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Dimensions of Structural Elements in Fusiform Ray of Sitka Spruce (*Picea sitchensis* (Bong.) Carr.) Affecting Radial Permeability*1

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ABSTRACT

The anatomical structure of fusiform ray was examined by scanning electron microscopy (and microscopic images were analysed by image analyser) to explain the differences in radial fluid uptake between the extremes in the radial treatment data, i.e. between the selected trees of QCI (Queen Charlotte Islands in Rhondda, South Wales) and SO (South Oregon in Dalby, North-East England) planted in the UK. The ray structure of these two seed origins was examined microscopically and different patterns of ray composition were observed. The most important anatomical features influencing radial permeability were the nature of fusiform ray, and the condition of the resin canals, epithelial cells and intercellular spaces in particular.

Keywords : sitka spruce, *Picea sitchensis*, radial flow, fusiform ray, resin canal, scanning electron microscopy, image analyser

1. INTRODUCTION

Wood shows anisotophy of flow and so major differences between in either of three anatomical directions, i.e. the fluid flow is the greatest in longitudinal direction (along the stem) following by tangential direction (across the grain), but is the lowest in radial direction (via the rays) [1].

The overall contribution to flow by rays and resin canals may be of secondary importance since they form a small fraction of the wood volume. However, when flow into a pole or post is considered the zone treated by longitudinal flow is beneath the ground line so radial flow and penetration is very important [2]. In this concept, both uniseriate and fusiform rays offer the major flow path in the radial direction. Ray tracheids are usually more effective in conduction than ray parenchma cells [3] but reverse has also been found in some species [4].

The presence of resin canals has generally been thought to have no significant influence on the radial permeability [5] because they are almost always clogged with resin [6]. In dispute of this statement, there is some experimental evidence that resin canals and either intercellular spaces [7] or epithelial cells [8] may be of secondary important radial flow path.

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Table 1. Means of density (d, kgm^{-3}) and the percentage of void volume filled by fluid in both radial (RVVF%) and longitudinal (LVVF%) flow directions, and disc diameter (D, cm) in 2 m height of all the five trees (T) of QCI and SO in both trial sites [9]

	Rhondda				Dalby			
T	D	d	RVVF%	LVVF%	D	d	RVVF%	LVVF%
QCI	11.5	422	48 max	63	14.5	469	21	81
1								
2	11.6	499	22	60	15.0	373	16	63
3	12.0	404	34	53	16.0	419	27 max	81
4	14.0	387	22	47	16.5	369	9	54
5	14.5	415	29	79	17.9	343	27	72
mean	12.7	425	31	60	16.0	395	20	70
SO	10.3	527	13	51	12.0	457	9	83
1								
2	11.6	473	12	52	12.5	437	16	75
3	12.4	466	16	48	12.9	323	23	63
4	12.8	421	10 min	47	15.2	404	7 min	65
5	13.0	435	21	79	16.4	401	12	74
mean	12.0	464	14	55	14.0	404	13	72

In this study, therefore, the anatomical structure of fusiform ray was examined by scanning electron microscopy and microscopic images were analysed by image analyser to explain the differences in radial permeability between the extremes in the radial treatment data, i.e. between the trees of the seed origins QCI (Queen Charlotte Islands) and SO (South Oregon) that are grown in UK [9].

2. MATERIAL and METHODS

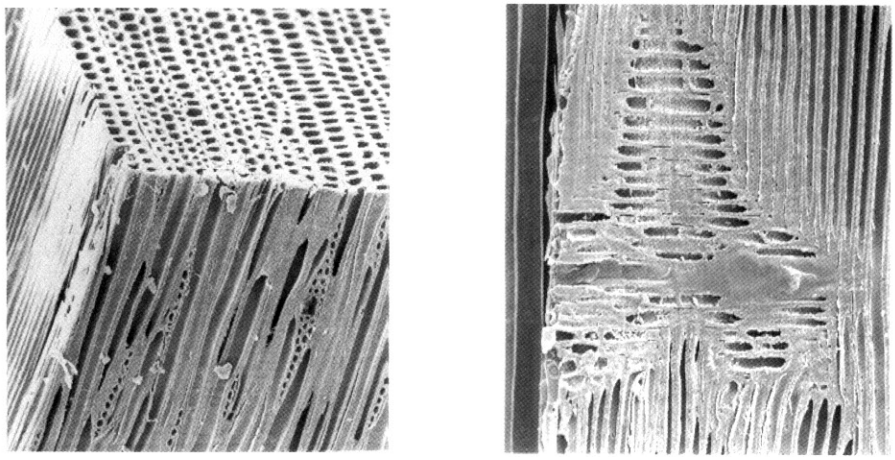
Emphasis on anatomical analysis was particularly given to the seed origin extremes of RVVF% (percentage of void volume filled in radial direction) in QCI (Queen Charlotte Islands) and SO (South Oregon) from the trial sites Rhondda (South Wales) and Dalby (North-East England), respectively.

As shown by Usta [9], the greatest percentage of void volume filled by preservative radially occurred at the 2 m height above ground in tree 1 seed origin QCI of Rhondda with some 48% higher compared with the lowest in tree 4 SO of Dalby (7%), thus these extreme trees of the two seed origins have specifically been chosen (Table 1).

The internal structure of fusiform ray was investigated from both tangential-longitudinal and radial-longitudinal sections (Fig. 1) of the experimental samples which were cut from the sapwood zone (at 2 m above ground level) of Tree 1 of QCI in Rhondda (South Wales) and Tree 4 of SO in Dalby (North-East England).

After adhesion onto aluminium stubs with double-sided tape and coating with gold to a nominal thickness of 400 Å in a Polaron E5000 sputter coater, the wood specimen was examined at 10KV in an Hitachi S520 SEM.

Digital images (taken at a magnification of



(a) (b)

Fig. 1. Study sections for investigation of the internal structure of fusiform ray: (top) tangential-longitudinal section, (down) radial-longitudinal section (This SEM pictures taken from the Tree 1 of QCI in Rhondda) (a, ×250; b, ×500).

Table 2. Mean dimensions of the structural components of fusiform ray tissue in QCI (Rhondda) and SO (Dalby), and descriptive statistics of the experimental data

Parameter	QCI	SO	p-value	significance
Fusiform Ray				
Quantitative area (μm^2)	10.2	5.4	0.000	***
Height (μm)	344.6	256.7	0.045	*
Width (μm) at the center point	37.8	27.0	0.000	***

* = 95%, *** = 99.9%

1000×) were captured at various points across growth rings attempting to follow individual rays and printed on a sony thermal image printer. The pictures were then analysed by a monochrome (64 grey level) Image Analysis System (Seescan plc) to measure the parameters of fusiform ray across entire growth rings.

3. RESULTS and DISCUSSION

Data from the scanning electron microscope analysis of fusiform ray are given in Tables 2~5.

The quantitative area of fusiform ray was significantly (p=0.000) greater in QCI (10.2 μm^2) than in SO (5.4 μm^2) (Table 2). Further, fusiform ray tissue was found to be taller and wider in QCI (344.6 μm, 37.8 μm) than in SO (256.7 μm, 27.0 μm). The difference in height was statistically significant (p=0.045) while the width was very highly significantly different (p = 0.000).

The dimension of resin canal was also found two times larger in QCI than in SO either vertically or horizontally (Table 3). In this case, both height (p=0.022) and width (p=0.010) of the resin canal were significantly greater in QCI (30.9 μm, 15.9 μm) than in SO (18.2 μm, 9.1 μm)

Table 3a. Dimensions of resin canal in fusiform ray of QCI (Rhondda) and SO (Dalby), and descriptive statistics of experimental data

Parameter	QCI	SO	p-value	significance
Resin Canal				
Lumen area (μm^2)	0.44	0.13	0.023	*
Height (μm)	30.9	18.2	0.022	*
Width (μm)	15.9	9.1	0.010	**

* = 95%, ** = 99%

Table 3b. Dimensions of the epithelial cells in fusiform ray of QCI (Rhondda) and SO (Dalby), and descriptive statistics of experimental data

Parameter	QCI	SO	p-value	significance
Epithelial Cell				
Lumen area (μm^2)	0.034	0.018	0.000	***
Height (μm)	9.7	6.7	0.104	NS
Width (μm)	4.4	3.3	0.000	***
Wall thickness (μm)	3.6	8.4	0.000	***
Number	5	6	0.203	NS

*** = 99.9%, NS = not significant

Table 4. Dimensions of the ray parenchyma cells in fusiform ray of QCI (Rhondda) and SO (Dalby), and descriptive statistics of experimental data

Parameter	QCI	SO	p-value	significance
Ray Parenchyma				
Lumen area (μm^2)	0.059	0.053	0.019	**
Height (μm)	244.3	180.1	0.059	NS
Width (μm)	7.1	6.5	0.021	*
Wall thickness (μm)	12.6	10.9	0.109	NS
Number	23	18	0.096	NS

* = 95%, ** = 99%, NS = not significant

with the largest lumen area as well (QCI: 0.44 μm^2, SO: 0.13 μm^2).

The diameter of ray parenchyma cell in fusiform ray was significantly (p=0.019) larger in QCI (0.059 μm^2) than in SO (0.053 μm^2) (Table 4). Each seed origin showed quite different results in both total height and mean width for ray parenchyma cell in fusiform ray. QCI was slightly taller (p=0.059) and was considerably wider (p=0.019) in comparison to those of SO (QCI: 244.3 μm, 7.1 m, SO: 180.1 μm, 6.5 μm). The number of ray parenchyma cell per fusiform ray along height was also greater in QCI (23) than in SO (18), although the differences were not statistically significant (p=0.096).

Table 5. Dimensions of ray tracheids in fusiform ray of QCI (Rhondda) and SO (Dalby), and descriptive statistics of the experimental data

Parameter	QCI	SO	p-value	significance
Ray Tracheid				
Lumen area (μm^2)	0.031	0.028	0.716	NS
Height (μm)	20.8	17.5	0.175	NS
Width (μm)	3.5	3.9	0.667	NS
Wall thickness (μm)	22.6	14.9	0.000	***
Number	4	3	0.198	NS

*** = 99.9%, NS = not significant

Likewise, the size components of ray tracheid in fusiform parenchyma was conversely different in either seed origin although the differences in all the three cases (i.e. height, width, area) were not significant (Table 5). The total height of ray tracheids in fusiform ray was greater (p=0.175) in QCI (20.8 μm) than in SO (17.5 μm), the mean width ray tracheids in fusiform ray was marginally wider (p=0.667) in SO (3.9 μm) than in QCI (3.5 μm) but in spite of the variations between the height and width, the ray tracheid diameter in fusiform ray was almost similar (p=0.716) in both seed origins (QCI: 0.031 μm^2, SO: 0.028 μm^2).

4. CONCLUSIONS

The principal objective of this article was to recognise and understand the structural features (both direct and indirect) which influence the fluid flow in the radial direction of Sitka spruce by examination of most (QCI, Rhondda, South Wales) and the least (SO, Dalby, North-East England) radially permeable samples.

Analyses of the data collected during the course of this study showed that the dimensions of the structural elements in fusiform ray were greater in QCI than in SO. However, as no other investigations exist as to the variation of radial flow via fusiform ray in Sitka spruce, the results of this investigation has to be tested and further evidence is needed.

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