CHEMICAL COMPARISON OF TWO ECOTYPES OF LOBLOLLY PINE (*PINUS TAEDA* L.)[1]

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(Received 31 August 1982)

ABSTRACT

Loblolly pine from the continuous range in east Texas was compared with an apparently drought-resistant ecotype, the so-called "Lost pines" or "Bastrop pines." The Bastrop pines are found in a small area of central Texas isolated from the rest of the loblolly range, and in a region receiving considerably less rainfall. Determinations made were: holocellulose, alpha cellulose, ash, specific gravity, and percentages of earlywood and latewood. Nutrient analyses for levels of sodium, potassium, calcium, magnesium, zinc, manganese, and copper were also performed. It was found that the earlywood of the east Texas population had significantly greater levels of holocellulose and alpha cellulose. Regression analyses were performed relating the nutrient values to the chemical components. The appearance of potassium and magnesium in these equations, for the Bastrop pines, may indicate physiological adaptation to the more xeric environment.

Keywords: Loblolly pine, Bastrop pine, drought resistance, chemical composition.

INTRODUCTION

The continuous range of loblolly pine extends approximately 125 miles into the eastern part of Texas, and is delineated by decreasing rainfall amounts. The so-called "Bastrop pines" or "Lost pines" are found in an area 120 miles west of the continuous range of the Southern pines, in Bastrop, Caldwell, and Fayette counties. These counties receive 10–20 inches less annual rainfall than does the area of east Texas in the continuous loblolly range.

Some of the first work on drought resistance in the Bastrop pines was begun by Zobel (1953), Zobel and Goddard (1955), and van Buijtenen (1963). The results of these earlier studies indicate that a difference does exist between the Bastrop pines and loblolly pines from the continuous range of the species. Further work on verification that the Bastrop pines are indeed drought-resistant has been performed by Knauf and Bilan (1974), Haugen (1972), and Davies (1973). These later studies indicate a number of physiological adaptations that equip the individuals for survival in more xeric environments. There have been discussions of levels of carbohydrates and sugars in drought-resistant plants in general and Bas-

[1] Published as Alabama Agricultural Experiment Station Journal Series No. 9-810102.

trop pines in particular (Gilmore 1956), but no consideration of structural polysaccharides.

The current study was undertaken to compare relative levels of certain chemical constituents and physical properties of each ecotype and to elucidate any differences that may be present. These data may indicate what modifications in chemical components have taken place and their impact on the drought resistance that has been reported in the Bastrop population. The parameters of interest were: percentages of holocellulose, alpha cellulose, ash, earlywood, and latewood. Also determined were specific gravity and levels of sodium, calcium, potassium, magnesium, zinc, manganese, and copper.

METHODS AND MATERIALS

Five trees from each population were selected from five-year-old growing stock that had been established in a small research nursery. The nursery was located on the campus of Stephen F. Austin State University in Nacogdoches, Texas, which is within the continuous range of loblolly pine. The trees, therefore, had been subjected to conditions prevalent within the east Texas portion of the loblolly pine range. The trees were of uniform height and had been grown with a 2- × 2-foot spacing. The material for analysis was taken from within 24 inches of the ground. The wood from the last growing season was removed and separated into earlywood and latewood portions. It should be borne in mind that the trees were only five years old and therefore all analyses were performed on juvenile wood. The samples were air-dried, ground, and sieved. The portion that passed a number 40 screen and was retained on a number 60 screen was used in the analyses.

The wood samples were extracted with alcohol : benzene (1:2 v/v) and then sequentially washed with alcohol and cold water and allowed to air-dry. Holocellulose was determined by the Chlorite-Acetic Acid Method (Jayme 1942; Wise 1945; Wise et al. 1946). Alpha cellulose was isolated by digestion with 17.5% sodium hydroxide (Burkart 1963). Ash analyses were performed in accordance with TAPPI standard T15. After ashing, each sample was dissolved in dilute hydrochloric acid and diluted with distilled water. Nutrient analyses were then performed with a Jarrel-Ash JA 82-270 Atomsorb Flame Spectrophotometer. These samples were analyzed for sodium, potassium, calcium, magnesium, zinc, manganese, and copper. Specific gravity determinations were performed by Smith's maximum moisture content method (1954). Annual ring widths and amounts of earlywood and latewood were determined with an Addo ring measuring device. All determinations were performed in duplicate on each individual tree sample and were averaged to yield the values used in the statistical analyses.

RESULTS

Tables 1 and 2 show the mean and standard deviation of each constituent from the two ecotypes for earlywood and latewood, respectively. *T*-tests were performed on the original data; values not underscored by the same line differ significantly at the 5% level. The only significant differences detected between the two ecotypes occurred in the levels of holocellulose and alpha cellulose in the earlywood. The east Texas population was found to have significantly greater amounts of these components than the Bastrop population.

TABLE 1. *Major wood quality and mineral nutrient levels in earlywood from Bastrop and east Texas loblolly pine ecotypes.*

Parameter	East Texas	Bastrop
Holocellulose %	79.92 ± 1.10	77.12 ± 0.72
Alpha cellulose %	43.70 ± 0.86	41.71 ± 1.28
Ash %	0.54 ± 0.11	0.47 ± 0.07
Sodium ppm	164.25 ± 38.60	213.99 ± 133.67
Potassium ppm	1,484.85 ± 237.16	1,646.67 ± 330.13
Calcium ppm	420.66 ± 151.38	411.81 ± 157.16
Magnesium ppm	235.58 ± 36.95	249.53 ± 12.72
Zinc ppm	13.93 ± 7.10	11.92 ± 2.29
Manganese ppm	50.68 ± 27.92	37.07 ± 4.82
Copper ppm	10.75 ± 0.12	13.05 ± 4.82
Earlywood %	55.48 ± 2.80	50.71 ± 9.87
Specific gravity	0.31 ± 0.03	0.40 ± 0.09

Values underscored by the same line do not differ at the 5% level.

TABLE 2. *Major wood quality and mineral nutrient levels in latewood from Bastrop and east Texas loblolly pine ecotypes.*

Parameter	East Texas	Bastrop
Holocellulose %	81.86 ± 1.01	80.67 ± 2.11
Alpha cellulose %	50.34 ± 2.08	49.67 ± 2.71
Ash %	0.63 ± 2.08	0.55 ± 0.12
Sodium ppm	202.26 ± 214.64	121.88 ± 40.13
Potassium ppm	1,803.52 ± 215.84	1,817.86 ± 237.66
Calcium ppm	272.53 ± 28.32	334.51 ± 167.03
Magnesium ppm	297.13 ± 32.48	297.17 ± 22.44
Zinc ppm	11.97 ± 2.40	10.91 ± 0.24
Manganese ppm	43.53 ± 16.25	30.55 ± 14.04
Copper ppm	10.91 ± 0.16	0.76 ± 5.98
Latewood %	44.52 ± 3.80	49.29 ± 8.87
Specific gravity	0.54 ± 0.02	0.55 ± 0.07

Values underscored by the same line do not differ at the 5% level.

TABLE 3. *Major wood quality and mineral nutrient levels from composite samples of Bastrop and east Texas loblolly pine ecotypes.*

Parameter	East Texas	Bastrop
Holocellulose %	80.79 ± 0.91	78.92 ± 1.30
Alpha cellulose %	46.67 ± 1.44	45.70 ± 2.12
Ash %	0.58 ± 0.09	0.50 ± 0.03
Sodium ppm	183.25 ± 100.86	172.70 ± 92.85
Potassium ppm	1,627.22 ± 204.86	1,731.82 ± 266.45
Calcium ppm	356.90 ± 80.45	375.20 ± 119.83
Magnesium ppm	262.59 ± 32.23	272.25 ± 14.60
Zinc ppm	13.30 ± 4.22	11.41 ± 1.19
Manganese ppm	47.37 ± 21.92	33.98 ± 12.12
Copper ppm	10.83 ± 0.07	11.45 ± 5.17
Specific gravity	0.41 ± 0.02	0.47 ± 0.08

Values underscored by the same line do not differ at the 5% level.

TABLE 4. *Regression analyses relating wood quality parameters and nutrient found in the east Texas ecotype.*

Regression equation	Adjusted R-square	Probability of a greater F
% holocellulose earlywood = 8.87Cu + 0.02Na − 0.04Zn − 17.45	0.99	0.01
% alpha cellulose earlywood = 0.02Mg + 39.92	0.30	0.20
% ash earlywood = 0.0007K − 0.59Cu + 5.91	0.99	0.01 >
Specific gravity earlywood = 0.0002K + 0.32Cu − 2.79	0.93	0.03
% holocellulose latewood = 0.15Mg + 77.28	−0.0047	0.39
% alpha cellulose latewood = 0.01Na − 48.90	0.38	0.16
% ash latewood = −0.0003Na − 0.0002K + 0.34	0.99	0.01 >
Specific gravity latewood = 0.09Cu − 0.44	0.02	0.07
% holocellulose composite = 7.25Cu + 0.02Mg − 0.004Na − 0.88	0.99	0.01 >
% alpha cellulose composite = 2.55Cu + 9.56	0.68	0.01 >
% ash composite = 0.0004K − 0.0003Na + 0.002	0.82	0.01 >
Specific gravity composite = 0.0002Ca + 0.25	0.17	0.13

TABLE 5. *Regression analyses relating wood quality parameters and nutrients found in Bastrop pine.*

Regression equation	Adjusted R-square	Probability of a greater F
% holocellulose earlywood = 0.05Mg + 63.84	0.86	0.02
% alpha cellulose earlywood = 0.11Mn + 37.72	0.70	0.05
% ash earlywood = 0.006Mn − 0.00006K + 0.32	0.97	0.02
Specific gravity earlywood = −0.0002K + 0.80	0.88	0.01
% holocellulose latewood = 10.76Zn − 0.01K − 27.54	0.98	0.01
% alpha cellulose latewood = 13.90Zn − 0.01K − 85.20	0.92	0.04
% ash latewood = 0.0005K − 0.28	0.72	0.04
Specific gravity latewood = 0.002Na + 0.0003Ca + 0.002Cu + 0.64	0.99	0.01 >
% holocellulose composite = 0.18Mg + 2.30Zn + 1.42	0.80	0.01 >
% alpha cellulose composite = 0.16Mg + 0.87	0.78	0.01 >
% ash composite = 0.002Mg + 0.04	0.42	0.03
Specific gravity composite = 0.002Mg + 0.02	0.43	0.02

TABLE 6. *Regression analyses relating wood quality parameters and nutrients in combined east Texas and Bastrop data.*

Regression equation	Adjusted R-square	Probability of a greater F
% holocellulose earlywood = 0.05Mn + 76.33	0.30	0.06
% alpha cellulose earlywood = 0.04Mn + 41.02	0.22	0.10
% ash earlywood = 0.0008Na + 0.0002K + 0.31	0.47	0.04
Specific gravity earlywood = −0.0001K + 0.57	0.15	0.15
% holocellulose latewood = 0.01Ca + 84.18	0.38	0.03
% alpha cellulose latewood = 0.23Cu + 52.36	0.05	0.25
% ash latewood = 0.0003K − 0.04	0.43	0.02
Specific gravity latewood = 0.001Mg − 0.002Mn − 0.0001K + 1.22	0.77	0.01
% holocellulose composite = 0.14Mg + 1.06Zn + 14.09	0.56	0.01
% alpha cellulose composite = 0.11Mg + 0.39Zn + 5.85	0.61	0.01 >
% ash composite = 0.0002K − 0.0004Na + 0.10	0.41	0.01 >
Specific gravity composite = 0.0002Mg − 0.000Ca + 0.04	0.34	0.01 >

Composite results, based on the percentage of earlywood and latewood in each sample, are shown in Table 3. The holocellulose of the east Texas group was again found to be significantly greater than the Bastrop ecotype. No other statistical differences were found.

In an effort to relate the levels of the various parameters to the nutrient levels, forward stepwise regressions were performed on the data from each ecotype. The regression equations, adjusted R-square values and probability of greater F values are shown in Tables 4–6.[2]

Table 4 contains the results of the regressions performed on the east Texas population. Within the earlywood section of the ring, significant relationships were found for holocellulose, ash, and specific gravity. The only significant relationship detected for the latewood portion was that of ash percentage. The composite samples that combined earlywood and latewood showed significant linear equations for holocellulose, alpha cellulose, and ash.

Regression results for the Bastrop ecotype are reported in Table 5. All equations are statistically significant for this group. It is interesting to note that magnesium appears in all of the equations for the combined earlywood-latewood data for the Bastrop group, whereas it is not present in the east Texas population. Further, the east Texas group shows no single element comparable in importance to magnesium in the Bastrop population.

The last set of regression analyses (Table 6) did not separate the ecotypes, but attempted to determine if overall relationships could be found. The most inclusive of these analyses combined earlywood and latewood, as well as both ecotypes into a single set of data. The various parameters were again weighted, based on the percentage of earlywood and latewood. All relationships were found to be significant at the 5% level, but the R-square values were somewhat low, particularly in comparison to those found in previous analyses. As was pointed out earlier, magnesium again seems to be the predominate element in these analyses. By sorting this data into earlywood and latewood categories, two additional sets of analyses were generated. Neither had particularly high R-square values, although significant relationships were indicated for ash in the early wood, and holocellulose, ash, and specific gravity in the latewood.

CONCLUSIONS

Physiological investigations have indicated that differences exist between the loblolly pines found within the continuous range and those of the Bastrop ecotype. The differences that have been reported are largely adaptations to the more xeric environment in which the Bastrop pines are found. The amount of holocellulose found in this research for the individuals in the Bastrop population may represent a defense mechanism for drought tolerance. Furthermore, it is interesting to note that the levels of the constituents in Bastrop pine are related to the levels of both potassium and magnesium. It has been reported that potassium is important in

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[2] The adjusted R-square value is used with small sample sizes, and calculated by the following equation:

$$\text{Adjusted R-square} = 1 - (\text{total degrees of freedom}/\text{error degrees of freedom})(1 - R^2).$$

This value can be a negative number, and is indeed negative for the east Texas latewood holocellulose.

controlling the action of guard cells which control stomatal opening (Fischer 1968). Haugen (1972) and Bilan et al. (1977) found that the behavior of the stomates in Bastrop pine is similar to plants found in xeric environments. Although potassium content was not found to be statistically greater in the Bastrop pines, it was higher than the east Texas ecotype in both earlywood and latewood. Magnesium, which was generally higher in the Bastrop pines, is essential for the biosynthesis of chlorophyll and may be a response to droughty conditions.

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