GENETIC VARIATION OF CONES, SEEDS, AND NURSERY-GROWN SEEDLINGS OF BALDCYPRESS (TAXODIUM DISTICHUM (L.) RICH.) PROVENANCES

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Abstract.--Genetic variation of baldcypress seed and cone characteristics and nursery-grown seedlings was explored through the use of two open-pollinated seed source collections made in the fall of 1980 and 1981. Source and family-within-source effects were significant for cone size and seed weight. Family-within-source was the only significant effect for number of seeds per cone and number of insect galls per cone. Differences in height and diameter growth were unrelated to source, but family differences were highly significant. The wide range of variability indicates a potential for genetic gain in the growth of baldcypress.

Additional keywords: Height growth, diameter growth, geographic variation, *Cecidomyiidae*.

Baldcypress (Taxodium distichum (L.) Rich.) is a commercial forest tree species commonly found in the bottomlands and swamps of the southern and southeastern United States. An estimated 155.7 million cubic meters of natural second-growth baldcypress is growing on commercial forest lands in the South (Williston et al. 1980). Much of this growing stock is of harvestable size or will attain such size within the next 25 years and cutting of these stands is increasing. These trees occupy vast acreages of permanently or periodically flooded sites and these low, wet sites are difficult to regenerate when harvested. In most cases, baldcypress may be the only commercial species that can be used to regenerate such sites. It is capable of fast growth and high-quality trees are in high demand for cypress lumber.

Little is known about regeneration or management of baldcypress. Natural regeneration is difficult to obtain making artificial regeneration a more feasible and viable alternative. The focus then shifts to finding the best genotypes for improved planting stock. While genetic variation in baldcypress is not well documented, there is limited evidence in the literature to support its existence (Beilman 1947, Correll and Johnston 1970, Flint 1974, McMillan 1974, Sharma and Madsen 1978). Information is presented here on the genetic variation of the cones and seeds of mature baldcypress trees and the height and diameter growth of one-year-old seedlings.

METHODS

Seed Collection

Two seed-source collections were made, one in the fall of 1980 (Collection [5 sources) and the second in the fall of 1981 (Collection II, 9 sources).

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These sources and their respective longitudes and latitudes are listed in table 1. Five individual parent trees were chosen from natural baldcypress stands located near each designated source. When possible, the selected parent tree was of the best form and vigor relative to other trees around it. However, due to a poor seed year in 1980, the selection criteria for Collection I was mainly finding a seed-bearing tree near the desired location. Twenty-five open-pollinated cones were collected from each parent tree, constituting a half-sib family.

Table 1.--Longitudes and latitudes of selected geographic seed sources of baldcypress - 1980 and 1981

Source	Location	Longitude	Latitude
		COLLECTION I - 1980	
1	Falfurrias, TX	90°10'	27°20'
2	Edgerly, LA	93°30'	30°15'
3	Simpson, LA	93°00'	31°15'
4	Stamps, AR	93°30'	33°20'
5	Quitman, LA	92°45'	32°20'
6	Woodworth, LA	92°30'	31°25'
7	Avery Island, LA	91°55'	29°55'
8	Pierre Part, LA	91°20'	30°05'
9	Lebeau, LA	91°35'	30°45'
10	Crossett, AR	91°55'	33°25'
11	Carbondale, IL	89°20'	37°05'
12	Stoneville, MS	90°55'	33°25'
13	Baton Rouge, LA	91°10'	30°30'
14	La Place, LA	90°30'	30°05'
15	Franklinton, LA	90°15'	30°55'
		COLLECTION II - 1981	
1	Natchez, MS	91°25'	31°35'
2	Alexandria, LA	92°30'	31°20'
3	Bogalusa, LA	89°50'	30°45'
4	Gibson, LA	91°00'	29°40'
5	La Place, LA	90°30'	30°05'
6	Stoneville, MS	90°55'	33°25'
7	Illinois/Kentucky	89°00'	36°55'
8	Monticello, AR	91°45'	33°37'
9	Bunkie, LA	92°10'	30°55'

Seed Handling

After collection, the cones were air-dried in a greenhouse and seeds were separated from the cones by hand. After cleaning and counting the seeds from Collection I, they were wrapped in heavy, porous nylon cloth to protect them from natural elements, and stratified by sinking them in a pond from February 19, 1981 to April 21, 1981 (61 days).

Following stratification, the seeds were planted from April 21, 1981 to May 5, 1981 in nursery beds in a compact family design following the procedure designated by Wright (1976). The design was replicated four times. All sources were randomized within each replication and families were randomized within sources. Approximately 40 seeds were planted per family per replication in rows 10 cm apart with 5 cm between seeds within a row.

Seed and Cone Data

The number of seeds per cone was the only seed/cone data taken for Collection I. All seeds, regardless of viability, were recorded as such; no effort was made to determine viability. While handling Collection I, numerous cone galls were observed. This led to recording the number of galls per cone for Collection II to determine if the number of galls per cone affected other variables.

The number of seeds per cone was recorded for Collection II. In addition, axil size (size of the cone in the same plane as the stem), cross-section size (size of the cone in the plane perpendicular to the stem), and individual seed weight were recorded. To determine seed weight, 25 cleaned seeds were randomly selected from a family within a given source and individually weighed on a Mettler balance to the nearest .1 milligram. Twenty-one out of 45 families were sampled this way.

Nursery Measurements

Germination counts for Collection I were made every two or three days following planting for a 41 day period. Germination was recorded when the hypocotyl broke through the soil surface. Height from groundline to the top of the terminal bud and diameter at groundline were measured after one growing season in the nursery.

Statistical Analysis

Analysis of variance was performed on the seed and cone data for both collections. The Statistical Analysis System (SAS) procedures ANOVA and GLM were used (Barr et al. 1979). Variance components were estimated with the SAS procedure NESTED and correlation coefficients were calculated to determine significant relationships between variables.

Due to highly variable germination compounded by severe damping off in the nursery beds, the number of seedlings per family within source was extremely unbalanced. Whole families were missing from many sources and complete sources were missing in replications II, III, and IV. After several unsuccessful attempts at conventional analysis, the decision was made to analyze the heights and diameters of seedlings from replication I only. Replication I was the most uniform with respect to missing families and sources, but was still unbalanced. Therefore, analysis of variance for unequal numbers of observations (using GLM) was performed on the height and diameter data for replication I. All four replications of germination data were analyzed.

Least squares means for heights and diameters of the families were calculated from the raw data. Least squares means are estimates of the expected arithmetic means if equal numbers of observations per class had been available (Barr et al. 1979).

RESULTS AND DISCUSSION

Seed and Cone Characteristics

Collection I.--Mean number of seeds per cone was 14. Values ranged from 2 to 30 seeds per cone. There were no significant source effects but family-within-source was significant at the .01 level of probability.

Collection II.--The mean number of seeds per cone was 17 with a range of 5-34 seeds. Family-within-source variation was the only significant effect (.01 level). A t-test indicated a significant difference at the .01 level of probability between the mean number of seeds per cone for Collection I (14) and Collection II (17). This indicates that in a poor seed year when fewer trees have cones on them those that do have cones have fewer seeds per cone. In both collections the average number of seeds per cone was lower than the average of 18-30 reported in the literature (Bonner 1974, Mattoon 1915).

The number of seeds per cone was positively correlated with axil size (r=.59) and cross-section size (r=.57), indicating the larger the cones, the greater the number of seeds. Mean axil size was 24.2 millimeters. Statistics analysis revealed significant source (.05 level) and family-within-source (.01 level) differences. Axil sizes ranged from 14.0 mm to 39.0 mm. Almost 20 percent of the variation in axil size was attributable to source of the cones while family-within-source was responsible for roughly 40 percent. There were no recognizable trends or patterns with regard to source effects on axil size. Mean cross-section was 24.6 millimeters (range 16.0-36.0 mm). Family-within-source was the only significant source of variation. As expected, cross-secti size and axil size are highly correlated (r=.84).

Mean seed weight was 97.3 milligrams (range 36.2-196.5 mg). Seed weight was significantly affected by source (.05 level) and family-within-source (.01 level). Twenty-one percent of the variation in seed weight was due to source. However there was no apparent geographical trend. Family-within-source effects accounted for 24 percent of the variation. McMillan (1974) found source differences in the mean seed weights of baldcypress seeds collected from Illinois, Kentucky, Mississippi, Texas, and Mexico. Seeds from southern Texas and Mexico were the lightest, but this was attributed to interspecific variation father than geographic variation as T. mucronatum is the common cypress species of the area. Overall mean seed weight was 97.1 mg in that study. Seed weight was also influenced by size of the cone and the number of seeds per cone. Seed weight was positively correlated with axil size (r=.53), cross-section size (r=.52), and number of seeds (r=.17).

Research results have shown significant relationships between the weight of the seed and other characteristics such as germinative capacity, survival, and seedling size in many tree species (Korstian 1927, Perry and Coover 1933, Righter 1945, Shoulders 1961, Spurr 1944). With respect to baldcypress, it appears that by collecting larger cones (or selecting for large cone size in a breeding program), not only can the number of seeds be increased but seed weight and possibly germination and seedling size can be improved.

During seed handling of Collection I, numerous insect galls were observed inside the cones. The causal insect is probably a cone midge of the family Cecidomyiidae, possibly the same insect responsible for the familiar leaf gall on baldcypress. However, the taxonomy and identification are still uncertain, as are the mode of action and possible effects. It appears that the larvae of the midge feed on the endosperm, hypocotyl, and radicle portion of the seed and possibly use the seed coat as material for the gall itself. Based on personal observations, it appears that the seeds next to the gall are generally devoid of a solid embryo, misshapen, and lighter.

The mean number of galls per cone was 8. This is almost 50 percent of the mean number of seeds per cone. The number of galls per cone ranged from zero to 40 and varied significantly among parent trees. There were no significant differences in number of galls per cone among sources.

Just what effect these galls have on baldcypress seed viability remains to be seen. There was no significant correlation of galls with the total number of seeds per cone. When seed counts were made, anything recognizable as a baldcypress seed was counted and no effort was made to determine viability even though there were obvious physical differences in appearance. Distinguishing between viable and non-viable seed may provide different results.

The number of galls per cone was negatively correlated with seed weight (r=-.40) in that lower seed weights were associated with higher number of galls. It is apparent that the causal insect utilizes or removes some portion of the seed in the production of the gall or causes a reduction in embryo size, thus reducing seed weight. This could impact germination values or seedling sizes in light of the literature discussed in the section on seed weights. It seems prudent that when collecting seed with numerous cone galls, an effort should be made to collect extra cones to insure an adequate amount of usable seed.

Germination

Overall germination in the nursery was poor, with a mean germination of 15.5 percent (range 0.0-80.0%). Results of previous studies show ranges in germination of 25 to 75 percent (Beilman 1947) and 40 to 60 percent (Mattoon 1915); Bonner (1974) reported 74 percent germination in laboratory tests based on full seeds only. Seeds in this study were not chosen by this criterion, although an effort was made to discard obviously inviable seed. Germination data, as well as height and diameter data, were taken on Collection I only. The low overall germination is probably a result of the generally poor quality of the seed. The high germination figures for some families (70 to 80 percent) would indicate that there was nothing wrong with the stratification procedures or germination conditions.

There were significant differences in percent germination due to **source** as well as family-within-source at the .01 level. Fifty percent of the variation in germination was due to source, while 28 percent was due to family-within-source. Families from La Place, Louisiana, had the highest mean germination (45.8 percent) and were significantly different from the other sources, however there was no particular geographical trend.

/ Personal communication with Dr. Richard Goyer, Associate Professor of Entomology, Louisiana State University.

Height and Diameter of Seedlings After One Growing Season in the Nursery

Height.--The mean height for all seedlings was 81.4 centimeters. There were no significant source effects but family-within-source variation was significant at the .01 level of probability. The family with the tallest seedlings was from Avery Island, Louisiana, and the mean family height was 104.3 cm. The family with the shortest seedlings (52.6 cm) was also from Avery Island (table 2). This wide range in height growth between two families from one source and the large amount of family variation indicates a high degree of genetic diversity among individual trees in natural stands of bald-cypress. The mean height growth of the top ten percent of the families was 99.4 cm a 22.5 percent gain when compared to the overall mean height of 81.4 cm.

Table 2.--Least squares means in centimeters for diameter and height of one-year-old baldcypress seedlings by source and family

SRC[1]	FAM	DIA	HT	SRC	FAM	DIA	HT	SRC	FAM	DIA	HT
7	5	1.9	104.3	11	4	1.2	79.3	10	2	1.0	79.9
13	3	1.8	83.0	11	2	1.2	98.4	12	4	1.0	87.4
1	2	1.7	87.3	12	5	1.2	89.5	8	5	1.0	80.9
3	2	1.6	87.2	11	3	1.2	77.6	11	5	1.0	73.2
4	1	1.5	80.0	6	5	1.2	91.5	14	3	1.0	78.2
7	4	1.5	96.7	6	2	1.2	75.0	10	3	1.0	77.6
13	5	1.5	100.8	4	5	1.2	78.0	8	2	1.0	76.0
4	4	1.5	77.0	3	4	1.2	80.0	6	4	1.0	60.0
5	5	1.4	100.0	3	3	1.2	82.0	14	2	1.0	82.4
5	2	1.4	75.8	2	4	1.2	84.7	15	2	2.0	73.5
7	2	1.3	96.0	9	4	1.2	70.3	12	2	0.9	83.5
1	3	1.3	92.8	11	1	1.2	92.4	14	4	0.9	78.4
3	1	1.3	90.0	2	1	1.2	75.7	8	4	0.9	71.6
4	2	1.3	74.0	2	3	1.2	78.4	12	1	0.9	67.3
9	5	1.3	83.8	13	4	1.2	68.5	1	4	0.9	57.0
14	1	1.3	86.5	10	4	1.1	86.2	10	5	0.9	76.0
3	5	1.2	85.0	9	2	1.1	92.5	8	1	0.9	67.2
2	2	1.2	90.1	15	1	1.1	80.2	10	1	0.8	75.2
9	1	1.2	88.9	14	5	1.1	90.1	12	3	0.8	77.3
4	3	1.2	76.4	2	5	1.1	71.4	7	1	0.8	52.6
5	3	1.2	73.2	7	3	1.0	64.5				

1/ SRC = source, FAM = family, DIA = diameter, HT = height.

Selection of families with an ability to make rapid early height growth is especially important in establishing baldcypress plantations. In areas subject to flooding, keeping the tops above the water line is necessary to insure survival. Baldcypress also appears to be non-competitive with annual weeds and brush. The taller a seedling when planted, the greater the advantage it will have with competing vegetation. By planting seedlings from superior families, survival should improve, cultural treatments (i.e. disking, mowing) could be reduced, and, possibly, the rotation period would be shortened.

Diameter.--The mean ground-line diameter for all seedlings was 1.1 cm. Source effects were not significant, but family-within-source was highly significant. The family with the largest mean diameter (1.9 cm) was from Avery Island, Louisiana and was also the family with the tallest seedlings (table 2). This is not surprising as height and diameter were found to be highly correlated (r=.75). At 0.8 cm, members of the family with the smallest mean diameter were also from Avery Island.

The same opportunities for exploiting the wide genetic diversity in baldcypress to improve early height growth exist for diameter growth, but on a larger scale. The top ten percent of the families have a mean diameter of 1.6 cm. This represents a 50 percent gain in diameter growth over the grand mean for all families of 1.1 cm.

There is a high degree of family variation in early height and diameter growth for baldcypress. Thus parent tree selection by progeny testing should yield a good opportunity for genetic gain.

SUMMARY AND CONCLUSIONS

There was very little evidence of geographic variation exhibited by one-year-old baldcypress seedlings in the nursery. No source variation was found for height and diameter growth. Mean seed weight and germination were significantly affected by source. It is probable that the scope of this study was not large enough to detect geographic variation, as this was a limited-range study relative to the natural range of baldcypress. However, the lack of geographic variation could also be due to the similarity of the sites on which it is found throughout its natural range.

Seed and cone characteristics showed significant family variation and significant relationships between the size of the cones and the number of seeds per cone. The number of seeds per cone was lower than that previously reported. In addition, the number of galls per cone and seed weight were negatively correlated.

The high degree of family influence on the genetic variability of height and diameter growth indicates a potential for genetic gain in the growth of baldcypress. However, progeny testing in the field for longer periods of time must be completed before reliable data can be obtained.

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