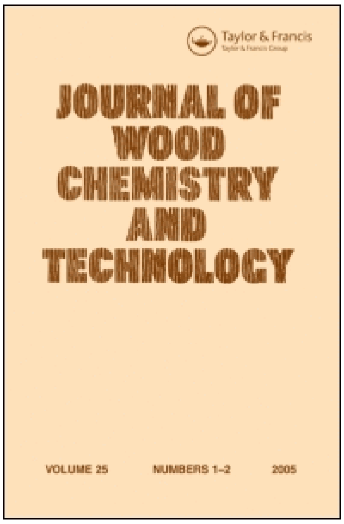

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VARIATION OF SPECIFIC GRAVITY, FIBRE LENGTH & CELL WALL THICKNESS IN YOUNG SALIX CLONES

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ABSTRACT

Specific gravity, fibre length and cell wall thickness of various hybrid Salix clones were compared. The densest clone was 1.47 times denser than the least dense clone. The highest specific gravity was 0.5, found in Salix viminalis L. whereas the lowest was 0.372, found in Salix dasyclados L. The clone with longest fibre was 1.34 times that of the clone with shortest fibre. Clones with long fibre also showed high specific gravity such as Salix viminalis L. The cell wall thickness in Salix clones varies from 0.0025 mm to 0.0037 mm or 1.48 times from minimum to maximum cell wall thickness. Since the above fibre properties indicate various paper strength characteristics such as flexibility coefficient and felting index, it is possible to select clones with superior characteristics for propagation as suitable source for pulp and paper industry.

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INTRODUCTION

The suitability or quality of wood for a particular purpose such as raw material for pulp and paper industry is determined by variability of one or more of the dimensional and physical characteristics which affect its structure and its physical properties.

The measurable variables in wood are influenced by several factors such as changes in the cambium as it ages, genetic controls that govern the form and growth of the tree and environmental influence. In the present case, all the clones have been grown in the same experimental plots and hence environmental influence will be minimum. Therefore, genetic controls will be of prime consideration.

Of great importance to an intensive culture program is the selection of superior genotypes to improve such characteristics as wood fibre yield, quality and uniformity. The existence of variation in the natural population is the key to genetic improvement. Patterns of variation in such property as wood density in Salix were identified by Sennerby et al[1] and Flower-Ellis and Olsson[2]. These studies involved comparison of young Salix clones grown in nursery plantations. Wood density was found to vary considerably from clone to clone. However, no relationship between specific gravity in mature willow clones was reported. Lehtonen et al[3] reported variation of specific gravity in mature Sallow (Salix caprea L.) wood. The existence of variation in wood density in young woods from the different clones bring question as to whether variations in wood density exist in mature wood and therefore the justification of the present work.

Numerous papers have outlined prospects of hardwood breeding and for many species reviews of genetic characteristics have been prepared primarily towards using this knowledge to estimate wood quality and to establish tree improvement programs aimed at altering wood properties in future generations. Specific gravity is perhaps the most studied property of wood. This property has been found to be a highly heritable trait in conifers and can be used as a direct indicator of pulp yields[4]. Both specific gravity and fibre lengths are two important physical characteristics influencing production rate and end product properties in the pulp and paper industry. This research, therefore, deals with the variation of specific gravity as well as fibre length among trees from different clones.

The objective of this paper is to study the variability of fibre length, cell wall thickness and specific gravity in the young hybrid Salix clones.

EXPERIMENTAL PROCEDURES

Sampling of Material

Hybrid Salix trees, healthy and free from defects, were selected from Ontario Ministry of Natural Resources Newell tract forest. The trees were sampled at four different heights, diameter at breast height (DBH), 25%, 50% and 75% of total height of the tree. In the laboratory, four 2.5 cm thick discs were removed from each sample location for growth increment, specific gravity and fibre length measurements. All these discs were kept frozen until ready for use.

Mean radii were measured in each disc and growth increments were recorded for each ring in this mean diameter. Once the measurements were taken, specific gravity and fibre length measurements could be taken from this mean diameter. Four samples, two from either side of the mean radius were removed from each growth layer for specific gravity determination. Such samples were taken from each height.

Specific Gravity Measurement

Determination of specific gravity was carried out on all wood samples based on the principle of maximum moisture content on a green volume basis[5]. This method is ideal for determining the specific gravity of small wood samples such as portions of increment cores. This method uses the well-known relationship between maximum moisture content and specific gravity and obviates the direct determination of the volume of the sample.

Immediately after the samples were taken out of the freezer, they were numbered and placed in capped glass vials with a fungicide in water as a preservative. The vials were put in a desiccator, vacuum was applied until the samples had absorbed water to a maximum constant weight. Vacuum was maintained intermittently for 10 days to saturation and the water was changed every alternate day. Because of the smallness of the samples, weighing bottles were used to avoid loss or gain of moisture. The samples were weighed on an automatic semi-microbalance which was connected to an Apple Computer. Each saturated sample was taken from the desiccator and the excess water was removed with a damp cloth. The difference in the two weights of weighing bottle and the weighing bottle plus the sample gave the weight of the saturated wood sample. The samples were dried in an oven at 103°C to 105°C until a substantial constant weight was obtained and then transferred rapidly to a desiccator and allowed to reach equilibrium temperature before the oven drying weight was obtained.

Fibre Length Measurement

Fibre length samples were removed from the same disc and same sample location as those for the specific gravity. Samples were taken from each growth layer and from each height. Modified Franklin method[6] was used for the determination of fibre lengths. This involved treating with a solution of equal parts of glacial acetic acid and 30-35% hydrogen peroxide and suspending the samples, placed in test tubes, in boiling water. It was observed that the time taken for wood samples to be uniformly white was about 6.5 hours. Slides were prepared from dilute fibre suspensions for measurement of fibre length and width.

All the slides were permanent slides which involved covering the fibres with a cover slip using permount and curing first in air for 48 hours and eventually at 50-60°C in a forced draft oven for at least 2 days or until the permount was found to have dried. Fibre lengths were measured by placing the slides in a microscope and focusing the shadow of fibres in a flat surface. Measurements were made and recorded with an Apple II digitizer. Veniers were used for calibration.

Cell Wall Thickness Measurement

Transverse tissue sections of the stem from each hybrid Salix clone were prepared[6]. Plant tissue was dehydrated in water-alcohol mixture and infiltrated with Parowax. Then, Paraplast was used as embedding medium for the fibre. A sliding microtome, Spencer model 860, was used for sectioning and the microtome sections were placed on clean slides flooded with 3% formalin.

An analysis of variance was performed on all data to determine the significance of variance in specific gravity, fibre lengths and cell wall thickness between different clones. Significance was tested at the 0.05 level of probability in all cases[7].

RESULTS AND DISCUSSION

Variation of Specific Gravity

The yield of pulp expressed as ratio of usable fibre for certain quantity of raw material in the form of chips tends to be a direct function of specific gravity. High specific gravity would mean more dry matter contained in the volume of chips that can be packed into a digester. Specific gravity thus proves to be of great significance to the relative economics of small wood pulping.

Clonal specific gravity for wood without bark varied between 0.361 to 0.532 with an average of 0.510 as shown in Table 1. Ranking order of the clones was tested by Duncan's multiple range of test as shown in Table 1. When the range of the specific gravity was evaluated, it became clear that the densest clone was 1.47 times denser than the least dense clone. This ratio seems to be one of the same range as reported by Flower-Ellis[2]. Very high specific gravity for Salix dasyclados L. The same trend was also reported by Sennerby-Forsse[8]. However, it was to be noted that whereas the specific gravity reported here are based on maximum moisture content method[5], the values reported by Sennerby-Forsse were based on the weight of the wood dried at 80°C, not at 104-105°C, as is used to determine absolutely dry weight.

The variation of mean specific gravity within clones is high and they can be grouped in different classes according to wood density. This ranking seems to hold over years as similar variation of specific gravity among similar clones was also observed in an earlier study[9].

Specific gravity values have been reported on the whole tree juvenile Salix material[10]. Salix L. has a specific gravity of 0.424, two year old Salix exigua nutt

TABLE 1.

Comparison of Average Wood Specific Gravity in 13 Salix Clones According to Duncan's Multiple Range Test

Clone	Mean Wood Specific Gravity	
SP1	0.510	a*
SAD1	0.503	a
SV1	0.500	ab
SF1	0.441	bc
SP3	0.416	bc
SA7	0.393	cde
SB1	0.392	cdef
SA25	0.390	efg
SAC1	0.383	efgh
SH3	0.379	efghi
SA6	0.378	ghij
SD1	0.372	ijk
SA11	0.361	ijkl

* Values followed by the same letter are not significantly different at p=0.05 level.

has values ranging from 0.36 to 0.38 and Salix caprea has a value of 0.406. Twenty one Salix clones samples in Sweden had values ranging from 0.266 to 0.397[11]. In comparison to published information the values obtained in this study rank well respect to their specific gravity values.

Variation of Fibre Length

Similar to specific gravity, the average fibre lengths in different hybrid Salix clones vary significantly. This is evident from data on Table 2 where clones were

TABLE 2.

Comparison of Average Wood Fibre Length in 11 Salix Clones According to Duncan's Multiple Range Test

Clone	Mean Fibre Length, mm	
SA25	0.667	a*
SF1	0.638	a
SV1	0.637	a
SD1	0.621	ab
SA6	0.614	abc
SB1	0.610	abcd
SAD1	0.533	de
SP1	0.514	ef
SAC1	0.502	efg
SP3	0.499	efgh
SH3	0.486	fghi

* Values followed by the same letter are not significantly different at p=0.05 level.

ranked according to Duncan's multiple range test. The fibre length varies between 0.486 mm and 0.667 mm with an average value of 0.575 mm as shown in Table 2. The clone with longest fibre was found to be having 1.34 times longer fibre than the clone with shortest fibres.

There are several published reports of fibre lengths in willow wood[12,13]. In both softwoods and hardwoods the most valuable, and also the most abundant cell type is found in the xylem. In hardwoods this cell type is the fibre or fibre tracheids. Papermaking is directly related to fibre dimensions. Long fibres impart high tear, burst, tensile and fold resistance properties to the pulp and the resultant papers.

The fibre lengths of Salix viminalis (adult tree) were found to be approximately 1 mm and for young tree (2 to 3 years) they range from 0.4 to 0.55

mm. The reported fibre lengths for Salix triandra are from 0.4 to 0.7 mm with a mean value of 0.55 mm and for Salix viminalis 'Romanin' are from 0.25 to 0.55 mm with a mean length of 0.40 mm[13]. The average fibre length quoted for slender willow (Salix exigua) is 0.47 mm (stem)[14].

Contrary to general expectation, it was found that in Salix, clones with higher specific gravity also show longer fibre and low density clones showing shorter fibres. Species such as Salix viminalis having a high specific gravity also show a long fibre.

This was also found by McAdam[14]. However, species such as Salix purpurea show a shorter fibre with their dense wood characteristics.

Unlike specific gravity, affected by several factors such as cell wall thickness and lumen diameter, fibre length may be a genetic characteristics and therefore between species may not be related with specific gravity. Most studies need to be done to characterise relationship of fibre length differences or variation among different species.

Variation of Cell Wall Thickness

Cell wall thickness is highly correlated with specific gravity. In addition, they affect pulp and paper strength. Thick cell walls tend to produce paper of high tear resistance but low burst and tensile strength and fold resistance. The cell wall thickness in the Salix clones varies from 0.0025 mm to 0.0037 mm or 1.48 times from minimum to maximum cell wall thickness as indicated in Table 3. This variation is identical to variation of specific gravity among different willow clones as shown previously in Table 1.

Expected Pulp Fibre Properties from Such Wood Fibre

The above fibre characteristics such as cell wall thickness, fibre length and wood characteristics such as specific gravity have important functional relationships with different paper strength characteristics, important to pulp and paper industry. Therefore data on fibre characteristics were considered in the form of combined values or coefficients.

Table 4 shows fibre pulping characteristics which express bonding power of the cells to develop different strength characteristics in papermaking. The two

TABLE 3.

Comparison of Average Cell Wall Thickness in 11 Salix Clones According to Duncan's Multiple Range Test

Clone	Mean Cell Wall Thickness, mm	
SA25	0.0037	a*
SF1	0.0036	a
SA6	0.0032	ab
SAC1	0.0031	bc
SV1	0.0031	bcd
SP1	0.0030	de
SB1	0.0029	de
SAD1	0.0028	def
SD1	0.0026	defg
SP3	0.0025	defgh
SH3	0.0025	defghi

* Values followed by the same letter are not significantly different at p=0.05 level.

most important characteristics which influence the increased strength development in a paper is the length of the fibres and the ease with which the fibres can be collapsed. Generally the longest fibre cells with the thinnest walls make the best paper but predictions based on these criteria alone are unreliable - there appears to be some unknown factors.

The flexibility coefficients (lumen diameters/cell diameter) which is positively related to breaking length, showed clonal variation and are in general agreement with similar tree species. The felting index which is directly correlated to burst and tensile strength, also show high clonal variation. Expecting two clones, SF1 and SAD1, all the Runkel ratio values from different clones are less than one and considered to indicate papermaking suitability when values are less than unity. Clearly the clones are well within this threshold limit.

TABLE 4.

Fibre Pulping Characteristics of 11 Salix Clones

Clone	Flexibility Coefficient (Lumen dia. / Cell dia.)	Felting Index (Cell length / cell dia.)	Cell Length / Thickness Ratio	Runkel Ratio (Double Cell Wall / lumen dia.)
SAC1	0.5571	23.11	161.77	0.5163
SH3	0.3270	21.70	194.40	0.6831
SF1	0.3139	28.61	177.22	1.0285
SP3	0.3802	29.01	199.60	0.7645
SP1	0.4460	29.20	171.33	0.7643
SD1	0.3570	29.29	238.85	0.6869
SV1	0.3974	33.35	205.48	0.8169
SA25	0.3479	27.56	180.27	0.8789
SAD1	0.2921	30.11	190.36	1.0832
SB1	0.4318	31.26	210.17	0.5701
SA6	0.4719	29.24	191.88	0.6458
Ave.	0.3330			

It has been shown by many investigators[15] that the strength properties of paper depend in a large degree on the intrinsic strength of the fibres and on certain fibre dimensions. It is true, generally, that longer fibres and a low ratio of the cell wall thickness to lumen diameter are characteristics of fibres that produce the strongest papers. Fibre flexibility which would be enhanced by the low ratio of the wall thickness to lumen diameter contributes to paper strength because of increased degree of interfibre contact and bonding.

Salix have shorter fibres than does the standard, but their walls to lumen ratios are also much lower, a possible reason for relatively good properties of some of the species. They undoubtedly are very flexible and for those species that gave the combination of flexibility and intrinsic strength a strong pulp results.

From the analysis carried out on individual data on specific gravity, fibre length and cell wall thickness from different hybrid Salix clones, it appears that there are significant differences among the clones on all these intrinsic properties, and therefore it is possible to select clones with superior characteristics for propagation as suitable source for pulp and paper industry.

CONCLUSION

This study has shown that there were significant clonal differences for specific gravity, fibre length and cell wall thickness. Clones with longest fibre also show high specific gravity. By correlating these physical properties with various paper strength properties such as flexibility coefficient and felting index, it is possible to select superior clones for propagation as a raw material for pulp and paper industry.

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