AGRICULTURAL INTERCROPPING IN COTTONWOOD PLANTATIONS

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CHAPTER I

INTRODUCTION

Eastern cottonwood, the fastest growing tree in the Southern Hardwood forest, can also be one of the most financially rewarding when grown in intensively managed plantations. Cottonwood (*Populus deltoides* var *deltoides* Bartr.) is referred to as one of the most site-demanding of all timber species, attaining its best growth only within a narrow range of site conditions (20).

Soils best suited for maximum growth of cottonwood are silt loams and sandy loams with good internal drainage, high nutrient content, especially nitrogen, large quantities of available bases, and that remain moist throughout the growing season. Soils of this type are also excellent for growing high-value crops such as cotton and soybeans. Hence, cottonwood planting is often restricted to lands subject to occasional flooding. Such is the case in the Mississippi River alluvial plain where 40,000 acres of the species have been planted, mostly in the flood-prone batture[1] lands (10).

Many potential sites filling the above requirements can be found in Southeastern Oklahoma on alluvial soils of the Red River flood plain. Strine (60) surveyed soils of the Red River's alluvial plain with the intention of identifying soils suitable for commercial cottonwood

[1]Batture refers to those lands located between the main levees of the Mississippi River.

production. Soil physical and chemical properties known to be highly correlated with good cottonwood growth, along with measurements of natural stands on representative sites were the criteria for determining a particular soil's capability for growing cottonwood.

The subject of this thesis involved eastern cottonwood plantation culture on two of the seven soils selected for study by Strine (60). The soils on which the study was installed are Idabel silt loam[2] and Oklared very fine sandy loam.[3] After testing these sites for parameters important to good cottonwood growth, Strine (60) produced the results in Tables X and XI (Appendix). Data collected in a natural stand of cottonwood growing on an Idabel silt loam gave an indication of cottonwood potential on the most productive Southeastern Oklahoma sites. The stand had a site index of 120 feet (30 years) and contained 52,000 board feet of standing timber per acre (60).

Many landowners in the flood plain area have cutover stands of cottonwood which could be improved by planting and intensive culture of superior clonal stock. Wood markets in this area of Oklahoma are well developed and cottonwood plantation management opportunities should expand as markets in this heavily forested region continue to grow (65). The fast growth rate of cottonwood is an added incentive to investors, since investment periods can be shortened.

One possibility for reducing the amount of money invested over time is intercropping the areas between rows of trees with high quality

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[2]Family-coarse-loamy, mixed thermic; Sub-Group-Fluventic Eutrochrept; Order-Inceptisols (55).

[3]Family-coarse-loamy, mixed, calcareous, thermic; Sub-Group Typic Udifluvent; Order-Entisols (55).

forage crops. Both winter and summer cropping of the unoccupied area between tree rows could provide high quality forage and recover at least some, and perhaps all, of the costs of plantation establishment.

Measurement of several different types of plant-related parameters was necessary to effectively quantify the effects of intercropping on cottonwood trees as compared to intensive cultivation of trees without intercropping. Test measurements used for these comparisons included:

(1) periodic recording of soil moisture using a neutron probe device

(2) foliar nutrient analysis for cropped versus cultivated crops

(3) tree height growth and survival

Samples were also taken in the intercropped areas to estimate total crop production and income potential.

The major emphasis in this report will follow the intercropping theme with a quantification of the effects of intercropping forage crops in plantations on tree growth. Comparisons will be made with trees grown in intensively cultivated plots.

Benefits derived from the sale or use of the intertilled forage crops could possibly recover the costs of plantation establishment. This income could reduce or eliminate the investment carried at interest until a harvest of trees, thereby increasing the return on investment.

The objective of the study was to quantify the effects and test the potential of intertilling forage crops in first-year cottonwood plantations.

Plantation establishment and management was also an area of concentration in this study. The literature review, covered in the next chapter, is a survey of both plantation management and intercropping research.

CHAPTER II

LITERATURE REVIEW

Ecology and Site Requirements

Eastern cottonwood has been the subject of a wide range of research efforts. Work has been concentrated in the South where cottonwood volume totals over 500 million cubic feet,[1] over 90 percent of which is commercially valuable eastern cottonwood. But the land base for cottonwood production is shrinking because even this valuable timber species with its fast growth rate and well-developed market for uses such as container veneer, lumber, pulpwood, and specialties, including toothpicks and matches, cannot preempt soybean production on sites which are suitable for growing either species. Soybean acreage has increased 65 percent since 1965, much of this new cropland resulting from clearing activities in natural stands of cottonwood (59). This expansion of the agricultural land base, along with the highly successful efforts of the United States Corps of Engineers to stabilize the banks of the Mississippi River, has seriously reduced the acreage of cottonwood in natural stands. Since cottonwood does not normally succeed itself on sites where it was once established naturally, research was necessary to discover new methods and improve on old methods of commercial propagation of the species.

[1]Table XIX in the Appendix is provided to aid in converting from English to Metric units or Metric to English.

Private industry, university research teams, and the United States Forest Service have cooperated in the development of programs for the regeneration of cottonwood. These efforts have led to the successful establishment of approximately 40,000 acres of cottonwood plantations (10). Research efforts have been concentrated in the areas of the ecology of the species and site requirements, methods of plantation establishment and protection, development and testing of genetically improved clonal planting stock, and profit potential of plantations. In addition, research from European countries has provided information on intertilling of agricultural crops in Populus plantations.

Eastern cottonwood is found along streams and on bottomlands from southern Quebec and southern Ontario west to southeast North Dakota, south to western Kansas, western Oklahoma, southern Texas and east to northwestern Florida and Georgia (Figure 1). Occurrence in higher elevations of the Appalachians is rare and the species has scattered occurrence in the New England states (20). Its best commercial development is attained on the alluvial bottomlands of the Mississippi River and its tributaries, including the Red and Arkansas Rivers, from southern Missouri to Louisiana (20, 31). Cottonwood grows in a humid climate, except for the western one-third of its range which is sub-humid to semi-arid (Figure 1). In these drier climates cottonwood is usually associated with river and stream bottoms. Rainfall throughout the range of eastern cottonwood varies from 20 inches in western portions of the range to a high of 60 inches annually in southern areas. In the Lower Mississippi Valley, where cottonwood attains its best growth, precipitation averages 51 inches annually with 20 inches falling during the growing season, April through August (20).

Natural regeneration of cottonwood requires a moist seedbed of bare mineral soil, one of the most ideal sites being newly formed

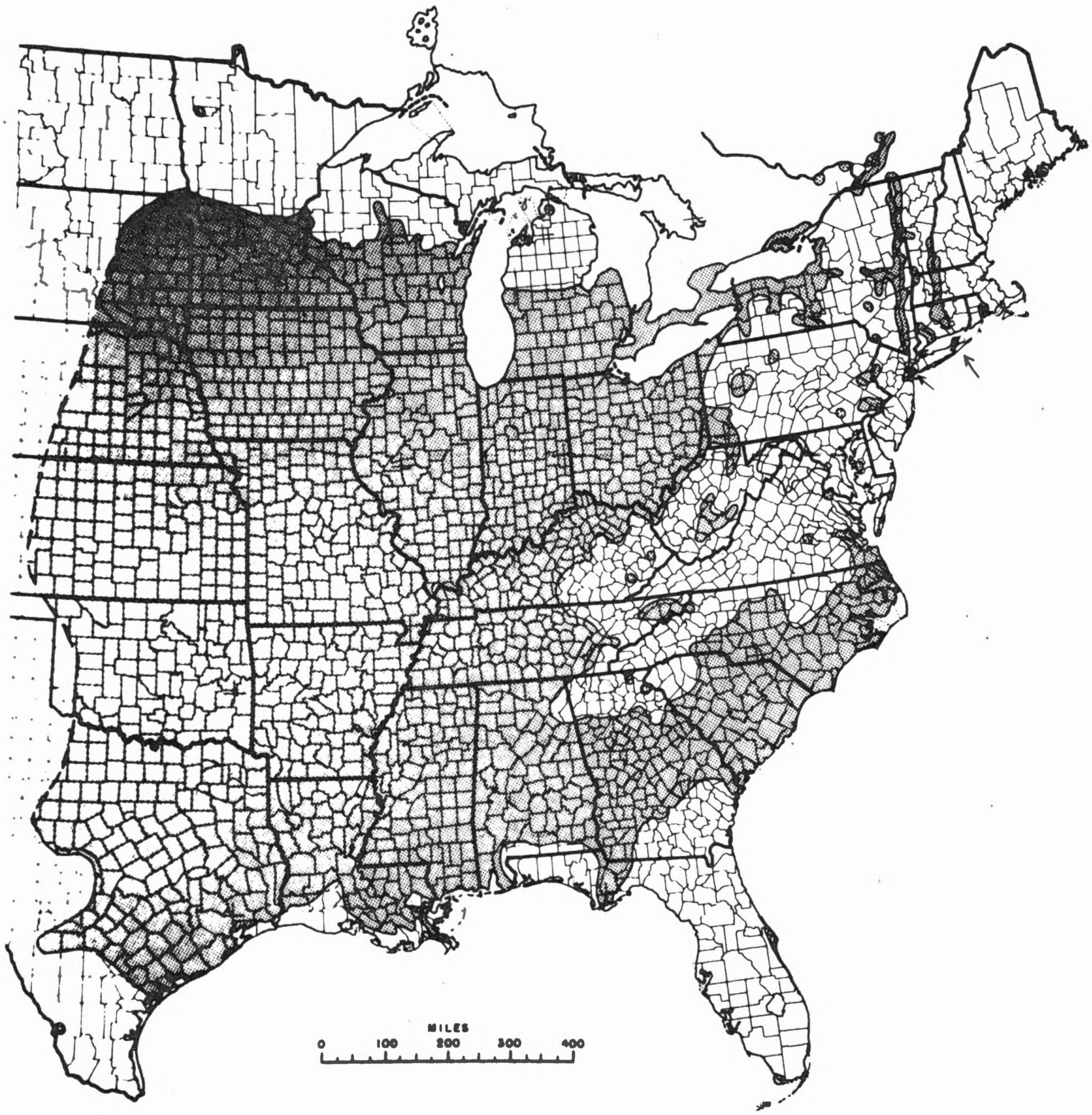

Figure 1. The Natural Range of Eastern Cottonwood (*Populus deltoides* Bartr. var. *deltoides*) (Reprinted from Fowells, Agriculture Handbook No. 271 (10))

accretion land along large rivers (20, 36, 47). Flowering takes place from February to April with seedfall occurring the same year from April until August (20). It is imperative that the seed reach a moist seedbed, since unless floating or submerged in water, they will perish in less than a week (20).

Eastern cottonwood achieves its best growth on moist, well-drained fine sandy loams or silt loams (8, 20, 31, 35, 36). The importance of physical characteristics of the soil is emphasized in a report by Broadfoot (8). He used inherent soil moisture condition, soil texture, and internal drainage as a guide for estimating the site index for cottonwood on potential sites.

Soil chemistry and inherent fertility are also important factors to consider in selecting sites for cottonwood production. Blackmon (3) demonstrated a response to nitrogen in Sharkey clay[2] soils of the Mississippi River Alluvial Plain even though the soil generally had sufficient levels of nitrogen for good cottonwood growth. The poor physical condition of the soil limited root development to the upper 20 centimeters of the soil profile after four years' growth. This lower volume of soil occupied by the roots had reduced nutrient and moisture uptake enough to severely retard growth of the cottonwood on the clay soils. Blackmon (3) suggested that the restricted root growth was one reason cottonwood growth on the better clay soils compared so poorly to growth attained on the Commerce silt loam,[3] for example, on

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[2]Family-very fine, montmorillonitic, non-acid, thermic; Sub-Group-Vertic Haplaquepts; Order-Inceptisols (56).

[3]Family-fine, silty-mixed, non-acid, thermic; Sub-Group-Aeric Fluvaquents; Order-Entisols (56).

which cottonwood growth is excellent. On the Commerce silt loam soils site indices often exceed 120 feet at 30 years (16).

Another physical characteristic of the site, especially important to young cottonwood, is the depth of the water table. In a study using barrels filled with sand and planted with cottonwood cuttings, Broadfoot (9) regulated water table depths using perforations in each barrel at different levels. Results, including examination of root and height development, showed that juvenile cottonwood is benefited by water tables which reach the lower portions of its normal root zone. A water table high enough to saturate the soil, however, was found likely to cause mortality near the end of the second growing season.

Information on a soil's physical characteristics coupled with some knowledge of the chemistry of the soil can go far towards classifying the suitability of the site for growing cottonwood. The alluvium or "new land," on which cottonwood becomes established naturally, often contains mineral nutrients washed from the rich topsoils of the prairie and piedmont. Alluvium along small streams is usually leached and tends to be less fertile and more acidic than soils deposited along major rivers. Soils deposited along these major rivers, such as the Red, Arkansas, and Mississippi, have a neutral to alkaline pH and often support excellent pure stands of cottonwood (36). The importance of soil fertility in selecting sites for cottonwood production was noted in a study by Switzer, et al. (62). In comparing data from 16-year-old poplar to loblolly pine plantations of the same age, these researchers found nutritional requirements of the poplar to be twice that of the pine. Quantities of nutrient accumulation of poplar plantations and natural stands ranked in descending order were found to be $Ca \gg N \geq K \gg Mg \geq P$.

These authors concluded that poplars require large quantities of the bases Ca, K, and Mg. So for best results it was recommended that land managers should consider physical properties of the soil along with the quantity of available bases present when evaluating potential sites for cottonwood plantings. White and Carter (67) analyzed the soils on which eight different pure stands of cottonwood occurred. These workers found that extractable soil Ca levels were three times greater in soils supporting the best stand than in soils supporting the poorest stand. A study of the correlation between extractable soil K and height growth showed that K^+ ion content accounted for 94 percent of the variation in growth in seven out of eight stands studied.

The use of fertilization to improve nutrient levels and growth of cottonwood is usually not practiced commercially but has been studied as a potential means for increasing growth rates in plantations. Blackmon (3) found that cottonwood growing in plantations on Sharkey clay did not respond to N fertilization until age four when it was apparent that competition among trees had begun. After three years of cultivation and N fertilization in cottonwood plantations, Crown Zellerbach[4] (12) found no differences in growth of trees in plots receiving both cultivation and fertilization and those receiving only cultivation. Crown Zellerbach researchers had shown that continued intensive cultivation in the second growing season caused large increases in foliar N levels (13). Arid (1), in further studies of the relationship between cultivation and foliar N levels, also concluded that cultivation increased levels of nitrogen nutrition. The foliar N

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[4]Crown Zellerbach, a nationwide timber industry, conducts forestry research.

deficiency level for cottonwood appears to be about two percent (3). Blackmon (4) has recognized the development of certain trends in poplar fertilization; these include:

(1) Nitrogen is of almost universal importance.

(2) Poplars on strongly acid soils require large doses of lime.

(3) Poplar responses to fertilizer, particularly N are usually of short duration.

(4) Foliar N deficiency level as measured in mature leaves appears to be about two percent.

(5) Fertilization appears economically feasible only on poor sites--particularly those impoverished by agricultural cropping. A tradeoff between fertilization and cultivation may be possible.

(6) The influence of fertilization on wood properties is not known but appears related to genotype.

(7) Fertilization appears to decrease the incidence of insects and disease, but results are not conclusive (p. 348).

As mentioned in the previous discussions of site selection for optimum cottonwood growth, best production can be expected on moist, well-drained, fine sandy loams, or silt loams. Considering the high cost of plantation establishment, failure to select sites carefully and properly to be planted to cottonwood may result not only in disappointing growth or perhaps complete failure of the planting effort, but a substantial financial loss as well.

Plantation Establishment

Successful plantation establishment depends on the implementation of a package of techniques which has been developed for plantation management. These include careful site selection, which was discussed previously, site preparation, use of quality planting stock from superior clones, proper timing and technique of planting, intensive cultivation during at least the first year following planting, and protection from insects and deer.

Once a site has been chosen for cottonwood culture, it is intensively prepared for planting. In this operation, which accounts for 65 to 70 percent of the total cost of plantation establishment, all woody vegetation is sheared to two inches below the ground surface (27). Root rakes are used to windrow the debris for burning. Kaskurewicz, et al. (27) points out that debris close to the perimeter of the area may be used for construction of a 15-foot-high barrier to exclude deer. Chunks of wood and other small debris can be removed with a high-dump rake on a farm tractor. This operation reduces damage to the young sprouts during early cultivation and makes the final site preparation and planting easier and more efficient (24, 37). A 12-foot tandem disk pulled by a crawler tractor is best for preparing a planting bed.

Summer fallowing is recommended by Blackmon (4) as a means of improving survival and growth on old field sites. This treatment, which involves disking the planting site periodically between June and August the summer prior to planting, is beneficial because it temporarily improves soil structure and reduces competing vegetation, especially Johnson grass.

The high cost of care and establishment of a plantation dictates that along with careful site selection, only the best planting stock should be used. Lending credence to this advice by L. C. Maisenhelder (31) is the fact that all commercial cottonwood plantations established in the lower Mississippi Valley in 1976 used genetically improved planting stock (27). These consisted of clones listed by Randall (48) as superior and adapted to the area.

Variations in type of planting stock has been researched to a limited extent. Foresters have experimented with rooted cuttings, sometimes planted as much as three feet deep, long unrooted cuttings, tall one-year saplings, and the standard for commercial planting, a 20-inch unrooted cutting. Blackmon (5) found that 30-inch cuttings or 32-inch seedlings deep planted in holes nine inches in diameter proved to have no advantage in height, diameter, growth, or survival, over 20-inch unrooted cuttings. Blackmon conceded that some advantage may be gained from deep planting on severely compacted medium-textured old field sites. Longer cuttings have been recommended for dry sites (31, 61). McKnight, et al. (37), stated that rooted cuttings and seedlings will grow best on adverse sites, but that these sites are usually not suited to intensive culture. Kaskurewicz (28), however, reported that long cuttings planted at a depth adjusted for the soil texture can extend the range of planting conditions to sites previously considered unproductive for cottonwood. Phares and White (45) used deep-planted seedlings in Iowa to increase survival. On a Buckner loamy sand where survival of deep-planted, unrooted cuttings was 85 percent, survival rates of 98 percent were achieved with deep-planted large seedlings. Although costs for this type of planting stock would be high, these workers remind planters that at the wide spacings currently used for cottonwood, planting stock costs would represent a small part of total investment.

Long rooted cuttings have also been tried in areas where cutting survival is not a serious problem. In one such study Randall and Krinard (49) planted long rooted cuttings averaging eight feet tall when planted. At the end of one growing season average height (planted height plus height growth) was 17.9 feet and survival averaged 90 percent. Long unrooted cuttings in this study averaged only 46 percent survival. The authors suggest that this method is especially suited to planters wishing to grow large sawtimber and veneer trees at wide spacings. They also recommend this method if a planter wishes to alleviate deer damage without fencing the area, or in cases where early season cultivation may prove difficult.

Experienced silviculturists should be able to adapt various types of planting stock to sites formerly considered unsuited for cottonwood growth. Most sites commercially planted to cottonwood are in the lower Mississippi Valley where plantation establishment is usually successful with 20-inch unrooted cuttings planted 18 inches deep. Cuttings should range from 3/8 inch to 3/4 inch diameter at the small end. These are ordinarily planted in subsoil slits (31).

One of the greatest advantages of using cuttings is the ease of genetic control (37). This feature, along with the low cost of planting stock production in cutting nurseries, ease of handling, and the relative ease of rooting which cottonwoods enjoy, precludes the use of any other method of regeneration, except perhaps in very special cases.

McKnight and Bisterfeldt (37) also point out that planting production is enhanced by use of cuttings. They report that one man can plant five acres daily of subsoil trenches on a 10 x 10 foot spacing, but 23 acres per day can be planted by two men using a tractor-drawn planting machine.

According to McKnight (35), cuttings should be planted from December to early March for best success. Maisenhelder (31) recommends planting any time from first severe frost until bud-break in the spring, but says February is the best month for favorable soil moisture conditions.

Whatever time of planting is used, cuttings should always be taken from vigorously-growing one-year-old dormant shoots. Cuttings damaged by disease or insects should be culled. Small cuttings are subject to excessive drying and contain too little stored food to give the new shoot a good start. Cuttings should not be exposed at any time to drying conditions (35).

Retreatment of the cuttings by soaking them in water prior to planting can increase survival by enhancing rooting (31, 44). Soaking improves moisture status of the planted cutting. In a comprehensive study of rooting of cottonwood cuttings, Zsuffa (68) named environmental factors affecting rooting, including soil pH, temperature, soil nutrient status, aeration, and length of the photo-period.

Briscoe (7), pointed out that cuttings taken in fall and winter rooted better than those cut in spring or summer. DePhillipis (14) found the most important environmental influences affecting rooting to be light, temperature, and moisture. He reports that light has a negative influence on rooting, and moisture is an absolute necessity.

Internal as well as environmental factors affect rooting. Internal factors include genetical, morphological, and physiological characteristics of the cutting (68). Genetical factors exert considerable influence over rooting success, with significant differences occurring between seed sources, families, and clones. The most important morphological factor affecting rooting was the time of differentiation of root primordia.

The last of the internal factors affecting rooting are the physiological characteristics of the cutting. For instance, according to Frison (21), young cottonwood tissue roots better than old. Another physiological phenomenon he points out is that cuttings taken from basal, middle, and apical parts of one-year-old stems exhibit differences in rooting ability, with those cuttings from basal portions rooting best.

Research and practice have shown that rooting is stimulated most by adequate soil moisture and temperature and a high moisture content of the cuttings (14, 37, 44).

Kirnard and Johnson (30) gave recommendations for initial spacings based on a ten-year cottonwood plantation spacing study. These authors report merchantable growth of up to 3.4 cords per acre annually for the first 10 years. They recommend spacings of 8 x 9 feet or 12 x 12 feet for pulpwood production. Merchantable volume was higher in the 8 x 9 foot spacing by nine percent, but this increase was attained with 44 percent more trees. These figures indicate that the 8 x 9 foot would be more expensive to plant, tend, and harvest compared to the 12 x 12 foot. In this study a 16 x 18 foot spacing proved better for sawtimber than either the 4 x 9, 8 x 9, or 12 x 12, yielding trees two to five inches larger in diameter. They pointed out that trees in this spacing would require artificial pruning if the grower wished to restrict knots to an eight-inch core.

One of the most important parts of a silvicultural system for successful plantation establishment of cottonwood is cultivation (35, 29). Alluding to the importance of cultivation, Arid (1) pointed out that competition for nutrients and moisture between trees and herbaceous vegetation begins as soon as demand exceeds supply. Arid thought the most important advantage of cultivation was a reduction in competition for moisture and nutrients. Cultivation was found to increase soil O_2 or CO_2 concentration, eliminate toxic interactions between trees and herbaceous vegetation, and change the soil microbial population. It is a widely known and accepted fact among cottonwood growers that the species requires at least a one-year advantage over its competition if it is to survive (34). McKnight (33) stated that weeds should be eliminated from plantations until the crowns close.

In a comprehensive paper on techniques for plantation establishment, McKnight (35) recommended the use of shovel-type plows mounted on cultivators for best weed control. Eventually, when the trees are too tall to pass under the tool bar without being damaged, cultivation should be performed with a tandem disk.

Cultivation should begin early in the growing season and continue throughout July at intervals frequent enough to keep weeds under control (31, 29, 27). Kaskurewicz, et al., (27) also pointed out that the frequency of cultivation and the proper time to cease cultivation treatments depends on both weather conditions and density of the weeds.

As mentioned, cultivation has an important influence on first-year survival. Intensive cultivation throughout the first growing season can double or perhaps even triple the growth that can be expected when only a minimum of weed control is practiced (35). In a Crown Zellerbach Corporation report, it was stated that there were no differences in survival of trees cultivated during the first year of growth and those cultivated two years. However, data from a portion of this 55 acre plantation showed that second-year cultivation increased diameter at breast height (d.b.h.) by 61 percent and height increment by 31 percent over that recorded for trees cultivated only one year. It was also noted that second-year cultivation nearly tripled foliar nitrogen content compared to those trees which had been cultivated for only one year.

Kennedy, et al. (29), suggests that the benefits of extending cultivation past the first growing season are probably related to the condition of the trees and site. These researchers agree that extending cultivation past the first growing season may improve growth and survival where weed infestations are heavy or trees are small. These benefits may not occur if this is not the case. McKnight (35) suggests that the last cultivation be done with only the front section of a tandem disk. This allows soil to be thrown around the base of the tree, covering weeds, thus aiding tree growth. Trees will also benefit from rainwater collecting in the resulting depression.

Research foresters have been experimenting with chemical weed control as a means of effectively reducing competition from herbaceous vegetation. Merritt (34) gives two reasons why chemical control of weeds may have advantages over mechanical weed control: the possibility of damage to new shoots by cultivation and occasional equipment failure at critical periods. In Merritt's study, application of Amazine for weed control resulted in significantly greater height growth (at the one percent level of probability) by rooted cuttings of _P. deltoides_ Bartr. and _P. eugenei_, as compared to trees in plots with no weed control. Unfortunately, no comparisons were made with trees which had received mechanical cultivation.

Protection

Arid (1), in field tests with Raverdeau poplar (a natural hybrid cross between *P. deltoides* and *P. nigra*) and Carolina poplar, found that treatments of either tilling or spraying resulted in significant positive effects on tree height, volume, and leaf weight. Spraying controlled weeds better than tilling early in the growing season, but spray plots had more weeds in the latter part of the growing season. Trees in spray plots were taller than trees in tilled plots. Arid contends that this is due to the better control of weeds early in the growing season when most height growth occurs. By mid-July most height growth on trees in control plots had stopped. Leader growth of trees in sprayed or tilled plots continued past September 7, when trees on control plots had already set terminal buds, indicating that the spraying and tilling treatments had prevented early moisture deficiencies and resulting cessation of growth.

McKnight (35) pointed out that there is merit to chemical weed control as a pre-emergence treatment during site preparation. According to McKnight, however, it is possible that chemicals strong enough to kill established weed seedlings would also be likely to damage cottonwood trees in their early stages of growth. It is obvious that more research is needed before chemical weed control becomes a major part of the commercial cottonwood producer's silvicultural program for plantation management. Mechanical cultivation seems to be a reliable means of weed control which is consistently rewarded with dramatic increases in growth in most situations.

In establishing plantations of eastern cottonwood, each part of the silvicultural prescription is vital to success. Protection from insect damage is especially important in the cottonwood plantation. In Genetics of Eastern Cottonwood, Ernst Shreiner (52) wrote:

> If poplars are not the most pest-ridden of the world's timber trees they certainly rank high in this respect; but few genera of timber trees, if any, offer better possibilities for rapid genetic improvement in pest resistance (p. 7).

The following paragraphs are a brief summary of the types of protection problems existing in plantations, the impact of insects and diseases, and short and long-range steps to avoid catastrophic losses.

Of the various diseases affecting cottonwood trees, cankers are often considered the most important, at times causing up to 20 percent mortality in first-year plantings (38). Cankers may affect the main stem, branches, or twigs, causing either mortality or dieback (66). It is noted that canker incidence is usually highest under conditions of stress (38). This is why severe problems often exist when cottonwood is planted on unsuitable sites.

The *Septoria musiva* Peck fungus acts as a pioneer organism, creating openings in the bark for other canker-causing fungi (18). *S. Musiva* appears first as spots on the leaves of cottonwood, later spreading to branches and stems, forming small cankers that provide entrances for other canker-producing microorganisms. A canker caused by the fungi *Cytospora chrysosperma* Fr. is an example of a disease-causing organism using *S. musiva* as a pioneer agent. This canker is most severe on trees damaged by *S. musiva* or natural agents, including frost, fire, or drought (64).

Morris, et al. (38), lists five canker fungi which could cause mortality of cottonwood in the first growing season. This list includes S. musiva, which is often the pioneer for the other four, namely Fusarium solami (Mart.) Appel and Wr., Cytospora chrysosperma, Phomopsis macrospora Kobashi and Chiba, and Botryodiplodia theobromae Pat. Morris, et al. (38), pointed out that these fungi may gain entrance into older trees through mechanical or insect wounds. The fungi may not kill established trees, but can seriously damage them by weakening the stem, possibly causing wind breakage.

Filer (18) lists preventive actions as the best controls for S. musiva incidence. He suggests selection of vigorous and healthy cuttings for planting. Filer also recommends cultivation which will bury old leaves that might harbor inocula. Other measures which should reduce canker incidence include selection and breeding for resistance, proper site selection, and careful cultivation so as not to damage trees.

Although not as damaging as cankers, foliage diseases can reduce the vigor of stands if present during successive years. Foliage diseases occurring on P. deltoides include rusts, leaf spots and blotches, leaf and twig blight, leaf blister and antracnose (38). Foliage diseases damage trees primarily by retarding growth due to defoliation (51). More specifically, foliage diseases slow tree growth by having any one or a combination of the following effects: (1) reducing leaf photosynthetic area, (2) upsetting plant water balance through epidermal disruption, (3) redistribution of photosynthates through formation of metabolic sinks which compete with growing portions of trees, (4) changes in wood characteristics such as vessel-to-fiber ratio or fiber length,

(5) predisposition of trees to diseases or winter injury, and (6) shortening of growing seasons due to premature defoliation (49).

Many consider the various types of leaf rusts to be the most serious and widespread foliage disease. According to Hepting (24), the most common leaf rust in the United States and Canada is caused by Melampsora medusae Thum. Farmer (17) found rust resistance to be highly heritable in poplars, a characteristic which could yield promising results in breeding for rust resistance. Indeed, Morris, et al. (38), stated that rust-resistant clones are available for the Southern United States.

Insects as well as diseases can jeopardize the success of a cottonwood plantation. As with disease attacks, insect damage is greatest when trees are stressed, again emphasizing the importance of proper site selection (11). Morris, et al. (38), grouped insect pests into three major categories. These include those insects that (1) are native to the United States and cause considerable damage, often requiring artificial controls, (2) cause severe damage in small areas, but usually require only local control, and (3) appear only occasionally, but which may become important under favorable conditions.

The boring insects are particularly harmful; all parts of the tree including terminals, branches, trunk, and roots may be attacked by one or more of the boring insects (11). Insect borers can often cause severe damage in young plantations, especially the twig borer Gypsonoma hambachiana (Kearfott) and either of the clearwing borers Paranthrene dollii (Neum.) and P. tricinta (Harris) (11, 39). Twig-borer larvae tunnel inside the terminals of young cottonwood causing forked and crooked trunks and slow early growth (39, 38). The cottonwood borer, Plectrodera scalator, (Fab.), and its larvae have been known to severely damage young stands on sandy soils (38).

The clearwing borer Paranthrene dollii attacks the base of cottonwood trees and sometimes causes breakage. P. tricinta attacks terminals and breakage may occur at the entrance hole 18 to 24 inches below the terminal (38). The borer holes also provide entrance sites for canker-causing and wood-rotting fungi in both young and old stands.

In cottonwood stands of all ages, damage can result from attacks of poplar borers and carpenter worms. The poplar borer, Plectrodera scalator, damages trees throughout the southern states. The larvae of this one and one-half inch longhorn beetle tunnel into the base of the young tree and downward into the roots, often going unnoticed unless breakage occurs (38). To minimize damage, plantations should be planted only on good sites, with implementation of cultural practices that maintain vigorously-growing, healthy trees.

Insects also attack the foliage of cottonwood. One of the more serious pests in this category is the cottonwood leaf beetle, Chrysomela scripta (Fab.). Both the adult and larval forms of this insect feed on new leaves, killing terminals and often leaving only the veins and midrib of leaves (38). The resultant slower growth in young plantations may reduce the individual tree's ability to compete with weeds, and could affect survival, if for some reason cultivation is delayed (41). Ladybug (Coleomagilla maculata) predation provides natural control of early spring population peaks, but a second peak in late summer will require artificial controls if populations are very high (38, 41).

An answer to the question of how to prevent heavy losses in young plantations due to the ravages of insect and disease attack may lie in breeding for resistance to these destructive biotic agents. Many authors agree that selecting clones resistant to insects and disease should be an integral part of any tree-improvement program (38, 51, 24) (63).

Resistance of individual cottonwood trees in plantations due to genetic variation to some insects and diseases has been noted by tree breeders. Resistance to the following insects and diseases has been observed: (1) the leaf curl mites, (2) the *Chairophorons* species of aphids, (3) leaf diseases, including Septoria leaf spot, *Melampsora* leaf rust, and *Marssonina* leaf blight, and (4) two of the canker fungi, *Fusarium* and *Septoria* species (63). Thiegels and Land (63) recommended that before starting a tree-breeding program, the researchers should have a thorough knowledge of the physiology of both disease and insect organisms and the host plant, in this case *Populus deltoides*. It is stressed that the breeder should be aware of any correlations in the host plant between age, physiological condition, and insect and disease resistance. For example, correlation between age of rootstock and the incidence of stem and leaf diseases was studied by Filer, et al. (19). They found that sprouts growing from older root stocks had a higher incidence of both leaf and stem disease. It was noted that seven-year-old rootstocks yielded cuttings with a 22 percent incidence of stem canker. Sprouts from two-year-old roots had 0.5 percent canker incidence and those from one-year-old roots had less than 0.1 percent canker infection. Reports such as these emphasize the need for researchers to distinguish carefully between the expression of physiologic condition and genetic effect when selecting for resistant clones.

Without proper preventative measures, the buildup of insect populations in cottonwood plantations is almost inevitable. As discussed previously, resistance offers possibilities for control of some insects and diseases. In the case of the leaf beetle, natural predation by lady bug beetles often controls early population peaks but is inadequate for late summer controls (38, 40). For this reason, chemical controls often prove more reliable.

According to Olivera and Abramson (42), systemic insecticides provide the best control of borers, defoliators, and sapsucking insects which damage *P. deltoides*. They advise using good cultural practices as a means of reducing the need for chemical controls; they point out that the expense of chemical controls is justified only when insects threaten stand establishment.

The cultural requirements for cottonwood plantation management are as intensive as for any major United States pulp or timber species. These cultural activities require substantial investment. Dutrow, et al. (16), calculated the rate-of-return (ROR) for perpetual nine-year pulpwood rotations on high and average sites in the Lower Mississippi Valley. Initial establishment costs of $125.00 per acre and stumpage prices of $4.00 per cord would yield a five percent ROR on a high site.[5] Growing soybeans on the site the first year after land clearing would allow a 7.5 percent ROR if combined with a 10-year pulpwood rotation on a high site and stumpage prices of $4.00 per cord. A move to a 21-year sawtimber rotation with soybeans the year before planting would boost the ROR to eight percent, assuming a sawtimber stumpage price of $30.00 per

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[5]Figures based on 1970 prices.

1000 board feet, and no change in land-clearing costs, establishment costs, and cordwood values. It is very unlikely that stumpage values will decrease, and the establishment costs of later plantings on a site previously occupied by a plantation should be lower than on previously forested areas.

Intertilling

Intertilling of agricultural crops in young cottonwood plantations could further enhance the rate-of-return figures for both pulpwood and sawlog rotations. Cottonwood growers are planting fewer trees per acre than ever before, as they learn more about the importance of vigorous crown development in Populus deltoides. This practice leaves large areas of the plantation unproductive for up to three years in some cases. Much time and money is spent keeping these inter-row areas free of weeds and competing vegetation until the trees can effectively compete for light, moisture, and nutrients. Intertilling with annual crops would provide more complete utilization of the site. At the same time the crops could produce an annual income.

Intertilling of annual food and forage crops has been widely developed and researched in European countries (2, 23, 25, 53, 58) where the intensive silviculture of the Populus species had its origins. Reasons for intercropping have included weed control, supplementary food source, added income, site amelioration, and production of forage for livestock. Income from the intertilled crops could help recover costs incurred in plantation establishment, maintenance, and protection.

A review of the literature on intertilling for the years 1948-1974 brought to light promising reports on the potential for agricultural intercropping in cottonwood plantations. The reported effects of intertilling on tree growth ranged from no effect (2, 58) to an increase in height and diameter growth (23, 25, 43, 53). Georgopoulos (23) reported that intertilling with maize in widely-spaced poplar plots increased basal area increment and mean d.b.h. After one growing season in which maize and tobacco were intercropped, Schroder (53) reported an increase in tree height growth in poplars from 4-12 percent over plots which were not intercropped. It was not mentioned whether or not fertilization was included in the intercropping program. He also found that returns from the intercropped plots repaid the cost of site preparation, which consisted of shallow disking. Soules (58), however, found little variation in height or diameter increment between intercropped plots and trees-only plots. In an experiment involving intercropping with cereals, Barnond (2) pointed out that while intertilling these crops did not depress tree growth, it should be accompanied by fertilization.

Pavsa (43) used a system of intercropping with potatoes the first year of plantation establishment. He then intercropped corn for two years and an oats-clover mixture the fourth year. With this technique he found that the poplar trees had a higher increment and were more free from disease than forest-grown trees. Joachim, et al. (25), also related a reduced incidence of disease to intercropping accompanied by cultivation.

Research showed that increased utilization of the site by the trees as the stand developed was reflected in a loss of production by the intertilled crops. Soules (58), for example, reported a loss in the production of maize by the fourth year of 93 percent. Dorbronic (15) reported maize production in intertilled crops to be 56 percent of that in open-grown areas by the third year. Over the same period production of intercropped wheat crops fell to 38 percent of open-grown wheat.

Intertilling may offer other advantages which could increase survival and early growth in Populus plantations. Maran, et al. (32), stated that wheat, oats, rye, and barley improve the microclimate by lowering the soil temperature. He suggests that the lowering of soil temperatures would reduce moisture losses and be especially beneficial when afforesting dry and/or sandy areas. Maran identified weeds as our greatest enemy in foresting arid lands. They reported that in their study plots, weeds were responsible for removal from the soil by evapotranspiration of 70 mm of the 237 mm of rainfall that fell during the measurement period.

CHAPTER III

OBJECTIVES OF THE STUDY

The primary objective of this study was to investigate techniques for intercropping forage crops within cottonwood plantations in a manner compatible with plantation management of cottonwood. Tree height growth, survival, and nutrient status parameters were used to compare the effects of the different cultural treatments on the cottonwood trees, especially intercropping versus clean-disking.

Data collected with the following set of minor objectives as guidelines was the basis for drawing conclusions about the potential of intercropping young cottonwood plantations:

(1) Compare the foliar nitrogen status of intercropped and non-intercropped trees.

(2) Compare tree height growth and survival for different clones, soil types and cultural treatments.

(3) Measure production of the forage crops in the first year.

(4) Compare moisture content of the soil among different soil types and cultural treatments.

(5) Test for an improved method of cottonwood plantation establishment on alluvial soils in Southeastern Oklahoma.

CHAPTER IV

METHODS AND PROCEDURES

The experimental plantings were established on two distinct soil types; they were Idabel silt loam and Oklared very fine sandy loam. The test sites occupied approximately 1.6 acres on each soil type and were divided into six .25-acre plots on each site. Three different cultural practices were randomly assigned with two plots on each site receiving identical treatments. The three cultural methods used in conjunction with establishment of the cottonwood plantation were:

(1) Intercropping between tree rows with a rye-vetch winter crop and Korean lespedeza as a summer crop.

(2) Intercropping between tree rows with an oats winter crop and Korean lespedeza summer crop.

(3) Maintaining the area between tree rows free of all vegetation by disking when necessary to control competing vegetation.

Each of the twelve plots, six on each site, contained 48 planting planting spots established on a spacing of 14 x 14 feet. Each plot contained four replicates. A replicate consisted of three four-tree plots. Each four-tree plot in a replication represented a different clone. Three different clones were used for planting material. Clones were randomly assigned to positions within each replicate. One border row was installed around the aggregate of six plots on each site. The complete layout of the research design is shown in Figure 2.

The site was prepared for crop and tree planting on October 22, 1977. Following thorough seedbed preparation by disking to a depth of eight inches with a tandem disk, winter crops were planted in designated areas on November 8, 1977. Winter crops were planted with a 12-foot 6-inch-wide grain drill. The Elbon rye and Nora oats were seeded at the rate of 100 pounds per acre; after inoculation with Rhizobium spp. bacteria, hairy vetch was sown on the rye-vetch plots with a hand-operated mechanical seeder at the rate of 20 pounds per acre. At the time of seeding, fertilizer with an analysis of 17-17-17 ($N-P_2O_5-K_2O$) was applied at the rate of 200 pounds per acre.

Four-foot cuttings used in the study were donated by the Southern Hardwoods Laboratory of the United States Forest Service, Stoneville, Mississippi and by the Anderson-Tully Company. Following collection during late December and early January, cuttings were soaked in water with two-thirds of their length submerged for 10 days.

After soaking in water, the cuttings were bundled in groups of fifty; these bundles were then wrapped in heavy plastic with water-soaked spagnum moss packed around the ends of the cuttings to prevent excessive drying. The bundles of cuttings were then transported to the Weyerhaeuser Company nursery operation at Valiant, Oklahoma and placed in a cold storage unit until planting time.

The planting operation began on January 5, 1978. Holes for the four-foot cuttings were drilled to a depth of 45 inches with a tractor-mounted auger. To insure against poor survival, two cuttings were planted at each planting spot. The two cuttings were planted at

OKLARED VERY FINE SANDY LOAM

1 Trt. 1 3.54 3.85 3.19 2.17 2.68 2.72	4 Trt. 3 4.20 3.69 2.95 1.78 1.99 1.95
2 Trt. 2 5.36 4.49 3.67 2.88 3.24 3.27	5 Trt. 1 3.28 4.00 3.20 2.31 2.68 2.67
3 Trt. 3 4.14 3.91 3.16 2.06 2.61 2.51	6 Trt. 2 3.73 4.21 3.51 2.48 2.79 2.68

IDABEL SILT LOAM

7 Trt. 1 3.77 3.80 3.48 2.94 3.36 3.28	10 Trt. 3 6,43 3.89 3.30 2.54 3.22 3.19
8 Trt. 2 6.92 7.72 5.79 3.36 4.37 4.35	11 Trt. 1 10.91 7.30 4.86 3.50 4.03 4.06
9 Trt. 3 12.24 9.09 5.12 3.02 3.45 3.58	12 Trt. 2 9.60 6.26 3.79 2.95 3.67 3.93

Trt. number refers to the treatment applied as described below:

Trt. 1. Tree plots winter cropped with a rye-vetch mixture; after harvesting the rye-vetch crop in May, the plots were summer cropped with Korean lespedza.

Trt. 2. Tree plots winter cropped with oats and summer cropped with Korean lespedza.

Trt. 3. Cultural treatments on these plots consisted of clean disking throughout the growing season.

The numbers in the upper right hand corner of each square is the plot number.

The numbers in the array on the left side of each plot diagram are moisture readings (total inches of water in the top 48 inches of soil) as measured on the following dates in 1978: 6–10, 6–29, 7–19, 8–16, 9–29, and 10–14.

Figure 2. Field Layout and Design of Treatments Applied in the Cottonwood Intercropping Study

opposite sides of the hole, and the soil was packed carefully around the cuttings to eliminate air spaces.

Planting on the Oklared site was completed by February 26, after the work schedule was interrupted by severe winter weather. Planting on the Idabel silt loam site was completed by March 4, 1978. These planting dates are within the time span recommended for cottonwood planting by Briscoe (7). In the interim between cold storage and planting, cuttings were soaked again in water for periods of up to 48 hours.

The rye-vetch treatment plots were harvested on April 23, 1978. Immediately prior to harvest, samples were taken within each treatment plot for per-hectare production estimates and green-to-dry weight ratios. The six randomly-located crop production subsamples per plot were two feet by three feet in area. If measurable amounts of vetch were present, the rye and vetch were weighed separately. All rye and vetch plants within the six square foot area were weighed in the field immediately after shearing two inches above ground level with hand-operated shears. A small portion of the sample from each six-square-foot sample plot (about ¼ kg) was weighed separately, then taken to the laboratory for oven-drying and again weighed so that a green-to-dry weight ratio could be established. This allowed conversion of two-by-three-foot sample plot weights from green to dry-weight figures.

Once the sampling operation was completed, the rye-vetch crop was harvested with a six-foot tractor-pulled rotary mower. Since the aim of the intercropping program was forage production, the hay was raked and removed from the plots.

After removal of the rye-vetch residues, the plots were disked to prepare a seedbed for broadcast seeding of Korean lespedeza. The lespedeza was then sown at the rate of 25 pounds per acre with a hand-operated broadcast seeder. Seeding of the lespedeza was accomplished on the same day that the winter crop was harvested.

By May 15 the oat crop was ready for harvest, since seedheads had formed with the grain at the "milk stage". The four oat-intercropped plots were sampled for green and dry weight production figures following the same procedures used in the rye-vetch plots. The area was then disked to prepare a seedbed of Korean lespedeza. On the same day, the lespedeza was seeded at the rate of 25 pounds per acre, again with a hand-operated seeder.

For those plots scheduled to receive the disking treatment throughout the growing season, disking was required five times for weed control on the silt loam site and four times on the sandy site. The plots were disked in both directions with a six-foot tandem disk pulled by a 40-horsepower gasoline tractor. Three hours were required to disk the four plots.

As early as June 9, grasshopper (Romulae microptera) infestations had become a serious problem within the study area. Grasshoppers had begun feeding on practially all the tender growing shoots at this time, severely inhibiting height growth of the young cottonwood trees. Along with the grasshopper invasion, the cottonwood borer (Plectrodera scalator) was occasionally sighted within the study area. The larvae of this beetle tunnel into the roots of cottonwood to feed, and are capable of killing small trees. The adult beetles feed on leaf tissue and the bark of small twigs, sometimes girdling and killing the twigs.

In an effort to control these particular pests, a spraying program was initiated, using a 44 percent Sevimol[R] emulsifiable concentrate at the rate of ½ oz. per gallon of water in a three gallon hand-pump, pressurized sprayer.

Periodic moisture readings were taken in each of the 12 treatment plots. This was accomplished with a neutron-probe device coupled with an electronic scaler. Readings were taken periodically throughout the growing season from an access tube centrally located in each plot. Access tubes were five-foot lengths of one and one-half inch EMT-thinwall galvanized pipe. A vertical hole for the pipe was drilled with a 1½ x 60 inch hand-operated auger. The pipe was then forced into these holes by hand or with the aid of a sledge hammer, placing a steel cap on the pipe while using the hammer to eliminate the chance of any damage which might prevent the neutron probe from fitting tightly on the pipe.

Soil moisture readings were taken at six-inch intervals from the soil surface to a depth of 48 inches. The recordings of soil moisture were made on six different occasions from June 19 to October 14 at approximately 25-day intervals. A computer program converted the readings from the scaler to total inches of water per six-inch interval of depth in the profile. The program also produced a figure for total inches of water for the top 48 inches of soil.

Final height and survival counts were taken on September 2, 1979. At that time the lesser of the two cutting sprouts at each planting spot was removed by shearing the sprout at ground level. Heights were recorded to the nearest 0.1 foot.

Foliar samples were taken from the cottonwood trees in mid-August. Nitrogen content as a percent of total dry matter was determined by the Oklahoma State University Agronomic Services Laboratory. A modified macro-Kjeldahl technique was used for the foliar nitrogen tests.

Comparisons of foliar nitrogen levels were made on the basis of soil type and intercropping treatment.

Analysis of variance was used to measure and compare the performance of the trees and the crop species on the two soil types. Analyses were made of height and survival, foliar nitrogen levels, soil moisture, and crop production in response to the applied treatments. Tests producing observed significance levels of 0.05 were considered statistically significant. Hereafter, the work "significant" is used in a statistical sense.

CHAPTER V

RESULTS AND DISCUSSION

Soil Moisture

The extremely dry weather extant during this study was doubtless the most limiting factor affecting the growth of the cottonwood trees.

Soil moisture was significantly affected by soil type and date of reading. There was also a significant interaction between soil type and date. There were no significant interactions of crop species with soil type and date nor were there significant differences among crop species (Table XVI, Appendix).

The results of moisture readings by soil type and date are given in Table I. Readings from the six plots on each soil type were averaged to produce the figures presented in this table. The significance of the date of moisture readings as it affects soil moisture, becomes apparent upon examination of the reduction in soil moisture as the growing season progresses. Note the greater range of difference for soil moisture readings on the silt loam as compared to the sandy loam soil. Moisture levels on the sandy loam soil were more consistent throughout the growing season.

Differences in total inches of stored water in the top 48 inches of soil were significant between soil types, and responsible in large measure for the differences in productivity of the two soils. The extent of the difference in the potential of the two sites to store water becomes readily apparent when the soil moisture figures are compared graphically in Figure 3.

TABLE I

TOTAL INCHES OF WATER IN THE TOP 48 INCHES OF SOIL AS MEASURED USING A NEUTRON PROBE*

Date	Oklared Sandy Loam	Idabel Silt Loam
	Inches of Water	
June 10	4.03	8.30
June 29	4.12	6.35
July 19	3.30	4.40
August 16	2.30	3.05
September 29	2.67	3.70
October 14	2.65	3.75

* Each reading is an average of six tubes located in a first-year cottonwood plantation.

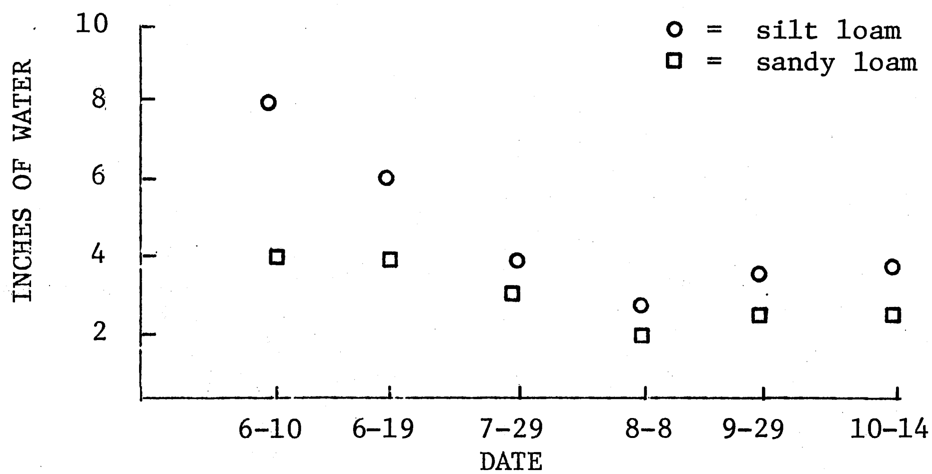

Figure 3. Inches of Water in the Top 48 Inches of Soil Related to Soil Type and Time of Measurement

The fact that intercropping did not significantly affect soil moisture lends support to the theory that intercropping with winter forage crops will not reduce a site's potential for cottonwood tree growth insofar as moisture availability during the growing season is concerned.

In an effort to analyze more closely the effects of soil moisture on stand parameters affecting cottonwood growth and survival, an intensive study was designed in which periodic recordings were made of height growth and survival of the trees on plots three and nine. These two plots were clean-disked throughout the growing season. The following is a detailed description of the methods used and the results obtained from this small-scale, intensive study of soil moisture and its effects on cottonwood growth and survival.

Data collection began on May 15, 1978, approximately one month after leaf flush occurred. Tree height and survival, and soil moisture were measured as nearly as possible on three-week intervals until September 22, 1978. This provided data for six three-week measurement periods. Six variables thought to influence first-year height growth of cottonwood were recorded. Below is a listing of these variables along with an explanation of the meaning of each:

(1) soil type - either Idabel silt loam or Oklared very fine sandy loam.

(2) period - designated as 1, 2, 3, . . ., 6, and representing three-week intervals beginning May 15; period 1 occurring between May 15 and June 10, etc.

(3) clone - Stoneville 66, 92, or 109.

(4) height growth - the average increase for the four trees in a four-tree plot. The best of the two cuttings at each planting spot was recorded to the nearest 0.1 foot.

(5) precipitation - precipitation was recorded by measurement period with daily precipitation data from the Idabel weather station (nearest reporting station), used as a source of information.

(6) soil moisture - recorded as total inches of water in the top 48 inches of soil and measured with a neutron probe. One access tube was located in each of the four replicate plots on each soil type.

Height growth figures, precipitation, soil moisture, and survival are given according to measurement period and soil type in Table II. It is apparent that plot 9 on the Idabel silt loam has a greater capacity to store rainfall. The capacity to store greater amounts of

TABLE II

COTTONWOOD TREE HEIGHT AND SURVIVAL WITH SOIL MOISTURE AND PRECIPITATION DATA (1978)*

Date	Height Growth (feet)	Precipitation (inches)	Soil** Moisture (inches)	Survival %
		Idabel Silt Loam		
5-15/6-10	1.2	3.20	12.24	98
6-10/7-1	1.5	0.00	10.67	98
7-1/7-21	0.5	0.22	7.12	98
7-21/8-8	0.1	1.75	4.07	98
8-8/9-2	0.3	0.34	3.24	94
9-2/9-22	0.4	3.03	3.15	88
		Oklared Sandy Loam		
5-15/6-10	0.5	3.20	4.14	100
6-10/7-1	0.7	0.00	4.03	96
7-1/7-21	0.3	0.22	3.54	94
7-21/8-8	0.0	1.75	2.61	94
8-8/9-2	0.1	0.34	2.34	94
9-2/9-22	0.2	3.03	2.42	92

* Data from plots 3 and 9 only; survival and height measured on last day of each period.

** Total water in top 48 inches of soil.

water results in higher site productivity, provided that at least some of this additional storage is available for plant growth. The greater height growth on the Idabel silt loam indicates a higher site productivity as compared to height growth on plot 3 of the Oklared sandy loam site.

Height growth during the first three-week measurement period was less than the growth during the second period. Growth after the second period was reduced by a severe drought during June, July, August, and most of September (Table XVII, Appendix), and an unusually high population of grasshoppers. Grasshopper damage manifested itself in the destruction of an extremely high percentage of the growing tips of main stems and branches. Feeding was concentrated on the tender stems for several inches back from the growing tip. The new growth was severed in this manner, resulting in a loss of height. Coincident with growth-depressing drought conditions, the grasshopper attack was deleterious to tree growth since energy, nutrients, and water, basic requirements for growth, are at a premium during a drought year. These elements were being expended with no net increase in growth.

The data in Table II shows that from the onset of the growing season, trees on the silt loam site grew faster than trees on the sandy loam soil. Damage resulting from the drought and the grasshopper feeding was reflected by the almost complete cessation of growth shown in periods 3, 4, and 5. Survival rates for trees on the two soils were not significantly different. Tree survival was acceptably high with 88 percent of the planting spots on the silt loam and 92 percent on the sandy loam soil represented by a living tree at the end of the growing season (Table II).

The interaction between height growth, period, and soil moisture as the growing season progressed is shown in Figures 4 and 5. Figure 4 is a representation of this relationship for the Oklared very fine sandy loam, and Figure 5 reflects data from the Idabel silt loam site.

It is apparent from Figures 5 and 6 that while the magnitude of each factor is quite different from one soil type to another, the general relationship between soil moisture and periodic height growth over time follows a pattern common to both sites. Note that height increment during period "2" is greater, even though soil moisture is below that measured in period "1". This pattern is consistent with the normal growth curve of most tree species. After the rapid increase in increment observed in period "2", height growth and soil moisture are more closely related.

According to the data in Figures 4 and 5, the Idabel silt loam is capable of a much higher retention of precipitation.[1] The smaller increase in total inches of water on the sandy loam site as a result of the rainfall netted a greater increase in height increment (compare Figures 4 and 5). This is probably due to the fact that the higher percentage of silt and clay on the silt loam held most of the water at a tension so great that it was rendered unavailable to the trees. It is interesting to note that during the drought periods of 4, 5, and 6, differences in amounts of stored water in the two soils were very slight. During this time, little height growth occurred on either site, indicating the existence of a moisture level which is critical for height

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[1]Since the plots are less than 100 meters apart, the assumption was made that each plot received equal rainfall amounts.

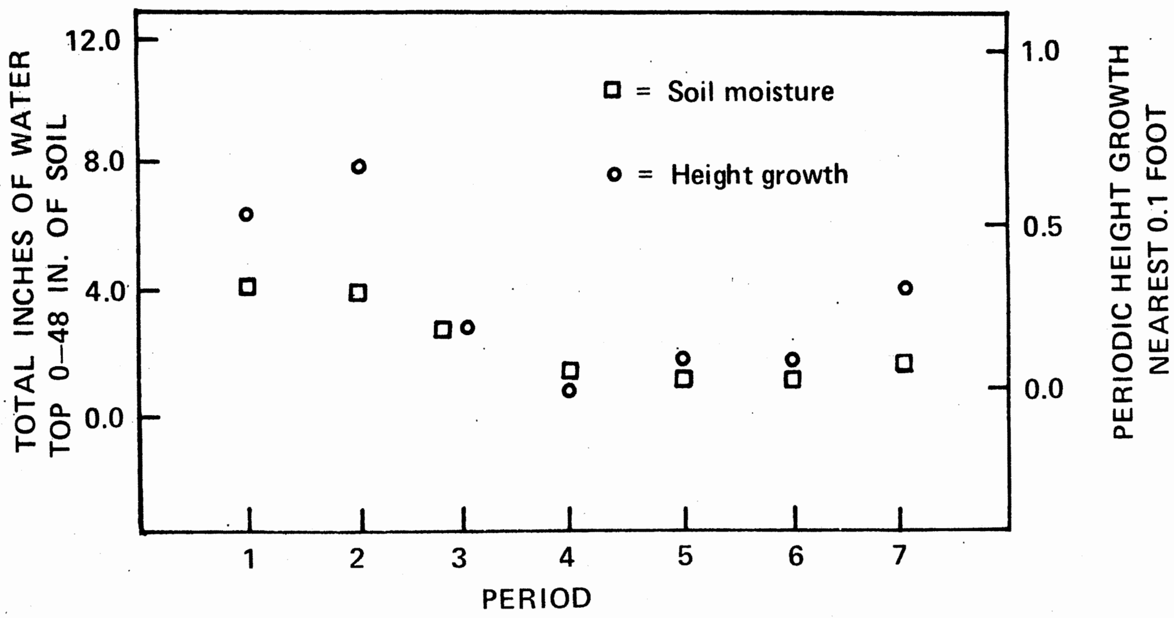

Figure 4. The Relationship of Soil Moisture to First-Year Periodic Height Growth of Cottonwood on an Oklared Sandy Loam Soil

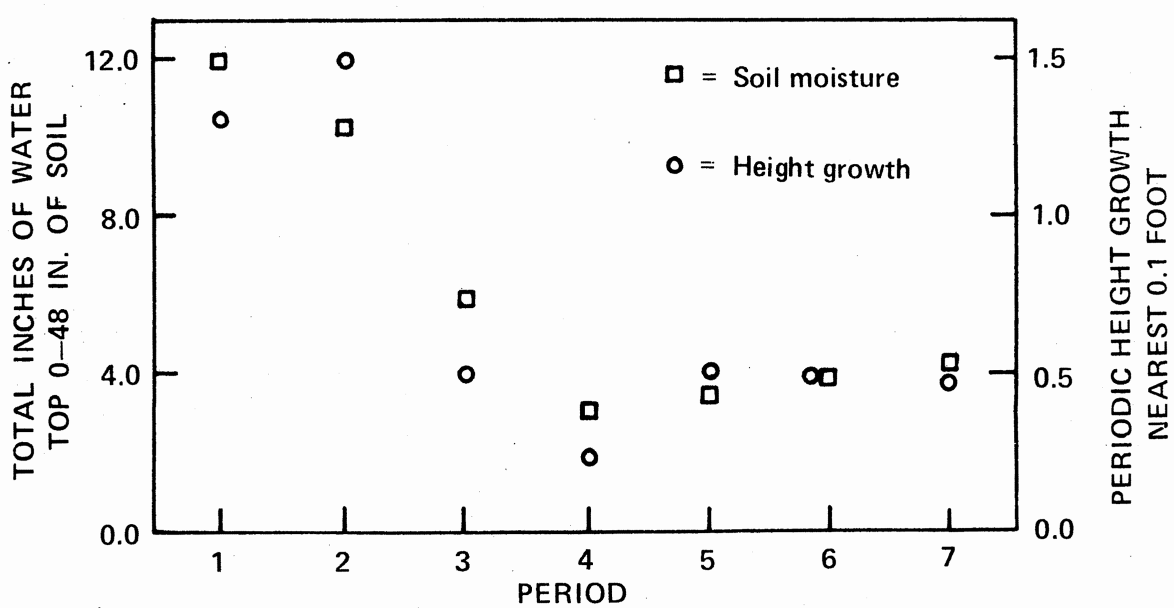

Figure 5. The Relationship of Soil Moisture to First-Year Periodic Height Growth of Cottonwood on an Idabel Silt Loam Soil

growth. The amount of total moisture necessary for height growth of cottonwood seems to be slightly higher for the silt loam soil than for the sandy loam.

A characteristic of the soil profile on the Idabel soil is the existence of a layer of fine silt and clay particles creating a "perched" water table. This layer was found at a depth of 24 inches on the Idabel soil. This layer of fine soil particles effectively impedes water percolation through the profile. This phenomenon is reflected in the soil moisture readings shown in Table III. Note that, disregarding the surface reading (the result of a rain shower the previous evening), moisture content increases to some point in the profile, then decreases. The decrease is due to the impedance of normal percolation below the level of the layer of fine material.

It is doubtful that the slight increase in the moisture readings on the Oklared site at a depth of 42 inches (Table III) was indicative of increased moisture retention at that point, depending on the accuracy of the instrument. The presumed lack of a layer of fine material on the Oklared very fine sandy loam soil capable of retaining water within reach of the cottonwood tree roots contributes to the lower productivity of the Oklared site as compared to the Idabel silt loam.

Total height increased markedly on both sites early in the growing season when conditions for growth were favorable (Figure 6). Similarly, survival was not sharply reduced until later in the growing season when an additional reduction in stored moisture on the two soils apparently exceeded the limits of stress which could be withstood by the trees (Figure 7). This concludes the detailed discussion of soil moisture, tree height growth, and survival, as recorded on plots 3 and 9.

TABLE III

CHANGES IN SOIL MOISTURE CONTENT WITH DEPTH ON AN OKLARED SANDY LOAM AND AN IDABEL SILT LOAM OBSERVED ON JUNE 29, 1978

Depth of Reading (inches)	Oklared Sandy Loam (Total Inches Water)	Idabel Silt Loam (Nearest 0.01 Inch)
6	0.59	1.06
12	0.27	0.88
18	0.32	1.36
24	0.38	1.94
30	0.46	1.84
36	0.55	1.13
42	0.68	0.41
48	0.63	0.39

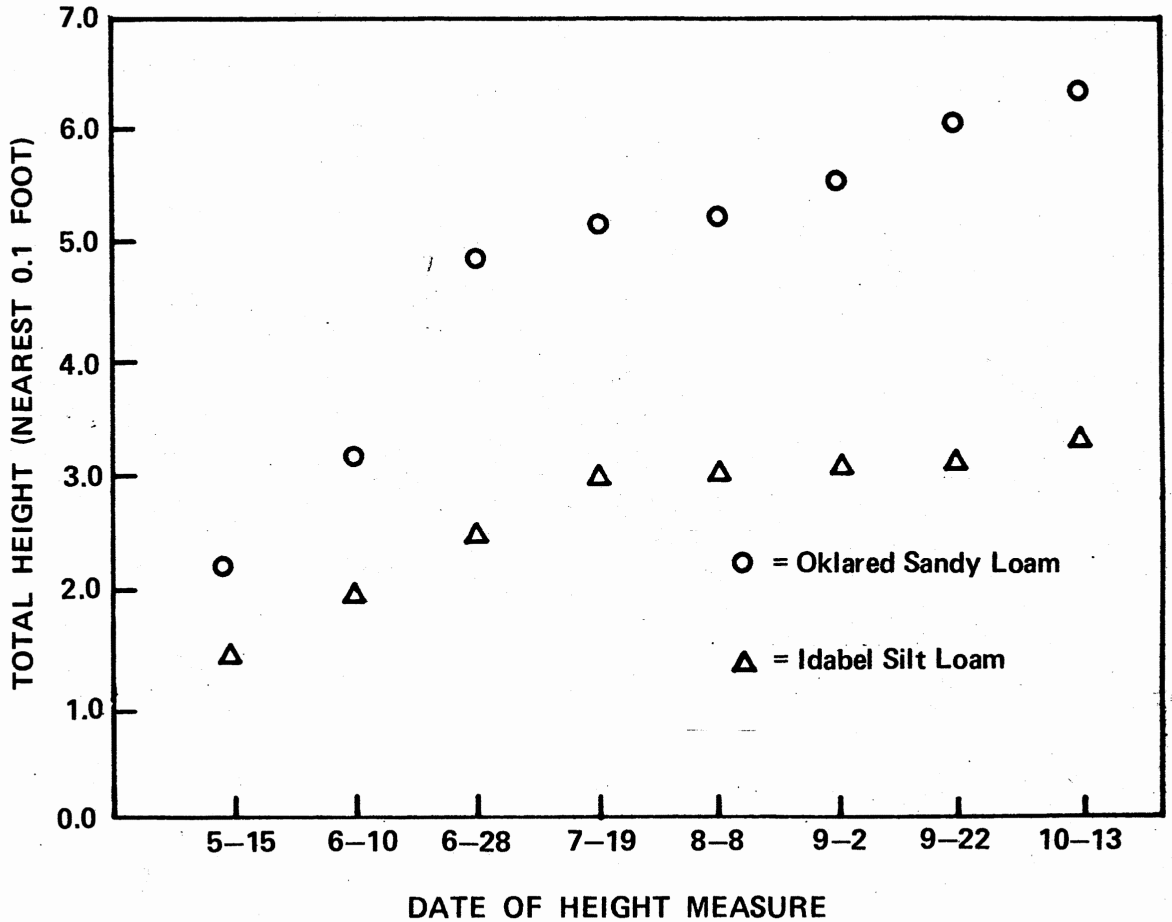

Figure 6. Plot of First-Year Height Growth Versus Time for Cottonwood on Two Alluvial Soils of Southeastern Oklahoma

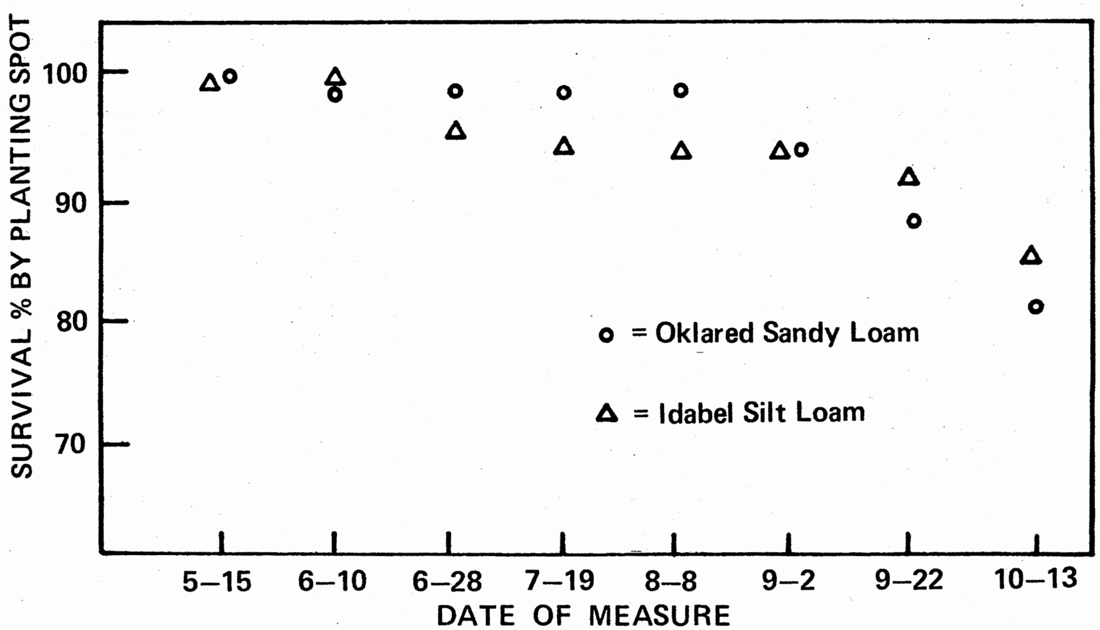

Figure 7. Plot of Planting Spot Survival Versus Time for First-Year Cottonwood on Idabel Silt Loam and Oklared Sandy Loam Soils

Tree Survival

There was no significant difference in survival percentages of the cottonwood by clone, soil type X clone interaction, or the interaction between forage species intercropped and clone (Table XIII, Appendix). Apparently, the extreme limiting effects of soil moisture on cottonwood growth and survival precluded the expression of clonal effects. The survival was adversely affected by intercropping on the silt loam soil but not on the sandy loam (Table IV). Tree survival was also significantly affected by crop and soil type X crop interaction. The significant effect of soil type was apparently induced by the lespedeza summer crop. The lespedeza did not become established on the Oklared site and, hence, did not compete with the cottonwood trees. On the Idabel silt loam soil the lespedeza and associated weed species persisted well into the growing season and effectively competed with the cottonwood trees for available moisture. The results of this presumed competition had a severe impact on survival percentages of cottonwood trees on the silt loam soil as shown by the data presented in Table IV. According to the results in Table IV the rye-vetch winter-cropping program had a more severe impact on tree survival than did the oats intercrop or the clean-disking treatment. Average tree survival on the two rye-vetch intercropped plots was 63 and 96 percent (Table IV). It is possible that some site or biotic factor which escaped detection was responsible for the low survival (63 percent) on one of the rye-vetch intercropped plots.

TABLE IV

FIRST-YEAR SURVIVAL RESULTS OF EASTERN COTTONWOOD RELATED TO CULTURAL TREATMENT AND SOIL TYPE

Cultural Treatment	Survival Percent (9-2-78)			
	Oklared sandy loam		Idabel silt loam	
	Range**	Average	Range	Average
Rye-Vetch Intercrop	94	79	33	33*
	63		33	
Oats Intercrop	96	96	27	51*
	96		75	
Clean Disking	94	94	94	84
	94		74	

*These plots also received the lespedeza summer cropping treatment.

**Range shows survival results from each of the two plots receiving the treatment.

With the previously-mentioned exception of plot 1 where survival was unexplainedly low, there were no significant differences between tree survival in other plots on the Oklared very fine sandy loam soil receiving the three treatments. Significant differences between tree survival percentages for the cultural treatments used on the silt loam reflected the effects of the competition from the lespedeza summer crop which persisted until early July before succumbing to the effects of drought. The low survival percentages reported from the summer-cropped plots on the silt loam soil emphasize the incompatibility of the cottonwood trees with any competition for moisture and nutrients. A summer cropping system which provides for cultivation of a small area (perhaps one meter square) around each tree might allow uninterrupted tree growth. Such a system could increase site utilization during the first year. However, since tree cultivation was not a part of the summer cropping program of this study, the probability of the success of such a program is problematical.

Plots 9 and 10 on the silt loam site received the clean-tilled disking treatment. Survival was 94 percent on plot 9 and 80 percent on plot 10. This 14 percent difference in survival percentages suggested the existence of a considerable degree of variability on the Idabel silt loam site. Considering the unusually dry conditions (Table XVII, Appendix) of the growing season, it was suspected that soil moisture was the primary factor affecting the survival differences between these two plots.

The results of soil moisture readings taken on plots 9 and 10 are shown in Table V.

TABLE V

DIFFERENCES WITHIN THE SILT LOAM SITE WITH REFERENCE TO AMOUNTS OF WATER STORED IN THE TOP 48 INCHES OF SOIL (1978)

Date	Idabel Silt Loam	
	Inches of Water	
	Plot 9	Plot 10
June 10	12.2	6.4
June 29	9.1	3.9
July 19	5.1	3.3
August 16	3.0	2.5
September 29	3.5	3.2
October 14	3.6	3.2

The large differences in stored water between these two plots which existed during the first half of the growing season probably were responsible for the tree survival differences noted earlier.

Tree Height

There were significant differences in tree height between the two soil types and the three different cultural treatments. The interaction between soil type and crop had a significant effect on tree height. There were also significant differences in tree height between plots. Neither replication, clone, nor crop X clone interaction significantly affected tree height (Table XIV, Appendix). Average height of trees on the six plots on the Oklared site was 2.7 feet. For the two plots on the silt loam with acceptable survival rates, i.e., the clean-disked plots, height averaged 4.7 feet.

Differences in height were even more pronounced than survival differences between these two plots. Average height at the end of the growing season on plot 9 was 5.7 feet as compared to 3.6 feet on plot 10. Standard tests used to classify soils on the basis of texture did not detect any differences which would imply a lower productivity on plot 10. Characteristics of the soil profile discussed in the soil moisture sections seem to be more important in affecting the productivity of a site with reference to the growth of eastern cottonwood. The differences in soil moisture which affected survival, as discussed earlier, evidently had an impact on height growth as well. Apparently, the silt loam site was not as uniform as was the test site on the Oklared sandy loam (Table VI).

TABLE VI

AVERAGE HEIGHT BY PLOT, SOIL TYPE, AND CULTURAL TREATMENTS FOR FIRST-YEAR COTTONWOOD TREES

Cultural Treatment	Plot	Average Height (ft.)	Average Height for Treatment
	Idabel Silt Loam		
Rye-Vetch Intercrop*	7 11	2.4 3.2	2.8
Oats Intercrop*	8 12	2.9 3.1	3.0
Clean-Disking	9 10	5.7 3.6	4.7
	Oklared Sandy Loam		
Rye-Vetch Intercrop	1 5	2.0 2.4	2.2
Oats Intercrop	2 6	2.7 2.8	2.8
Clean-Disking	3 4	2.9 3.0	3.0

* These plots were summer cropped with Korean lespedeza.

Note the uniformity of average tree height figures on the sandy site for each of the three cultural treatments. The silt loam site had average tree heights of 5.7 and 3.6 feet for plots 9 and 10 respectively. It is possible that plot 10 was situated outside the area on which the silt loam soil was deposited, since it was located at the opposite corner of the test area from plot 9.

Foliar Nitrogen Test Results

Nitrogen amounts contained in foliage tissue is often used to determine the nutritional status of plants (46). The foliar nitrogen analysis used in this study was designed to test for possible effects of intercropping on the nitrogen uptake of the cottonwood trees.

Analysis of variance of the foliar nitrogen (N) results indicated that there were no clonal differences in N content measured as a percent of total dry weight. Due to the failure of the clone to significantly affect foliar nitrogen levels, clonal effects are not included in the following discussion of foliar N results. Crop X clone and soil type X clone interactions were not significant (Table XV, Appendix).

Crop and soil type did significantly affect foliar N levels. The relationship between soil type, intercropped species, and foliar N levels is presented in Table VII.

The differences between foliar N levels reflects the significance of cultural treatment. Evidently the increased production of the rye-vetch crop as compared to the oats resulted in greater utilization of available N, leaving lower amounts of this nutrient available for tree growth. Similarly, on the clean-disk plots, trees encountered little or no competition for nitrogen, hence the higher reported N levels.

It is possible that the N levels would be higher had moisture not been so limiting during the extremely dry growing season. Nitrogen uptake can be limited by severe drought (46). While limited uptake due to drought would result in lower figures for foliar N, it does not negate the relative differences between foliar N levels in trees receiving different treatments.

TABLE VII

THE RELATIONSHIP BETWEEN CULTURAL TREATMENT, SOIL TYPE, AND FOLIAR N LEVELS IN A FIRST-YEAR COTTONWOOD PLANTATION

Cultural Treatment	N as a % of Total Dry Wt.
Oklared Sandy Loam	
Rye-Vetch Intercrop	1.13
Oats Intercrop	1.33
Clean-Disking	1.52
Idabel Silt Loam*	
Clean-Disking	1.83

* No foliar samples were taken from the intercropped plots on the silt loam due to the low survival on these plots.

Work has been done which indicates that a certain percentage of N in foliar tissue can be termed a "critical percentage". Levels of foliar N measured below this critical percent are said to indicate that available N has become a limiting factor affecting tree growth. Blackmon (3) reported that this critical level is two percent for cottonwood.

Since none of the samples tested in the study contained foliar N levels as high as two percent, it can be presumed that practically all the trees in the study were experiencing growth potential limitations due to the limited available nitrogen. This condition was intensified by the intercropping scheme, and the fact that nitrogen levels in the soils were very low (60). As reported in Table VII, the oat and rye-vetch intercropping reduced foliar N levels of the cottonwood trees by 0.2 and 0.4 percent respectively, compared to trees in the clean-tilled plots.

The fact that foliar N levels on the plots which received the clean-disking treatment were in the critical percent range as well as the intercropped trees suggests that a higher rate of N fertilization is needed. Monetary returns from the intercropped plot's forage yields as a result of increased fertilization would probably cover the costs of additional nitrogen applications.

Application of nitrogen to a clean-tilled cottonwood plantation, however, would be a questionable enterprise from the standpoint of a satisfactory return on investment. This aspect of plantation management is discussed more fully in later sections dealing with the intercropping system.

The inadequate nitrogen supply detected by low levels of foliar nitrogen could have been partly due to poor water relations resulting from the droughty conditions encountered in this growing season (46). It is doubtful, however, that all of the difference between the reported levels and an acceptable level of foliar N of two percent or better was due to drought. Apparently, both soils have inadequate soil nitrogen, making nitrogen a limiting factor affecting the growth of the cottonwood trees.

Crop Production Discussion

Winter crop production was very successful on both soil types. Following a harsh winter of snow, ice, and below normal temperatures (Table XVIII, Appendix), the favorable conditions for growth in the spring resulted in a vigorous crop of rye-vetch and oats. The uniformity of cultural treatment, fertilization rate, seeding rate and method, and production sampling technique, allowed differences in productivity between the two sites to be clearly expressed.

A summary of per-hectare production figures from the two soil types tested for rye-vetch and oat production is given in Table VIII.

Analysis of variance showed that per-hectare dry-weight was significantly affected by soil type and crop. There were no significant soil type X crop interactions (Table XVI, Appendix). The significance of soil type manifested itself in increased production of each crop when results from the sandy loam site were compared to those from the silt loam. A study of the figures in Table VIII show that Nora oat production on the silt loam was slightly more than twice the dry weight production of that crop on the sandy loam soil. Similarly, dry weight tonnage on the silt loam site for the rye-vetch crop was two and one-half times that measured on the more sandy Oklared site.

The significance of species of crop planted on crop yield is apparent when the figures from Table VIII are examined. The rye-vetch crop consistently produced more tonnage than oats. Rye-vetch yields were 2.06 and 1.88 times as great as oat yields on the Idabel silt loam and Oklared very fine sandy loam sites, respectively.

TABLE VIII

PRODUCTION RESULTS OF TWO FORAGE CROPS INTERCROPPED IN A FIRST-YEAR COTTONWOOD PLANTATION

Intercropped Species	Plot	Production/Plot (metric tons dry wt./ha)	Average Production (metric tons dry wt./ha)
		Idabel Silt Loam	
Nora Oats	8	1.69	2.35
	12	3.00	
Hairy Vetch-Elbon Rye	7	4.38	4.68
	11	4.97	
		Oklared Very Fine Sandy Loam	
Nora Oats	2	1.04	1.04
	6	1.04	
Hairy Vetch-Elbon Rye	1	0.78	1.37
	5	1.95	

With the exception of oat production on the silt loam site, there were no significant differences between plots of the same crop on a given soil type. Crop production figures for each plot on the two soil types are given in Table VIII. Note the similarity of crop yields on the Oklared site (Table VIII). These production figures attest to the uniformity of the Oklared soil.

TABLE IX

A COMPARISON OF ELBON RYE AND OAT FORAGE YIELDS ON THE INTERCROPPED PLOTS IN THE COTTONWOOD INTERCROPPING STUDY TO YIELDS IN OTHER TESTS THROUGHOUT OKLAHOMA

Soil Type	Lbs. Fert. Applied N	P	K	No. of Harvests	Rye	Oats[4]
					(metric tons dry wt/ha)	
Idabel Silt Loam[1]	34	34	34	1	4.84	2.34
Oklared Sandy Loam[1]	34	34	34	1	1.95	1.02
Parsons Soil (Muskogee)[2]	180	30	50	3	2.91	1.89
Teller Loam (Perkins)[3]	120	0	0	3	5.09	3.12

[1]Fertilizer applied at time of seeding.

[2]Family-fine, mixed, thermic; Sub-Group-Mollic-Albaqualfs; Order-Alfisols (57).

[3]Family-fine-loamy, mixed, thermic; Sub-Group-Udic Argiustolls; Order-Mollisols (54).

A split fall and spring nitrogen application on the sandy site would probably have reduced the differences in yields of the two sites. It is likely that most of the nitrogen applied in the fall at the time of seeding was leached through the profile and the sandy site, and became unavailable for crop utilization.

In Table IX, data from crop yield tests in Oklahoma are compared to yields obtained in the intercropping study. Even at the very low fertilization rates used in the study, the yields from the Idabel silt loam compared favorably with the other test sites in terms of production of both oats and rye. Yields on the Oklared very fine sandy loam were considerably lower than forage yields on the other three soils used in the comparison. Yields on the Parsons and Teller loams were 33 and 62 percent higher, respectively, than production figures reported from the Oklared site in the intercropping study. It should, however, be noted that the Parsons and Teller soils received 180 and 120 pounds of nitrogen per acre, respectively. The Oklared site received only 34 pounds of nitrogen at the time of seeding. Continued research on the Idabel and Oklared sites will test the production of these agricultural crops on the two soils under a more intensive fertilization program.

Possible Practical Applications of Intercropping

The following is a comprehensive discussion of specific benefits which the intercropping program could have. Special reference is made to private landowners raising cattle who wish to initiate a cottonwood planting program on their lands.

The silvicultural requirements of cottonwood make plantation management of this species an expensive proposition. Fertilizer costs, site preparation costs, insect controls, harvesting, cultural treatments, and administrative costs such as land taxes, would probably place the return on investment of growing cottonwood on most sites in southeastern Oklahoma below acceptable levels. The intercropping scheme of planting winter forage crops between tree rows provides a means whereby costs for the above-mentioned items can be recovered at an early date by providing valuable, high quality forage for the landowner's winter feeding program.

A livestock owner would probably be wise to allow only small calves to graze these intercropped areas until the trees were sufficiently large, to minimize cattle damage to the small trees. Young calves would inflict little damage to trees after the second growing season, or earlier, depending on the growth rate of the trees on the particular site. Large cattle must be excluded from the plantation area during the early years of tree development.

The possibility that the intercropped area could not be grazed for two years would mean that the forage produced in the plantation during that time would have to be removed from the area for livestock consumption. This operation could be performed with a single or multiple-harvest system.

Under a single-cropping system, the crop could be harvested during the late spring or early summer, then baled for use during the following winter or whenever needed. Use during the following winter is specified for the single-harvest system, since at the late spring or early summer harvest cut, conditions for forage production on existing pasturage are usually favorable enough that no additional supply is needed.

A multiple-harvesting system would involve several cuts of the winter crop beginning as early as November, with the last cutting operation occurring sometime from April until mid-June, depending on the crop species. Under the multiple-harvest program, the forage could be baled and used as described in the discussion of single-harvest cuts. It would also be possible that after cutting and removal from the plantation, the forage could be fed to livestock immediately, or as needed during the winter. Advantages over the single-harvest system are that no provisions for storage would be absolutely necessary, if the forage was fed to the cattle immediately after cutting. This would mean no expense incurred for storage and a reduction in handling costs.

Yields for the two systems would probably be about the same on a given soil type (Table IX).

In summarizing the intercropping discussion, it could be said that cottonwood plantation establishment coupled with winter cropping could be a valuable asset for the private landowner who raises cattle or sells hay and wishes to establish a cottonwood plantation. Many ranchers in southeast Oklahoma would stand to gain (i.e., increase their investment returns) by feeding larger quantities of high quality forage to their stock.

CHAPTER VI

CONCLUSIONS

Under the conditions encountered in this study, soil moisture was the dominant factor influencing periodic height growth. Since soil moisture dropped steadily throughout the growing season, there was a strong relationship between soil moisture and growth period. The prolonged drought which occurred during the course of this study obviously magnified the importance of soil moisture. Given more usual rainfall amounts, the effect of other factors may have been expressed.

The period of greatest height growth of the cottonwood trees was the late spring and early summer when conditions for growth were most favorable. How favorable conditions will be is highly dependent on site factors, especially the capacity of a soil to retain rainfall in amounts that will be available for later plant use. Layers within the soil profile which are relatively impervious to water and hence can prevent unrestrained percolation of gravitational water can improve a site's productivity if not located too near the surface. Close proximity to the surface will not allow sufficient infiltration to recharge the soil's water supply. This can be especially critical on some alluvial soils which are underlain by deep sand deposits, as are the soils included in the experiment described in this paper.

Average height growth on the sandy site was not impressive when compared to height growth rates recorded for cottonwood on better sites.

Survival was acceptably high, however, and height growth during years of precipitation amounts approaching the average for the area should produce more promising results. The severe impact of the grasshopper infestations cannot be excluded from a discussion of height growth, since less than a dozen trees in the entire study escaped some form of grasshopper damage. Continued growth of roots in succeeding years, more favorable precipitation, and the absence of an unusually high grasshopper population will probably result in increased rates of height growth as the stand develops. Drought conditions and high grasshopper populations are probably related and should occur rarely to the degree encountered in this study.

Tree height on the silt loam site was generally better than was reported from the sandy loam. Trees on the silt loam averaged 4.8 feet, with heights ranging from a low of 3.5 feet to a high of 9.0 feet. The 9.0-foot tree escaped grasshopper damage to its terminal shoot. The three United States Forest Service clones, which originated from the flood plain of the Mississippi River, in west-central Mississippi, out-performed Oklahoma clones which had been tested earlier on the same site.[1] The Oklahoma clones were not superior clones, whereas the three clones had undergone rigorous testing trials prior to their registration.

The extremely droughty conditions encountered during the course of the study provided a severe test of the potential survival capability of the four-foot cuttings. Survival rates of 79-94 percent on plots not summer cropped attested to the vitality of the four-foot cuttings. The

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[1]Personal communication, Dr. Charles G. Tauer, Oklahoma State University Forestry Department, April 13, 1979.

length of the cutting provided depth to reach areas of the soil profile where moisture levels were highest.

Stored moisture varied considerably with depth in the profile. It appeared that the depth at which the greatest amounts of moisture were stored was dependent on the existence of layers of fine material which resulted from the natural peculiarities of the depositional patterns of the Red River. These layers of finer particles exhibited a differential resistance to unimpeded percolation of water. The holes drilled for planting the cuttings penetrated this layer. It is possible that water drained through this perforation, creating a more favorable environment for root growth than would have existed had 20-inch cuttings been planted with only eighteen inches of cutting length below the soil surface.

The intercropping system provides a means of cottonwood plantation establishment whereby costs of establishment and cultural practices might be recovered while the trees are growing to rotation age. Proper management of the agronomic crops can bring good returns to cattlemen who have commercial quality lands suitable for growing cottonwood. Additionally, the intercropping program will provide needed winter forage to supplement the landowner's winter-feeding program.

The winter-cropping program did not directly interfere with growth or survival of the cottonwood trees. However, there existed in the winter-cropped plots an apparent shortage of available nitrogen. This was shown by the reduced levels of foliar nitrogen in the cottonwood trees on these plots. A spring application of nitrogen would certainly enhance the crop production on intercropped plots. Additional applications of nitrogen would probably raise nitrogen content in the cottonwood foliage to levels indicating a sufficient supply of this essential element.

Continued research will investigate the long term effects of winter-cropping on cottonwood production. For the present, it appears that winter-cropping is quite compatible with cottonwood plantation management. By adhering to fertilizer recommendations based on soil tests and yield goals for the particular crop grown, growth of agronomic crops should not interfere with sound management of the cottonwood trees.

Recommendations

(1) Use cuttings at least four-feet long. This helps insure penetration to reservoirs of stored moisture, thereby greatly enhancing survival and growth of the trees.

(2) After taking cuttings from the nursery, soak them in fresh water prior to storage and again prior to planting.

(3) Cull diseased and insect-infested cuttings from all planting material.

(4) Plant cuttings in late winter so that roots can begin growth prior to leaf flush.

(5) Provide protection from cattle, insects, fire, and disease if necessary.

(6) Plant winter varieties of forage crops which mature early in the growing season. May 1-15 maturation of the forage crop will reduce competition of the crops with the cottonwood trees.

(7) Plant crop varieties suited to the climate and soils of the area.

(8) If fall and spring harvests of the forage crop are planned, plant in mid-September for maximum forage yields and increase the amounts of fertilizer applied at seeding time.

(9) Follow fertilizer recommendations of a soil testing laboratory; base applications of nitrogen on a particular yield goal as recommended in extension fertilizer bulletins.

Private landowners can plan now to capitalize on a wood market which is expected to double by the year 2000. Intercropping provides immediate benefits in the form of valuable winter forage with the possibility of producing high-quality stands of cottonwood trees.

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APPENDIX

ANALYSIS OF VARIANCE TABLES

TABLE X

SUMMARY OF SOIL TESTING RESULTS
FOR IDABEL SILT LOAM*

Depth (in.)	Percent					lbs/ac				
	Sand	Silt	Clay	OM	pH	Mg	Ca	K	P	CEC (meq/100gm)
0-6	34	43	23	1.62	7.9	505	5085	377	35	23.0
6-12	36	49	15	0.67	8.1	405	4937	255	14	23.2
12-18	35	49	16	0.55	8.2	330	5212	260	7	25.7
18-24	44	41	15	0.45	8.2	317	5192	242	10	14.4
24-30	47	41	12	0.37	8.3	262	4600	207	11	17.6
30-36	50	38	12	0.32	8.2	252	4582	200	10	25.1
36-42	60	31	9	0.20	8.3	220	4097	153	7	17.2
42-48	65	25	10	0.22	8.3	232	4135	149	10	14.1
48-54	59	20	21	0.45	8.2	367	5190	233	8	20.5

* Each value in the table is the mean of four soil samples.

TABLE XI

SUMMARY OF SOIL TESTING RESULTS FOR
OKLARED VERY FINE SANDY LOAM*

Depth (in.)	Percent Sand	Silt	Clay	OM	pH	lbs/ac Mg	Ca	K	P	CEC (meq/100gm)
0-6	52	39	9	1.20	8.1	187	4375	257	37	13.3
6-12	65	28	7	0.30	8.4	155	3827	125	10	9.1
12-18	71	23	6	0.20	8.4	120	3695	105	9	7.9
18-24	74	21	5	0.17	8.4	110	3425	97	9	7.8
24-30	77	20	3	0.10	8.4	127	3360	77	10	8.3
30-36	77	17	6	0.12	8.4	95	3150	90	10	6.9
36-42	80	17	3	0.10	8.4	90	2728	75	10	6.2
42-48	54	39	7	0.22	8.3	151	4105	127	10	9.9
48-54	57	31	12	0.30	8.4	220	4372	157	10	13.4

* Each value in the table is the mean of four soil samples.

TABLE XII

ANALYSIS OF SOIL MOISTURE

Source	df	MS	F	Observed Significance Level
Soil Type [1]	1	54.95	9.49	0.0217
Cultural Treatment [1,2]	2	2.35	0.41	0.6836
Soil Type x Cultural Treatment [1]	2	0.28	0.05	0.9533
Plot (Soil Type, Cultural Treatment)	6	5.79	4.34	0.0029
Date [3]	5	22.28	16.68	0.0001
Soil Type x Date [3]	5	5.36	4.01	0.0066
Cultural Treatment x Date [3]	10	0.51	0.38	0.9448
Soil Type x Cultural Treatment x Date [3]	10	0.14	0.11	0.9996
Plot x Date (Soil Type, Cultural Treatment)	30	1.34	4.38	0.0001

[1] Plot (Soil Type, Cultural Treatment) used as an error term.

[2] Cultural Treatments are defined on page 32.

[3] Plot x Date (Soil Type, Cultural Treatment) used as an error term.

TABLE XIII

ANALYSIS OF TREE SURVIVAL

Source	df	MS	F	Observed Significance Level
Soil Type[1]	1	21.78	37.77	0.0009
Cultural Treatment[1]	2	5.64	9.79	0.0129
Soil Type x Cultural[1] Treatment	2	3.60	6.25	0.0341
Plot (Soil Type, Cultural Treatment)	6	0.58	4.37	0.0003
Clone[2]	2	0.16	0.19	0.83
Soil Type x Clone[2]	2	0.16	1.94	0.19
Cultural Treatment x Clone[2]	4	0.10	1.24	0.34
Soil Type x Cultural Treatment x Clone[2]	4	0.46	5.67	0.009
Plot x Clone (Soil Type, Cultural Treatment)	12	0.08	0.62	0.83
Residual	540	0.14	5.88	0.0001

[1]Plot (Soil Type, Cultural Treatment) used as an error term.

[2]Plot x Clone (Soil Type, Cultural Treatment) used as an error term.

TABLE XIV

ANALYSIS OF TREE HEIGHT

Source	df	MS	F	Observed Significance Level
Soil Type[1]	1	147.82	239.39	0.0001
Cultural Treatment[1]	2	50.86	82.37	0.0001
Soil Type x Cultural Treatment[1]	2	19.93	32.27	0.0001
Plot (Soil Type, Cultural Treatment)	6	15.54	25.16	0.0001
Clone[2]	2	0.22	0.15	0.86
Soil Type x Clone[2]	2	0.70	0.48	0.63
Cultural Treatment x Clone[2]	4	0.68	0.47	0.76
Soil Type x Cultural Treatment x Clone[2]	4	0.71	0.48	0.75
Plot x Clone (Soil Type, Cultural Treatment)	12	1.46	2.36	0.0063
Residual	366	0.63	10.00	0.0001

[1]Plot (Soil Type, Cultural Treatment) used as an error term.

[2]Plot x Clone (Soil Type, Cultural Treatment) used as an error term.

TABLE XV

ANALYSIS OF FOLIAR NITROGEN

Source	df	MS	F	Observed Significance Level
Group [1,2]	3	0.413	82.56	0.0022
Plot (Group)[2]	3	0.005	0.75	0.5609
Clone[2]	2	0.006	0.95	0.4381
Group x Clone[2]	6	0.061	1.52	0.3109
Plot x Clone (Group)	6	0.007		

[1]Group represents the four treatment-soil type combinations described below:

(1) rye-vetch intercropping on the Oklared very fine sandy loam site

(2) oats intercropping on the Oklared very fine sandy loam site

(3) clean-disking on the Oklared very fine sandy loam site

(4) clean-disking on the Idabel silt loam

TABLE XVI

ANALYSIS OF CROP PRODUCTION

Source	df	MS	F	Observed Significance Level
Soil Type[1]	1	86830851285022240	30.87	0.0001
Cultural Treatment[1]	1	57272854342139296	20.36	0.0001
Soil Type x Cultural[1] Treatment	1	12159002141814080	4.32	0.0440
Plot (Soil Type, Cultural Treatment)	4	8817798631783456	0.78	0.5424

[1]Plot (Soil Type, Cultural Treatment) used as an error term.

TABLE XVII

PRECIPITATION DATA SUMMARY FOR 1978

Month	Precipitation Amounts (in.) 1978	Normal	Deviation from Normal
JAN	3.24	3.41	-0.17
FEB	2.51	3.93	-1.42
MAR	3.85	4.48	-0.63
APR	3.48	5.71	-2.23
MAY	4.46	6.42	-1.96
JUN	0.94	3.45	-2.51
JUL	1.57	3.57	-2.00
AUG	0.74	2.70	-1.96
SEP	3.03	4.03	-1.00
OCT	1.92	3.56	-1.64
NOV	11.76	3.47	+8.29
DEC	3.17	3.40	-0.23
	40.67	48.13	7.46

Source: National Oceanic and Atmospheric Administration. <u>Climatological Data for Oklahoma</u>. United States Department of Commerce, National Climatic Center, Asheville, N.C., Vol. 86-7, 1977-8.

TABLE XVIII

TEMPERATURE DATA SUMMARY
FOR FALL AND WINTER
OF 1977 and 1978*

Month	Average (°F)	Departure From Normal
	— 1977 —	
OCT	64.9	0.00
NOV**	--	--
DEC	43.8	-1.3
	— 1978 —	
JAN	31.2	-12.0
FEB	34.7	-12.2
MAR	51.5	-2.0
APR	64.1	0.4
MAY	70.2	-0.5

* As recorded at Idabel, OK weather station.
** No data reported for this month

Source: National Oceanic and Atmospheric Administration. Climatological Data for Oklahoma. United States Department of Commerce, National Climatic Center, Asheville, N.C., Vol. 86-7, 1977-8.

TABLE XIX

FACTORS FOR METRIC TO U.S. OR U.S. TO METRIC CONVERSION

LENGTH

U.S. TO METRIC	METRIC TO U.S.
1 inch = 25.40 millimeters	1 millimeter = 0.03937 inch
1 inch = 2.540 centimeters	1 centimeter = 0.3937 inch
1 foot = 30.480 centimeters	1 meter = 39.37 inches
1 foot = 0.3048 meter	1 meter = 3.2808 feet
1 yard = 91.440 centimeters	1 meter = 1.0936 yards
1 yard = 0.9144 meter	1 kilometer = 0.62137 mile
1 mile = 1.609 kilometers	

AREA

U.S. TO METRIC	METRIC TO U.S.
1 sq. inch = 645.16 sq. millimeters	1 sq. millimeter = 0.00155 sq.inch
1 sq. inch = 6.4516 sq. centimeters	1 sq. centimeter = 0.1550 sq.inch
1 sq. foot = 929.03 sq. centimeters	1 sq. meter = 10.7640 sq.feet
1 sq. foot = 0.0929 sq. meter	1 sq. meter = 1.196 sq.yards
1 sq. yard = 0.836 sq. meter	1 sq. hectometer = 2.471 acres
1 acre = 0.4047 sq. hectometer	1 hectare = 2.471 acres
1 acre = 0.4047 hectare	1 sq. kilometer = 0.386 sq.mile
1 sq. mile = 2.59 sq. kilometers	

MASS (Weight)

U.S. TO METRIC	METRIC TO U.S.
1 ounce (dry) = 28.35 grams	1 gram = 0.03527 ounce
1 pound = 0.4536 kilogram	1 kilogram = 2.2046 pounds
1 short ton (2000 lb.)= 907.2 kilograms	1 metric ton = 2204.6 pounds
1 short ton (2000 lb.)= 0.9072 metric ton	1 metric ton = 1.102 tons (short)

TABLE XX

DOLLAR VALUES FOR YIELDS OF THE INTERTILLED FORAGE CROPS

Crop Species	Yield[1]	Value[2]
	— Idabel Silt Loam —	
Elbon rye-hairy vetch	4.84	$ 266.20
Nora Oats	2.35	129.25
	— Oklared Very Fine Sandy Loam —	
Elbon rye-hairy vetch	1.95	107.25
Nora Oats	1.04	57.20

[1]Units are in metric tons of oven dry weight per hectare.

[2]Computed for a market value of $55 per metric ton.

VITA[2]

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