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Vessel Element Length Related to the Physiological Traits of Leaves in *Fagus crenata* Seedlings Originated from Different Provenances

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Abstract: The study was achieved to understand the relationships between vessel element length and physiological traits of the leaves in *Fagus crenata* seedlings originated from different provenances and grown in the Chichibu Research Forest of Tokyo University. The results underlined that the variations in the vessel elements length were related to variations of the transpiration rate and stomatal conductance in response to the provenance variation.

Key words: *Fagus crenata*, stomatal conductance, transpiration rate, vessel element length

INTRODUCTION

In hardwoods, water is mainly transported from roots to leaves through the vessel elements in the stem. The relationships between hydraulic conductance in the stem, which is closely related to the anatomical characteristics of the vessel elements, and physiological characteristics of leaves have been observed by many researchers (Sperry *et al*., 1993; Santiago *et al*., 2004). Thus, variation in physiological characteristics of leaves, which is believed to be caused by provenance variation, might be in harmony with the variations of water hydraulic conductance in stem and anatomical characteristics of the vessel elements in hardwoods with large geographical distribution. The relationships between physiological trait of leaves and anatomical characteristics of the vessel elements including average vessel area, vessel number per mm^2 and vessel area percentage in *Fagus crenata* seedlings originated from different provenances were investigated by Bayramzadeh *et al*. (2008). However, there have been no studies, to our knowledge, of the relationships between vessel element length and physiological trait of the leaves in the widely distributed hardwoods. This study may help us to explain that how hydraulic system in broadly dispersed hardwoods react to the new environmental conditions.

The main purpose of the present study was to investigate whether or not provenance variation in physiological trait of the leaves were related to that in vessel element length in the hardwoods with large geographical distribution. The authors examined *Fagus crenata* because its plantation is currently performed in Japan for water preservation purpose.

Since water movement in diffuse-porous hardwoods such as *Fagus crenata* generally occurs in several outermost annual rings within sapwood area, (Chaney and Kozlowski, 1977; Utsumi *et al*., 1998), the authors investigated the relationships between vessel element length in all annual rings within sapwood and physiological traits of the leaves.

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MATERIALS AND METHODS

The authors used thirteen-years-old *Fagus crenata* seedlings grown from the seeds that had been collected from the seven different provenances in Japan, Kurikomayama, Nishikawa, Oohirahara, Hiruzen (Japan Sea side), Ogawa (Pacific Ocean side), Minakami and Chichibu (central part of Japan). The seeds were planted in an experimental nursery established in Chichibu Research Forest of Tokyo University (35° 59' N, 139° 04' E) in 1992.

As the variation in different characteristics of leaf and vessel elements between seedlings of each provenance was negligible (Fig. 1), four seedlings of each provenance were selected for measurements of the vessel element length. For measurement of vessel element length, vessel elements were macerated by the method described originally by Franklin (1945). The whole lengths of the one hundred vessel elements were measured, including the tails, (Kitin *et al*., 1999) in each annual ring.

Measurements of the stomatal conductance and transpiration rate were carried out on six fully expanded leaves (sunned leaves from the middle part of crown) of five seedlings per provenance in the early August, 2005. Stomatal conductance and transpiration rate were measured using LI-1600 Steady State Porometer (LI-COR, Inc). Measurements were made on cloud-free days between 11:30 am and 13:30 pm and repeated on five sunny days (Nardini and Salleo, 2000; Uemura *et al*., 2000; Eguchi *et al*., 2004).

Statistical analysis were carried out with StatGraphics Plus 5.1 (Stat Point, Inc., Northern Virginia, USA). Tukey's Honestly Significant Differences (HSD) procedure was used to compare the means of studied parameters in different provenances of *Fagus crenata*, as the number of provenances was more than four. Simple regression analysis was used to analyze the relationship between the vessel elements length and physiological traits of the leaves.

RESULTS AND DISCUSSION

As shown in Fig. 1a, vessel element length was statistically different among the provenances ($p<0.05$). Hiruzen showed maximum values for vessel element length in all annual rings from the pith side to the bark side, except annual ring number six (e.g., 401 and 481 μm in annual ring number one and five, respectively). According to the dissimilarity of the vessel elements length among different provenances of *Fagus crenata*, it can be noted that the length of the fusiform cambial cells are also different among the different provenances of *Fagus crenata*, because the length of the vessel elements have been found to be equivalent to those of fusiform cambial cells in diffuse porous hardwoods (Chalk and Chattaway, 1934; Butterfield, 1973; Kitin *et al*., 1999). Thus, according to the above mentioned explanation and regarding the equivalency of the vessel element length and the length of the fusiform cambial cells in diffuse porous hardwoods, it can be suggested that the differences in the vessel element length and length of the fusiform cambial cells might be driven from genetic variation among the seed sources.

Figures 1b and c showed that transpiration rate and stomatal conductance were statistically different among the studied provenances ($p<0.05$). As shown in Fig. 1b and c, transpiration rate and stomatal conductance were the highest in Chichibu (17.03 μg cm^{-2} sec^{-1} and 1.79 cm sec^{-1}, respectively) and the lowest in Nishikawa (10.21 μg cm^{-2} sec^{-1} and 0.80 cm sec^{-1}, respectively). The results of the physiological characteristics of leaves were in agreement with the previous researches reporting variations in foliar traits of *Fagus crenata* originated from different provenances (Koike and Maruyama, 1998). Koike and Maruyama (1998) reported differences in the maximum photosynthetic rate, stomatal conductance and transpiration rate among different provenances of *Fagus crenata*.

As the present seedlings were grown in the same plantation, the observed foliar differences might be explained by the genetic variation among seed sources.

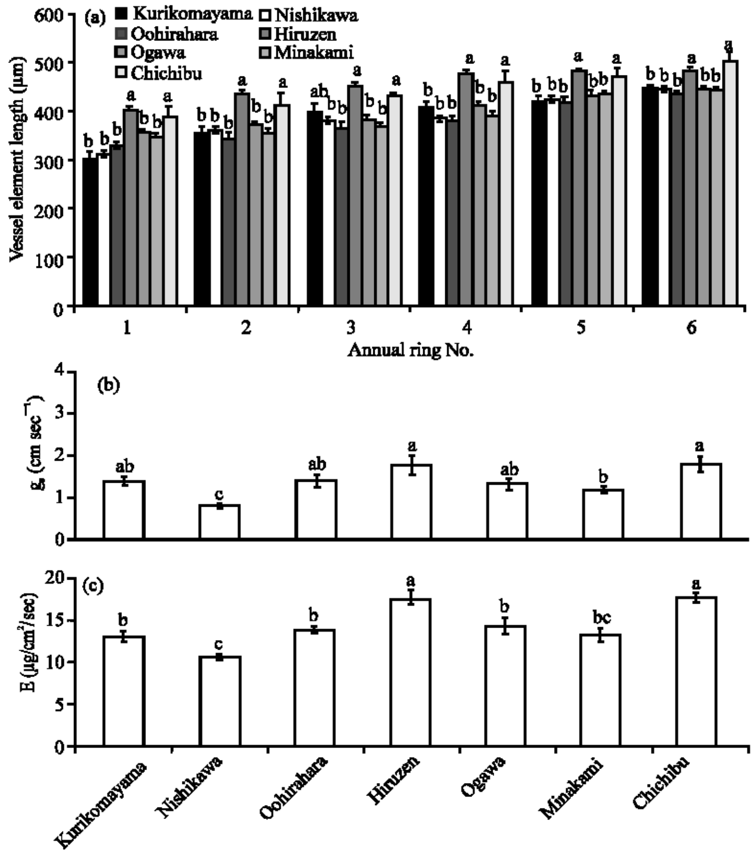

Fig. 1: (a) Vessel element length from the pith side (annual ring number one) to the bark side (annual ring number six), (b) stomatal conductance, g_s, and (c) transpiration rate, in different provenances of *Fagus crenata*. n for xylem studies = 4, n for foliar studies = 5. Bars show SE Means with the same letter(s) are not significantly different at p<0.05 by Tukey's HSD procedure

Table 1: The correlation coefficients (r) between vessel element length in the annual rings number one to six (pith to bark side) and physiological traits of the leaves of seven provenances of *Fagus crenata*

Vessel element length	E (µg cm^{-2} sec^{-1})	g_s (cm sec^{-1})
Annual ring number one	0.89**	0.86**
Annual ring number two	0.88**	0.87**
Annual ring number three	0.89**	0.88**
Annual ring number four	0.90**	0.89**
Annual ring number five	0.87**	0.86**
Annual ring number six	0.93**	0.89**

E: Transpiration rate, g_s: Stomatal conductance, n = 7, **p<0.01;*p<0.05

Table 1 shows the relationships between physiological traits of the leaves and vessel element length in all annual rings from the pith side to the bark side. Significant (p<0.01) simple relationship (positive) were observed between vessel element length in all annual rings with transpiration rate and stomatal conductance. Calkin *et al.* (1986) proved that pit membrane resistance is the major component of the total resistance in the *Petris vittata*. Assuming that the pit membrane resistance represents a major component of the total resistance to flow then it can be said that long conduits offer little hydraulic resistance and consequently higher hydraulic conductivity (Hacke and Sperry, 2001). Therefore, the observed close positive relationships between the vessel element length and leaves physiological traits of the *Fagus crenata* might be related to the above-mentioned fact.

Studying the correlation between anatomical characteristics of the vessel elements and physiological trait of the leaves in *Fagus crenata*, Bayramzadeh *et al*. (2008) reported highly correlated relationships between physiological trait of the leaves, vessel number per mm^2 and vessel area percentage in *Fagus crenata* seedlings originated from different provenances and grown under the same environmental conditions. This finding for *Fagus crenata* is similar to the results of Lindorf (1997) and Fei *et al*. (2000), which reported a relationship between the vessel elements and leaf characteristics in *Sessea corymbiflora and Fagus lucida*, respectively, in response to the provenance variation.

Thus, it can be concluded that vessel elements anatomy and physiological traits of the leaves respond together, as a unit, to the provenance variation in some diffuse porous hardwoods and *Fagus crenata* seems to be an example of this strategy.

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