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Effects of Climate Variation on Radial Growth of *Pinus densiflora* in Okutama, Tokyo, Japan

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S u m m a r y

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The effects of climate variation on radial growth of *Pinus densiflora* and other four coniferous species in Okutama, Tokyo, were investigated by dendroclimatic analysis. Tree-ring indices of annual ring width and annual mean density were used as an index of radial growth. In *P. densiflora*, wood anatomical features of the number of tracheid cells, cell radial diameter, and cell-wall thickness were measured by image analysis. The relationships between tree-ring indices and wood anatomical features were analyzed. As a result, annual ring width was significantly correlated with the number of cells within annual ring, and also was significantly and positively correlated with mean temperature in March of the current year. Annual mean density was significantly correlated with mean cell radial diameter within annual ring and mean cell-wall thickness within annual ring, and also was significantly and positively correlated with mean temperature in July of the current year. Moreover, these relationships were maintained in recent 47 years.

Introduction

Against the global warming, a forest is expected to act as a source of absorption and storehouse of Carbon dioxide (FORESTRY AGENCY 2003). It is informative to grasp the effects of climate variation on the growth of a tree which formed a forest. Generally dendroclimatic analysis is applied as one of the studying methods of the relationship between the radial growth of a tree and climate variation (SCHWEINGRUBER 1987, COOK & KAIRIUKSTIS 1990). By most of research using

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dendroclimatic analysis, tree-ring indices of annual ring width and annual mean density are used as an index of radial growth (NOBORI 1994, FUJIWARA & al. 1999). However, the relationships between tree-ring indices and wood anatomical features are obscure, and reports are limited (YASUE & al. 2000, WANG & al. 2002).

The purpose of this study was to discuss the effects of climate variation on radial growth of *P. densiflora* in Okutama, Tokyo. Firstly, the relationships between tree-ring indices and monthly mean temperature were investigated using dendroclimatic analysis to *P. densiflora* and other four coniferous species. Secondly, wood anatomical features were measured by image analysis. And the relationships between tree-ring indices and wood anatomical features were investigated.

Material and Methods

Study site and samples

This study site is located in Okutama Experimental Forest, Tokyo University of Agriculture (35°49′ N, 139°05′ E, elevation 650-1450 m above sea level), about 50 km west of Tokyo. Annual total precipitation was 1668 mm. Annual mean temperature was 13 °C. And minimum temperature was -5.5 °C. Sample trees were selected from *P. densiflora* (n = 20). And also *Abies firma* (n = 29), *Cryptomeria japonica* (n = 23), *Chamaecyparis obtusa* (n = 23), and *Tsuga sieboldii* (n = 14) were selected to compare with *P. densiflora*.

Dendroclimatic analysis

An increment core of 5 mm of diameter was taken from two different radial directions of each tree at breast height in the summer of 2002. The increment cores were cut transversely into strips with thickness of 1.5 mm, air-dried, and soft X-rayed. Tree-ring indices of annual ring width and annual mean density were measured from the X-ray negative film using the densitometer, DENDRO 2003 (Walesch Electronic). Cross-dating was performed visually and by a statistical method with the program COFECHA (HOLMES 1983, 1994). Standardization was performed by fitting smoothing splines with the program ARSTAN (COOK 1985). This filter reduces the amplitude to less than 50% in the range of 10 years and longer frequency. Then, tree-ring chronologies of five species were developed. And, simple correlation coefficients between tree-ring chronologies and monthly mean temperature chronologies were calculated. Climate data was collected at meteorological station which is located about 10 km east of this study site. Monthly climate data for 13 months from October of the previous year to October of the current year were applied to calculate the correlation coefficients. The statistical period was 47 years (1954-2000).

Image analysis of wood anatomy

Four strips of *P. densiflora* which were subjected to dendroclimatic analysis were used for image analysis. The four stripes were chosen from different individuals. Each strip was divided into about 1 cm portions. Then, the cross sections with a thickness of 15 µm were sectioned by sliding microtome. The cross sections were stained with Gentian Violet solution and were permanently mounted on microscope slides. Images of the each cross section with annual ring were captured with a CCD camera attached to a light microscope. The resolution of captured images was 0.68 µm/pixel. The images were processed and analyzed with the NIH-image program version 1.61 (RASBAND 1996) in combination with a Cell Dimension Analysis Macro program (KOBAYASHI 1997). The number of tracheid cells was counted. And also, cell radial diameter and cell-wall thickness were measured along five radial files of tracheid in each annual ring (18 annual rings, 1984-2001).

Results and Discussion

The length of tree-ring chronologies of five species were all 100 years or more. The relationships between tree-ring indices of five species and mean temperatures were shown in Table 1. The correlation coefficients between mean temperature in March of the current year and annual ring width were positively significant in common with five species. And also, the correlation coefficients between mean temperature in July of the current year and annual mean density were positively significant in common with four species except for *C. obtusa*.

Table 1. Relationships between tree-ring indices and mean temperatures. Positively significant coefficients ($p < 0.05$) are indicated circles. The statistical period was 47 years (1954-2000).

	Previous year					Current year							
annual ring width	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.
A. firma			●		●	●			●				●
P. densiflora						●							
C. japonica				●	●	●						●	
C. obtusa						●							
T. sieboldii				●	●	●							
annual mean density	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.
A. firma										●	●		
P. densiflora						●			●	●			
C. japonica								●		●			
C. obtusa						●		●	●				●
T. sieboldii										●			

Chronologies of mean temperature in March of the current year and annual ring width showed similar pattern in recent 47 years (1954-2000) (Fig. 1). Chronologies of mean temperature in July of the current year and annual mean density also showed similar pattern in recent 47 years.

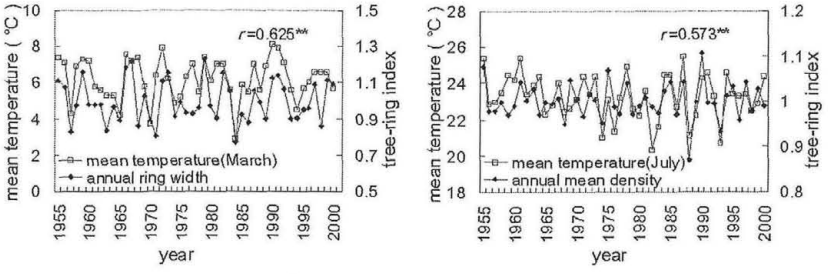

Fig. 1. Relationship between tree-ring chronologies of *P. densiflora* and mean temperature chronologies. **, $p < 0.01$. The statistical period was 47 years (1954-2000).

In the four trees of *P. densiflora*, the correlation coefficients between tree-ring indices and wood anatomical features were calculated (Fig. 2). Annual ring width was significantly and positively correlated with the number of cells within

annual ring. Annual mean density was significantly and negatively correlated with mean cell radial diameter within annual ring, and significantly and positively correlated with mean cell-wall thickness within annual ring. The correlation coefficients between mean cell radial diameter within annual ring and mean cell-wall thickness within annual ring were not significant.

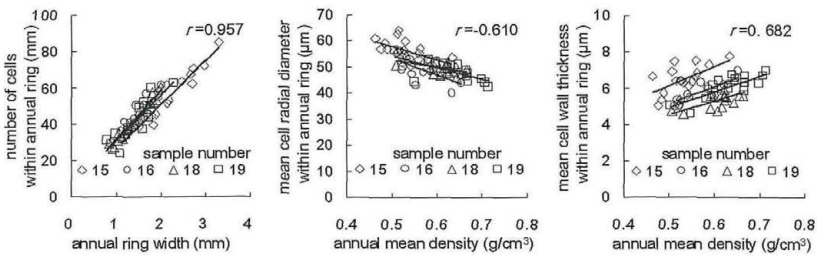

Fig. 2. Relationships between tree-ring indices and wood anatomical features. These correlation coefficients were average of the four trees.

In conclusion, the relationships between tree-ring indices and monthly mean temperatures were similar trend among five coniferous species. In *P. densiflora* on behalf of five coniferous species, chronologies of tree-ring indices and monthly mean temperatures showed similar pattern in recent 47 years (1954-2000). In *P. densiflora*, the relationships between tree-ring indices and wood anatomical features were found.

Therefore, we thought that the relationship of radial growth of *P. densiflora* and climate variation in Okutama, Tokyo is maintained in recent 47 years (1954-2000).

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