COTTONWOOD SITE EVALUATION

IN OKLAHOMA

By

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CHAPTER I

INTRODUCTION

Eastern cottonwood (Populus deltoides Bartr.), one of the fastest-growing commercial tree species in the United States, is found on alluvial soils along streams and on bottomlands over most of the eastern United States (Figure 1). It ranges from southern Michigan westward to eastern South Dakota, southward through east Texas, eastward along the Gulf Coast to northwestern Florida, into Georgia, South Carolina and up the Atlantic Coast. Eastern cottonwood rarely occurs in the Appalachian Mountains and has scattered occurrence in some of the New England States. The most productive areas suited for the commercial production of eastern cottonwood are located along the Mississippi River and its major tributaries from southern Missouri to Louisiana (26).

Eastern cottonwood will grow on a wide variety of soils, ranging from loamy sands to heavy clays, but it grows best on moist, well-drained, medium textured sandy loams or silt loams on the flood plains of rivers. One of the most critical properties of a good cottonwood site is a continuous supply of moisture in the upper part of the profile throughout the growing season. Sandy loam or silt loam-textured soils are capable of holding ample soil moisture needed for good cottonwood growth. Unlike heavy clay soils, they contain enough coarse-sized material for good internal drainage. Cottonwood also requires a soil

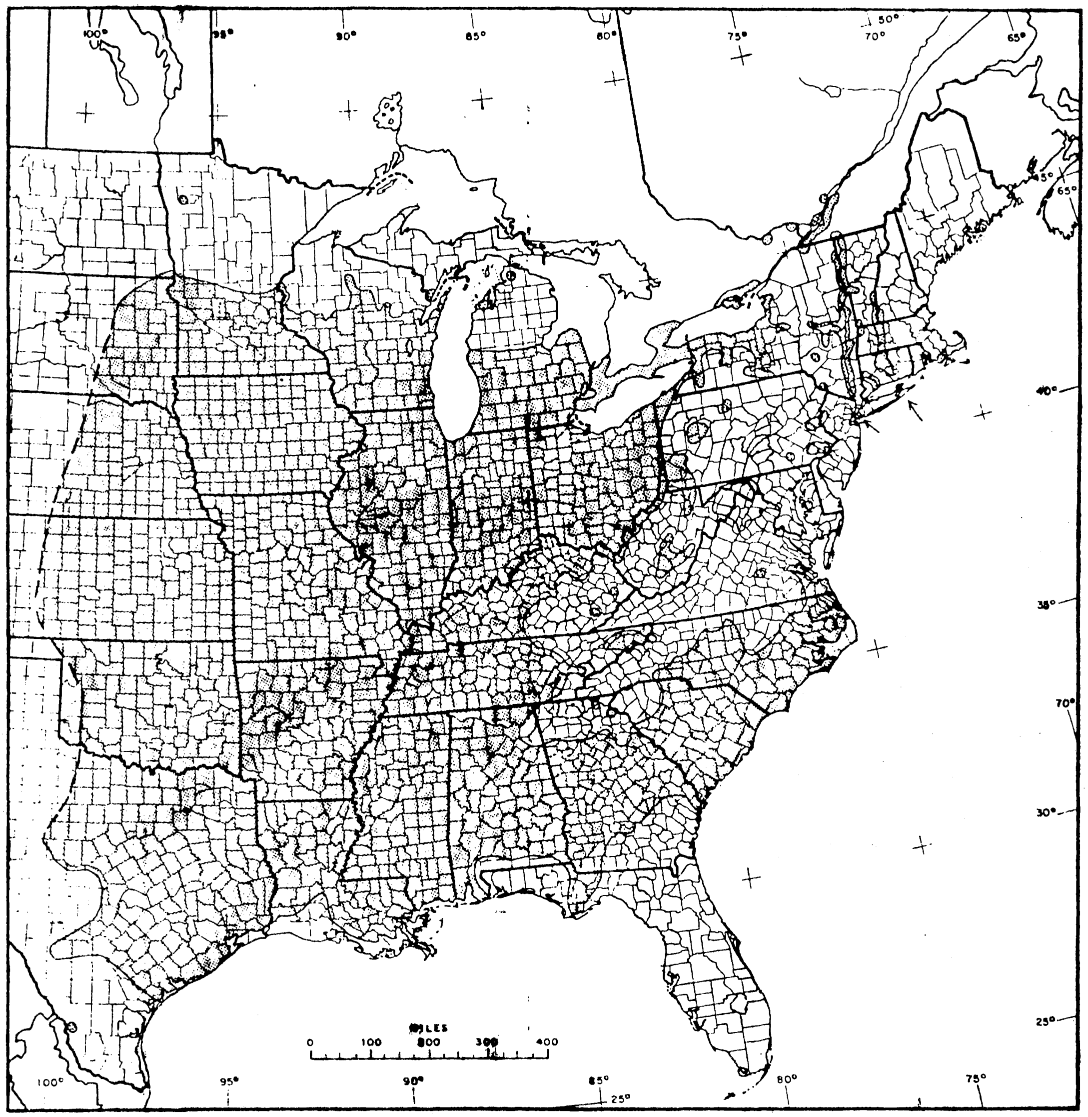

Figure 1. Natural Range of Eastern Cottonwood (Populus deltoides Bartr.). (Reprinted from U.S.D.A., Forest Service, American Woods Series FS-231.)

that is high in fertility. The silt loam soils usually do not require fertilizer to produce good growth of cottonwood.

In the Lower Mississippi River Valley, the most productive cottonwood sites are located on the batture lands (areas between the levee and the river). On good sandy loam or silt loam soils on these lands, eastern cottonwood can attain heights greater than 120 feet in 30 years. Some of the soil series in the batture lands capable of supporting good cottonwood growth include Commerce silt loam, Robinsonville very fine sandy loam, Crevasse loamy sand and Mhoon silt loam. Sharkey clay and Alligator clay are examples of soils that produce poor or below average growth.

Eastern cottonwood is a highly intolerant pioneer species. Natural stands of cottonwood normally become established only on newly-formed land along the banks of major rivers. With increasing stream stabilization and the rising demand for agricultural lands, the acreage of natural cottonwood stands has been declining. Contrarily, the demands for cottonwood and other hardwood species have been steadily increasing. Although there is very little specific information on the demand for cottonwood products, the Forest Service, U. S. Department of Agriculture, predicts that by the year 2000 the demand for hardwood lumber will have increased by 50 percent (37). Hardwood plywood demands are expected to double and the demands for hardwood pulpwood will quadruple (29).

The rising demand for cottonwood, coupled with the depletion and nonrenewal of natural stands, has given forest landowners the incentive to establish cottonwood plantations. As of 1976, there were 40,000 acres of cottonwood plantations in the Lower Mississippi River Valley (9). Most (82 percent or 33,000 acres) of the plantations are from 1 to 10 years in age and 70 percent of the owners plan to plant more cottonwood in the next five years than they did in the last five years. All planters used some improved cottonwood clones. This indicates that the interest in cottonwood plantation establishment is growing, and with this growing interest, more research is needed to provide future planters with the information they need for growing cottonwood commercially.

Although limited cottonwood research has been accomplished in Oklahoma, early results (38, 39) reveal that some soils in the state may have the potential to produce excellent growth of cottonwood. Intensive culture of genetically-improved cottonwood may some day turn poorly utilized sites along the major rivers of the state into productive and useful areas for timber production and related activities.

This thesis reports the early results of site evaluation studies for cottonwood plantations in Oklahoma.

CHAPTER II

LITERATURE REVIEW

The importance of establishing and managing plantations and natural stands of eastern cottonwood has been recognized by foresters since the early part of this century. Some of the basic principles of cottonwood management devised by Williamson (43) over 60 years ago are still being used today.

Natural reproduction of cottonwood occurs only when strict site conditions are met. The seed has to reach a moist, bare mineral seedbed within a few days after falling from the tree or it will not germinate. Because of the short length of time that the seed is viable, natural regeneration of cottonwood is usually limited to sandbars and newly-deposited soils along the banks of large rivers.

Johnson (15) reported on an attempt to duplicate natural conditions for cottonwood reproduction in existing stands along the Mississippi River by mechanically removing the vegetation and litter. Strips of various widths were cleared of all vegetation to encourage natural regeneration of cottonwood from adjacent seed trees. After three years, the stocking on the test areas ranged from 70 to 85 percent on bulldozed strips to 25 percent on strips plowed with a fire plow. The results of this study indicated that the surface soil must be removed, not merely turned over, for successful natural regeneration of cottonwood. Burkhardt (8), reporting on the use of a giant plow to stimulate natural reproduction of cottonwood, stated that initial results indicate sandy sites can be adequately stocked by this method at one-third the cost of planting cottonwood cuttings. Although these methods of regeneration are less costly than planting cuttings or seedlings, they are limited in their application and are seldom used for cottonwood establishment. The reasons are they do not allow the use of genetically improved clonal material, and the resulting stands cannot be cultivated for weed control.

Plantation establishment is the most widely practiced method of regenerating cottonwood for commercial production, in spite of the larger capital investment required. To insure successful establishment, several procedures must be followed.

One of the most critical decisions a prospective cottonwood planter has to make is the selection of a productive site for the plantation. The best soils for cottonwood plantations are medium-textured soils, such as sandy loams or silt loams that are well aerated and will receive ample moisture throughout the growing season from a water table fairly close to the surface or from lateral movement of water through the soil (7, 10, 21, 24, 25, 26, 27). Broadfoot (4) has stated that the optimum depth to the water table is 24 inches, and that the early growth and survival of cottonwood is strongly influenced by the amount of available water in the soil. Cottonwood also requires a soil that contains a good supply of nutrients, especially nitrogen, phosphorus, and potassium (11, 28, 42). Several authors (3, 7, 22, 26) have stated that deep, sandy ridges or former sandbars are not suitable for cottonwood growth because they are relatively infertile and become excessively dry during the latter part of the growing season.

McKnight (26) pointed out that for maximum growth, cottonwood plantations should be located on fertile, alluvial soils in the flood plains of large rivers such as the Mississippi, Red, Arkansas or the St. Francis. Broadfoot (3) has suggested two methods for classifying various soils in the Lower Mississippi Valley for cottonwood production. One method is based on the physical properties of the soil, such as texture, internal drainage and the inherent moisture conditions. Identification of a particular soil according to standard soil series is the key to the other method of site classification.

Other important criteria to consider in site selection include accessibility, size and the possibility of flooding. Cottonwood one year of age or older can withstand prolonged flooding, if the water is cool and moving, but newly-established cottonwood plantations are likely to be damaged. Kennedy and Krinard (18), reporting on the effects of the Mississippi River flooding in 1973, stated that planted cottonwood survived in good condition, if the trees were not completely submerged by the flood waters. Hosner (13, 14) reported that upon flooding, cottonwood seedlings developed adventitious roots and survived eight days of complete inundation but recovered slowly. Maisenhelder and McKnight (23) found that seedlings may survive better than unrooted cuttings if the site is subjected to flooding shortly after planting.

Intensive site preparation is also required to insure successful establishment and early growth of a cottonwood plantation. Heavily wooded sites should be cleared of all vegetation and the debris either piled or windrowed. The windrowed slash can be positioned around the perimeter of the planting site to form a deer barrier, or it may be burned in place (26). According to Thielges, et al. (36), ashes from the burned slash can improve cottonwood growth by increasing the availability of phosphorus, potassium, calcium and magnesium in the soil.

McKnight (26) has recommended plowing old field sites to a depth of 16 to 20 inches before planting to break up any plow pans that may have developed from past agricultural operations. Broadfoot and Bonner (5) reported that compacted soil is detrimental to the early growth of young cottonwood plantations. Their results have indicated that cottonwood grows and develops best in soils at a bulk density of 1.4 gm./cc, while soils with bulk density of 1.6 gm./cc may cause greatly reduced growth of cottonwood.

Baker and Blackmon (1) found that summer fallowing and herbicide application improved survival and growth of planted cottonwood on old field sites by 17 percent and 3.4 feet in height, respectively.

Cottonwood plantations can be established by planting dormant, unrooted cuttings or seedlings. Most commercial planters prefer unrooted cuttings because of their ease in handling, storage and planting. Planting 20-inch cuttings 18 inches deep in the soil is the most widely-accepted method of plantation establishment in the Lower Mississippi Valley. However, several researchers have discovered that deep planting of long cuttings or rooted seedlings may increase survival and growth of cottonwood on problem sites, especially on very sandy soils that tend to be dry.

Kaszkurewicz (16) has developed guidelines for deep planting of cottonwood by using a tractor-mounted auger to bore the planting holes. His results showed that deep planting on a loamy sand in Louisiana increased survival by 38 percent and first-year height growth by 1.1 feet. White (41) described a method of deep planting cottonwood which utilizes ordinary farm equipment that could be used by private, non-industrial planters. Minckler and Woerheide (30) reported the successful establishment and early growth of deep-planted cottonwood in southern Illinois. Phares and White (32) noted that deep-planted cottonwood cuttings survived better than standard cuttings, but that the standard cuttings outgrew slightly the deep-planted cuttings on loamy sands in northeastern Missouri and southeastern Iowa.

Regardless of the planting method used to establish cottonwood plantations, the plantation has little chance of success without proper weed control. According to Maisenhelder (22), it is essential to cultivate a cottonwood plantation during its first year. Cultivation not only eliminates weeds, but it also conserves soil moisture, provides good aeration, and incorporates organic matter into the soil. Krinard (20) worked with different methods of weed control and concluded that cultivation is still the most effective method of controlling weeds during the first year of growth. Data from Crown Zellerbach's Fitler Managed Forest has shown that cottonwood plantations will produce 31 cubic feet of wood per acre per year if the plantation is cultivated the first year of a 12-year rotation. Cultivation during the second and third year will increase growth of planted cottonwood to 222 and 300 cubic feet of wood per acre per year respectively. Kennedy (17) stated that extreme care must be taken to insure that the cuttings are not covered with soil nor damaged during cultivation. According to his results, the survival of cuttings completely covered by cultivation was 60 percent as compared to 90 percent in properly cultivated plots.

Woessner (44) reported that Trifluralin applied at the rate of one pound of active ingredient per acre gives good weed control only for the first part of the growing season. Other herbicides that satisfactorily control weeds in hardwood plantations include atrazine, simazine, or a mixture of the two (2, 12, 19). Bey and Williams (2) and Brynes, et al. (6) reported that dalapon applied at a rate of 5 to 10 pounds per acre effectively controls many annual and perennial grasses in hardwood plantings.

Cottonwood research in Oklahoma is a relatively new field. Walker (38) reported on the early development of a natural cottonwood stand in central Oklahoma. Stand and stock tables for natural stands were prepared by Walker (39, 40) from data collected from this stand. His studies indicate that to recover maximum wood volume, thinnings must be made at relatively short intervals of two or three years.

Posey, et al. (33) sampled the variation in cottonwood stands along the major rivers in Oklahoma and discovered that cottonwood from eastern Oklahoma has longer fibers, lower specific gravity, faster growth, straighter stems, fewer limbs, fewer sprouts per stump and is more susceptible to drought than trees from western Oklahoma. The cottonwood studies in Oklahoma have indicated a promising future for this tree as a commercial species in the state, but more research work is required to fully identify its potential. Additional research is needed in developing and testing cottonwood clones capable of increasing commercial timber production, and in selecting favorable soils for cottonwood plantations.

The study reported in this thesis is concerned with site selection and establishment of cottonwood plantations in Oklahoma. This is the first reported study in Oklahoma which examines the potential of selected soils for the commercial production of cottonwood.

CHAPTER III

OBJECTIVES OF THE STUDY[1]

This study was undertaken with the following goals in mind: (a) identification of commercial quality cottonwood sites in Oklahoma and (b) development of procedures for growing cottonwood on such sites in Oklahoma.

Identification of commercial quality cottonwood sites in Oklahoma was accomplished by the use of soil surveys of selected counties in Oklahoma in conjunction with a soil sampling and testing program. Trial plantings were established in southeastern and central Oklahoma to develop procedures for growing cottonwood in the state and to further test the production capability of various soils.

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[1]This study presents the preliminary results of the long-term project MS-1572, Cottonwood Site Identification and Production in Oklahoma.

CHAPTER IV

A STUDY OF POTENTIAL COTTONWOOD SITES

Analysis of Seven Alluvial Soils

In initiating a study of potential sites for cottonwood plantations, it was logical that the most productive soils in the state should be considered first. Therefore, seven alluvial soils located on the Red River flood plain in southeastern Oklahoma were selected for study (Table I). These seven river-deposited soils occupy approximately three percent (53,000 acres) of the total land area in McCurtain and Choctaw counties and are highly suited for agricultural crops as well as for timber production. All of the soils, except the Garton silt loam, belong to the Severn-Oklared-Gallion soil association. Garton silt loam is included in the Pledger-Roebuck-Redlake association.

The soils of the Severn-Oklared-Gallion association are characterized as deep, nearly level to very gently sloping, well-drained, loamy soils on the flood plains and terraces of the Red River (34). These soils weathered from loamy alkaline sediments under a cover of forest vegetation. The major soils in this association are Severn, Oklared and Gallion. The minor soils are Caspiana, Coushatta and Idabel. Most of these soils are used for cultivated crops and improved pasture, but they are capable of producing excellent growth of bottomland hardwoods, such as sycamore, willow, ash and cottonwood, with no severe

TABLE I

SOILS SELECTED AS POTENTIAL COTTONWOOD SITES*

Soil Series	Family	Sub-Group	Association
Caspiana loam	Fine-silty, mixed, thermic	Typic Argiudoll	Severn-Oklared-Gallion
Coushatta silty clay loam	Fine-silty, mixed, thermic	Fluventic Eutrochrept	Severn-Oklared-Gallion
Gallion very fine sandy loam	Fine-silty, mixed thermic	Typic Hapludalf	Severn-Oklared-Gallion
Garton silt loam	Fine, mixed, thermic	Aquic Argiudoll	Pledger-Roebuck-Redlake
Idabel silt loam	Coarse-loamy, mixed thermic	Fluventic Eutrochrept	Severn-Oklared-Gallion
Oklared very fine sandy loam	Coarse-loamy, mixed, calcareous, thermic	Typic Udifluvent	Severn-Oklared-Gallion
Severn very fine sandy loam	Coarse-loamy, mixed, calcareous, thermic	Typic Udifluvent	Severn-Oklared-Gallion

* Information taken from Soil Survey of McCurtain County, as published by the Soil Conservation Service, U.S. Department of Agriculture.

management problems. The main concerns for the management of these soils are to maintain soil structure and fertility.

The soils in the Pledger-Roebuck-Redlake association are deep, nearly level, moderately well-drained, clayey soils on the flood plains of the Red River (34). These soils were formed under a cover of trees and weathered from clayey and loamy sediments. The Garton series is considered a minor soil in this association. The soils of this association are used mainly for the production of cultivated crops. The Garton series, like the soils of the Severn-Oklared-Gallion association, is capable of producing good bottomland hardwood growth with no severe management limitations. The main concerns of management of these soils are maintenance of surface drainage, good soil structure and protection from flooding.

Each of the seven soils selected as potential cottonwood sites was studied from profiles examined in four locations, roughly every ten to twenty miles along the Red River flood plain. Samples were taken from each soil profile every six inches to a depth of 54 inches and tested for the following:[1]

1. Percent sand
2. Percent silt
3. Percent clay
4. Percent organic matter
5. Calcium (lbs/ac)
6. Magnesium (lbs/ac)
7. Phosphorus (lbs/ac)
8. Potassium (lbs/ac)
9. pH
10. Cation exchange capacity (meq/100gm)

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[1]Soil testing was done at the Oklahoma State University Agronomy Department soil testing laboratories.

Total nitrogen was to be determined for the soil samples, but early results indicated that it was very low and further testing was discontinued.

Field data indicate that Idabel silt loam is perhaps the best soil for cottonwood production in the Red River flood plain. A natural stand on this soil in McCurtain County, Oklahoma, had a site index of 120 (120 feet of height growth in 30 years) and contained 52,000 board feet per acre. This is comparable to growth on Commerce silt loam, one of the best cottonwood soils in the Lower Mississippi Valley.

The Idabel silt loam soil possesses the important physical and chemical properties necessary for good cottonwood growth. The mean percentages of silt and clay in the profile decrease with depth (0 to 54 inches) from 49 percent to 20 percent for silt and from 23 percent to nine percent for clay (Figure 2). Conversely, the mean percentage of sand increases from 34 percent at the zero to six-inch depth to 65 percent at the 48 to 54-inch depth. Analysis of variance indicated that the sand, silt and clay fractions do not vary significantly with depth in the profile (Table II).[2] The mean percentage of silt varies significantly between the locations of the four soil samples, while the mean percentages of sand and clay show little variation. The higher proportion of silt and clay in the upper part of the profile is needed to hold ample soil moisture at the root zone throughout the growing season, while the high sand content in the lower part of the profile allows good internal drainage. The pH of the soil ranges from 7.9 at the zero to six-inch depth to 8.2 at the 48 to 54-inch depth and varies

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[2]Tests of significance were conducted at the 0.01 level. Throughout the thesis, the word "significant" is used in a statistical sense.

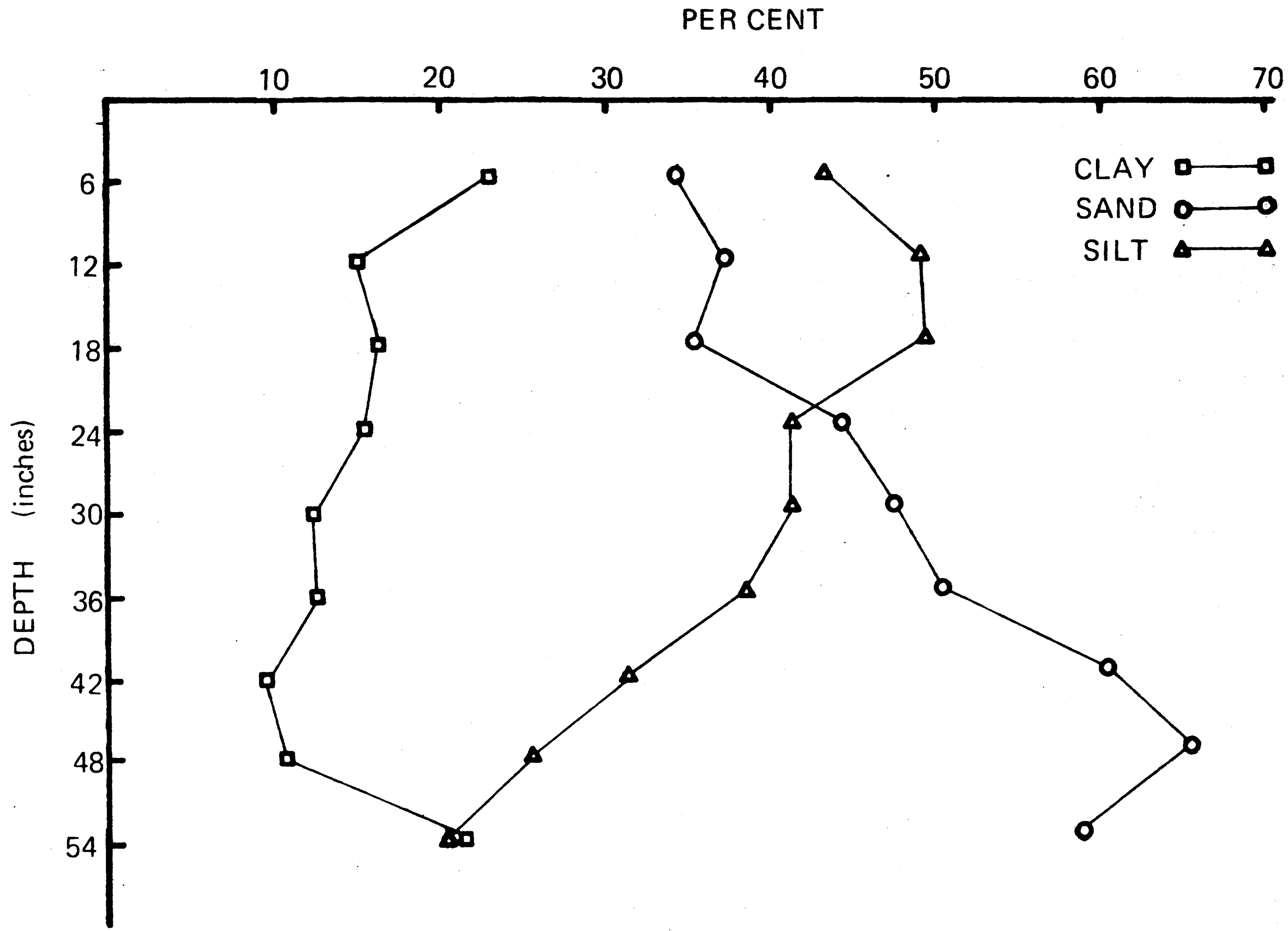

Figure 2. Sand, Silt and Clay Fractions of Idabel Silt Loam.

TABLE II

ANALYSIS OF VARIANCE FOR
IDABEL SILT LOAM*

Variable	Source Of Variation			
	Total (df = 35)	Location (df = 3)	Depth (df = 8)	Error (df = 24)
Sand	548.4571	1105.3333	549.5000	478.5000
Silt	283.8857	925.3333	411.6250	161.1250
Clay	109.3682	103.5185	87.7361	177.3102
pH	0.0317	0.0313	0.0628	0.0214
Organic Matter	0.2213	0.2699	0.7500	0.0391
Calcium	3240378.02	4826202.78	798181.94	3856215.28
Magnesium	35492.3016	7647.2222	34656.9444	39251.3889
Potassium	14862.2857	34607.8519	18589.7500	11151.6019
Phosphorus	187.5516	377.9537	310.5694	122.7454
CEC	98.1248	468.0890	79.0490	58.2378

* Each value in the table is the "mean square" for that particular source of variation.

significantly with depth but does not vary significantly among locations (Table III). The cation exchange capacity (CEC), ranging from 14 meq/100gms to 26 meq/100gms, varies significantly between locations but shows no significant variation due to depth. The mean percentage of organic matter, decreasing with depth, varies significantly between locations and depths. Potassium, calcium and magnesium show little variation among locations or depths. Potassium and magnesium decrease with increasing depth throughout the rooting zone of the soil. Depth has very little effect on the mean calcium content of the soil, while phosphorus decreases with depth.

Oklared very fine sandy loam contains less silt and clay throughout most of its profile than the Idabel series. The mean percentages of sand, silt and clay in the profile are shown in Figure 3. Silt decreases from 39 percent at the zero to six-inch depth to 17 percent at the 36 to 42-inch depth and then increases to 39 percent at the 42 to 48-inch depth. The mean clay content, following generally the same pattern as the silt content, ranges from nine percent at the zero to six-inch depth to 12 percent at the 48 to 54-inch depth. The mean sand, silt and clay fractions of the soil show no significant variation due to depth in the profile (Table IV). The mean sand and silt content of the soil varies significantly among locations, while the mean clay content does not.

The mean pH of the Oklared series ranges from 8.1 at the zero to six-inch depth to 8.4 at the 48 to 54-inch depth and varies significantly between locations and depths (Table V). The mean phosphorus, potassium, organic matter, magnesium and calcium levels do not vary significantly with locations or depths. The CEC varies significantly among locations

TABLE III

SUMMARY OF SOIL TESTING RESULTS
FOR IDABEL SILT LOAM*

Depth (in.)	Percent Sand	Percent Silt	Percent Clay	Percent OM	pH	lbs/ac Mg	lbs/ac Ca	lbs/ac K	lbs/ac 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.

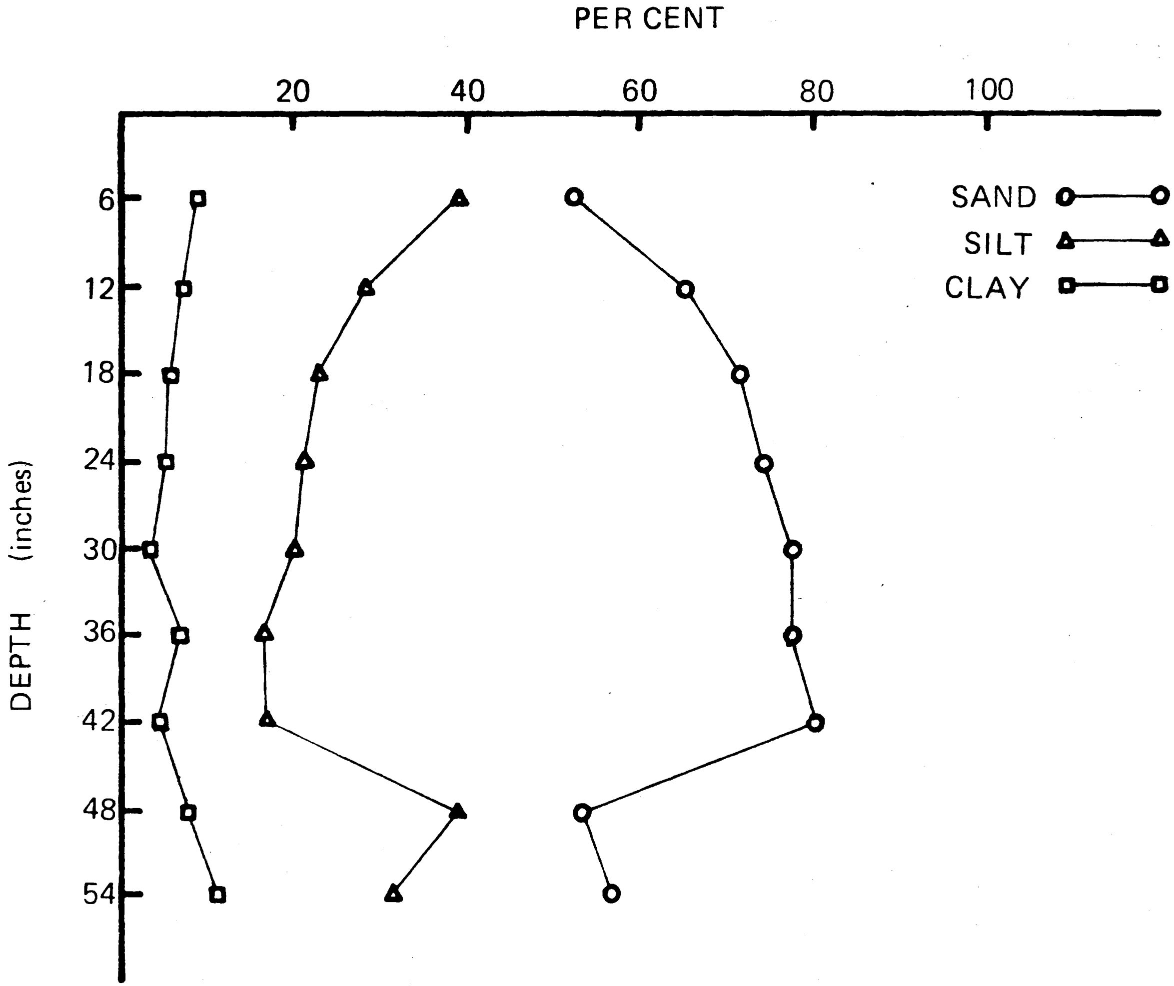

Figure 3. Sand, Silt and Clay Fractions of Oklared Very Fine Sandy Loam.

TABLE IV

ANALYSIS OF VARIANCE FOR OKLARED
VERY FINE SANDY LOAM*

Variable	Source of Variation			
	Total (df = 35)	Location (df = 3)	Depth (df = 8)	Error (df = 24)
Sand	473.3143	1964.5519	477.0000	284.1852
Silt	342.1206	1878.2222	304.5278	162.6389
Clay	43.1587	39.5185	34.6944	46.4351
pH	0.0294	0.1841	0.0407	0.0063
Organic Matter	0.1723	0.1721	0.4759	0.0711
Calcium	1295310.71	3272232.41	1205006.25	1078296.99
Magnesium	8099.2857	10869.4444	7706.2500	7884.0278
Potassium	7955.587	15291.6667	12869.4444	5400.0000
Phosphorus	188.9016	247.2593	328.1319	135.1967
CEC	33.1302	198.1267	96.9118	14.5785

* Each value in the table is the "mean square" for that particular source of variation.

TABLE V

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

Depth (in.)	Percent				pH	lbs/ac				CEC (meq/100gm)
	Sand	Silt	Clay	OM		Mg	Ca	K	P	
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.

but not depths. Calcium, magnesium, potassium and the CEC decrease with increasing depth to the 42 to 48-inch depth and then increase slightly. Phosphorus decreases to the 6 to 12-inch depth and then remains constant throughout the profile.

The Severn very fine sandy loam series varies significantly between locations and depths in the mean percentage of sand and silt in the profile (Table VI). Like the Oklared soil, the Severn soil contains less silt and clay throughout most of its profile than the Idabel soil. The mean percentage of silt, ranging from 47 percent at the zero to six-inch depth to 18 percent at the 48 to 54-inch depth, declines with depth (Figure 4). The mean percentage of clay also decreases with increasing depth from 17 percent at the zero to six-inch depth to five percent at the 48 to 54-inch depth. Clay does not vary significantly between locations or depths. The mean sand content increases from 32 percent at the zero to six-inch depth to 77 percent at the 48 to 54-inch depth. The mean pH also increases significantly with increasing depth from 7.7 at the zero to six-inch depth to 8.4 at the 48 to 54-inch depth and shows no significant variation among locations (Table VII).

The calcium content of the Severn soil changes very little with depth in the profile, while magnesium, potassium, CEC and the organic matter decrease with increasing depth. Phosphorus decreases from the zero to six-inch depth to the 12 to 18-inch depth and then remains constant throughout the profile. Magnesium shows little variation between locations or depths. Organic matter and phosphorus show significant variation between depths but not locations. Potassium varies significantly between locations only.

TABLE VI

ANALYSIS OF VARIANCE FOR SEVERN
VERY FINE SANDY LOAM*

Variable	Source of Variation			
	Total (df = 35)	Location (df = 3)	Depth (df = 8)	Error (df = 24)
Sand	512.3643	3190.1759	499.3750	181.9676
Silt	321.5897	2485.2129	252.4861	74.1713
Clay	56.2635	59.9629	58.2778	55.1296
pH	0.0616	0.0774	0.1573	0.0278
Organic Matter	0.3250	0.2603	0.8286	0.1653
Calcium	1579659.92	7316506.48	498459.03	1222954.40
Magnesium	26185.0000	6249.0000	22310.2500	22993.5833
Potassium	9633.2540	36936.1110	14348.6111	4648.6111
Phosphorus	95.5516	38.3241	190.5069	71.0532
CEC	117.0572	919.3632	69.0494	32.7716

* Each value in the table is the "mean square" for that particular source of variation.

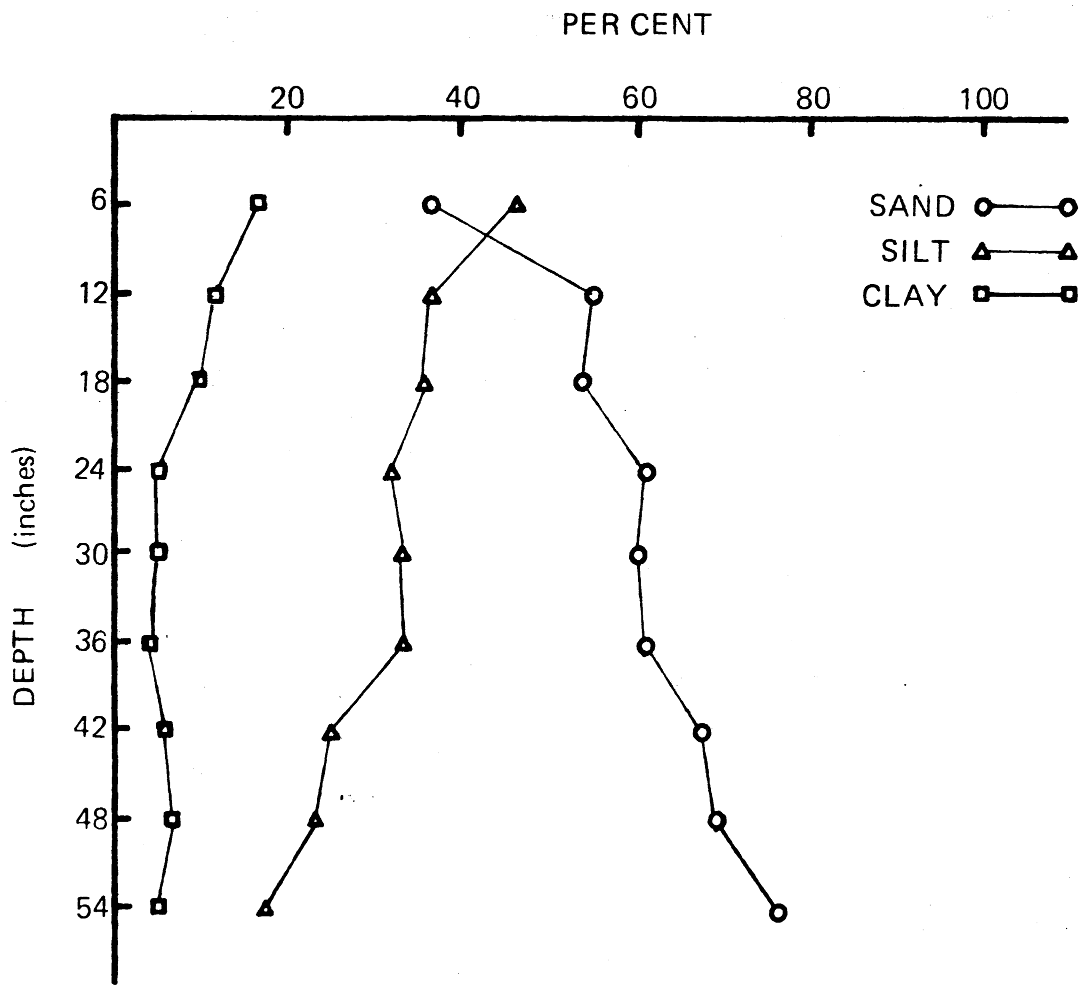

Figure 4. Sand, Silt and Clay Fractions of Severn Very Fine Sandy Loam.

TABLE VII

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

Depth (in.)	Percent Sand	Percent Silt	Percent Clay	Percent OM	pH	lbs/ac Mg	lbs/ac Ca	lbs/ac K	lbs/ac P	CEC (meq/100gm)
0-6	37	47	17	1.55	7.7	359	4690	297	30	21.4
6-12	55	37	12	0.62	8.1	295	3825	167	14	12.0
12-18	54	36	10	0.47	8.1	290	3575	150	11	13.6
18-24	61	33	6	0.17	8.3	177	3687	177	10	11.9
24-30	60	34	6	0.27	8.3	172	3905	137	8	14.0
30-36	61	34	5	0.20	8.3	167	3787	132	11	8.6
36-42	68	26	6	0.17	8.3	172	3720	105	9	9.4
42-48	69	24	7	0.15	8.3	202	3955	125	8	14.4
48-54	77	18	5	0.15	8.4	147	3457	100	9	7.4

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

The sand, silt and clay fractions of the Caspiana loam series, as depicted by Figure 5, show significant variation between locations, but not between depths in the profile (Table VIII). The mean percentage of silt fluctuates between 35 to 45 percent throughout the profile. The mean clay content increases from 17 percent at the zero to six-inch depth to 32 percent at the 24 to 30-inch depth, and then decreases to 27 percent throughout the remainder of the profile. The percentage of sand decreases from 43 percent at the zero to six-inch depth to 27 percent at the 18 to 24-inch depth, and then increases to 40 percent at the 48 to 54-inch depth. The mean pH increases significantly from 6.1 at the zero to six-inch depth to 6.8 at the 48 to 54-inch depth, but shows no significant variation between locations (Table IX).

The Caspiana series contains more potassium and magnesium throughout most of its profile than any of the other soils. The mean magnesium content increases from 640 pounds per acre at the zero to six-inch depth to 1700 pounds per acre at the 24 to 30-inch depth. Potassium increases from 300 pounds per acre at the zero to six-inch depth to 480 pounds per acre at the 24 to 30-inch depth. Magnesium varies significantly among locations and depths, while potassium shows significant variation between locations only.

Calcium, phosphorus and the CEC vary significantly between locations but not between depths. Calcium increases with depth to the 24 to 30-inch depth, then decreases throughout the profile. Phosphorus remains constant in the profile with increases at the 18 to 24-inch depth and the 36 to 42-inch depth. The CEC increases from the upper six inches of the profile to the 6 to 12-inch level, then remains fairly constant to the 48 to 54-inch depth. The percent organic matter

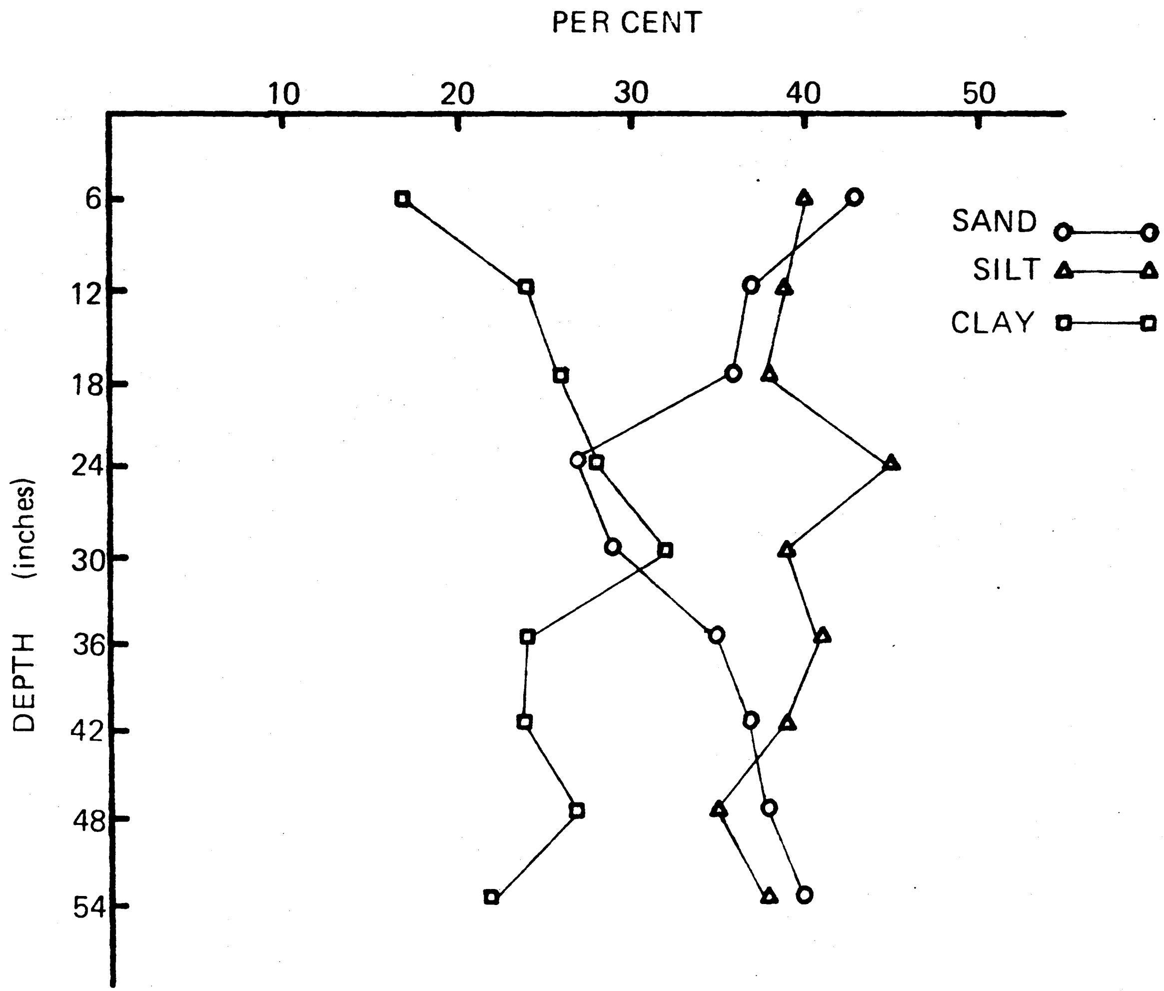

Figure 5. Sand, Silt and Clay Fractions of Caspiana Loam.

TABLE VIII

ANALYSIS OF VARIANCE FOR
CASPIANA LOAM*

Variable	Source of Variation			
	Total (df = 35)	Location (df = 3)	Depth (df = 8)	Error (df = 24)
Sand	258.3706	2062.6944	87.9653	89.6319
Silt	76.9873	465.0000	28.5694	44.6250
Clay	100.5039	641.5833	72.3611	42.2500
pH	0.1081	0.3425	0.1526	0.0639
Organic Matter	0.3837	1.9455	0.7181	0.0770
Calcium	7096634.1	63828465.9	1560906.9	1850397.6
Magnesium	293886.74	1719500.85	371098.61	89947.69
Potassium	91893.075	964344.102	10858.549	9848.206
Phosphorus	751.5016	3179.444	177.3819	639.3819
CEC	429.3140	4228.9648	59.0143	77.7909

* Each value in the table is the "mean square" for that particular source of variation.

TABLE IX

SUMMARY OF SOIL TESTING RESULTS
FOR CASPIANA LOAM*

Depth (in.)	Percent Sand	Percent Silt	Percent Clay	Percent OM	pH	lbs/ac Mg	lbs/ac Ca	lbs/ac K	lbs/ac P	CEC (meq/100gm)
0-6	43	40	17	1.45	6.1	646	2794	297	46	26.1
6-12	37	39	24	1.20	6.6	1037	4367	366	45	35.6
12-18	36	38	26	1.00	6.7	1202	4262	403	47	37.1
18-24	27	45	28	0.77	6.6	1468	4735	452	57	37.2
24-30	29	39	32	0.62	6.5	1714	4885	480	42	32.7
30-36	35	41	24	0.45	6.6	1400	4402	430	38	34.8
36-42	37	39	24	0.40	6.7	1281	3817	402	54	36.9
42-48	38	35	27	0.35	6.7	1448	3745	389	38	35.8
48-54	40	38	22	0.20	6.8	1376	4215	404	41	29.6

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

decreases significantly with depth and varies significantly between locations.

The Coushatta silty clay loam series contains the highest percentage of silt of the seven soils examined (Figure 6). The mean silt fraction increases from 47 percent at the zero to six-inch depth to 59 percent at the 18 to 24-inch depth and decreases to 40 percent at the 48 to 54-inch depth. The mean clay content is highest in the top 30 inches of the profile and decreases throughout the remainder of the profile. Clay ranges from 29 percent at the zero to six-inch depth to 26 percent at the 24 to 30-inch depth; then to 14 percent at the 48 to 54-inch depth. The mean percentage of sand ranges from 24 percent at the zero to six-inch depth to 46 percent at the 48 to 54-inch depth. Clay content shows little variation while the sand and silt content vary significantly between locations (Table X). The sand content also varies significantly between depths in the profile.

The mean pH, ranging from 7.8 to 8.4 increases with depth in the top 30 inches and remains constant throughout the remainder of the profile (Table XI). The mean percentage of organic matter decreases with increasing depth, with a slight increase at the 30 to 36-inch depth. Phosphorus and potassium follow the same pattern as the organic matter, but an increase occurs at the 18 to 24-inch depth. Magnesium and calcium decrease with depth. The CEC increases in the top six inches of the profile and then decreases with depth with an increase at the 30 to 36-inch depth. Phosphorus, organic matter, CEC and the pH do not vary significantly between locations, but show significant variation due to depth. Calcium and magnesium do not vary between depths or locations, while potassium varies significantly between locations and depths.

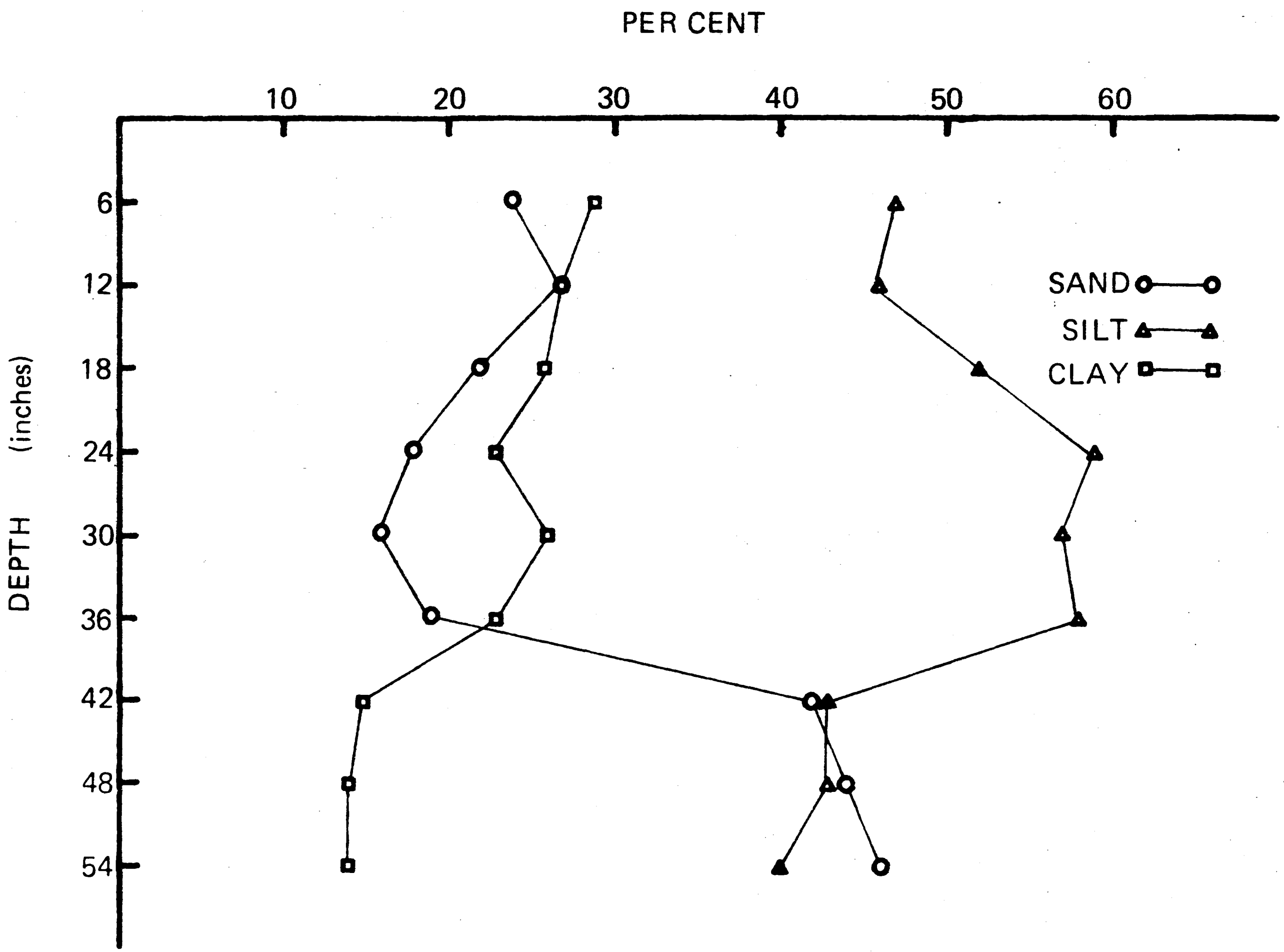

Figure 6. Sand, Silt and Clay Fractions of Coushatta Silty Clay Loam.

TABLE X

ANALYSIS OF VARIANCE FOR COUSHATTA
SILTY CLAY LOAM*

Variable	Source of Variation Total (df = 35)	Location (df = 3)	Depth (df = 8)	Error (df = 24)
Sand	334.1968	946.6667	546.1111	187.0000
Silt	163.7714	692.2963	203.5000	84.4629
Clay	224.4444	426.2222	140.9444	277.0556
pH	0.0405	0.0929	0.1049	0.0125
Organic Matter	0.3085	0.3906	0.9392	0.0879
Calcium	4105806.88	9412512.62	4295825.03	3379129.29
Magnesium	50677.9429	57064.8889	47280.0000	51012.2222
Potassium	44098.307	119623.312	82906.875	21721.505
Phosphorus	158.7111	248.0741	248.1736	117.7199
CEC	144.9328	494.0358	97.0946	117.2410

* Each value in the table is the "mean square" for that particular source of variation.

TABLE XI

SUMMARY OF SOIL TESTING RESULTS FOR
COUSHATTA SILTY CLAY LOAM*

Depth (in.)	Percent Sand	Percent Silt	Percent Clay	Percent OM	pH	lbs/ac Mg	lbs/ac Ca	lbs/ac K	lbs/ac P	CEC (meq/100gm)
0-6	24	47	29	1.77	7.8	690	7620	634	28	18.6
6-12	27	46	27	0.75	8.1	475	6542	342	10	28.4
12-18	22	52	26	0.57	8.2	485	6472	270	6	25.1
18-24	18	59	23	0.55	8.2	451	7455	369	18	22.0
24-30	16	57	26	0.40	8.2	517	7352	327	6	18.1
30-36	19	58	23	0.50	8.3	502	6595	277	3	29.7
36-42	42	43	15	0.17	8.3	337	5160	187	8	15.0
42-48	43	43	14	0.25	8.3	365	5267	182	8	20.0
48-54	46	40	14	0.25	8.4	352	4915	162	7	18.0

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

The mean clay content of the Garton silt loam series increases from 19 percent at the zero to six-inch depth to 32 percent at the 18 to 24-inch depth and remains constant to the 48 to 54-inch depth. The mean percentage of silt ranges from 30 percent at the zero to six-inch depth to 41 percent at the 48 to 54-inch depth. The mean percentage of sand decreases with depth from 51 percent at the zero to six-inch depth to 31 percent at the 48 to 54-inch depth (Figure 7). The sand, silt and clay content show significant variation among locations but do not vary significantly with depth (Table XII). The mean pH remains constant throughout most of the profile and does not vary appreciably with locations or depth. It increases with depth in the top 12 inches and in the lower six inches of the profile from 6.9 to 7.3 and from 7.3 to 7.5 respectively (Table XIII).

The Garton series, like the Caspiana series, is high in magnesium. The mean magnesium content increases from 730 pounds per acre at the zero to six-inch depth to 1,190 pounds per acre at the 48 to 54-inch depth and varies significantly between locations and depth. Potassium and calcium decrease with depth and show little variation due to locations or depth. The CEC also decreases with depth but varies significantly between locations only. Phosphorus increases in the top 12 inches of the profile but then decreases throughout the rest of the profile. The percent organic matter decreases with depth throughout most of the profile, but shows an increase near the 18-inch depth. The organic matter varies significantly between locations and depth, while phosphorus varies between locations only.

The Gallion very fine sandy loam series contains a high percentage of silt throughout its profile. The mean silt content decreases from

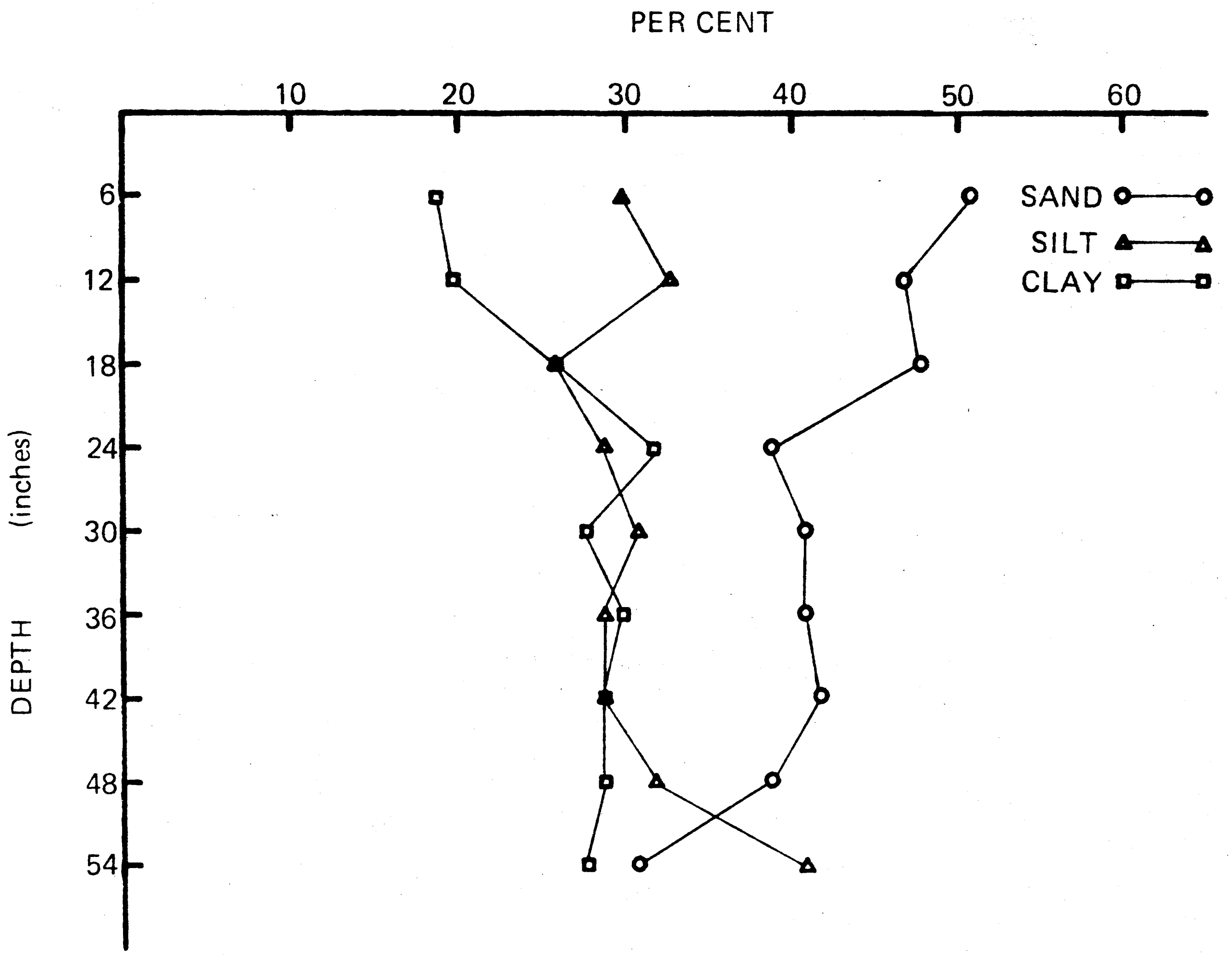

Figure 7. Sand, Silt and Clay Fractions of Garton Silt Loam.

TABLE XII

ANALYSIS OF VARIANCE FOR
GARTON SILT LOAM*

Variable	Total (df = 35)	Location (df = 3)	Depth (df = 8)	Error (df = 24)
	Source of Variation			
Sand	299.0825	2547.7407	140.4236	70.8866
Silt	74.6500	457.7314	74.3750	26.8564
Clay	124.5611	925.2870	76.6736	40.4329
pH	0.6742	6.4632	0.0761	0.1499
Organic Matter	1.3351	2.4736	2.4337	0.8265
Calcium	6062771.4	24976053.6	1598287.1	5186772.5
Magnesium	89333.930	114807.852	174788.944	44539.685
Potassium	30655.492	118401.185	17103.778	24204.519
Phosphorus	352.2906	1114.2963	398.2778	241.7129
CEC	73.0957	114.4285	25.0656	83.9391

* Each value in the table is the "mean square" for that particular source of variation.

TABLE XIII

SUMMARY OF SOIL TESTING RESULTS
FOR GARTON SILT LOAM*

Depth (in.)	Percent Sand	Percent Silt	Percent Clay	Percent OM	pH	lbs/ac Mg	lbs/ac Ca	lbs/ac K	lbs/ac P	CEC (meq/100gm)
0-6	51	30	19	2.55	6.9	728	5407	432	36	25.5
6-12	47	33	20	1.17	7.3	612	3330	202	50	18.1
12-18	48	26	26	2.00	7.3	788	5505	411	37	23.9
18-24	39	29	32	1.22	7.3	1130	5012	335	23	24.8
24-30	41	31	28	0.67	7.3	1102	4627	325	26	20.9
30-36	41	29	30	0.57	7.3	1102	4812	327	24	21.4
36-42	42	29	29	0.40	7.3	1072	4870	330	22	23.7
42-48	39	32	29	0.42	7.3	1075	4647	302	21	21.8
48-54	31	41	28	0.35	7.5	1190	5060	320	20	19.4

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

42 percent at the zero to six-inch depth to 25 percent at the 42-inch depth and then increases to 48 percent at the 48 to 54-inch depth (Figure 8). The mean percentage of sand increases from 36 percent at the zero to six-inch depth to 46 percent at the 30 to 36-inch depth and decreases to 31 percent at the 48 to 54-inch depth. The mean clay fraction of the soil, ranging from 21 percent at the zero to six-inch depth to 22 percent at the 48 to 54-inch depth, shows slight increases in the 24 to 42-inch zone. The texture and the pH of the soil vary significantly with locations, but show no significant variation due to depth (Table XIV). The pH increases from 6.5 at the zero to six-inch depth to 7.1 at the 48 to 54-inch depth (Table XV).

The Gallion series also has a large amount of magnesium in the soil. The mean magnesium content increases from 670 pounds per acre at the zero to six-inch depth to 1,500 pounds per acre at the 42 to 48-inch depth. Phosphorus and the organic matter decrease with increasing depth throughout the profile, while potassium, calcium and the CEC increase with depth. Magnesium and the organic matter vary significantly between depths only. Potassium, calcium and phosphorus vary significantly between locations but show no variation between depths. The CEC does not vary significantly between locations or depth.

Evaluation of the soils in terms of horizon depth, texture and nitrogen content, in relation to cottonwood establishment and survival, suggest the following management potentials: (a) The Idabel silt loam, Garton silt loam, Caspiana loam and Gallion very fine sandy loam should be superior to the Oklared very fine sandy loam, Severn very fine sandy loam and Coushatta silty clay loam. The Idabel, Garton, Caspiana and Gallion series contain more ideal ratios of silt and clay in their

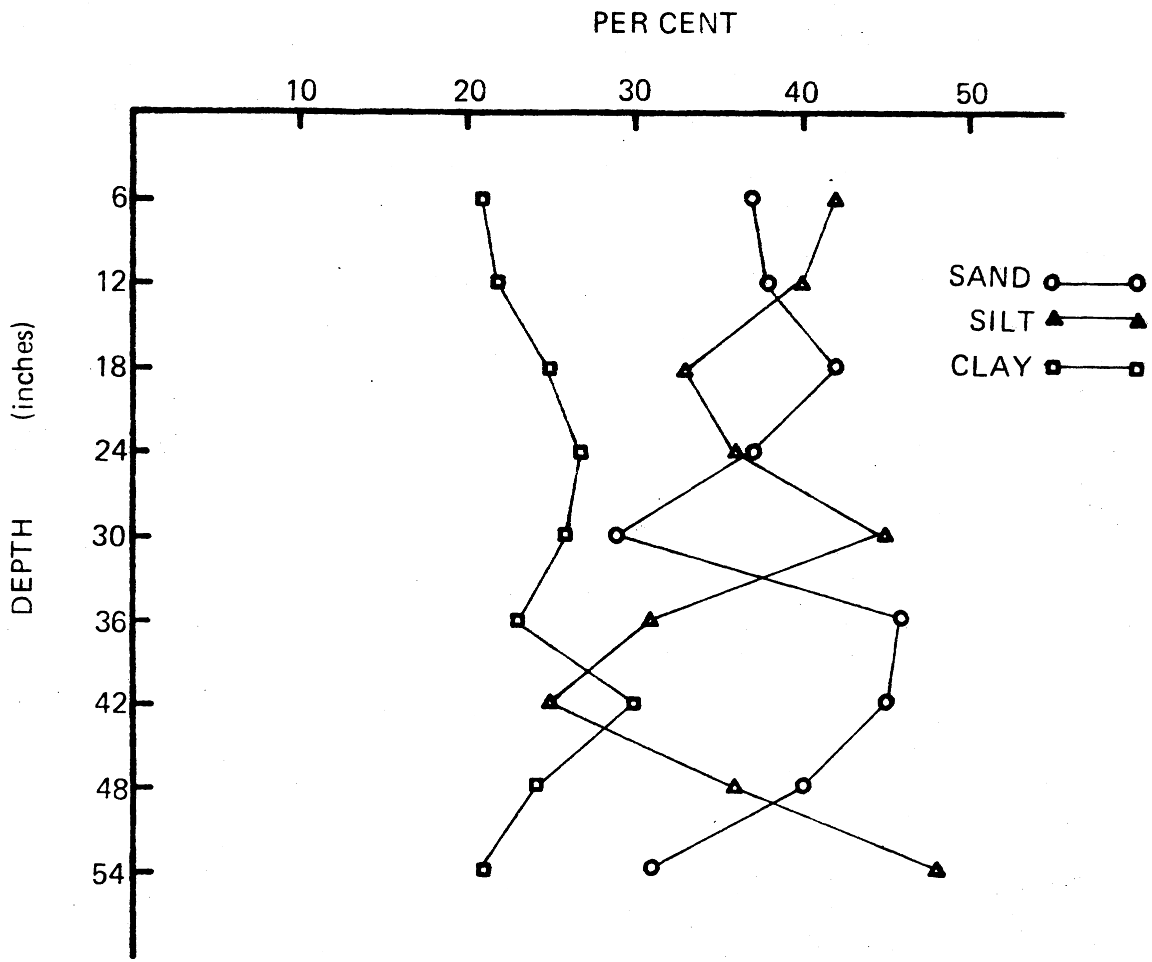

Figure 8. Sand, Silt and Clay Fractions for the Gallion Very Fine Sandy Loam.

TABLE XIV

ANALYSIS OF VARIANCE FOR GALLION
VERY FINE SANDY LOAM*

Variable	Source of Variation Total (df = 35)	Location (df = 3)	Depth (df = 8)	Error (df = 24)
Sand	246.1357	1755.2870	130.7500	95.9537
Silt	211.1071	682.7685	153.8750	171.2269
Clay	47.0286	301.7778	17.8125	24.9236
pH	0.1403	0.3685	0.1209	0.1183
Organic Matter	0.3479	1.1948	0.8219	0.0840
Calcium	2394476.43	221154.63	2165618.75	2493665.05
Magnesium	322779.20	2471282.07	266494.50	72977.91
Potassium	25833.7421	50300.3241	13336.1628	26941.2824
Phosphorus	416.4087	1179.9537	706.8194	224.1620
CEC	127.5756	1051.1181	19.4214	48.1843

* Each value in the table is the "mean square" for that particular source of variation.

TABLE XV

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

Depth (in.)	Percent Sand	Percent Silt	Percent Clay	Percent OM	pH	lbs/ac Mg	lbs/ac Ca	lbs/ac K	lbs/ac P	CEC (meq/100gm)
0-6	37	42	21	1.67	6.5	665	2880	252	49	16.8
6-12	38	40	22	1.02	6.6	792	2942	252	60	18.2
12-18	42	33	25	1.00	6.6	918	3817	417	55	20.3
18-24	37	36	27	0.62	6.6	1180	3237	277	38	19.4
24-30	29	45	26	0.62	6.8	1148	4770	333	30	21.8
30-36	46	31	23	0.50	6.7	1207	2972	250	28	21.0
36-42	45	25	30	0.25	6.7	1212	2602	227	23	19.3
42-48	40	36	24	0.35	6.8	1531	3012	296	28	24.2
48-54	31	48	21	0.35	7.1	1089	4297	298	32	21.0

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

profiles than the Oklared or Severn series. (b) The more sandy Oklared and Severn soils will not hold as much available soil moisture for newly-established cottonwood plantations and will dry out more quickly than the soils of the Idabel, Garton, Caspiana or Gallion series. (c) The high clay content below the 36-inch depth of the Coushatta silty clay loam series may act as a barrier to the root penetration of planted cottonwood on this soil. The soils of the Idabel, Garton, Caspiana and Gallion series do not contain a high percentage of clay in the lower portion of their profiles. Therefore, there should be no adverse effect on root penetration in these latter soils. (d) The low nitrogen content of all of the soils may reduce somewhat the survival and early growth of planted cottonwood on these alluvial soils. This fact might make the addition of nitrogen fertilizer to these soils logical. All seven soils contain enough calcium, magnesium, potassium and phosphorus to sustain the early growth of cottonwood.

Analysis of variance shows significant differences between soils for all of the variables tested (Table XVI). The amount of variation in these soils is characteristic of soils located on the flood plains of large rivers. The variation between soil series, along with the variation within a given soil series between locations, substantiates the necessity of a soil sampling and testing program associated with cottonwood site selection and establishment. Before establishing a cottonwood plantation, the soil should be thoroughly sampled and analyzed to determine if it possesses the necessary requirements for good cottonwood growth (see pp. 6-7).

TABLE XVI

ANALYSIS OF VARIANCE FOR THE COMBINED DATA
OF THE SEVEN SELECTED SOILS*

Variable	Source of Variation Total (df = 251)	Soil (df = 6)	Depth (df = 8)	Error (df = 48)
Sand	535.5861	6824.9762	511.2946	319.9717
Silt	254.2759	2038.2222	266.1071	193.8085
Clay	156.3699	2427.0595	43.3929	74.1845
pH	0.6487	20.8027	0.5665	0.0248
Organic Matter	0.4807	2.0634	5.8893	0.1767
Calcium	4472341.8	36738581.4	2675115.1	1574528.3
Magnesium	300192.38	7740799.56	144288.91	129966.64
Potassium	40038.941	362863.034	57189.543	18803.936
Phosphorus	478.6687	7477.2857	1256.6200	183.8753
CEC	197.3605	2254.7479	41.6005	55.6378

* Each value in the table is the "mean square" for that particular source of variation.

Plantation Establishment, 1975

Location of Planting Sites

Trial plantings were established in the spring of 1975 on the flood plain of the Red River in McCurtain County near Harris, Oklahoma, to examine further the productivity of selected soils for cottonwood. These plantings are located on privately-owned land approximately 200 yards from the river. The soils selected as planting sites in the 1975 study included Idabel silt loam (Coarse-loamy, thermic Fluventic Eutrochrept), Oklared very fine sandy loam (Coarse-loamy, mixed, calcareous, thermic Typic Udifluvent), and Severn very fine sandy loam (Coarse-loamy, mixed, calcareous, thermic Typic Udifluvent).[3] These soils were selected as representatives of two broad textural soil classes. A heavy clay soil was not included due to the relatively poor growth of cottonwood on clay soils as demonstrated in numerous studies (7, 21, 24, 26).

The climate of McCurtain County is warm and moist in nature, with rains of high intensity and hot summers. The annual precipitation at Idabel, the closest weather reporting station to the planting sites, averages 47 inches, with most of it occurring in the spring. The least amount of precipitation occurs in the autumn months. The precipitation at the Idabel reporting station for 1975 and 1976 amounted to 46 and 42 inches respectively. Over half of this precipitation fell during the spring and early summer months. Relatively dry periods occurred in late summer and early fall for both years (Figure 9).

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[3]Due to excessive cattle damage, the Oklared and Idabel sites were disked and replanted in 1976. The Severn site, also damaged by cattle in 1975, was not replanted in 1976.

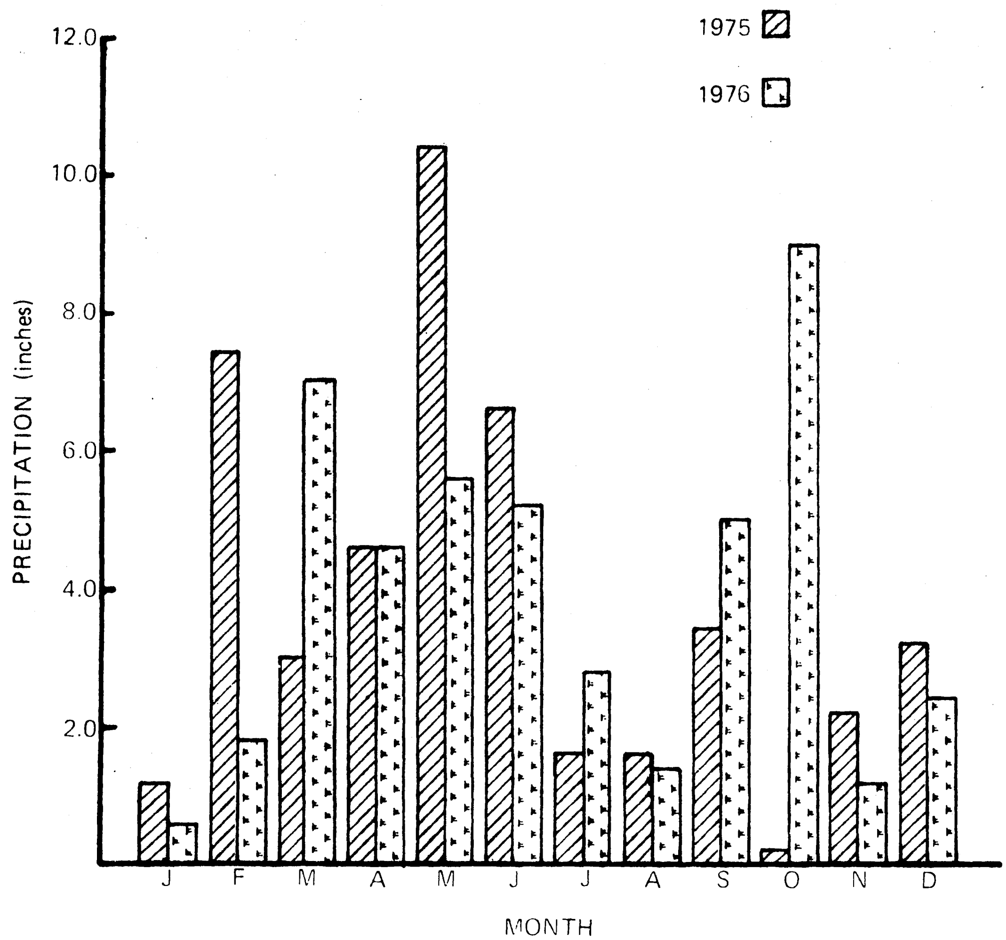

Figure 9. Annual Precipitation for 1975 and 1976 as Reported by the River Weather Reporting Station, Idabel, Oklahoma.

The average daily maximum temperature in McCurtain County ranges from 54 degrees Fahrenheit in January to 94 degrees Fahrenheit in July and August. Average daily minimum temperatures range from 30 degrees Fahrenheit in January to 68 degrees Fahrenheit in July. Summers are usually hot and humid, while winters are mild but well-defined. Seasonal changes are gradual.

The growing season in McCurtain County, averaging 220 days in the southern portion of the county, is one of the longest in the state. The last freeze of the spring occurs in late March and the first fall freeze occurs in early November.

The vegetation on the planting sites consisted of native grasses and annual weeds with scattered seedlings of willow, pecan and cottonwood on the Idabel site. Natural stands of mature cottonwood and willow along the banks of the Red River indicate that the alluvial soils in the flood plain are capable of supporting good cottonwood growth. A six-year old natural stand of cottonwood near the Idabel planting site averages 4.7 inches in diameter and 43 feet in height.

Soil Analyses of Planting Sites

Samples of the three soils were taken in the center of each clonal subplot planting site. Profiles were sampled every six inches to a depth of 60 inches. The profile sample locations were determined systematically for each plot by locating them at the mid-point of the plots between the second and third rows of each clone (Appendix A). The percentages of sand, silt and clay were determined for each sample. Amounts of calcium, magnesium, potassium and phosphorus were computed in pounds per acre, the organic matter in percent, and the cation exchange capacity in milliequilvants per 100 grams of soil. These latter tests were run on four soil samples from the top 24 inches of each soil because of the high percentage of sand in the lower portion of the profiles of all three soils. Statistical analysis of the soil test results was accomplished by the use of analysis of variance. The soil test results and conclusions apply only to the three soils at this particular location.

The sand, silt and clay fractions of the three soil profiles are depicted in Figures 10, 11 and 12.[4] The sand content of the three soils increases with depth while the silt and clay percentages decrease with depth. The Idabel soil contains less sand and more silt and clay in the upper portion of the profile than the Severn or Oklared soils. However, all three soils contain over 85 percent sand below the 42-inch depth. The Oklared and Severn soils are very sandy throughout and contain small amounts of finer textured particles in their profiles. According to the soil test results, the Severn soil is somewhat more sandy than the Oklared soil.

Analysis of variance of the sand, silt and clay fractions of the soils indicates significant differences for these factors between soils and between depths within the soil profiles (Table XVII). A significant interaction was also found between depth and the sand, silt and clay content of the three soils. Regression analysis indicates a positive correlation between depth and the percentage of sand in all three soils (Appendix B). Conversely, a negative correlation exists between depth and the silt and clay fractions of the three soils.

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[4]The data presented in the context are the mean values of five soil samples.

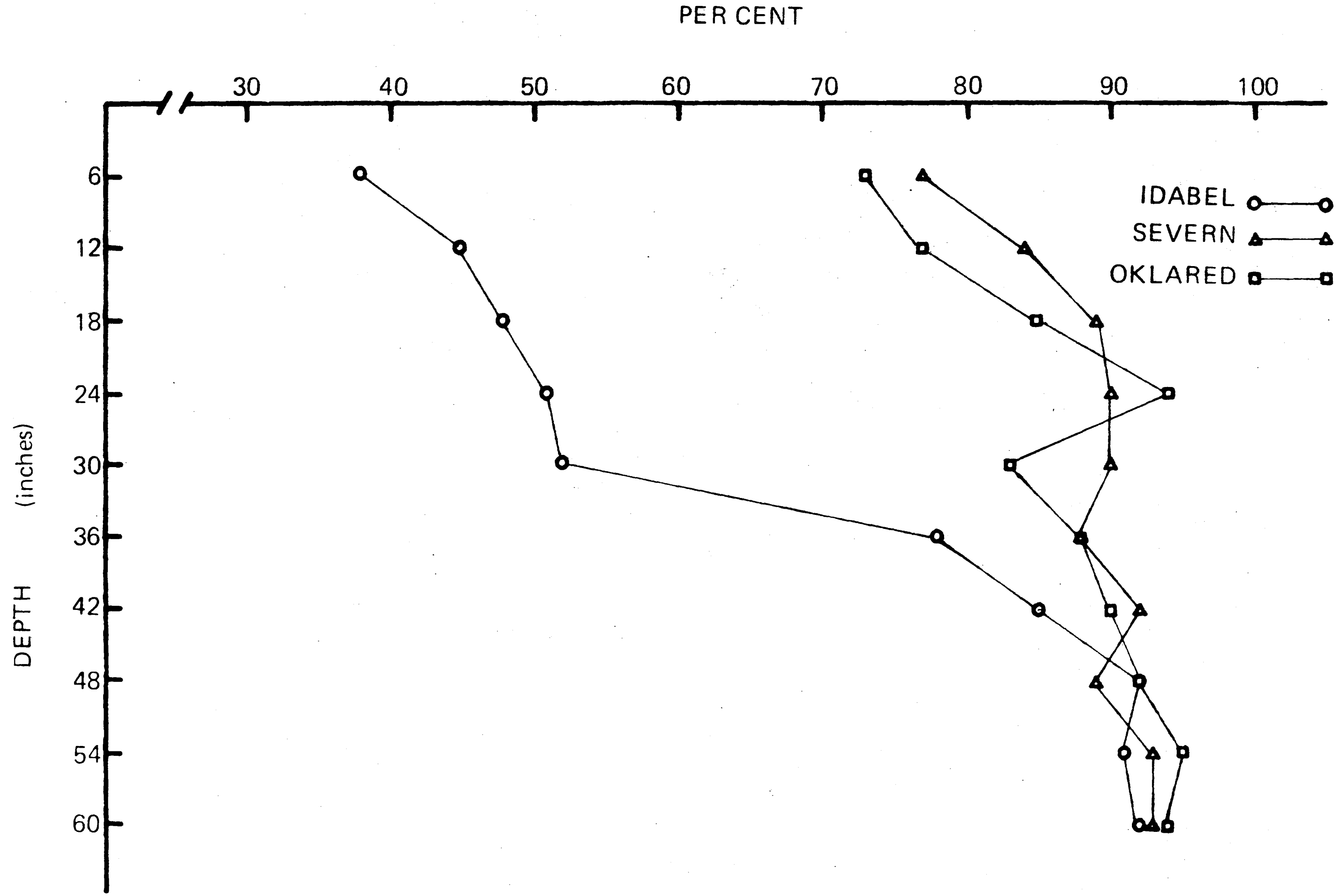

Figure 10. Sand Content of Three Selected Alluvial Soils Located on the Flood Plain of the Red River in Southeastern Oklahoma.

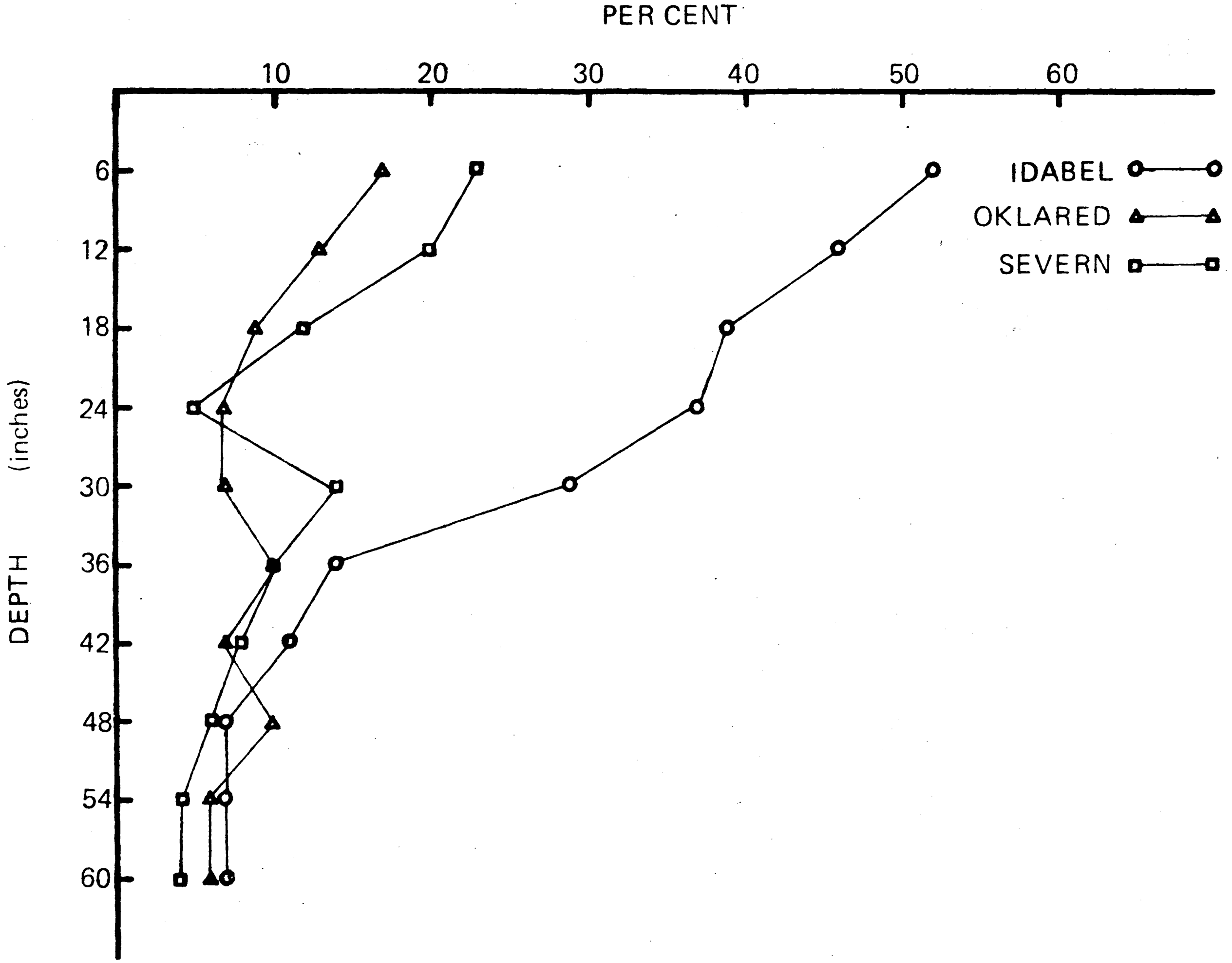

Figure 11. Silt Content of Three Selected Alluvial Soils Located on the Flood Plain of the Red River in Southeastern Oklahoma.

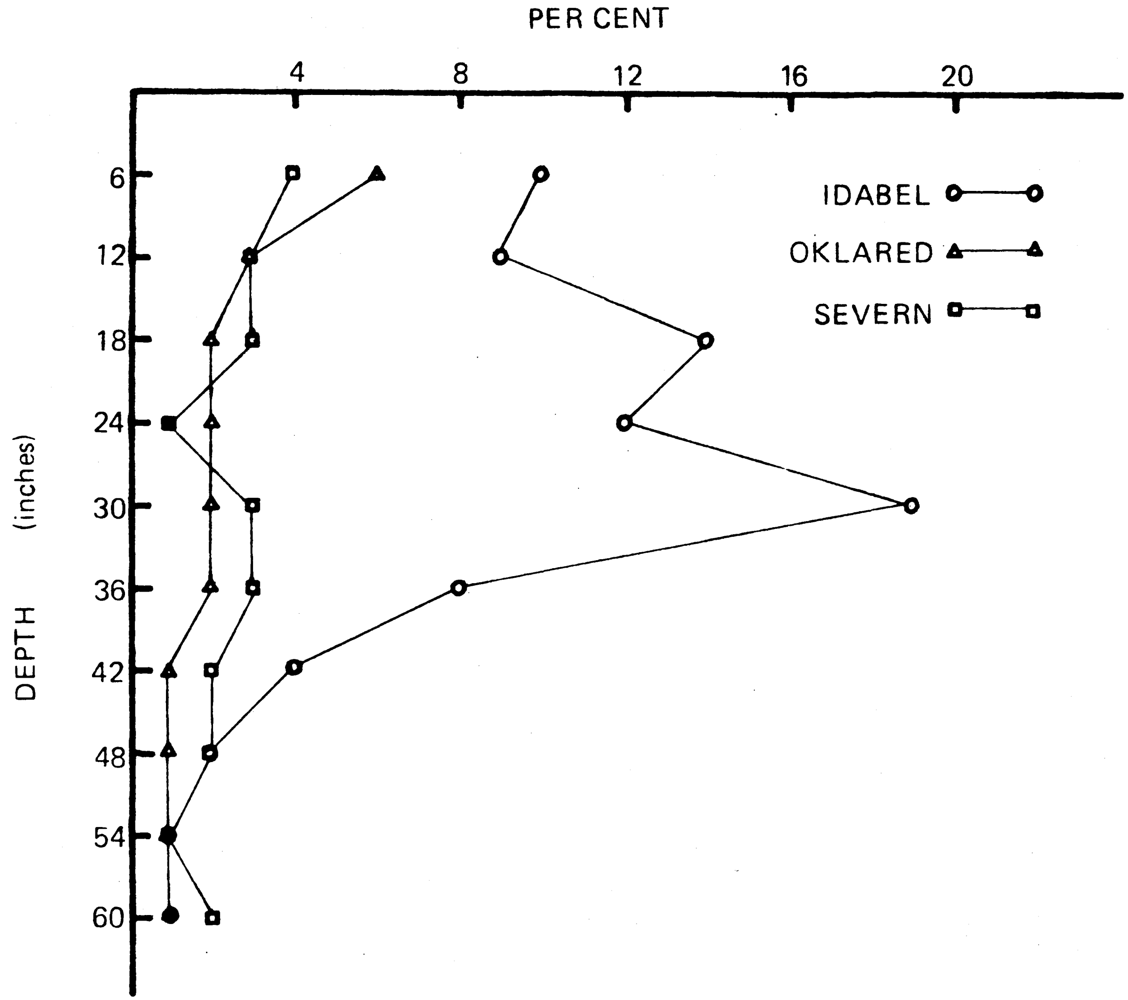

Figure 12. Clay Content of Three Selected Alluvial Soils Located on the Flood Plain of the Red River in Southeastern Oklahoma.

TABLE XVII

ANALYSIS OF VARIANCE FOR THE SAND, SILT, AND CLAY CONTENT OF THREE SELECTED ALLUVIAL SOILS IN SOUTHEASTERN OKLAHOMA*

Variable	Source of Variation						
	Total (df=149)	Clone (Rep) (df=4)	Soil (df=2)	Error a** (df=8)	Depth (df=9)	Soil*Depth (df=18)	Error b*** (df=108)
Sand	467.76483	6765.36000	1598.37333	719.74333	1966.37333	564.84889	149.53852
Silt	273.33016	883.30667	3789.08667	377.31167	1156.91037	357.23481	90.31370
Clay	34.76617	70.75666	508.82000	47.71166	84.32888	51.66444	16.74888

* Each value in the table is the "mean square" for that particular source of variation.

** Error a = Soil*Clone

*** Error b = Clone (Depth)* Clone (Soil) Depth

The organic matter content of the three soils differs significantly between the soils but shows no significant difference due to depth in the top 24 inches of the profile (Table XVIII). The percentage of organic matter in the Oklared and Severn soils decreases with depth from 0.91 percent at the zero to six-inch depth to 0.13 percent at the 18 to 24-inch depth and from 0.58 percent at the zero to six-inch depth to 0.17 percent at the 18 to 24-inch depth respectively (Figure 13). The organic matter in the Idabel soil decreases from 0.86 percent at the zero to six-inch depth to the 12-inch depth, but then increases to 1.17 percent at the 18 to 24-inch depth.

The pH, calcium and phosphorus vary significantly with depth in all soils, but show no significant difference between the soils. There are significant differences in the CEC between soils but no meaningful differences due to depth. The pH of the Idabel soil remains constant at 7.7 throughout the top 24 inches of its profile (Table XIX). The pH of the Oklared soil ranges from 7.4 at the zero to six-inch depth to 7.8 at the 18 to 24-inch depth (Table XX). The Severn soil, having the highest pH values of the three soils, ranges from 7.5 at the zero to six-inch depth to 7.9 at the 18 to 24-inch depth (Table XXI).

Calcium decreases with depth in the Oklared and Severn soils, while phosphorus and the CEC decrease with depth in all three soils. The calcium content of the Idabel soil decreases in the upper 12 inches of the profile, but then increases to 10,814 pounds per acre at the 18 to 24-inch depth. The Idabel soil contains a greater amount of calcium than either the Severn or Oklared soil.

Potassium and magnesium show no significant differences between soils or between depths in each soil profile. The potassium content in

TABLE XVIII

ANALYSIS OF VARIANCE FOR PH, ORGANIC MATTER, CALCIUM, MAGNESIUM POTASSIUM, PHOSPHORUS, AND CEC OF THREE SELECTED ALLUVIAL SOILS IN SOUTHEASTERN OKLAHOMA

Variable	Source of Variation						
	Total (df=59)	Clone (Rep) (df=4)	Soil (df=2)	Error a** (df=8)	Depth (df=9)	Soil*Depth (df=6)	Error b*** (df=36)
pH	0.0549	0.0677	0.5117	0.1349	0.2471	0.0323	0.0236
Organic Matter	0.2840	0.1446	2.5121	0.1041	0.4840	0.3226	0.1926
Calcium	11757129.0	14559973.3	71968592.1	10083738.1	46442135.5	9609700.3	5939972.7
Magnesium	56078.665	3767.250	263785.950	66497.700	14478.861	84285.861	46801.861
Potassium	496636.31	623961.60	1383849.60	717525.60	473715.20	699036.80	352289.60
Phosphorus	153.1207	586.7132	339.4082	191.8032	538.6295	91.4535	64.1505
CEC	77.4324	101.5431	646.4123	70.4237	115.0224	23.5456	50.5496

* Each value in the table is the "mean square" for that particular source of variation.

** Error a = Soil*Clone

*** Error b = Clone (Depth)* Clone (Soil) Depth

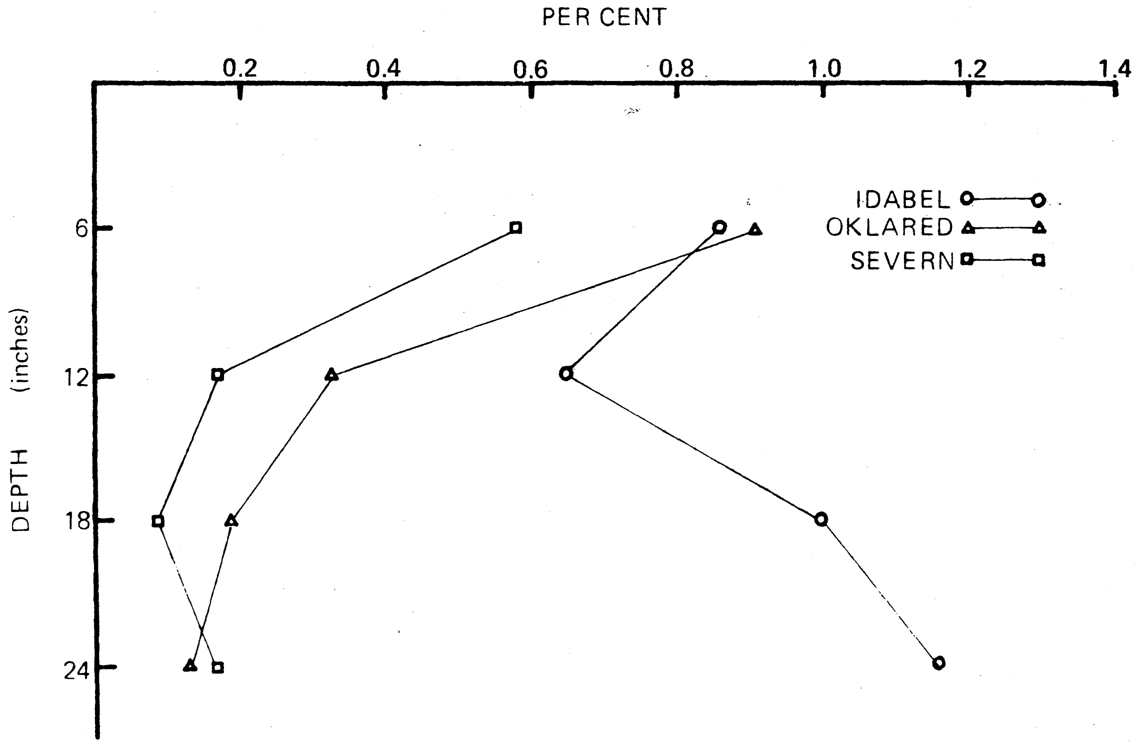

Figure 13. Organic Matter Content of Three Selected Alluvial Soils Located on the Flood Plain of the Red River in Southeastern Oklahoma.

TABLE XIX

SUMMARY OF SOIL TESTING RESULTS FOR THE IDABEL SILT LOAM PLANTING SITE*

Depth (in.)	Percent					lbs/ac				
	Sand	Silt	Clay	OM	pH	Mg	Ca	K	P	CEC (meq/100gm)
0-6	38	52	10	0.85	7.7	254	8246	585	22	18.9
6-12	45	46	9	0.65	7.7	274	7786	576	9	19.8
12-18	47	39	14	1.01	7.7	456	10814	705	18	19.5
18-24	51	37	12	1.16	7.7	492	3562	701	6	13.8
24-30	52	29	19							
30-36	78	14	8							
36-42	85	11	4							
42-48	92	7	1							
48-54	91	7	2							
54-60	92	7	1							

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

TABLE XX

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

Depth (in.)	Percent					lbs/ac				
	Sand	Silt	Clay	OM	pH	Mg	Ca	K	P	CEC (meq/100gm)
0-6	77	17	6	0.91	7.4	408	6067	475	31	13.0
6-12	84	13	3	0.32	7.5	245	4549	1622	16	9.5
12-18	89	9	2	0.18	7.7	216	4114	922	20	5.3
18-24	90	8	2	0.13	7.8	72	2633	250	12	4.5
24-30	90	8	2							
30-36	88	10	2							
36-42	92	7	1							
42-48	89	10	1							
48-54	93	6	1							
54-60	93	6	1							

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

TABLE XXI

SUMMARY OF SOIL TESTING RESULTS FOR THE SEVERN VERY FINE SANDY LOAM PLANTING SITE*

Depth (in.)	Percent					lbs/ac				
	Sand	Silt	Clay	OM	pH	Mg	Ca	K	P	CEC (meq/100gm)
0-6	73	23	4	0.58	7.5	182	5750	370	15	12.6
6-12	77	20	3	0.16	7.6	101	4862	264	16	7.6
12-18	85	12	3	0.09	7.8	91	4229	245	10	5.8
18-24	94	5	1	0.17	7.9	187	2328	321	8	7.0
24-30	83	14	3							
30-36	87	10	3							
36-42	90	8	2							
42-48	92	6	2							
48-54	95	4	1							
54-60	94	4	2							

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

the Idabel soil increases with depth from 585 pounds per acre at the zero to six-inch depth to 701 pounds per acre at the 18 to 24-inch depth. The amount of potassium in the Severn soil and the Oklared soil decreases with increasing depth. In the Oklared soil potassium ranges from 475 pounds per acre at the zero to six-inch depth to 1,620 pounds per acre in the six to 12-inch level to 250 pounds per acre at the 18 to 24-inch depth. In the Severn soil, potassium ranges from 370 pounds per acre at the zero to six-inch depth to 321 pounds per acre at the 18 to 24-inch depth. Magnesium decreases with depth in the Oklared soil and increases with depth in the Idabel soil. The range of magnesium for the Oklared soil is from 408 pounds per acre at the zero to six-inch depth to 72 pounds per acre at the 18 to 24-inch depth. The magnesium content of the Idabel soil ranges from 254 pounds per acre at the zero to six-inch depth to 492 pounds per acre at the 18 to 24-inch depth. The amount of magnesium in the Severn soil decreases with depth in the top 18 inches of the profile, but then it increases at the 18 to 24-inch depth. It ranges from 182 pounds per acre at the zero to six-inch depth to 187 pounds per acre at the 18 to 24-inch depth in this soil.

Planting Procedures

Five U. S. Forest Service superior cottonwood clones served as planting stock for the trial plantings. These clones, developed at the Southern Forest Experiment Station located at Stoneville, Mississippi, include Stoneville clones 66, 67, 74, 92 and 109. Material from these clones was acquired by the Anderson-Tulley Company of Vicksburg, Mississippi for site testing on Mississippi River bottomland soils for eventual sawlog production.[5] These particular clones were selected for planting on the basis of their performance in earlier tests conducted at Stoneville and Vicksburg, and their availability. A complete description and early clonal testing results of these clones have been published by Mohn, et al. (31).

In 1975 site preparation for all three sites consisted of fall plowing and spring disking prior to planting. In the spring of 1975, four 15-tree rows of each clone were planted on each site in a completely randomized block design. Two additional rows were planted around each plot to reduce any border effect on the plot trees. The trees were planted on 14 by 14-foot centers to facilitate the use of 12-foot cultivators for weed control and for optimum pulpwood and sawlog rotations. Each plot was approximately 2.25 acres in size and contained 300 plot trees within the border rows.

Dormant, unrooted 20-inch cuttings were used in all of the 1975 plantings. Iron rods were used to make the holes for planting the cuttings vertically, 18 inches deep in the soil. After the cuttings were inserted in the ground, the holes were closed tightly to prevent the cuttings from drying out before they had a chance to root.

Weeds were controlled by cross-disking the plots three times during the early part of the growing season and hand-hoeing once close to the trees. Dowpon was also applied to control grasses in the plantings.

In late summer, cattle got into the plantings and caused considerable browse damage. After surveying the damage, it was decided that the

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[5]Cuttings from these clones were furnished through the courtesy of Mr. E. C. Brukhardt, Forester for the Anderson-Tulley Company, Vicksburg, Mississippi.

plantations should be disked and replanted the next spring. Because the survival on the Oklared and Severn sandy soils was so low (26 and 33 percent, respectively), replanting was necessary in order to find a method to attain a commercially acceptable level of stocking. Although no height measurements had been taken, survival counts had been made prior to the cattle damage.

Survival Results and Analyses

Table XXII summarizes the survival of cottonwood plantings established in 1975 on the three soils in southeastern Oklahoma, as of July 1, 1975. The ranking of clones by survival within each plot is almost identical for all three soils. Clone 66 had the greatest survival (73 percent) of the five clones planted on the research plots. The rank of the remaining clones in descending order is as follows: Clone 92 (54 percent), Clone 67 (45 percent), Clone 109 (37 percent) and Clone 74 (27 percent).

Data were subjected to arc sine transformation and Chi Square tests as described by Steel and Torrie (35) to test differences in the survival of the clones within each plot. Statistical analysis indicates that the only significant difference between the survival of the two best clones (Clone 66 and Clone 92) occurs on the Severn plot. However, the survival of Clone 66 is significantly better than the survival of the poorest clone (Clone 74) on all three plots.

Comparing survival by soil, the survival of cuttings on the Oklared very fine sandy loam plot (26 percent) and on the Severn very fine sandy loam plot (33 percent) are very low compared to that on the Idabel silt loam plot (83 percent). All five clones performed best on the Idabel

TABLE XXII

SURVIVAL OF PLANTED COTTONWOOD CUTTINGS ON THREE ALLUVIAL SOILS IN SOUTHEASTERN OKLAHOMA AS OF JULY, 1975

Clone Number	Plot 1 Oklared v.f. sa. loam		Plot 2 Idabel Silt loam		Plot 3 Severn v.f. sa. loam		Totals		Rank (by highest number of trees living)
	Number Trees Living*	Percent Living	Number Trees Living	Percent Living	Number Trees Living	Percent Living	Number Trees Living	Percent Living	
66	33	55.0	57	95.0	42	70.0	132	73.3	1
67	19	31.7	51	85.0	11	18.3	81	45.0	3
74	1	1.7	38	63.5	9	16.5	48	26.7	5
92	22	36.6	57	95.0	19	31.8	98	54.3	2
109	4	6.7	45	75.0	17	28.4	66	36.7	4
Total Number Trees	79		248		98		425		
Percent Living		26.4		82.7		32.7		47.3	

* Each figure in the body of the table is the number of trees surviving in a given clone out of 60 cuttings planted.

plot. The survival on the Idabel plot, ranging from a low of 64 percent (Clone 74) to 95 percent (Clone 66), is high enough to be considered adequate stocking for a commercial planting operation, while the survival on the Oklared and Severn plots is less than the recommended minimum survival of 80 percent for adequate stocking. The range of survival for the Oklared and Severn plots is from 55 percent (Clone 66) to 2 percent (Clone 74) and from 73 percent (Clone 66) to 27 percent (Clone 74) respectively.

The higher survival on the Idabel plot appears to be attributable to the greater water-holding capacity and inherent fertility supplied by the higher silt and clay fractions in its profile. The Idabel silt loam soil, averaging 55 percent silt and clay in the upper 24 inches of the profile compared to 15 percent in the Oklared and Severn sandy loam soils, holds more soil moisture for a longer period of time than the sandy loam soils. This greater amount of available water in the soil can sustain newly-established cottonwood trees through extended dry periods during the summer. Conversely, the sandy loam soils of the Oklared and Severn series become too dry during July and August for 20-inch cuttings to survive. Consequently the survival of planted cottonwood on these soils is lower by 54 percent.

Plantation Establishment, 1976

Planting Procedures

Due to the low survival of the trial plantings in 1974, different planting techniques were tried in 1976 in an attempt to increase the survival of cottonwood cuttings on the sandy loam sites. The planting stock, number of trees per row, spacing, size of plots and the number of trees per plot were the same as the 1975 planting. The major difference between the two designs was the type of cuttings used. In 1976, two rows of four-foot unrooted cuttings and two rows of greenhouse-rooted 12-inch cuttings of each clone were planted side by side, instead of four rows of 20-inch unrooted cuttings.

The 12-inch cuttings were rooted in a greenhouse in a mixture of sand and peat moss in one-quart plastic containers. Greenhouse survival for all clones averaged over 88 percent. Prior to planting, the rooted cuttings were allowed to harden-off for 10 to 14 days in a screened enclosure outside the greenhouse.

Due to weed-control by cultivation in 1975, site preparation for the 1976 plantings consisted merely of roto-tilling properly-spaced rows prior to planting. In the spring of 1976 two rows of four-foot, dormant, unrooted cuttings and two rows of 12-inch, rooted cuttings were planted on the Idabel silt loam site and on the Oklared very fine sandy loam site. The Idabel site was planted as a control plot for comparison with the sandy loam Oklared soil. Prior to planting, a two-strand electric barbed wire fence was constructed around the plots to provide additional protection from cattle.

Planting holes for the four-foot cuttings were made to a depth of 45 inches with a tractor-mounted, 12-inch auger. The four-foot cuttings were then inserted into the holes and the soil was packed firmly around the cuttings. An iron rod and a small gasoline-powered auger were also tried as planting tools to make the deep planting holes, but the tractor-mounted auger was found to be the quickest and most efficient method of deep planting. The iron rod was found to be difficult to extract from the soil, while the holes made by the small auger proved difficult to refill. The planting hole made by the tractor-mounted auger facilitated the refilling of the hole by eliminating the possibility of air pockets around the cutting.

Planting of the shorter, rooted cuttings was accomplished by the use of hand-operated post hole diggers. The planting holes were dug deep enough so that the root system was buried no more than one and one-half to two inches below the soil surface. Extreme care was taken to avoid disturbing the root system when the cuttings were removed from the rooting containers and planted in the ground.

Due to unexpected logging activities in natural stands of mature cottonwood adjoining the research plots, cattle were allowed into the plantings in mid-summer. Although attempts were made to repair the damage to the fences caused by the loggers, the cattle gained access to the plots twice during the summer. Subsequent investigations indicated that all of the cuttings on both plots had been browsed by cattle at least once during the summer. However, survival counts had been made each month. Most of the surviving four-foot cuttings had leafed out a third time by the end of the growing season, attesting to their vitality.

Survival Results and Analyses

Survival counts of the plantings were made in May, June and July prior to the cattle browsing. A final survival count was also made in November following cattle browsing. Table XXIII summarizes the survival of four-foot dormant, unrooted cuttings and 20-inch unrooted cuttings on the Oklared sandy loam soil. The survival of four-foot cuttings in July, 1976, was substantially better than that for the 20-inch unrooted cuttings in 1975 on the Oklared very fine sandy loam soil. The survival

TABLE XXIII

COMPARISON OF SURVIVAL OF TWENTY-INCH AND FOUR-FOOT CUTTINGS, JULY, 1975, JULY, 1976[1]

Clone	No. Surviving[2]		Percent	
	1975 Twenty-Inch	1976 Four-Foot	1975 Twenty-Inch	1976 Four-Foot
66	33	21	55.0	70.0
67	19	26	31.7	86.7
74	1	25	1.7	83.3
92	22	28	36.6	93.3
109	4	28	6.7	93.3
Total	79	128	26.4	85.3

[1]This table presents the survival of twenty-inch unrooted cuttings planted in 1975 and four-foot unrooted cuttings planted in 1976 on the Oklared very fine sandy loam site.

[2]The values in the table are the number surviving out of 60 for the twenty-inch cuttings and 30 for the four-foot cuttings.

in July 1975 for all clones averaged 26 percent, whereas the use of four-foot cuttings increased survival to 85 percent under the same field conditions. Among the five clones the difference in survival in July, 1975, ranged from 1.7 percent for Clone 74 to 55 percent for Clone 66. With the use of four-foot cuttings, in July, 1976, there was a spread in survival percentage from 70 percent for Clone 66 to 93 percent for Clones 92 and 109. This striking improvement in survival would be very acceptable for a commercial operation.

By November, 1976, the survival of deep-planted four-foot unrooted cuttings on the Oklared very fine sandy loam site ranged from 90 percent (Clones 92 and 109) to 60 percent (Clone 66), while the survival of rooted 12-inch cuttings on the same site was near zero (Table XXIV). These percentages are below those for July, 1976, by three percent (Clones 92, 109), and 23 percent (Clone 74). Arc sine transformation of the survival data and a subsequent Chi Square reveals a significant difference between the survival of the two types of planting methods.

Although other factors may be involved, planting the cuttings 45 inches deep in the soil appears to be the major factor in their greater survival over the 12-inch rooted cuttings. The deep planting technique allows the cuttings to reach receding available soil moisture during extended dry periods during the summer. Also, the four-foot cuttings contain more stored food to support early root and shoot growth. Conversely, the rooted cuttings with eight-inch root development before planting, did not develop a root system deep enough to reach the available soil moisture during dry periods. Consequently, as the surface soil becomes dry, the rooted cuttings perish, while the deep-planted

TABLE XXIV

SURVIVAL OF FOUR-FOOT AND ROOTED CUTTINGS ON TWO ALLUVIAL SOILS IN SOUTHEASTERN OKLAHOMA PLANTED IN 1976, AS OF NOVEMBER 5, 1976

Clone	Plot No. 1 Oklared very fine sandy loam				Plot No. 2 Idabel silt loam			
	Type of Cutting[1]				Type of Cutting			
	Four-Foot		Rooted		Four-Foot		Rooted	
	No. Trees Surviving[2]	Percent	No. Trees Surviving	Percent	No. Trees Surviving	Percent	No. Trees Surviving	Percent
66	18	60.0	2	6.7	18	60.0	23	76.7
67	23	76.7	0	0.0	24	80.0	0	0.0
74	18	60.0	0	0.0	17	56.7	22	73.3
92	27	90.0	0	0.0	17	56.7	18	60.0
109	27	90.0	0	0.0	18	60.0	24	80.0
Totals	113	75.3	2	1.3	94	62.7	87	58.0

[1]Four-foot, unrooted, dormant cuttings planted 45 inches deep. Twelve-inch rooted cuttings planted 8 inches deep.

[2]Number surviving out of 30 trees.

cuttings survive by taking advantage of available moisture deep in the soil profile.

This reasoning is also supported by the survival data of the heavier textured Idabel silt loam plot. Mean survival of all clones shows there are no significant differences in the survival of the four-foot (63 percent) and rooted cuttings (58 percent) on this plot. The small difference in survival between the two planting methods can be attributed to the greater water holding capacity of the top 24 inches of the Idabel soil. The greater amount of silt and clay in the upper portion of the profile can hold more available water, and therefore it will not dry out as quickly as the Oklared soil. The available soil moisture in the surface of the Idabel soil is within the reach of the root system of the rooted cuttings, and therefore they can survive the dry periods during the summer.

Figure 14 further illustrates the ability of deep-planted cuttings to reach soil moisture at greater depths than conventional 20-inch cuttings or rooted cuttings. The roots at the bottom of the cutting will enable it to obtain moisture at the 45-inch depth, if the surface becomes excessively dry. Although not pictured, a deep-planted cutting from the Idabel plot was also excavated, revealing the same general rooting pattern as the two from the Oklared plot.

Figures 15 and 16 depict the survival pattern of the number of four-foot unrooted and 12-inch rooted cuttings on the two soils. Although the survival of the rooted cuttings eventually dropped below that of the four-foot cuttings on the Idabel plot, it was not as dramatic as the decrease in the survival of the rooted cuttings in the Oklared plot. The technique of deep planting four-foot cuttings almost tripled

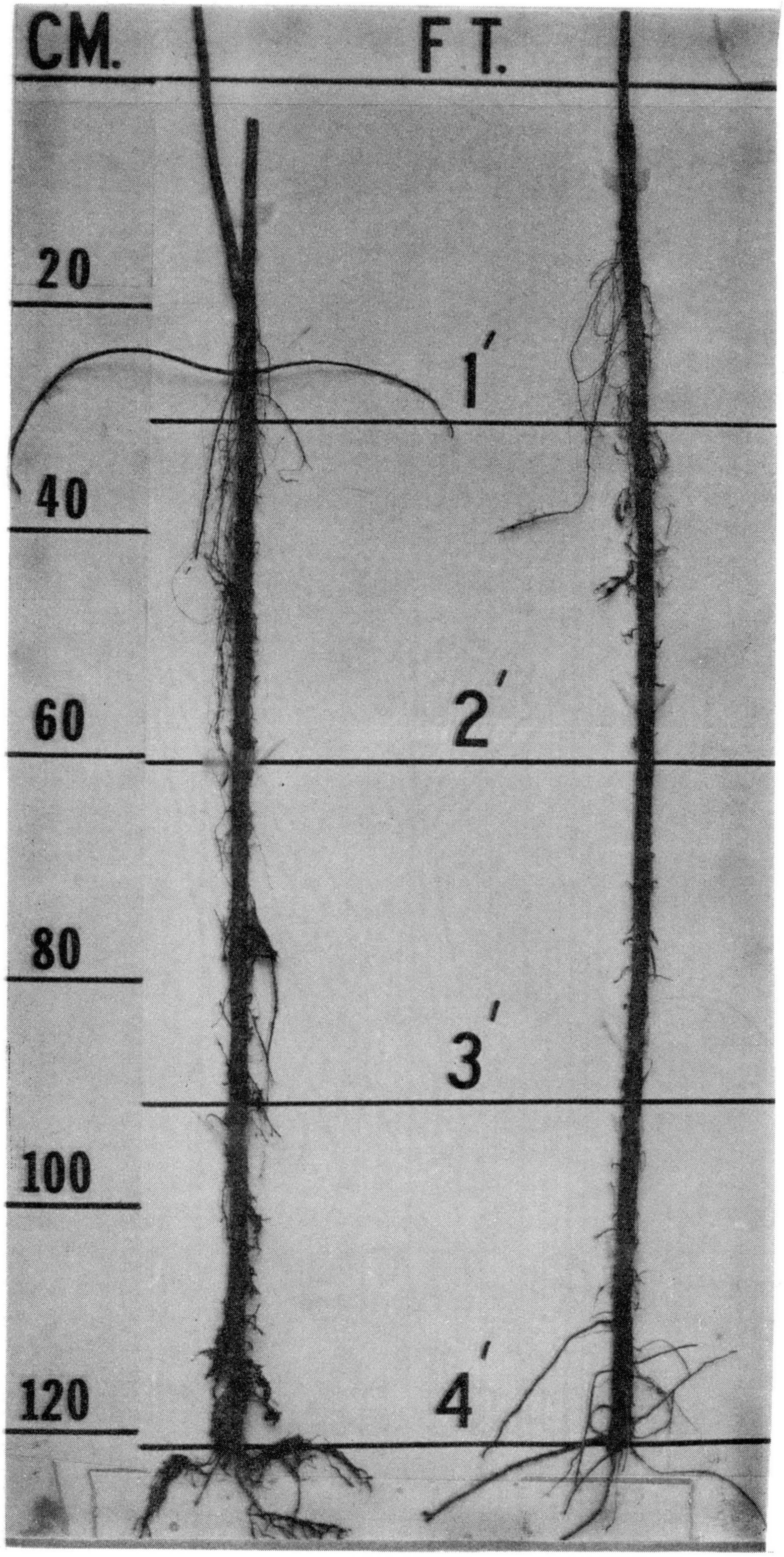

Figure 14. Rooting Pattern of Four-Foot Cottonwood Cuttings Planted 45 Inches Deep on Oklared Very Fine Sandy Loam Soil.

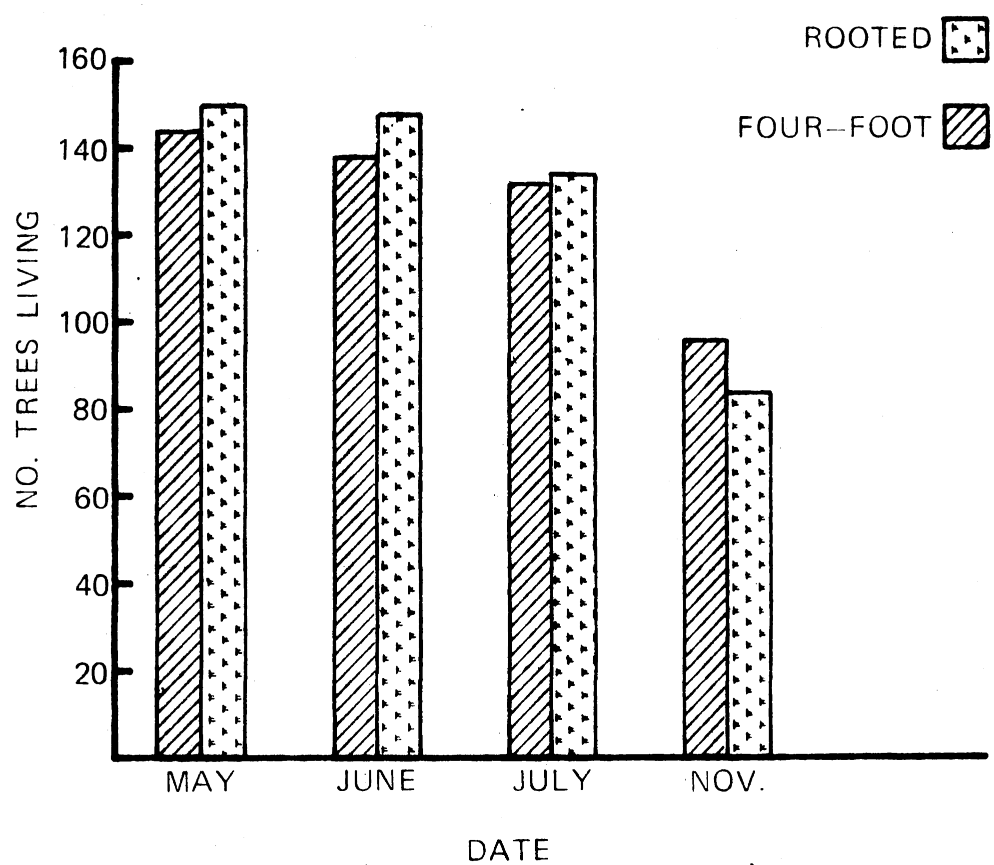

Figure 15. Survival of Four-Foot and Rooted Cottonwood Cuttings on the Idabel Silt Loam Site Planted in 1976, as of November 5, 1976.

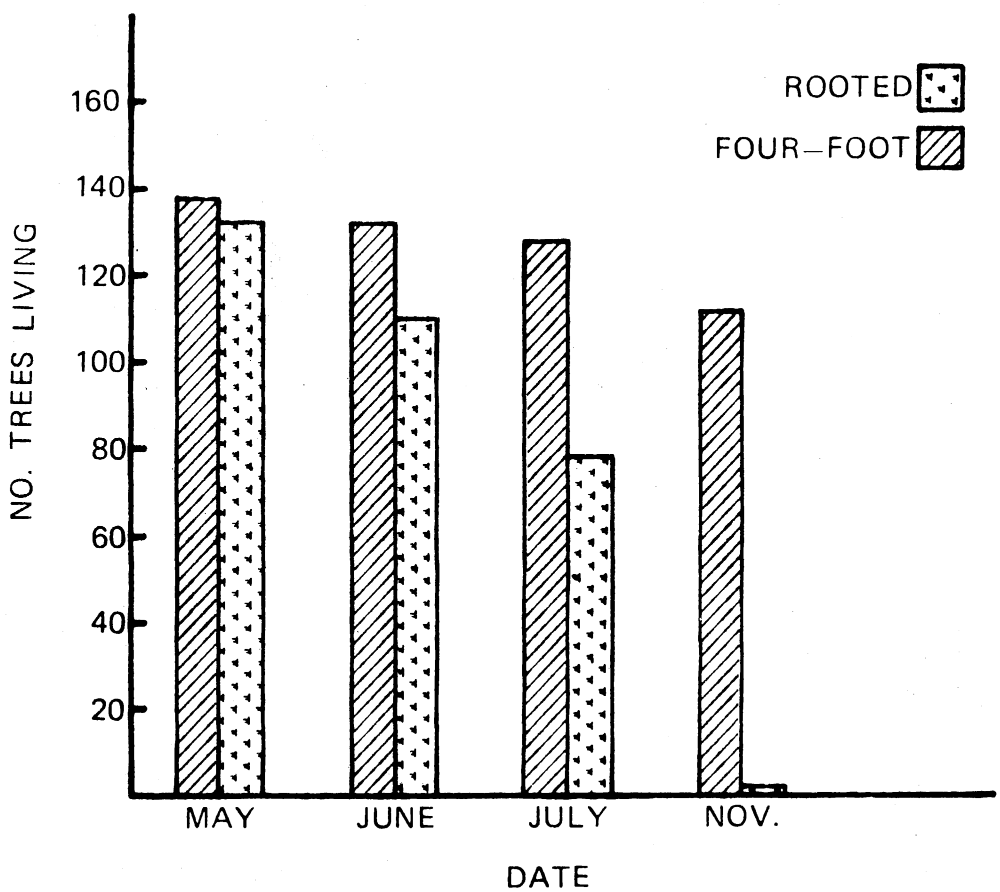

Figure 16. Survival of Four-Foot and Rooted Cottonwood Cuttings on the Oklared Very Fine Sandy Loam Site Planted in 1976, as of November 5, 1976.

the survival of cuttings on the Oklared plot over the conventional 20-inch cuttings used in the 1975 trial plantings on the same plot.

In addition to the plantings in southeastern Oklahoma, a trial planting of the five U. S. Forest Service clones was established near Stillwater in central Oklahoma in the spring of 1976. Conventional 20-inch, unrooted cuttings were used in this planting. This planting was established for demonstration purposes and to serve as an indication of how improved cottonwood clones will perform in this area. The soil on the planting site is a Port silt loam (Fine-silty, mixed, thermic, Cumulic Haplustoll), one of the most productive bottomland soils in central Oklahoma.

Due to an extremely dry spring and summer, the survival of the planted cuttings on this site averaged below 50 percent. However, in comparing the survival of the clones on this planting site with the survival results on the Red River planting sites, the ranking of the clones by survival is exactly reversed. Clone 66 showed least survival while Clone 67 was highest. This supposedly can be explained by differences in the soils and climates of the two areas, differences between clones, and clone x site interactions. Also, these clones originated in Mississippi and are probably poorly adapted to the prolonged dry periods encountered in central Oklahoma.

Insect and Disease Problems

Insects and diseases did not seriously affect the cottonwood plantings during the first growing season. Grasshoppers caused some damage to the terminals and leaves of some of the cottonwood trees in the 1976 plantings in southeastern Oklahoma. Damage caused by the cottonwood twig borer (Gypsonoma hambichiana) and the cottonwood borer (Plectrodera scalator) has been noted in the natural stands adjacent to the planting sites. The cottonwood twig borer, along with the poplar tent maker (Ichthyura inclusa), has caused considerable damage to cottonwood planted on the demonstration site near Stillwater, Oklahoma.

CHAPTER V

SUMMARY

One of the most intensive soil sampling and testing programs undertaken in the state was employed to study the potential of selected soils to produce cottonwood in southeastern Oklahoma. Data was collected and analyzed for approximately 390 soil samples from seven selected alluvial soils located on the flood plain of the Red River in southeastern Oklahoma. These soils include Caspiana loam, Coushatta silty clay loam, Gallion very fine sandy loam, Garton silt loam, Idabel silt loam, Oklared very fine sandy loam and Severn very fine sandy loam.

Analysis of the soil testing results indicate that all of the soils contain enough of the essential nutrients to support the growth of cottonwood, and that the limiting factor of cottonwood production appears to be the soil's ability to hold available moisture throughout the growing season. Significant differences were found between soil series for all variables tested on the soils.

To further examine the potential of these soils as commercial quality cottonwood sites, trial plantings of U. S. Forest Service superior clones were established in 1975 and 1976. The soils selected as planting sites in the 1975 study included Idabel silt loam, Oklared very fine sandy loam and Severn very fine sandy loam. The Idabel and Oklared sites were replanted in 1976 to test planting techniques to overcome low survival on sandy loam soils.

The 1975 survival of planted cottonwood on the Oklared and Severn sites was very low (26 percent and 33 percent respectively) compared to the survival on the Idabel site (83 percent). The greater survival on the Idabel silt loam site can be attributed to the greater water-holding capacity of its silt and clay fractions in the upper portion of its profile. The upper 18 inches of the sandy loam sites becomes too dry in mid-summer to support the growth of 20-inch cuttings.

To increase the survival of cottonwood on the sandier soils, deep-planted, four-foot unrooted cuttings and 12-inch greenhouse, rooted cuttings were planted on the Oklared site in 1976. Similar cuttings were also planted on the Idabel soil in 1976 to provide a comparison and check against the 1975 plantings. The four-foot cuttings tripled the survival percentages on the Oklared site over the previous year, while the survival of the 12-inch rooted cuttings on the Oklared site was almost zero. The survival of the four-foot and 12-inch rooted cuttings on the Idabel site was lower than the 1975 survival of 20-inch unrooted cuttings planted on the same plot.

Insects and diseases had no adverse effect on the survival of the cottonwood plantations during the first year of growth.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

The conclusions and recommendations of the study are based on data from intensive soil sampling and laboratory analysis of seven alluvial soils located on the flood plain of the Red River in southeastern Oklahoma. In addition, data and experience gained from trial plantings of cottonwood established on three of these soils provide important information. These conclusions apply only to cottonwood establishment on the Red River flood plain in southeastern Oklahoma. More valid conclusions should be expected as the study progresses and as more soils are tested as potential cottonwood sites.

Acquired data and experience suggest:

1. Eastern cottonwood has the potential of achieving good growth on some of the alluvial soils on the flood plain of the Red River in southeastern Oklahoma.
2. The water-holding capacity of a soil is the critical factor controlling survival of planted cottonwood in southeastern Oklahoma.
3. A soil sampling and testing program is essential for the determination of site characteristics for cottonwood plantations.
4. Idabel silt loam is a better soil for the establishment of cottonwood plantations than the Oklared very fine sandy loam or Severn very fine sandy loam soil.

5. U. S. Forest Service Clone 66 showed superior survival on all soils planted in 1975 with 20-inch cuttings. Clones 92 and 109 had the highest survival on the sandy loam soil in 1976, while Clone 67 showed a commercial survival rate on the silt loam soil.

6. Cottonwood plantations can be established on heavier textured soils, such as the silt loams, by using 20-inch unrooted cuttings.

7. Deep-planted four-foot, unrooted cuttings are recommended for cottonwood plantation establishment on the sandy soil sites.

8. The use of 12-inch greenhouse-rooted cuttings is not advantageous for plantation establishment.

9. Protect newly-established cottonwood plantations from cattle with good fencing.

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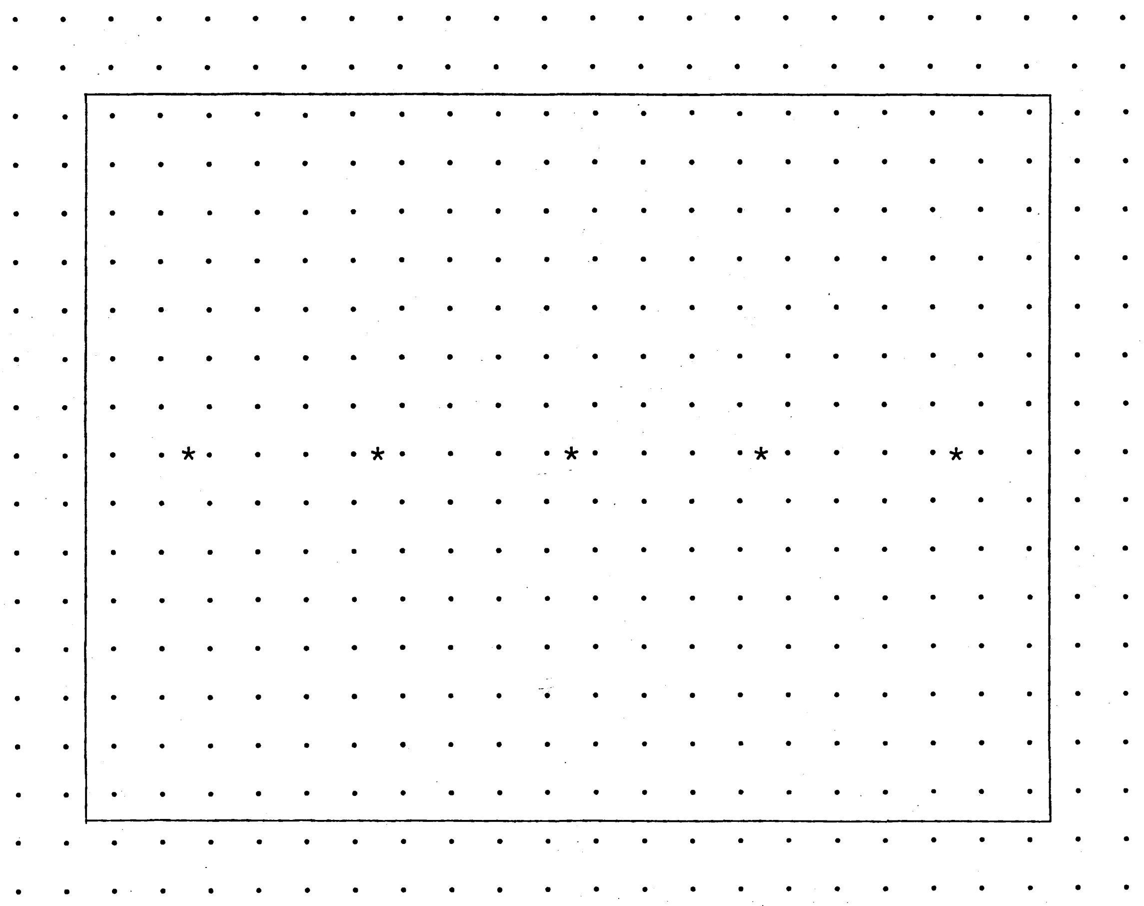
APPENDIXES

APPENDIX A

RESEARCH DESIGN USED FOR TRIAL PLANTINGS



Notes: Each of the 5 clones were planted in four-row blocks (15 trees per row) on 14 by 14 foot spacing, two additional border rows planted around the plot; *denotes soil sampling locations.

Figure 17. Research Design Used for Trial Plantings Showing Location of Soil Sampling Sites.

APPENDIX B

REGRESSION ANALYSIS OF THREE ALLUVIAL SOILS

TABLE XXV

REGRESSION ANALYSIS OF THE SAND CONTENT FOR IDABEL SILT LOAM

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB > F	R-SQUARE	C.V.
REGRESSION	13	25919.60000000	1993.83076923	6.33398	0.0001	0.69579620	26.40199 %
ERROR	36	11332.20000000	314.78333333			STD DEV	PCSAND MEAN
CORRECTED TOTAL	49	37252.00000000				17.74213441	67.20000

SOURCE	DF	SEQUENTIAL SS	F VALUE	PROB > F	PARTIAL SS	F VALUE	PROB > F
CLONE	4	3525.80000000	2.80018	0.0396	3525.80000000	2.80018	0.0396
D1	1	20472.32969697	65.03626	0.0001	13.91173809	0.04419	0.8347
D2	1	14.25606061	0.04529	0.8327	25.46925983	0.08091	0.7777
D3	1	996.70212121	3.16631	0.0836	31.39273416	0.09973	0.7540
DEPTH	6	910.71212121	0.48219	0.8181	910.71212121	0.48219	0.8181

SOURCE	B VALUES	T FOR HO:B=0	PROB > |T|	STD ERR B	STD B VALUES
INTERCEPT	90.34399999	0.30840	0.7596	292.94013995	0.0
D1	-6.64044444	-0.21023	0.8347	31.58728626	-4.19262073
D2	0.26566667	0.28445	0.7777	0.93397396	11.35955872
D3	-0.00263580	-0.31580	0.7540	0.00834650	-6.80163626

TABLE XXVI

REGRESSION ANALYSIS OF THE SAND CONTENT FOR OKLARED VERY FINE SANDY LOAM

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB > F	R-SQUARE	C.V.
REGRESSION	13	1545.04000000	118.84923077	4.72624	0.0002	0.63054621	5.67011 %
ERROR	36	905.28000000	25.14666667			STD DEV	PCSAND MEAN
CORRECTED TOTAL	49	2450.32000000				5.01464522	88.44000

SOURCE	DF	SEQUENTIAL SS	F VALUE	PROB > F	PARTIAL SS	F VALUE	PROB > F
CLONE	4	498.72000000	4.95811	0.0030	498.72000000	4.95811	0.0030
D1	1	670.72969697	26.67271	0.0001	42.15631989	1.67642	0.2036
D2	1	151.29696970	6.01658	0.0191	40.59998325	1.61453	0.2120
D3	1	145.22181818	5.77499	0.0215	40.26669421	1.60127	0.2139
DEPTH	6	79.07151515	0.52407	0.7875	79.07151515	0.52407	0.7875

SOURCE	B VALUES	T FOR H0:B=0	PROB > |T|	STD ERR B	STD B VALUES
INTERCEPT	-23.17919999	-0.27995	0.7811	82.79673901	0.0
D1	11.55946667	1.29477	0.2036	8.92784545	28.45703325
D2	-0.33542222	-1.27064	0.2120	0.26397884	-55.92160411
D3	0.00298519	1.26541	0.2139	0.00235906	30.03552411

TABLE XXVII

REGRESSION ANALYSIS OF THE SAND CONTENT FOR SEVERN VERY FINE SANDY LOAM

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB > F	R-SQUARE	C.V.
REGRESSION	13	12551.24000000	965.48000000	8.88324	0.0001	0.76234821	12.11673 %
ERROR	36	3912.68000000	108.68555556			STD DEV	PCSAND MEAN
CORRECTED TOTAL	49	16463.92000000				10.42523647	86.04000

SOURCE	DF	SEQUENTIAL SS	F VALUE	PROB > F	PARTIAL SS	F VALUE	PROB > F
CLONE	4	8126.92000000	18.69365	0.0001	8126.92000000	18.69365	0.0001
D1	1	2806.72969697	25.82431	0.0001	0.09641024	0.00089	0.9764
D2	1	578.67272727	5.32428	0.0269	0.00369524	0.00003	0.9954
D3	1	464.92205128	4.27768	0.0459	0.00223140	0.00002	0.9964
DEPTH	6	573.99552448	0.88021	0.5201	573.99552448	0.88021	0.5201

SOURCE	B VALUES	T FOR H0: B=0	PROB > |T|	STD ERR B	STD B VALUES
INTERCEPT	70.78080000	0.41120	0.6834	172.13093768	0.0
D1	0.55280000	0.02978	0.9764	18.56061516	0.52500645
D2	-0.00320000	-0.00583	0.9954	0.54880091	-0.20581762
D3	0.00002222	0.00453	0.9964	0.00490438	0.08625737

TABLE XXVIII

REGRESSION ANALYSIS OF THE SILT CONTENT FOR IDABEL SILT LOAM

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB > F	R-SQUARE	C.V.
REGRESSION	13	16362.04000000	1258.61846154	7.92708	0.0001	0.74110423	50.48307 %
ERROR	36	5715.88000000	158.77444444			STD DEV	PCSILT MEAN
CORRECTED TOTAL	49	22077.92000000				12.60057318	24.96000

SOURCE	DF	SEQUENTIAL SS	F VALUE	PROB > F	PARTIAL SS	F VALUE	PROB > F
CLONE	4	2026.52000000	3.19088	0.0239	2026.52000000	3.19088	0.0239
D1	1	13399.27515152	84.39189	0.0001	3.30935563	0.02084	0.8860
D2	1	374.25606061	2.35716	0.1335	8.14589926	0.05130	0.8221
D3	1	332.88673660	2.09660	0.1563	11.05570937	0.06963	0.7934
DEPTH	6	229.10205128	0.24049	0.9590	229.10205128	0.24049	0.9590

SOURCE	B VALUES	T FOR H0:B=0	PROB > |T|	STD ERR B	STD B VALUES
INTERCEPT	24.11520000	0.11591	0.9084	208.04789242	0.0
D1	3.23875556	0.14437	0.8860	22.43348534	2.65620947
D2	-0.15024444	-0.22651	0.8221	0.66331406	-8.34485002
D3	0.00156420	0.26338	0.7934	0.00592773	5.24309658

TABLE XXIX

REGRESSION ANALYSIS OF THE SILT CONTENT FOR
OKLARED VERY FINE SANDY LOAM

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB > F	R-SQUARE	C.V.
REGRESSION	13	884.86000000	68.06615385	4.07772	0.0006	0.59555250	43.55663 %
ERROR	36	600.92000000	16.69222222			STD DEV	PCSILT MEAN
CORRECTED TOTAL	49	1485.78000000				4.08561161	9.38000

SOURCE	DF	SEQUENTIAL SS	F VALUE	PROB > F	PARTIAL SS	F VALUE	PROB > F
CLONE	4	361.48000000	5.41390	0.0019	361.48000000	5.41390	0.0019
D1	1	327.40909091	19.61447	0.0001	45.54823957	2.72871	0.1073
D2	1	44.30454545	2.65420	0.1120	44.97803430	2.69455	0.1094
D3	1	84.59265734	5.06779	0.0306	45.27614325	2.71241	0.1083
DEPTH	6	67.07370629	0.66971	0.6765	67.07370629	0.66971	0.6765

SOURCE	B VALUES	T FOR H0:B=0	PROB > |T|	STD ERR B	STD B VALUES
INTERCEPT	123.40159999	1.82932	0.0756	67.45747773	0.0
D1	-12.01551111	-1.65188	0.1073	7.27383642	-37.98640744
D2	0.35304444	1.64151	0.1094	0.21507304	75.58773276
D3	-0.00316543	-1.64694	0.1083	0.00192201	-40.90073263

TABLE XXX

REGRESSION ANALYSIS OF THE SILT CONTENT FOR SEVERN VERY FINE SANDY LOAM

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB > F	R-SQUARE	C.V.
REGRESSION	13	6147.24000000	472.86461538	4.95279	0.0002	0.64138510	93.59294 %
ERROR	36	3437.08000000	95.47444444			STD DEV	PCSILT MEAN
CORRECTED TOTAL	49	9584.32000000				9.77110252	10.44000

SOURCE	DF	SEQUENTIAL SS	F VALUE	PROB > F	PARTIAL SS	F VALUE	PROB > F
CLONE	4	4163.72000000	10.90271	0.0001	4163.72000000	10.90271	0.0001
D1	1	1396.56000000	14.62758	0.0005	0.08289086	0.00087	0.9767
D2	1	132.75151515	1.39044	0.2461	0.22714598	0.00238	0.9614
D3	1	103.18918415	1.08080	0.3054	0.24341598	0.00255	0.9600
DEPTH	6	351.01930070	0.61276	0.7204	351.01930070	0.61276	0.7204

SOURCE	B VALUES	T FOR H0:B=0	PROB > |T|	STD ERR B	STD B VALUES
INTERCEPT	13.13280000	0.08140	0.9356	161.33054083	0.0
D1	0.51257778	0.02947	0.9767	17.39602492	0.63803183
D2	-0.02508889	-0.04878	0.9614	0.51436626	-2.11494933
D3	0.00023210	0.05049	0.9600	0.00459665	1.18077600

TABLE XXXI

REGRESSION ANALYSIS OF THE CLAY CONTENT FOR IDABEL SILT LOAM

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB > F	R-SQUARE	C.V.
REGRESSION	13	1935.64000000	148.89538462	3.32298	0.0024	0.54544737	85.38088 %
ERROR	36	1613.08000000	44.80777778			STD DEV	PCCLAY MEAN
CORRECTED TOTAL	49	3548.72000000				6.69386120	7.84000

SOURCE	DF	SEQUENTIAL SS	F VALUE	PROB > F	PARTIAL SS	F VALUE	PROB > F
CLONE	4	389.32000000	2.17217	0.0911	389.32000000	2.17217	0.0911
D1	1	746.72727273	16.66513	0.0002	3.65070113	0.08147	0.7769
D2	1	242.42424242	5.41032	0.0258	4.80751949	0.10729	0.7451
D3	1	177.56643357	3.96285	0.0541	5.18887052	0.11580	0.7356
DEPTH	6	379.60205128	1.41196	0.2363	379.60205128	1.41196	0.2363

SOURCE	B VALUES	T FOR H0:B=0	PROB > |T|	STD ERR B	STD B VALUES
INTERCEPT	-14.45920000	-0.13083	0.8966	110.52225127	0.0
D1	3.40168889	0.28544	0.7769	11.91744494	6.95860126
D2	-0.11542222	-0.32755	0.7451	0.35237542	-15.99015802
D3	0.00107160	0.34030	0.7356	0.00314902	8.95930205

TABLE XXXII

REGRESSION ANALYSIS OF THE CLAY CONTENT FOR OKLARED VERY FINE SANDY LOAM

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB > F	R-SQUARE	C.V.
REGRESSION	13	122.26000000	9.40461538	3.71561	0.0011	0.57296841	72.97920 %
ERROR	36	91.12000000	2.53111111			STD DEV	PCCLAY MEAN
CORRECTED TOTAL	49	213.38000000				1.59094661	2.18000

SOURCE	DF	SEQUENTIAL SS	F VALUE	PROB > F	PARTIAL SS	F VALUE	PROB > F
CLONE	4	15.28000000	1.50922	0.2192	15.28000000	1.50922	0.2192
D1	1	60.90242424	24.06154	0.0001	0.06561474	0.02592	0.8730
D2	1	31.85606061	12.58580	0.0011	0.11206333	0.04427	0.8345
D3	1	8.14174825	3.21667	0.0813	0.14680441	0.05800	0.8111
DEPTH	6	6.07976690	0.40034	0.8741	6.07976690	0.40034	0.8741

SOURCE	B VALUES	T FOR H0:B=0	PROB > |T|	STD ERR B	STD B VALUES
INTERCEPT	-0.22240000	-0.00847	0.9933	26.26809782	0.0
D1	0.45604444	0.16101	0.8730	2.83244872	3.80446454
D2	-0.01762222	-0.21041	0.8345	0.08374994	-9.95595693
D3	0.00018025	0.24083	0.8111	0.00074843	6.14562874

TABLE XXXIII

REGRESSION ANALYSIS OF THE CLAY CONTENT FOR SEVERN VERY FINE SANDY LOAM

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB > F	R-SQUARE	C.V.
REGRESSION	13	295.74000000	22.74923077	7.82358	0.0001	0.73857450	69.31792 %
ERROR	36	104.68000000	2.90777778			STD DEV	PCCLAY MEAN
CORRECTED TOTAL	49	400.42000000				1.70522074	2.46000

SOURCE	DF	SEQUENTIAL SS	F VALUE	PROB > F	PARTIAL SS	F VALUE	PROB > F
CLONE	4	260.12000000	22.36416	0.0001	260.12000000	22.36416	0.0001
D1	1	15.70969697	5.40265	0.0259	0.08251754	0.02838	0.8672
D2	1	0.87272727	0.30014	0.5872	0.10456220	0.03596	0.8507
D3	1	0.18051232	0.06208	0.8047	0.11108127	0.03820	0.8461
DEPTH	6	18.85706294	1.08084	0.3924	18.85706294	1.08084	0.3924

SOURCE	B VALUES	T FOR H0:B=0	PROB > |T|	STD ERR B	STD B VALUES
INTERCEPT	-1.06880000	-0.03796	0.9699	28.15487648	0.0
D1	0.51142222	0.16846	0.8672	3.03589717	3.11447566
D2	-0.01702222	-0.18963	0.8507	0.08976551	-7.02033063
D3	0.00015679	0.19545	0.8461	0.00080219	3.90243934

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