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Seasonal Variation in Major Soil Nutrients and Microorganisms at the Plantations of *Pinus koraiensis* S. et Z. Following Clearcut of *Quercus mongolica* Fisch.

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신갈나무林의 皆伐後 잣나무 人工造林에 따른 主要 土壤 微生物相 및 養料相의 季節的 變異

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Summary

Seasonal variation of the soil microorganisms involved in carbon and nitrogen mineralization and major soil nutrients such as nitrogen and phosphorus were investigated in a 30-year-old *Quercus mongolica* Fisch. stand and in 8-, 18-and 28-year-old *Pinus koraiensis* S. et Z. plantations following clearcut of *Quercus mongolica* Fisch. This study was conducted at the Seoul National University Forests placed along Mt. Taewha located in Sanglim-lee, Docheok-myon, Kwangju-gun, Kyonggido, Korea.

Seasonal variation in soil physicochemical conditions was greatly fluctuated at 8-year-old *Pinus koraiensis* plantation than at other stands due to clearcutting. The factors which were significantly different among those stands were contents of total N, C, P, soluble salts, moisture and ammoniun N, and pH. Total nitrogen and available phosphorus gradually decreased after clearcutting, but were recovered after about 20 years. Contents of moisture, ammonium N, soluble salts and total carbon were reduced by the clearcut, but the maturation of the stand improved soil conditions at all of the stands. The populations of soil microorganisms involved in carbon and nitrogen mineralization were not significantly changed by the clearcut.

Thus, the establishment of *P. koraiensis* plantation following clearcut of *Q. mongolica* changed total nitrogen and carbon contents, but did not disturb greatly the forest soil condition.

INTRODUCTION

A soil type determines a type of vegetation but its character is at the same time moulded by the vegetation, particularly by the amount and nature of the soil organic matter which is formed during the decomposition of the plant litter. In general, the rates of degradation and decomposition differ depending upon the upper layer plant species, and the contents of carbon, nitrogen and phosphorus of tree stands vary greatly due to the litter types (Anderson, 1973-a; -b). Especially, on shallow soils a large proportion of total ecosystem nutrients is influenced by the vegetation. Therefore, the removal of nutrients by the timber harvest may have more impact on nutrient status of stands growing on shallow soils (Green and Grigal, 1980)

Because of the conservative nature of nutrient cycling, mature forest stands make only minimal demands on the soil for nutrients. Although the annual uptake of nutrients by a vigorous stand of trees approaches that of an agricultural crop, on an area basis, a large percentage of the absorbed nutrients are returned to the forest floor through leaching from the forest canopy or as litterfall. The slow decomposing litter releases nutrients for reuse by the vegetation, so that only small additional amounts of nutrients are needed to sustain tree growth and bolewood production. However, disturbances of forests by both natural and human activities are apparently common occurrences even in natural forests. Major disturbances can have dramatic effects on nutrient cycling. Forest management activities that produce changes in stand structure and species composition probably alter the soil. The forest ecosystem a stand reforested after clearcutting might be greatly disturbed.

Studies on nutrient pools and flux in forest ecosystems can provide a portion of the data needed to allow maximum production. The cycles of essential elements are also convenient entry points for ecosystem analysis, and the nutrient flux is essential to the continuity and stability of the ecosystem and may strongly affect productivity. It is well known that the cycle of nitrogen which is the critical nurtient in most forest ecosystems and that of carbon occupying most of forest floor in forest ecosystems influence forest productivity (Coleman ***et al.***, 1983; Pritchett, 1979)

By virtue of their effects on nutrient cycling in the biosphere, microbes have a great significance in the biogeochemistry of the elements. Availability of the nutrients markedly influences plant vigor and consquently productivity. Microbial processes affecting nutrient availability, thus play a vital role in ecosystem function (Alexander, 1977, Richards, 1987).

Rolfe ***et al.*** (1978) emphasized that the nutrient flux was essential to the continuity and stability of the ecosystem, and many studies have been done on the influences of soil nutrients flux by the silvicultural practices. Matson and Vitousek (1981) manifested that increase in soil temperature and soil moisture availability caused by clearcutting induced increase in decomposition, nitrogen mineralization and nitrification. However, careful logging and long-term harvest are needed to keep stability of soil nutrient capacity, because clearcutting makes disturbances of forests (Hornbeck ***et al.***, 1986). Lindberg and Popovic (1978, 1980) reported that clearcutting did not make significant changes in nutrient flux, but it made the seasonal fluctuations of nutrient flux increase. Lane (1975) reported that the conversion of hardwoods to pines did not produce significant changes in nutrient status and its microbial population for 7 years.

The oaks grow naturally at temperate forest zone in Korea. Especially, the stands of ***Quercus mongolica*** Fisch. occupy most of natural forests in Korea, ***Pinus koraiensis*** S. et Z. has been planted widely in Korea because it is native species and produces good timber as well as useful pine nuts. Most of these oak stands have been converted into either ***P. koraiensis*** or ***Larix leptolepis*** plantations. It can be thought that the reforestation by ***P. koraiensis*** after clearcutting of oak stands may alter the soil condition.

The objective of this study was to compare the soil microorganisms involved in carbon and nitrogen mineralization and the variation in major nutrients such as nitrogen and phosphorus at a 30-year-old ***Quercus mongolica*** stand and in 8-, 18- and 28-year-old ***Pinus koraiensis*** plantations following clearcut of ***Quercus mongolica.***

MATERIALS AND METHODS

Study Area

The investigation was performed at the Seoul National University Forests (127°18′E, 37°18′N) placed along Mt. Taewha (642 m from the sea level) located in Sanglim-lee, Docheok-myeon, Kwangju-gun, Kyonggi-do, Korea(Figure 1). The experimental plots were set up at a 30-year-old ***Quercus mongolica*** Fisch. stand regenerated from sprouts and three ***Pinus koraiensis*** S. et Z.

Plantations which were 8-, 18- and 28-year-old, respectively(Table 1). Annual temperature averaged

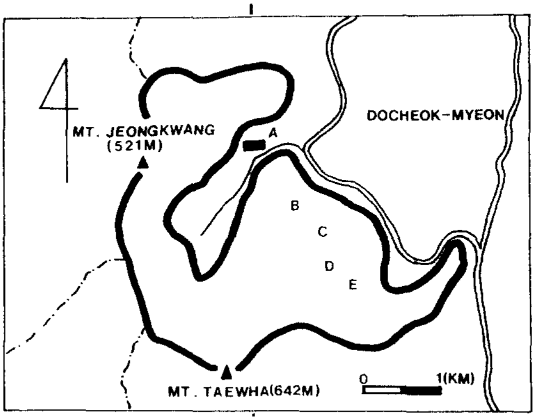

Fig. 1. Location map of Seoul National University Forests in Kwangju-gun, Kyonggi-do, Korea and the experimental sites: A for the Maintenance Office of the University Forests, B for *Q. mongolica* stnad, C for *P. koraiensis* (8-year-old), D for *P. koraiensis*(18-year-old) and E for *P. koraiensis* (28-year-old) plantations.

11.3°c and annual total precipitation showed about 1050 mm in the Maintenance Office of University Forests during the experimental period.

Collection of Soil Samples

Three sampling plots (10 m X 10 m) were set up to collect soil samples from each of the stands. The 20 sample places were located in each sampling plot and cores were collected up to 15 cm in the upper soil using soil probe (1.9 cm in diameter). The soil cores were sampled each month from September 1987 to August 1988 and stored at a refrigerator (4°C) for less than 5 days. Those samples were diluted with 0.85% saline solution to determine the population of cellulose-hydrolyzing fungi and denitrifying bacteria, and also with phosphate buffer solution to determine the population of nitrifying bacteria. Sample solutions for determining inorganic nitrogen were stored at a refrigerator (4°C) after extraction by 2M KCl solution The other samples for analyzing major soil minerals were air-dried and filtered with an 0.5 mm sieve.

Nutrient Analysis of Soil

Soil pH (1: 2.5, soil/ distilled water) was measured with a pH/ion-meter (Ultralab 2500), and soluble salts(1: 5, soil/distilled water) with a conductivity meter (Jenway 4010) Ammonium N, nitrates and total nitrogen contents were determined by micro-Kjeldahl method. Available phosphorus was determined by Bray No 1 method, and the carbon contents by Walkley-Black method.

Moisture contents were measured gravimetrically after drying at 105°C for 72 hours The amount of soil respiration was determined by the method used for long-term measurement of CO_2 evolution rates(Page, 1982)

Determination of Soil Microorganism Population

The population of soil microorganisms was determined by dilution methods The concentrations of diluted sample solution were 10^{4}, 10^{5}, 10^{6}, 10^{7}, of 10g soil, respectively The population of cellulose-hydrolyzing fungi were counted with serial count method on top-agar plate after incubation for three weeks MPN (Most Probable Number) method (Halvorson and Ziegler, 1983) were used to determine the population of nitrifying and denitrifying bacteria. Nitrifying bacteria were divided into two groups: one was the bacterial taking part in the conversion mechanism of ammonium N to nitrites represented by Nitrosomonas,

Table 1. Geographical descriptions of experimental plots*

Species	Age (Year)	Aspect	Altitude (m)	Slope(°)	Soil texture
Quercus mongolica	30	N 40° E	200 – 250	25 – 35	loam
Pinus koraiensis	8	N 45° E	150 – 200	15 – 20	sandy loam
Pinus koraiensis	18	N 45° E	200 – 250	15 – 20	loam
Pinus koraiensis	28	N 50° E	100 – 150	10 – 15	loam

*All of the data were approximated

and another the bacteria participating the conversion mechanism of nitrites to nitrates represented by Nitrobacter. The population of nitrifying bacteria was observed bimonthly. Denitrifying bacteria were incubated on KNO media, and their population observed monthly by the MPN method (Page. 1982).

RESULTS AND DISCUSSION

Soil Physiochemical Conditions

Soil acidity was slightly higher in October, November and March than other months, and was the greatest in the 8-year-old *P. koraiensis* plantation(Figure 2).

The pH value was lower at oak stand than in *P. koraiensis* plantations. This result was opposite to the report of Brady (1974) that pine litter made pH value in the forest soil decreased. There were large fluctuations in pH value in the 8-year-old *P. koraiensis* plantation, of which results were similar to those reported by Lindberg and Popovic (1978, 1980) who found the pH fluctuations in some years after clearcutting.

The soil moisture contents were greater at oak stand than at other stands, whereas those were lower in 8-year-old ***Pinus koraiensis*** plantation than at other stands(Figure 3). Moisture content was influenced by precipitation and/ or the thawing of soils. Thus, it was high during thawing season (February and March) and rainy season (July). It was also influenced by the vegetation and litter layers which covered the soil surfaces, thus it was the greatest at the oak stands because of good vegetation and litter layers. Howeever, it was small in the 8-year-old ***P. koraiensis*** plantation where not only few litter layers but low-graded vegetation were covered under. Soil moisture content was positively correlated with soluble salts (r = 0.83), ammonium salts (r = 0.58) and total nitrogen contents.

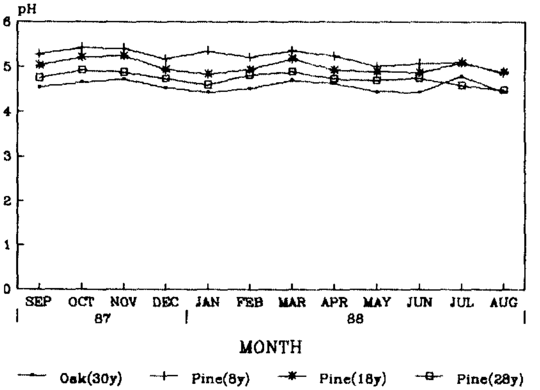

Fig. 2. Seasonal variation in pH value for each stand

The amount of soluble salts, and the concentration of available minerals to plants in soils, were the largest at oak stands and the smallest in the 8-year-old *P. koraiensis* plantations during the growing season. The amount of soluble salts were in the 28-year-old *P. koraiensis* plantations was in between oak stands and the 8-or 18-year-old *P. koraiensis* plantations(Figure 4). The amount of soluble salts was not significantly different among the months, but it was relatively large in winter. Soluble salts were positively correlated with moisture contents (r = 0.83) and total nitrogen contents (r = 0.66).

The amounts of total carbon were the largest at the oak stand, and followed by those in the 18-year-old *P. koraiensis* plantation, those in the 28-year-old *P. koraiensis* plantation and those in the 8-year-old *P. koraiensis* plantation indescending order (Figure 5).

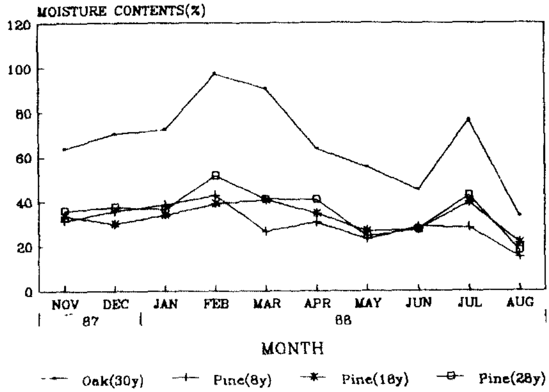

Fig. 3. Seasonal variation in moisture contents for each stand.

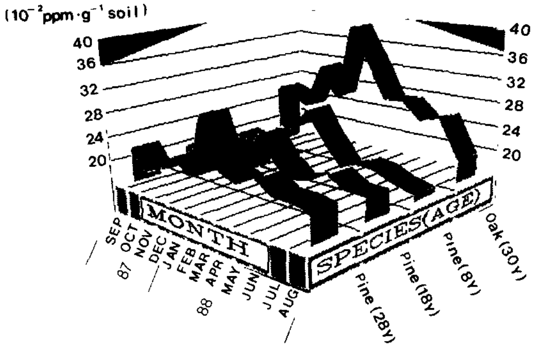

Fig. 4. Seasonal variation in soluble salts for each stand

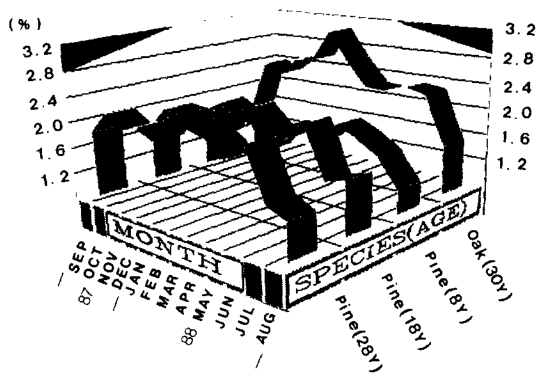

Fig. 5. Seasonal variation in total carbon contents for each stand

This phenomenon indicated that there were more organic matters at oak stands than in *P. koraiensis* plantations established less than 30 years. Total carbon content increased from late fall to winter, and decreased in spring. That is, organic matters were more accumulated from late fall to winter, and decreased in spring. Seasonal variation in soil organic matter showed slightly different patterns for each stand. Thus it could be thought that soil characters were determined by the species composition and their ages(Kim, 1965, Swift ***et al.***, 1978). Total carbon contents were correlated with total nitrogen contents (r = 0.25). It seemed that the accumulation of organic matter induced increase of nitrogen contents.

Total nitrogen content was greater at oak stands than at other stands, especially during the growing season

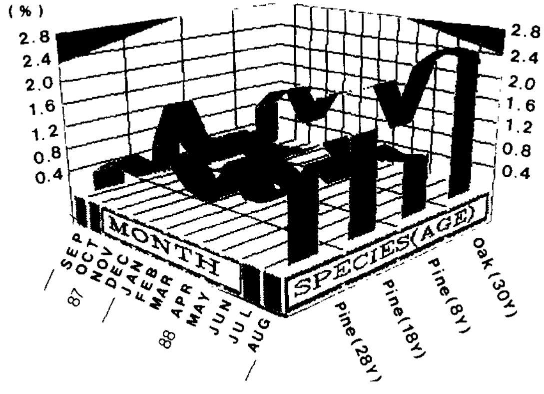

Fig. 6. Seasonal variation in total nitrogen contents for each stand

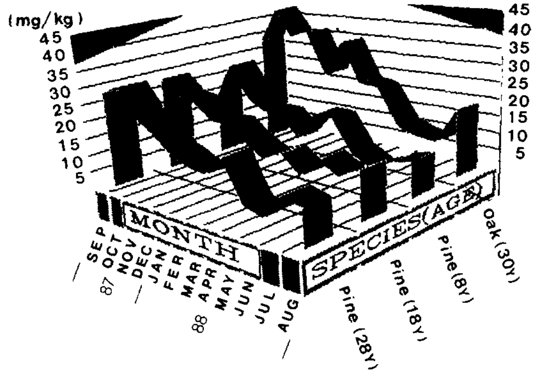

Fig. 7. Seasonal variation in ammonium salts for each stand

(Figure 6). Total nitrogen contents were positively correlated with soluble salts (r = 0.66) and ammonium salts (r = 0.34), but not with nitrates.

Ammonium salts were also greater at oak stands than at other stands shown in nitrogen contents, but a peak occurred in October (Figure 7). The amounts of ammonium salts were abundant from fall to winter and little in summer at each stand. Ammonium salt was positively correlated with nitrifying bacteria I and II (r = 0.38 and 0.36, respectively), but negatively correlated with denitrifying bacteria(r = -0.20). It could be thought that ammonium salts were dependent upon the bacteria involved in nitrogen mineralization.

Available phosphorus contents were not significantly different among the stands, but those were very small during the winter months (December and February). The variation of available phosphorus contents fluctuated differently for each stand

The C/ N-ratio was greater at pine plantations than at oak stand. The mean values of C/ N-ratio at the oak stand was 18.2, and 28.4 at pine plantations The C/ P-ratio was greater at oak stand than at other stands. The C/ P-ratio was positively correlated with moistuer contents (r = 0.46), ammonium salts (r = 0.39) and total nitrogen contents (r = 0.54). The mean value of C/ P-ratio at the oak stand was about 100, and that in *P. koraiensis* plantations was about 50.

Soil Microorganism Populations

Positive correlation (r = 0.54) was shown between the nitrifying bacteria I and II. The population of both nitrifying bacteria was large in November, of which results were coincided with those reported by Montes and Christensen (1979) Their variations were positively correlated with ammonium salts, but not with nitrates. However, negative correlations were found between nitrifying bacteria and C/ N-ratio That is, much carbon sources disturb the activity of nitrifying bacteria in limited nitrogen sources. There were no differences in the population of nitrifying bacteria among the stands

The population of denitrifying bacteria fluctuated with peaks, January and May or June(Figure 8). Higashida and Takao (1985; 1986) reported that the peak of fluctuation occurred in May and August, but in this study the peak was rather shown in January. The different results shown in this study from Higashida and Takai (1985; 1986)'s report seemed to be due to the differences in sampling season for the population of bacteria. The phases of fluctuation for each stand were similar, and they were negatively correlated with C/ N-and C/ P-ratios.

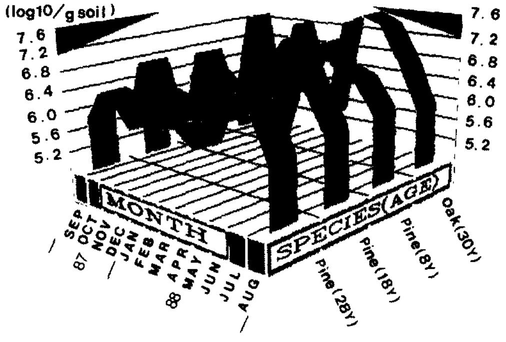

Fig. 8. Seasonal variation in the population of denitrifying bacteria for each stand

Cellulose hydrolyzing fungi were not significantly different at the 5% level among the stands, and fluctuated greatly with a peak in June. They were not correlated with soil respiration. This result was different from those reported by Kanazawa and Miyashita (1987), which was ascribed to some experimental error and/ or the deficiencies for soil respiration data. Soil respiration was greater at oak stands than at other stands. It is thought that there were many carbon sources in oak stands. That is, microbial respiration decreased after clearcut due to the loss in carbon sources But, soil respiration was not correlated with carbon and cellulose hydrolyzing fungi, which was different from the report by Kanazawa and Miyashita (1987). The data used were only those collected from July to September Thus, their seasonal variations were not able to be reported.

Silvicultural Practices and Nutrient Status

The factors which were significantly different at the 5% level among all the stands were total nitrogen, total carbon, available phosphorus, soluble salts, moisture contents, ammonium salts and soil pH.

Most of the nutrients were shown larger at oak stands. Total nitrogen and available phosphorus were shown smaller in the *P. koraiensis* plantation. This seemed that the total nitrogen content and available phosphorus decreased gradually after clearcutting, but were recovered after about 20 years. Moisture contents, the amounts of ammonium salts, total carbon and soluble salts were the smallest in 8-year-old *P. koraiensis* plantation That is, moisture contents, the amounts of ammonium salts and soluble salts were decreased by clearcutting, but the maturation of the stand improved gradually the status of nutrients

Nutrient flux in the 8-year-old *P. koraiensis* planta-

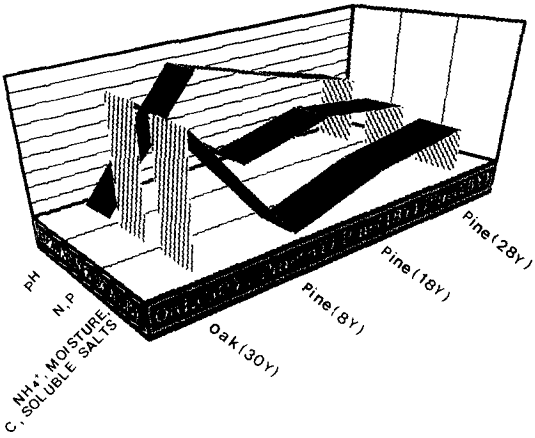

Fig. 9. The status of soil pH, ammoniuum salt, moisture, available phosphorous and soluble salt at each stand.

tion expressed as the *ratios of range* to mean was the greatest in the ammonium salts and followed by descending order. C/N-ratio nitrates, moisture contents, C/P-ratio and total carbon contents This result was the same as reported by Peterson and Hammer(1986)

Moisture content was positively correlated with denitrifying bacteria as reported by DeCatanzaro ***et al.***(1987), but negatively *correlated* with nitrifying bacteria and cellulose hydrolyzing fungi as reported by Ross(1987).

Microbial populations were not different among all the stands. In general, it might be said that the chemical conditions were different between oak stand and pine plantation Thus, there were differences in decomposition rate and the population *rate and soil microorganism* population as reported by Lane (1975)

Therefore, from the results described above, the establishment of ***P. koraiensis*** plantation following clearcut of *Q. mongolica* induced some changes in total nitrogen contents and carbon contents, but did not disturb seriously to the forest soils in this area.

要 約

本 硏究는 京畿道 廣州郡 都尺面 祥林里, 泰樺山에 所在한 서울大學校 農科大學 附屬 演習林에서, 30年生 신갈나무林과 신갈나무林을 皆伐한 後 植栽한 8年, 18年, 28年生 잣나무 林分을 對象으로, 森林土壤의 主要 養料 및 微生物의 季節的 變異 및 林分間의 變異를 알아보고자 遂行하였으며 그 硏究 結果는 다음과 같다.

土壤의 變異를 나타낸 因子는 全窒素 含量, 炭素 含量, 土壤酸度, 有效燐酸 含量, 溶解性 鹽基, 水分 含量 및 암모늄태 窒素 등이었다.

窒素 含量과 有效 燐酸 含量과 암모늄태 窒素 및 溶解性 鹽基, 炭素의 含量은 皆伐에 따라 그 含量이 줄게 되지만, 林分의 生長과 더불어 증가하게 된다.

炭素 및 窒素의 無機化에 관여하는 微生物 數는 皆伐에 의해 影響을 받지 않았다. 따라서, 신갈나무林의 皆伐후 造成된 잣나무林에서 炭素 및 窒素 含量이 變化를 일으켰지만, 실제로 森林土壤의 이화학적 성질에 미치는 影響은 매우 심각한 問題는 아니라고 判壇된다.

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Table 2. Soil respiration at each stand (unit: $mgCO_2\ m^{-2}\ h^{-1}$)

Species	July	August	September
Quercus mongolica (30-y)	104.53 (2.45)*	166.10 (12.27)	141.53 (23.44)
Pinus koraiensis (8-y)	188.47 (10.58)	172.33 (6.52)	143.37 (5.55)
Pinus koraiensis (18-y)	65.63 (10.65)	105.97 (5.76)	121.00 (11.64)
Pinus koraiensis (28-y)	92.03 (12.45)	106.33 (0.97)	102.30 (11.45)

*The data in the parenthesis indicate standard errors

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