韓國林學會誌 65:54-59. 1984
Jour. Korean For. Soc. 65:54-59. 1984

Stand Structure, Volume, and Biomass Production of 9-year-old *Alnus hirsuta* var. *sibirica* grown in Minirotation[1]

Jeong Soo Oh[2] · Jong Won Kim[2] · Yong Ho Jeong[2] ·
Min Yung Oh[2] · Sung Kul Park[2] · Suk Kwon Kim[2]

물갬나무 9年生의 林分構造와 材積 및 Biomass 生産에 關한 研究[1]

呉正洙[2] · 金鍾元[2] · 程龍鎬[2] · 呉敏榮[2] · 朴勝杰[2] · 金錫權[2]

ABSTRACT

Research was conducted in a minirotation plantation with four different planting densities at Tatae-ri, Chongwoon-myon, Yangpyong-gun, Kyonggi-do, to investigate the relation between volume and biomass production. Nine-year-old *Alnus hirsuta* var. *sibirica* analyzed to determine volume yield and weight equations for aboveground parts. The results suggest that the most suitable harvesting or thinning period at highly dense plots, more than 6,000 trees per hectare, is five years after planting, and the most fitted regression equation model for estimating aboveground biomass or total tree biomass is $\log Y = b_0 + b_1 \log d^2 h$.

Key words: Alnus hirsuta *var.*sibirica; *stand structure; biomass production; regression equation; minirotation.*

要 約

물갬나무의 集約栽培에 依한 森林 Biomass와 幹材生産 效率과의 關係를 究明하여 森林 生産性 向上을 圖謀코자 1975年 京畿道 楊平郡 青雲面 多大里에 密度別(ha當 3000, 6000, 9000 및 12000本)로 試驗 造林을 實施하여 集約 管理한 結果 植栽密度 ha當 6000本 以上 高密度區의 適正 收穫期(또는 間伐時期)는 植栽 5年後로 推定되며 地上部 biomass量 또는 單木當 biomass量의 推定式은 $\log Y = b_0 + b_1 \log d^2 h$ 가 가장 適合하였다.

INTRODUCTION

Many studies on the biomass of trees and forest stands have been made since the 1970s. Methods of measurement of biomass and biomass production, as applied to the different components of trees and to whole stands, have been considered and evaluated by Young(1976), Crow(1978), Hitchcock (1979), Schlaegel(1982), .and Stiell(1982). The present interest in the dry weight of trees is at least partly because research workers are becoming increasingly interested in the biological productivity of forest ecosystems for the utilization of wood as a renewable natural resources of both energy and chemicals (Granthan and Ellis, 1974; Hyun and

[1]接受 8月 3日 Received August 3, 1984.
[2]林業試驗場 Forest Research Institute, Seoul, Korea.

Lee, 1979; Lee and Hyun, 1980). In this context, assessments, comparisons and predictions are greatly meaningful if expressed as dry weights (Parde, 1980).

The experiment reported here was conducted to determine the effects of plant spacings on the growth, change of stand structure, volume yield, nine-year productivity and distribution of each component of *Alnus hirsuta* var. *sibirica* which is a fast-growing and widely planted hardwood tree in Korea, grown in minirotation.

MATERIALS AND METHODS

The *Alnus hirsuta* var. *sibirica* plantation in this study was located at Tatae-ri, Chongwoon-myon, Yangpyong-gun, Kyonggi-do (37°34′N, 127°44′E). It was established in the spring of 1975 on a well prepared site. The study design was a randomized complete block with three replications and it covered 6 hectares.

The plant spacings were 1.8m x 1.8m (3000 trees/ha), 1.29m x 1.29m (6000 trees/ha), 1.05m x 1.05m (9000 trees/ha), and 0.91m x 0.91m (12000 tress/ha). Each treatment plot covered 0.5 hectares, and height and basal diameter were measured for every tree in a 100m^2 plot within each plot.

The management was intensive: Each year, at the beginning of May, the plantation was fertilized. From 1975 to 1983, 9 year after planting, 165 kg/ha ('75-76), 219 kg/ha ('77-79), and 600 kg/ha ('80-83) of NPK fertilizer were applied.

After nine full growing seasons (end of September of 1983), three trees were subjectively selected from each diameter class and harvested. Fresh weights were determined immediately for each component seperately. A 5cm- Disc in width was taken from butt to tip by Huber's formula. Ten centimeter long Bolts were taken from the base-, mid-, and tip-point of upper-, middle-, and lower-branch of crown position. Dead branches, cones, and leaves were selected randomly from the aggregate of the sample trees. The samples were placed in plastic bags and conveyed to the laboratory. All specimens were weighed green and then oven-dried at 80°C until no further weight loss was detected. Oven-dry matter was obtained for each component specimen and its oven-dry to green matter ratio determined.

RESULTS AND DISCUSSION

Stand Structure

Change of stand densities: The general spacing effects of 4 different densities are illustrated in Figure 1. At 3000 trees/ha, little density competition was shown until the fifth year. At 6000 trees/ha, an abrupt reduction of density occured in the 6th year after planting. At 9000 and 12000 trees/ha, an abrupt reduction of density also occured in the 5th year after planting.

Table 1 illustrates the growth of height, diameter and volume at nine-year old plantations. Here mean height and mean DBH decreased with increasing densities. Volume yield and average annual increment of the different densities are shown in Table 2. At 3000 trees/ha, a gradual increase of volume was shown through 9 successive years, and in other plots, average annual increments were decreased.

Frequency distribution of DBH class is shown in Figure 2. At 3000 trees/ha, the distribution was

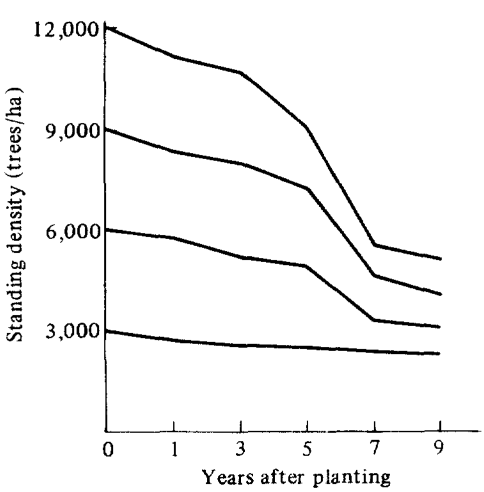

Fig. 1. Natural decrease of stand density at *Alnus* plantations.

normal, and in other plots the distribution curves showed a left-side screw (left kurtosis). Table 3 presents the regression model for estimating average height of 4 different densities. The r^2-values were larger than 0.93 with two exceptions.

Competition-density effect: Analysis was applied to the mean single tree volume using reciprocal equation model $1/V = A\rho + B$. As shown in Figure 3, the volume decreased with increasing densities and ages.

Table 1. Height, DBH, and volume growth at 9-yr-old *Alnus* plantations of 4 different densities.

Planting density (trees/ha)	Density after 9-yr (trees/ha)	Mean height (m)	Mean DBH (cm)	Volume (m^3/ha)
3,000	2,267	9.4	9.7	92.5
6,000	2,933	9.5	8.0	75.3
9,000	4,100	8.5	7.0	76.5
12,000	4,833	8.0	7.0	89.8

Table 2. Volume increase and its average annual increment of *Alnus* plantations at 4 different densities.

Plantation	Volume (m^3/ha)				Average annual increment (m^3/ha/yr.)			
age	3,000	6000	9000	12000	3000	6000	9000	12000
5	27.2	43.5	41.8	56.3	5.4	8.7	8.4	11.3
6	31.9	40.8	34.9	40.8	5.3	6.8	5.8	6.8
7	56.5	51.6	54.0	54.0	8.1	7.4	7.7	7.7
8	74.2	66.8	66.1	70.2	9.3	8.4	8.3	8.8
9	92.5	75.3	76.5	89.8	10.3	8.4	8.5	10.0

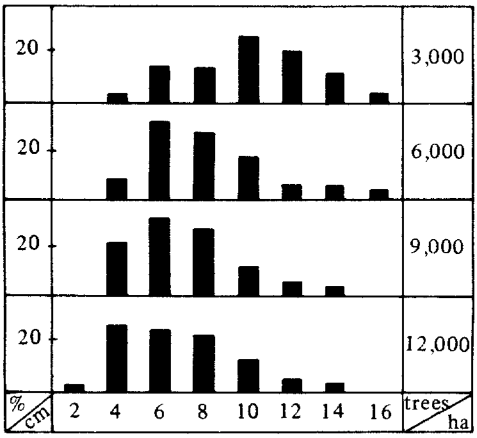

Fig. 2. Frequency distribution of DBH of 9-yr-old *Alnus* plantations with different densities.

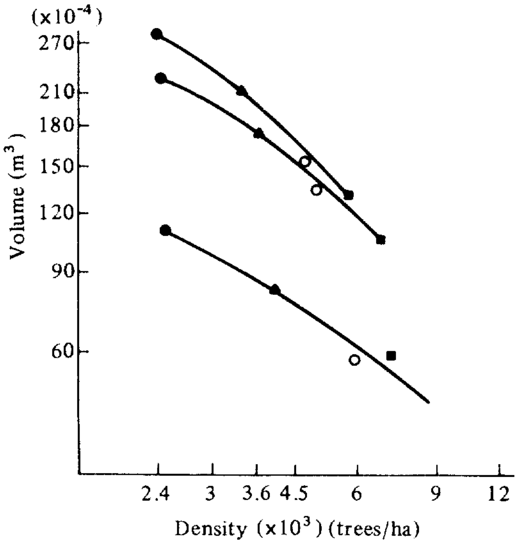

Fig. 3. Competition - density effect.

Dry Weight Biomass

Table 4 shows above-ground biomass for each component of 9-year-old stand. The proportions of each biomass component measured were stems 64.8-73.8%, live branches 19.8-25.3%, leaves 5.3-8.8%, dead branches 0.6-1.5%, and cones 0.2-0.5%. The proportion of stem increased with increasing densities, while that of branches decreased. These results were similar to those with red pine (*Pinus resinosa* Ait.) reported by Alemdag and Stiell (1982).

Figure 4 gives the patterns of standing crop distribution of the different densities and of DBH class. At 3000 trees/ha, total biomass production was the highest, because the standing crops are distributed in a high DBH class comparatively.

Table 5 presents the regression equation for estimating above-ground biomass and total tree

Table 3. Regression equation for estimating average height of 9-yr-old *Alnus* stand with 4 different densities.

Planting density (trees/ha)	Density after 9-yr (trees/ha)	Regression equation	r^2
3,000	2,267	$Y = \frac{D}{0.34 + 0.06 D}$	.936**
6,000	2,933	$Y = \frac{D}{0.30 + 0.05 D}$	.919**
9,000	4,100	$Y = \frac{D}{0.31 + 0.06 D}$	.937**
12,000	4,833	$Y = \frac{D}{0.41 + 0.04 D}$	.913**

Table 4. Above-ground biomass of each component of 9-yr-old *Alnus* plantations.

Density after 9-yr. (trees/ha)	Dry Weight (tons/ha)					
	Stem	Live branch	Dead branch	Leaves	Cones	Total
2,267	48.46	18.89	0.49	6.56	0.39	74.79
	(64.8)*	(25.3)	(0.6)	(8.8)	(0.5)	(100.0)
2,933	40.91	12.04	0.85	3.05	0.23	57.08
	(71.9)	(21.1)	(1.5)	(5.3)	(0.4)	(100.0)
4,100	34.47	10.98	0.51	3.92	0.16	50.04
	(68.9)	(21.9)	(1.0)	(7.9)	(0.3)	(100.0)
4,833	46.48	12.47	0.56	3.36	0.09	62.96
	(73.8	(19.8)	(0.9)	(5.3)	(0.2)	(100.0)

* Figures in parenthesis are percentage of total biomass.

Table 5. Regression equation for estimating dry weight biomass of each component of 9-yr-old *Alnus* at different densities.

Planting density (trees/ha)	Component	Regression equation	r^2
3,000	Stem	$Y = 0.02848(D^2 H)^{0.92092}$	.994**
	Branches	$Y = 0.00095(D^2 H)^{1.24684}$	.938**
	Leaves	$Y = 0.00002(D^2 H)^{1.60537}$	.933**
	Total	$Y = 0.02380(D^2 H)^{1.00191}$	.986**
6,000	Stem	$Y = 0.01708(D^2 H)^{0.99710}$	.992**
	Branches	$Y = 0.00021(D^2 H)^{1.43482}$	.932**
	Leaves	$Y = 0.00006(D^2 H)^{1.40918}$	.944**
	Total	$Y = 0.01302(D^2 H)^{1.08255}$	.987**
9,000	Stem	$Y = 0.03144(D^2 H)^{0.89986}$	.989**
	Branches	$Y = 0.00159(D^2 H)^{1.17438}$	.951**
	Leaves	$Y = 0.00020(D^2 H)^{1.30362}$	.888**
	Total	$Y = 0.02847(D^2 H)^{0.97151}$	.991**
12,000	Stem	$Y = 0.04185(D^2 H)^{0.86839}$	.969**
	Branches	$Y = 0.00235(D^2 H)^{1.10029}$	.967**
	Leaves	$Y = 0.00126(D^2 H)^{0.98845}$	.845**
	Total	$Y = 0.03942(D^2 H)^{0.92359}$	.975**

D and H indicate basal diameter and height, respeceivelv.

** indicates significance at the 1% level.

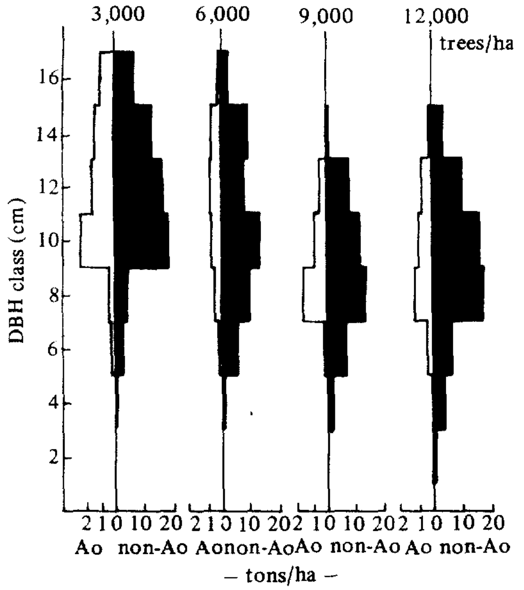

Fig. 4. Patterns of standing crops distribution by density and by DBH class. Ao and non-Ao indicate assimilative organ, and non-assimilative organ, respectively.

biomass. This regression for estimating each component biomass as a function of d^2h was found to be applicable to the *Alnus hirsuta* var. *sibirica* plantation. Such results were similarly shown reports on *Pinus sylvestris* L. studied by Attiwill and Ovington (1968) and *Pinus virginiana* Mill. studied by Madgwick (1971).

CONCLUSION

1) For a thinning or harvesting operation under under minirotation at a highly dense plot (more than 6000 trees/ha), about 5th year after planting seems to be the most suitable.
2) Regression equation model for estimating average height, $Y = D/(b_0 + b_1D)$, can be applied with high confidence.
3) Single-tree equations for *Alnus* plantation based simply on DBH and height, would give satisfactory ovendry biomass estimates for the whole tree and for the component stem, live branches, and leaves.

LITERATURE CITED

1. Alemdag, I.S. and W.M. Stiell. 1982. Spacing and age effects on biomass production in Red pine plantations. For. Chron. pp. 220-224.
2. Attiwill, P.M. and J.D. Ovington. 1968. Determination of forest biomass. Forest Sci. 14: 13-15.
3. Crow, T.R. 1978. Common regressions to estimate tree biomass in tropical stands. Forest Sci. 24:110-114.
4. Grantham, J.B. and T.H. Ellis. 1974. Potentials of wood for producing energy. J. For. 72: 552-556.
5. Hitchcock, H.C., III. and J.O. McDonnell. 1979. Biomass measurement: a synthesis of the literature. Norris, Tennessee, Division of Land and Forest Resources, Tennessee Valley authority. 59pp.
6. Hyun, S.K. and D.K. Lee. 1979. The importance of intensive forestry management for fiber and energy production in Korea. Jour. Korean For. Soc. 44:43-47.
7. Lee, D K. and S.K. Hyun. 1980. Woody biomass products as an energy source. Korean National Academy of Sciences Journal. XIX. Natural Sciences Series. pp. 239-253.
8. Madgwick, H.A.I. 1971. The accuracy and precision of estimates of the dry matter in stems, branches, and foliage in an old-field *Pinus virginiana* stand. pages 105-112 *in* H.E. Young, ed. Forest Biomass Studies. Working Group on Forest Biomass Studies. Section 25, Yield and Growth, XVth IUFRO Congress, University of Florida. Gainesville, Florida, U.S.A., March 15-20, 1971.
9. Parde, J. and DR. H.C. 1980. Forest biomass. Forestry Abstracts Review Article. 41(8): 343-362.
10. Schlaegel, B.E. 1982. Boxelder (*Acer negundo* L.) biomass component regression analysis for the Mississippi Delta. Forest Sci. 28(2): 355-358.

11. Young, H.E. 1976. A summary and analysis of weight table studies. Pages 251-282 *in* H.E. Young, ed. Oslo Biomass Studies. Papers presented during the XVth IUFRO Congress. Oslo, Norway, June 22, 1976.