



Growth Performance Assessment of *Chamaecyparis obtusa* Stand in Gyeongnam Province, S. Korea

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Abstract: Growth causes in trees to change in volume (size) and shape or form. These changes can be positive or negative and it is the result of different factors either biotic or a biotic. A stand or individual trees have characteristic growth patterns and understanding the sources of change or factors that are influencing the growth is crucial for the productivity of forests. In this study the growth performance of *Chamaecyparis obtusa* (*C. obtusa*) was studied to assess the growth condition of young stand in the Gyeongnam province since the time of plantation. Historical tree growth was measured using standard forest growth evaluation (height and root collar diameter measurement) techniques to analyze increment from individual trees at seventy two sites in eight cities and counties. The relationship between soil properties, climate, altitude and aspect with tree growth was evaluated. The results of the study showed variation of growth pattern for the same species of similar age categories at different sites and the combined effects of climate, soil properties, altitude, aspect and management are the strongest drivers of changes in the growth. It was recommended to consider the above factors for further expansion of plantation of the species and apply periodic silvicultural treatments to the stands in order to facilitate the growth and wood quality.

Keywords: Growth, Silviculture, Soil Properties, Climate Change, Forest Productivity

1. Introduction

Chamaecyparis obtusa, also known as Hinoki Falsecypress, is a conifer in the cypress family Cupressaceae, native to and widely distributed in Japan and South Korea [1]. Even though it's native to the mentioned countries, due to the various benefits of the species, *C. obtusa* is used in horticulture and numerous cultivars, obtained in Japan, Europe, the United States and New Zealand, are in the trade [2]. It is an evergreen tree, to 20m (70 feet) tall and 6 m (20 feet) wide in its native habitat with a pyramidal shape.

As conifers are known to everyone as a conspicuous kind of evergreen trees, *C. obtusa* among the conifer is a very important tree species [3]. The species deserves to get the name "versatile tree" for its multi-function and benefits. For instance, the essential oil from *C. obtusa* has therapeutic

potential against respiratory inflammation related disease; suppresses proliferation of breast cancer cells; constitutes source of anti-inflammatory drugs; and touching Hinoki with the soles of the feet induces physiological relaxation [4-7]. Hinoki cypress, *C. obtusa*, is the representative tree of forest bathing, and essential oil from *C. obtusa* is widely used in commercial products [8]. Also, the essential oils of *C. obtusa* have antibacterial and antifungal effects and several products such as hygienic bands, aromatics, and shampoos contain this oil as a natural source of antimicrobial/antifungal agents; moreover, it can be used as a 'human-friendly' alternative insect repellent [9, 10].

The species is particularly suitable for the clonal propagation of dwarf forms ('tennis ball conifers') with compact growth selected from cuttings from witches brooms; these grow often very slowly and are therefore considered ideal for pot-grown patio plants, rockeries [2]. Interestingly,

some consumers suffering from baldness and/or other forms of hair loss have reported a hair growth promoting effect of shampoos containing these oils. Moreover, the essential oils of *C. obtusa* found to promote hair growth in an animal model [10].

On the other hand, the wood of *C. obtusa* has been used for centuries in construction of temples and other traditional buildings because of its fine quality and high durability in outdoor conditions. The species have an old history of being used for construction due to the bending strength and rigidity of aged Hinoki wood people used in temple structures for about 1300 in Japan [11]. The Japanese have largely turned to sources outside Japan to obtain timber of related species, especially those occurring on the Pacific coast of North America [2, 12]. Also *C. obtusa* has a beneficial influence on the soil properties; soil pH and exchangeable K and Mg contents [13]. Thus, in this study the growth performance of

this versatile tree was assessed in order to get information about its status and to suggest management mechanisms in the province.

2. Materials and Methods

2.1. Site Description

The study was carried out in the Gyeongsangnam-do province of S. Korea. Among the eighteen cities and counties in the province, (44%) eight cities and counties were purposively selected for the study. Selection of the study site was done by based on the availability of the required stand type, location of the cities and counties and the agro-ecological condition of the cities and/or counties. The following figure shows cities and counties included in the study (Figure 1).

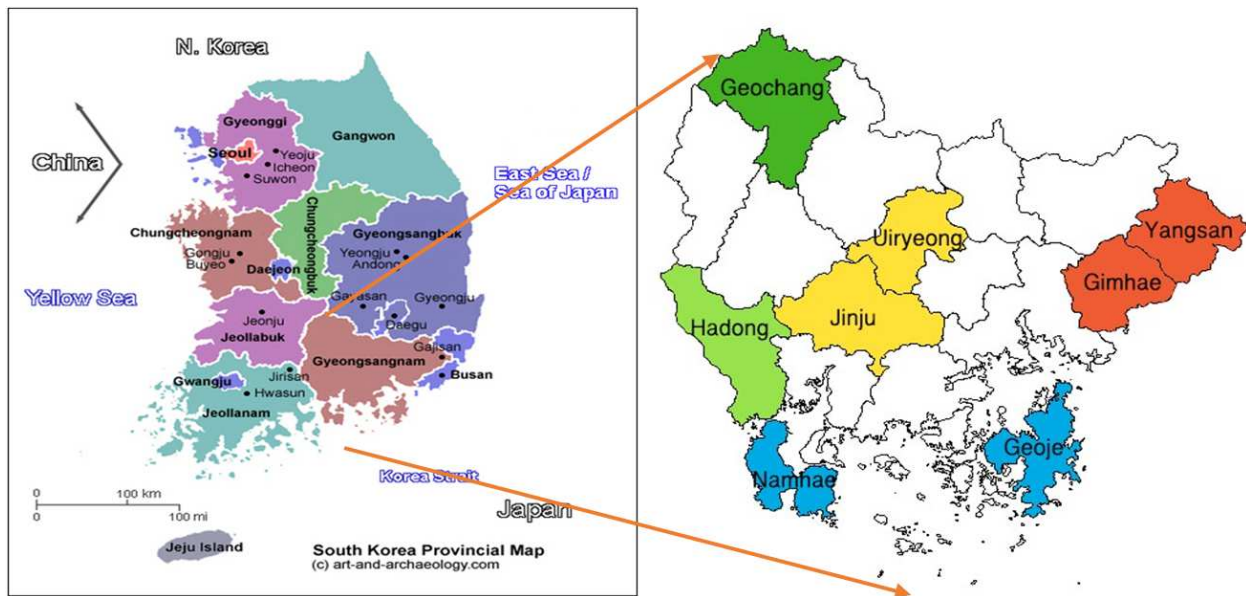


Figure 1. Locations of the study areas (shaded areas represent sample study cities and counties).

2.2. Sampling Methods for Tree Data Collection

At each selected city and county a 20*20m (400m²) quadrats for sample collection were used and the growth attributes of *C. obtusa* species such as height, root collar diameter (RCD), assessment of performance and health condition were recorded following the quadrat method [14].

On the other hand, tree status (live or dead) were also recorded and spacing between planted saplings was measured. Landforms, altitude and slope of the sites were assessed (Table 1). Soil samples were also collected from each quadrats where the measurement of growth of trees was conducted.

Table 1. Background information of the study areas.

Site	Logging rate (%)	Altitude (m)	Aspect	Slope (%)	Spacing (m)	RCD (cm)	Height (m)	Land feature
Hadong	5-100	70-650	N, SW	5-15	2*2	6.8	5.0	Mountainous
Gimhae	5-100	60-438	SE, W	5-20	3*3	5.6	4.3	Mountainous
Jinju	5-100	62-195	E, NW	5-20	2*2	4.4	3.0	Mountainous
Geochang	5-100	263-465	SE, S	5-15	2*2	5.4	4.3	Mountainous
Namhae	0-80	141-233	NE, E	5-20	2*3	8.3	4.9	Mountainous
Yangsan	0-50	128-603	W, SE	10-15	2*3	6.2	3.4	Mountainous
Uiryeong	10-100	36-164	SW, NE	10-25	2*3	5.8	3.7	Mountainous
Geoje	0-100	23-290	W, NE	10-30	3*3	6.51	3.7	Mountainous

Logging rate = trees left on the site during site preparation and its coverage in %, RCD = root collar diameter.

2.3. Climate Condition of the Study Areas

To examine the variation of climatic conditions mainly average annual temperature and total annual precipitation a data of ten years (Tables 2 and 3) were used in order to

evaluate the impacts of changes in the climatic condition on the growth pattern of *C. obtusa* species. Both the average annual temperature and total precipitation data were collected from Korean metrological station.

Table 2. Average annual temperature of ten years in the study areas.

Site	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Hadong	13.0	13.1	12.8	13.3	13.0	13.3	13.8	13.3	13.1	13.7
Gimhae	15.5	15.3	14.6	14.9	14.8	15.3	15.4	14.6	14.8	15.5
Jinju	13.8	13.1	13.0	12.7	13.4	13.2	13.4	13.8	13.5	13.4
Geochang	11.8	11.6	11.4	12.0	12.0	12.4	12.7	12.2	12.3	12.7
Namhae	14.2	14.1	13.9	14.8	14.7	14.7	15.1	14.9	14.6	15.2
Yangsan	14.7	14.6	14.3	15.0	14.6	14.9	15.3	15.1	14.8	15.4
Uiryeong	17.2	17.3	16.0	16.6	15.3	16.3	17.0	17.0	17.2	17.6
Geoje	14.4	14.1	14.2	14.9	14.8	14.9	15.6	15.2	15.0	15.6

Table 3. Average total precipitation of ten years in the study areas.

Site	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Hadong	2189.5	2013.1	1914.2	1254.8	1539.1	1397.2	1530.0	770.8	1601.4	1769.9
Gimhae	1353.4	1537.5	1432.2	1057.5	1634.8	1030.0	1633.9	755.8	1469.7	1494.0
Jinju	1896.0	2026.4	1752.9	1221.4	1644.9	1319.9	1734.6	766.7	1605.4	1481.6
Geochang	1548.5	1321.3	1538.8	1085.9	1242.5	1028.7	1229.8	782.8	1215.6	1232.4
Namhae	2160.2	2183.4	2208.7	1590.5	2058.5	1789.3	2405.2	1157.8	2203.6	2171.7
Yangsan	1462.5	1606.4	1621.4	1093.0	1767.6	1234.5	1937.7	720.5	1589.2	1536.1
Uiryeong	918.0	1766.3	1403.6	989.9	1380.5	1077.2	1473.8	876.8	876.8	1272.7
Geoje	1959.7	1734.6	2037.0	1258.1	2256.9	1774.3	2221.1	1411.1	2507.1	2507.1

2.4. Data Analysis

For the analysis of growth at different sites one-way analysis of variance (ANOVA) was used to determine statistically significant differences in means among variables and an F-test was used to determine equality of group means [14]. Pearson's correlation coefficient was used to measure the relationship between annual height growth, RCD to soil, climate, and ecological variables. Also comparison of growth of height and RCD were computed by sorting data in their age categories and site. Total growth pattern was prepared by using graphical representation of the data for each site.

Table 4. Average soil properties of the study areas.

City/County	MC (%)	OM (%)	pH (H ₂ O)	Avail. P (ppm)
Hadong	23.6±0.47b	4.1±0.09b	4.9±0.02e	54.0±2.4a
Gimhae	20.4±0.36d	2.8±0.10c	4.0±0.02f	24.0±1.6c
Jinju	13.6±0.04f	4.9±0.16a	4.5±0.02d	30.3±0.8b
Geochang	17.4±0.23e	1.3±0.05d	4.6±0.05c	30.0±2.2b
Namhae	21.8±0.19c	2.7±0.05c	4.7±0.01c	19.3±1.0c
Yangsan	25.2±0.61a	3.0±0.07c	4.5±0.02d	19.3±0.6d
Uiryeong	21.7±0.25c	1.5±0.03d	5.2±0.02a	18.8±0.4e
Geoje	22.5±0.25c	3.0±0.09c	4.7±0.01b	22.2±1.0c

Analysis of the distribution of annual average temperature and precipitation from the neighboring respective metrological station at each study cities and counties and site was conducted. The variation of annual precipitation ($p < 0.005$, $F = 31.8$) and air temperature ($p < 0.001$, $F = 1.6$) were significantly high. A relatively strong positive correlation

3. Results

Soil properties at all the sites were relatively acidic (pH 4-5.2). However, it was identified that soil organic matter and available phosphorous content were relatively varied. The stand at sites with higher soil organic matter, moisture content and available phosphorous showed relatively higher growth indicating that soil property has an influence on the performance of *C. obtusa* species. Averages of soil properties of the study areas are presented in the table below (Table 4).

between growth of average annual root collar diameter (RCD) and precipitation ($r = .33$, $p = .01$) was observed. Among the ecological factors altitude and aspect were negatively related to the growth of both height and RCD ($p = .05$).

As trees grow, they require more space for crown

expansion which has advantage for the growth performance. In this study there was a significant relationship between planting spacing and growth of both height and RCD (Table 4). The spacing was negatively related to tree height growth

($r = -.037, p = .05$). Among the soil factors, available phosphorous was negatively related to both height, RCD and it was significantly related ($p = .05$) to growth of the stands.

Table 5. Pearson's correlation coefficient between ecological and climate factors and growth parameters.

	Height (m)	Altitude (m)	Slope (%)	pH	Avail. P	Tem (°C)	Precipi (mm)	Aspect	MC (%)	Spacing (m)
RCD (cm)	.682**	-.233*	0.127	0.101	-.242*	0.181	.339**	-0.189	0.038	0.026
Height (m)		-0.107	0.122	0.075	-0.034	0.109	0.091	-0.191	0.058	-0.037

** . Correlation is significant at the 0.01 level (2-tailed), * . Correlation is significant at the 0.05 level (2-tailed).

Growth Performance at Different Plantation Sites

Measurement of diameter at breast height (DBH) for mature stand or RCD for young stand and height provides important information about the performance of the stands. From the inventory results, in the study sites the growth performance of the stand was relatively good. The growth of the stands at different sites resulted significant differences in their growth of height and RCD ($p < .05$). Growth of height and root collar diameter of all stands at all sites were almost similar except few sites (Figures 2 and 3). As seedlings overtopped by other trees or shrubs will die out, there was growth variation observed at sites where plantation undertaken at the understory of other trees (partial logged sites) which might be the result of potential competent and under topping effects of mature trees.

Growth of the species was observed relatively higher at the site where the soil pH was acid (Table 5, Figures 2 and 3) indicating that the species preference of relatively acidic soil.

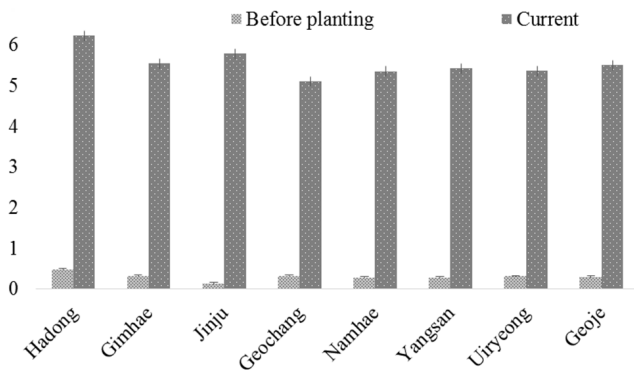


Figure 2. Averages of change in RCD growth performance of *C. obtusa* at the study sites.

Conditions of soil available phosphorous varied from 54 ppm to 18.8ppm and performance of the species at the site where the higher available phosphorous showed a significant difference ($p < .05$) of growth of height and root collar

Table 6. ANOVA for growth performance of height and RCD of *C. obtusa* stand at different sites.

Source of Variation	SS	df	MS	F	P-value
Between Groups	4.962718	15	0.330848	4.449374	0.0000011
Within Groups	9.517863	128	0.074358		
Total	14.48058	143			

Moreover, management practices applied to the stand found to be among the factors influenced the growth

diameter. Generally, there was statistically significant difference in the collar diameter increment ($p < .05$) of trees after plantation at all the study areas.

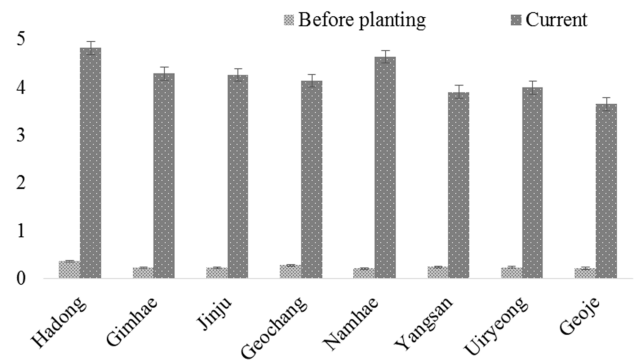


Figure 3. Averages of height growth changes in performance of *C. obtusa* at the study sites.

From the evaluation of growth performance of height and RCD, among the sites Hadong depicted the highest average collar diameter increment (5.76cm) and while Geochang showed the least RCD increment (4.81cm). In both sites there was a significant variation ($p < .05$) in soil properties mainly soil organic matter, moisture content and available phosphorous (Table 5). At all sites the performance of growth pattern varied as to the management and silvicultural treatment applied. Sites where pruning and cleaning of climbers conducted resulted higher RCD growth than others (Figure 3). On the other hand, growth tended to decline at higher altitude and northern region showed relatively better growth.

From the result the analysis of one way ANOVA, there was a significant difference ($p < 0.0000011$) in growth patterns of height and RCD between sites. The study revealed that site factors (soil properties, climate condition, altitude, aspect and spacing) and species growth parameters were significantly related (Table 6).

indicating that sites where pruning and cleaning of woody climbers has been conducted showed better growth. Similarly,

site preparation before planting and availability of mature trees on the sites influenced the growth patterns as overtopping and competing component to the plantation.

4. Discussion

It is very important to detect changes which occurs in forest growth and productivity due to the global change [15]. Discovery of change in forest growth, health and productivity needs inventory of forests to gain the latest information on tree and stand growth relevant for ecological, economic and social aspects of forest management [16]. As a result, forest monitoring has become a key issue in national and international environmental and developmental policy process [17]. Since, it helps to assess the productivity by evaluating special and temporal changes of forests, understanding dynamics of forests from local to global scale is crucial for policymaking and sustainable development [18].

The result of this study showed a significant variation in growth performance of *C. obtusa* stand in the Gyeongnam province of South Korea. The differences in growth performance such as height, root collar diameter and volume could be attributed from different factors. Based on the previous studies in different parts of the world, the growth performance of plantation is expected to be related to the fit between the environmental parameters, site conditions and management [19, 22]. From the result of the current study the pattern of growth of the same species planted at different sites showed variation in growth performance which resulted from soil properties, variation in climate condition, aspect, altitude and management methods.

A site with relatively higher available soil phosphorous showed best performance of growth in height and RCD. As phosphorous is among the crucial soil nutrient for the growth and productivity of trees, optimum supply of the nutrient increases the health and growth of forest [23, 24]. Also phosphorus availability may shape plant–microorganism–soil interactions in forest ecosystems [25]. This leads to stable soil properties as well as dynamics of soil systems [26]. Consequently, in the study sites the areas where higher soil phosphorous observed, the organic matter content was also higher. Thus, the pattern of growth varied with the necessary soil properties required for plant growth. On the other hand, soil pH was among the main important soil properties influencing growth of the species. Other studies also revealed that the growth of *C. obtusa* was regulated by soil pH, indicating that soil pH has a noticeable effect on the growth performance of the species [27- 30].

Additionally, climate is the strongest driver of spatial variation in tree growth, and climate change may therefore have large consequences for forest productivity [31]. Among the tree growth affecting factors, temperature and precipitation are the most readily measurable and in this study the variation in climate condition mainly annual average temperature and annual total precipitation also influenced the growth of the species. It was confirmed that the relationship between *C. obtusa* growth and change in

climate variables was negative [32]. Variation in precipitation affect the above ground net productivity, depending on whether extreme precipitation led to increased or decreased soil water content [33]. Similarly, variation in temperature influence the growth pattern of trees [34, 35]. A shorter and less intense dry period and higher temperatures led to higher tree growth rates [31]. On the other hand, management methods directly influence the growth of trees [36]. For instance, pruning directly manipulates crown extent and so has profound implication on the growth pattern and wood quality. Also, as competition plays a significant role, silvicultural practices are essential for growth of forest [37]. Generally, the combined effects of climate, soil properties, altitude, aspect and management are the strongest drivers of changes in the growth of *C. obtusa* trees.

5. Conclusion

Forest growth and productivity has always been a major concern of foresters, land managers and enterprises due to the complexity in the ecosystem, climate change and ever increasing demands of forest products. The dynamics of forest growth is the result of the characteristics of climate, altitude, aspect, soil properties mainly nutrients and moisture content, pH, and structures of the soil significantly related to tree growth. Management method is another element influencing the growth of forests. Thus, improved knowledge of these factor is crucial for sustainable production management and utilization plantation forests. The current study results can help in forest production, decision making process and further expansion of the species *C. obtusa* in the Gyeongsangnam-do province.

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