FORESTRY TYPE CONVERSION ON THE "CROSS TIMBERS" AREA IN OKLAHOMA

By

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I dedicate this thesis to my wife, Linda, who chose to stay with and support me in all my decisions knowing it meant personal sacrifice for her; to my son, Sean Corey, who was a real helper by providing that special lift in spirit which often made the load bearable; and to my parents who never lost faith in me.

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CHAPTER I

INTRODUCTION

By 1975 the world wood requirements will be 560 million cubic meters more than were required in 1961. An increase of 43 percent is predicted by Fugall (1967) for industrial wood use alone and three-fifths of this increase will be needed for chipping and/or pulping. In the South it will be necessary to double timber growth before the end of the current century to meet estimated population needs in the year 2000 (Southern Forest Resources Council, 1972).

In the past it has been possible for forest managers to increase timber supplies by planting open areas and improving the quality of timber stands. Today, open areas are approaching complete utilization. Hence it is imperative for foresters to develop ways to use marginal sites, specifically low quality hardwood stands. Developing these marginal sites is becoming more urgent since the land base is constantly being eroded by expansion of population centers, construction of highways, and dams. Since the natural vegetation has little commercial value on low quality hardwood sites, forest type conversion would be a primary way to improve the productivity of these areas and increase timber supplies.

The "Cross Timbers" area of Oklahoma would lend itself to this type of conversion if pine could be established economically there. Finding a pine species capable of withstanding its limiting environmental factors would enable approximately 6,214,000 acres to be converted in Oklahoma. An additional 25,000,000 acres of low quality hardwood sites throughout the South could then be examined for potential production (Anderson and Guttenberg, 1971).

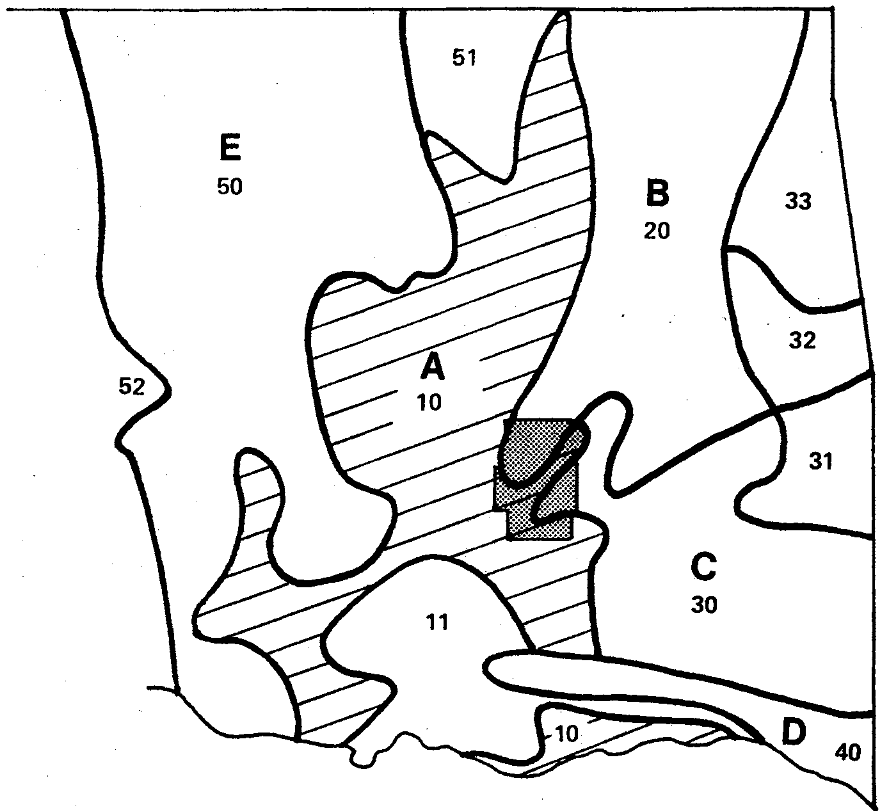
The purpose of this study is to determine if low quality hardwood stands on Hector-Hartsell soils in the "Cross Timbers" area of Oklahoma are biologically suited for conversion to pine. This thesis deals principally with site preparation, survival, growth, and rabbit damage during the first growing season.

The "Cross Timbers" Area

The "Cross Timbers" area of Oklahoma (see Figure 1) is best described by Gary and Galloway (1959, pp. 30-31) as follows:

> The Cross-Timbers is a large wooded area of rolling to hilly sandstone uplands extending from the Kansas line to Texas. It is an area of scrubby timber in which old growth is more or less open and park-like. Cutting and burning have caused prolific sprouting of the post and blackjack oaks to form many brushy thickets. Since the large areas lie between the eastern and central prairies they were dreaded by early travelers who had to cross the timber belt on foot or on horseback - hence the name "Cross-Timbers." ...The soils of the Cross-Timbers are moderately leached and are of the Red-Yellow Podzolic zone. Many Lithosols occur in the area. Soils are generally light colored moderately acid, and have reddish sandy clay loam subsoils. Considerable invasion of oaks has occurred on these lands in the past half century, particularly on the moderate depth to very shallow soils. These soils are generally very low in phosphorous and nitrogen and low in potassium and calcium.

Rainfall varies from an annual average of 39.09 inches in northeast Oklahoma to 37.05 inches in the south-central; and from 33.14 inches in the west to 41.87 inches in the east (see Figure 2). The growing season ranges from 200 days in the north to 230 days in the south. Growing season precipitation is shown in Figure 3.



[A] SOUTHWESTERN PRAIRIES COTTON AND FORAGE REGION
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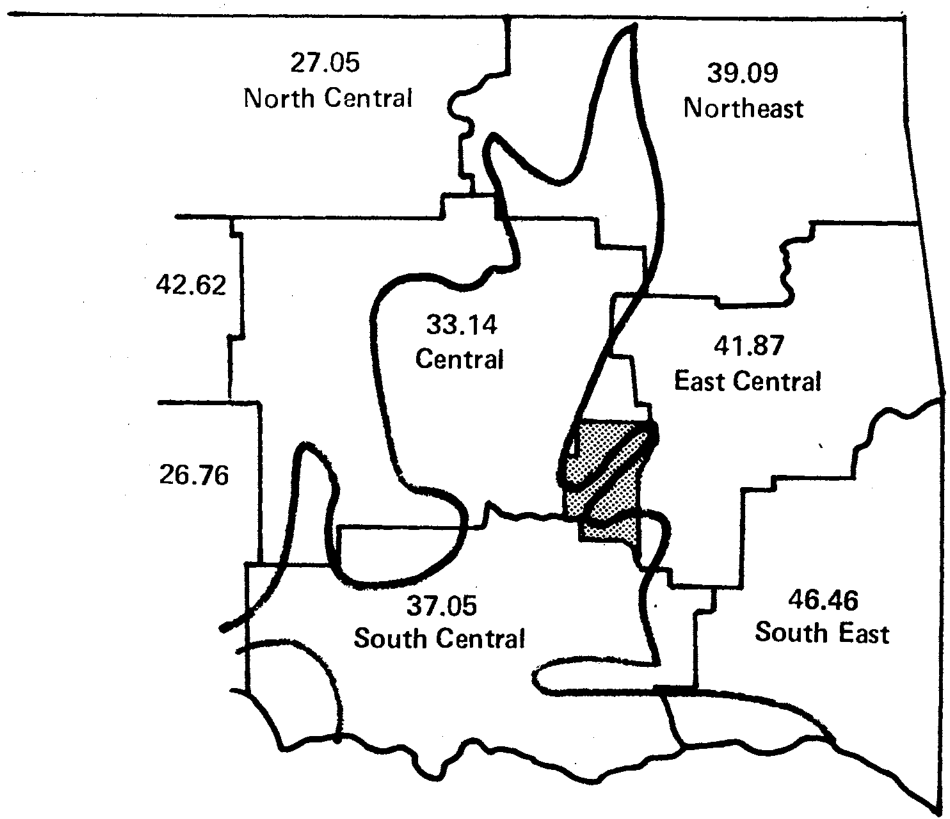
Shaded Area is Hughes County, Oklahoma
Lined Area is "Cross Timbers" Area

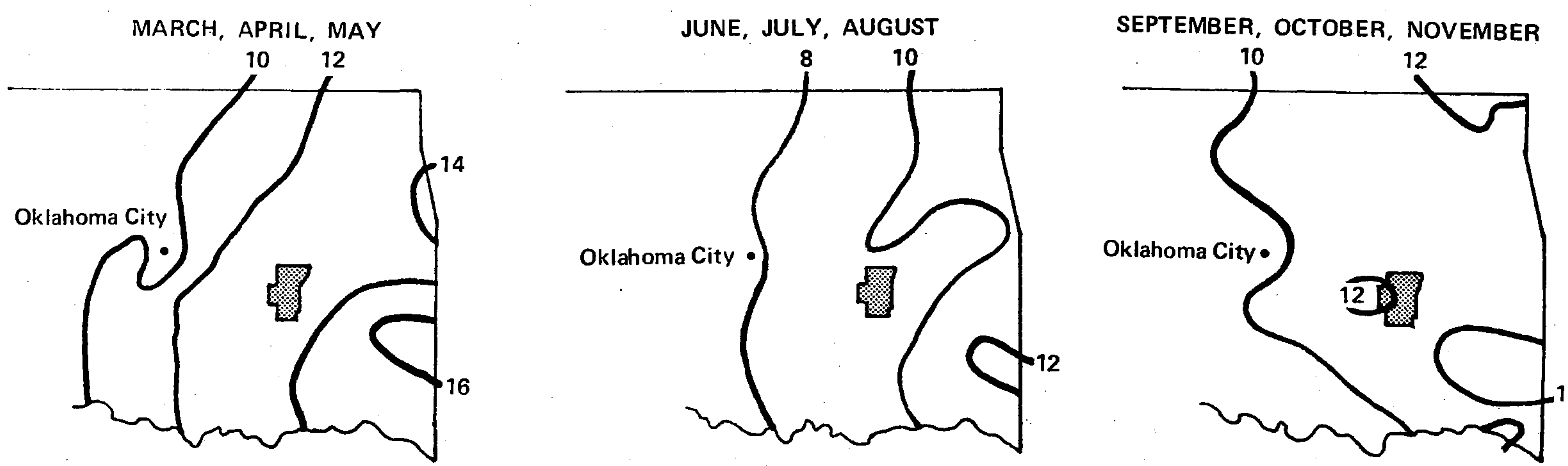
Source: Nelson, Thomas C. and Walter M. Zillgitt, "A Forest Atlas of the South," Southern Forest Experiment Station and Southeastern Forest Experiment Station. U.S.D.A. Forest Service.

Figure 1. Land Resource Areas in Central and Eastern Oklahoma



Source: Nelson, Thomas C. and Walter M. Zillgitt, A Forest Atlas of the South, Southern Forest Experiment Station and Southeastern Forest Experiment Station. U.S.D.A. Forest Service.

Figure 2. Mean Annual Precipitation Amounts in Inches by Regions for the "Cross Timbers" Area of Oklahoma



Source: Nelson, Thomas C. and Walter M. Zillgitt, "A Forest Atlas of the South," Southern Forest Experiment Station and Southeastern Forest Experiment Station. U.S.D.A. Forest Service.

Figure 3. Mean Precipitation Amounts in Inches by Three Month Intervals for Growing Season in Oklahoma

The Problem

Most of the problems associated with forest type conversion on low quality hardwood stands are interrelated biologically and economically. Some of the factors affecting success include site, topography, soil moisture, vegetative competition, and climate.

Site quality generally determines the type of timber crop which can be produced; i.e., high quality sites for lumber and plywood logs; low quality sites for pulpwood and posts. The end product of the timber stand influences the amount of money which can be spent to establish it. Basic to the success of timber production in the "Cross Timbers" area is the establishment of good timber stands in the most economical manner. Due to the poor site quality of this area, production of short rotation crops such as pulpwood or posts would seem to be most feasible.

When establishing new stands of trees, the most costly step is usually site preparation prior to planting or direct seeding. Many methods are used for site preparation, but basic to them all is the purpose of preparing the land to give the trees or seeds a better chance for survival and growth. This generally includes reduction of competing vegetation and, in the case of direct seeding, exposure of mineral soil for better germination and establishment. The methods used in this study (aerial spraying and prescribed burning), are usually the least costly of those available.

Topography is important because of aspect and slope. Aspects which allow the sun's rays to beam directly on the site raise ground temperature and aid in drying the soil. Therefore, sites with aspects which allow only indirect rays often have higher survival and growth rates. Proper slope is important, especially in direct seeding, to guard against seeds being washed downhill or buried before they can germinate.

Soil moisture is necessary for the survival and growth of newly planted seedlings, and for attaining proper seed germination. Soil moisture is often a deciding factor in determining whether to plant seedlings or to direct seed. Soil moisture is critical for success in the "Cross Timbers" because of the area's shallow soil and low rainfall. Moisture distribution throughout the summer months is more important than moisture amount in these shallow soils because of the soil's inability to retain moisture for long periods of time.

Vegetation competition can affect success of establishment in several ways. Oaks and grasses are the predominant natural vegetation in this area. In the fall, when oaks lose their leaves the accumulated litter can keep the seeds from reaching mineral soil, thus preventing germination. In addition, oaks compete strongly for sunlight and soil moisture during the growing season, often slowing the pine growth. If the oaks are removed or killed, the native grasses present usually spread rapidly and often compete successfully for moisture. Grass may provide beneficial shade for young seedlings when there is adequate soil moisture, and kill seedlings by moisture competition during times of moisture stress.

Many climatic factors affect success, but precipitation amount and distribution throughout the year are the most pertinent in the "Cross Timbers" area. Drought is often a serious problem. Therefore, success here demands a drought resistant tree. Drought resistance is best defined by Hopkins (1971) as follows:

> Drought resistance is defined on the basis of a plant's capacity to survive periods of drought. Total resistance

> represents a combination of drought avoidance, or the ability of a plant to exclude the drought from its tissues, and drought tolerance which is the degree of drought within the plant tissues that it can survive (Hopkins, 1971b, pp. 6-7).

The ability of a tree to withstand drought and the cost of establishing pine on the "Cross Timbers" area are two of the most important factors of forest type conversion on these lands. This thesis should give some insight into drought resistant species and establishment success in the "Cross Timbers" area, but economic data will be included in a subsequent report. A good discussion of economic factors relative to converting southern oak-pine types is provided by Anderson and Guttenberg (1971).

Species Selection

The criteria used to select the species to be used in the study were varied. In addition to drought resistance, the species' value as a pulpwood-producing tree was considered. Using these two general criteria, five species were selected for the study.

Loblolly pine (*Pinus taeda* L.) and shortleaf pine (*Pinus echinata* Mill.), both native Oklahoma species, were selected because of their high value as pulpwood producers and the close proximity of their natural ranges to the study area. Virginia pine (*Pinus virginiana* Mill.), a common species throughout the Appalachian region, was selected primarily because of its importance as a pulp tree and also because it has had good survival and growth on shallow soils in similar studies (Russell and Mignery, 1968; Maple, 1965). *Pinus pinaster* Ait., an exotic species to the United States, was selected because of its known drought resistance in its native ranges. Many studies conducted in Australia using *Pinus pinaster* have shown that it does very well under poor moisture conditions and makes a good pulpwood tree (Hopkins, 1971a; Hopkins, 1971b). *Pinus brutia* Ten., another exotic species to the United States, was selected because its native range encompasses many areas with poor moisture conditions and also because of the availability of seed.

Previous Works

Several investigators have attempted to solve many problems associated with forest type conversion on hardwood sites. Anderson and Guttenberg (1971) provide an excellent discussion of the economics of converting southern oak-pine types. Their production functions and investment guide can be applied to this and to any similar study in the South.

Phares and Liming (1960) compared seeded and planted shortleaf pine on low-grade oak stands in the Missouri Ozarks. Site preparation consisted of clearcutting the hardwood overstory and spot seeding cultivated spots. Their results showed that at the end of one growing season more seeded spots remained stocked than did the planted ones. In one growing season the seeded trees had outgrown the planted trees. They concluded that seeded pine outgrew planted pine under all degrees of hardwood competition.

Thor and Huffman (1969) compared seeded and planted loblolly pine on low quality hardwood forests in Tennessee. Two different site preparation methods were used: 1) double disking with a bulldozer, and 2) plowing of fire lanes. There was an untreated control. Later, burning and direct seeding were added to the study. Based on five year growth data, their conclusions stated that planted trees would produce at least two more cords per acre at 15 years than would seeded trees. They also concluded that burning and silvicide injection may reduce hardwood competition sufficiently to permit planted seedlings to develop normally.

Russell and Mignery (1968) conducted an intensive study comparing direct-seeded loblolly, shortleaf, and Virginia pine on hardwood sites in the Tennessee Highlands. Their study compared seven variables: 1) repellent treatment, 2) seedbed preparation, 3) seedspot preparation, 4) stratification, 5) month of seeding, 6) species, and 7) seeding method. They concluded that direct seeding of loblolly, shortleaf or Virginia pine, is practical for converting low-grade hardwood stands on the Cumberland Plateau and Highland Rim of Tennessee.

Marler (1963) studied loblolly and shortleaf pine survival during a three year period in Virginia. His study compared species, planting season (fall, winter, and spring), physiographic province (coastal plain, piedmont, and mountain), planting sites (field, cut-over, disked, bull-dozed woodland, and strip mined lands), and planting year. Marler concluded that the year planted, the time of year, and the planting site all had a considerable effect on planting survival. He recommended spring planting (late February) to secure maximum survival.

Similar studies referred to in this thesis include Maple (1965), Russell (1964), Phares and Liming (1961), Campbell and Mann (1973), and Bilan and Stransky (1966).

CHAPTER II

METHODS

Experimental Design

In February 1973 the first three of nine replications were established to study the feasibility of forest type conversion on the "Cross Timbers" area of Oklahoma. Three more replications were established in the spring of 1974 and the final three replications are to be established in the spring of 1975. The final evaluation of the study will continue for twenty years before final evaluation.

A randomized block with plots equaling .1 acre, replicated three times is being used. Each replication contains five plots with five treatments being assigned at random, one treatment to each plot. Table I summarizes the five treatments which were used. Each replication is 288 feet by 80 feet with each plot being 56 feet by 80 feet with a two foot border strip separating plots within replications. This thesis deals with the first three replications planted and seeded in February 1973. Data on survival, growth, and rabbit damage were collected after one growing season.

Site Description

The site of this study is located in Hughes County, Oklahoma, two miles east of Lamar, Oklahoma, in the "Cross Timbers" area (T7N, R12E, E1/2, NW1/4, Sec. 18). The vegetation consists primarily of post oak

TABLE I

FIVE TREATMENTS APPLIED TO EACH REPLICATION
ON THE "CROSS TIMBERS" AREA

Treatment	Species	Method of Establishment	No. Planted Per Plot	Total Planted	No. Seeds Per Plot	Total Seeded
1	Pinus taeda	Handplanted on 6' X 8' spacing	72	216		
2	Pinus taeda	Direct Seeded at 1 lb./acre			1600	4800
3	Pinus echinata	Handplanted on 6' X 8' spacing	72	216		
4	Pinus echinata	Direct Seeded at 1/2 lb./acre			1200	3600
5	Pinus virginiana +	Handplanted on 6' X 8' spacing	24	72		
	Pinus pinaster +	Handplanted on 6' X 8' spacing	24	72		
	Pinus brutia	Handplanted on 6' X 8' spacing	24	72		

(Quercus stellata Wangenh.), blackjack oak (Quercus marilandica Muench.), white oak (Quercus alba L.), hickory (Carya spp.), and tree huckleberry (Vaccineum arboreum).

All three replications were planted in a small, narrow valley cut by a stream which is active after most normal rains. Replications I and III occur on north-facing aspects with slopes varying 25 to 30 percent. Replication II occurs on an east-facing aspect with a 10 to 15 percent slope. Replications II and III being located near the bottom of the valley are sheltered from much of the area's wind. Replication I, however, is located on a ridge top with continuous wind exposure. All three replications occur on Hector-Hartsell soils which are typical of the "Cross Timbers" soils.

Site Preparation

During the winter of 1969 the area was subjected to a moderately heavy wildfire prior to the scheduled aerial chemical spray. This wildfire appeared to have girdled many hardwoods up to three inches in diameter. Soon after this fire the entire study area was fenced to exclude cattle, and firebreaks were constructed aroung each replication.

On June 8, 1970 the area was aerial sprayed using a mixture of two pounds (acid equivalent) of 2,4,5,-T plus one pound (acid equivalent) of picloram (Triethylamine) per acre. The herbicide treatment was applied as a diesel oil in water emulsion at a rate of five gallons per acre. The overall treatment appeared to be effective with only a few small areas not being adequately controlled. The resulting percent defoliation in October 1970 was: 1) blackjack oak, 83%; 2) white oak, 87%; 3) winged elm, 82%; 4) hickory, 55%; and 5) huckleberry, 67%.

In December of 1972 the area was prescribed burned, to remove grasses and ground litter in order to prepare the site for planting and direct seeding. Although the grasses were very moist at the time of burning a good burn was achieved. Only bunch grass stalks two to three inches high remained and good mineral soil exposure was achieved.

Species Source

The source for loblolly pine seedlings was Oklahoma. Stock 1-0 seedlings were grown at the Oklahoma State Nursery in Broken Bow, Oklahoma. They were not from genetically improved seed but were nursery run stock. Open pollinated loblolly pine seed (Clone 79), and shortleaf pine seed (Clone 21), were collected from the Oklahoma State University seed orchard located in Idabel, Oklahoma. The loblolly ortet of clone 79 is located in Hemstead County, Arkansas. The shortleaf ortet of clone 21 is located in McCurtain County, Oklahoma.

The Virginia pine seedlings were grown from genetically improved seed of a northern Alabama source. The seedlings were grown and furnished by the Kimberly-Clark Company.

The *Pinus pinaster* seedlings were grown from seed of four different provenances listed below:

1) Marghese, Galgaccio, Levie and Porte Vecchio Corsica,
2) Half sib families from St. Pee seed orchard on the South Atlantic Coast of France,
3) Tuscon Hills of Italy,
4) Portugal.

The source of *Pinus brutia* was Turkey.

Planting Methods

All seedlings to be planted were handgraded 1-0 stock with the exception of the *Pinus pinaster* and *Pinus brutia* which were handgraded, root-pruned 2-0 stock. Handgrading criteria were root collar diameter and form. The seedlings were lifted and placed immediately in plastic bags filled with sphagnum moss until the time of planting. The Virginia pine seedlings were placed in refrigeration at 40°F. until time of planting since they were received several days before planting.

All seedlings were planted on a six foot by eight foot spacing with eight feet between rows and six feet within rows. This spacing allowed for six rows of 12 seedlings or 72 seedlings per plot. Plastic clothes line, marked at six-foot intervals. was used to insure uniformity in spacing and alignment.

All seedlings were hand planted using planting bars with special care being given to insure proper closure of the planting hole. Planting proved to be very difficult when exact six-foot intervals between trees were required, due to the large rocks present within this type soil. The majority of seedlings were planted within a radius of one foot from the desired location however.

Direct Seeding Method

Loblolly pine was seeded at the rate of one pound of seed per acre and shortleaf pine was seeded at the rate of one-half pound of seed per acre as recommended by Derr and Mann (1971). Germination tests were conducted prior to seeding to assure sufficient germination rates for seed lots being used. All seed was stratified for 20 days in plastic bags using the method described by Hosner, Dickson, and Kahler (1959).

All seeds were treated with repellents to insure protection from birds and rodents. The repellent coating was a blend of Arasan-75 and Endrin 50-W applied over a Dow Latex 512-R sticker. Arasan was applied at 6.0 percent of the dry weight of seed and Endrin at 1.5 percent as used in the study by Russell and Mignery (1968). The areas to be seeded were divided into four equal sections, marked, and hand seeded with equal amounts of seed.

Methods of Measurement

In December 1973 following one complete growing season, all desired measurements were taken. Attempting to locate the direct seeded trees earlier would have been very difficult and would have resulted in many trees being missed. Waiting until December to take measurements gave the herbaceous vegetation time to cure and facilitated the search.

Since all seedlings were planted on a known spacing, every planted seedling or its assigned position was located. Then, either the measurements made on surviving trees were recorded or the dead or absent tree was noted. Surviving trees were measured to the nearest .1 foot for height. In some places, the cause of death was obvious such as a fallen limb from the dead hardwood trees; and this type failure was noted. All damage which could be identified was also noted.

At the time of planting it was observed that several cottontail rabbits (Sylvilagus spp.) were in the area. Soon after planting it was evident that many trees of all species were being bitten off within an inch or two inches of the ground. At the time of measurement many surviving trees showed signs of being recently clipped, and others had already partially recovered by lateral branch growth. Height measurements were made on these damaged trees as well as on the undamaged trees and the rabbit damage was noted.

By measuring in this manner it was possible to obtain and record data for any specific tree in the study. This procedure will allow future comparisons of damaged versus undamaged trees by identifying the status of individual trees.

Tally of the direct-seeded plots required making allowances for possible variation due to seeding method. It was observed that when hand sowing the seed, some of the seeders overcompensated in their attempt to obtain evenness by overseeding the borders of each of the four quarters of the plot. As a result of this manner of seeding, the area in the center of the plot where the four sections join was more heavily seeded than the centers of the four sections. If the plots were tallied by randomized mil-acre plots it was feared that too many mil-acre plots might fall in the center of the plot causing an overestimate of the stocking rate. To improve the estimate of stocking, another method of sampling was attempted. The plot was divided into fourths which resulted in the plot being divided into 16 equal sections of four rows and four columns. Four of these 16 sampling plots were selected for measurement in the following manner. One row and one column were chosen at random and the section where they crossed was measured. This row and column was not replaced and another row and column pair was selected at random from those remaining. The process was repeated one more time, leaving the fourth section pre-determined.

Each of these four sections, measured 14 feet by 20 feet, or 1/16th of the total area in the plot. Each section was measured by two men for surviving seedlings. To insure that the same amount of area would be tallied each time, plastic (P.V.C.) pipe was used to form a rectangle with an inside measurement of 14 feet by 20 feet. This rectangle could be separated into sections and moved from one area to another area. After the pipe had been placed in the proper area, four corridors 5 feet by 14 feet were measured and marked with nylon cord. These corridors were searched for seedlings one at a time insuring complete coverage of the 14 feet by 20 feet area. When a seedling was discovered, a small surveyor's flag was placed next to it to help prevent its being stepped on by the searchers, and also to facilitate making a rough geographic map of each tree's location.

Analysis of Variance (ANOVA)

Three Analysis of Variance tables were calculated. Only three species, loblolly, shortleaf and Virginia pine were used in the ANOVA. Due to the small number of degrees of freedom associated with the study at this particular point, it was not possible to make statistical correlations on many aspects of the data. New experiments are being added which should make correlations possible on future data. Hopefully, a good correlation test can be conducted on rabbit damage and survival in this expanded study.

CHAPTER III

RESULTS AND DISCUSSION

This study was originally planned to begin in the spring of 1972, but was delayed for one year. Due to this delay, two of the species to be planted, Pinus pinaster and Pinus brutia were two years old at the time of the 1973 planting. During this extra year's growth, while in the nursery both species had developed massive root systems and had to be severely root pruned. It is suspected that this severe root pruning caused the very low survival for these species in the first year's planting. At the time of this writing survival of 1-0 seedlings of these same two species from the 1974 planting indicates that much higher survival rates can be expected with these species. Due to these very low survival rates in the first planting, these two species were excluded from the analysis of variance tables and must not be considered as having had a fair test of their worth. However, for completeness Pinus brutia and Pinus pinaster are included in the discussion of results.

Precipitation

As stated in the introduction, the precipitation amount during the first year after planting is critical for germination and survival. To estimate the amount of precipitation which fell on the site, data from the nearest reporting weather station (Okemah, Oklahoma) were collected.

This station is located 24 miles north northwest of the study site. Monthly precipitation amounts for the ten years previous to 1973 were also collected from the same weather station. The 1973 monthly precipitation amounts were plotted against the ten-year average as is shown in Figure 4.

The year 1973 was wetter than the previous ten years by 8.89 inches. The total rainfall measured at the Okemah station for 1973 was 51.84 inches. June was the wettest month with 8.83 inches of precipitation and Frebruary the dryest month with 1.17 inches of precipitation. Figure 4 shows that the high yearly reading is achieved in the three months of June, September, and November in which there was 24.57 of the 51.84 inches of precipitation recorded for 1973.

Due to high temperatures and low rainfall, June, July, and August are usually the most critical months for the survival of young seedlings in Oklahoma. The rainfall recorded in June (8.83 inches), was 5.07 inches above the ten-year average. The rainfall recorded in July (1.47 inches), was 2.32 inches below the ten-year average; and the rainfall recorded in August (2.43 inches), was .5 inches below the ten-year average.

Handplanted Seedling Results

Loblolly Pine

Table II summarizes the study results obtained with loblolly pine. Of 216 seedlings planted, 209 survived the first year for a 96.7 percent survival rate. In the loblolly pine survival study by R. L. Marler (1963), described in the introduction, the best results, 81.4 percent, were on field sites of the Piedmont provinces. Although these two

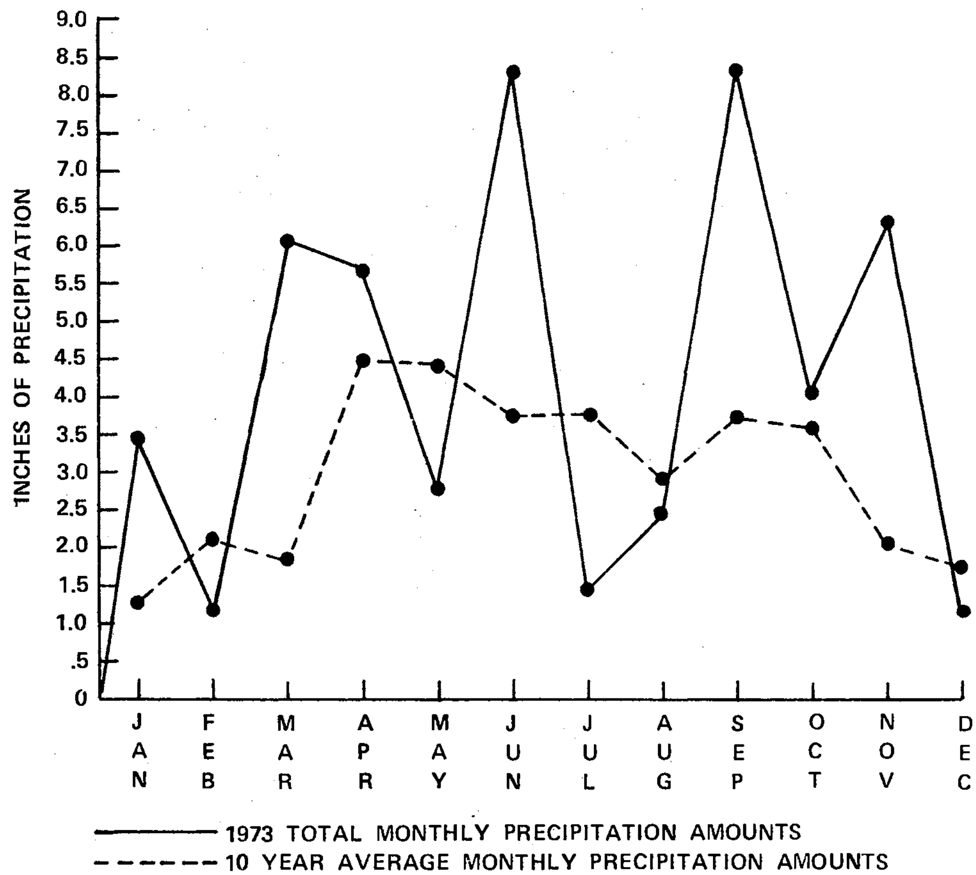


Figure 4. Plot of 1973 Monthly Precipitation Amounts Against the Previous Ten Year Average Monthly Precipitation Amounts

TABLE II

SUMMARY OF RESULTS FOR HANDPLANTED LOBLOLLY PINE

Variables	Rep. I	Rep. II	Rep. III	Average
Percent Survival	94.4	97.2	98.6	96.7
Number Surviving	68	70	71	209
Number That Died	4	2	1	7
Percent of Surviving Trees Which Were Rabbit Damaged	19.1	20.0	18.3	19.1
Number Trees Rabbit Damaged	13	14	13	40
Number Trees Undamaged	55	56	58	169
Height of Undamaged Trees (in.)				
Mean	15.2	18.6	17.1	17.0
Standard Deviation	3.9	4.1	4.6	4.3
Coefficient of Variation (%)	25.2	22.3	27.2	25.5
Range	16	18	23	25
Height of Rabbit Damaged Trees (in.)				
Mean	11.5	9.5	10.7	10.6
Standard Deviation	1.5	1.6	2.7	2.1
Coefficient of Variation (%)	13.0	17.7	25.7	20.4
Range	5	6	8	9
Height of Rabbit Damaged and Undamaged Trees Combined (in.)				
Mean	14.7	16.8	16.0	15.9
Standard Deviation	3.8	5.2	5.0	4.8
Coefficient of Variation (%)	26.4	31.3	31.5	30.7
Range	16	23	25	26

studies were on quite different sites, it is felt that the survival in this study is outstanding by any comparison.

Of the surviving seedlings, 19.1 percent or 40 trees were damaged by rabbits. As noted earlier, many of the damaged trees had recovered from the rabbit clipping by lateral branch growth. The average height of the rabbit damaged trees was 10.6 inches, while the average height of the undamaged trees was 17.0 inches. Twelve of the undamaged trees were taller than 25 inches, with the tallest being 32 inches. The 17.0 inches in height growth compares favorably with that given by Bilan and Stransky (1966) for loblolly pine grown on soils of the Texas "Post-Oak Belt."

When replications are compared, the mean height of undamaged trees in replications II and III is greater than that for replication I. This suggests that replication I was less favorable for growth than replications II and III. The average height in replication I is 2.6 inches below the averages of replications II and III with no trees taller than 25 inches being found in replications I.

Shortleaf Pine

Shortleaf pine results are summarized in Table III. Of 216 seedlings planted, 175 survived the first year for an 81 percent survival rate. The 81 percent rate also exceeds by 10.7 percent that given by R. L. Marler (1963) for the best shortleaf survival rate on mountain provinces.

Of the surviving trees 49.7 percent were damaged by rabbits. The average height of the rabbit damaged trees was 9.2 inches while undamaged trees is in the range given by Bilan and Stransky (1966) for

TABLE III

SUMMARY OF RESULTS FOR HANDPLANTED SHORTLEAF PINE

Variables	Rep. I	Rep. II	Rep. III	Average
Percent Survival	91.6	72.2	79.1	81.0
Number Surviving	66	52	57	175
Number That Died	6	20	15	41
Percent of Surviving Trees Which Were Rabbit Damaged	22.7	71.1	61.4	49.7
Number Trees Rabbit Damaged	15	37	35	87
Number Trees Undamaged	51	15	22	88
Height of Undamaged Trees (in.)				
Mean	17.0	16.2	15.3	16.5
Standard Deviation	5.1	4.5	4.9	4.9
Coefficient of Variation (%)	30.1	27.7	32.0	30.2
Range	24	16	17	24
Height Rabbit Damaged Trees (in.)				
Mean	10.4	8.8	9.2	9.2
Standard Deviation	2.3	3.1	3.3	3.1
Coefficient of Variation (%)	22.5	34.4	35.8	33.4
Range	9	13	14	15
Height of Rabbit Damaged and Undamaged Trees Combined (in.)				
Mean	15.5	11.0	11.5	12.9
Standard Deviation	5.4	4.9	4.9	5.5
Coefficient of Variation (%)	34.8	44.4	42.8	42.6
Range	24	19	23	27

height of shortleaf pine after one growing season on the Texas "Post-Oak Belt." There were three shortleaf seedlings taller than 25 inches with the tallest being 30 inches.

When the replications are compared there appears to be some correlation between percent rabbit damage and percent survival. Replication I has the lowest percent of rabbit damage to surviving trees and the highest percent survival. Replication II has the highest percentage of rabbit damage for surviving trees and the lowest survival rate. Replication III is intermediate to replication I and replication II in both percent survival and percent rabbit damage.

Clipped trees exhibited partial recovery by lateral branch growth supporting the findings of Hunt (1968) which stated that, after a period of time, clipped trees would recover and equal unclipped trees in height growth. However, Crouch (1973), in a study in Texas found that the difference between the average height of clipped trees and unclipped trees continued to widen during four growing seasons following the damage. More time is needed before this study can support any of the above findings.

Virginia Pine

Table IV summarizes the Virginia pine results. Of 72 seedlings planted, 63 survived the first year for an 87.5 percent survival rate. This survival rate is 5.7 percent greater than that given by Maple (1965) for Virginia pine on silty clay loam soils in the Ozark Highlands.

Of the 63 surviving trees, 14 were rabbit damaged, giving a 22.2 percent rabbit damage rate. The mean height of these damaged trees was 10.2 inches. The average height of the undamaged trees was 17.7 inches

TABLE IV

SUMMARY OF RESULTS FOR HANDPLANTED VIRGINIA PINE

Variables	Rep. I	Rep. II	Rep. III	Average
Percent Survival	100.0	91.6	70.8	87.5
Number Surviving	24	22	17	63
Number That Died	0	2	7	9
Percent of Surviving Trees Which Were Rabbit Damaged	25.0	9.0	35.2	22.2
Number Trees Rabbit Damaged	6	2	6	14
Number Trees Undamaged	18	20	11	49
Height of Undamaged Trees (in.)				
Mean	18.1	17.9	17.0	17.7
Standard Deviation	4.4	3.9	3.6	3.9
Coefficient of Variation (%)	24.3	21.8	21.3	22.4
Range	19	15	11	19
Height of Rabbit Damaged Trees (in.)				
Mean	10.3	12.5	9.5	10.2
Standard Deviation	3.7	0.7	2.8	3.0
Coefficient of Variation (%)	36.0	5.6	30.3	30.1
Range	9	1	7	9
Height of Rabbit Damaged and Undamaged Trees Combined (in.)				
Mean	16.1	17.4	14.4	16.1
Standard Deviation	5.4	4.0	4.9	4.9
Coefficient of Variation (%)	33.4	23.2	34.6	30.5
Range	20	15	17	20

and the average of both damaged and undamaged trees combined is 16.1 inches. Three trees were taller than 25 inches.

When the three replications are compared, replication III shows a survival rate of 70.8 percent, which is much lower than either replication I (100 percent), or replication II (91.6 percent). No logical explanation can be given for this difference.

Pinaster Pine

Table V summarizes the results obtained with *Pinus pinaster* in the study. Of 72 seedlings planted, 28 survived the first year for a 38.8 percent survival rate. As stated before, *Pinus pinaster* was two years old at planting time. When the seedlings were lifted from the seedbed, they had massive root systems with some lateral roots measuring 24 inches in length. To facilitate planting with planting bars all trees were root pruned to four inches lateral root length. This severe pruning probably adversely affected the seedlings with respect to their recovery from the shock of root pruning and transplanting, thus limiting their survival ability. Therefore, the figures given for *Pinus pinaster* are included only for completeness.

Of the 28 surviving trees, six were damaged, giving a 21.4 percent rabbit damage rate. The average height of the rabbit damaged trees was nine inches. The average height of undamaged trees was 12.9 inches and the combined average of rabbit damaged and undamaged trees was 12.0 inches.

A comparison of rabbit damage by replications shows that replication II suffered the most losses having only one surviving tree which also sustained rabbit damage. The average height for trees in replication I is 4.1 inches more than for those in replication III. This fact

TABLE V

SUMMARY OF RESULTS FOR HANDPLANTED PINASTER PINE

Variables	Rep. I	Rep. II	Rep. III	Average
Percent Survival	54.1	4.1	58.3	38.8
Number Surviving	13	1	14	28
Number That Died	11	23	10	44
Percent of Surviving Trees Which Were Rabbit Damaged	30.7	100.0	7.1	21.4
Number Trees Rabbit Damaged	4	1	1	6
Number Trees Undamaged	9	0	13	22
Height of Undamaged Trees (in.)				
Mean	15.3		11.2	12.9
Standard Deviation	3.8		3.3	4.0
Coefficient of Variation (%)	24.8		29.5	31.0
Range	10		12	14
Height of Rabbit Damaged Trees (in.)				
Mean	10.7	6	5	9
Standard Deviation	4.1			4.2
Coefficient of Variation (%)	34.0			47.1
Range	10			10
Height of Rabbit Damaged and Undamaged Trees Combined (in.)				
Mean	13.9	6	10.7	12.0
Standard Deviation	4.3		3.5	4.3
Coefficient of Variation (%)	31.2		33.3	35.6
Range	15		13	15

is interesting since both have nearly the same total for surviving trees. Another interesting observation is that all the trees in replication I are from the Corsican source while all trees in replication III were of the mixed French and Italian sources. It should also be noted that all replication II trees were of Portugese source, and only one survived. However, due to the possible effects of root pruning, valid conclusions cannot be made.

Brutia Pine

Table VI summarizes the *Pinus brutia* results. Of 72 trees planted, only 11 survived the first year giving a 15.2 percent survival rate. *Pinus brutia* seedlings were root pruned for the same reasons that the pinaster pines were. This root pruning apparently adversely affected the survival and growth of *Pinus brutia* as it did for *Pinus pinaster*.

Of the 11 surviving trees, six were rabbit damaged giving a 54.5 percent rabbit damage figure; and, the average height for these trees was 9.8 inches. The average height of undamaged trees was 15.6 inches. The combined average of both damaged and undamaged trees was 12.4 inches.

Summary of Planted Species

Table VII summarizes the results of Tables II through VI by species only. Figure 5 is a bar graph illustrating the height of all five species for undamaged, rabbit damaged, and the combined average of undamaged and rabbit damaged trees. Figure 6 is a bar graph showing a comparison of seedling survival percent versus rabbit damage percent for all five species.

It will be assumed throughout the rest of this section, that there

TABLE VI

SUMMARY OF RESULTS FOR HANDPLANTED BRUTIA PINE

Variables	Rep. I	Rep. II	Rep. III	Average
Percent Survival	12.5	8.3	25.0	15.2
Number Surviving	3	2	6	11
Number That Died	21	22	18	61
Percent of Surviving Trees Which Were Rabbit Damaged	33.3	0	83.3	54.5
Number Trees Rabbit Damaged	1	0	5	6
Number Trees Undamaged	2	2	1	5
Height of Undamaged Trees (in.)				
Mean	10.0	10.0	20.0	15.6
Standard Deviation	9.8	5.6		7.6
Coefficient of Variation (%)	52.1	56.5		49.1
Range	14	8		20
Height of Rabbit Damaged Trees (in.)				
Mean	12		9.4	9.8
Standard Deviation			2.7	2.7
Coefficient of Variation (%)			29.7	27.6
Range			7	7
Height of Rabbit Damaged and Undamaged Trees Combined (in.)				
Mean	16.6	10.0	11.1	12.4
Standard Deviation	8.0	5.6	4.9	6.0
Coefficient of Variation (%)	48.4	56.5	44.7	48.3
Range	14	8	13	20

TABLE VII

SUMMARY OF RESULTS FOR ALL HANDPLANTED SPECIES

Variables	Loblolly Pine	Shortleaf Pine	Virginia Pine	Pinus pinaster	Pinus brutia
Percent Survival	96.7	81.0	87.5	38.8	15.2
Number of Surviving Trees	209	175	63	28	11
Number of Trees That Died	7	41	9	44	61
Percent Surviving Rabbit Damaged Trees	19.1	49.7	22.2	21.4	54.5
Number of Trees Rabbit Damaged	40	87	14	6	6
Number of Trees Undamaged	169	88	49	22	5
Height of Undamaged Trees (in.)					
Mean	17.0	16.5	17.7	12.9	15.6
Standard Deviation	4.3	4.9	3.9	4.0	7.6
Coefficient of Variation (%)	25.5	30.2	22.4	31.0	49.1
Range	25	24	19	14	20
Height of Rabbit Damaged Trees (in.)					
Mean	10.6	9.2	10.2	9.0	9.8
Standard Deviation	2.1	3.1	3.0	4.2	2.7
Coefficient of Variation (%)	20.4	33.4	30.1	47.1	27.6
Range	9	15	9	10	7
Height of Rabbit Damaged and Undamaged Trees Combined (in.)					
Mean	15.9	12.9	16.1	12.0	12.4
Standard Deviation	4.8	5.5	4.9	4.3	6.0
Coefficient of Variation (%)	30.7	42.6	30.5	35.6	48.3
Range	26	27	20	15	20

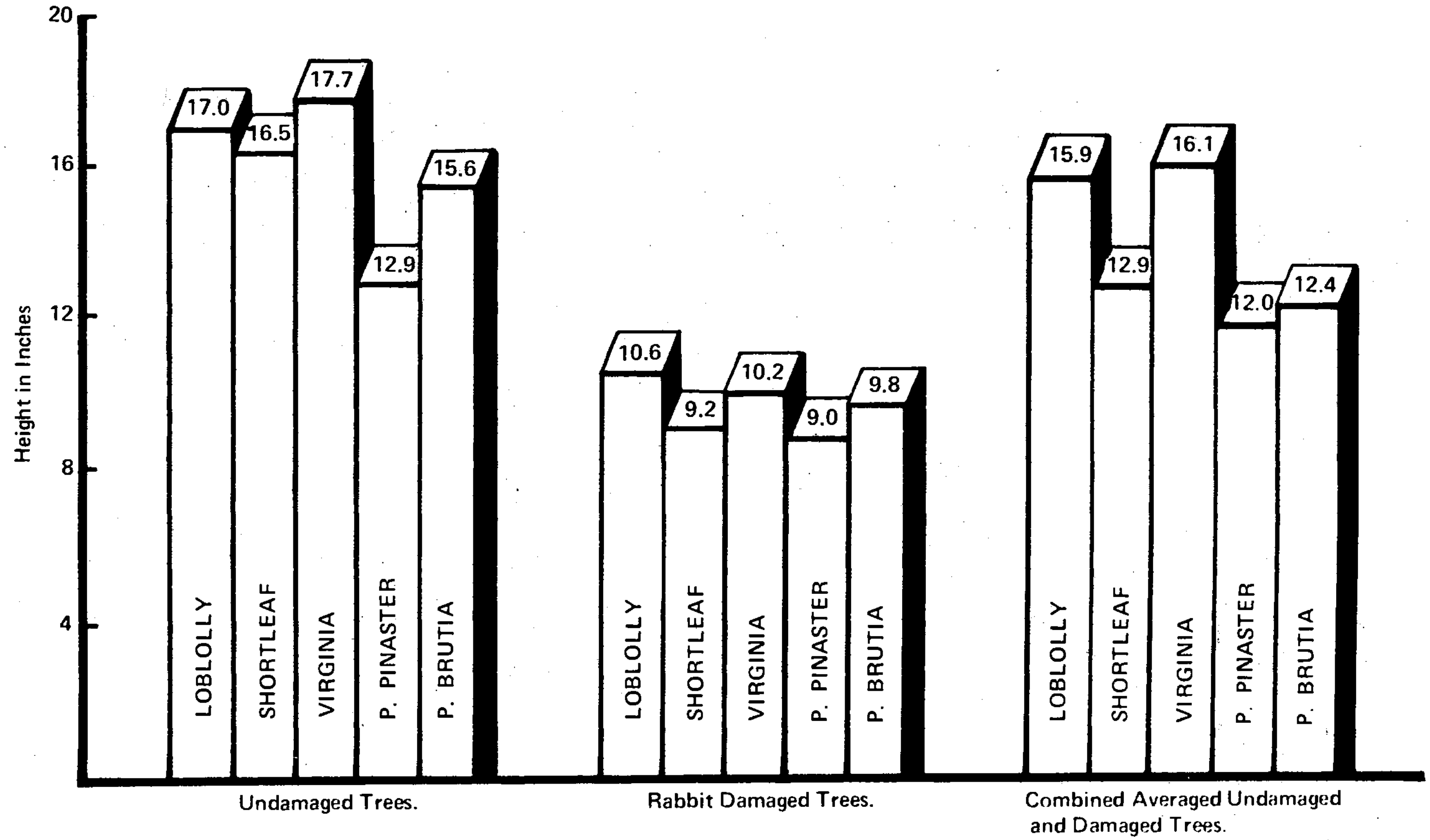


Figure 5. Bar Graph Illustrating Height of All Five Handplanted Species for Undamaged, Damaged, and Combined Average

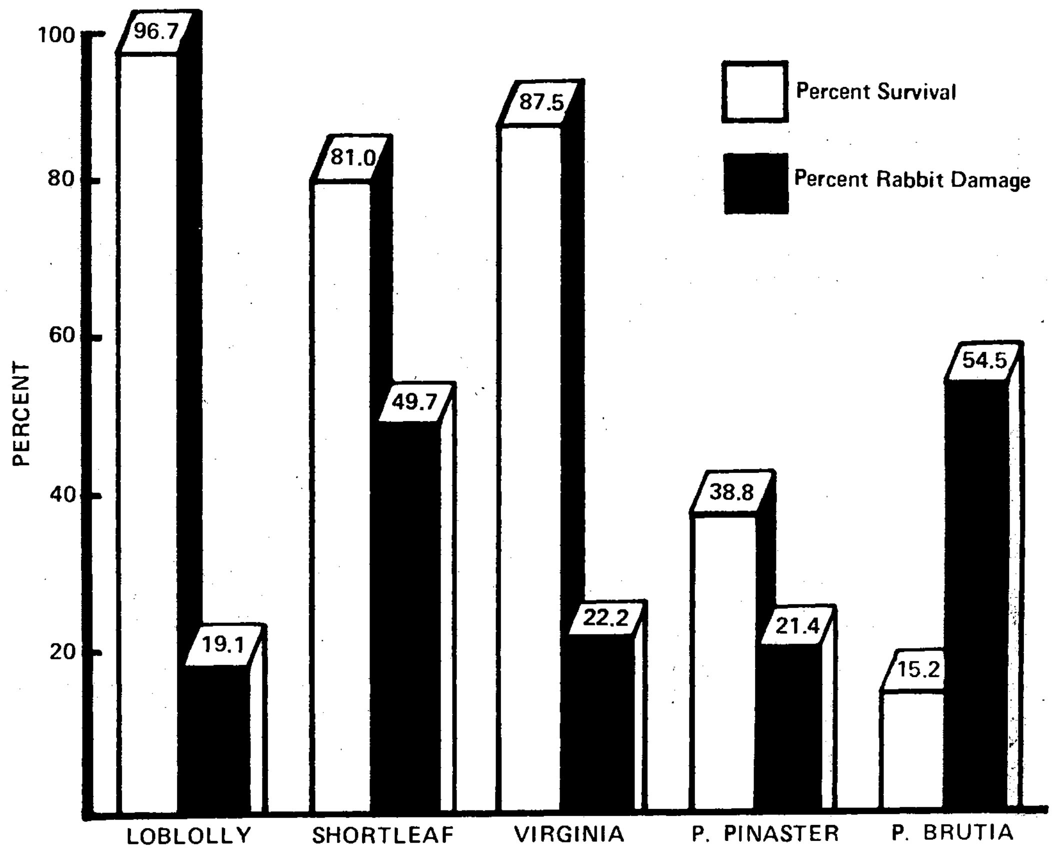


Figure 6. Bar Graph Showing A Comparison of Seedling Survival Percent Versus Rabbit Damage Percent for All Five Species

were too few Pinus pinaster and Pinus brutia seedlings surviving for valid comparisons. Only loblolly, shortleaf and Virginia pine can be validly compared.

Of the three species, loblolly pine had the best survival percent; Virginia ranked second and shortleaf, third. Again, the data would indicate an association between percent survival and percent rabbit damage as indicated by the inverse relationship of the figures. Loblolly pine had the highest percent survival, 96.7 percent, and the lowest percent of rabbit damage to the surviving trees, 19.1 percent. Shortleaf pine had the lowest percent survival, 81 percent, and the highest percent rabbit damage to surviving trees. It is unfortunate that a valid statistical comparison cannot be made. However, these data indicate that cottontail rabbits have shown a definite preference for shortleaf pine over loblolly or Virginia pine.

For undamaged trees Virginia pine averaged the tallest of the three species with 17.7 inches, and shortleaf pine averaged the shortest with 16.5 inches. Loblolly was intermediate with 17.0 inches. This same rank order for height held constant for damaged trees and also for the combined average of damaged and undamaged trees.

The variable used to construct Table VIII was height in inches. There was no significant variation across replications for this variable.

The second line entry "Species" is statistically significant at the .18 probability level (probability of a larger value of F). It is concluded that there is a difference of practical significance in height growth between the three species. One reason for this significance is, obviously, the degree of rabbit damage to shortleaf pine which lowered its overall height figure.

TABLE VIII

ANALYSIS OF VARIANCE FOR HEIGHT
IN INCHES BY SPECIES

Source	d.f.	Sum of Squares	Mean Square	F
Replication	2	2.06	1.03	.735
Species	2	5.88	2.94	2.10
Damaged	1	200.53	200.53	143.23**
Species X Damage	2	0.22	0.11	.0786
Residual	10	14.07	1.40	

As would be expected, the third line entry in Table VIII "Damage" is highly significant at the .005 probability level. This significance shows statistically what can be seen in the field; i.e., there is a large difference in height between the rabbit damaged trees and the undamaged trees.

The fourth line entry in Table VIII "Species X Damage" is not statistically significant. However, the data in Table III and Table VII strongly suggest that there is some correlation between rabbit damage and species. Added improvements to the study will allow more accurate statistical comparisons.

The ANOVA's of rabbit damage and survival for the three species indicated no statistical significance for either characteristic. These ANOVA's are printed in Appendix A.

An explanation for the high survival may be the amount of precipitation during the first year. Even though the year's total precipitation amount exceeds the ten-year average by 8.89 inches, it is important that during June, July and August, two of these months (July and August) the precipitation was below normal. It is concluded therefore, that during the most critical months for survival of young seedlings, precipitation amounts were not appreciably above normal for the period.

Direct Seeding Results

Determining a successful seeding operation is more difficult than determining the success of a handplanted operation. The principal method of gauging the success of direct seeding has been by a stocking survey to determine if an adequate number of seedlings survived to produce the desired yield associated with a particular site. The stocking survey is usually conducted one or two years after seeding.

The number of surviving seedlings necessary for adequate stocking varies with species. Foresters in the South generally accept the guideline figures of 1300 seedlings per acre as preferable and will accept a minimum of 600 seedlings per acre for shortleaf and loblolly pine at one year of age (Cobb, 1965). The above figures were used as the criteria for success or failure in this direct seeding operation. Three levels of success or failure were used: 1) 600 seedlings per acre was considered minimum and any number less than 600 was considered a failure, 2) 1300 seedlings per acre was considered best but an acceptable range from 600 to 2000 was set and any number within that range was considered a success, and 3) 2000 seedlings per acre was set as the upper limit of success and any higher number was considered overstocked and would most likely have to be pre-commercially thinned. Table IX summarizes the results from the direct seeding operation. The table gives stocking rates in stems per acre for shortleaf and loblolly pine. Stems per acre figures are given for species (averaged across replications), replications, and the 14 foot by 20 foot sampling plots which were sampled in each plot. An askerisk (*) by a number indicates that the number is below minimum; a plus sign (+) by a number indicates that the number is above the acceptable limits or overstocked. All other numbers not marked as above are within acceptable limits.

Shortleaf pine had an acceptable number of stems per acre when averaged over all three replications. Of the three replications, replication II was understocked and the other two replications were within acceptable limits. Of the 12 sampling plots, (four from each replication), four were understocked, one was overstocked, and nine were within

TABLE IX

STOCKING RATE/STEMS PER ACRE FOR DIRECT SEEDED SHORTLEAF AND LOBLOLLY PINE

Variables	Shortleaf Pine	Loblolly Pine
Species	1186	1633
Replication I	1283	933
Sampling Plot 1	155*	777
Sampling Plot 2	1710	777
Sampling Plot 3	1617	777
Sampling Plot 4	808	1399
Replication II	466*	1400
Sampling Plot 1	622	115*
Sampling Plot 2	310*	1244
Sampling Plot 3	466*	2332+
Sampling Plot 4	466*	1866
Replication III	1827	2566+
Sampling Plot 1	1710	3887+
Sampling Plot 2	1399	3110+
Sampling Plot 3	3576+	3265+
Sampling Plot 4	622	0*
Number of Understocked Sampling Plots	4	2
Number of Overstocked Sampling Plots	1	4
Number of Sampling Plots Within Limits	9	8

* Indicated understocking
\+ Indicated overstocking

limits. Three of the understocked sampling plots were in replication II, and, of the nine which were within limits, four barely exceeded the minimum 600 stems per acre.

Loblolly pine had an acceptable number of stems per acre when averaged over all three replications. Of the three replications, replication III was overstocked and replications I and II were within limits. Of the 12 sampling plots (four from each replication), four were overstocked, two were understocked, and eight were within limits. All but one of the overstocked sampling plots were in replication III.

The data suggest that an understocking difficulty is present with shortleaf pine while an overstocking difficulty exists with loblolly pine. More definitive results will be available at the end of the second season.

Grass competition was originally believe to be too severe, especially in terms of moisture competition, for adequate survival to occur. However, with the occurrence of very good stocking rates for both loblolly and shortleaf pine, it appears that the grasses may have provided beneficial shade for the seedlings as suggested by other investigators. Smith and Clark (1960) found that Engelmann spruce survived best on seedbeds receiving 30 percent of full sunlight, and Wagg and Hermann (1962) stated that shading had little effect on germination of ponderosa pine but it did increase survival. To lend further support to this suggestion it was observed in this study that seedings were nearly always located in very grassy areas, and few seedings were located in grassless areas.

CHAPTER IV

CONCLUSIONS

The conclusions of the study are based on data collected on trees grown on Hector-Hartsell soils of the "Cross Timbers" area in Hughes County, Oklahoma. Therefore, these conclusions do not necessarily apply to all "Cross Timbers" areas since local conditions may vary. These conclusions are also based on only one growing season which makes up only one-third of the total study. It is expected that there will be more valid conclusions made when the entire study is completed.

The conclusions based on these data are:

1. It is biologically possible to establish pine on the "Cross Timbers" area of Oklahoma during years of adequate moisture.

2. It is better to plant than to direct seed because of the greater growth of planted trees during the first year.

3. Loblolly, shortleaf, or Virginia pine can be planted with success.

4. Due to their high survival rate and good growth, loblolly and Virginia pine are the preferred species for planting.

5. Due to its poorer survival and higher percent of rabbit damage, shortleaf pine is not as desirable as loblolly or Virginia pine for planting.

6. Cottontail rabbits prefer shortleaf pine to loblolly or Virginia pine as evidenced by clipping.

7. Loblolly pine is preferred to shortleaf pine for direct seeding operations because of its higher survival rate.

8. It is highly possible that, in the future, landowners in the "Cross Timbers" area of Oklahoma can include short rotation timber crops as a land use alternative.

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APPENDIX A

TABLE X

ANALYSIS OF VARIANCE FOR PERCENT RABBIT DAMAGE BY SPECIES

Source	d.f.	Sum of Squares	Mean Square	F
Replication	2	401.32	200.66	.635
Species	2	1899.66	949.83	3.007
Error	4	1263.37	315.84	

TABLE XI

ANALYSIS OF VARIANCE FOR PERCENT SURVIVAL BY SPECIES

Source	d.f.	Sum of Squares	Mean Square	F
Replication	2	243.09	121.54	1.181
Species	2	375.63	187.81	1.825
Error	4	411.47	102.86	

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