NATURAL VARIATION IN SPECIFIC GRAVITY, FIBER LENGTH, AND RADIAL GROWTH OF EASTERN COTTONWOOD

By

JIMMIE ALLEN BUXTON

Bachelor of Science

Oklahoma State University

Stillwater, Oklahoma

1967

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
MASTER OF SCIENCE
May, 1970

NATURAL VARIATION IN SPECIFIC GRAVITY,

FIBER LENGTH, AND RADIAL GROWTH

OF EASTERN COTTONWOOD

Thesis Approved:

Dale E Weibel
Thesis Adviser

Robert M. Reed

Clayton E. Posey

D. Durham
Dean of the Graduate College

ACKNOWLEDGEMENTS

Funds for this research were made available by the Oklahoma Agriculture Experiment Station, project M. S. 1349.

The author wishes to acknowledge and express appreciation to Dr. Dale E. Weibel and Dr. Robert M. Reed, Professors of Agronomy, Oklahoma State University for their counseling and advice in this study. Dr. Clayton E. Posey, Associate Professor of Forestry, Oklahoma State University, is singled out for his significant contribution in development of this study. His consistent encouragement, patience, and good advice have been a major formative influence on my work in this study.

TABLE OF CONTENTS

LIST OF TABLES

Table | Page

LIST OF FIGURES

Figure | Page

CHAPTER I

INTRODUCTION

The establishment of new forest products industries in close proximity to Oklahoma's wood producing counties will cause intensification of forest management practices in these areas. With this prospect in mind, much interest has been generated as to how the quality and quantity of the important fiber producing tree species can be improved. Initial investigations reveal that considerable research has been performed and data collected on most commercially important coniferous species. However, very little research has been initiated on the hardwood fiber producing species in the area.

Populus has attracted the attention and interest of the forest geneticist because of its fiber producing capacity, a very important economic trait, and its ease of propagation. No other forest tree of the northern hemisphere has received so much attention with the possible exception of pine. In addition to its value as a pulping species, *Populus* is commonly sawed into dimension lumber and used for cooperage. Eastern cottonwood (*Populus deltoides* Bart.) being one of the most abundant, rapid growing, easily reproduced, bottomland hardwoods of Oklahoma, will achieve greater commercial importance as pulping demands increase in the future.

Heredity and environmental influence upon forest trees has interested foresters since the early nineteen hundreds. Foresters have studied the physical properties of trees and the natural variables which act upon them. Two very important physical properties of trees are specific gravity and fiber length.

Specific gravity is one of the oldest and most important criteria of wood quality. This physical property is closely related to many other physical and mechanical properties of wood (18). The fiber producing industries have long been interested in specific gravity because of the direct relationship between specific gravity, yield, and strength of paper.

Fiber length is the other important physical property which varies considerably throughout the tree. These cells are related directly to many other wood properties. Fiber length has been used for years by the pulp and paper industries as an index to the quality, strength, and type of paper produced.

A review by Dinwoodie (9) reveals many conflicting conclusions; however, he stated that the main factors controlling the strength of paper are specific gravity and fiber length.

A knowledge of the degree, patterns, and causes of variation in specific gravity and fiber length of eastern cottonwood is a prerequisite to the efficient planning of a tree improvement program.

The purpose of this research is to help provide a foundation for a cottonwood improvement program for Oklahoma. Understanding the elements which influence the pulp qualities of eastern cottonwood is vital and essential to a program designed to improve the quality of wood. The objectives of this investigation are:

1. To determine the phenotypic patterns of geographic variation, and to determine the cause of such variation.

2. To determine the relationship of specific gravity, fiber length, and growth rate to certain environmental variables.
3. To determine the influence of wood extractives on specific gravity.

CHAPTER II

REVIEW OF LITERATURE

Forest trees grown over a wide geographic range frequently display large amounts of phenotypic variation in one or more wood properties. This variation is distinguishable between populations grown in different localities. It is also recognized that large variation occurs between trees, and within trees (7, 11, 13, 14, 15). Phenotypic variation associated with geographic origin, between trees in stands, and within trees is due to environmental and genetic factors.

Geographic variation usually occurs in definite patterns, depending on the environmental variable under consideration. Climatic patterns usually change gradually over a species range. Phenotypic variation in a given trait changes gradually over the species range reflecting the environmental variation.

Specific Gravity

Investigators of the mechanical and physical properties of wood have long recognized and associated the importance of specific gravity with various strength properties and other important factors related to the use of wood.

An average specific gravity value for eastern cottonwood throughout its natural range was reported to be 0.43 by Markwardt and Wilson in 1935 (21).

The specific gravity of eastern cottonwood was determined from dimension lumber which was collected throughout the state of Illinois by Peterson et al. (23). They reported a broad specific gravity range of 0.32 to 0.67. The mean for the total sample was 0.43, a value which supports Markwardt and Wilson's findings.

A more recent study of the specific gravity of eastern cottonwood in east-central Illinois was undertaken by Walters and Bruckmann (30). A specific gravity range of 0.287 to 0.518 was observed. The average specific gravity value for all samples was 0.37.

It should be noted that specific gravity is lowest near the pith and increases with distance from the pith (5, 11). Walters and Bruckmann in their research used the terminal one inch of radial growth as the basis for their specific gravity values. As a result, they did not compare specific gravity of the same age or ages. Therefore, a large variation was introduced resulting in a large specific gravity range.

Stands of eastern cottonwood approximately one hundred fifty miles apart on the Mississippi River (one area near Clarksdale and the other near Vicksburg, Mississippi) were sampled by Farmer and Wilcox (11). It was observed that specific gravity varied significantly from 0.32 to 0.46. The trees sampled varied in age from twenty-one to twenty-two years of age. The mean value of 0.38 compares closely to other published means (21, 23, 30).

Farmer and Wilcox (11) also determined that specific gravity increases from the pith outward. This same relationship was observed in aspen (Populus tremuloides Michx.) by Brown and Valentine (5).

A study by Paul (22) into the variation of specific gravity of the Populus species and hybrids has shown that large amounts of variation exist and may be found among stands and within the same site.

Farmer and Wilcox (11) also found that most of the specific gravity variation was associated with individual trees. However, a smaller, but statistically significant variation was caused by differences between stands. The difference between areas was not significant.

Van Buijtenen's (28) study of aspen (Populus tremuloides Michx.) showed that specific gravity variation was associated with trees belonging to the same clone.

The study conducted by Paul (22) on the specific gravity of Populus species and hybrids has also shown that low specific gravity is associated with rapid growth. A study by Bray et al. (3) into the relationship between growth rate and specific gravity reaffirmed Paul's findings that rapid growth in the genus Populus and hybrids results in a relatively low specific gravity. Other investigations have substantiated these findings as all show a significant negative correlation between specific gravity and growth rate (7, 19, 28).

On the other hand, Brown and Valentine (5) found both positive and negative correlations between growth rate and specific gravity. Walters et al. (30), disregarding age, found no correlation between the terminal radial growth and specific gravity. A slight, but statistically insignificant negative relationship between specific gravity and radial growth in eastern cottonwood was revealed by Farmer and Wilcox (11). Gohre's (16) investigation into Populus hybrids yielded no correlation between specific gravity and ring width.

A study by Paul (22) on the relationship between specific gravity and age showed that age of a tree does not show a consistent relationship to specific gravity. However, Farmer and Wilcox (11) reported an increase in specific gravity with age.

The relationship between specific gravity and sex was studied by Walters et al. (30). Their study indicated that sex of trees within a stand contributed little to the variation in specific gravity. Farmer and Wilcox's (11) study on sex-related traits found no relationship between specific gravity and sex. However, Farmer and Wilcox revealed that males were slightly, but insignificantly larger in diameter and heigth than females.

Fiber Length

Fiber length is a wood quality factor which has been the subject of a considerable amount of research. Many investigators have concluded that fiber length should be given consideration along with other factors in tree breeding programs (7, 10, 12, 24, 27).

Four vigorously growing eastern cottonwoods were selected from the Pottsville tract on the Shawnee National Forest by Kaeiser (17). The fiber length from this study averaged 1.081 mm for all samples and ranged from .90 mm to 1.20 mm.

Dinwoodie (9), Spurr et al. (27), Chalk et al. (8), and Gerry's (13) investigations revealed that fibers near the pith are usually very short, but increase rapidly in length from the pith outward toward the periphery through a number of annual rings until a constant size is reached. This relationship was originally observed by

Sanio (2) in 1872 (translated by Bailey and Shepard in 1915), as a result of studies into the wood properties of Scotch pine (*Pinus sylvestis*).

The investigation of wood fibers of eastern cottonwood by Kaeiser (17) reaffirmed Sanio's findings that fiber length increased with the number of rings outward from the pith.

Fiber lengths of both fast and slow growing black cottonwood (*Populus trichocarpa* Torr. & Gray) were measured at comparable heights and ages by Kennedy (19). He revealed that age from the pith had a significant effect on fiber length.

Several other studies on wood properties of pine, especially southern pines, have shown that a large amount of variation is found in tracheid length within a single tree, between trees of the same stand, and between trees of different stands. Excellent research reviews are presented by Zobel et al. (32) and Goggans (14, 15).

Investigations regarding variation in eastern cottonwood are very limited. However, there is no reason to expect cottonwood to deviate greatly from established patterns.

A review of the investigations concerning the relationship between growth rate and fiber length has revealed inconsistencies. Spurr and Hyvarinen (27) concluded that rapid growth produces long fibers. An investigation by Chalk et al. (8) into storied hardwoods[1] revealed an absence of a relationship between growth rate and fiber

---

[1] Storied hardwoods are a group of highly specialized hardwoods possessing short and uniform fusiform cambial initials more or less grouped symmetrically in horizontal rows.

length. However, Chalk reported a negative correlation between growth rate and fiber length in non-storied hardwoods.

Studies undertaken by Kennedy (19), Kennedy and Smith (20), Cech, Kennedy, and Smith (7), and van Buijtenen (28) to determine the effect of growth rate on fiber length of black cottonwood all showed that fiber length increased significantly as growth rate increased.

CHAPTER III

PROCEDURE

Stratification of Plots

Twenty-five temporary plots were established at approximately sixty-mile intervals beginning at the eastern boundary of Oklahoma and extending westward along the Red River, the Cimarron River, and the South Canadian River to their headwaters (Figure 1).

Description of Area Sampled

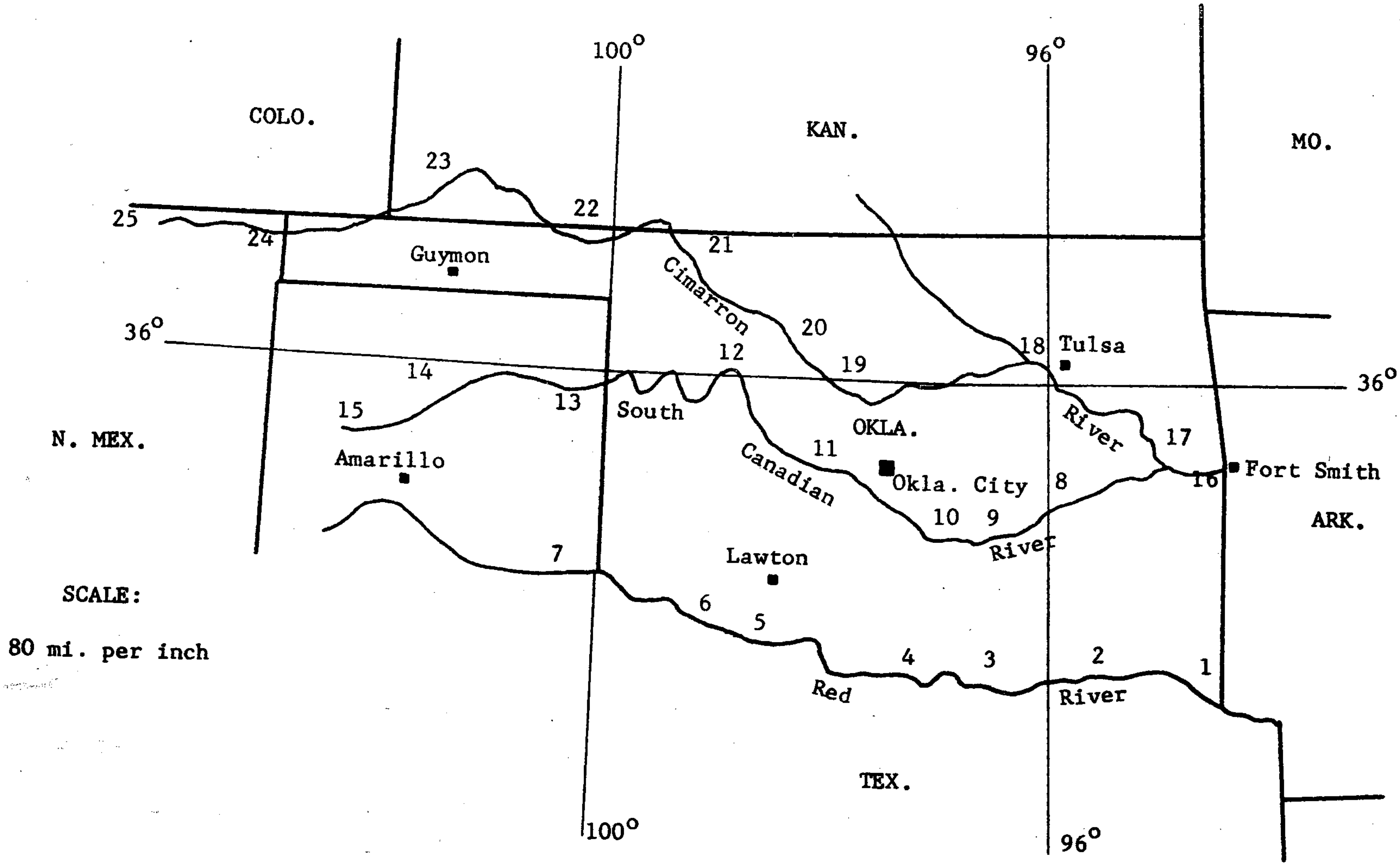
The investigation encompassed a large geographic area. The annual rainfall varied from in excess of fifty inches in the southeast portion of the study area to less than ten inches in the northwest portion. Elevation ranged from approximately three-hundred feet near plot 1 to in excess of five-thousand feet near plot 25. The topography varies from flat plains in the central portion of the study area to undulating hills, plateau and mountains in the very western portion. The soils are alluvial and very sandy in texture.

Selection of Trees

Selection of ten trees at each plot was based principally on two factors, their age class and phenotypic superiority. The age class selected ranged from seven to ten years. Criteria for phenotypic superiority was based on superior height and diameter growth in relation to

FIGURE 1

STRATIFICATION OF PLOTS



other members of the stand of the same age group. Trees selected as superior in height and diameter were evaluated visually for flat limb angle, branch size and small crown size.

Securing Borings

Each sample tree was bored with a twelve mm increment borer to obtain one increment core extending completely through the tree at diameter breast height; i. e., four and one-half feet above the ground. All cores were placed in plastic tube containers which were transferred to the laboratory and placed in cold storage at approximately thirty-five degrees Fahrenheit until they could be prepared for analysis.

Preparation of Cores

Cores were removed from cold storage, divided at the pith, and labeled. Bark was removed from the terminal end of each core and annual rings counted for total age determination. Radial growth of the third through the seventh annual ring was measured on all cores. Radial growth of the sixth and seventh annual rings was also measured on all cores.

Specific Gravity

Five growth rings, representing the third through the seventh annual rings, were used for the specific gravity determination.

All specific gravity values were determined by the maximum-moisture technique as outlined by Smith (25). Essentially, this method states that wood substance has a constant density. A density value of

1.50 was used as the density of wood substance for cottonwood. Specific gravity was determined by obtaining the water saturated wood weight and its ovendry weight. Water saturation weight was obtained by subjecting the samples to water emersion and to alternate vacuum and atmospheric pressure treatment until there was no evidence of weight increase.

The specific gravity was determined from the following relationship:

$$\text{Specific Gravity} = \frac{1}{\frac{Mm - Mo}{Mo} + \frac{1}{1.50}}$$

Where:

Mm = Saturated weight of sample

Mo = Ovendry weight of sample

A Mettler automatic balance was used to obtain all weight measurements.

It was anticipated that extraneous materials such as waxes, fats, resins, oils, and tannins would influence significantly the specific gravity calculations. Therefore, a modification of the alcohol-benzene method was adopted to remove these materials (1).

The Soxhlet extraction apparatus was used to remove the extractives. A mixture of one volume of ethyl alcohol and two volumes of c.p. benzene served as reagent.

The sequence of extraction was as follows:

1. Core segments were soaked in the reagent for four hours.
2. Extraction of the cores in the reagent for eight hours.

3. Cores were removed from the extractor and soaked in 95 percent ethanol for four hours.
4. Cores extracted for eight hours in ethanol.
5. Cores were extracted in distilled water for a period of eight hours.
6. Cores were placed in an open container of water and boiled for four hours.

To determine the influence of extractives on specific gravity, ten randomly selected cores were measured for specific gravity. These cores were then extracted with the alcohol benzene solvent to remove the extractives. Specific gravity was determined again to obtain the differential weight.

Specific gravity was reduced by a constant 0.01. Since very little variation was caused by extractives, the extractive process was terminated.

Maceration

Samples for fiber length determination were obtained from the same cores used for the specific gravity determination. The sixth and seventh annual rings were removed from each core. The two annual ring samples for each core were sliced in a radial direction, parallel to the longitudinal axis. Each wood sample was then placed in a separate vial. The maceration fluid consisted of one part glacial acetic acid and one part thirty percent hydrogen peroxide (6). The capped vials were placed in an oven for forty-eight hours at fifty to fifty-five degrees Centigrade or until the samples turned silver in color. Samples were then removed from the oven, the maceration fluid was removed by a vacuum device, and the vials were refilled with water. The vials were then shaken violently to separate the fibers. After fiber separation, the water was removed. One drop of basic fuchsin was used to stain the fibers and two drops of formaldehyde for preservation.

Fiber Length

Two slides were prepared for each annual ring of each core for a total of eight slides per tree. Ten whole fibers were measured from each slide. The "Bioscope" Model 60 with variable magnification was used for projecting fibers onto a graduated bull's eye (31).

Plot Data and Environmental Variables

For each tree selected as a sample tree, the following information was collected and recorded: (1) tree height, (2) diameter breast height, (3) basal area per acre, (4) tree sex, and (5) total age.

Data on longitude, latitude, and elevation for each temporary plot was also collected (see Table I). Longitude and latitude was recorded to the nearest fifteen minutes. Elevation was determined to the nearest twenty feet.

The proximity of each temporary plot to one of the twenty-five weather stations in the study area was also determined. The average monthly rainfall for the spring (April and May), summer (June, July, and August), fall (September and October), and winter (November, December, January, February, and March) periods were determined from the precipitation records, along with the average annual rainfall. All precipitation data was calculated so that the precipitation corresponded to the year in which the annual ring grew.

TABLE I

SUMMARY OF PLOT LONGITUDE, LATITUDE, AND ELEVATION ALONG THE RED RIVER, SOUTH CANADIAN RIVER, AND CIMARRON RIVER

Red River

Plot	Longitude	Latitude	Elevation
1	94° 30'	33° 45'	310 ft.
2	95° 30'	34° 00'	410 ft.
3	96° 30'	33° 45'	500 ft.
4	97° 15'	34° 00'	680 ft.
5	98° 30'	34° 15'	940 ft.
6	99° 15'	34° 30'	1230 ft.
7	100° 30'	34° 30'	1820 ft.

TABLE I, Continued

South Canadian River

Plot	Longitude	Latitude	Elevation
8	95° 45'	35° 15'	600 ft.
9	96° 45'	34° 45'	840 ft.
10	97° 15'	35° 00'	1000 ft.
11	98° 15'	35° 30'	1400 ft.
12	99° 00'	36° 00'	1650 ft.
13	100° 15'	35° 45'	2300 ft.
14	101° 15'	35° 45'	2750 ft.
15	102° 30'	35° 00'	3800 ft.

TABLE I, Continued

Cimarron River

Plot	Longitude	Latitude	Elevation
16	94° 30'	35° 15'	400 ft.
17	95° 15'	35° 45'	500 ft.
18	96° 00'	36° 00'	590 ft.
19	97° 15'	36° 00'	830 ft.
20	98° 15'	36° 15'	1130 ft.
21	99° 15'	36° 45'	1500 ft.
22	100° 15'	37° 00'	2300 ft.
23	101° 30'	37° 30'	2800 ft.
24	103° 00'	37° 00'	4300 ft.
25	104° 00'	36° 45'	6500 ft.

From temperature records, average monthly temperatures for the spring, summer, fall, and winter periods were determined. In addition the following was also determined from the temperature records: (1) average annual temperature, (2) mean daily maximum for August, (3) mean daily minimum for January, (4) average maximum for August, and (5) average minimum for January. Temperature data was based on the average recorded temperature as far back as records were available.

Of the many environmental variables presented in this chapter, only the following will be used: average annual rainfall, number of frost free days, and mean daily minimum temperature for January.

Although all possible correlations were computed and considered, the environmental variables mentioned above were selected over the others because their correlations overshadowed and better expressed the relationships under consideration.

Analyses of Data

Evaluation of variation in specific gravity, fiber length, and growth rate was accomplished by employing the hierachal classification. The hierarchal classification was selected because the investigation into variation involved repeated sampling and subsampling. The hierarchal analysis of variance described by Snedecor (26) was used to test the significance of variation.

Three analyses of variance were calculated using three variables, namely: (1) specific gravity (unextracted), (2) fiber length (sixth and seventh annual rings), and (3) radial growth (annual rings three through seven).

Plot 16 was omitted from all three analyses of variance because it was felt that the data from plot 16 was misleading. Three major rivers, each with a gene pool, converge just above plot 16. Therefore, three major gene pools are contributing additional variation to the individuals in plot 16 (Figure 1).

The simple correlation coefficient method was used to measure the degree of linear association between all variables involved. Duncan's (26) new multiple range test was employed to test four variables as follows: (1) specific gravity (unextracted), (2) fiber length (sixth and seventh annual rings), (3) radial growth (annual rings six and seven combined), and (4) radial growth (annual rings three through seven).

The statistical analyses were computed with an IBM 360 electronic computer at the Oklahoma State University Computer Center.

CHAPTER IV

RESULTS AND DISCUSSION

Natural Variation of Specific Gravity

The six characteristics measured are listed in Table II, along with their means and ranges. The means and ranges in Table II are based on plot averages, and thus do not show the extremes. However, Table III presents the means and ranges for each of the twenty-five plots.

It is recognized that specific gravity is lowest near the pith and increases from the pith outward (5, 11). Specific gravity determinations of this study were obtained from wood near the pith, i. e., earlywood. Therefore, earlywood specific gravity of this study is at its lowest and should increase with distance from the pith.

Mean plot specific gravity ranged from 0.36 to 0.44 (Table III). The overall mean specific gravity for annual increments three through seven was 0.382. These specific gravity means are close to other published means obtained from latewood specific gravity (11, 21, 23, 30). These observations are encouraging because they imply high initial specific gravity.

The very nature of this study suggests extensive variation because the study area encompasses a large geographic area with its wide climatic, ecological, and edaphic ranges.

TABLE II

MEANS AND RANGES FOR GROWTH AND WOOD VARIABLES BASED ON TWENTY-FIVE PLOT MEANS

Variables	Mean Values	Range Min	Range Max
FIBER LENGTH (mm)			
At 6 Years	1.114	.94	1.29
At 7 Years	1.016	.93	1.26
RADIAL GROWTH (Inches)			
At 3-7 Years	1.816	.83	3.46
At 6 Years	.383	.16	.72
At 7 Years	.354	.16	.63
SPECIFIC GRAVITY			
At 3-7 Years	.382	.36	.44

TABLE III

MEANS AND RANGES FOR SEVERAL WOOD CHARACTERISTICS
BASED ON PLOT DATA

RED RIVER PLOTS	SPECIFIC GRAVITY $\bar{X}$	Min	Max	FIBER LENGTH 6 (mm) $\bar{X}$	Min	Max	FIBER LENGTH 7 (mm) $\bar{X}$	Min	Max	RADIAL GROWTH (Inches) $\bar{X}$	Min	Max
1	.37	.35	.41	1.29	1.19	1.40	1.26	1.12	1.40	2.99	1.80	4.75
2	.38	.36	.43	1.18	1.08	1.27	1.12	.98	1.26	1.96	.75	2.97
3	.37	.34	.41	1.18	1.10	1.33	1.12	1.01	1.30	3.46	1.93	5.52
4	.39	.36	.44	1.09	.98	1.18	1.07	.96	1.24	2.34	1.24	3.07
5	.44	.40	.48	1.05	.83	1.24	1.06	.89	1.24	1.87	.68	3.49
6	.40	.36	.48	1.11	.93	1.25	.93	.80	1.08	1.37	.82	2.08
7	.40	.36	.44	1.00	.89	1.13	.95	.83	1.12	1.96	1.36	2.61

TABLE III, Continued

SOUTH CANADIAN RIVER PLOTS	SPECIFIC GRAVITY			FIBER LENGTH 6 (mm)			FIBER LENGTH 7 (mm)			RADIAL GROWTH (Inches)		
	$\bar{X}$	Min	Max	$\bar{X}$	Min	Max	$\bar{X}$	Min	Max	$\bar{X}$	Min	Max
8	.38	.30	.45	1.18	1.02	1.29	.96	.84	1.07	1.45	.53	2.76
9	.41	.38	.46	1.12	.93	1.29	1.04	.95	1.17	1.79	1.02	2.50
10	.42	.38	.47	1.05	.92	1.15	.96	.81	1.12	1.61	.85	2.78
11	.40	.38	.43	1.15	1.08	1.24	.97	.84	1.11	1.25	.76	1.67
12	.42	.39	.46	1.06	.94	1.23	1.01	.89	1.19	1.33	.92	1.84
13	.43	.41	.48	1.13	1.01	1.24	1.00	.89	1.14	1.39	.72	2.98
14	.39	.36	.44	1.07	.97	1.18	.97	.82	1.12	.97	.62	1.35
15	.42	.39	.48	1.10	.94	1.26	.97	.76	1.16	.83	.42	1.50

TABLE III, Continued

CIMARRON RIVER PLOTS	SPECIFIC GRAVITY			FIBER LENGTH 6 (mm)			FIBER LENGTH 7 (mm)			RADIAL GROWTH (Inches)		
	$\bar{X}$	Min	Max	$\bar{X}$	Min	Max	$\bar{X}$	Min	Max	$\bar{X}$	Min	Max
16	.40	.37	.44	1.15	1.02	1.25	1.05	.94	1.18	2.90	1.46	4.09
17	.37	.33	.46	--	--	--	1.04	.91	1.29	3.34	2.26	4.90
18	.37	.33	.42	1.08	.93	1.23	.98	.98	1.20	2.41	1.50	3.83
19	.37	.36	.42	1.18	1.05	1.34	1.01	.89	1.16	1.90	1.33	2.28
20	.40	.36	.44	1.13	.98	1.31	1.00	.92	1.12	1.26	.67	2.08
21	.44	.39	.50	1.18	1.11	1.26	1.04	.93	1.17	1.72	1.10	2.38
22	.40	.36	.46	1.12	1.05	1.19	.96	.79	1.07	1.64	1.05	2.43
23	.42	.39	.44	.94	.88	1.00	.93	.80	1.03	1.42	.76	2.35
24	.42	.37	.50	1.09	1.02	1.21	1.00	.88	1.23	1.44	.75	2.19
25	.36	.32	.43	1.12	1.04	1.21	1.00	.82	1.13	1.51	1.04	2.15

Large specific gravity variation is exhibited by the broad specific gravity range 0.30 to 0.50 (Table III). Similar ranges in latewood specific gravity have been reported by Farmer and Wilcox (11), Peterson et al. (23), and Walters and Bruckmann (30). Figure 2 presents specific gravity variation graphically and reveals a typical bell-shaped distribution curve.

Perhaps the most important facts revealed by studying phenotypic variation of specific gravity are the patterns and trends that have been suggested. The most striking variation pattern in specific gravity is the within stand variation. Within stand variation in this study is presented in Table III where the plot ranges represent variation from tree to tree within that plot. As Table III indicates, a large variation is present in each stand.

Stand variation is represented by differences or variation between plots. Stand variation was noticably large but it did not appear to be as pronounced as within stand variation.

Table IV presents a comparison of several important wood characteristics. An important variation trend in specific gravity is evident from Table IV. A gradual but relatively constant increase in specific gravity occurs from east to west. This observation implies that a positive relationship exists between specific gravity and increasing longitude of the study area.

Less evident, but as important, is the positive relationship suggested between specific gravity and latitude. Specific gravity appears to increase as the latitude of the study area increases.

Radial growth rates appear to decrease with corresponding increases in both longitude and latitude of the study area. Thus, it appears that

FIGURE 2

FREQUENCY DISTRIBUTION OF SPECIFIC GRAVITY FOR 250 CORE SAMPLES

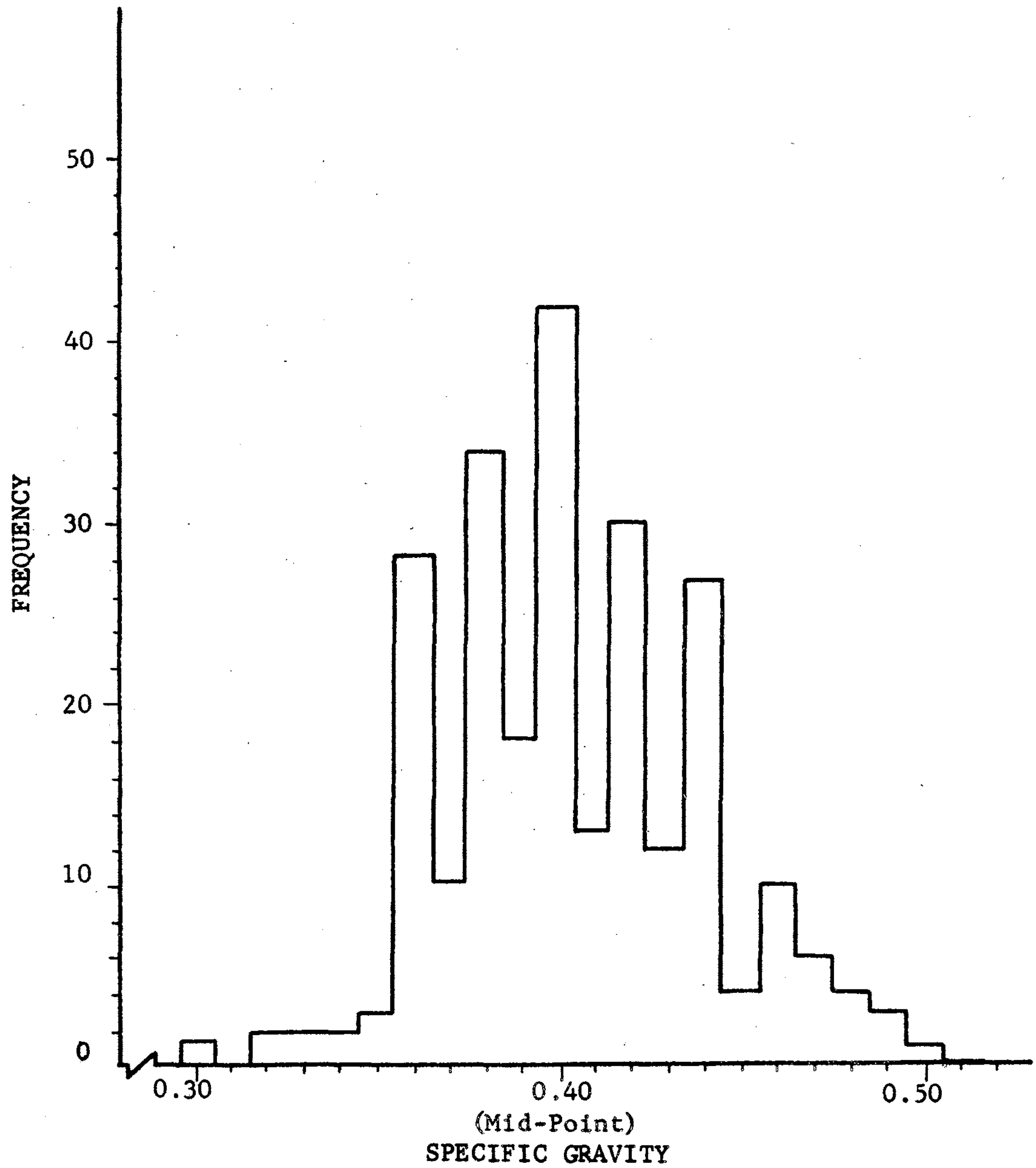


TABLE IV

COMPARISON OF SEVERAL WOOD CHARACTERISTICS
BASED ON PLOT DATA

Red River Plots	Longitude	Latitude	Elevation (Feet)	$\overline{X}$ Annual Rainfall (Inches)	Specific Gravity	3-7 Radial Growth (Inches)	6-7 Fiber Length (mm)	6-7 Radial Growth (Inches)
1	94° 30'	33° 45'	310	44	.37	2.99	1.28	.50
2	95° 30'	34° 00'	410	48	.38	1.96	1.16	.42
3	96° 30'	33° 45'	500	33	.37	3.46	1.16	.70
4	97° 15'	34° 00'	680	29	.39	2.34	1.08	.46
5	98° 30'	34° 15'	940	29	.44	1.87	1.06	.46
6	99° 15'	34° 30'	1230	23	.40	1.37	1.02	.31
7	100° 30'	34° 30'	1820	18	.40	1.96	0.98	.35

TABLE IV, Continued

South Canadian River Plots	Longitude	Latitude	Elevation (Feet)	$\overline{X}$ Annual Rainfall (Inches)	Specific Gravity	3-7 Radial Growth (Inches)	6-7 Fiber Length (mm)	6-7 Radial Growth (Inches)
8	95° 45'	35° 15'	600	36	.38	1.45	1.08	.31
9	96° 45'	34° 45'	840	38	.41	1.79	1.08	.40
10	97° 15'	35° 00'	1000	34	.42	1.61	1.01	.34
11	98° 15'	35° 30'	1400	30	.40	1.25	1.06	.25
12	99° 00'	36° 00'	1650	33	.42	1.33	1.04	.25
13	100° 15'	35° 45'	1230	23	.43	1.39	1.07	.24
14	101° 15'	35° 45'	2750	17	.39	.97	1.03	.23
15	102° 30'	35° 00'	3800	19	.42	.83	1.04	.16

TABLE IV, Continued

Cimarron River Plots	Longitude	Latitude	Elevation (Feet)	$\bar{X}$ Annual Rainfall (Inches)	Specific Gravity	3-7 Radial Growth (Inches)	6-7 Fiber Length (mm)	6-7 Radial Growth (Inches)
16	94° 30'	35° 15'	400	39	.40	2.90	1.10	.72
17	95° 15'	35° 45'	500	36	.37	3.34	1.04	.63
18	96° 00'	36° 00'	590	36	.37	2.41	1.03	.47
19	97° 15'	36° 00'	830	34	.37	1.90	1.10	.36
20	98° 15'	36° 15'	1130	24	.40	1.26	1.07	.27
21	99° 15'	36° 45'	1500	28	.44	1.72	1.12	.31
22	100° 15'	37° 00'	2300	20	.40	1.64	1.04	.33
23	101° 30'	37° 30'	2800	18	.42	1.42	.94	.31
24	103° 00'	37° 00'	4300	14	.42	1.44	1.05	.30
25	104° 00'	36° 45'	6500	17	.36	1.51	1.06	.28

radial growth may be inversely related to specific gravity. A relationship of this nature has been found by others (3, 7, 19, 22, 28).

Some of the specific gravity variation seems to be related to longitude, latitude, and radial growth. These associations suggest that specific gravity may be influenced by many environmental variables.

Natural Variation of Fiber Length

Investigators recognize that fiber length increases with the number of rings from the pith until a constant size is reached (8, 9, 13, 17, 27). Juvenile fibers were measured in this study, i. e., short fibers near the pith.

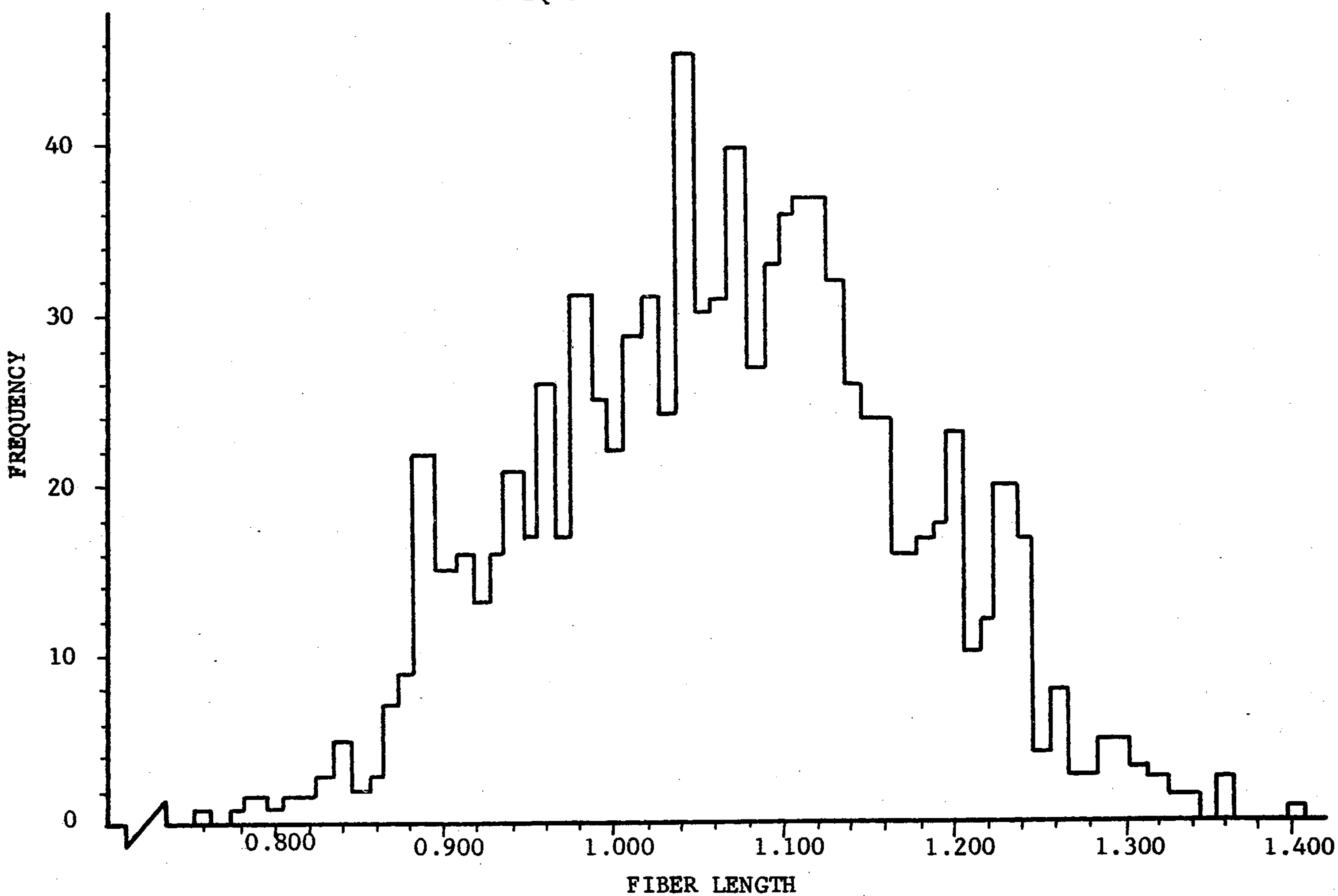
The combined fiber length of the sixth and seventh annual rings, based on plot averages, varied from 0.935 mm to 1.275 mm, a range similar to that reported for mature fibers of eastern cottonwood by Kaeiser (17). The mean fiber length for all plots was 1.065, which was similar to that reported by Kaeiser (17). Moderately long initial fiber length is suggested by this comparison.

Fiber length of the sixth annual ring for all plots was longer than the fiber length of the seventh annual ring. Radial growth of the sixth annual ring was also greater than the radial growth of the seventh annual ring. In addition, plots possessing the longer fibers generally expressed larger radial growth (Tables III and IV). Rapid growth appears to result in relatively long fibers. This observation supports the findings of others (7, 19, 20, 27).

Phenotypic variation in fiber length was relatively large. Fiber length variation ranged from 0.76 mm to 1.40 mm. This large variation is shown in Figure 3. As expected, fiber length variation fits the typical bell-shaped distribution curve.

FIGURE 3

FREQUENCY DISTRIBUTION OF FIBER LENGTH



Fiber length variation patterns in the study area were pronounced. The most evident was the large within stand variation patterns (Table III). Moderately large variation among stands for fiber length is also evident in Table III.

The most pronounced fiber length trend was the gradual decrease in fiber length with corresponding increases in longitude. A somewhat less apparent trend was the decrease in fiber length with increased latitude of the study area (Table IV). As mentioned earlier, radial growth appears to be related similarly with longitude and latitude. It appears that fiber length and radial growth change together with changes in longitude and latitude of the study area. This suggests that environmental influences are pronounced on both fiber length and radial growth.

Natural Variation of Radial Growth

The mean radial growths for the sixth and seventh annual increments are 0.383 inches and 0.354 inches, respectively. The overall average radial growth for the third through the seventh annual ring was 1.816 inches (Table II).

Pronounced phenotypic variation in radial growth is evident in Table III. Radial growth ranges from 0.42 inches to 4.90 inches. Table III also reveals large within stand and among stand variation.

Radial growth and average rainfall appear to decrease with corresponding increases in both longitude and latitude of the study area. Therefore, it is suggested that radial growth may be related to average precipitation.

Analysis of Variance

The "source" column in the analysis of variance is subdivided into the following: rivers, plots, trees, and cores (Table V). This notation is read: rivers, plots on rivers, trees on plots, and cores in trees, respectively. Variation between rivers is represented by rivers; stand variation is represented by plots on rivers; and within stand variation is represented by trees on plots.

In the analysis of variance the mean square for cores was used to test the statistical significance of trees. The mean square for trees was used to test differences among plots. The mean square for plots was used to test the significance of rivers.

The F test indicated that the differences among plots and among trees was highly significant for specific gravity, fiber length and radial growth. Similar findings in variation of specific gravity and fiber length have been reported for the genus Populus by Farmer and Wilcox (11), Paul (22), and van Buijtenen (28).

Difference between rivers was significant for growth rate. Variation in specific gravity and fiber length between rivers was not significant. It should be noted that three rivers were involved in this study; consequently, the degrees of freedom were extremely small. Thus, the small degrees of freedom for rivers probably masked the expression of fiber length and specific gravity.

The variance component percentage for plots indicates that differences between plots on rivers is responsible for the largest portion of the variation in specific gravity, fiber length, and growth rate.

Differences between trees in plots for specific gravity, fiber length, and growth rate are responsible for a relatively moderate

TABLE V

ANALYSIS OF VARIANCE FOR FIBER LENGTH, SPECIFIC GRAVITY, AND RADIAL GROWTH BY CORES, TREES, PLOTS, AND RIVERS

<u>Specific Gravity</u>

SOURCE	d.f.	S.S.	M.S.	F CALCULATED	VARIANCE COMPONENT	VARIANCE COMPONENT %
Total	479	7020.5000				
Rivers	2	325.2265	162.6132	1.323 NS	.24967	1.7
Plots	21	2580.3515	122.8738	8.589 **	5.42843	36.3
Trees	216	3089.9218	14.3051	3.350 **	5.01718	33.5
Cores	240	1025.0000	4.2708	--	4.27083	28.5

** Significant at the 1 percent level
NS Not Significant

TABLE V, Continued

Fiber Length

SOURCE	d.f.	S.S.	M.S.	F CALCULATED		VARIANCE COMPONENT	VARIANCE COMPONENT %
Total	479						
Rivers	2	3054.0000	1527.0000	1.925	NS	4.46355	5.2
Plots	21	17147.5625	816.5505	12.675	**	37.60639	43.6
Trees	216	13915.3125	64.4227	2.697	**	20.26736	23.5
Cores	240	5733.1250	23.8880	--		23.88802	27.7

** Significant at the 1 percent level
NS Not Significant

TABLE V, Continued

Growth Rate

SOURCE	d.f.	S.S.	M.S.	F CALCULATED	VARIANCE COMPONENT	VARIANCE COMPONENT %
Total	479					
Rivers	2	683947.7500	341973.8750	4.973 *	1716.5245	22.5
Plots	21	1443966.7500	68760.3212	17.801 **	3244.8782	42.6
Trees	216	834355.5000	3862.7569	2.655 **	1203.9701	15.8
Cores	240	349156.0000	1454.8166	--	1454.8167	19.1

* Significant at the 5 percent level

** Significant at the 1 percent level

portion of the variation (Table V). The importance of these observations is that relatively moderate genotypic differences are implied to exist.

Core differences or variations were shown to be responsible for a great deal of variation in specific gravity, fiber length, and growth rate.

Duncan's New Multiple Range

The importance of the Duncan's new multiple range test lies in the fact that it shows where significant differences exist (Table VI).

Generally, plots with the shortest fibers, highest specific gravity, and lowest growth rate were located in the western portion of the study area and were significantly different from those in the east. As expected then, the plots with the longest fibers, lowest specific gravity, and highest growth rates were located in the eastern portion of the study area.

Correlations

All possible correlations were computed and considered. Several environmental factors were ignored because their relationship was overshadowed and better expressed by other environmental variables. Of the many environmental variables presented in Chapter III, only those shown in Table VII will be used.

Specific Gravity Correlation

Several factors are correlated with specific gravity. As indicated by the phenotypic trends of specific gravity, a positive relationship is

TABLE VI

DUNCAN'S NEW MULTIPLE RANGE

Specific Gravity

RANK	PLOT NO.	$\bar{X}$	UNDERLINED * RANKED MEANS
1	25	36.200	
2	01	37.150	
3	17	37.200	
4	18	37.300	
5	03	37.700	
6	19	37.800	
7	02	38.400	
8	08	38.900	
9	04	39.150	
10	14	39.450	
11	06	40.150	
12	07	40.150	
13	16	40.400	
14	11	40.500	
15	22	40.500	
16	20	40.700	
17	09	41.850	
18	24	42.150	
19	23	42.500	
20	15	42.550	
21	12	42.800	
22	10	42.900	
23	13	43.300	
24	21	44.750	
25	05	44.950	

* Each set of underlined ranked means is significantly different from all other sets.

TABLE VI, Continued

Fiber Length
(6th and 7th Annual Rings)

RANK	PLOT NO.	$\overline{X}$	UNDERLINED * RANKED MEANS
1	23	0.940	
2	07	0.980	
3	10	1.010	
4	06	1.020	
5	18	1.030	
6	14	1.030	
7	17	1.040	
8	22	1.040	
9	12	1.040	
10	15	1.040	
11	24	1.050	
12	05	1.060	
13	25	1.060	
14	11	1.060	
15	20	1.070	
16	13	1.070	
17	04	1.080	
18	08	1.080	
19	09	1.080	
20	16	1.100	
21	19	1.100	
22	21	1.120	
23	02	1.160	
24	03	1.160	
25	01	1.280	

TABLE VI, Continued

Radial Growth
(6th and 7th Annual Rings)

RANK	PLOT NO.	$\overline{X}$	UNDERLINED * RANKED MEANS
1	15	0.160	
2	14	0.230	
3	13	0.240	
4	11	0.250	
5	12	0.250	
6	20	0.270	
7	25	0.280	
8	24	0.300	
9	06	0.310	
10	21	0.310	
11	23	0.310	
12	08	0.310	
13	22	0 330	
14	10	0.340	
15	07	0.350	
16	19	0.360	
17	09	0.400	
18	02	0.420	
19	04	0.460	
20	05	0.460	
21	18	0.470	
22	01	0.500	
23	17	0.630	
24	03	0.700	
25	16	0.720	

TABLE VI, Continued

Radial Growth
(5 Years)

RANK	PLOT NO.	$\bar{X}$	UNDERLINED * RANKED MEANS
1	15	0.8305	
2	14	0.9735	
3	11	1.2500	
4	20	1.2650	
5	12	1.3385	
6	06	1.3705	
7	13	1.3975	
8	23	1.4200	
9	24	1.4480	
10	08	1.4555	
11	25	1.5125	
12	10	1.6160	
13	22	1.6440	
14	21	1.7295	
15	09	1.7920	
16	05	1.8785	
17	19	1.9005	
18	02	1.9635	
19	07	1.9660	
20	04	2.3435	
21	18	2.4150	
22	16	2.9015	
23	01	2.9985	
24	17	3.3400	
25	03	3.4685	

TABLE VII

CORRELATION COEFFICIENTS FOR RADIAL GROWTH, WOOD PROPERTIES, AND ENVIRONMENTAL VARIABLES

VARIABLES	SPECIFIC GRAVITY	RADIAL GROWTH 3-7	RADIAL GROWTH 6	FIBER LENGTH 6	RADIAL GROWTH 7	FIBER LENGTH 7
Specific Gravity	-----	-.494	-----	-.517	-----	-----
Radial Growth 3-7	-.494	-----	.950	.424	.897	.658
Radial Growth 6	-----	.950	-----	-----	.865	.558
Fiber Length 6	-.517	.424	-----	-----	-----	.660
Radial Growth 7	-----	.897	.865	-----	-----	.571
Fiber Length 7	-----	.658	.558	.660	.571	-----
Longitude	.472	-.649	-.561	.595	-.690	-.531
Latitude	-----	-.446	-.459	-.416	-.438	-.563
Elevation	-----	-.541	-.506	-----	-.573	-.398
Mean Daily Minimum Temperature for January	-.431	.578	.553	.497	.621	.548
Average Number of Frost Free Days	-----	.509	.497	.429	.522	.595
Average Annual Rainfall	-.464	.549	.446	.628	.599	.595

found with longitude of the study area (Table VII). However, area latitude and elevation were not significantly correlated with specific gravity. This observation was anticipated because latitude and elevational gradients were not as pronounced as was longitude.

The strong positive correlation between specific gravity and longitude indicates that eastern cottonwood's specific gravity increases in areas of low rainfall and cold winters. This is supported in that specific gravity is negatively related to average annual rainfall and mean daily minimum temperature for January.

A relatively strong negative correlation between specific gravity and fiber length suggests that specific gravity increases as fiber length decreases or vice versa.

Specific gravity is also negatively correlated with radial growth. This relationship suggests that specific gravity changes inversely with a change in growth rate.

Fiber Length Correlations

Fiber length was correlated with numerous variables. As expected, fiber length was generally negatively related to longitude, latitude, and elevation. Fiber length generally increased with a decrease in longitude, latitude, and elevation. Fiber lengths of the sixth annual increment, longitude and elevation were exceptions (Table VII).

Environmental factors related to longitude, latitude, and elevation were positively related to fiber length. These are: number of frost free days, average annual rainfall, and the mean daily minimum temperatures for January. This observation implies that fiber length increases with corresponding increases in the number of frost free days, inches of average annual rainfall, and minimum mean daily temperatures.

A positive correlation was found between fiber length and radial growth. This suggests that fiber length increases with corresponding increases in radial growth.

It appears that fiber length and specific gravity are influenced by their environment and change with changes in longitude, latitude, and elevation.

Radial Growth Correlations

Numerous variables were correlated with radial growth. Phenotypic trends suggested negative correlations between radial growth and longitude, latitude, and elevation of the study area. As expected, radial growth was negatively related to longitude, latitude, and elevation. In other words, radial growth decreases with corresponding increases in longitude, latitude, and elevation.

It is pointed out that radial growth is positively correlated with: average annual rainfall, average number of frost free days, and mean daily minimum temperature. Thus, radial growth decreases with increasing longitude, latitude, and elevation. The radial growth relationship between fiber length and specific gravity may be misleading because the relationship directly and indirectly involves many distinguishable and undistinguishable variables which are not controllable.

CHAPTER V

SUMMARY AND CONCLUSIONS

The primary purpose of this investigation was to determine the phenotypic patterns of geographic variation, relationships between fiber length, specific gravity, growth rate, and certain environmental variables. Also to determine the cause of such variation and/or the relationships where found.

Twenty-five temporary plots were located on the Red River, the South Canadian River, and the Cimarron River. Ten trees were sampled per plot. Plot stratification occurred at approximately sixty-mile intervals which began at the eastern boundary of Oklahoma and continued to the headwaters of each river.

Data on six traits of eastern cottonwood were collected along with certain environmental variables. Fiber length, specific gravity, and growth rate were subjected to analysis of variance to determine the source of influence on variation. Simple linear correlations and Duncan's new multiple range test were employed to help determine relationships and causes of relationships.

Geographic variation between rivers was only significant for radial growth. The analysis of variance also indicated highly significant differences among plots and among trees for specific gravity, fiber length, and radial growth

Plot variation was responsible for the largest portion of the variation in specific gravity, fiber length, and radial growth. The variation caused by differences between plots is probably a reflection of the difference in plot environment.

Tree differences were also responsible for a large portion of the variation in specific gravity, fiber length, and radial growth. Relatively moderate genotypic differences are implied by this observation.

Differences among cores are shown to be responsible for a significant portion of the variation in specific gravity, fiber length, and radial growth. This finding suggests that a poor estimate of cores was obtained by using only two increment cores per tree. In a study which involves a large geographic area, more than two increment cores per tree is desirable for improved accuracy.

Fiber length was negatively correlated with longitude, latitude, and elevation. Specific gravity exhibited a reversal of this variation trend for longitude. Specific gravity was not correlated with latitude and elevation.

Radial growth was negatively correlated with longitude, latitude, and elevation. Apparently, these trends resulted from adaptation to the gradients of the environment and interactions between environment and heredity.

Fiber length and radial growth are positively correlated with average annual rainfall, days without frost, and January's lowest average daily temperature. Specific gravity is negatively correlated with these three variables.

This study has shown that a strong positive relationship exists between fiber length and growth rate. Growth rate's effect on specific gravity revealed a strong negative relationship. The significance of these relationships suggest that rigorous selection for either long fibers or high specific gravity would result in deleterious effects on fiber length, specific gravity, and growth rate. It seems desirable to select the fastest growing eastern cottonwood that has initially high specific gravity and long fibers.

Observations and tests suggest strongly that specific gravity, fiber length, and growth rate are influenced by their environment. However, tests also suggest that these traits are inherited. Data indicated that improvement can be realized through individual tree selection, pending heritabilities studies.

The findings of this investigation are encouraging and suggest further research is needed in the area of heritability.

LITERATURE CITED

1. Anon. 1954. Tentative Method of Test for Alcohol-Benzene Solubility of Wood (D1107-50T). ASTM Standards on Wood, Wood Preservatives, and Related Materials, 178-179.

2. Bailey, I. W., and H. B. Shepard. 1915. Sanio's Laws for the Variation in Size of Coniferous Tracheids. Botanical Gazette 60: 66-71.

3. Bray, M. W., and B. H. Paul. 1942. Pulping Studies on Selected Hybrid Poplars. Paper Trade Journal 115: 33-38.

4. Panshin, A. J., C. DeZeeuw, and H. P. Brown. 1964. Textbook of Wood Technology. Vol. I. McGraw-Hill, New York, 643 pp.

5. Brown, I. R., and F. A. Valentine. 1963. Natural Variation in Specific Gravity and Fiber Length in Populus tremuloides Clones. Tenth Northeastern Forest Tree Improvement Conference. Proceedings 10: 25-41.

6. Brugger, M. M. 1967. Personal Communications.

7. Cech, M. Y., R. W. Kennedy, and J. H. G. Smith. 1960. Variation in Some Wood Quality Attributes of One-Year-Old Black Cottonwood. TAPPI 43: 857-859.

8. Chalk, L., E. B. Marstrand, and J. P. DeC. Walsh. 1955. Fibre Length in Storeyed Hardwoods. ACTA Botanica Neerlandica 4: 339-347.

9. Dinwoodie, J. M. 1963. Forestry Abstracts, Vol. 23, No. 3 (4156): 478. Variation in Tracheid Length in Picea sitchensis Carr.

10. Duffield, J. W. 1961. Genetic Improvement of Wood Quality. Forest Products Journal 11: 211-213.

11. Farmer, Jr., R. E., and J. R. Wilcox. 1966. Specific Gravity Variation in Lower Mississippi Valley Cottonwood Populations. TAPPI 49: 210-211.

12. Farmer, Jr., R. E., and J. R. Wilcox. 1964. Cottonwood Improvement System for Commercial Planters. U. S. Forest Service Research Note SO-7. Forest Service, U. S. Department of Agriculture, Southern Forest Experiment Station.

13. Gerry, E. 1915. Fiber Measurement Studies, Length Variations: Where They Occur and Their Relation to the Strength and Uses of Wood. Science 41: 179.

14. Goggans, J. F. 1961. The Interplay of Environment and Heredity as Factors Controlling Wood Properties in Conifers. School of Forestry, N. C. State College, Technical Report 11: 56 pp.

15. Goggans, J. F. 1962. The Correlation, Variation, and Inheritance of Wood Properties in Loblolly Pine. School of Forestry, N. C. State College, Technical Report 14: 155 pp.

16. Gohre, K. 1960. Forestry Abstracts, Vol. 21, No. 4 (4896): 647. The Distribution of Density in Poplar Stems.

17. Kaeiser, M. 1956. Variation in Fiber Length of Eastern Cottonwood. Forest Products Laboratory, Forest Service, U. S. Department of Agriculture, Report No. 2047: 4 pp.

18. Kellogg, R. M., and G. Ifju. 1962. Influence of Specific Gravity and Certain Other Factors on the Tensile Properties of Wood. Forest Products Journal 12: 463-470.

19. Kennedy, R. W. 1957. Fiber Length of Fast and Slow Grown Black Cottonwood. Forest Chronicle 33: 46-50.

20. Kennedy, R. W., and J. H. G. Smith. 1959. The Effects of Some Genetic and Environmental Factors on Wood Quality in Poplar. Pulp and Paper Magazine of Canada 59: 37-38.

21. Markwardt, L. J. and F. R. C. Wilson. 1935. Strength and Related Properties of Wood Grown in the United States. U. S. Department of Agriculture, Technical Bulletin 479: 99 pp.

22. Paul, B. H. 1956. Specific Gravity of Populus Species and Hybrids. Forest Products Laboratory, Forest Service, U. S. Department of Agriculture, Report No. 2060: 9 pp.

23. Peterson, K. R., J. K. Guiher, and C. S. Walters. 1959. The Specific Gravity of Eastern Cottonwood Grown in Illinois. University of Illinois, Agriculture Experiment Station, Forestry Note 80: 1 pp.

24. Schreiner, E. J. 1958. Possibilities for Genetic Improvement in the Utilization Potentials of Forest Trees. Silvae Genetica 7: 122-128.

25. Smith, D. M. 1955. A Comparison of Two Methods for Determining the Specific Gravity of Small Samples of Second-Growth Douglas Fir. U. S. Department of Agriculture, Forest Products Laboratory Report 2033: 13 pp.

26. Snedecor, G. W. 1946. Statistical Methods, Fourth Edition, Iowa State College Press, 485 pp.

27. Spurr, S. H., and M. J. Hyvarinen. 1954. Wood Fiber Length as Related to Position in Tree and Growth. Botanical Review 20: 561-575.

28. van Buijtenen, J. P., D. W. Einspahr, and P. N. Joranson. 1959. Natural Variation in Populus tremuloides Michx. TAPPI 42: 819-823.

29. Valentine, F. A. 1962. Natural Variation in Specific Gravity of Populus tremuloides Michx. Wood in Northern New York. Ninth Northeastern Forest Tree Proceedings 9: 17-24.

30. Walter, C. S., and G. Bruckmann. 1965. Variation in Specific Gravity of Cottonwood (As Affected by Tree Sex and Stand Location). Journal of Forestry 63: 182-185.

31. Wilson, J. W. 1954. Fiber Technology I. Pulp and Paper Magazine of Canada 55: 84-91.

32. Zobel, B. J. 1961. Inheritance of Wood Properties in Conifers. Silvae Genetica 10: 65-96.

VITA

Jimmie Allen Buxton

Candidate for the Degree of

Master of Science

Thesis: NATURAL VARIATION IN SPECIFIC GRAVITY, FIBER LENGTH, AND RADIAL GROWTH OF EASTERN COTTONWOOD

Major Field: Agronomy

Biographical:

Personal Data: Born in Chickasha, Oklahoma, August 28, 1942, the son of Wilbur Allen and Barbara J. Buxton.

Education: Graduated from Oklahoma Military Academy, Claremore, Oklahoma, in May, 1960; received the Bachelor of Science degree with a Major in Forestry from Oklahoma State University in May, 1967; completed the requirements for the Master of Science degree at Oklahoma State University, May, 1970.

Professional Experience: Forestry Aide, United States Forest Service, summer, 1965; Graduate Research Assistant, Department of Forestry, Oklahoma State University, 1967-1968; presently employed as Forester, United States Department of the Interior, Bureau of Land Management.