Site Evaluation for Western Catalpa In North Central Oklahoma

By
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The western, or hardy, catalpa (*Catalpa speciosa,* Ward.) has long been a popular species for postlot planting in the midwest and prairie states. Its rapid growth, lightness and durability of wood, ease of handling, and staple-holding qualities have made it the choice of many post growers.

As indicated by literature on the species and by observations of many foresters and post producers, catalpa is extremely sensitive to site variation. Of all the commercial species of trees it is one of the most demanding in its soil and site requirements. Because little is known about the exact nature of these demands upon the soil, it has been difficult to select sites for catalpa production with any degree of certainty that plantings would succeed.

The study reported in this bulletin was undertaken in an effort to correlate productive capacity of existing catalpa plantations with physical and chemical characteristics of the soils upon which they were located.

Previous Site Evaluation Studies

Much recent work has been done in relating the growth of forest trees to soil properties, particularly in the Southern Pine Region (2, 7, 8). Research on catalpa is much more limited and dates back to the early part of the century. Hall (4), in a series of observations made in 1901 and 1902 on four large plantations in Kansas, concluded as follows: "Catalpa reaches its best growth only on rich soil . . . . the Yaggy plantation, which shows great variation in soil fertility, has given no return on poor, sandy soil, while on rich loams it has given a clear annual profit of $21.55 per acre (1902). Depth and porosity are as important as fertility. An impervious layer of clay near the surface is prohibitive of successful growth. If the clay is not too dense, however, and occurs beneath several feet of good soil, it is highly beneficial, as in that case it forms a foundation for the soil and retains fertility and moisture."

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U.S.D.A. Circular 82 (6) reports that "Catalpa requires a deep, fertile, porous soil for good growth, and it cannot succeed on heavy, poorly drained land. It is not adapted to poor sandy or stiff clay soils or to those which have a tenacious gumbo subsoil. It will not tolerate a strongly alkaline soil. It has been proved that the returns realized from a crop grown on the best soil are proportionately very much greater than those obtained from poor land in the same locality."

In working with slash pine in northern Florida Barnes and Ralston (1) found that the two factors having greatest influence upon growth were (a) the depth to a mottled horizon (organic hardpan horizons were considered as mottled horizons) and (b) the depth to a fine textured horizon. The mottled horizons were indicative of poor drainage, and hence were associated with poor sites if they occurred close to the surface. On the other hand, fine textured horizons proved to be associated with good sites if they were close enough to the surface to serve as a floor for the water storage reservoir, and so prevent a too rapid downward movement of the soil moisture.

Working with shortleaf pine in Missouri, Dingle and Burns (3) found that 72 percent of the variation in site quality was associated with (a) the thickness of the A horizon, and (b) the percentage of clay in the "A" horizon. Coile (2), working with soil-site relationships for shortleaf and loblolly pine on the lower Piedmont of North Carolina, found close correlation between the thickness of the "A" horizon, the imbibitional value of the "B" horizon, and the growth of the two species.

Zahner (7, 8), in studying soil-site relationships for pine species in south Arkansas and north Louisiana, determined that (a) thickness or texture of the surface soil, (b) texture of the subsoil, and (c) percent or degree of slope were closely correlated with site quality. In zonal soils, the thickness of the surface layer was useful in estimating site quality. In azonal soils, where the surface layer blends gradually into the subsoil so that its thickness cannot accurately be measured, the texture of the surface layer was a useful guide in estimating site quality. Root growth in the pines was largely regulated by soil moisture and soil aeration. Root growth decreased if moisture was inadequate or aeration insufficient. Subsoil texture, fine enough to support mositure but not so dense as to restrict aeration, formed an optimum condition for root extension and tree growth. The topography also was partly responsible for regulating moisture and aeration. Welldrained, small stream flood plains offered optimum conditions, followed by terraces, gentle slopes, upland flats, and steep slopes and ridges, in that order.

Harper (5), studying tree growth in the western portions of Oklahoma, concluded that an accurate knowledge of the mechanical composition of the soil profile helps materially in determining where trees are more apt to grow, if planted in regions of low rainfall.

Procedure

Catalpa plantations used in the study were:

1. The so-called "apiary" postlot on the University Farm, west of Stillwater, Payne county.

2. The Forestry Department postlot on Cow Creek, on the University Farm, northwest of Stillwater, Payne county.

3. A 12-acre plantation on Bear Creek bottom, one mile north of the community of Fallis in west central Lincoln county.

4. A 12-acre plantation east of Arcadia on U. S. Highway 66, Oklahoma county (known as the Keely plantation).

5. A plantation 4 miles northeast of Edmond on U. S. Highway 77, Oklahoma county.

6. A plantation 3 miles west of the junction of State Routes 33 and 40, in Payne county (known as the Hastings plantation).

7. A plantation at the west edge of the town of Perkins, Payne county.

The ages of seedlings and sprouts in the various plantations chosen varied only from nine to eleven years. This eliminated the "age" variable.

Each plantation was divided in so far as possible, into areas of similar productivity, using as an index the average height of the dominant and co-dominant trees in the stands. Productivity was classified into three levels: A, high; B, average; and C, poor or none. Tree heights corresponding to these three levels are shown in Table 1. In the two plantations on the University farm variation in productivity could not be precisely differentiated, and some areas had to be classified as A-B or B-C.*

Within each productivity area in each of the plantations, two or three 1/50-acre circular plots were established for study.

Each plot was then classified as being either bottomland or upland. Any plot which could not be classified as being on true bottomland was classified as upland. The upland plots varied considerably in topographic location, therefore they were further classified as being on upland prairie, deep sand, slope, or old terrace.

The foregoing series of classifications resulted in a total of 44 plots, of which 32 were classified as bottomland and 12 as upland. The numbers of plots within each category are shown in Tables 2 and 3.

Tree and soil data were then secured for each plot.

The tree data included: number of living trees; number of dead trees, and gaps in spacing; age of seedlings or sprouts; heights; diameters; and basal areas (Tables 4 and 5).

Soil samples obtained at the center of each plot were analyzed for percentages of sand, silt, and clay; available potassium and phosphorus; percent nitrogen; pH; and percent organic matter.

Soil samples were taken to an average depth of 60 inches, with a minimum depth of 49 inches and maximum of 90. Separate samples were taken for each change in color or texture of soil, the texture being determined by careful "feel" tests. From 4 to 15 samples were taken from each hole; the average number of samples per hole was 8 (Table 6).

Four tree and stand variables and six soil variables were then subjected to correlation. Separate correlations were run for the bottomland and upland plots, and also for each of three soil depths: 0 to 12 inches; 12 to 24 inches; and 24 to 36 inches.

The tree and stand variables used were:

1. Height of dominant trees.

* Since only one plot fell in the A-B clas ification and only 3 plots fell in the B-C classification, the data obtained was not subjected to correlation analyses.

2. Average diameter (diameter of the tree of average basal area).
3. Basal area (stem cross-sectional area of trees 4.5 feet above ground).
4. Survival (number of live trees).

Soils variables used were:

1. Silt-plus-clay percentage.
2. Organic matter in percent.
3. Nitrogen in percent.
4. Available phosphorus in pounds per acre.
5. Available potassium in pounds per acre.
6. pH.

Results

Soil data are summarized in Table 6, tree data in Tables 1, 4, and 5.

Table 7 presents correlations of the tree and soil factors for bottomland and upland plots.

Topographic Location

No "A" (high) productivity level was found on an upland plot. Several "B" (average) level plots were located on old terraces and lower slopes, and one "A-B" plot was on an old terrace. One "B" level plot was located on deep upland sand. Plots on prairie upland and upper slopes were characterized in every instance by "C" productivity (poor to none).*

Acidity (pH value)

The multiple correlations showed little apparent relationship between productivity and acidity at least in the first foot of soil and within the range of pH values encountered (4.8 to 7.9). In the second and the third feet there appeared to be some negative correlation between pH and average diameter. If this is accepted at face value, slightly acid conditions in the lower levels are indicated as being desirable.

*In observations made outside the plantations used in this study, it was noted that catalpa comparable to "A-B" and "B" levels was being produced on deep, fine sands on upland in Kingfisher and Grant counties.

No relationship between acidity and productivity could be observed by examination of the original data. Upland "C" samples showed the highest acidity; on the other hand, maximum pH values of 7.7 to 7.9 also were found in the upland "C" samples. Bottomland "C" samples showed less variation in pH values than either upland "C" or bottomland "A" samples, and they tended to show basic rather than acid reactions.

Nitrogen and Organic Matter

The high correlations between nitrogen and silt-plus-clay, and organic matter and silt-plus-clay were expected. Low nitrogen is characteristic of the sandier bottomland soils in the area where these plantations are located. However, correlations were significantly negative between height and nitrogen, and height and organic matter. These latter correlations can be nothing other than the trailer effect of an unfavorable relationship between silt-plus-clay and the general growth of stand. They cannot be interpreted to mean that nitrogen has an adverse effect upon tree development. In fact, they may point to the possibility of improving good sites with nitrogen fertilizer, though this has not been experimentally proved.

Silt-plus-clay percentage

The correlation coefficients show a highly significant negative relationship between the height of dominant trees and the silt-plus-clay percentage in the first foot of soil for both bottomland and upland plots. The higher the percent of silt-plus-clay, the poorer the site quality. This relationship also holds in the third foot, but is of borderline significance in the second foot. In other words, the sandier, coarser textured soils provide better sites for catalpa. It is also quite evident that soil conditions in the first foot of soil are more important in determining site quality than those existing at the deeper levels.

Since average diameter and height are highly correlated, the negative correlation between silt-plus-clay and average diameter naturally follows.

A significant correlation exists between silt-plus-clay and potassium in the bottomland plots but not in the upland. Why this relationship does not carry over to the upland plots is unaccounted for.

A significant relationship between silt-plus-clay and number of live trees was expected. Loss of trees through lateral competition is always greatest on the most productive sites where trees on a given spacing come into competition with each other at an earlier age and to a greater degree. On these better sites, crown differentiation is expressed quickly, with suppression mortality following.*

Trailer effects of the positive correlation of silt-plus-clay and number of live trees show up in the negative correlations between the number of live trees and height, diameter, and basal area. These correlations are limited to the bottomland plots.

Available Phosphorus

On bottomland plots (but not on upland), phosphorus showed a highly significant negative correlation with the number of live trees. Were it not for the fact that the usual trailer correlations are absent, this might be interpreted to mean there is a direct relationship between the amount of phosphorus in the soil and the site quality. However, significant positive correlations with height, diameter, and basal area do not appear in this case, and it is therefore difficult to read any meaning into these correlations.

Basal Area

Basal area is a function of average diameter and number of trees per unit area. The correlation coefficients of the two variables average-diameter and number-of-live-trees are of opposite sign for each of the other variables, and the basal area coefficient falls somewhere between these values in each case.

Conclusions

The results obtained in this study make possible the following statements concerning the quality of sites for growing catalpa.

(1) The surface foot of soil is more important in determining site index than the deeper layers of soil.

(2) On bottomland sites where soil moisture is plentiful, the silt-plus-clay content of the soil is a most important governing factor. Soils composed of not more than 50 percent silt-plus-clay in the first foot level are characteristic of the most productive sites. Rapidly declining

* Of course, the risk of mortality the first season following seeding or planting is apt to be higher on poor sites, and occasionally this becomes important when climatic or other factors are critical before the seedlings become firmly established.

productivity is associated with increasing silt-plus-clay percentage in the upper soil layer. In general, the productive bottomland areas showed higher silt-plus-clay percentages in the lower layers than in the first foot level. A maximum percentage of 65 in the second foot and 90 in the third and fourth feet was recorded on plots within the "A" productivity range.

(3) Bottomland "C" sites were characterized by high (70 percent or more) silt-plus-clay in the surface foot of soil, and productivity showed a strong negative correlation with the increasing silt-plus-clay percentages. On upland sites the silt-plus-clay content of the soil was also negatively correlated with productivity, but it should be pointed out that the ranges of the silt-plus-clay percentages were much lower on the upland than on the bottomland plots.

These findings strongly suggest that soil moisture becomes the limiting site factor in both instances, i.e., the upland soils are droughty and bottomland soils with high silt-plus-clay percentages are poorly drained and poorly aerated.

(4) Chemical composition of the soil had little influence upon the site quality. This points to the greater significance of the mechanical properties, the texture and structure, and the water infiltration rates and water retaining properties of soil as governing factors in catalpa production.

TABLE 1.—Tree heights as related to productivity level.

Productivity Level	Height of Dominant Trees			Height of Co-dominant Trees		
	Maximum	Minimum	Average	Maximum	Minimum	Average
	feet	feet	feet	feet	feet	feet
A	42	25	33.3	35	20	29.8
B	29	18	24	25	17	21
C	14	8	10.4	11	6	8.1

TABLE 2.—Distribution of plots between bottomland and upland, and among productivity levels.

Productivity Level	Bottomland Plots		Upland Plots	
	Number of Plots	Pct. of Total	Number of Plots	Pct. of Total
A	15	46.9	0	0
A-B	3	9.4	1	8.3
B	10	31.3	5	41.7
B-C	1	3.1	0	0
C	3	9.3	6	50.0
Total	32	100.0	12	100.0

TABLE 3.—Distribution of upland plots by topographic location and production level.

Topographic Location of Plot	Number of Plots in Productivity Level:					
	A	A-B	B	B-C	C	Total
Upland prairie					3	3
Upland deep sand			1			1
Slope			3		3	6
Old terrace		1	1			2
Total	0	1	5	0	6	12

TABLE 4.—Tree distribution by diameter classes (all figures on per acre basis).

Productivity Level	Diameter classes, by inches								
	Less than .6	1	2	3	4	5	6	7	Total
	No.	No.	No.	No.	No.	No.	No.	No.	No.
A	--	10.0	160.0	185.0	265.0	205.0	105.0	25.0	955.0
B	4.6	50.0	236.4	322.7	209.1	90.9	18.2	---	931.9
C	485.7	485.7	107.1	7.1	----	---	---	---	1,085.7

TABLE 5.—Mortality, spacing, basal area, average diameter (figures on per acre basis).

Productivity Level	Live Trees	Mortality	Original Trees	Original Spacing	Present Spacing	Present Basal Area	Present Average Diameter
	No.	No.	No.	feet	feet	Sq. ft.	inches
A	955.0	155.0	1,110.0	6.3	6.8	90.84	4.23
B	931.9	109.1	1,041.0	6.5	6.8	55.43	3.36
C	1,085.7	164.3	1,250.0	5.9	6.3	5.64	0.64

TABLE 6.—Summary of soil analyses by productivity levels and soil depths.

Productivity Level	Soil Depth 0-12 inches			Soil Depth 12-24 inches			Soil Depth 24-36 inches			Soil Depth 36-48 inches		
	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average
					Silt-plus-clay (percent)							
A	49.4	9.0	26.6	65.5	5.8	35.4	87.9	12.1	38.4	92.0	16.0	40.6
B*	53.7	15.2	32.0	81.0	10.3	35.5	89.2	13.5	42.1	86.0	16.4	49.0
B**	62.1	15.3	25.8	53.7	15.3	26.8	48.3	5.0	21.3	48.4	2.8	17.3
C*	89.8	72.5	81.1	72.3	67.3	69.8	76.2	55.2	65.7	73.6	65.0	69.3
C**	49.6	14.5	33.3	68.3	13.5	33.5	62.2	9.3	29.0	55.3	8.0	25.1
					Hydrogen-Ion Concentration (pH)							
A	7.6	6.1		7.9	5.4		7.9	5.4		7.8	5.4	
B	7.5	6.0		7.5	5.9		7.5	5.8		7.5	5.7	
C*	7.2	6.7		7.5	6.9		7.5	7.2		7.6	7.3	
C**	7.5	5.3		7.7	4.8		7.9	5.1		7.8	5.4	
					Available Phosphorus (lbs. per acre)							
A	74	22	44	84	13	39	68	9	34	65	8	32
B	64	9	38	65	6	33	65	5	32	64	5	30
C*	46	46	46	40	34	37	32	28	30	30	27	29
C**	56	4	24	56	5	26	38	5	24	39	6	24
					Available Potassium (lbs. per acre)							
A	432	138	241	400	117	204	375	98	186	372	92	183
B	599	112	266	416	77	218	335	71	200	303	65	189
C*	456	220	338	362	230	296	335	213	284	267	187	227
C**	760	103	274	760	89	250	430	79	187	430	70	178
					Organic Matter (percent)							
A	1.64	0.32	0.83	1.73	0.28	0.74	1.63	0.21	0.72	1.46	0.22	0.63
B	2.69	0.23	0.99	1.48	0.05	0.67	1.37	0.15	0.70	1.19	0.53	0.66
C*	2.60	2.05	2.33	1.90	1.68	1.79	1.23	1.20	1.22	1.06	0.93	1.00
C**	1.29	0.28	0.78	0.98	0.21	0.62	0.72	0.18	0.53	0.72	0.15	0.47
					Nitrogen (percent)							
A	.086	.008	.040	.093	.013	.039	.084	.013	.038	.076	.013	.037
B*	.132	.015	.046	.077	.010	.037	.072	.009	.035	.065	.008	.032
C*	.126	.108	.117									
C**	.058	.012	.038	.048	.010	.033	.042	.008	.028	.038	.007	.025

* Bottomland plots.
** Upland plots.

TABLE 7.—Simple Correlation Coefficients of the Variables.

	1. Ht. Dom.	2. Avg. Dia.	3. Basal Area	4. Live Trees	5. % Silt + Clay	6. Org. Mat.	7. % Nitro.	8. Lbs. P/Ac.	9. Lbs. K/Ac.	10. pH
					Bottomland Plots					
Soil Depth 0-12" †										
1. Ht. Dominant		.925**	.693**	—.411*	—.572**	—.496**	—.562**	.127	—.401*	—.228
2. Average Diameter			.762**	—.390*	—.553**	—.402*	—.527*	.195	—.336*	—.316
3. Basal Area				.234	—.293	—.340	—.385*	—.128	—.195	—.234
4. Live Trees					.375*	.211	.265	—.468**	.238	.297
5. % Silt + Clay						.783**	.844**	.074	.362*	—.103
6. Organic Matter							.877**	.300	.468**	—.087
7. % Nitrogen								.162	.491**	—.123
8. Lbs. P per acre									.240	.033
9. Lbs. K per acre										.164
10. pH										
Soil Depth 12-24" †										
1. Ht. Dominant		.925**	.693**	—.411*	—.343	—.501**	—.389*	.258	—.373*	—.303
2. Average Diameter			.762**	—.390	—.278	—.363*	—.297	.291	—.323	—.395*
3. Basal Area				.234	.056	—.080	—.054	—.058	—.196	—.263
4. Live Trees					.468**	.447*	.384*	—.541**	.217	.344*
5. % Silt + Clay						.782**	.720**	.000	.616**	.693**
6. Organic Matter							.851**	.064	.447*	.028
7. % Nitrogen								.086	.378*	.087
8. Lbs. P per acre									.132	—.034
9. Lbs. K per acre										.178
10. pH										
Soil Depth 24-36" †										
1. Ht. Dominant		.925**	.693**	.411*	—.407*	—.457*	—.418*	.146	—.477**	—.368*
2. Average Diameter			.762**	—.390*	—.324	—.263	—.289	.224	—.423*	—.437*
3. Basal Area				.234	.011	.048	—.004	—.171*	—.343	—.329
4. Live Trees					.529**	.500**	.450*	—.605**	.173	.316
5. % Silt + Clay						.828**	.775**	.058	.563**	.256
6. Organic Matter							.920**	.072	.560**	.129
7. % Nitrogen								.089	.551**	.177
8. Lbs. P per acre									.205	—.086
9. Lbs. K per acre										.376
10. pH										

Table 7.—(Continued).

Upland Plots

Soil Depth 0-12" † †									
1. Ht. Dominant	.941**	.954**	—.599	—.837**	—.791*	—.839**	.374	.126	.148
2. Average Diameter		.985**	—.599	—.887**	—.902**	—.948**	.453	.453	.095
3. Basal Area			—.575	—.860**	—.839**	—.894**	.369	.369	.169
4. Live Trees				.715*	.430	.596	—.573	—.573	—.029
5. % Silt + Clay					.790*	.889**	—.352	—.001	.068
6. Organic Matter						.971**	—.373	—.135	.109
7. % Nitrogen							—.471	—.156	.138
8. Lbs. P per acre								—.787*	—.274
9. Lbs. K per acre									—.438
10. pH									
Soil Depth 12-24" † †									
1. Ht. Dominant	.941**	.954**	—.599	—.558	—.787*	—.847**	.304	.109	—.018
2. Average Diameter		.985**	—.599	—.548	—.892**	—.948**	.399	.100	—.075
3. Basal Area			—.575	—.520	—.828**	—.890**	.308	.013	—.041
4. Live Trees				.568	.447	—.651*	—.430	—.156	—.073
5. % Silt + Clay					.642*	.658*	.048	.100	.564
6. Organic Matter						+ .960**	—.287	—.107	.290
7. % Nitrogen							—.420	—.143	.202
8. Lbs. P per acre								.760*	—.026
9. Lbs. K per acre									—.335
10. pH									
Soil Depth 24-36" §									
1. Ht. Dominant	.936**	.970**	—.573	—.631*	—.760*	—.804*	.207	.055	—.094
2. Average Diameter		.987**	—.579	—.729*	—.910**	—.954**	.304	.038	—.155
3. Basal Area			—.564	—.708*	—.865**	—.903**	.231	.043	—.121
4. Live Trees				—.632*	.374	.581	.296	—.075	—.003
5. % Silt + Clay					+ .798**	.780*	.088	.135	.142
6. Organic Matter						.957**	—.174	—.062	.329
7. % Nitrogen							—.320	—.101	.299
8. Lbs. P per acre								.350	.300
9. Lbs. K per acre									—.401
10. pH									

* Significant, 5% level
** Significant, 1% level
† N = 29
† † N = 9
§ N = 8

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2-60/3M