Genetic variations of wood properties and growth characters of Korean pines from different provenances

WANG Hui-mei, XIA De-an, WANG Wen-jie, YANG Shu-wen
(*Northeast Forestry University, Harbin 150040, P. R. China*)

Abstract: Totally 26 provenance stands of 17-year-old Korean pine were selected for investigating wood properties and growth characters in Mao'ershan Experimental Forest Farm of Northeast Forestry University in 1999. The anatomical property indexes, including tracheid length, tracheid diameter and wall-indiameter ratio, and the physical property indexes, such as growth ring width, late wood percentage and growth ring density, were measured for wood properties. Growth character indexes, including tree height and diameter at breast height, were also measured. The analytical results showed that there exited obviously difference in wood property indexes between different provenances, which is suggested that wood properties are controlled by their genetic differences. The growth character indexes of Korean pines presented significant difference and they might also be controlled by their genetic differences. Most parameters of wood properties mainly varied in the direction of longitude, but the parameters of growth characters varied in the direction of latitude.

Keywords: Korean pine; Provenance trial; Wood properties; Geographical variation; Genetic variation
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Introduction

There existed greatly genetic variations in different species, different individuals of the same species in the same geographical regions as well as different species in different geographical regions in broadleaved (Einspahr *et al.* 1970) and coniferous forests (Zobel *et al.* 1989). Korean pine (*Pinus koraiensis*) is one of the important timber trees in northeast China. Acknowledge of its genetic variations is important for the study of timber-aimed breeding and further reasonable utilization of Korean pinewood. However, there were few reports on the genetic variation of wood properties and growth characters of Korean pines from different provenances. With measurements of 26 provenance experimental stands of 17-year-old Korean pine, this article analyzed the genetic variations of wood properties and growth characters.

Materials and methods

Experimental materials

In Mao'ershan Experimental Forest Farm of Northeast forestry University (127° 28′ 20″-127° 43′ 14″ E, 45° 14′ 30″ - 45° 29′ 20″ N), Shangzhi County, Heilongjiang Province, totally 26 provenance experimental stands of 17-year-old Korean pine were selected in 1999. The trees from different provenances were randomly planted in five replicate plots in 1982. There were 100 individuals in each replicate plot. The diameter at breast height (DBH) and tree height of all the trees in each replicate plots were measured in order to calculate out the average DBH and tree height. Based on this data, three trees in 3-selected replicate plots were cut as sample tree. Sample stem was taken from each sample tree by cutting at the height of 40 -140 cm.

Experimental methods

Tracheid length measurement

The tracheid length was measured on photo electricity projection instruments with nitric acid digest and isolation method (Guo 1999). Thirty data were measured for each sample.

Tree ring width and late wood ratio

The micrometer (resolution is 0.01 mm) was used to measure the tree ring width and late wood width (Guo 1999). Late wood ratio was calculated by the formula (1)

$$R_l = \frac{W_l}{W} \times 100\ \% \qquad (1)$$

Where, R_l is late wood ratio, W_l is late wood width and W is tree ring width.

Tree ring density measurement

The *X*-ray microdensity scanner was used to determine tree ring density. Scanning rate was 1.6 cm per min. The data were recorded by floppy disk and tree ring density was post-calculated by computer (Guo 1999).

Wood rigidity measurements

The wood rigidity was measured by omnipotent pressure measure system through an electric pressure sensor (Guo

Biography: WANG Hui-mei (1973-), female, assistant professor in Northeast Forestry University, Harbin 150040, P R China.
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1999).

Growth parameter measurement

For each provenance, DBH and tree height of 10 randomly selected trees were measured in every five replicate plots.

Data analysis

The parameters of wood properties and growth characteristics of Korean pines from different provenances were analyzed by trend surface analysis and iterative regression technique. All the data were analyzed by using Statistics for windows 6.0.

Results and discussion

Genetic variation of wood properties

The statistical results of wood properties of Korean pine from different provenances were listed in Table 1. The variation coefficient of late wood was 19.3%, which was highest of all the other parameters. However, the variation coefficient of timber length was just 0.06% (Table 1). Each parameter between different provenances in wood properties was analyzed by double-factor ANOVA. The results showed that the difference in wood property between different provenances was significant (Table 1). It is clear that genetic variation in wood properties might be significant.

Heretability of wood properties

Heretability parameters were calculated according to the results of ANOVA (Table 2). The results showed that parameters of all the wood properties were affected by their gene to some extent, in particularly the tracheid length and wood density. Wood density and tracheid length are two important intrinsic properties and are often used as target properties (Zobel *et al.* 1984; Zobel *et al.* 1989). These two parameters are closely correlated with dry matter production per unit volume, wood dynamic characteristics and quality of paper pulp (Cheng 1995). Therefore, our results indicated that genetic selection among different Korean pine provenances might improve their wood utilization if the heretability of wood density and tracheid length were properly considered.

Table 1. Statistical results of wood properties of Korean pine from different provenances

Parameter	Mean	Variation range	Standard deviation	Variation coefficient (%)	*F*-value
Tracheid length	1.44 mm	1.15 - 1.64 mm	0.114	6.9	30.44**
Tracheid diameter	39.77 μm	36.49 - 44.88 μm	2.086	5.2	14.99**
Tracheid length-width ratio	37.51	31.24 - 42.01	0.025	0.1	11.72**
Wall-indiameter ratio	0.32	0.27 - 0.37	0.024	7.5	1.60**
Wood density	0.42 $g\cdot cm^{-3}$	0.38 - 0.45 $g\cdot cm^{-3}$	0.017	4.0	4.24**
Growth ring width	3.73 mm	2.88 - 4.67 mm	0.244	6.5	4.87**
Late wood percentage	14.90%	7.90% -22.5%	0.029	19.3	1.70**
Wood rigidity	39.38 $kg\cdot cm^{-2}$	32.03 - 45.97 $kg\cdot cm^{-2}$	3.333	8.5	3.71**

Notes: **---- significant difference (p<0.01).

Table 2. Heretability of wood properties of Korean pine from different provenances

Parameter	Tracheid length /mm	Tracheid diameter /μm	Tracheid length-width ratio	Wall-indiameter ratio	Wood density /$g\cdot cm^{-3}$	Growth ring width /mm	Late wood percentage (%)
F- value	6.938	2.601	3.056	1.601	9.603	5.566	1.571
Heretability	0.856	0.615	0.673	0.375	0.896	0.820	0.363

Genetic variation of growth character parameters

The parameters of growth character between different provenances were analyzed by ANOVA (Table 3). The results showed that there was significant difference in the growth_characters between different provenances. It appears that further practice on genetic improvement, particularly on selection of fast-growth provenances might be feasible.

Table 3. Growth characteristics of Korean pine from different provenances

Parameter	Mean	Variation range	Standard deviation	Variation coefficient	*F*-value
Tee height (m)	4.46	4.04 - 4.76	0.165	3.7	0.013
DBH (cm)	6.32	5.23 - 7.09	0.428	6.8	0.011

Geographical variation of wood properties

Recent study indicated that phenotypic variation of wood properties in some tree species closely correlated with their inhabited environment (Li 1993). In order to confirm this hypothesis on Korean pine, the methods of iterative regression and trend surface analysis were used to discuss the geographical variation of wood properties of Korean pine from different provenances. Latitude and longitude were used as independent factors and wood property indexes were used as dependent factor. The result showed that most of the regression formulas are statistically significant (Table 4). It is clear that Korean pine has geographical variation. Tracheid length increased in direction from northwest to southeast, which was in the directions of longitude and latitude but longitude had a stronger weight (Fig. 1 a). However, tracheid diameter increased in direction from north to south but there was slight variation in the longitude (Fig. 1 b). Wood density decreased in direction from north to south. The result showed that it varied in direction of latitude but not longitude (Fig. 1 c). The variation of wood rigidity was similar to wood density (Fig. 1 d). Tree ring width was also latitude-dependent variation and increased in direction from north to south (Fig. 1 e). Variation of late wood ratio varied in the direction of both latitude and longitude but longitude took a weaker weight. (Fig.1 f). These results indicated that, besides the faster cell division rate in low latitude, tracheid diameter might be one reason why provenances in low latitude grow faster than that in high latitude.

Geographical variation of growth characters

Growth status of tree is affected by the inhabited location and specific environment (Li 1993). A combined method of iterative regression and trend surface analysis was used to discuss the geographical variation of growth characters of Korean pine from different provenances (Table 5, Fig. 2). The results showed that both tree height and DBH varied in the direction of latitude, that is, both tree height and DBH decreased with the increase in latitude. This was accordance with some of the wood property indexes in geographical variation such as tracheid diameter and tree ring width (Fig. 1).

Table 4. Trend surface analysis of wood properties of Korean pine from different provenances

Parameter	Trend equation	R-square	Significance level
Tracheid length	Y=-2.306+0.0312x_1-0.0002 x_2^2	0.5846	0.0020
Tracheid diameter	Y=-0.4511-0.0025x_1x_2	0.4511	0.0240
Tracheid length-width ratio	No factor entered		
Wall-indiameter ratio	No factor entered		
Wood density	Y=0.3469+0.0004 x_2^2	0.4540	0.0198
Late wood percentage	Y=0.7729-0.0061x_1+0.0001 x_2^2	0.6781	0.0011
Tree ring width	Y=6.064-0.0012 x_2^2	0.5187	0.0066
Wood rigidity	Y=25 034+0.0070 x_2^2	0.4406	0.0243

Notes: 1) x_1=longitude; x_2=latitude; 2) equations in the table have been sieved by step regression.

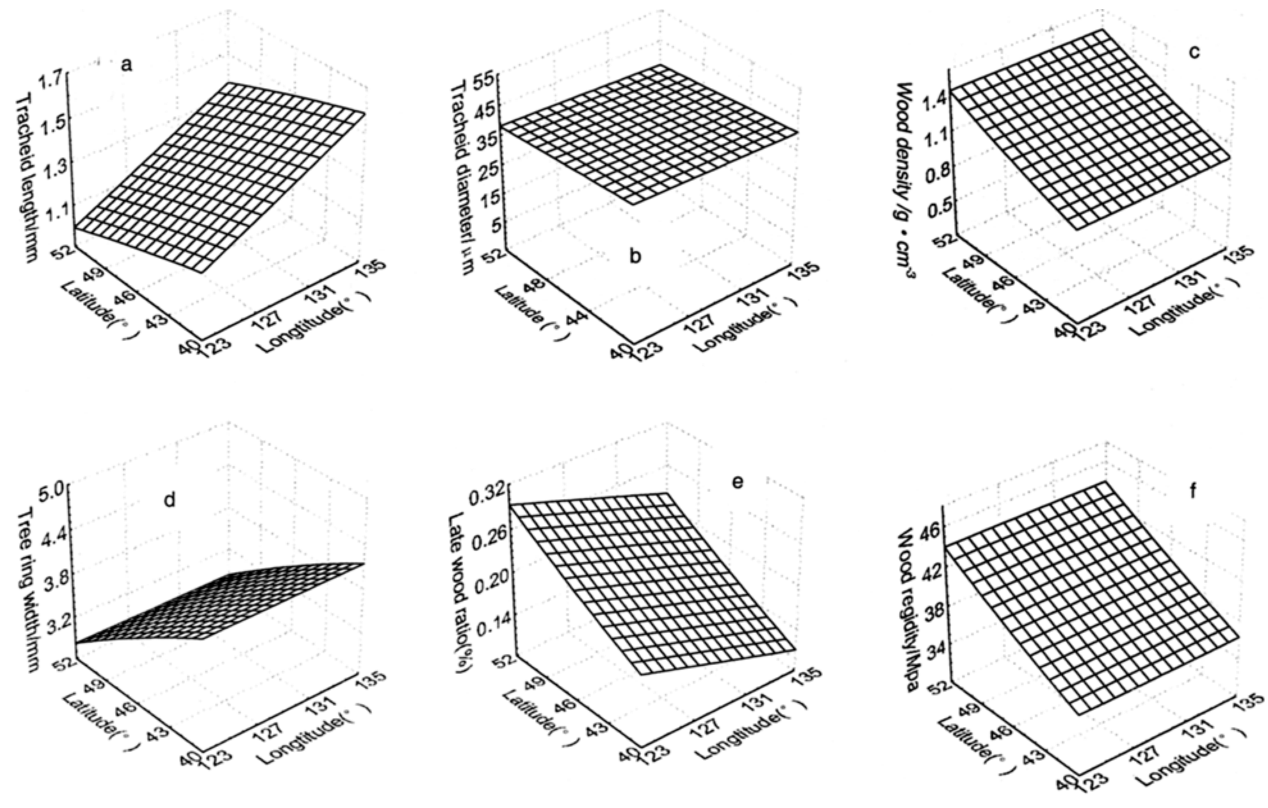

Fig. 1 Trend surface analysis of wood properties of Korean pine from different provenances

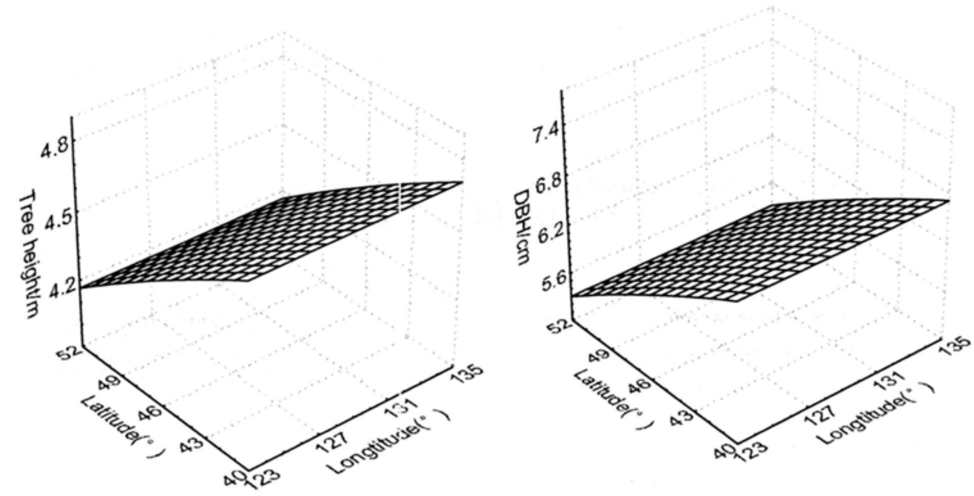

Fig. 2 Trend surface analysis of growth characters of Korean pine from different provenances

Table 5. Trend surface analysis of growth characteristics of Korean pine from different provenance

Parameter	Regression equation	Multiple regression coefficient	Significance level
Tree height	Y=5.4897-0.00049 x_2^2	0.6213	0.001
DBH	Y=8.7642-0.0012 x_2^2	0.5732	0.003

Notes: x_1-longitude; x_2-latitude.

Conclusions

1). All the parameters of wood properties of Korean pine presented significant differences between different provenances, that is to say, different wood properties were controlled by gene to some extent.

2). The growth characters of Korean pine from different provenances were evidently different. They were controlled by their heredity in a middle intensity.

3). Some wood property parameters including tracheid length and late wood ratio were both latitude and longitude dependent geographical variation, however, wood density, wood rigidity and tree ring width basically varied in the direction of latitude.

4). Growth characters of Korean pine basically varied in the direction of latitude.

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