wind direction to lay out seed orchards so that all clones are placed to leeward of all other clones an equal number of times. Seed orchards must fulfil a number of conditions if the seed collected from them is to be of predictable parentage. With polycross designs, one such condition is that the pollen cloud must be evenly rnixed over the orchard, which it can not be on sites with a constant prevailing wind. Polycross designs are thus unsuitable and directional designs are needed. With directional designs, if pollination is assumed to occur downwind of the male parent, seed collected from any one clone has a calculable probability of containing genes from all other clones in the orchard.

Lay-outs based on BOSE's balanced incomplete block designs for three treatments in a block are shown to be suitable and an example is given of an orchard for thirteen clones which has been planted at Muguga, Kenya. The basic unit is a long narrow strip parallel to the wind direction, in which the clones are arranged in columns of three, but it is possible to break the strip into blocks of convenient length to suit any shape of site available.

While these orchards were designed for Kenya conditions with constant winds and a long pollination season, they may be applicable to other sites with a steady prevailing wind, where polycross designs are less suitable.

References

BOSE, R. C.: On the construction of balanced incomplete block designs. Ann. Eugen. 9, 353—399 (1939). — BOYER, W. D.: Longleaf pine pollen dispersal. For. Sci. 12, 367—368 (1964). — EAST AFRICAN METEOROLOGICAL DEPARTMENT: Collected climatological statistics for East African stations, Part 1, 46—78, E. A. C. S. O., Nairobi (1964). — FAULKNER, R.: Seed orchards in Britain. Report on forest research for the year ended March 1964, H. M. S. O. (1965). — FREEMAN, G. H.: The use of cyclic blanced incomplete block designs for directional seed orchards (in *press*). — HANANI, H.: The existence and construction of balanced incomplete block designs. Ann. Math. Statist. 32, 361—386 (1961). — LANNER, R. M.: Needed: a new approach to pollen dispersal. Silvae Genetica 15, 50—52 (1966). — NAMKOONG, G., SNYDER, E. B., and STONECYPHER, R. W.: Heritability and gain concepts for evaluating breeding systems such as seedling orchards. Silvae Genetica 15, 76—83 (1966). — SILEN, R. R.: Pollen dispersal in Douglas Eir. J. Forestry 60, 790—795 (1962). — WRIGKT, J. W.: Pollen dispersion studies: some practical applications. J. Forestry 51, 114—118 (1953).

Micropulping Loblolly Pine Grafts Selected for Extreme Wood Specific Gravity

By J. P. VAN BUIJTENEN, D. W. EINSPAHR and JOHN R. PECKHAM[1])

(Received for publication February 24, 1967)

Introduction

Loblolly pine possessing high wood specific gravity is desirable as pulpwood because of its potentially high yield per volume, leading to a higher cellulose production per acre for the same growth rate. It also results in a more efficient use of machinery in the pulp mills. Loblolly pine of low wood specific gravity is desirable for its more favorable pulp and papermaking properties.

The relationship of wood specific gravity to pulp and papermaking properties is quite complex. Wood specific gravity is the average result of a great variety of properties such as specific gravity of the cell wall material, microporosity of the cell walls, proportions of springwood and summerwood, wall thickness and fiber dimensions within springwood and summerwood, and amount of extractives in the wood. To gain a complete understanding it is necessary to accumulate information on the relationship between each of these factors contributing to wood specific gravity and the various pulp and papermaking properties.

Considerable evidence has accumulated that wood specific gravity is strongly inherited. It is, therefore, expected that the associated pulp and papermaking properties are also under strong genetic control. This needs to be verified experimentally. In addition, quantitative information about the relationships is needed. Thus the objectives of the study described in this paper are:

1. To compare the pulp and papermaking properties of several clones selected for high wood specific gravity with several clones selected for low wood specific gravity.

2. To determine the relative importance of the various anatomical faotors influencing wood specific gravity.

3. To determine the influence of these factors on pulp and papermaking properties.

4. To get sorne indication of the inheritance of these wood and pulp properties.

For a literature review of the variation and inheritance of wood properties, one is referrod to GOGGANS (1961). Excellent literature reviews on the influence of wood properties on pulp and papermaking properties were made by DADSWELL, et *al.* (1959), BESLEY (1959), and DINWOODIE (1965).

In general, an increase in wood specific gravity has been associated with a decrease in bursting strength and an increase in tear strength. More recently, studies by BAREFOOT (1966) and WANGAARD (1966) indicated strong influence of some of the fiber dimensions on pulp and papermaking properties.

Material and Methods

1. Materials

Three loblolly pine clones selected for high wood specific gravity and three clones selected for low wood specific gravity were used in this study. From each clone four grafts were selected, resulting in a total of 24 trees. The trees were approximately 10 years old. The wood was collected in the form of increment cores with a diameter of 11 mm. taken

Tabele 1. — Standard micropulping conditions

Wood charge, moisture free basis, g.	20
Maximum temperature, °C.	172
Time to maximum temp., min.	120
Time at maximum temp., min.	90
Liquor ratio, ml./g. ovendry	12
Liquor analysis	
Active alkali, as NaOH, g./l.	40
Sulfidity, %	24,7

[1]) J. P. VAN BUIJTENEN, Silviculturist I, Texas Forest Service, College Station, Texas, at present Research Geneticist, Northeastern Forest Experiment Station, Durham, New Hampshire. D. W. EINSPAHR, Chief, Genetics and Physiology Group, Biology Section, The Institute of Paper Chemistry. JOHN R. PECKHAM, Project Supervisor, The Institute of Paper Chemistry.

at a height of 4 to 5 ft. From each tree enough cores were collected to contain 25 grams of dry wood for pulping studies plus an additional 2 cores for the study of wood anatomy. Duplicate samples were obtained from the first two trees in each clone.

2. Measurements on the wood

Measurements on the wood included specific gravity, percent summerwood, fiber length, fiber diameter, cell wall thickness, and number of fibers per unit of cross-sectional area in the springwood and summerwood portions of the

Table 2. — Wood properties determined on increment cores of six loblolly pine clones

Tree no.	Specific gravity, g./cm.^{3}	Summerwood, %	Diameter of springwood tracheids, μ	Wall thickness of springwood tracheids, μ	Diameter of summerwood tracheids, μ	Wall thickness of summerwood tracheids, μ	Packing density, g./cm.^{3}	Fiber length, weighted average, mm.	Alcohol benzene extractives, %	Lignin, %
B—1	.348	18.4	34.9	4.86	26.1	9.1	.782	2.41	6.44	30.5
B—2	.370	14.1	31.6	5.16	25.0	9.6	.782	2.33	7.70	30.7
B—3	.366	18.2	31.7	4.82	25.6	9.7	.792	2.32	6.13	30.8
B—4	.364	17.4	32.1	4.92	24.7	9.9	.772	2.39	6.45	30.3
Average	.362	17.0	32.6	4.94	25.3	9.6	.782	2.36	6.68	30.6
C—1	.374	21.9	37.3	5.82	24.6	9.5	.760	2.28	5.22	30.8
C—2	.360	18.0	36.1	5.36	26.3	10.2	.769	2.18	5.38	30.8
C—3	.345	12.8	34.5	4.78	25.8	8.7	.815	2.20	6.83	31.5
C—4	.366	18.8	33.4	4.59	25.4	9.2	.823	2.33	4.90	30.4
Average	.361	17.9	35.3	5.14	25.5	9.4	.792	2.25	5.58	30.9
D—1	.431	22.9	33.5	5.74	28.5	9.8	.849	2.35	4.58	29.4
D—2	.413	25.1	36.4	5.88	30.2	11.1	.810	2.48	4.74	28.5
D—3	.413	23.6	35.2	5.57	25.5	9.6	.828	2.58	4.42	30.4
D—4	.409	21.6	37.9	6.15	29.7	9.8	.832	2.54	4.69	29.8
Average	.417	23.3	35.7	5.83	28.5	10.1	.826	2.49	4.61	29.5
X—1	.319	12.7	34.3	4.56	27.8	9.4	.769	2.44	4.62	30.0
X—2	.342	16.1	36.1	4.70	26.6	8.8	.815	2.50	5.01	29.4
X—3	.337	20.4	35.5	4.92	25.0	8.4	.758	2.48	5.22	30.2
X—4	.324	15.6	36.4	3.95	29.0	8.3	.873	2.37	4.88	30.4
Average	.330	16.2	35.6	4.53	27.1	8.7	.795	2.45	4.93	30.0
Y—1	.321	16.7	38.9	5.30	25.1	9.0	.732	2.44	6.04	30.2
Y—2	.316	15.0	37.0	4.78	28.4	9.1	.764	2.48	4.21	31.0
Y—3	.323	10.4	37.5	5.22	26.6	9.4	.765	2.60	5.30	31.6
Y—4	.329	13.4	36.1	4.87	26.9	8.9	.785	2.42	5.87	30.4
Average	.322	13.9	37.4	5.04	26.7	9.1	.756	2.49	5.36	30.8
Z—1	.352	8.0	36.5	6.12	28.6	10.5	.754	2.46	7.90	30.0
Z—2	.311	8.0	34.3	5.12	24.1	8.6	.725	2.57	6.40	29.8
Z—3	.305	7.4	35.0	4.82	28.3	8.6	.756	2.51	8.20	29.6
Z—4	.290	6.1	34.1	4.84	27.0	7.9	.716	2.41	6.42	30.3
Average	.315	7.4	35.0	5.22	27.0	8.9	.734	2.49	7.23	29.9

Table 3. — Statistical analysis of wood properties determined on increment cores of six loblolly pine clones

Source of variation	Degrees of freedom	Wood specific gravity, g./cm.^{3}		Percent summerwood		Diameter of springwood tracheids, μ		Wall thickness of springwood tracheids, μ		Diameter of summerwood tracheids, μ	
		SS	MS	SS	MS	SS	MS	SS	MS	SS	MS
Total	23	.0319		660.82		84.54		6.65		69.57	
Clones	5	.0284	.0057	545.94	109.19	48.21	9.64	3.61	.72	29.95	5.39
Error	18	.0036	.0002	114.88	6.38	36.33	2.02	3.04	.17	42.62	2.37
$\frac{S^2_c}{S^2_c + S^2_e}$			.87		.80		.49		.45		.24
F			28.50[2])		17.11[2])		4.78[2])		4.29[2])		2.28

Source of variation	Degrees of freedom	Wall thickness of summerwood tracheids, μ		Packing density g./cm.^{3}		Fiber length weighted average, mm.		Alcohol benzene extractives, %		Lignin, %	
		SS	MS	SS	MS	SS	MS	SS	MS	SS	MS
Total	23	12.50		0.4		.28		27.46		14.16	
Clones	5	5.37	1.07	0.2	0.042	.19	.38	15.69	3.14	7.31	1.46
Error	18	7.14	0.40	0.1	0.008	.09	.005	11.77	0.65	6.85	0.38
$\frac{S^2_c}{S^2_c + S^2_e}$			.30		.50		.61		.49		.42
F			2.71		5.25[2])		7.20[2])		4.80[2])		3.84[1])

[1]) Significant at 5% level
[2]) Significant at 1% level

tree. All determinations except fiber length were made by the Texas Forest Service.

Specific gravity was determined using the oven-dry weight in grams, divided by the green volume in cm^3. Dry weight was determined by drying the cores for 24 hours at 105° C, allowing them to cool for 30 minutes in a desiccator and weighing them on an electric balance to the nearest milligram. Green volume was determined as the product of the length of the core in mm. and the cross-sectional area, determined on a sample of 25 cores. The method was checked against the submersion method and the maximum moisture method of determining volume. All three methods were in close agreement. The cores were stored in 70% alcohol and used to prepare microtome sections. The technique of measuring percent summerwood, fiber wall thickness, fiber diameter, and number of fibers per cross-sectional area was described in detail by VAN BUIJTENEN (1964).

Fiber measurements were made by the Fiber Microscopy Laboratory of The Institute of Paper Chemistry and were determined on unbeaten pulp samples produced by the micropulping procedure described below. Measurements were based upon 1400 to 1500 fibers and included not only intact fibers, but cut and broken fibers as well.

3. Micropulping

This portion of the study was carried out by the Pulping Laboratory of The Institute of Paper Chemistry. The increment core samples were stored in a constant temperature and humidity room until they had reached an equilibrium weight. Each core was then split twice in a guillotine paper trimmer. The first lengthwise cut made with the grain, removed approximately 20% of the core, which was retained for grinding into meal for determination of extractives and lignin content. The remainder of the core was divided in half lengthwise, parallel to the grain, and reduced in length to about 3/8-inch pieces. They were returned to the constant temperature room until needed for pulping. The micropulping was carried out under conditions given in *Table 1*. At each cook, seven samples were treated, one sample from each of the clones and a control. The control was obtained by slicing one-half inch disks of southern pine wood into uniform chips. The chips were well mixed and a representative sample was charged to the 7th digester each time a cooking series was made. The equipment and procedure are described in detail by THODE, *et al.* (1961).

The pulps obtained from the digesters were agitated in a Waring Blendor. The pulp slurry was then decanted on filter paper, drained, and washed prior to the determination of the unscreened yield. The permanganate number was measured by TAPPI Standard T 214 m-50. Handsheets were prepared following TAPPI T 205 m-60, but the weight of pulp used was 1.0 gram instead of 1.2 grams oven-dry. These were tested for basis weight, caliper, apparent density, formation, and zero-span tensile strength as described by WINK, *et al.* (1962).

Table 4. — Pulp and papermaking properties obtained from increment cores

Tree no.	Yield,%	Permanganate number	Apparent density	Formation	Zero-span tensile strength, lb./in.
B—1	40.5	22.0	10.6	36.6	55.4
B—2	39.2	21.4	10.4	39.6	50.0
B—3	39.7	20.1	10.3	46.1	52.1
B—4	39.6	19.0	10.0	41.7	55.1
Average	39.8	20.6	10.3	41.0	53.2
C—1	40.0	19.9	9.6	40.8	58.0
C—2	38.4	20.4	10.0	39.8	55.3
C—3	38.0	20.8	11.1	39.7	55.9
C—4	39.9	20.0	9.6	40.6	58.4
Average	39.1	20.3	10.1	40.2	56.9
D—1	41.4	20.6	9.9	36.1	52.6
D—2	42.8	20.2	8.9	36.9	57.7
D—3	40.9	21.2	10.3	38.8	55.3
D—4	41.8	21.0	10.3	38.5	59.0
Average	41.7	20.8	9.9	37.6	56.2
X—1	39.8	21.6	11.6	38.8	52.8
X—2	42.0	20.9	11.3	37.8	58.8
X—3	41.1	21.3	11.6	34.2	54.2
X—4	40.6	19.3	11.2	40.3	57.6
Average	40.9	20.8	11.4	37.8	55.9
Y—1	40.0	20.9	10.9	38.0	57.0
Y—2	40.8	21.0	11.1	38.0	56.4
Y—3	39.1	20.0	11.0	38.0	58.6
Y—4	41.5	23.1	11.1	32.8	53.4
Average	40.4	21.3	11.0	36.7	56.4
Z—1	40.2	20.8	11.0	41.4	61.4
Z—2	39.4	21.2	11.8	37.4	59.9
Z—3	39.0	21.9	12.7	37.8	60.1
Z—4	39.6	17.3	12.3	41.5	63.8
Average	39.6	20.3	12.0	39.5	61.3

Results and Discussion

A summary of the wood properties determined on the increment cores is given in *Table 2*. An analysis of variance of these data is given in *Table 3*. Since the population studied consisted of selected materials, no meaningful estimates of heritability, applicable to a normal population can be made. It is, however, clear that very strong genetic differences in wood specific gravity and percent summerwood exist, while tracheid diameter, wall thickness, and tracheid length, are inherited to a lesser extent. There also appear to be genetic differences in extractives and lignin content.

Table 5. — Statistical analysis of pulp and papermaking properties obtained from increment cores

Source of variation	Degrees of freedom	Percent yield		Permanganate number		Apparent density		Formation		Zero-span tensile strength, lb./in.	
		SS	MS	SS	MS	SS	MS	SS	MS	SS	MS
Total	23	33.02		44.76		18.16		203.20		273.94	
Clones	5	15.48	3.10	1.88	.38	12.38	.000248	55.04	11.01	135.35	27.07
Error	18	17.54	.97	42.88	2.38	5.78	.000032	148.16	8.23	138.59	7.70
$\frac{S^2_c}{S^2_c + S^2_e}$			.35		—		.63		.08		.39
F			3.18[1]		.16		7.71[2]		1.34		3.52[1]

[1]) Significant at 5% level
[2]) Significant at 1% level

Table 6. — Significant simple correlation coefficients between wood properties and pulp and papermaking properties determined on increment cores

Wood properties	Pulp and papermaking properties	Correlation coefficients
Wood specific gravity	Yield	.430[1])
	Apparent density	—.816[2])
Percent extractives	Yield	—.535[2])
Percent lignin	Yield	—.653[2])
Percent summerwood	Yield	.544[2])
	Apparent density	—.789[2])
	Zero-span tensile strength	—.429[1])
Tracheid diameter, springwood	Zero-span tensile strength	.431[1])
Tracheid wall thickness, springwood	Apparent density	—.461[1])
Tracheid diameter, summerwood	All properties	NS
Tracheid wall thickness, summerwood	Apparent density	—.754[2])
Packing density	Apparent density	—.444[1])
Fiber length	All properties	NS

[1]) Significant at 5% level
[2]) Significant at 1% level

Different clones have different packing densities of the cell walls.[2]) This may be associated with differences in percent summerwood, since it has been reported (SMITH, 1964) that differences in packing density between summerwood and springwood may occur, or it may indicate a higher packing density throughout the tree. This matter is at present being studied further.

The pulp and papermaking properties obtained from the increment cores are presented in *Table 4.* The statistical analysis is given in *Table 5.* Strong genetic differences in apparent density of the handsheets are present, while zero-span tensile strength shows differences significant at the 5% level only.

To evaluate the relationships between the various wood properties on the one hand and the pulp and papermaking properties on the other hand, a multiple correlation analysis was made. The significant simple correlation coefficients are shown in *Table 6.* Pulp yield is significantly related to wood specific gravity, percent extractives, percent lignin and percent summerwood. The apparent density of the handsheets is highly correlated with wood specific gravity and percent summerwood. Apparent density also shows a relationship with tracheid wall thickness and packing density. The tracheid wall thickness in the summerwood appears to be especially important. This ties in very closely with the results obtained by BAREFOOT (1965). Zero-span tensile strength shows fairly weak correlations with percent summerwood and the tracheid diameter of the springwood.

The multiple regression analyses were made using a program which stepwise eliminates non-significant variables until only those variables significant at a specified level are retained. In the following multiple regressions, variables significant at the 5% level were retained.

To determine the influence of various wood properties on specific gravity an analysis was made using specific gravity as the dependent variable and the following independent variables: percent extractives, percent lignin, percent summerwood, diameter of the springwood tracheids, wall thickness of the springwood tracheids, diameter of the summerwood tracheids, wall thickness of the summerwood tracheids, and tracheid length. The variables significant at the 5% level were: percent summerwood, diameter of the springwood tracheids, wall thickness of the springwood tracheids, and diameter of the summerwood tracheids. The regression equation is given in *Table 7.*

The association of pulp yield with the following wood properties was calculated: specific gravity, percent extractives, percent lignin, percent summerwood, packing density, and permanganate number. Only percent extractives and percent lignin were significant at the **5%** level. The regression equation is given in *Table 7.*

Zero-span tensile strength might be dependent on specific gravity, percent extractives, percent lignin, percent summerwood, diameter of the springwood tracheids, wall thick-

[2]) Packing density is defined as the specific gravity of the cell walls as they are observed under the light microscope. It is calculated as the wood specific gravity divided by the percent cross-sectional area occupied by the cell walls.

Table 7. — Results of multiple regression analysis between wood properties and pulp and papermaking properties[1])

Dependent variable	Independent variable	Regression coefficient	"t"	Prob. level	R^2
Wood	con	.2633			.92
Specific	% su	.0047	9.91	1.000	
Gravity	d sp	—.0074	5.47	1.000	
	w sp	.0338	6.85	1.000	
	d su	.0039	2.64	.984	
Pulp Yield	con	74.47			.65
	% ext	—.49	3.66	.999	
	% lig	—1.04	4.67	1.000	
Zero-span	con	107.17			.73
Tensile	% lig	—1.57	2.70	.986	
Strength	% su	—.31	4.24	1.000	
	d sp	.89	4.40	1.000	
	perm nr.	—1.42	4.17	.999	
Apparent	con	20.63			.85
Handsheet	s g	—18.08	5.36	1.000	
Density	d sp	—.13	2.50	.978	
	w sp	.77	3.11	.994	
	d su	.16	3.03	.993	
	w su	—.76	4.27	1.000	
Formation	con	57.10			.14
	d sp	—.52	1.87	.926	

[1]) Abbreviations used are:

Prob. Level	= Probability level
"t"	= Student's "t" test
R^2	= Coefficient of determination = amount of variation accounted for by the regression
con	= Constant factor
% su	= Percent summerwood
d sp	= Diameter of springwood tracheids
d su	= Diameter of summerwood tracheids
w sp	= Wall thickness of springwood tracheids
% ext	= Percent extractives
% lig	= Percent lignin
perm nr.	= Permanganate number
s g	= Wood specific gravity
w su	= Wall thickness of summerwood tracheids

ness of the springwood tracheids, diameter of the summerwood tracheids, wall thickness of the summerwood tracheids, tracheid length, permanganate number, basis weight, apparent handsheet density, and formation. The multiple regression analysis established that the percent lignin, percent summerwood, diameter of the springwood tracheids and the permanganate number were significant at the 5% level. The regression equation is given in *Table 7*.

The relationship between apparent density and the following variables was studied: specific gravity, percent summerwood, diameter of the springwood tracheids, wall thickness of the springwood tracheids, diameter of the summerwood tracheids, wall thickness of the summerwood tracheids, and packing density. Specific gravity, diameter of the springwood tracheids, wall thickness of the springwood tracheids, diameter of the summerwood tracheids, and wall thickness of the summerwood tracheids were significant at the 5% level.

The multiple regression analysis of formation on specific gravity, percent summerwood, diameter of the springwood tracheids, wall thickness of the springwood tracheids, diameter of the summerwood tracheids, wall thickness of the summerwood tracheids, packing density and tracheid length gave negative results. None of the variables were significant at the 5% level. The strongest correlation was shown by the diameter of the springwood tracheids. It was significant at the 8% level.

Acknowledgements

The authors are indebted to Mrs. M. M. Mohammed for many hours of painstaking work in obtaining the wood property data. Appreciation is also expressed to the members of the Technology Section of The Institute of Paper Chemistry for their contribution to the pulping phases of the program and to W. Wink and members of the Paper Evaluation Section for making the zero-span tensile strength measurements.

Summary

A cooperative study was undertaken by The Institute of Paper Chemistry and the Texas Forest Service to compare the pulp and papermaking properties of three loblolly pine clones selected for high wood specific gravity with three clones selected for low wood specific gravity. The trees were approximately 10 years old.

The study had the additional objectives of determining: the relative importance of the various anatomical factors influencing wood specific gravity; the effect of these factors on pulp and papermaking properties; and the amount of genetic variation of these wood and pulp properties.

It appears that the major factors influencing wood specific gravity in this predominantly juvenile wood are percent summerwood, wall thickness of the springwood tracheids and diameter of both springwood and summerwood tracheids.

The main effect of wood specific gravity is on the apparent density of the handsheets. The cross-sectional dimensions of the tracheids also have strong effect.

Percent summerwood primarily affects zero-span tensile strength.

The diameter of the springwood fibers has a broad influence on handsheet properties including zero-span tensile strength, apparent density and perhaps formation.

An increase in percent lignin decreases yield and zero-span tensile strength. The effect on strength could possibly be indirect, through a correlation between the amount of compression wood and lignin content.

Percent extractives influences only pulp yield.

Indications are that wood specific gravity and percent summerwood are inherited strongly, while tracheid dimensions are inherited to a lesser extent. Percent lignin and percent extractives are also under moderate genetic control.

In the material used for this study, strong genetic differences in apparent handsheet density are present. Pulp yield and zero-span tensile strength show small but significant genetic differences.

Literature Cited

Barefoot, A. C., Hitchings, R. G., and Ellwood, E. L.: Wood characteristics and kraft paper properties of four selected loblolly pines. III. Effect of fiber morphology in pulps examined at a constant permanganate number. Tappi 49 (4): 137—147 (1966). — Besley, Lowell: Relationship between wood fibre properties and paper quality. Proc. of 3 Symposia of Wood Quality, Ontario Dept. of Lands and Forests, Res. Report No. 48, pp. 22—29 (1959). — Dadswell, H. E., and Wardrop, A. B.: Growing trees with wood properties desirable for paper manufacture. Appita 12 (4): 129—136 (1959). — Dinwoodie, J. M.: The relationship between fiber morphology and paper properties: a review of literature. Tappi 48 (8): 440—447 (1965). — Goggans, J. F.: The interplay of environment and heredity as factors controlling wood properties in conifers with special emphasis of their effects on specific gravity. N. C. State College, School of Forestry, Tech. Report 11, 56 pp. (1961). — Smith, Diana M., and Miller, Regis B.: Methods of measuring and estimating tracheid wall thickness of redwood (*Sequoia sempervirens* [D. Don] Endl.). Tappi 47 (10): 263—277 (1964). — Thode, Edward F., Peckham, John R., and Daleski, Edward J.: An evaluation of certain laboratory pulping methods. Tappi 44 (2): 81—88 (1961). — van Buijtenen, J. P.: Anatomical factors influencing wood specific gravity of slash pine and the implication for the development of a high-quality pulpwood. Tappi 47 (7): 401—407 (1964). — Wangaard, F. F., Kellogg, R. M., and Brinkley, A. W., Jr.: Variation in wood and fiber characteristics and pulp-sheet properties of slash pine. Tappi 49 (6): 263—277 (1966). — Wink, W. A., and Van Eperen, R. H.: The development of an improved zero-span tensile test. Tappi. 45 (1): 10—24 (1962).