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Studies on Variability of Wood Properties in Stem of *Pinus koraiensis* (II)*1

- Differences in Tracheid Length, Microfibril Angle, and Compression Strength in South and North Sides of Stem -

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ABSTRACT

Tracheid length, microfibril angle, and compression strength were examined in south and north sides of Pinus koraiensis. The sample tree was 57 years old and had been planted in central Korea. Tracheid length on the south side of the tree ranged from 2.87 to 3.40mm and on the north ranged from 3.60 to 3.53mm and mean values were 3.15 mm for the south and 3.26mm for the north. Tracheid length was 0.11mm longer on the north side than on the south. Microfibril angle on the south side ranged from 12.6° to 20.3° and that on the north from 6.8° to 13.5°; mean values were 16.6° on the south side and 9.6° on the north. Microfibril angle was 7.0° greater on the south side than on the north side. For compression strength on the south and north sides, significant difference at the 95% level was found only at 1.3m above the ground level of the sample tree; for compression limit stress, significant difference at this level was found at 1.3 and 5.3m above the ground level. However, compression strength and compression limit stress were greater on the north side than on the south side.

Keywords : *Pinus koraiensis*, tracheid length, microfibril angle, compression strength

1. INTRODUCTION

Korean pine (*Pinus koraiensis* Sieb. et Zucc) is a prominent reforestation species in Korea. About 86,000 ha have been planted, which account for about 30% of plantation forests in Korea. Korean pine is generally harvested 30 to 40 years after planting. Information on the variation of wood properties within the tree stem is very important for more efficient utilization of and development of new uses for Korean pine. Although some reports on the anatomical and physical properties of Korean pine have been published (Lee, 1974 · 1982; Kang, 1993), no work has been reported on the differences in wood qualities on the cardinal direction of the stem in Korean pine. In previous work (Kim, 1995), green moisture content, density, and shrinkage were investigated in the stem of Korean pine from green to the ovendried state. In the present study, we examined variation in tracheid length, microfibril angle, and compression properties in the south and north sides of Korean pine stem.

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2. MATERIALS & METHODS

2. 1 Sample trees

Two 57-year-old trees were felled from plantations in central Korea (Chungcheongbukdo). The stand stock was 300 trees/ha. Height and diameter at breast height of sample trees were respectively 20 m and 35 cm for sample No. 1 and 23 m and 39 cm for sample No. 2.

Two discs about 10 cm thick were taken from 0.3, 1.3, 2.3, 3.3, 4.3, and 5.3m above ground level of the sample tree (Fig. 1 A), and a diametric strip about 10 cm wide (including pith) and about 10 cm along the grain was taken from each disc (Fig. 1 B). Specimens for measurement of tracheid length, microfibril, angle and compression properties were taken from the diametric strip.

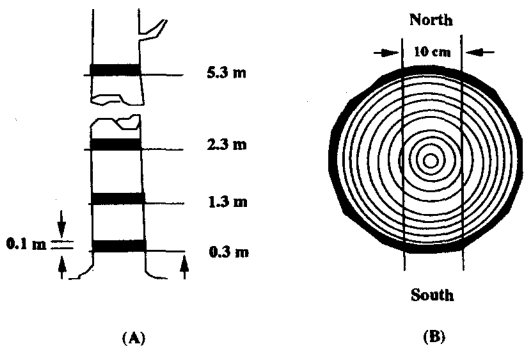

Fig. 1. Sampling discs and a diametral strip.

2. 2 Sampling procedure

For determination of tracheid length, specimens were taken from even-numbered annual rings from the pith from each diametric strip. For determination of microfibril angle, specimens were taken from every fifth annual ring from the pith, on south and north sides of the stem. For the test on compression strength parallel to grain, 2- by 2- by 4-cm (longitudinal direction) specimens were taken from the pith outward consecutively on south and north sides of the stem.

2. 3 Measurement techniques

Length of tracheids in earlywood and latewood was determined after defibration with Schultze's solution. Tracheids were stained with safranin and mounted on glass; 20 measurements were made at random on each specimen. The demarcation between earlywood and latewood was determined by the color change in the ring.

The microfibril angle was determined on 20- to 25μm-thick radial microtome sections of earlywood and latewood by iodine crystal technique (Sentt & Bendsten, 1985). The average microfibril angle of earlywood and latewood was based on 10 determinations.

Before testing, specimens for the test on compression strength parallel to grain were conditioned to about 12% moisture content at 65% relative humidity and 20℃.

3. RESULTS & DISCUSSION

3. 1 Tracheid length

Fig. 2 shows the variation of tracheid length from pith to bark in Korean pine. Tracheid length increased with age from pith to annual rings 16 to 20, and then leveled off. Juvenile wood and mature wood were demarcated by rings 16 to 20 from the pith. Kang (1993) reported almost the same number of annual rings demarcating juvenile and mature wood in Korean pine. Fukuzawa (1967) and Watanabe *et al.* (1963, 1964) reported the same results for Japanese cedar (Cryptomeria japonica D. Don). Fig. 3 shows tracheid length on the south and north sides of Korean pine. The values in Fig. 3 are mean values of both (No. 1 and No. 2) sample trees.

Tracheid length on the south side of sample No. 1 ranged from 2.87 to 3.28mm and on the north side, from 3.07 to 3.53mm; mean values for the south and north sides were 3.14mm and 3.28mm, respectively. In sample No. 2, tracheid length on the north side was 0.09mm longer than that on the

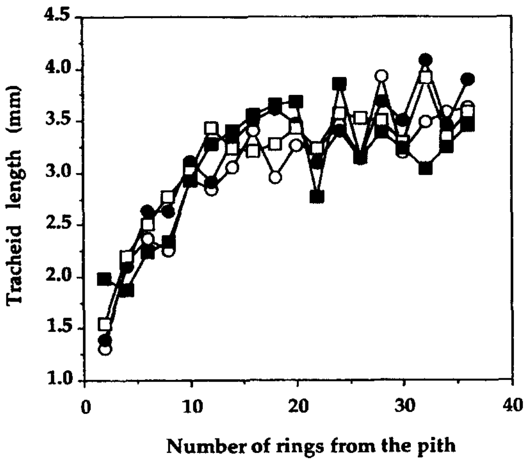

Fig. 2. Variation of tracheid length from the pith to bark for Korean pine.

Legend: ○ : Earlywood on the South,
□ : Latewood on the South,
● : Earlywood on the North,
■ : Latewood on the North.

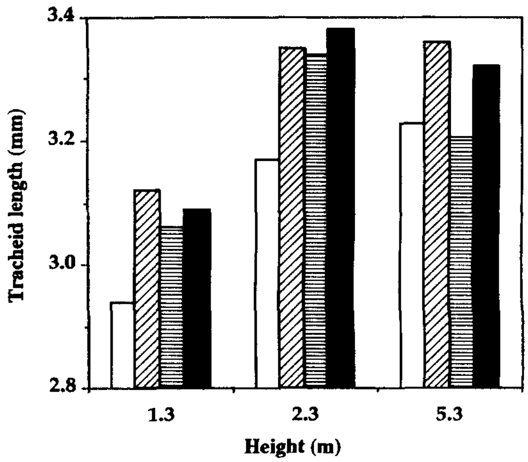

Fig. 3. Techeid length on the south side and north side of Korean pine.

Legend: □ : Earlywood on the South,
▤ : Latewood on the South,
▨ : Earlywood on the North,
■ : Latewood on the North.

south side. Liese and Ammer (1958) reported that fiber length on the south side of poplar (*Populus robusta*) was shorter than that on other cardinal sides. They attributed this difference to an increased cambium activity resulting from greater warmth of this side. Liese and Dadswell (1959) measured tracheid length in three softwoods (*Pseudotsuga taxifolia*, *Pinus radiata*, and *P. pinaster*) and fiber length in five hardwoods and a bamboo. They reported that tracheid length on the sunny side was shorter than that on the shady side and attributed this difference to greater warmth on the sunny side and consequent increase in cambial activity. Because cells on the sunny side became differentiated much earlier than those on the shady side, tracheids and fibers were shorter on the sunny side. Therefore, tracheids in conifers and fibers in hardwoods are shorter on the sunny side than on the shady side.

3. 2 Microfibril angle

Fig. 4 shows the variation in microfibril angle from pith to bark in Korean pine (sample No. 1). Microfibril angle was greater on the south side than

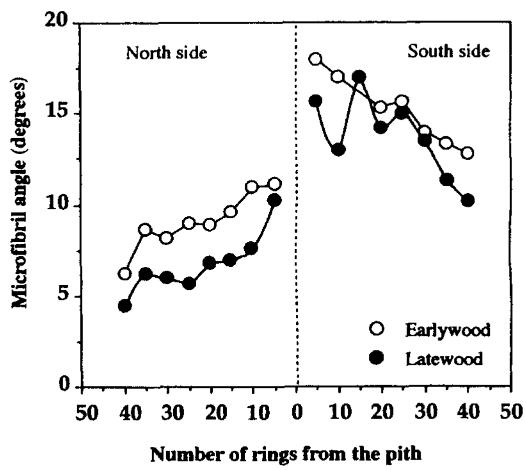

Fig. 4. Variation of microfibril angle from the pith to bark for Korean pine.

on the north side, was greater in earlywood than in latewood on both sides, and decreased from the pith outward. Hiller (1964) and Watanabe *et al.* (1964) reported the same results for softwoods. For samples No. 1 and 2, microfibril angle on the south side was greater than that on the north side at each

Table 1. Duncan's multiple range test for shrinkage of Korean pine (Kim, 1995).

Variable		Cardinal direction			
Sapwood	SR*[1]	N 3.23 (a)*[2]	W 2.84 (ab)	E 2.77 (b)	S 2.25 (c)
	ST	N 7.23 (a)	E 6.61 (ab)	W 6.27 (b)	S 5.99 (b)
	SL	N 0.36 (a)	S 0.30 (a)	W 0.28 (a)	E 0.15 (a)
	SV	N 10.45 (a)	E 9.40 (b)	W 9.11 (bc)	S 8.24 (c)
Heartwood	SR	N 3.11 (a)	W 2.83 (ab)	E 2.78 (b)	S 2.61 (b)
	ST	N 7.11 (a)	W 7.02 (a)	E 6.94 (a)	S 6.04 (b)
	SL	S 0.32 (a)	N 0.28 (a)	W 0.27 (a)	E 0.20 (a)
	SV	N 10.25 (a)	W 9.82 (a)	E 9.74 (a)	S 8.66 (b)

Notes: N : North, W : West, E : East, S : South.

*[1] SR : Radial shrinkage, ST : Tangential shrinkage, SV : Volumetric shrinkage.

*[2] The same letters in parenthesis indicate no significant difference.

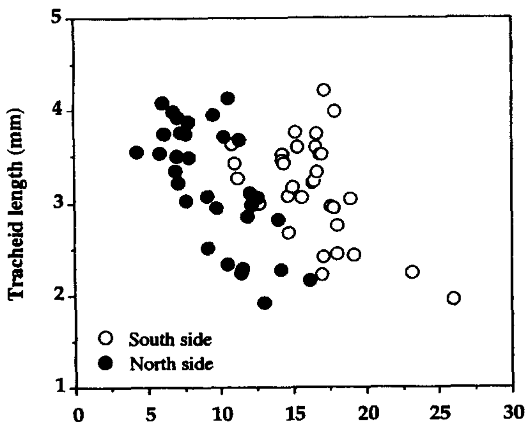

Fig. 5. Relationship between tracheid length and microfibril angle for Korean pine.

height with significant differences at the 99% level, with the exception of earlywood on the south side at 1.3m. In earlywood at 1.3m, although there was no significant difference at 95% level, microfibril angle on the south side (13.3°) was greater than that on the north side (10.9°). The difference between microfibril angle (including earlywood and latewood) on south and north sides was 6.0° for sample No. 1 and 8.0° for sample No. 2.

Shrinkage in the tangential direction decreased as microfibril angle increased. Kim (1995) reported that tangential, radial, and volumetric shrinkage were greatest on the north side (Table 1). This was ascribed to the greater microfibril angle on the south side compared to the north side.

Fig. 5 shows the relationship between tracheid length and microfibril angle, clearly indicating that tracheid length tends to decrease with increasing microfibril angle. Hiller (1964) and Watanabe *et al.* (1964) reported the same tendency in softwoods.

3. 3 Compression strength parallel to grain

Table 2 shows compression strength parallel to grain and proportional limit stress parallel to grain on south and north sides at each height. Fig. 6 shows average compression strength parallel to grain of both sample trees. Mean values were always greater on the north side than on the south side. Although the difference in compression strength and proportional limit stress between south and north sides was not found throughout the samples, the greater microfibril angle on the south side might play an important role in compression strength because compression strength parallel to grain decreased as microfibril angle increased.

4. CONCLUSION

For the efficient utilization of and development of new uses for Korean pine (*Pinus koraiensis*), a prominent reforestation species in Korea, variation

Table 2. Mechanical properties of Korean pine.

Height	Side		Compressive Strength (kgf/cm²)			Propotional limit (kgf/cm²)		
			No.1 Tree	No.2 Tree	Mean	No.1 Tree	No.2 Tree	Mean
0.3m	South	Mean (SD)	395 (37)	400 (42)	398	261 (51)	262 (44)	262
	North	Mean (SD)	441 (52)	391 (38)	416	314 (67)	291 (48)	303
	Level of significance		NS	NS		NS	NS	
1.3m	South	Mean (SD)	374 (59)	367 (54)	371	238 (71)	268 (68)	253
	North	Mean (SD)	449 (41)	355 (45)	402	321 (37)	221 (49)	303
	Level of significance		*	NS		*	NS	
2.3m	South	Mean (SD)	434 (54)	347 (49)	391	299 (47)	210 (37)	255
	North	Mean (SD)	429 (79)	372 (36)	401	347 (70)	229 (70)	288
	Level of significance		NS	NS		NS	NS	
5.3m	South	Mean (SD)	410 (44)	410 (45)	406	296 (31)	264 (39)	280
	North	Mean (SD)	470 (64)	385 (42)	428	370 (63)	323 (87)	347
	Level of significance		NS	NS		*	NS	

Notes; SD : Standard deviation, * : Significant difference at 95% level, NS : Not significance at 95% level.

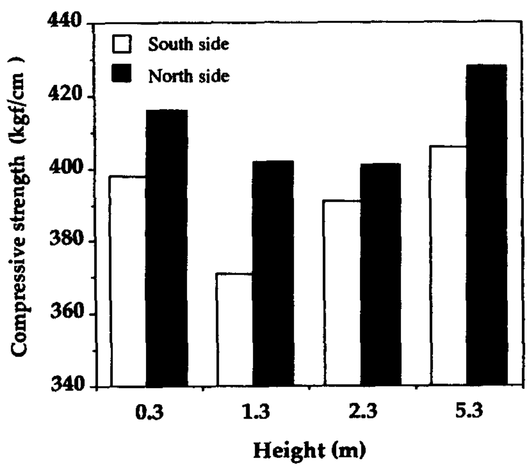

Fig. 6. Compressive strength parallel to the grain on the south and north sides for Korean pine.

in tracheid length, microfibril angle, and compression strength were examined. on the south and north sides of the stem. The results are summarized as follows:

1. Tracheid length increased with age from pith to annual rings 16 to 20 and then leveled off. Juvenile wood and mature wood were demarcated by rings 16 to 20 from the pith.
2. Mean tracheid length was 3.15mm on the south side of the stem and 3.26mm on the north side.
3. Microfibril angle was 16.6° on the south side and 9.6° on the north. A negative relationship was found between tracheid length and microfibril angle.
4. Compression strength and proportional limit stress (mean values of samples No. 1 and 2) was greater on the north side than on the south. However, significant differences for compression strength were found only at 1.3 and 5.3m above ground level.
5. Tangential shrinkage was greater on the north side than on the south, probably as a result of lower microfibril angle on the north side.

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