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Studies on Biomass for Young *Abies koreana* Wilson

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Abstract : This study was undertaken to compare the biomass of *Abies koreana* growing at two sites. A 10×10m plot was established in each site of a natural stand in Mt. Jiri and a plantation in Gyeongsan nursery. Five trees of *A. koreana* were randomly selected in each site. The following traits were investigated from each tree : height, basal diameter, age, weight of stem, branches, and needles as above-ground traits and weight of total roots, horizontal roots, and vertical roots as below-ground traits. In Gyeongsan nursery, age of sample trees was negatively correlated with both height and weight of total stem, while height was highly correlated with weight of horizontal roots. There was high correlation between the basal diameter and weight of total stem, and between the basal diameter and weight of roots. In Mt. Jiri stand, most of the above-ground traits except age were significantly correlated with the below-ground traits. The linear regression equation between the cross section area of base (X) and the weight of total stem (Y) in Gyeongsan nursery was Y=12.66X-12.92, and correlation was significant (R^2=0.89). The linear regression equation between the cross section area of base(X) and the weight of total branches (Y) in Mt. Jiri stand was Y=25.51X+6.00, and correlation was highly significant (R^2=1.0).

Key words **:** *biomass, natural stand, plantation,* Abies koreana

Introduction

About 40 *Abies* species have distributed mainly in the cold and sub-cold zones of Russia, North America, China, Japan and Korea (Lee, 1970). *Abies koreana*, a native species in Korea, was designated as a new species by Nakai and Wilson in 1915. *A. koreana* naturally grows in Mt. Halla, Mt. Mudeong, Mt. Baekun, Mt. Gaya, Mt. Deokyou, and Mt. Jiri in Korea, at the elevation of 500~2,000 meters (Lee and Hong, 1995).

A. koreana is not only an indigenous species but also rare species in Korea. Since its habitat is limited on sub-alpine, the population of *A. koreana* is so small for genetic transformation that evolution is impossible. It is easily damaged but hardly restored. These make *A. koreana* to be the most endangered species in Korea (Kim *et al.*, 1997). With these reasons many people are interested in studying on a declination of *A. koreana.* It has been reported that the mortality of *A. koreana* is increased compared with other high-elevation species. The number of *A. koreana* is decreasing because the density of dominance. *A. koreana* in the middle and lower classes is dramatically decreased compared to that of the upper class (Gu *et al.,* 2001). The declination of *A. koreana* may also be caused by global warming (Kim, 1994) or by typhoon and spring drought (Gu *et al.*, 2001).

In order to find reasonable solution for the problems, studies on accurate determination and estimation of biomass productivity of *A. koreana* in present should be preceded. In addition, precise monitoring about changes of ecosystem through short or long term will be necessary.

Estimation of above- and below-ground biomass of trees are required in different areas of climate changes, forest management, forest growth models and forest ecosystem studies (Bartelink, 2000; Drexhage and Colin, 2001; Drexhage and Gruber, 1999; Gruber, 1992; Gruber and Lee, 2005a, b; Kurz *et al.*, 1996; Lacointe, 2000; Laiho and Finer, 1996; Lebaube *et al.*, 2000; Lee, 2001, 2004; Lee and Hwang, 2000; Sanantonio, 1990; Son *et al.*, 2001). The growth of trees between above- and below-ground parts is very closely related and maintained by balancing (Lacointe, 2000; Sanantonio, 1990; Shinozaki *et al.*, 1964).

This study was undertaken to compare the biomass production of young *A. koreana* growing in natural forest and artificial plantation.

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Materials and Methods

1. Study site

To investigate the difference in biomass production and growth of *A. koreana* associated with different environments, Mt. Jiri and Gyeongsan nursery were selected (Figure 1).

A. koreana in Mt. Jiri grows naturally, but that in Gyeongsan city was planted artificially in a nursery. Site information is given in Table 1.

A. koreana was planted by 1.5m×1.5m in Gyeongsan nursery with the planting density of 4,096 trees/ha. *A. koreana* in the experimental site of Mt. Jiri was a dominant species and other species such as *Quercus mongolica* Fisch., *Fraxinus chiisanensis* Nakai. and *Pinus koraiensis* Sieb. et Zucc. were also distributed in the site. The density of *A. koreana* in the site of Mt. Jiri was 1,172 trees/ha (Park *et al.*, 2006).

2. Data collection and analyses

At the Mt. Jiri stand, a 10m×10m investigation plot was established. Five trees of *A. koreana* were selected randomly in October (Mt. Jiri) and November (Gyeongsan), 2005 when the tree growth was stopped, considering environmental or physiological seasonal effects on the trees. Ten traits were evaluated from each sample (Table 2). Height, diameter, and age were measured for above ground traits. In addition, branches and needles of *A. koreana* were separated from the main stem and weighed.

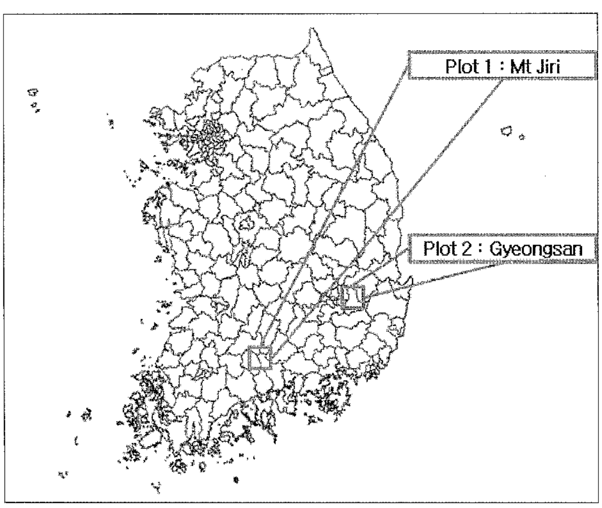

Figure 1. Location of *Abies koreana* studied sites in Korea.

Table 2. Abbreviations of evaluated traits.

AGE	Tree age
H	Height
BD	Basal diameter
CAB	Cross section area of base
WTS	Weight of total stem
WTB	Weight of total branches
WTN	Weight of total needles
WHR	Weight of horizontal roots
WVR	Weight of vertical roots
WTR	Weight of total roots

For below-ground biomass, horizontal and vertical roots were separated and the weight of the horizontal and vertical roots and total root weight were measured. To measure dry weight, stem, branch, needle, and roots of each tree samples were dried at room temperature followed by oven-dried at 95°C for 24 hours. Data on above- and below-ground biomass were analyzed by correlation procedure using the SAS-PROC GLM (general linear model) statistical program (SAS Version 8.2). A linear regression equation was estimated using basal diameter, cross section area of base, height, and age as X explanatory independent variables and weight of total stem, branches, needles, and roots as Y dependent variables.

Results

1. General characteristics

The average age of *A. koreana* in Mt. Jiri stand (24.4 years old) was older than that of Gyeongsan (11.4 years old) (Table 3). Trees in Gyeongsan nursery were even-aged due to artificial planting, but the age of trees in Mt. Jiri was ranged 14 to 32 years. Mt. Jiri (1.17m) showed longer than Gyeongsan (0.71m) in mean height. However, the height growth of Gyeongsan was superior since the trees are two times younger than those of Mt. Jiri. Basal diameter was not different between Gyeongsan (2.7 cm) and Jiri (2.9 cm). The basal diameter of *A.*

Table 1. Description of experimental sites.

Site	Latitude	Longitude	Elevation (m)	Annu. mean temp. (°C)	Annu. mean humidity (%)	Annu. precipitationl (mm)	Soil acidity (pH)	Soil hardness (kg/cm^2)	Soil humidity (%)	No./ha
Mt. Jiri	N35° 18'00.2"	E127° 33'43.4"	1,324	13.7	64.9	85.8	6.7	2.3	39.0	1,172
Gyeongsan	N35° 49'65"	128° 45'40"	104	12.2	74.0	109.7	4.9	1.8	9.4	4,096

Table 3. Data of investigated variables including total (above-ground, below-ground) biomass for 8- to 32-year-old *Abies koreana* in the studied sites.

Stands	Sample tree No.	AGE (year)	H (m)	BD (cm)	CAB (cm^2)	WTS (g)	WTB (g)	WTN (g)	WHR (g)	WVR (g)	WTR (g)
Gyeongsan	1	10	0.70	2.3	4.15	46.2	29.8	37.4	27.9	26.0	53.9
	2	13	0.68	2.8	6.15	67.0	39.0	74.1	23.0	55.0	78.0
	3	13	0.51	2.9	6.60	60.4	54.1	97.0	25.1	65.0	90.1
	4	13	0.79	3.0	7.07	70.2	69.8	161.0	60.4	92.0	152.4
	5	8	0.88	3.4	9.07	110.0	58.0	117.0	61.9	84.0	145.9
	mean	11.4	0.71	2.9	6.61	70.8	50.1	97.3	39.7	64.4	104.1
	S.D.	±2.3	±0.1	±0.3	±1.7	±23.8	±15.8	±46.1	±19.7	±26.0	±43.2
Mt.Jiri	1	14	0.45	1.0	0.79	11.8	24.1	40.9	7.0	7.3	14.3
	2	23	0.70	2.0	3.14	37.8	86.0	95.1	21.9	21.4	43.3
	3	28	1.22	3.0	7.07	173.5	186.6	118.1	100.7	93.9	194.6
	4	32	1.38	3.5	9.62	442.7	258.8	238.1	158.2	78.8	237.0
	5	25	2.10	4.0	12.56	688.7	320.7	311.9	259.5	177.7	437.2
	mean	24.4	1.17	2.7	6.63	270.9	175.2	160.8	109.5	75.8	185.3
	S.D.	±6.7	±0.6	±1.2	±4.8	± 289.4	± 121.5	±111.0	±103.8	±67.8	±170.0

AGE: Tree age, H: Height, BD: Basal diameter, CAB: Cross section area of base, WTS: Weight of total stem, WTB: Weight of total branches, WTN: Weight of total needles, WHR: Weight of horizontal roots, WVR: Weight of vertical roots, WTR: Weight of total roots.

koreana in Mt. Jiri was more variant than that of Gyeongsan. There was a great difference in mean dry weight of total stem between Gyeongsan and Mt. Jiri sites, 70.8 g and 270.9 g, respectively. The difference may be caused by the density of wood structure resulted from slow growth of the trees in Mt. Jiri. Mean weight of total branches and needles from Gyeongsan site were 50.1 g and 97.3 g, respectively, and those from Mt. Jiri were 175.2 g and 160.8 g, respectively. In Gyeongsan nursery, mean weight of vertical roots (64.4 g) was higher than that of horizontal roots (39.7 g) indicating that vertical roots were developed more than horizontal roots. The more development of vertical roots and height of the trees in Gyeongsan nursery may be caused by a competition among densely planted trees.

However, mean weight of horizontal roots (109.5 g) in Mt. Jiri was higher than that of vertical roots (75.8 g) in which the horizontal roots were more developed because of an abundant fertile surface soil and inclination. Naturally regenerated trees in Mt. Jiri stand provides an excellent growth environment for horizontal roots and branches. In contrast, vertical growth was poor because of light reduction by shading of upper leaf layers.

2. Correlation among investigated traits in Gyeongsan nursery

Correlation coefficient of investigated traits (Table 2) including above- and below-ground biomass of Gyeong-

Table 4. Correlation coefficients among investigated variables including above- and below-ground biomass for 8- to 13-year-old *Abies koreana* in the Gyeongsan plantation.

	AGE	H	BD	CAB	WTS	WTB	WTN	WHR	WVR	WTR
Above-ground biomass										
Age(AGE)										
Height(H)	-0.63*									
Basal diameter(BD)	-0.24	0.47								
Cross section area of base(CAB)	-0.30	0.50	0.99**							
Weight of total stem(WTS)	0.56	0.69*	0.92**	0.94**						
Weight of total branches(WTB)	0.15	0.30	0.77*	0.74*	0.53					
Weight of total needle(WTN)	0.19	0.38	0.74*	0.72*	0.52	0.98**				
Below-ground biomass										
Weight of horizontal roots(WHR)	-0.12	0.83**	0.70*	0.72*	0.73*	0.76*	0.78*			
Weight of vertical roots(WVR)	0.07	0.42	0.89**	0.87**	0.70*	0.96**	0.97**	0.78*		
Weight of total roots(WTR)	-0.15	0.63*	0.85**	0.85**	0.75*	0.93**	0.94**	0.93**	0.96**	

*P≤0.1; **P≤0.05

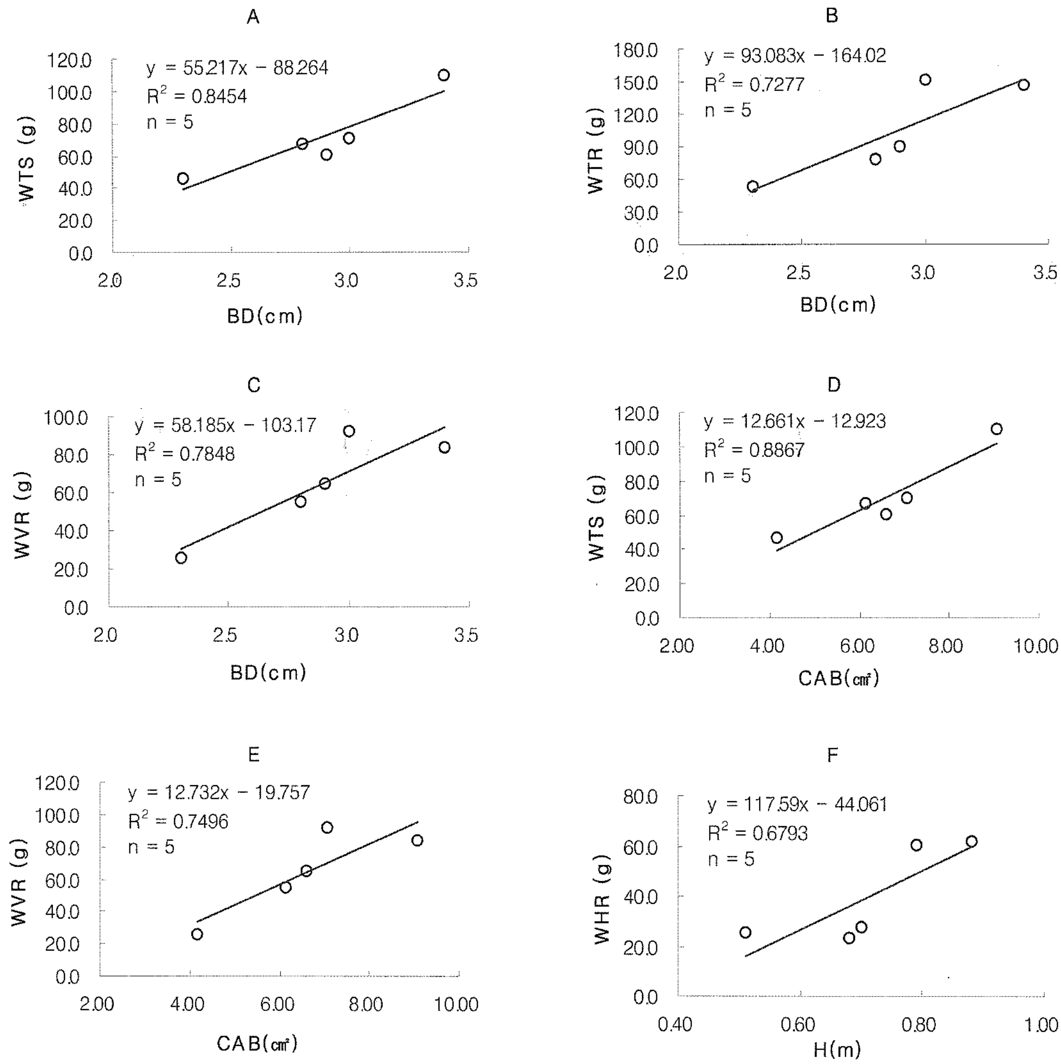

Figure 2. Relationships between investigated variables including above- and below-ground biomass for 8- to 13-year-old *Abies koreana* in the Gyeongsan plantation. BD: basal diameter, WTS: weight of total stem, WTR: weight of total roots, WVR: weight of vertical roots, CAB: cross section area of base, H: height, WHR: weight of horizontal roots.

san nursery was shown in Table 4. Age of trees was negatively correlated with height (r= -0.63). Correlation coefficient between height and other traits was relatively low, but positive correlation was shown between height and weight of total stem (r=0.69) and between height and weight of horizontal roots (r=0.83). Basal diameter was highly correlated with most of the traits except age and height. The weight of total stem was highly correlated with the basal diameter (r=0.92) and the cross section area of base (r=0.94). There was high correlation between the weight of total branches and the weight of total needle (r=0.98). These traits were also correlated with most of the below-ground biomass traits.

A linear relationships between independent variables (H, DBE, and CAB) and dependent variables (WTS, WVR, WHR, and WTR) of *A. koreana* in Gyeongsan nursery were shown in Figure 2. The linear regression equation for DBE and WES was

Y = 55.22X-88.26, and correlation between the two variables was very high (R^2=0.85). The linear regression equation for BD and WTR was Y = 93.08X-164.02 and that of BD and WVR was Y = 58.19X-103.17. Coefficient of determination was 0.73 and 0.78, respectively. Correlation between CAB and WTS was significant (R^2=0.89) and regression equation was Y = 12.66X-12.92. The linear regression equation for CAB and WVR was Y = 12.73X-19.76, and the determination coefficient was 0.75. The regression equation for H and WHR was Y = 117.59X-44.06, and the determination coefficient was 0.68. Generally, height and age have positive relationship, but the low correlation between the two variables in Gyeongsan nursery may be caused by the same age of the trees planted artificially.

3. Correlation among investigated traits in Mt. Jiri stand

Correlation coefficient of investigated traits (Table 2) including above- and below-ground biomass of Mt. Jiri

Table 5. Correlation coefficients among investigated variables including above- and below-ground biomass for 14- to 32-year-old *Abies koreana* in the Mt. Jiri stand.

	AGE	H	BD	CABE	WTS	WTB	WTN	WHR	WVR	WTR
Above-ground biomass										
Age(AGE)										
Height(H)	0.61*									
Basal diameter(BD)	0.82**	0.95**								
Cross section area of base(CAB)	0.73*	0.98**	0.99**							
Weight of total stem(WTS)	0.54	0.96**	0.90**	0.96**						
Weight of total branches(WTB)	0.75*	0.97**	0.99**	0.99**	0.95**					
Weight of total needle(WTN)	0.62*	0.95**	0.93**	0.96**	0.99**	0.96**				
Below-ground biomass										
Weight of horizontal roots(WHR)	0.58	0.99**	0.93**	0.98**	0.99**	0.97**	0.97**			
Weight of vertical roots(WVR)	0.51	0.98**	0.90**	0.94**	0.91**	0.93**	0.89**	0.96**		
Weight of total roots(WTR)	0.56	0.99**	0.93**	0.97**	0.97**	0.96**	0.95**	0.99**	0.99**	

*P≤0.1; **P≤0.05

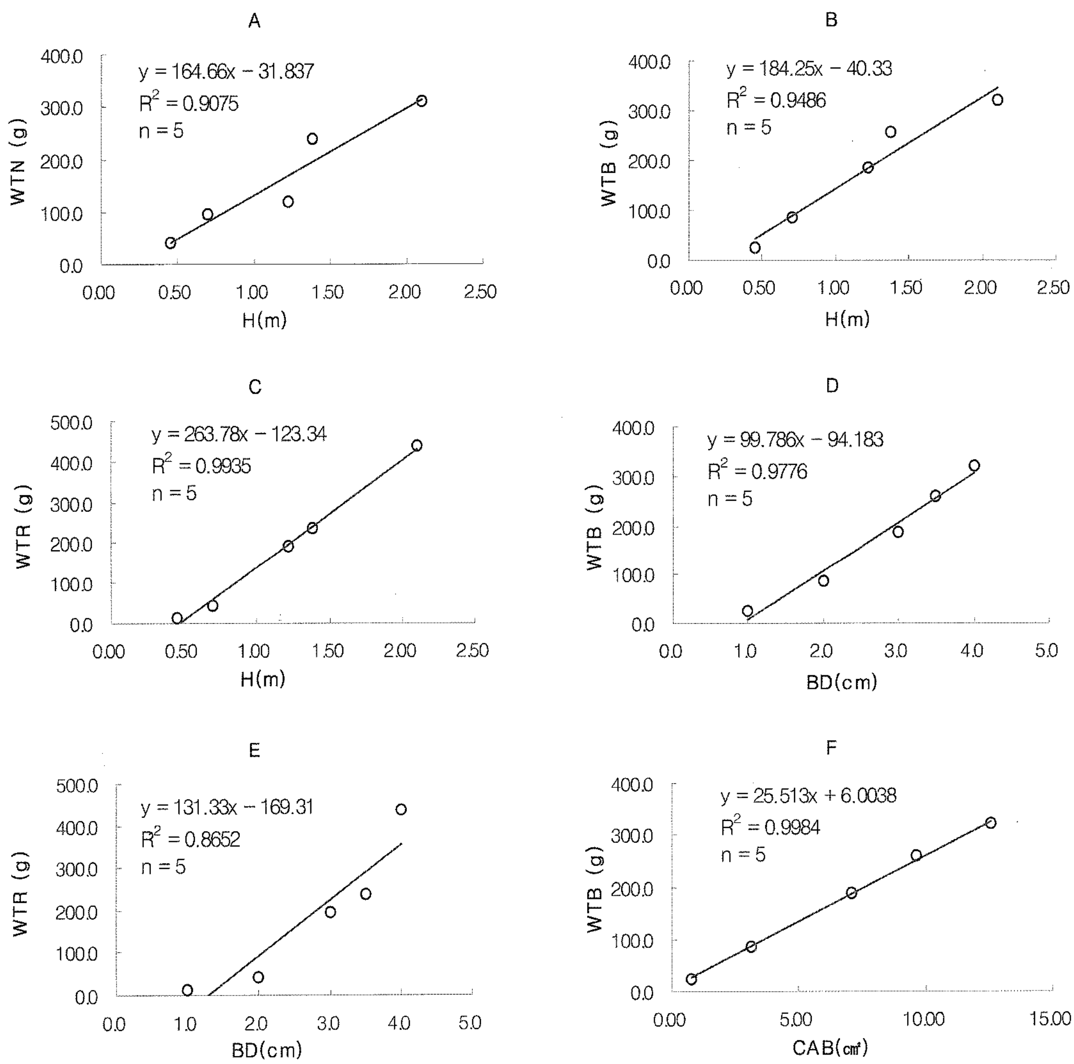

Figure 3. Relationships between investigated variables including above- and below-ground biomass for 14- to 32-year-old *Abies koreana* in the Mt. Jiri stand. H: height, WTN: weight of total needle, WTB: weight of total branches, WTR: weight of total roots, BD: basal diameter, CAB: cross section area of base.

stand was shown in Table 5. Age of trees was significantly correlated with BD (r=0.82) at 5% level, and also correlated with H (r=0.61), CAB (r=0.73), WTB (r=0.75) and WTN (r=0.62) at 10% level. Height was significantly correlated with all of the investigated traits except age at 5% level. BD and CAB were highly correlated with most of the traits. Above-ground biomass, WTS, WTB, and WTN, was significantly correlated with most of the above-ground and below-ground traits.

A linear relationships between independent variable (H, BD, and CAB) and dependent variable (WTB, WTN, and WTR) of *A. koreana* in Mt. Jiri were shown in Figure 3. The linear regression equation for H and WTN was Y = 164.66X-31.84, and the two traits were highly correlated (R^2=0.91). Correlation between H and WTB was also significant (R^2=0.95), and the linear regression equation was Y = 184.25X-40.33.

The linear regression equation for H and WTR was Y = 263.78X-123.34 (R^2=0.99), and Y = 99.79X-94.18 (R^2=0.98) for BD and WTB. Correlation between BD and WTR was relatively high (R^2=0.87), and regression equation was Y = 131.33X-169.31.

Correlation between CAB and WTB was very significant (R^2= 0.99) and regression equation was Y= 25.51X + 6.00. As height and age of trees were increased, above- and below-ground biomass was also increased in Mt. Jiri.

Discussion

A relatively-estimated-equation using statistical methods can be applied easily in the field. Diameter at breast height (DBH) and height (H) can be used for estimating above- and below-ground biomass indirectly (Lee, 1996; Santantonio, 1990). The linear regression equations obtained this research may play an important role in estimating the biomass of mature trees by proving the correlation between above-ground and below-ground traits of young trees. Researches on the estimated-equation of relative growth applied with nonlinear regression curve representing the relationship between DBH and root biomass have been reported in various species (Canadell and Roda, 1991; Gruber, 1992; Kapeluck and Van Lear, 1995; Kuiper and Coutts, 1992; Pellinen, 1986; Santantoio *et al.*, 1997; Thies and Cunningham, 1996; Watson and O'loughlin, 1990).

Typically, height and diameter at breast height was closely related with below-ground biomass as well as above-ground biomass such as needle and branch biomass (Drexhage and Gruber, 1992; Lee, 2004; Gruber and Lee, 2005a; Shinazaki *et al.*, 1964). In Gyeongsan nursery, age of trees was not significantly correlated with most of the investigated traits. This insignificant correlation might be caused by severe competition on close planting and artificially planted trees with similar age of tree. Therefore, vertical growth like height and vertical root growth was caused due to these competitions. In contrast, Mt. Jiri showed highly significant correlation between age and above- and below-ground biomass. The reason seems likely that trees were naturally regenerated and had relatively less crown competition. In addition, *A. koreana* is a shade tolerant tree in young age, but it becomes a shade intolerant tree after maturation (Korea forest research institute, 1987).

The variation of correlation between below- and above-ground biomass depends on soil humidity, fertilizer and competition status (Lee, 2004). Naturally regenerated *A. koreana* of Mt. Jiri grows at the lower layer of mature trees resulting in superior growth of horizontal roots and branches, and retarded growth considering their age (Table 3). In this study, total biomass production of naturally regenerated stand is higher than that of artificially planted trees. However, high biomass production from Mt. Jiri may also be caused by mean age which is two times older than trees in Gyeongsan nursery.

Conclusion

In this study, we confirmed that there was significant difference in growth performance and biomass productivity of young *A. koreana* less than 5 cm in diameter growing in two different environments. Also, regression equations from the comparison between above- and below-ground biomass according to height and diameter of *A. koreana* will be useful for estimating the patterns of growth and biomass productivity of mature *A. koreana*.

Studies on adaptability and biomass production of *A. koreana* against changing environment is necessary to manage forests effectively. In order to monitor any changes in ecosystem correctly through short and long term period and to find a reasonable solution for the changes, more researches on estimating and evaluating current status biomass productivity of *A. koreana* should be conducted.

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