

## Regeneration Process of the Korean Beech (*Fagus multinervis* Nakai) Forest

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**ABSTRACT:** Regeneration process of the Korean beech (*Fagus multinervis* Nakai) forest was studied in relation to the distributional pattern and age structure. In this study, it was clarified that the Korean beech forest is regenerated in both way: seedlings (sexual reproduction) and sprouts (vegetative reproduction) formations. In the large gaps, seedling may be established, resulting in clusters of even-aged individuals. But in the small-sized gaps, there may be filled by the extension of surrounding trees and/or by the young trunks, which have sprouted from the base of stumps. As most gaps in the *F. multinervis* forest were derived from falling of a single stem, regeneration by sprouts seems to be more common than that by the seedlings.

**Key words :** *Fagus multinervis*, Gap, Korean beech forest, Regeneration, Seedling, Sprout, Stump

### INTRODUCTION

The regeneration process of temperate forests has been described by many researchers (Watt 1947, Jonse 1945, Honma and Kimura, Nakashizuka and Numata 1982 a, b, Kim *et al.* 1986). In general, replacement of individuals occurs in canopy openings originated from the falling down of old trees. Bray (1956) called such an opening a "gap". It has been reported that climax beech forests regenerated mainly by such gap formation. Most of beeches reproduce only from seeds in natural condition, but the Korean beech, an endemic species to Ulreung Island, Korea, reproduces seeds and sprouts which develop from the base of stumps. Natural sprouting is well known in the shrubby species and shade-intolerant tree species such as *Alnus* spp., *Populus* spp., etc. Sprouting is also found in secondary forests originating by logging. Characteristically, the Korean beech produces numerous sprouts (adventitious shoots), showing a coppice-like appearance even in the natural forest. Thus, besides the seed production, the vegetative reproduction plays an important role in the natural regeneration of this beech forest.

The present study aims to investigate the regeneration process of the Korean beech forest. Particularly, in this paper, the regeneration process is discussed in relation to the distributional pattern of individual trees and age structure of forest.

### STUDY SITES

The study plots were set up on the northern slope of Mt. Seonginbong (984.6 m), Ulreung Island, Korea. Two quadrats (50

m × 50 m and 25 m × 80 m) were located on gentle slopes (Qd. 1; N24W, 20°, Qd. 2; N65W and 10°) at 820-850 m in altitude.

The climate of this island is characterized by heavy snowfall in winter, due to the cold winds blowing across the East Sea from the Asian Continent. Mean annual precipitation is 1,485 mm, and much of them occur in winter. Moreover the intersection of two currents, the warm Tsushima Current and the cold Liman Current, is laid around the island, and thus the montane zone of this island has frequent fogs. There are only 49 days of fine weather in one year. Mean annual temperature is 12.0°C, mean daily maximum temperature of the warmest month is 27.2°C and mean daily minimum temperature of the coldest month is -15°C at 221 m in altitude (Meteorological data from Meteorological office of this island). Most of soils of the study sites in this island belong to the Brown Forest Soil Group derived from the volcanic ejecta (Machida *et al.* 1984).

The physiognomy of the study sites was characterized by the dominance of beech which formed large stumps (Fig. 1). The stumps are rather sparse than the single stems in the forest. This beech forest named as *Hepatico - Fagetum multinervis* Kim, Kimura and Yim 1986 by the phytosociological nomenclature.

### METHODS

The field surveys were carried out during summer and autumn of 1986-1995. In each quadrat, DBH (diameter of breast height), tree height and the number of stump sprouts of every trunk, and their distribution in the quadrat were measured, and crown projection diagrams were drawn. D<sub>0</sub> (diameter at the base), DBH (if

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Fig. 1. Physiognomy of *Fagus multinervis* forest(A) and a cluster of even-aged individual trees in Qd. 1(B).

measurable) and ages of all seedlings and saplings were also measured. Some of trees were harvested for the stem analysis.

Increment cores were sampled for the determination of tree ages with an increment borer at the height of 50 cm above the ground. The annual rings were counted with the aid of binocular microscope in the laboratory. The counted number of annual rings was used as stem ages. The age of the beech seedling were estimated by counting bud scars in the field.

In the present paper, I used some words under definitions as follows:

- Seedling; a juvenile shorter than 50 cm originated from seed
- Sapling; a young tree taller than 50 cm and with DBH less than 3 cm, originated from seed
- Trunk; a tree with DBH more than 3 cm, originated from either seed or sprout
- Individual tree; a tree with a trunk which reaching the canopy with/without sprouts
- Stump; an individual with more than 2 trunks which reaching the canopy

RESULTS

Stump structure of *F. multinervis*

There were 26 beech stumps in Qd. 1, and 16 stumps in Qd. 2. Shape and size of each stump were various(cf. Fig. 5). Thus, mean stumps diameter(MSD) was used to show the stump size. It was a mean of the longest diameter of a stump measured along the slope direction and d diameter at right angles to that. The maximum MSD of Qd. 1 was 4.56 m and that of Qd. 2, 5.26m. MSD frequency in Qd. 1 is shown in Fig. 2-a. Each stump has a large number of stump sprouts, with the maximum of 1,175 and 1,474 in Qd. 1 and Qd. 2. The DBH frequency of all stems of some randomly selected stumps in Qd. 1 is shown in Fig. 2.

For analysis of the age structure of stumps, three of them S-6(MSD; 0.75m), S-8(MSD; 1.40m) and S-26(MSD; 2.45m) were selected in Qd. 1. The former two were young stumps which do not have dead centers and the last was old one with 127 sprouts, 10 trunks and a dead center. On a stump which does not have a dead center, the age of the oldest trunk was regarded to be the same as a stump age: 109 years for S-6 and 120 years for S-8. The age of S-26 could not be estimated because of the dead center. The age distribution and height growth curves of all trunks of S-26 are shown in Fig. 3. From the DBH frequency of all stems, the age structure and height growth curves of trunks S-26, it is clear that trunks within a stump are replace by the sprouting stems.

A general shape of this beech stump is a circle with the tallest and oldest stem at the center and younger stems on the fringe. The circular arrangement of stems expands outward stump. Eventually, older stems at the center may get old and die. As

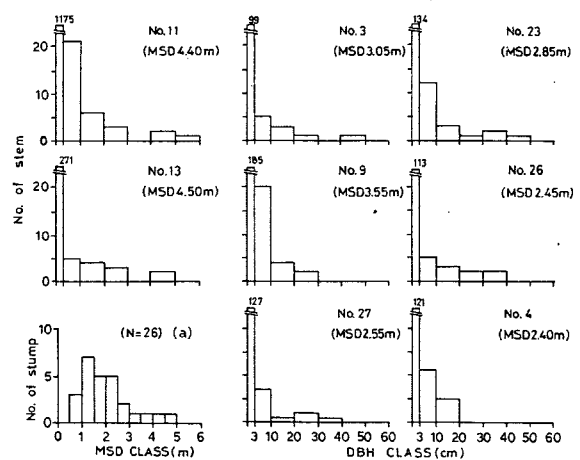
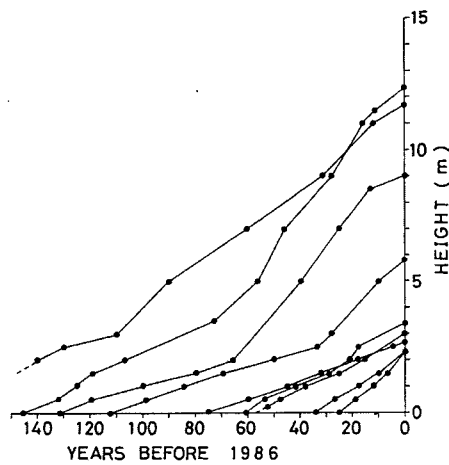


Fig. 2. Distribution of mean stump diameter(MSD) of all stumps(a) and DBH-class distribution of stems in randomly selected stumps in Qd. 1.



**Fig. 3.** Age composition and height growth curves of all stems (DBH > 3cm) of an old stump(S-26) in Qd. 1.

such senescence is repeated over time, a dead center is created at the center of the stump. Thus, an old stump is considered to be maintained by sprouting for a very long time. A stump may die someday in future, but we, with a short life, do not know the length of the life span of individuals of this beech.

**Forest structure**

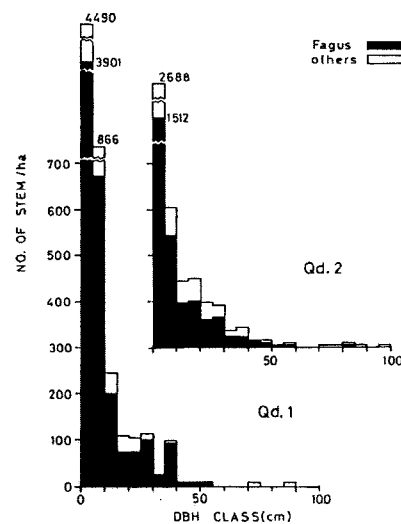
There were 9 woody species in all in the two quadrats. Total number of stems was 4,208(16,832 stems/ha) in Qd. 1 and 6,916(43,225 stems/ha) in Qd. 2, respectively. The number of trunks(DBH ≥ 3 cm) in Qd. 1 was 973 (3,892 trunks/ha), of which 538 trunks(2,154 trunks/ha) were beech, and 795 trunks(4,969 trunks/ha) in Qd. 2, with 707 beech trunks(4,417 trunks/ha). The ratio of basal areas and number of trunks of tree species in each quadrat were shown in Table 1. The DBH class distribution of all stems was shown in Fig. 4. The density of stems in Qd. 2 was much higher than that in Qd. 1. The total trunk density and the density of beech trunks of Qd. 2 were more than 1.2 times and 2 times as high as those of Qd. 1, respectively. However, the densities of canopy trees(tree height > 10m) were nearly equal. This fact shows that the difference in density between the two quadrats was the difference in density of small trunks and sprouts.

In spite of natural forest, most of the beech stems of these quadrats were originated from the stump sprouts. The proportion of sprout stems to all the stems was 87.5% in Qd. 1 and 95.8% in Qd. 2. Among them, 92.5% and 96.3% were beech in each quadrat. There were 225 seedlings in Qd. 1 and 285 seedlings in Qd. 2. Most of these seedlings were distributed in gaps or at the margin of gaps(Fig. 5), especially on the floor of deciduous herb type and of dead Sasa type. These facts suggest that the dense cover of Sasa and Rumohra standishii would strongly inhibit the establishment of tree seedlings. The inhibitory effect of Sasa on

**Table 1.** Floristic composition of tree species, the ratio of basal areas and No. of stems in Qd. 1 and Qd. 2

	Ratio of BA (%)		No. of stem (%)	
	Qd. 1	Qd. 2	Qd. 1	Qd. 2
<i>Fagus multinervis</i>	61.8	66.7	65.5	88.9
<i>Acer takesimense</i>	2.6	1.7	3.3	2.6
<i>Acer okamotoanum</i>	7.1	9.5	4.4	1.2
<i>Prunus takesimensis</i>	12.2	4.1	5.2	3.1
<i>Sorbus commixta</i>	7.1	5.6	16.5	2.1
<i>Tilia insularis</i>	5.7	11.5	1.7	0.7
Other species	3.5	0.9	3.4	1.4
<b>Total</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>
	<b>38.8</b>	<b>48</b>	<b>16,832</b>	<b>43,225</b>
	(m <sup>2</sup> /ha)		(no./ha)	

Other species : *Cornus controversa*, *Styrax obassia*, *Ulmus laciniata*.



**Fig. 4.** DBH-class distribution of all stems in Qd. 1 and Qd. 2.

the regeneration process has been also reported in the Japanese beech forest(Nakashizuka and Numata 1982 a,b).

The age structure of individual trunks was studied in Qd. 1 with an increment borer, the maximum ages of trunks could not be estimated, because most of trunks with more than 30cm in DBH had rotten centers. The maximum age of beech trunk without a rotten center was 120 years, measured on the oldest trunk(DBH: 27.6cm) of a young stump. Among the other species, there were no trees older than 128 years. It was suggested that beech has the longest life span of all species at the present sites. The age-class of all individual trunks was shown in Fig. 6. Many trees in each group were concentrated in a certain age-class. This suggests that most of those trees emerged simultaneously, and a few of them could reach the canopy.

**Distribution pattern**

It is indispensable to know the distributional pattern of trees in order to estimate the interaction among them. In particular, Iwao's  $m - m^*$  regression method (Iwao 1968, 1972, 1977) is convenient for detecting clumps.

Beech stems are grouped into the following four groups as follows;

A:  $DBH \leq 3$  cm, and height  $\leq 1.5$  m originated from seed

B:  $3 \text{ cm} < DBH \leq 10$  cm, and  $1.5 \text{ m} < \text{height} \leq 10$  m originated from seed

C:  $DBH > 10$  cm, and height  $> 10$  m individual trees and young stumps without dead center

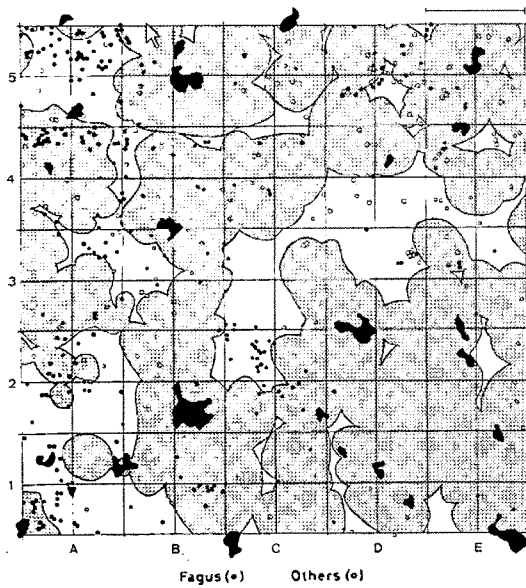
D: stumps which have dead centers

The stems of C reached the canopy. The stems of B were in the process of growth or were being suppressed by the stems of C and D.

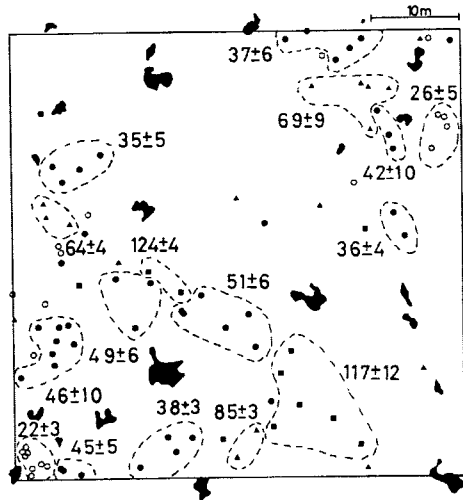
D showed a random or rather uniform distribution, while the other three groups showed a contagious pattern (Fig. 7). The latter three groups had a loose clump structure, and the clumps themselves were distributed nearly at random. Mean size of these clumps was detected by using  $\omega$ -index (Iwao 1972). Mean clump size was 25-100  $m^2$  for A, 25-200  $m^2$  for B and 50-200  $m^2$  for C, respectively.

The distributional relationships among the four groups were detected by using  $\omega$ -index (Iwao 1977). Considering the mean area of clumps and crowns of large stems in stumps (about 56.7  $m^2$  on the average for group D), four sizes of unit quadrat, 25, 50, 100, 200  $m^2$ , were used to detect the distributional relationship between the four groups. Group D has a negative relationship with group A and C (Table 2), while positive relationship with group B. In other words, seedlings and individual trees had a tendency not to distribute under the crowns of stumps. B and C showed a positive relationship with each other. These facts suggest that group B included the suppressed trees.

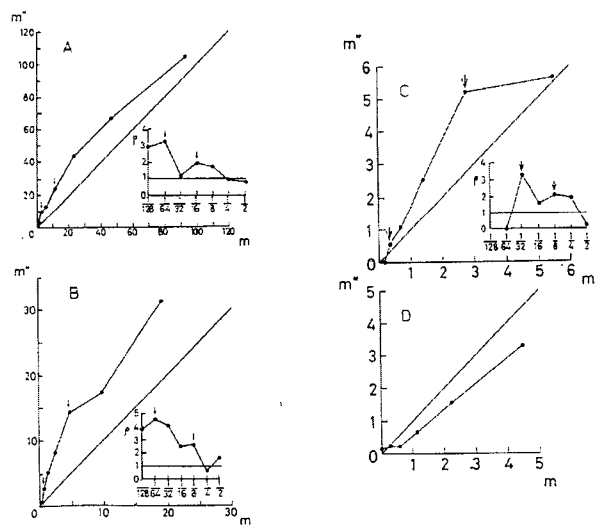
The establishment of beech seedlings is limited to gaps. As seedlings grow up, competition occurs among them, and a large number of individuals are naturally thinned. Consequently, only a few individuals can successfully form large stumps, and the dis-



**Fig. 5.** Distribution of all seedlings and saplings in Qd. 1. The crowns of stems above 10 m in height are shaded. Irregular solid spots indicate the location, shape and size of beech stumps.



**Fig. 6.** Ageclass distribution map of individual trees in Qd. 1. Even-aged clusters are grouped. An attached numerals shows the mean age of each cluster (Age class:  $\circ < 30$ ,  $\bullet 30-59$ ,  $\blacktriangle 60-79$ ,  $\blacksquare > 80$ ).



**Fig. 7.** The  $m - m^*$  relationships of beech trees. The lower-right graphs of A, B and C show the change of  $q$  index. Arrows indicate the mean clump size.

**Table 2.** Value of  $\alpha$ -indices showing distribution relationships among four groups

		B	C	D
25 m <sup>2</sup>	A	-0.080	-0.176	-0.500
	B	—	0.349	0.369
	C	—	—	-0.129
50 m <sup>2</sup>	A	-0.066	-0.144	-0.308
	B	—	0.346	0.544
	C	—	—	-0.919
100 m <sup>2</sup>	A	-0.121	-0.082	-0.183
	B	—	0.308	0.586
	C	—	—	-0.972
200 m <sup>2</sup>	A	-0.071	-0.038	-0.370
	B	—	0.457	0.591
	C	—	—	-0.981

tribution pattern of these large stumps becomes nearly random or uniform.

### Gaps

The open parts where tree crowns do not reach to the height of 10 m were regarded as gaps. In the case of gaps derived from the death of a single trunk of a stump, sprout trunks of the same stump may grow up to the canopy. And also, a very small gap may be filled by the extension of crowns of sprout trunks and surrounding trees before seedling or saplings in the gap have grown up to the canopy.

Among many gaps in Qd. 1, four gaps were selected for analysis of floristic composition, DBH-class (or  $D_0$ -class) and age-class distributions of young trees. As seen in Fig. 5, *F. multinervis* seedlings were found in most of the gaps. In general, there was no significant difference in the floristic composition in gaps between in Qd. 1 and Qd. 2, as far as the floor type was the same. Many seedlings were found on the floors of deciduous herb type and dead *Sasa* type in gaps and at the margin of gaps. In contrast, they were scarcely found under a dense cover of *Sasa* and of *Rumohara standishii*. A few seedlings of *Cornus controversa* and *Tilia insularis* were found only in the disturbed place covered by *Rumohara standishii*. As mentioned above, it may be certain that the dense cover of not only *Sasa* but also *Rumohara standishii*, an evergreen fern, will inhibit the establishment of beech seedling. Characteristically, there were no pioneer species in the gaps at the present site. This fact is in contrast with the Japanese beech forest where the occurrence of pioneer shrubby and subtree species has been reported (Honma and Kimura 1982, Nakashizuka and Numata 1982a, b, Hara 1983).

The trees of each gap were nearly even-aged, while the DBH-class (or  $D_0$ -class) distribution of trees had a somewhat wide range of distribution. It seems likely that most of the trees in each gap emerged simultaneously, followed by the competition among them which brought about the difference of dominant and

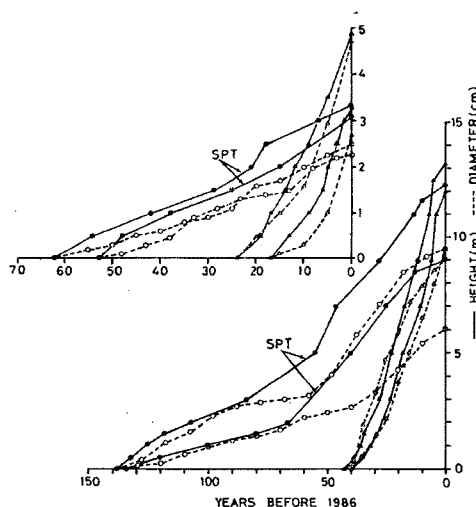
suppressed trees.

### The growth of trees

Canopy stems which originated from seedlings in gap grew rapidly. The oldest of them in Qd. 1 was 43 years. Average radial growth rate ( $Do/age/2$ ) was 2.18 mm/year and average height growth rate (height/age) was 30.7 cm/year. This growth rate was maximum for the sampled trees. In contrast, the radial and height growth rates of a canopy stem, which originated from a sprout were only 0.69 mm/year and 8.9 cm/year respectively (Fig. 8). Sapling in gaps also grew fast: for example, average radial growth rate of a sapling was 2.10 mm/year and average height growth was 21.3 cm/year. But sprout stems which nearly the same DBH with sampled saplings showed 0.34 mm/year for the radial and 5.37 cm/year for the height growth rate (Fig. 8).

In general, the growth of sapling and individual trees which may succeed to become dominant in gaps, were rather faster than that of sprout stems. Average growth rate of the former two were nearly the same. Fig. 9-a shows relationship between height and DBH of all beech stems, and Fig. 9-b shows relationship between stem ages and height of individual trees in Qd. 1. There was a positive relationship between stem ages and tree height. These facts indicated that there are many suppressed trees but a few successor trees in the natural beech forest.

As shown above, canopy stem originated from sprouts showed greater growth rates than small-sized sprout stems when the growth rates were calculated on total life. However, the growth rates calculated on the early few decades after initiation were nearly the same. All sprouts originated on the base of stumps and had to grow in deep shade under the canopy of the same stump before canopy opened. Thus, early growth patterns of the sprout stems were nearly the same.



**Fig. 8.** Comparison of radial and height growth between stems originated from seedlings and sprouts (SPT).

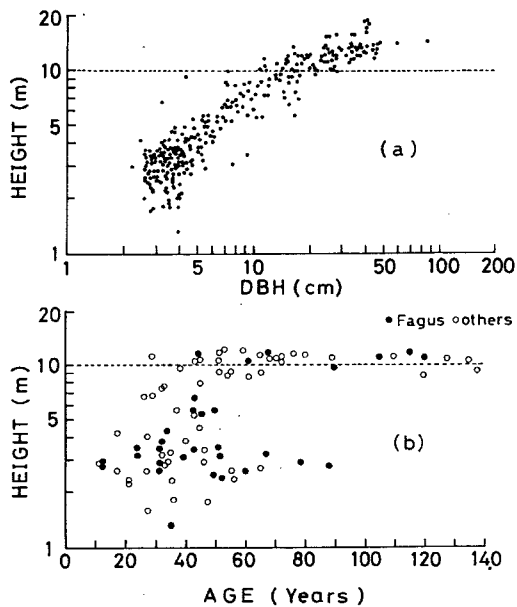


Fig. 9. Relationship between DBH and height of *F. multinervis* (a), and relationship between stem ages and height(b) of stems which originated from seedlings.

## DISCUSSION

Since Watt (1947), various kind of investigations have been carried out on vegetation from the aspect of forest structure, especially on the change of distribution pattern of trees through time.

Some studies on the Japanese beech (*F. crenata*) forests (Honma and Kimura 1972, Nakashizuka and Numata 1982, Hara 1983) reported that large trees were distributed either randomly or uniformly, while middle-or small-sized trees were distributed as clumps consisted of trees of nearly the same ages. After the gap formation by the falling down of old trees, dense group of seedlings are established and grow vigorously. As a consequence, *F. crenata* forest has a mosaic structure of clumps, and the regeneration process is repeated in every unit of this mosaic. This regeneration process of *F. crenata* forest, is the same as pointed out by Watt (1947). The present results verify that the regeneration process of *F. multinervis* forest is, in some respects, the same as that of *F. crenata* forest.

On the other hand, *F. multinervis* produces numerous sprouts on the base of stumps, and the stump expands outward with the circular arrangement of sprouting stems. Eventually, older canopy stems at center may die, and other trunks within the same stumps grow up to reach the canopy. As such replacement of the canopy stems by sprouting stems, the stump is con-

sidered to be maintained for a long time. Several authors pointed out that some component species respond to damage or disturbance with various forms of vegetative reproduction, which play an important role in forest regeneration. Marks (1974) cited some examples of forest communities reorganizing their structure after disturbance by means of different types of vegetative reproduction; production of epicormic branches of undamaged tree adjacent to or within an openings, and production of stump sprouts and/or root suckers from damaged individuals within opening. In the *F. multinervis* forest, stump sprouts, as well as seedling, doubtlessly play an important role in the regeneration processes.

In conclusion, the Korean beech forest regenerates in both ways; seedling formation (sexual reproduction) and sprout formation (vegetative reproduction). In a large gap, seedlings may be established, resulting in clusters of even-aged individuals. Gaps derived from the death of single trunk of the center of stumps and small-sized gaps may be filled by the young trunks which have sprouted from their base of stumps and/or the branch extension of surrounding trees. As most gaps in the Korean beech forest were derived from falling of a single stem, regeneration by sprouts seems to be more common than that by the seedlings.

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