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Relationships between Soil Factors and Growth of Annual Ring in *Pinus densiflora* on Stony Mountain

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바위산의 土壤要因과 소나무의 年輪生長 사이의 關係

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ABSTRACT

Relationships between soil factors and the growth of annual ring of *Pinus densiflora* grown on stony mountain were investigated at two sites of the different parent rocks: the one was formed by granite at Mt. Gwanag, Seoul and the other feldspar porphyry at Mt. Bipa, Daegu.

The growth of annual ring was influenced by the physical factors of soil, such as soil depth, field capacity and water content of soil, rather than by the chemical factors, such as total nitrogen, potassium and calcium of soil.

Of the soil factors affecting the growth of annual ring, soil depth, field capacity, water content of soil and organic matter closely interrelated with each other. All of these factors influenced water content of soil which might affect the water potential of *Pinus densiflora* leaves. In fact, the leaf water potential, affecting as the main factor for the growth of annual ring, of the pine grown in a deep soil was higher than that of the pine in a shallow soil.

INTRODUCTION

Forest area is more than 70% of the total territory in Korea. The area is almost occupied with mountainous district. Most of plants grown on the stony mountain may undergo drought due to shallow soil depth, coarse soil texture and high temperature on the rock surface (Kim *et al.*, 1977). Physical characters of soil closely relate with the growth of pine (Chandler *et al.*, 1943; Ralston, 1951; Coile, 1948; Row, 1960; Smally and Bower, 1971; Hebb and Burns, 1975). Drought of soils affects the water status of cell and restricts the plant growth (Coyne and Serrans, 1963; Hellebust, 1976; Skretkowicz and Thurtell, 1983; Handa *et al.*, 1983). The purpose of this study is to analyze relationships between the growth of annual ring of *Pinus densiflora* grown on the stony mountain and its soil factors, and to elucidate the main factor influencing the growth.

STUDY AREA

This study was carried out at sites of shallow soil with approximately 12 cm in depth where are underlain by an impermeable bedrock and not developed complete soil profile in both Mt. Gwanag, Seoul (37°27′ N, 126°57′ E) and Mt. Bipa, Daegu(35° 10′ N, 128。27′ E) (Fig. 1). Both study sites were dominated by *Pinus densiflora.*

Environmental conditions of study sites at Mt. Gwanag and Mt. Bipa were 28° and 31° in average slope, granite and feldspar porphyry in the parent rock, sand or sandy loam and sandy loam or clay loam in soil texture(Fig. 2), 2 and 37% in field capacity, 3 and 9% in organic matter content in the soil, 0.65 and 0.63 mg/g in total nitrogen (T-N), 98 and 107 ppm in potassium (K), 157 and 76 ppm in calcium (Ca), 4.4 and 4.5 in pH value, and 3 and 2 cm in average litter depth, respectively. Annual mean temperature at Mt. Gwanag with 11.9°C was lower than that at Mt. Bipa with 13.3°C, and annual mean precipitation of 1210 mm at Mt. Gwanag was more than that of 1015 mm at Mt. Bipa. However, in this study the difference of meteorological factors was neglected. Difference between temperatures on the projecting rock surface near the site and on the air was kept at approximately 10°C at Mt. Gwanag for afternoon(Fig. 3).

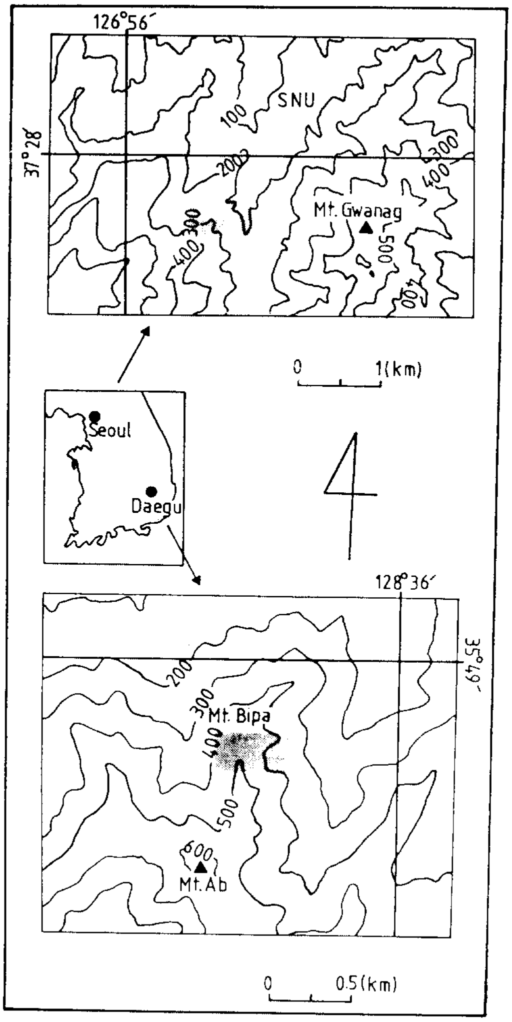

Fig. 1. Map showing study areas.

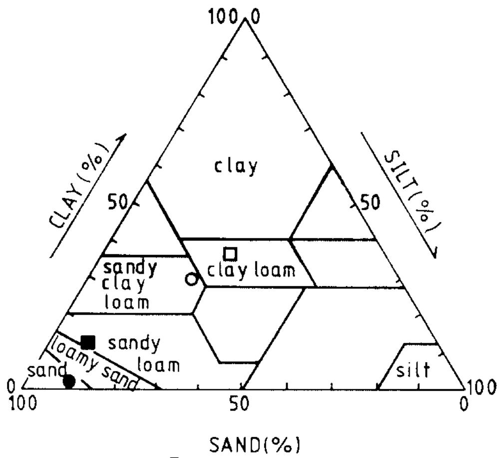

Fig. 2. Soil texture at study areas. Open circle, shallow soil on Mt. Bipa; closed circle, shallow soil on Mt. Gwanag; open square, deep soil on Mt. Bipa; closed square, deep soil on Mt, Gwanag.

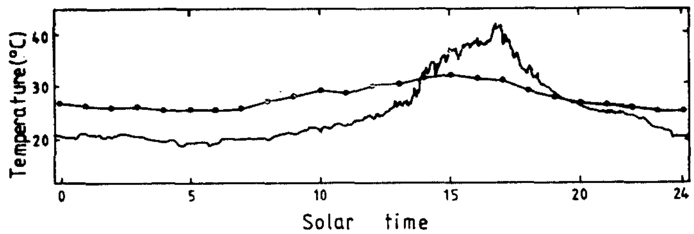

Fig. 3. Diurnal changes of air temperature(—•—) and rock surface temperature(——) measured at N-W aspect of Mt. Gwanag on August 16, 1984.

METHODS

To determine the growth in annual ring of ***Pinus densiflora*** the core at 30 cm high above ground was bored out with a increment borer and the width between the rings was measured from outmost ring to inner one with 0.1 mm precision by calipers. Tree height was measured with fishing pole. Water potential of ***Pinus densiflora*** leaves was measured by Shardakov method (Barrs, 1968). Samplings were made 48 and 69 samples at each study site of Mt. Gwanag and Mt. Bipa. Among the soil environmental factors soil depth, slope gradient and azimuth were measured with iron bar, clinometer and compass respectively, and soil texture was classified by method of Millar *et al.* (1965) after being sorted by Kühn apparatus, and field capacity and organic matter content were determined after Peters (1973) and Broadbent (1973), respectively, and T-N, K, Ca and pH after Jackson (1967). Relations between the growth of annual ring and soil factors were analysed by correlation. The relative importance of various soil factors to the growth of annual ring was evaluated by multiple regression.

RESULTS

Cumulative growths in annual ring of ***Pinus densiflora*** were directly proportional to its age in all cases (Fig. 4). The differences of the annual ring were more distinct between the soil depths than between the sites, that is, regression coefficients of the growth curves were within the range between 2.8 and 3.1 in the deep soils but between 1.2 and 1.3 in the shallow soils,

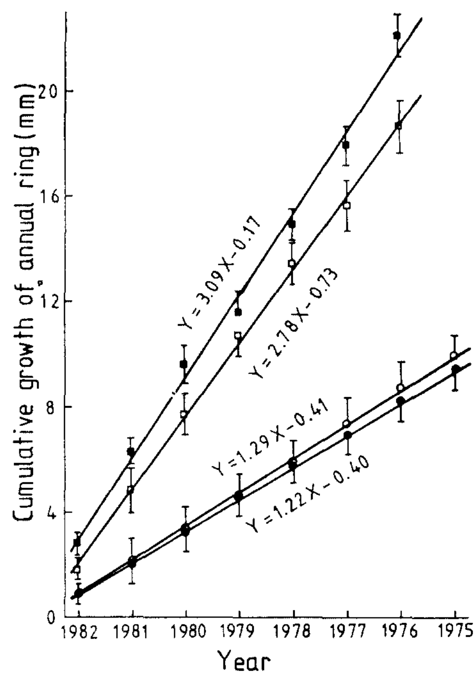

Fig. 4. Growth of annual ring. Open circle, shallow soil on Mt. Bipa; closed circle, shallow soil on Mt. Gwanag; open square, deep soil on Mt. Bipa; closed square, deep soil on Mt. Gwanag.

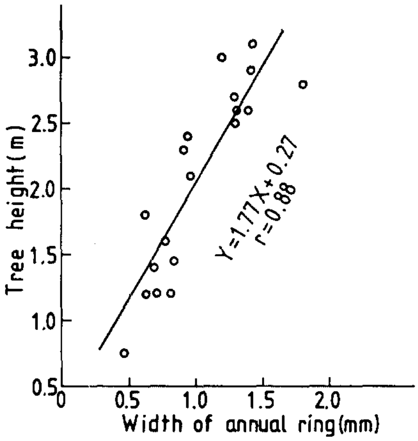

Fig. 5. Relationship between growth of annual ring and height of the same aged trees growing on N-W aspect of Mt. Gwanag.

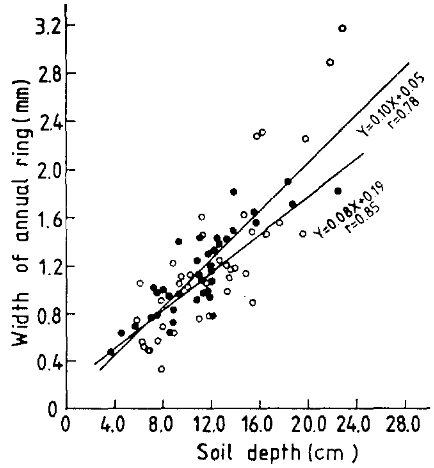

Fig. 6. Relationship between growth of annual ring and soil depth. Open circle, Mt. Bipa; closed circle, Mt. Gwanag.

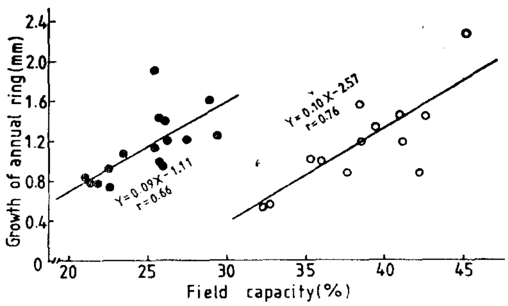

Fig. 7. Relationship between growth of annual ring and field capacity. Open circle, Mt. Bipa; closed circle, Mt. Gwanag.

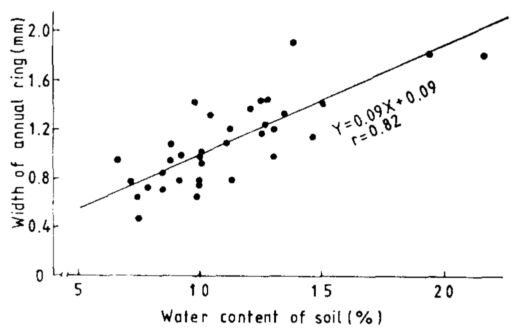

Fig. 8. Relationship between growth of annual ring and water content of soil measured on August 2, 1983 on Mt. Gwanag.

about 39 to 46% of that in the deep soils. In the study sites with the shallow soil, the growth in the annual ring of *Pinus densiflora* made correspond to the growth in tree height(Fig. 5).

The growth in the annual ring of *Pinus densiflora* substantially was proportional to the increase of soil depth with a few exception (Fig. 6). Increasing trend was greater at Mt. Bipa (regression coefficient, 0. 10) with sandy clay loam and clay loam than at Mt. Gwanag (0. 08) with sand and sandy loam, presumably owing to the difference of soil water content originated in the difference of field capacity between both sites.

In fact, the growth in annual ring of *Pinus densiflora* was increased as field capacity increased (Fig. 7). Field capacity of Mt. Gwanag, the range from 21 to 29%, completely differed from that at Mt. Bipa, the range from 32 to 45% (Fig. 7) because of the difference of soil textures originated in parent rocks (Fig. 2), that is, the former was about two thirds of the latter. However, the growths in annual ring in both sites were similar to each other.

Table 1. Correlation coefficients between annual ring and each soil environmental factors, and among soil environmental factors at Mt. Gwanag and Mt. Bipa

Factors	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}
Gwanag											
X_1=Annual ring (mm)		0.85**	0.66**	0.82*	−0.22	0.10	0.33*	0.18	0.03	−0.16	−0.03
X_2=Soil depth (cm)			0.51*	0.47**	−0.38*	0.16	0.02	0.25	0.09	−0.25	−0.12
X_3=Field capacity (%)				0.63**	0.07	−0.28	0.64**	0.07	0.08	−0.27	−0.04
X_4=Soil water content (%)					−0.01	0.10	0.41**	0.08	−0.14	−0.05	−0.14
X_5=Slope gradient (degree)						−0.10	0.09	−0.28	0.02	0.18	0.23
X_6=Litter layer (cm)							0.12	−0.14	−0.14	−0.17	0.20
X_7=Organic matter (%)								0.01	−0.02	0.12	0.32*
X_8=pH									0.14	−0.05	−0.14
X_9=Total nitrogen (mg/g)										0.06	−0.29
X_{10}=Potassium (ppm)											0.50**
Bipa											
X_1=Annual ring (mm)		0.78**	0.76**	0.78**	0.05	−0.20	0.29	−0.09	0.22	0.05	0.18
X_2=Soil depth (cm)			0.56**	0.82**	−0.01	−0.16	0.13	−0.19	0.08	−0.23	−0.18
X_3=Field capacity (%)				0.73**	0.36	−0.39	0.55*	−0.35	0.12	0.14	−0.42
X_4=Soil water content (%)					−0.16	−0.03	0.29	−0.04	0.35	−0.36	0.18
X_5=Slope gradient (degree)						−0.04	−0.03	−0.20	0.03	0.01	−0.25
X_6=Litter layer (cm)							0.07	0.13	0.05	0.04	0.24
X_7=Organic matter (%)								−0.07	0.09	0.28	−0.09
X_8=pH									0.15	−0.07	0.50**
X_9=Total nitrogen (mg/g)										0.07	−0.03
X_{10}=Potassium (ppm)											0.19
X_{11}=Calcium (ppm)											

* significant at 5% level ** significant at 1% level

From this result, it was known that the difference of growth between two sites was also affected by other factors than the field capacity of the soil.

The growth in the annual ring was increased directly proportional to the increase of the soil water content (Fig. 8 and 9). Although the soil water content changes day by day *in situ* after rainfall (Fig. 9) because of shallow soil depth, what the water content is maintained for the long period of times might promote the growth of annual ring. Zahner and Donnelly (1967) pointed out that the growth of annual ring of pine trees was closely related to the soil water content. Presumably, the soil water content has significant relation with the soil depth, particularly in the shallow soil (Table 1). Therefore sudden fluctuation of the soil water content was not due to the field capacity but due to the soil depth and high surface temperature on the rock (Fig. 3).

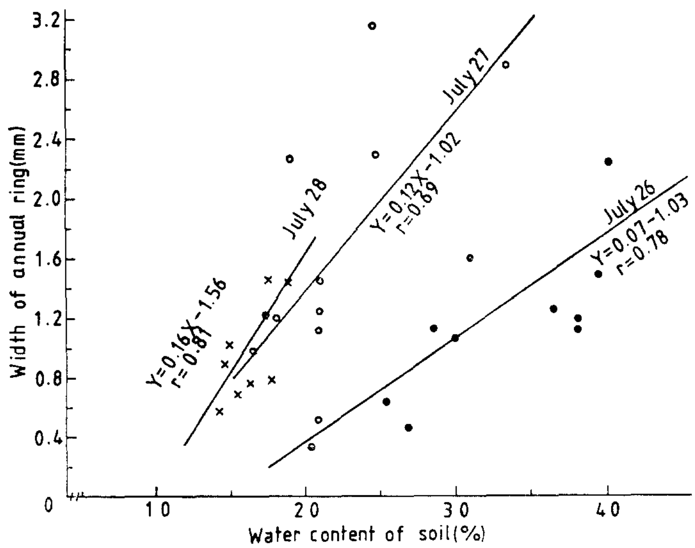

Fig. 9. Relationship between growth of annual ring and water content of soil on shallow soil within 12 cm in depth of Mt. Bipa.

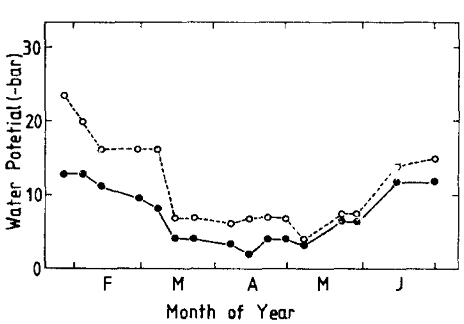

Fig. 10. Seasonal changes of water potential of *Pinus densiflora* leaf. Open circle, leaf grown in a shallow soil; closed circle, leaf grown in a deep soil.

Water potentials of *Pinus densiflora* leaves, a measure of water status of plant related with the growth, were determined for 6 months from January through June, 1983 (Fig. 10). The water potential of the leaves in the shallow soil was lower than that in the deep soil, particularly the difference between them was great during the winter and drought seasons. Such low water potential might inhibit the ring growth (Suh and Kim, 1981). In these sites of shallow soil, reduced growth of *Pinus densiflora* might be due to chronic experience in the low water potential.

DISCUSSION

Correlation coefficients were calculated between foregoing data on the growth in the annual ring and corresponding soil factors (Table 1). In both sites of Mt. Gwanag and Mt. Bipa, high positive correlations were between the growth and the soil depth (Fig. 6), and the soil water content (Fig. 8) and the field capacity (Fig. 7) and the soil organic matter (Table 1), but no data significant between the growth and soil nutrients, such as K and Ca content, or slope gradient, litter layer in certain case. From these results it can be seen that four positive factors related with water above mentioned contribute to grow plants, but nutrients do not.

To elucidate the important factors affecting on the four positive ones,correlation coefficients were obtained among all the soil factors in question(Table 1). The soil depth was closely related to the soil water content and to the field capacity with high significant. The soil water content was directly influenced by the amount of organic matter in the soil at Mt. Gwanag but not at Mt. Bipa. This reason is that because the soil of Mt. Gwanag is composed of sand or sandy loam with poor organic matter (3%) in contrast with that of Mt. Bipa of sandy clay loam to clay loam with rich organic matter (9%), the soil water content of the latter primarily depends on soil texture rather than organic matter. The field capacity was closely related to the amount of organic matter and also to the soil water content. Therefore, it is possible to explain that the field capacity as well as the water content increase necessarily if much organic matter, such as humus is mixed with the soil (Thompson and Troeh, 1982).

Multiple regression analysis was used to assess the relative importance of these soil environmental factors as they influence the growth of annual ring (Table 2). Partial regression coefficients in Mt. Gwanag were high in the order of soil water content, field capacity and soil depth and those of Mt. Bipa were the order of soil depth, field capacity and soil water content. Determination coefficients of multiple regression equations were significant in 1% level, as 0.74 and 0.79. From these results we found that 74 to 79% of the growth in annual ring was explained by above three positive factors, among these factors soil water

Table 2. Partial correlation coefficients and regression equation deduced from multiple regression analysis. *GA*; growth of annual ring, *SD*; soil depth, *FC*; field capacity, *WC*; water content of soil, R^2; coefficient of determination, p; probability

Sites	Soil depth	Field capacity	Water oontent of soil
Mt. Gwanag	0.1419	0.1965	0.6212**
	($GA=-0.4028+0.0090SD+0.0271FC+0.0641WC$, $R^2=0.7389$, $p>0.01$)		
Mt. Bipa	0.7738**	0.1396	0.0332
	($GA=-1.6840+0.1263SD+0.0282FC+0.0072WC$, $R^2=0.7868$, $p>0.01$)		

** significant at 1% level

content at Mt. Gwanag and soil depth at Mt. Bipa was the most important factor in the growth.

The positive interactions on the growth in annual ring and the soil factors were summarized on compartment model(Fig. 11). Parent material is resulted from rock and then soil is derived from weathering of the parent material. Soil texture is different according to the kind of rock and the degree of weathering, the longer period of weathering is, the finer particles are. Fine particles of soil increase the field capacity along with organic matter content of soil, and high field capacity makes the water content of soil kept for the longer time. And if the weathering is proceeded for a long times soil depth is also deepen and deep soil depth contribute to keep the water content of soil for the long time. On the other hand, in case of such stony mountain as this study site high temperature on the rock surface and increased evapotranspiration originated in the temperature promote the loss of soil water. Soil water content determined by various factors in this way directly influence the water potential of plant (Parker *et al*, 1982) and in the result it controls the growth of annual ring.

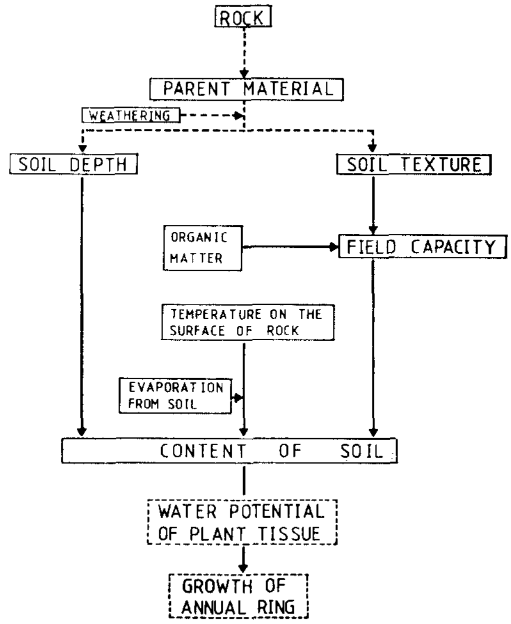

Fig. 11. Compartment model showing relationships among environmental factors and the growth of annual ring. Solid line (—), actual measure; dotted line(…), presumed measure.

摘 要

바위산에서 자라는 소나무의 연륜생장과 토양요인 사이의 관계를 연구하기 위하여, 모암이 다른 두 장소를 선정하여 토심의 깊이에 따른 토양의 물리화학적 성질과 연륜생장을 측정하였다.

토양요인과 연륜생장 사이 및 각 토양요인 사이의 상관을 분석한 결과, 연륜생장은 토양의 총질소, 칼륨 및 칼슘 등의 화학적 요인보다 토심, 포장용수량 및 토양수분함량 등의 물리적 요인과 관계되었다. 토심, 포장용수량, 토양수분함량 및 유기물함량은 상호 관계하여 소나무 잎의 수분포텐셜을 높이는데, 토심이 깊은 곳에서 자란 소나무 잎은 얕은 곳에서 자란 것보다 수분포텐셜이 높아서 연륜생장이 촉진되었다고 생각된다.

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