, and trash. The trash category consists of leaves, sticks, green sticktights, and other miscellaneous trash. Pecans recovered by hand were separated into unbroken pecans and broken pecans.

Annual Ryegrass Experiment

This experiment consists of eleven 1349 square m plots. The plots are located in an area which was planted with annual ryegrass seed in the autumn of 1975 and has reseeded itself each following autumn. During the 1977 growing season each plot received cultivation with a disk

[1] Bowie Industries, Inc., Bowie, Texas.

on different dates or different combinations of dates. The dates of cultivation are:

(a) June 1

(b) June 1 and August 15

(c) June 15

(d) June 15 and August 15

(e) July 1

(f) July 1 and August 15

(g) July 15

(h) July 15 and August 15

(i) August 1

(j) August 1 and August 15

(k) August 15

Treatments were arranged in a completely randomized design. Each plot contains three trees of the 'Western' cultivar. On November 1 leaf samples were collected and were subsequently analyzed for nitrogen by the macro-Kheldahl method (1). On November 10 visual grades were made by three individuals on the density and growth of the annual ryegrass cover at each tree.

On November 15 an open steel square measuring 30.5 cm on each side was tossed into each plot ten times at random constituting 10 replications. The number of ryegrass plants within the square was recorded and the plants were removed to be dried and weighed.

Yield, nut size, and kernel percentage were measured for each tree in the experiment.

Soil Compaction Studies

During 1976 numerous measurements of unconfined soil compressive strength were made at the Oklahoma Pecan Research Station using a pentrometer,[1] with the intention of relating soil compaction to soil management systems. Early in 1977 penetrometer measurements were abandoned in favor of bulk density measurements. Horizontal soil cores 2 cm in diameter and 10 cm long were carefully removed from soil profiles at 7.6 cm, 15.2 cm, 22.8 cm, and 30.4 cm. Soil cores were dried at 110 degrees C and bulk densities calculated.

Comparisons of bulk density were made in February of 1977 between the Haydon orchard near Okemah, Oklahoma, and the Colpit orchard at Catoosa, Oklahoma. These orchards are located on similar bottomland soils. The Colpit orchard is covered with a permanent tall fescue sod and, at the time of sampling, had not been recently tilled. The Hayden orchard has been planted with annual ryegrass and is cultivated annually after the ryegrass seed matures. Both orchards are open to cattle except just prior to and during harvest.

Comparisons of soil bulk density were also made between areas of heavy traffic and areas of moderate traffic. The soil cores were collected during May of 1977 from the clean cultivation plot mentioned in the section concerning the cultural treatments experiment. The heavily trafficked areas are the lanes over which the tractor[2] and 1893 l (500

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[1]Model CL-700, Soiltest, Inc., Evanston, Illinois.

[2]Model 4000, Ford Motor Co., Dearborn, Michigan.

gallon) orchard sprayer[1] travel when pesticide applications are made. The moderate traffic areas are outside these lanes and receive only tractor traffic during cultivations.

[1]Bean Speedsprayer, FMC Corp., Jonesboro, Arkansas.

CHAPTER IV

RESULTS AND DISCUSSION

Cultural Treatments Experiment

Tree Performance

No differences could be determined in nut size or nut quality between treatments (Table I). One may suspect that nut size would be decreased by a permanent sod or summer annual, but such was not the case. Perhaps differences would have become apparent with greater replication.

Yield was significantly greater in the rye and vetch cover crop treatment than in all other treatments except clean cultivation. Both of these treatments received four cultivations throughout the summer compared with only two cultivations for annual ryegrass.

Stem growth measurements reveal low vigor among trees in the tall fescue sod. This was predicted by the deficient level of nitrogen in the leaves at that time (Table II). The greatest stem growth occurred on trees receiving clean cultivation.

Soil management systems did not affect the leaf content of phosphorus, potassium, calcium, or zinc (Table II). Significantly higher magnesium levels occurred in trees in the rye and vetch and Korean lespedeza treatments. Nitrogen differences exhibited the most statistical significance in the leaf samples collected June 21. These

TABLE I

EFFECT OF CULTURAL TREATMENT ON TREE PERFORMANCE

Treatment	Stem growth (cm)	Yield kg/tree	Nut size nuts/kg	Nut quality kernel %
Rye and vetch cover crop with summer cultivation	7.6 ab[1]	6.8 b	234.4	57.2
Clean cultivation	9.5 b	5.4 ab	274.2	57.4
Tall fescue sod	6.4 a	2.1 a	259.9	58.2
Annual ryegrass cover crop with summer cultivation	6.8 ab	1.3 a	254.6	57.2
Korean lespedeza	7.9 ab	1.7 a	243.7	56.7

[1]Mean separation within columns is by Duncan's new multiple range test, 5% level.

TABLE II

EFFECT OF CULTURAL TREATMENT ON NUTRIENT LEVEL IN LEAVES

Treatment	%N[1]	%P	%K	%Ca	%Mg	ppm Zn	%N[2]
Rye and vetch cover crop with summer cultivation	1.96 ab[3]	0.13	0.53	1.29	0.93 b	29.0	1.60 a
Clean cultivation	2.10 bc	0.13	0.69	1.29	0.80 a	41.8	1.81 b
Tall fescue sod	1.89 a	0.13	0.66	1.35	0.87 ab	38.2	1.49 a
Annual ryegrass cover crop with summer cultivation	2.21 c	0.13	0.64	1.23	0.80 a	41.0	1.90 b
Korean lespedeza	2.12 bc	0.13	0.69	1.46	0.94 b	41.0	1.87 b

[1]Leaf samples collected June 21.

[2]Leaf samples collected September 22.

[3]Mean separation within columns is by Duncan's new multiple range test, 5% level.

differences continued throughout the season with trees in clean cultivation, annual ryegrass, and Korean lespedeza exhibiting higher nitrogen levels than trees in rye and vetch or tall fescue sod, possibly due to nitrogen utilization by the rye and tall fescue.

Harvest Efficiency

Debris. Weights of debris collected by the machine are shown in Table III. Differences between treatments in the amounts of shucks and trash recovered along with the pecans were significant. In general, the annual ryegrass and tall fescue treatments yielded the least shucks and trash, crimson clover and rye and vetch treatments yielded the most shucks and trash, and other treatments were intermediate.

Of the debris collected with the pecans, shucks and leaves and other trash have little resemblance to the pecan nut and are easy to remove, either by blowers or suction cleaners. On the other hand, soil, particularly clods of clay, are more difficult to discern from a pecan nut. Cleaners which remove all the lightweight materials will pass soil clods along with the nuts. Therefore, it becomes quite important that the soil management system used results in few soil clods for the machine to recover.

Table III shows the weights of soil recovered from the various management systems. As may be expected, the least amount of soil was removed from treatments which received no cultivation, e.g. tall fescue sod and Korean lespedeza. Significantly more soil was removed from the rye and vetch and clean cultivation treatments, and the most soil was removed from the perennial ryegrass and crimson clover treatments.

TABLE III

EFFECT OF CULTURAL TREATMENT ON RECOVERY OF DEBRIS

Treatment	First harvest (g)			Second harvest (g)		
	Shucks	Trash	Soil	Shucks	Trash	Soil
Rye and vetch cover crop with summer cultivation	61.6 b[1]	318.0 b	4155.3 b	14.3 bc	96.7 bc	1496.0 c
Clean cultivation	30.2 a	203.2 a	2454.1 b	5.4 a	66.9 ab	652.1 b
Tall fescue sod	7.2 a	102.5 a	16.3 a	2.3 a	54.8 a	8.3 a
Annual ryegrass cover crop with summer cultivation	11.8 a	107.0 a	175.4 a	3.9 a	49.8 a	68.4 ab
Korean lespedeza	20.5 a	177.2 a	4.6 a	7.3 ab	73.9 ab	0.5 a
Native grasses with summer cultivation	23.1 a	191.5 a	186.7 a	8.7 ab	70.5 ab	113.8 ab
Perennial ryegrass	30.6 a	202.1 a	7695.1 c	7.8 ab	76.3 ab	3189.1 d
Crimson clover	57.6 b	309.9 b	7241.1 c	18.2 c	119.5 c	2770.3 d

[1]Mean separation within columns is by Duncan's new multiple range test, 5% level.

The amount of soil removed by the mechanical harvester is in part a function of the amount of rainfall following the last date of cultivation. Following a cultivation, even though the soil surface has been smoothed, soil clods lie at the surface where the mechanical harvester's fingers can pick them out. Sufficient rainfall can apparently cause the soil at the surface to lose its discrete clodiness and become more cohesive. Hence, the perennial ryegrass and crimson clover treatments, which received only 64.5 mm of rain between cultivation and harvest operations, resulted in the most soil removal. Untested in this experiment is whether rolling the soil can simulate the effects of rainfall.

The presence of vegetation on the ground also seems to reduce soil removal. The clean cultivation treatment received its final cultivation on the same date as did annual ryegrass, but more closely resembles the rye and vetch treatment in the amount of soil removed.

<u>Pecan Recovery</u>. Table IV shows the mean values of pecans recovered. Recovery in the first pass over the test area ranged from 50.5 to 62.1 percent. Among these pecans breakage ranged from 6.2 to 13.2 percent. Fewer pecans were recovered in the second harvest, ranging from 10.1 to 14.6 percent, yet breakage was greater, ranging from 13.9 to 29.7 percent. This greater breakage is probably due to the wheels of the harvester driving over the unrecovered pecans.

Breakage, expressed as a percentage of the total weight of pecans, was greatest in the Korean lespedeza treatment and smallest in annual ryegrass, with all other treatments being intermediate.

Column four shows the percent of the total pecans recovered in two

TABLE IV

EFFECT OF CULTURAL TREATMENT ON MACHINE RECOVERY OF PECANS

Treatment	Percent recovered					Percent unrecovered		
	First harvest	Second harvest	Broken	Unbroken	Total	Broken	Unbroken	Total
Rye and vetch cover crop with summer cultivation	60.8 b[1,2]	10.7 a	5.8 ab	65.7 b	71.5 b	4.5 ab	24.0 abcd	28.5 a
Clean cultivation	59.8 b	10.1 a	6.2 ab	63.7 ab	69.9 ab	4.7 ab	25.4 bcd	30.1 ab
Tall fescue sod	58.5 b	11.5 ab	5.1 a	64.9 b	70.0 ab	8.1 b	21.9 abc	30.0 ab
Annual ryegrass cover crop with summer cultivation	57.6 b	11.9 ab	6.3 ab	63.2 ab	69.5 ab	2.1 a	28.4 cd	30.5 ab
Korean lespedeza	61.3 b	14.6 b	9.9 b	66.0 b	75.9 b	6.1 b	18.0 a	24.1 a
Native grasses with summer cultivation	50.5 a	12.1 ab	6.3 ab	56.3 a	62.6 a	4.7 ab	32.7 d	37.4 b
Perennial ryegrass	62.1 b	12.3 ab	8.5 b	65.9 b	74.4 b	7.1 b	18.5 ab	25.6 a
Crimson clover	56.3 ab	12.8 ab	6.8 ab	62.3 ab	69.1 ab	4.9 ab	26.0 bcd	30.9 ab

[1]Analysis of variance and mean separation were performed on arcsin transformed data.

[2]Mean separation within columns is by Duncan's new multiple range test, 5% level.

passes over the test area as unbroken pecans. Of the eight soil management systems tested only one, a winter cover crop of volunteer native grasses combined with summer cultivation, exhibited a significantly smaller recovery of unbroken pecans than did some of the other treatments. Contrary to the report of Hines (27) and Frost (18) a sod is not necessary for efficient mechanical harvesting. A winter cover crop with summer cultivation can result in acceptable harvester performance provided cultivations are not continued so late into the season as to result in a cloddy soil condition at harvest time.

The recovery percentages in this experiment appear lower than one might expect. The largest average recovery in two passes over the test area is 75.9 percent. It was observed that a large portion of the unrecovered pecans were those in the path of the rotary sweepers rather than those directly in the path of the pick-up fingers. In a routine harvest operation the harvester swaths would be overlapped and greater recovery could be expected.

Annual Ryegrass Experiment

Tree Performance

There were few differences in nut yield between cultivation dates (Table V). The only significant differences was a small yield from trees in the July 1 disking treatment. Since yields from trees in the July 1 + August 15 treatment were not significantly smaller than any other yields, the small yield in the July 1 treatment may be attributed to experimental error. A second disking appears to have neither increased nor decreased yield from that obtained with only one

TABLE V

EFFECT OF TIME OF CULTIVATION ON TREE PERFORMANCE

Date of cultivation(s)	Yield kg/tree	Nut size nuts/kg	Quality % kernel	Nitrogen % dry wt
June 1	12.7 ab[1]	149.1 a	58.0	1.60 d
June 1 + August 15	10.0 ab	159.5 ab	58.4	1.58 d
June 15	8.8 ab	191.9 bc	58.4	1.26 a
June 15 + August 15	10.1 ab	187.6 bc	58.6	1.30 ab
July 1	6.8 a	193.5 bc	58.3	1.27 a
July 1 + August 15	11.5 ab	202.4 c	59.2	1.32 ab
July 15	12.2 ab	199.6 c	57.5	1.32 ab
July 15 + August 15	12.2 ab	194.9 bc	58.9	1.44 bc
August 1	17.8 b	201.3 c	58.2	1.37 ab
August 1 + August 15	11.9 ab	202.0 c	57.6	1.33 ab
August 15	18.1 b	180.7 abc	58.0	1.51 cd

[1]Mean separation within columns is by Duncan's new multiple range test, 5% level.

cultivation.

In general, earlier cultivation resulted in larger nuts, probably due to moisture conservation. Once again the second cultivation did not produce results different from those treatments with only one disking.

No differences could be discerned in kernel percentage between treatments.

The earliest cultivation resulted in higher leaf nitrogen levels than all other treatments. In all cases except one this difference was significant at the five percent level. These increased nitrogen levels may be due to greater nitrogen availability because of more rapid soil organic matter decomposition and/or a decrease in weed competition. There were no differences in leaf nitrogen between one cultivation and two cultivations.

Ryegrass Establishment

Ryegrass establishment was measured in three ways, the number and dry weight of the plants in a given area, and visual grade. Table VI shows the results of these measurements and also a ratio of the dry weight to the number of plants. In terms of plant numbers, late cultivation appears to be no better or worse than early cultivation. In only one case did the second cultivation reduce the plant stand appreciably.

Dry weight of the plants in a given area is probably a better measure of the food available for grazing livestock. In this category only the June 1 treatment was significantly smaller than any others. The smaller amount of growth may be due to more competition by summer

TABLE VI

EFFECT OF TIME OF CULTIVATION ON RYEGRASS ESTABLISHMENT

Date of cultivation(s)	Density plants/ 929 sq cm[2]	Dry weight/ 929 sq cm	Mean weight[1] (g)	Visual grade[2]
June 1	120.5 ab[3]	1.6 a	.013 a	3.1 c
June 1 + August 15	115.5 ab	2.2 ab	.019 ab	3.0 c
June 15	115.3 ab	3.0 b	.026 abc	2.9 bc
June 15 + August 15	120.2 ab	3.1 b	.026 abc	2.2 abc
July 1	152.5 b	2.2 ab	.014 a	2.6 abc
July 1 + August 15	94.5 a	3.2 b	.034 c	1.4 a
July 15	107.5 ab	3.1 b	.029 c	2.6 abc
July 15 + August 15	125.4 ab	3.5 b	.028 c	1.8 ab
August 1	136.6 ab	3.3 b	.024 abc	2.2 abc
August 1 + August 15	151.0 b	3.5 b	.023 abc	2.7 abc
August 15	122.7 ab	3.0 b	.024 abc	2.7 abc

[1] Determined by dividing column two by column one.

[2] Based on a scale of 1=best, 5=worst.

[3] Mean separation within columns is by Duncan's new multiple range test, 5% level.

weeds. It may be due to the poorer growing conditions for plants which germinate in early summer than for plants which germinate in late summer or early fall.

Visual grade is probably the least accurate measurement of ryegrass establishment. By comparing column four with column tree of Table VI it may be seen that the visual grades were biased according to the average ryegrass plant size. The best average visual grade was assigned to the treatment with the largest plants. The worst visual grade was assigned to the treatment with the smallest plants.

Soil Compaction Studies

Variability in soil texture at the Oklahoma Pecan Research Station prevented establishment of a relationship between several cultural methods and soil compaction.

Comparison of a permanent tall fescue sod and annual ryegrass with annual cultivation revealed no differences in bulk density to a depth of 15.2 cm (Table VII). Any increase in porosity due to cultivation was lost between the time of cultivation in early summer and the time the soil core samples were collected the following February. The orchard in ryegrass shows a significantly greater bulk density at the 22.8 cm and 30.4 cm levels. This may be due to the increased traffic during annual cultivation and surface preparation.

Compaction by a tractor and sprayer during pesticide applications significantly increased soil bulk density to a depth of 22.8 cm (Table VIII). This increase was not unexpected, since fungicide applications

TABLE VII

EFFECT OF SOIL MANAGEMENT ON SOIL BULK DENSITY

Treatment	Bulk density (g/cm^3) Depth (cm) 7.6	15.2	22.8	30.4
Permanent tall fescue sod	1.37	1.37	1.43 a[1]	1.46 a
Annual ryegrass with summer cultivation	1.34	1.41	1.49 b	1.53 b

[1]Significant differences within columns were determined by t-test, 5% level.

TABLE VIII

EFFECT OF COMPACTION BY ORCHARD MACHINERY ON SOIL BULK DENSITY

Treatment	Bulk density (g/cm^3) Depth (cm) 7.6	15.2	22.8	30.4
Surface traveled by sprayer	1.54 b	1.65 b	1.66 b	1.58 a
Surface not traveled by sprayer	1.45 a	1.59 a	1.59 a	1.64 b

[1]Significant differences within columns were determined by t-test, 5% level.

had been made shortly after cultivation on April 1 and again after cultivation on April 28. The cultivated condition plus rainfall made the area extremely susceptible to compaction.

CHAPTER V

SUMMARY AND CONCLUSION

To be effective a pecan orchard soil management system must combine optimum tree performance with efficient mechanical harvesting. Permanent sods provide a surface compatible with mechanical harvesting, but constitute the least desirable management system in terms of tree growth and yield.

The objectives of this study were: (1) to determine the effect of five different management systems on tree growth, nut yield, and nut quality, (2) to measure the efficiency of a mechanical harvester operating on eight different soil surfaces, (3) to study the effect of timing and number of cultivations on the ability of annual ryegrass to establish from volunteer seed, and (4) to measure compaction as related to soil management practices.

Growth and yield of pecan trees were increased with multiple summer cultivations. Differences in nut size and nut quality between soil management systems could not be discerned.

Permanent sods are not necessary for efficient mechanical harvesting. Winter cover crops combined with summer cultivation may be just as effective as a permanent sod provided the soil is in a cloddy condition at the time of harvest.

Annual ryegrass has several attributes which may make it appealing to the pecan grower as a winter cover crop. The timing and number of cultivations does not seem to affect the ability of annual ryegrass to establish from volunteer seed provided at least one cultivation takes place after mid-June.

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APPENDIX

TABLE IX

RAINFALL AT SPARKS, OKLAHOMA, FROM JUNE 1 TO DECEMBER 31, 1977

Date	Rainfall (mm)
June 24	1.8
June 27	18.3
June 29	2.3
July 1	45.7
July 27	14.0
August 1	20.6
August 11	34.0
August 12	15.5
August 15	10.2
August 25	10.9
August 29	18.8
September 6	62.2
September 12	5.1
September 13	4.8
September 14	12.7
September 15	14.5
October 24	33.0
October 31	2.8
November 2	3.8
November 9	24.9
December 6	13.7

VITA[2]

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