Distribution of *Kalopanax septemlobus* and Its Growth in Northeast Asia

LEE, Don Koo* and KANG, Ho-Sang

Institution: Department of Forest Resources, College of Agriculture and Life Sciences, Seoul National University, Suwon 441-744, Republic of Korea

Abstract

Kalopanax septemlobus (Thunb.) Koidz., a deciduous tree, is distributed only in Northeast Asia such as Korean Peninsula, Japan, China and Far Eastern Russia with only one species within one genus. Its natural distribution covers from 23° to 47° N and from 88° to 145° E. The frequent appearance of *K. septemlobus* mixed with *Quercus, Acer, Betula* and *Carpinus* species was at north aspect and ridge slope where soil nutrient conditions were fertile in Gangwon Province, Korea. Its distribution patterns were clustered in the young stage while individually scattered in the mature stage. The annual DBH growth rates of dominant and co-dominant *K. septemlobus* were 5.8 mm/yr and 5.5 mm/yr, respectively, but only 1.1 mm/yr for the last 3 years for suppressed trees. *Kalopanax* seedlings were distributed in Korean pine plantation areas from 6 to 86 seedlings per 25m^2 and mean density was 35.1 seedlings/25m^2. The height growth rate of *Kalopanax* seedlings was 54.6%, whereas that of root-collar diameter was 18.7 % from May to October. The importance of *K. septemlobus* has been recognized in Korea due to high quality of the timber and medicinal uses. Saponin is a second metabolic product found in leaves, branches, roots and stem bark and in the young leaves (used as an edible herb in early spring). In Korea, *K. septemlobus* stands have been severely damaged by human activities. Stands of *K. septemlobus* should be protected, sustainably managed and improved by restoration techniques through the long-term research.

Key words: Distribution, Growth, *Kalopanax septemlobus*, LTER, Seedling, Survival rate

Introduction

The forests of Korea cover about 6.5 million ha, representing 65% of the total land area (Korea Forest Service 2001). Even though Korea has a high percentage of forested areas, the self-sufficiency rate of timber was only 6 % in 1999 and it is expected that Korea will suffer from a shortage of timber in near future. One of the main reasons for deforestation is over-exploitation and/or illegal cutting during Second World and Korean Wars. The Korean Government successfully achieved reforestation of deforested woodlots by massive plantation since 1959, of which result has brought some problems as simplification of stand structure and species composition without enough consideration of site characteristics (Lee *et al.* 2001a). The restoration approach by native species is becoming one of the main issues in forest ecosystem management and may contribute to the improvement of forest environmental conditions (Lee *et al.* 1999a).

Kalopanax septemlobus (Thunb.) Koidz. is a deciduous tree species of which height and diameter at breast height (DBH) can grow up to 30m and 1.8m, respectively (Lee 1988). It is the only species in its genus of the *Araliaceae* family (Ohashi 1994). The timber quality of *K. septemlobus* is very high and its stem bark has been used in traditional medicine for treating neuralgia, rheumatic arthritis, lumbago, furuncle, carbuncle, wound, diarrhea and scabies (Translation Committee of Dongeui Bogam 1984, Jiansu Xin Yi Xue Yuan 1986, Namba 1994). Many kinds of bioactive compounds from leaves, stem bark and roots of *Kalopanax* were reported for medicinal uses such as anti-diabetic, anti-inflammatory, anti-nociceptive, anti-rheumatoid and anti-fungal (Park *et al.* 1998, Lee *et al.* 2001b, Choi *et al.* 2001, Kim *et al.* 1998). A number of chemical constituents like saponin, (a secondary metabolic product) have been identified from this species (Lee *et al.* 2000, Shao *et al.* 1989, Shao *et al.* 1990). Therefore, it has been used not only for medicinal but for an edible purpose, particularly the young leaves (Lee and Kim 2000).

The illegal cutting of *Kalopanax* for various purposes severely reduces the density of the species and affects regeneration in the natural forests (Chang *et al.* 2001). However, there has been little research for the restoration of degraded *Kalopanax* stands or for its eco-friendly sustainable management.

The objectives of this paper were 1) to understand the geographical distribution in Northeast Asia and topographical distribution in Gangwon Province, Korea, and 2) to examine the growth of DBH of mature stage and natural regenerated seedlings as

(Accepted; July 19, 2002)

* Corresponding author: leedk@plaza.snu.ac.kr

well as its survival rates.

Materials and Methods

1. Geographical distribution by herbarium specimens

The herbarium specimens for the identification of geographical distribution of *K. septemlobus* in Korea, Japan and China have been examined. The institutions involved were 1) University Arboretum affiliated to College of Agriculture and Life Sciences, Seoul National University, 2) College of Natural Sciences, Seoul National University, 3) Chonnam National University, Korea, 4) Institute of Botany, the Chinese Academy of Sciences, Beijing, China, and 5) Herbarium, Biological Institute, Tohoku University, Sendai, Japan for the use of herbariums. Geographical distribution map of *K. septemlobus* was determined on the basis of the locations, which the specimens of *K. septemlobus* were collected.

2. Topographical distribution in Gangwon Province, Korea

Kalopanax trees are distributed throughout Korea. However, most areas except Gangwon Province have been disturbed by either forest fire or illegal cutting. The study plots were established for the topographical distribution of *Kalopanax* at two mountain areas such as Mt. Gariwang and Mt. Gyebang in northeastern part of South Korea (Fig. 1).

Most of the forests on the Korean Peninsula are in the deciduous broadleaved forest zone (Yim 1977). The dominant tree species of the study area in Mt. Gariwang (37°27'30"~37°30'30"N and 128°30'30" ~128°33'30"E) were *Quercus mongolica*, *Betula costata*, *Acer mono*, *Tilia amurensis*, *Cornus controversa*, *Fraxinus rhynchophylla* and *Carpinus cordata* (Suh and Lee 1998, Lee *et al.* 1994). Detailed survey for 330ha was conducted and 141 plots were established for vegetation analysis in 1997.

The Long-term Ecological Research (LTER) site of Korea Forest Research Institute on Mt. Gyebang is located in 37°44'N and 128°29'E. To understand the relationship between the distribution and micro-environmental condition of *Kalopanax*, one ha of the study plot was divided into 25 subplots of 0.04ha. The dominant tree species are *Quercus mongolica*, *Betula schmidtii*, *Kalopanax septemlobus*, *Tilia amurensis*, *Pinus densiflora* and *Abies holophylla* (Oh *et al.* 2000).

The mother rocks in the study areas on Mt. Gariwang are gneiss mixed with limestone while that of Mt. Gyebang is composed of granite partly mixed with gneiss.

Data was collected using the quadrat sampling method. The size of each quadrat was 20m × 20m and the number of quadrats surveyed at Mt. Gariwang and Mt. Gyebang was 10 and 25, respectively.

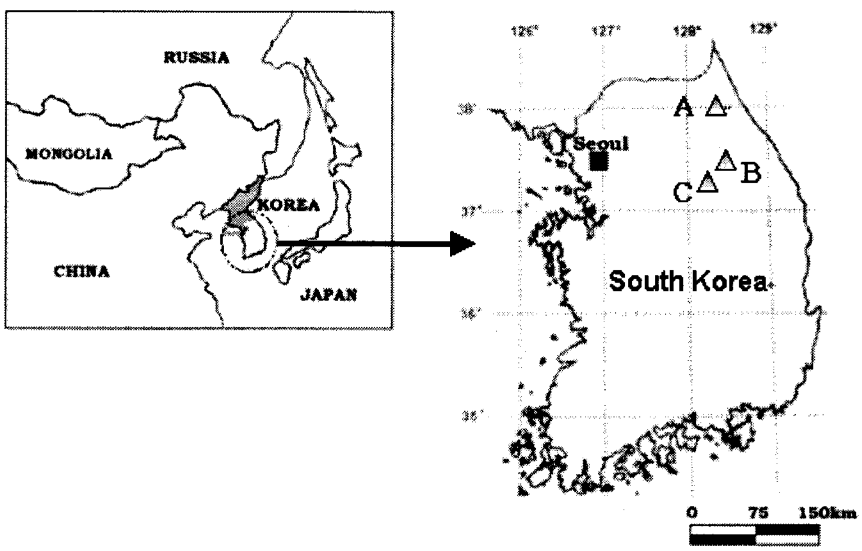
All individual trees with DBH above 2cm were recorded and the importance value (IV) was calculated from relative species density (RD) and relative coverage (RC) (Curtis and McIntosh 1951). The methods for calculation were as follows:

RD (%) = Number of species of individuals / total number of individuals × 100

RC (%) = Basal area at breast height for a species / total basal area at breast height for all species × 100

IV (%) = (RD + RC) / 2

The topographical and soil characteristics were



A: Mt. Jeombong, B: Mt. Gyebang, C: Mt. Gariwang

Fig. 1. Map of the study areas.

analyzed in each plot (Kalra and Maynard 1991).

3. Growth characteristics of *Kalopanax*

1) Diameter growth of adult tree

Girth band at breast height of *Kalopanax* in Mt. Gyebang was measured to determine the monthly DBH growth in each topographical site and crown class from 1998 to 2000. The relationship of the DBH growth, growing degree days (GDD; Σ(mean air temperature for day – 5)) and rainfall during May and September were examined (Kim *et al.* 1996).

2) Emergence, survival rate and growth of seedlings

To study the emergence, survival rate and growth of naturally regenerated seedlings of *Kalopanax*, three of 5m × 5m plots were established on June 2000. Eight of same size plots were also established on May 2001 in areas where *Pinus koraiensis* was planted in Mt. Jeombong (38°02'12"N and 128°26'39"E, elevation 850m, slope 5~10°). All of the *Kalopanax* seedlings within the plots were mapped and measured. Height, root-collar diameter and its survival rates were measured from June 2000 to October 2001.

Results and Discussion

1. Geographical distribution of *K. septemlobus* in Northeast Asia

Based on the locations collected for *Kalopanax* specimens, *K. septemlobus* was geographically distributed in all Korea and Japan, Far Eastern Russia and southern and eastern part of China (Fig. 2). It showed a broad range distribution of boreal forest areas of Sakhalin in Far Eastern Russia to subtropical regions of Japan and China (from 23° to 47° N and from 88° to 145° E).

Kalopanax has morphological variations and which occurs in extensive regions within Northeast Asia (Lee 1988, Nakai 1927). However, according to Ohashi (1994), the nomenclature of *Kalopanax* was clarified with *Kalopanax septemlobus* (Thunberg ex Murray) Koidzumi. In addition, the morphometric analysis by leaf samples from Korea, China and Japan supported that no strong discontinuities of leaf characters were existed among infraspecific taxa of *Kalopanax septemlobus* in Northeast Asia (Kim *et al.* 2002, submitted to Botanical Bulletin of Academia Sinica).

2. Topographical distribution in Gangwon Province, Korea

1) Mt. Gariwang

The IV of *Kalopanax* in this study area was 2.34. The highest IV was 14.72 for *Quercus mongolica*. Other dominant species were *Acer mono* with importance value of 8.26, *Fraxinus rhynchophylla* with 5.35, *Acer pseudosieboldianum* with 4.95, *Betula costata* with 4.70, and *Ulmus laciniata* with 4.35 (data not shown). Among the 141 plots in this study area, 10 plots of *Kalopanax* stand showed the high IV, compared with other plots as shown in Table 1.

The average IV of *Kalopanax* was 18.7 and the dominant tree species associated with *Kalopanax* were mostly *Quercus mongolica*, *Acer mono* and *Acer pseudosieboldianum*.

Kalopanax has complex seed dormancy with immature embryo and impermeable seed coat and its germination rate was very low and usually dispersed by birds (Young and Young 1994, Iida and Nakashizuka 1998). For that reason, its distribution patterns were clustered at the young stage while scattered individually at mature stages (Kim *et al.* 1994). In another report in 321ha, the IV of *Kalopanax* was only 1.7. The results from distribution analysis according to the topographical

Fig. 2. Geographical distribution of *Kalopanax septemlobus* in Northeast Asia

Table 1. Importance value of tree species in the canopy layers of *Kalopanax* stands in Mt. Gariwang

Species \ Plot no.	1	2	3	4	5	6	7	8	9	10	Average
KASE	19.1	19.0	28.3	11.8	21.0	16.0	26.9	14.9	15.9	13.8	18.7
QUMO	4.9	12.4		16.5		29.3	27.5	29.4	1.4	47.2	16.9
ACMO	21.9	1.6	19.0	7.4	15.8	3.8	0.8	3.5	13.7	2.4	9.0
ACPS		12.1	7.9	6.9	5.5	10.6	12.1	11.0	4.1	5.8	7.6
BECO	10.1	7.9			5.7	5.1	8.5		1.4	3.5	4.2
TIAM		3.6		7.9		2.4	4.4	5.9	1.0	3.5	2.9
CACO	7.8	2.5	5.5	4.1	2.8				20.6	1.2	4.5
STOB	5.6		5.9	5.7	2.2	1.3		1.5	3.8		2.6
BESC		0.7	9.5	14.6		1.7	2.7				2.9
ABHO	1.9	5.3	6.0	10.5	4.9		1.7				3.0
ULLA	7.3		4.3	1.8	11.5				9.1		3.4
FRRH	7.7			1.9		7.0	3.0	11.3			3.1
MAAM		3.3				9.1		6.3		5.5	2.4
MOBO	1.4			3.6	8.8	0.6	0.7				1.5
SOAL					2.0	0.9			8.2		1.1
COCO	8.0		5.1					5.1	8.5		2.7
FRMA		5.6			15.9				2.0		2.4
EUSA		2.2	1.5		2.0					3.2	0.9
MASI			1.3		2.0	2.5		2.0			0.8
LIOB		0.7		5.4					1.0		0.7
RHSC		21.7				8.6	10.1	9.1			5.0

KASE: *Kalopanax septemlobus*, QUMO: *Quercus mongolica*, ACMO: *Acer mono*, ACPS: *Acer pseudosieboldianum*, BECO: *Betula costata*, TIAM: *Tilia amurensis*, CACO: *Carpinus cordata*, STOB: *Styrax obassia*, BESC: *Betula schmidtii*, ABHO: *Abies holophylla*, ULLA: *Ulmus laciniata*, FRRH: *Fraxinus rhynchophylla*, MAAM: *Maackia amurensis*, MOBO: *Morus bombycis*, SOAL: *Sorbus alnifolia*, COCO: *Cornus controversa*, FRMA: *Fraxinus mandshurica*, EUSA: *Euonymus sachalinensis*, MASI: *Magnolia sieboldii*, LIOB: *Lindera obtusiloba*, RHSC: *Rhododendron schlippenbachii*

characteristics showed that the highest IV of *Kalopanax* in 340ha was in slope (4.9). The IV in the ridge-slope, valley-slope, ridge, and the summit of the mountain were 3.2, 1.3, 0.8, and 0.5, respectively (Lee *et al.* 1997, 1998, 1999b).

The topographical characteristics of the study plots were shown in Table 2.

The sites favorable for *Kalopanax* in these study areas were in ridge-slope site, high elevation (average altitude 970m), northern aspect and fertile soil. Kang and Lee (1998) also reported that *Kalopanax* stands were located at 1,000 to 1,200m in altitude, steep slope and ridge-slope areas with aspects facing northeast to northwest in Mt. Joongwang.

2) Mt. Gyebang

The dominant tree species in canopy layers of study areas were *Quercus mongolica*, *Acer pseudosieboldianum* and *Pinus densiflora* in ridge sites, whereas *Tilia amurensis*, *Betula schmidtii* in slope sites (Table 3 and Illustration 1). The density of *Kalopanax* in this site was 73 trees/ha. The altitude of this site was 1,130m facing north aspect. The frequency of *Kalopanax* in each plot was shown in Illustration 1.

The correlation coefficient between IV of *Kalopanax* and soil moisture was 0.65 and with diversity index was 0.46 and was negatively correlated with depth of litter layer. The result indicated that the litter layer was thin in the *Kalopanax* stands distributed at high species diversity in ridge-slope sites (Lee *et al.* 1999c).

3. Growth characteristics of *Kalopanax*

1) Diameter growth of adult tree

It is well known that soil properties vary widely along a topographic gradient from ridge top to valley floor (Garten *et al.* 1994). The productivity also changed in response to environmental gradient; light condition, temperature, topography (Kimmins 1997,

Table 2. Topographical and soil characteristics of *Kalopanax* stands in Mt. Gariwang

Plot number	1	2	3	4	5	6	7	8	9	10
Altitude (m)	775	1,050	850	925	925	1,000	1,015	1,075	925	1,150
Aspect (°)	5	325	315	315	325	290	273	270	325	270
Slope (°)	27	5	35	32	32	26	15	12	30	31
Topography	slope	ridge	ridge-slope	slope	valley-slope	ridge	ridge	ridge	valley	ridge
Depth of soil A layer (cm)	12	15	18	27	-*	16	12	15	41	5
Soil moisture (%)	36.3	35.0	48.0	35.8	49.7	36.6	33.8	40.1	40.9	44.7
pH	5.22	4.42	4.90	5.12	5.09	4.22	4.46	4.46	4.40	4.24
Total N (%)	0.49	0.20	0.45	0.46	1.15	0.26	0.54	0.62	0.52	0.58

*: not measured

Table 3. Importance value of tree species in the canopy layers of *Kalopanax* stands in Mt. Gyebang

Plot	QUMO	TIAM	BESC	ACPS	PIDE	KASE	ABHO	FRRH	MASI	PIKO	MAAM	ACMO	ULLA	COCO	ULDA
1			17.0	0.9		8.5	11.1		2.7	1.1	8.0		13.0		
2	6.5	22.5	6.1	5.3		19.7	9.4		8.5	4.1	6.5	1.0		0.7	
3	33.7	10.0	12.4	8.3	18.4	1.6	5.0	0.6	1.1	6.5	0.6				
4	29.4	9.3	10.6	3.8	37.2	3.6	0.7			3.4	1.2				
5	26.5	3.7	17.7	4.8	22.9	1.1	0.8	3.1		3.0	3.3	5.2		4.1	1.0
6	10.8	16.7	19.2	0.8		3.1	16.8	1.7	8.2			5.5	6.0		5.0
7	26.3	16.6		7.0		15.8		0.7	9.5	2.6	7.1	4.1	1.7		
8	53.6	5.9	15.0	8.5	4.3	1.5	4.8	1.8		2.9			1.6		
9	33.4	8.6	8.7	6.4	30.5	3.5		2.2		2.8	2.6				
10	33.7	5.3	9.8	9.4	19.3	0.5		3.1		0.6	9.2				
11	5.6	18.8	27.0	7.2		9.3	6.1		3.1	0.7		5.4	3.1	2.7	
12	30.0	10.5	16.9	7.9	3.2	1.9	8.6	0.7	11.1	0.7	1.9	1.3	1.2		
13	56.4	1.9	2.5	7.1	18.8	1.0	5.0	1.9	0.6	3.5	0.7		0.6		
14	69.5	5.2		11.3				2.9		8.3			1.0		
15	31.9	11.4	11.0	13.6	15.1	2.2		2.9	0.4	5.5	3.5				
16	10.6	34.8	1.9	2.8		13.6	7.0		4.4	0.7	6.6	4.1	7.4	0.6	
17	29.7	14.9	21.8	9.1		4.0	2.4		7.0	8.0	1.7				
18	47.3	1.6	20.1	16.3	6.4			1.2		3.9			1.4		
19	35.4	9.7	2.3	14.6	4.3	6.1		7.2		3.5	0.8	8.4	2.2		
20	27.9	20.8		8.5		7.5		12.7			4.1	1.9		9.1	
21	22.3	17.7	3.2	3.9		12.2	1.0	1.0	7.0	1.2		11.8	11.2	1.3	
22	32.5	11.3	17.7	11.9	2.7	2.9	1.5		9.7	1.0	1.4	0.5			
23	44.4	7.6	11.7	11.6	9.1	7.4		2.2	1.4	2.4			0.7		
24	11.6	21.7		15.2		5.6		16.7		0.8	6.8	7.2			5.2
25	25.4	19.6				3.4		14.1				7.6	11.7		5.4
Avg.	29.4	12.2	10.1	7.9	7.7	5.4	3.2	3.1	3.0	2.7	2.6	2.6	2.5	0.7	0.7

QUMO: *Quercus mongolica*, TIAM: *Tilia amurensis*, BESC: *Betula schmidtii*, ACPS: *Acer pseudosieboldianum*, PIDE: *Pinus densiflora*, KASE: *Kalopanax septemlobus*, ABHO: *Abies holophylla*, FRRH: *Fraxinus rhynchophylla*, MASI: *Magnolia sieboldii*, PIKO: *Pinus koraiensis*, MAAM: *Maackia amurensis*, ACMO: *Acer mono*, ULLA: *Ulmus laciniata*, COCO: *Cornus controversa*, ULDA: *Ulmus davidiana*

#1 (slope) 1) 6 2) 3) 4) 5) 8.3 6) 1.5 7) 1.80	#2 (ridge-slope) 1) 10 2) 6.16 3) 40.2 4) 9.0 5) 9.0 6) 2.5 7) 2.10	#3 (ridge) 1) 2 2) 5.19 3) 23.8 4) 6.7 5) 9.7 6) 2.0 7) 1.92	#4 (ridge-slope) 1) 3 2) 5.28 3) 28.0 4) 7.6 5) 30.0 6) 3.0 7) 1.65	#5 (ridge-slope) 1) 1 2) 5.22 3) 39.6 4) 11.5 5) 21.2 6) 2.0 7) 2.03
#6 (slope) 1) 2 2) 5.23 3) 47.3 4) 13.6 5) 13.4 6) 1.5 7) 2.14	#7 (ridge-slope) 1) 5 2) 6.36 3) 47.8 4) 11.4 5) 13.7 6) 1.5 7) 1.98	#8 (ridge) 1) 2 2) 4.99 3) 33.3 4) 6.6 5) 16.6 6) 2.5 7) 1.61	#9 (ridge) 1) 1 2) 5.34 3) 28.9 4) 7.2 5) 16.0 6) 4.0 7) 1.75	#10 (ridge-slope) 1) 1 2) 5.48 3) 32.3 4) 8.1 5) 15.1 6) 4.0 7) 1.77
#11 (slope) 1) 4 2) 5.87 3) 32.7 4) 6.6 5) 11.2 6) 2.0 7) 2.04	#12 (ridge-slope) 1) 2 2) 5.55 3) 33.9 4) 7.9 5) 18.6 6) 2.0 7) 2.05	#13 (ridge) 1) 1 2) 5.16 3) 31.7 4) 9.3 5) 16.7 6) 4.0 7) 1.54	#14 (ridge) 1) 0 2) 5.58 3) 33.9 4) 10.0 5) 11.7 6) 2.0 7) 1.00	#15 (ridge-slope) 1) 2 2) 5.04 3) 40.9 4) 10.5 5) 18.3 6) 5.0 7) 1.91
#16 (slope) 1) 5 2) 5.48 3) 39.9 4) 10.3 5) 8.2 6) 2.0 7) 2.02	#17 (ridge-slope) 1) 4 2) 5.21 3) 44.2 4) 10.6 5) 20.0 6) 2.5 7) 1.88	#18 (ridge) 1) 0 2) 5.20 3) 29.3 4) 5.6 5) 9.9 6) 2.0 7) 1.45	#19 (ridge-slope) 1) 3 2) 5.11 3) 37.9 4) 11.6 5) 12.2 6) 3.0 7) 1.96	#20 (ridge-slope) 1) 3 2) 5.73 3) 45.8 4) 12.1 5) 8.5 6) 1.0 7) 1.84
#21 (slope) 1) 4 2) 5.81 3) 37.6 4) 8.7 5) 19.8 6) 1.5 7) 2.08	#22 (ridge-slope) 1) 3 2) 5.57 3) 33.7 4) 7.1 5) 9.9 6) 2.0 7) 1.87	#23 (ridge) 1) 6 2) 4.96 3) 25.3 4) 6.3 5) 8.9 6) 1.0 7) 1.74	#24 (ridge-slope) 1) 2 2) 5.66 3) 55.1 4) 14.4 5) 30.3 6) 4.0 7) 1.99	#25 (ridge-slope) 1) 1 2) 5.69 3) 33.7 4) 8.1 5) 32.7 6) 6.0 7) 1.76

20m

Illustration 1. Topographical and soil characteristics of 25 study plots established by LTER site in Mt. Gyebang

#1 : Plot number, 1) number of *Kalopanax* tree, 2) soil pH, 3) soil moisture content (%), 4) soil organic matter (%), 5) total weight of organic matter (t/ha), 6) depth of litter layer (cm), 7) Shannon's diversity index

Katagiri 1988).

The annual DBH growth of *Kalopanax* by girth band according to the topographical sites and crown classes is shown in Table 4.

The dominant *Kalopanax* tree in valley areas indicated high growth of about 7.8mm per year, whereas suppressed ones showed almost no growth in ridge area. This result agrees with Kang and Lee (1998), which compared recent 30-year DBH growth of *Kalopanax* in each topographical site. Even though the DBH growth rate of *Kalopanax* was high in valley areas where soil moisture and nutrients contents are high, it was usually overcome by other tree species and released to ridge-slope areas.

The relationship between DBH growth rate and environmental factors was presented in Fig. 3.

In the results, it is believed that there is little relation between DBH growth and weather conditions

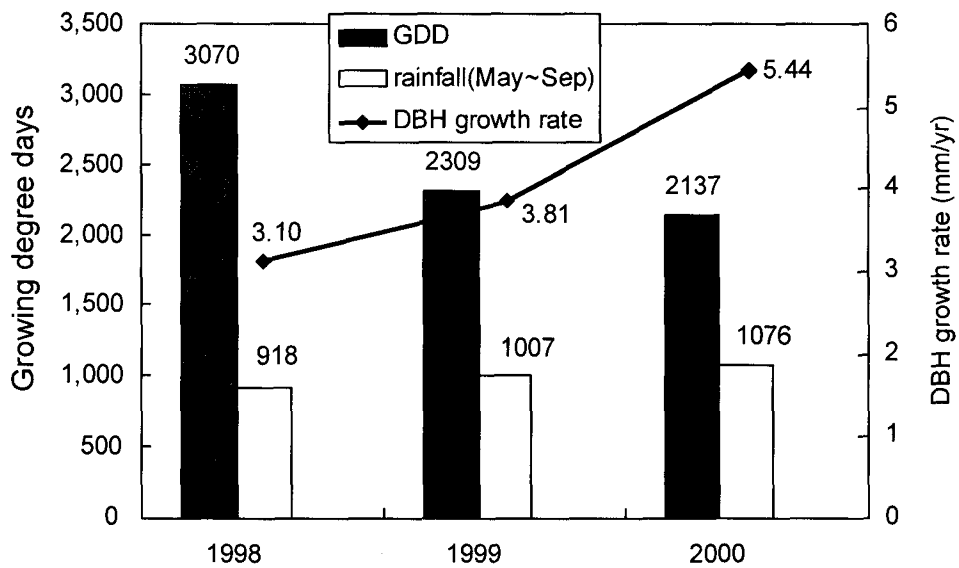


Fig. 3. Relationship between the environmental factors and DBH growth rate of *Kalopanax* in Mt. Gyebang

such as temperature and precipitation. DBH is mainly affected by topography and light conditions. However, more long-term observation is needed to prove this relationship.

2) Emergence, survival rate and growth of seedlings

Germination and emergence are strongly affected by micro-environmental conditions. Many researchers have reported on the relationships between micro-site conditions and seedling survival (Gobbi and Schlichter 1998, Nakamura 1996).

The seedlings of *Kalopanax* emerged in clumps and far from mother trees by birds (Yagihashi *et al.* 1998). Especially, the plantation areas are easily regenerated with little herb layer and low competition. It was found that *Kalopanax* seedlings were distributed in *Pinus koraiensis* plantation areas from 6 to 86 seedlings and mean density was 35.1 seedlings/25m^2 on May 2001 (Table 5).

The survival rate of *Kalopanax* seedlings during summer was higher than that during winter in this study area. The activities of wildlife such as voles seemed to be main cause for low seedling survival rate by damage to the roots during winter. Diseases by fungi and low light conditions from competition with herb and other tree species also induced a decrease in the survival rate of *Kalopanax* seedlings (Table 5).

Survival and growth of tree species in relation to light availability have been widely studied in natural environments (Chen *et al.* 1996, Shibata and Nakashizuka 1995). Many scientists have reported that survival rate of shade-intolerant species decreases with decreasing light availability while in shade-tolerant species it does not significantly change with light conditions (Kobe *et al.* 1995).

The height growth rate of *Kalopanax* seedlings was 54.6% and the root-collar diameter, 18.7% from

Table 4. DBH growth of mature trees by girth band in Mt. Gyebang

Topographical site	Crown class	1998 (mm)	1999 (mm)	2000 (mm)	Mean (mm) (1998-2000)
Valley	Dominant	6.53	8.50	8.31	7.78
Valley	Co-dominant	6.27	6.91	6.11	6.44
Valley	Co-dominant	4.07	5.73	5.67	5.16
Slope	Dominant	1.75	1.75	5.98	3.16
Ridge	Suppressed	0.03	0.03	3.47	1.18
Ridge	Suppressed	0.01	0.01	3.09	1.04
Mean (mm)		3.11	3.82	5.44	

Table 5. Emergence and survival rate of naturally regenerated *Kalopanax* seedlings in Mt. Jeombong

Plot	No. of *Kalopanax* seedlings			Survival rate (%)	
	June 2000	May 2001	Oct 2001	June 2000 ~ May 2001	June 2001 ~ Oct 2001
1	26	15	15	57.7	100.0
2	86	51	48	59.3	94.1
3	66	51	51	77.3	100.0
4	-*	52	44	-	84.6
5	-	35	30	-	81.1
6	-	45	45	-	100.0
7	-	33	33	-	100.0
8	-	52	50	-	96.2
9	-	18	17	-	94.4
10	-	28	28	-	100.0
11	-	6	6	-	100.0

* : not measured

Table 6. Height and root-collar diameter growth of naturally regenerated *Kalopanax* seedlings in Mt. Jeombong

Mean height (cm)		Height growth (cm/6months)	Mean root-collar diameter (mm)		Root-collar diameter growth (mm/6months)
May 2001	Oct 2001		May 2001	Oct 2001	
8.03	12.4**	4.4	3.3	4.0**	0.6

**: P<0.01 by GLM test for 5 plots

May to October 2001 (Table 6). Even though the light condition was low due to the shading of *P. koraiensis* trees, it showed high growth rate for six months. It is assumed that *K. septemlobus* is shade-tolerant at an early stage and maintains the activities of photochemical systems and CO_2 fixation systems in the low light intensity condition (Kim *et al.* 2001).

Acknowledgements

We would like to thank Dr. Joon Hwan Shin and Dr. Jong Hwan Lim in the Department of Forest Ecology, Korea Forest Research Institute for their help in the field study. Also thanks are given to Dr. Chin Sung Chang and Mr. Hui Kim in the Department of Forest Resources, Seoul National University for their assistance in the study. This research was supported by a grant from Korean Science and Engineering Foundation (KOSEF 996-0600-002-2, Ecology and Genetic Characters of *Kalopanax septemlobus* Growing in South Korea and Hokkaido, Japan).

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