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Distribution of *Acer palmatum* Seedlings under the Crown of the Maternal Tree

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To investigate the relationship between crown width of a parent plant and seedling distribution, seedling ages and sizes, and their distances from the maternal tree were surveyed under a maple (*Acer palmatum*) crown at Chungdam Park, Chungdam-dong, Kangnam-gu, Seoul, in 1998. Maple crown width increased 33.0 cm per year during the eight-year study. Seedlings ranged from 1 to 10 years old; their density was highest the third year, and decreased with age. Seedling-distribution ranges from the parent plant were 43 cm to 487 cm, and seedling density was highest at the border of the parent plant canopy. One-year-old seedlings were distributed broadly, but the main distribution areas became more distant from the maternal plant with seedling age. Seedling heights increased with age; differences between two consecutive ages were significant at the 0.1% level for ages less than 5 years, but not for over 6 years. For seedlings of the same age, heights were similar, but short under the tree crown, but were varied and taller outside the crown. The variation in seedling height increased with age and distance from the parent plant. In particular, seedlings older than 5 years that were distributed outside the crown showed conspicuous variations among distance classes. Therefore, maple seedlings were distributed to an appropriate distance at which their growth could be supported by the understory-light environment. This study demonstrated that new *A. palmatum* trees are not recruited from the seedlings growing beneath the crown but from those that grow vigorously outside the crown.

Keywords: Crown, Density, Maple (*Acer palmatum*), Seedling age, Seedling distribution, Seedling size

Plants produce many seeds, which are dispersed as far away as possible. However, the environment prevents all the seeds from germinating and developing into mature plants. The distance of seed dispersion varies among species (van der Pijl, 1972). Although small seeds generally can migrate a long distance, most fall near the maternal plant, and seed density is highest there (Hubbell, 1980; Dalling et al., 1998).

So many seeds land under the maternal plant crown, thus forming a seedling bank there (Streng et al., 1989). Two factors, however, are involved in the decrease in seedling density over time. One factor is abiotic influences, such as 1) light intensity, which is very low under the canopy, but increases nearer the canopy gap, and 2) the soil microenvironment, which varies with site (Runkle et al., 1995). Seedlings of various species have different tolerances for low light or a particular soil microenvironment (Huenneke and Sharitz, 1986; Gray and Spies, 1996). Except for those species that demand a large amount of infrared radiation, seedling growth is extremely limited under a dense canopy (King, 1975; Fenner, 1978). Therefore, seedling distribution tends to be denser in microenvironments that are more suited for future growth (Gross and Werner, 1982).

The other factor is biotic influences, such as predation by herbivores, competition for water and minerals among seedlings or between seedlings and the maternal plant, decay by pathogens, and allelochemicals that are secreted by the maternal plant or vegetative competitors (Janzen, 1970; Grubb, 1977; Fenner, 1978; Augspurger, 1983a; Schupp, 1988, 1995; Houle, 1992, 1994). In these cases, seedling density is highest at a particular distance from the maternal plant (Janzen, 1970).

It is unclear, however, whether seedling density depends on distance between the seedling and maternal plant, or on the density itself. Light is the main factor that limits understory plant growth (Grime, 1979; Chazdon, 1988; Lorimer et al., 1994; Sipe and Bazzaz, 1994; Gray and Spies, 1996; Lee, 1996). However, seedling survival depends not only on density, growth rate, growth period, and neighbors of cohort (Ross and Harper, 1972; Harper, 1977) but, also, on distance from the maternal plant and elapsed time. Generally, the no seed area between seedling and maternal plant increases over time (Augspurger, 1983b; Houle, 1998). Accordingly, the current population of seedlings moves toward the canopy gap,

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thereby decreasing competition among seedlings of the same species. When determining the optimum relationship between seedling growth and distance from the maternal plant, a canopy gap is necessary for maintaining a pure stand (Grubb, 1977; Runkle et al., 1995). As an example, sun trees produce and disperse their small seeds over a long distance, demonstrating a good, adaptive strategy (Crawley, 1986).

Acer is normally a late-successional species in Japan and North America, where it produces many light seeds that are dispersed by the wind (Streng et al., 1989). Because this is a shade-tolerant species, seedlings are produced under the canopy rather than in the canopy gap (Ishizuka and Sugawara, 1989; Burns and Honkala, 1990; Lorimer et al., 1994; Abe et al., 1995; Seiwa and Kikuzawa, 1996; Seiwa, 1998). The number of survivors decreases with distance, and mature plants are few (Hett, 1971). *Acer* is a shade-tolerant species, but its seedlings prefer high levels of solar radiation. Almost all the seeds of *Acer mono* and *Acer rubra* germinate primarily in the early spring, before trees are in full foliation and beginning another year of seed dispersion. In fact, 50 ~ 79% of the growth of a first-year seedling occurs during this two-month early season (Streng et al., 1989; Seiwa, 1998). By germinating and growing early in the season, seedlings can receive maximum solar radiation and reduce their susceptibility to damage from herbivores and pathogens (Seiwa, 1998).

The seedling growth of *A. mono, A. rubra*, and *Acer saccharum* is affected by radiation levels when located under the canopies of other species, but the main factor that regulates its growth under the maternal plant is not clear. Understory seedlings are important for assuring forest regeneration after site disturbances (Pickett and White, 1985). In temperate deciduous forests, *Acer* is one of the main woody plants in the late-successional stage, so studies on seedling recruitment are necessary. In Korea, *Acer* research has focused mainly on taxonomy and systematics (Park, 1984; Park and Kim, 1984a, 1984b; Chang, 1991, 1994; Park et al., 1993, 1994; Suh et al., 1996), physiology (Choe and Lee, 1995), seed germination (Kim, 1984), and distribution in the Korean peninsula (Kim et al., 1981). Little is known about its ecology.

This paper describes the maternal influences on seedling growth in *Acer palmatum*. Recruitment under the crowns was estimated by surveying seedling distribution, in terms of seedling density, age, and height, as well as the increase in maternal plant crown width.

STUDY AREA AND METHODS

The study area was previous described (Min, 2000), and was located in Chungdam Park, Chungdam-dong, Kangnam-gu, Seoul, Korea (37°31'N, 127°03'E). The total area of this park is 57,854 m^2, with an elevation of 68 m on the center peak and 37 m on the edge. The surveyed plants were located to the north of center. This particular site had a 20° slope and a 50-m elevation. Four maples (*A. palmatum*) were planted at 8-m spacings, and their crowns did not overlap. Human access was limited by fencing. The peripheral region contained two tree species, *Magnolia kobus* and *Pinus rigida*; as well as *Rosa multiflora, Forsythia koreana*, and *Pueraria thunbergiana* in the shrub layer; and *Scilla scilloides, Carex lanceolata, Spodiopogon sibiricus, Eupatorium rugosum, Persicaria perfoliata*, and *Youngia japonica* in the herb layer. The coverages of these layers varied by site and season. The litter layer was 10 cm. Good soil moisture conditions enabled fungi to grow in spring and summer. Few other plants besides maple seedlings were found under the maple crown.

The field survey was conducted from May 15 to 18, 1998. The maternal plant was 20 years old, 24.9 cm in dbh, 4.8 m tall, and was branched into two at 50 cm. Because the trunk was erect but with branches growing horizontally and sparsely, the understory solar radiation was feeble in the center, but increased with distance (Fig. 1). The lines for sampling were set up to the north and east of the maternal plant, and seedlings were surveyed in a fan-shaped quadrat that was 5 m in radius. No seedlings were located outside the circumference.

For each sampled seedling, age, height, and distance from the maternal plant were recorded. A total of 1078 seedlings were surveyed in the quadrat. The change in mother-crown width was estimated by measuring the internode length of 6, 8-year-old branches that were growing horizontally. The estimated length of the crown breadth for each year was based on the proportion between total crown width and internode length.

Eight years of data for air temperatures and precipitation were supplied by Seoul Station (37°34'N, 126°58'E, 85.5 m altitude see level; Korea Meteorological Administration, 1991-1998). These are shown in Table 1. The annual mean precipitation and air temperature were 12.7°C and 1,395.2 mm, respectively. Precipitation levels varied markedly, from 1,055.8 mm (1994) to 2,349.0 mm (1998). Monthly precipitation is uneven throughout the year; the rainy

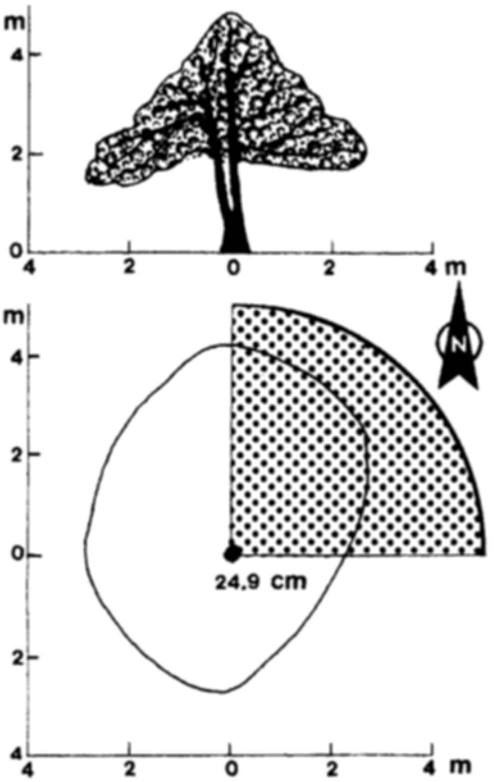

Figure 1. Diagram showing the profile (upper) and crown projection (lower) of the parent plant, and the location of quadrat (⁞⁞⁞).

season (July or August) accounts for 30% of the annual total. In contrast, air temperatures ranged from 12.0°C to 13.8°C, with no difference among the years. Monthly mean air temperatures varied from −1.8°C (January) to 25.5°C (August), but differences were minor among the same month for each year. During the growth season the main factor affecting plant growth probably was precipitation rather than air temperature. Foliation time for maple is from April to May (Min, 2000). Air temperatures and precipitation amounts during the early growing season were 10.2 ~ 15.6°C, 44.4 ~ 120.2 mm in April; 16.4 ~ 19.0°C, 29.3 ~ 291.3 mm in May; and 20.9 ~ 23.4°C, 70.7 ~ 234.1 mm in June, respectively. Because precipitation varied among years by 2.7 to 9.9 times, plants that are sensitive to soil moisture content probably were affected by the levels of precipitation in the early growth season.

RESULTS AND DISCUSSION

Changes in Crown Width

Table 2 shows the changes in crown width over eight years, as estimated from internode lengths. The mean internode length was 24.8 cm, with the longest (34.0 cm) being measured in 1993, the shortest (11.8 cm) in 1996. The crown width increased by 16.5 cm per year. The mother plant was 4.8 m tall, with a crown width of 6 m. Because the mother tree was wider than it was tall, the growth of twigs was more than that of trunk, which indicates that this plant had not been shaded by any other. Shade-tolerant species like maple show faster growth in their

Table 1. Climate of study area 1991-1998. P, precipitation (mm); T, air temperature (°C).

Year		Month												Total/ Mean
		1	2	3	4	5	6	7	8	9	10	11	12	
1991	P	14.4	28.4	65.5	48.5	83.2	81.8	487.8	68.2	175.2	27.3	35.0	42.9	1158.2
	T	−2.6	−0.9	4.9	13.0	17.5	22.6	24.3	25.5	21.1	13.8	6.5	2.2	12.3
1992	P	13.6	46.6	11.2	76.5	155.5	99.6	270.1	418.8	168.5	33.6	89.5	71.4	1454.9
	T	−0.2	0.7	7.6	12.0	16.4	20.9	24.8	24.8	20.9	14.0	6.2	1.5	12.5
1993	P	2.2	69.5	29.2	85.5	83.5	198.2	424.6	197.8	56.1	15.4	66.6	12.1	1,240.7
	T	−1.9	1.0	5.8	10.6	18.2	21.3	23.3	23.2	21.2	13.4	8.5	−0.2	12.0
1994	P	6.5	14.8	31.7	44.9	152.4	85.0	139.5	232.7	60.7	214.5	49.6	23.5	1,055.8
	T	−0.9	0.8	4.0	15.2	17.9	22.8	28.5	27.6	21.0	15.2	9.3	1.1	13.5
1995	P	11.6	5.2	60.6	44.4	60.6	70.7	436.1	786.6	47.2	39.3	32.9	3.4	1,598.6
	T	−2.1	1.2	6.0	11.3	17.1	21.6	24.5	26.0	20.0	15.5	6.2	−1.0	12.2
1996	P	16.3	1.0	77.9	62.0	29.3	249.7	512.8	132.4	11.0	90.3	62.9	11.0	1,256.6
	T	−2.2	−1.6	4.9	10.2	18.4	22.3	24.4	26.0	22.0	14.5	6.1	1.6	12.2
1997	P	16.8	39.6	25.3	56.1	291.3	110.0	299.6	117.2	76.9	45.5	93.8	38.1	1,210.2
	T	−3.2	0.7	6.8	13.0	17.0	23.4	26.1	26.8	20.2	13.4	8.8	1.8	12.9
1998	P	10.4	32.3	45.1	120.2	121.5	234.1	311.8	1237.8	177.9	27.3	26.9	3.7	2,349
	T	−1.3	3.4	7.3	15.6	19.0	21.9	24.9	25.0	23.0	17.0	7.3	2.3	13.8
Mean	P	11.5	29.7	43.3	67.3	122.2	141.1	360.3	389.9	96.7	61.7	57.2	25.8	1,395.2
	T	−1.8	0.7	5.9	12.6	17.7	22.1	25.1	25.6	21.2	14.1	7.4	1.2	12.7

Table 2. Internode length of maple twig and the estimated crown width from base of bole for eight years.

Year	Node length (cm)	Crown width from base of bole (cm)
1991	26.0 ± 4.1	167
1992	26.3 ± 4.1	187
1993	34.0 ± 5.7	213
1994	26.8 ± 6.0	233
1995	17.3 ± 5.3	246
1996	11.8 ± 5.1	255
1997	27.3 ± 3.6	276
1998	28.3 ± 7.7	299
Mean	24.8	

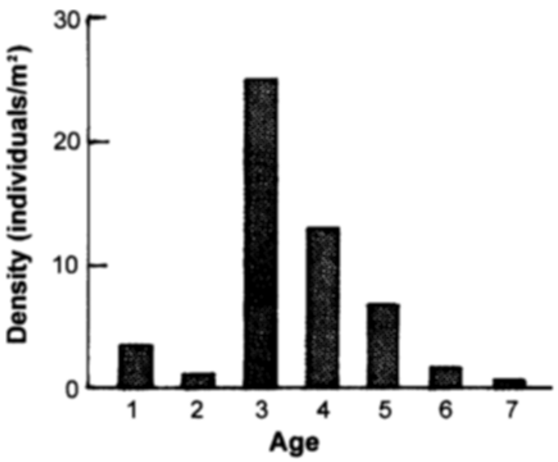

Figure 2. Variations in maple seedling density by age.

twigs than in the trunk when exposed to full light (Kuppers, 1989; King, 1990).

Seedling Distribution

Seedling ages ranged from 1- to 10-years-old, and the number of those older than 8-years was few (Fig. 2). Overall density was 52.1 individuals/m^2. The density of the 3-year-olds was 24.8 individuals/m^2, which was the highest for any age class. Seedling density decreased for those more than 3 years old. The 1- and 2-year-olds were less dense than the 3-year-olds, probably because of incomplete seeding, an unsuitable microsite (Huenneke and Sharitz, 1986), or space limited by other seedlings.

Because seeds can be more susceptible to predators as well as being incompletely formed during years of abundant production (and *vice versa*), the density of germinated seedlings does not show annual fluctuations in *Hamamelis virginiana* (de Steven, 1982). This phenomenon is not true in maple. The number of over 4-year-old seedlings abruptly decreased not only because the originally high density promoted self-thinning but also because of high seedling mortality (Hett, 1971; Streng et al., 1989). This trend also was seen in similar studies. *Quercus* and *Betula* seedlings, growing under dense crowns, showed poor growth and 70% mortality within five years (Lorimer, 1989; Runkle, 1990; Lorimer et al., 1994; Houle, 1998). This high mortality is thought to be a mechanism for controlling the density of mature plants (Clark et al., 1998).

Seedling distribution at 10-cm intervals of distance from the maternal plant is shown in Figure 3. The first seedlings were located 40 ~ 49 cm from the mother, at a density of 14.2 individuals/m^2. Seedling density increased to a maximum of 216.3 individuals/m^2 in the 240 ~ 249 cm interval, and decreased thereafter.

The lack of any seedlings within 40 cm of the maternal tree indicates that this area was unsuitable for growth. An allelopathical interaction has not been demonstrated in maple, as has been found with other species (Huenneke and Sharitz, 1986). Other factors may have been involved, such as shading or unsuitable topography. High seedling densities were found from 220 ~ 420 cm, and coincided with crown width. Seedlings tended to be distributed mainly at the periphery, which suggests that this area provided the seedlings with a good microenvironment, especially the proper light intensity (Grime, 1979; Chazdon, 1988; Gray and Spies, 1997; Seiwa, 1998). This result is supported by the model by Janzen (1970) in which seedlings were distributed at a constant distance from the maternal plant, but not beyond 490 cm. Conifer seedlings grow poorly under direct solar radiation (Gray and Spies, 1996), and this result might be similar to conifer.

When seedling distribution was classified according to age, 1-year-old seedlings were found at distances of 40 ~ 489 cm, particularly from 140 ~ 379 cm. Density for that age group was highest in the 170 ~ 179 cm interval, with 18.2 individuals/m^2, but was similar across almost the entire range.

Two-year-old seedlings primarily grew in the range of 80 ~ 479 cm, and 140-319 cm. Their greatest density was 10.3 individuals/m^2 at 180 ~ 189 cm, which was the lowest for any age class. Compared with the 1-year-olds, this distribution range was reduced and more distant from the maternal plant. The three-year-old seedlings were found at 50 ~ 469 cm, and were most dense, with 122.6 individuals/m^2, at 260 ~ 269 cm, i.e., the periphery of the maternal plant crown. Four-year-old seedlings were distributed in the range

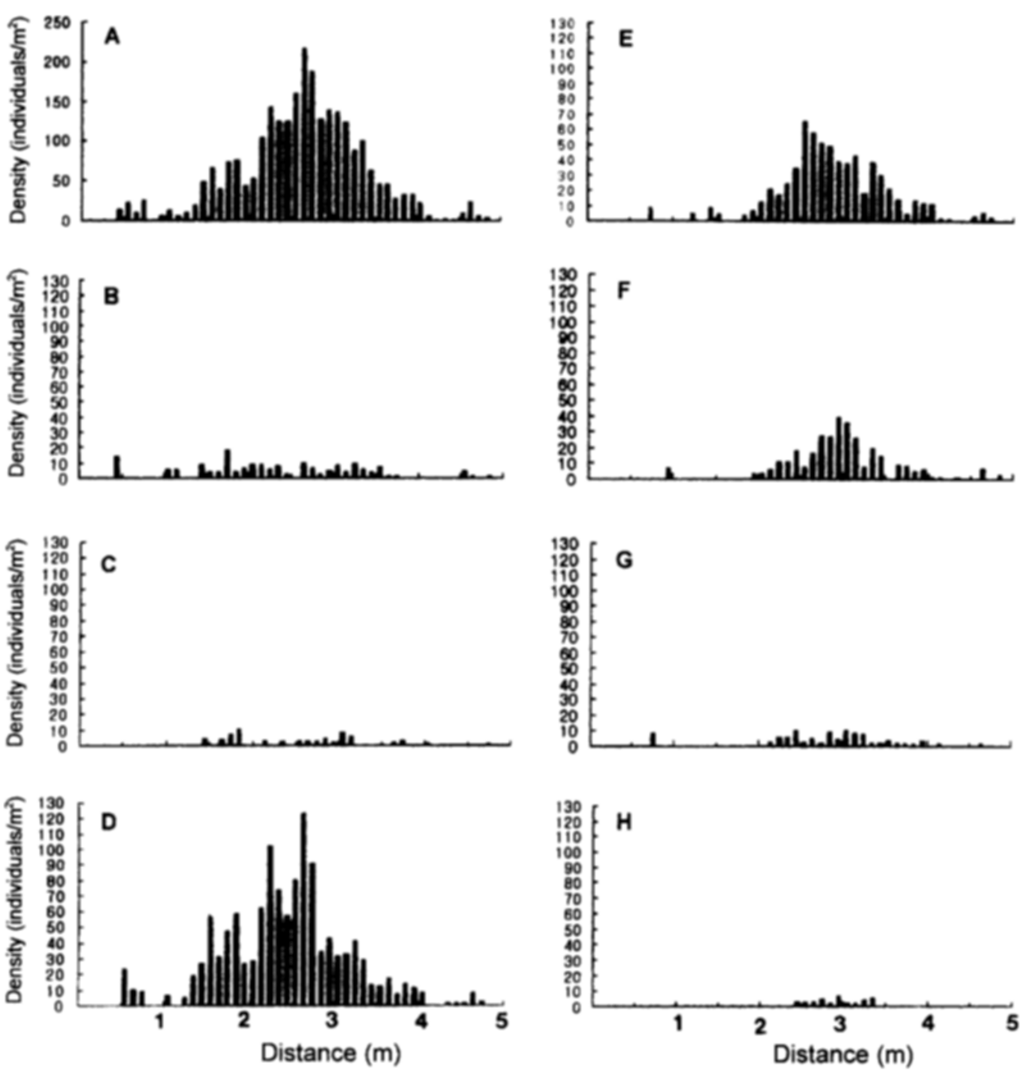

Figure 3. The density of maple seedlings by age, according to distance from maternal plant. A, total; B, 1-year; C, 2-year; D, 3-year; E, 4-year; F, 5-year; G, 6-year; H, over 7-year-old seedlings.

of 70 ~ 479 cm, and mainly at 180 ~ 429 cm. They were most dense at 250 ~ 259 cm, with 64.9 individuals/m^2. Compared with the 3-year-old seedlings, the most dense section was closer to the maternal plant, but the sections of main distribution were closer to the outside.

The distribution ranges for 5-year-old seedlings were at 180 ~ 429 cm, and at 190 ~ 419 cm. Their density increased from 6.7 individuals/m^2, at 190 ~ 199 cm, to 38.9 individuals/m^2 at 290 ~ 299 cm, then decreased. The main section of distribution was similar to that for the 4-year-olds, but the highest density section was 40 cm further from the maternal plant. Six-year-old seedlings were distributed from 210 ~ 419 cm. Their highest density was 10.4 individuals/ m^2 in the 290 ~ 299 cm section. The main distribution section was farther away from the mother than was that of the 5-year-olds. Seedlings that were older than 7 years were distributed in a narrow range and were less dense.

The general trends for *A. palmatum* seedling distribution included, first, an initial increase in seedling density up to 3 years, a decrease thereafter. This coincided with an abrupt decrease in survival rates from 1988 to 1995. Second, seedling density was highest at the periphery of the maternal plant crown and decreased to either side. The periphery probably provided a suitable growing environment. This phenomenon of seedling distribution had been described by the Janzen (1970) Model.

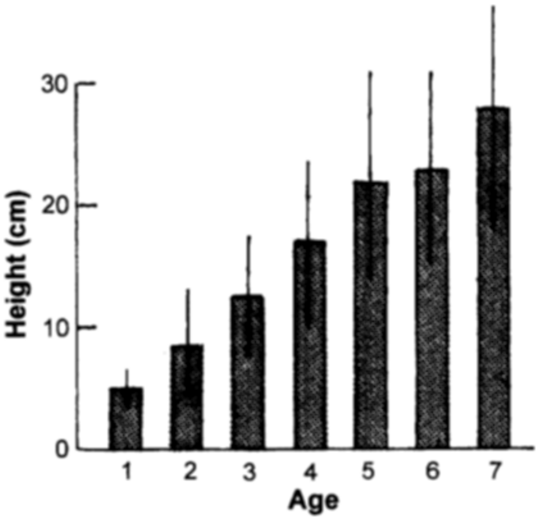

Figure 4. Changes in mean seedling size with age. Vertical lines represent SD.

Finally, older seedlings were found at greater distances from the maternal plant. Seedlings generally require more radiation as they age, and mature seedlings cannot grow under the crown of the maternal plant. This is why no seedlings older than 7 years were found under the study crown. When seeds are dispersed uniformly, 1-year-old seedlings that grow under the crown will not survive (Augspurger, 1983b; Houle, 1998). Therefore, new *A. palmatum* cannot be recruited from seedlings that germinate under the maternal plant crown. However, these mechanisms are worthy of additional study.

Seedling Size

The relationship between seedling sizes and age is shown in Figure 4. Seedling size increased with age; 1- and 7-year-old seedlings were 5.0 cm and 27.6

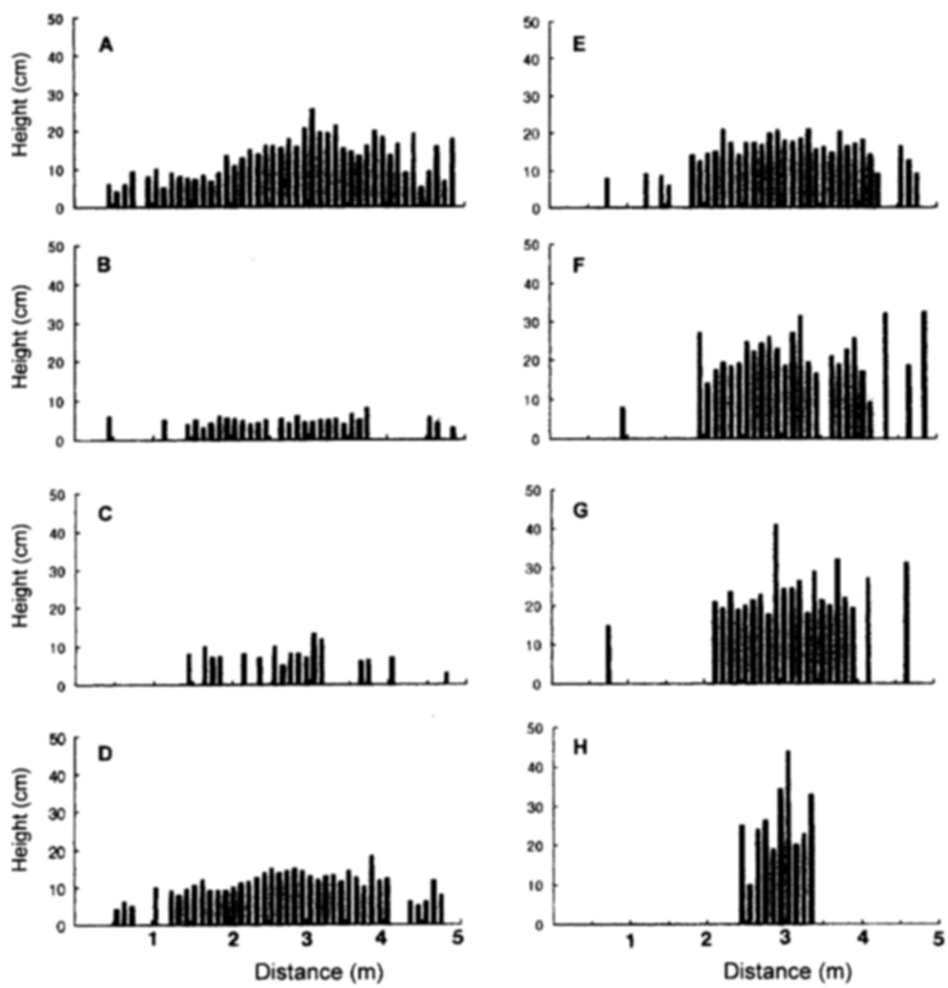

Figure 5. Seedling height in each age class, according to distance from maternal plant. A, total; B, 1-year; C, 2-year; D, 3-year; E, 4-year; F, 5-year; G, 6-year; H, over 7-year-old seedlings.

cm tall, respectively. Based on the student' *t*-test, seedling size differences between two consecutive years were significant at the 0.1% level for 1- to 5-year-olds, but not for older seedlings.

Seedling growth rates were normal for the first five years after germination, but decreased thereafter. Seedlings older than seven years were few, and manifested the Oskar syndrome (Grime, 1979; Silvertown, 1982). In needle-leaved (Wilson, 1991; Zobel and Antos, 1991; Gray and Spies, 1996) or broad-leaved (Lorimer et al., 1994) woody plants, most seedlings grow slowly when natural sunlight is blocked by more than 50% (Sasaki and Mori, 1981). As was also demonstrated in the current study, the main factor affecting maple cambial growth is light (Kobe, 1996).

Seedling size according to distance from the maternal plant is shown in Figure 5. The farther from the maternal plant, the larger the seedling. Seedling height was greatest in the 330 ~ 339-cm interval, but was variable in the other intervals. Seedlings tended to be shorter within 300 cm of the maternal plant because of insufficient sunlight. The variability in seedling height outside the crown was probably because seedling growth was not affected by the crown but, rather, by the microclimate or endogenous factors (Sasaki and Mori, 1981).

For seedlings less than four years old, height within age class was similar along the distance from the maternal plant. This was not true, however, for those seedlings older than five years. The maternal crown evidently had a smaller effect on the growth of young seedlings, but was more critical to mature seedling development. Because of this, many *A. palmatum* seedlings were generated but few grew into trees. However, after a natural disturbance, e.g., the death of the maternal plant, these seedlings would be released to re-populate a *A. palmatum* forest.

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LITERATURE CITED

Abe S, Masaki T, Nakashizuka Y (1995) Factors influencing sapling composition in canopy gaps of a temperate deciduous forest. Vegetatio 120: 21-32

Augspurger CK (1983a) Seed dispersal of the tropical tree, *Platypodium elegans*, and the escape of its seedling from fungal pathogens. J of Ecol 71: 759-772

Augspurger CK (1983b) Offspring recruitment around tropical trees: changes in cohort distance with time. Oikos 40: 189-196

Burns RM, Honkala BH (1990) Silvics of North America, Vol 20. USDA, Washington DC, USA

Chang C-S (1991) A morphometric analysis of genus *Acer* L., section *Palmata* Pax, series *Palmata*. Korean J Pl Taxon 21: 165-186

Chang C-S (1994) A critique of "Reexamination of vascular plants in Ullung Island, Korea II: Taxonomic identity of *Acer takesimense* Nakai (Aceraceae)". Korean J Pl Taxon 24: 279-284

Chazdon RL (1988) Sunflecks and their importance to forest understorey plants. Advances in Ecological Research 18: 1-63

Choe H-S, Lee H-J (1995) Seasonal changes of chlorophyll contents and photosynthetic rates in four species of maple trees in Korea. Korean J Ecol 18: 137-146

Clark JS, McCklin E, Wood L (1998) Stages and spatial scales of recruitment limitation in southern Appalachian forests. Ecol Monogr 68: 213-235

Crawley MJ (1986) Plant Ecology. Blackwell Scientific Publications, Oxford, London, p 496

Dalling JW, Swaine MD, Garwood NC (1998) Dispersal patterns and seed bank dynamics of pioneer trees in moist tropical forest. Ecology 79: 564-578

De Steven D (1982) Seed production and seed mortality in temperate forest shrub (witch-hazel, *Hamamelis virgiana*). J of Ecol 70:437-443

Fenner M (1978) Susceptibility to shade in seedlings of colonizing and closed turf species. New Phytol 81: 739-744

Gray AN, Spies TA (1996) Gap size, within-gap position and canopy structure effects on conifer seedling establishment. J of Ecol 84: 635-645

Gray AN, Spies TA (1997) Microsite controls on tree seedling establishment in conifer forest canopy gaps. Ecology 78: 2458-2473

Grime JP (1979) Plant Strategies and Vegetation Processes. John Wiley & Sons, New York

Gross KL, Werner PA (1982) Colonizing abilities of "biennial" plant species in relation to ground cover: implications for their distributions in a successional sere. Ecology 63: 921-931

Grubb PJ (1977) The maintenance of species-richness in plant communities: the importance of the regeneration niche. Biological Review 52: 107-145

Harper JL (1977) Population Biology of Plants. Academic Press, London

Hett JM (1971) A dynamic analysis of age in sugar maple seedlings. Ecology 52: 1071-1074

Houle G (1992) Spatial relationship between seed and seedling abundance and mortality in a deciduous forest of north-eastern North America. J of Ecol 80: 99-108

Houle G (1994) Spatiotemporal patterns in the component of regeneration of four sympatric tree species-*Acer rubrum*, *A. saccharum*, *Betula alleghaniensis* and *Fagus grandifolia*. J of Ecol 82: 39-53

Houle G (1998) Seed dispersal and seedling recruitment of *Betula alleghaniensis*: spatial inconsistency in the time. Ecology 79: 807-818

Hubbell SP (1980) Seed production and the coexistence of

tree species in tropical forests. Oikos 35: 214-229
Huenneke LF, Sharitz RR (1986) Microsite abundance and distribution of woody seedlings in a South Carolina cypress-tupelo swamp. Amer Midl Nat 115: 328-335
Ishizuka M, Sugawara S (1989) Composition and structure of natural mixed forests in central Hokkaido. II. Effects of disturbances on the forest vegetation patterns along the topographic moisture gradients. Journal of Japanese Forest Society 71: 89-98
Janzen DH (1970) Herbivores and the number of tree species in tropical forests. Amer Natur 104: 501-528
Kim CH (1984) Effect on the germination of maple seeds ripening. Dongkook University, J Agricultural Science 9: 23-38
Kim YS, Ko SC, Sim JK (1981) Distribution atlas of plants in Korea. VI. Atlas of Aceraceae 24: 191-216
King DA (1990) Allometry of saplings and understorey trees of a Panamanian forest. Functional Ecology 4: 27-32
King TJ (1975) Inhibition of seed germination under leaf canopies in *Arenaria serphyllifolia*, *Veronica arvensis* and *Cerastium holosteoides*. New Phytol 75: 87-90
Kobe RK (1996) Intraspecific variation in sapling mortality and growth predicts geographic variation in forest composition. Ecol Monogr 66: 181-201
Korea Meteorological Administration (1991-1998) Monthly weather report. Seoul, Korea
Kuppers M (1989) Ecological significance of above ground architectural patterns in woody plants: a question of cost-benefit relationships. TREE 4: 375-379
Lee DW (1996) Irradiance and spectral quality affect Asian tropical rain forest tree seedling development. Ecology 77: 566-580
Lorimer CG (1989) Relative effects of small and large disturbance on temperate hardwood forest structure. Ecology 70: 565-567
Lorimer CG, Chapman JW, Lambert WD (1994) Tall understorey vegetation as a factor in the poor development of oak seedlings beneath mature stands. J Ecol 82: 227-237
Min BM (2000) Comparison of Phenological Characteristics for Several Woody Plants in Urban Climates. J Plant Biol 43: 10-17
Park C-W, Oh S-H, Shin H (1993) Reexamination of vascular plants in Ullung Island, Korea II: Taxonomic identity of *Acer takesimense* Nakai (Aceraceae). Korean J Pl Taxon 23: 217-231
Park C-W, Oh S-H, Shin H (1994) Character analysis and taxonomic identity of *Acer takesimense* Nakai. Korean J Pl Taxon 24: 285-294
Park KW (1984) A morphological and anatomical study on the leaves of the genus *Acer* in Korea. J Korean For Soc 64: 1-9
Park KW, Kim SS (1984a) Taxonomical studies of the genus *Acer* in Korea by the morphological characteristics of stipules. J Korean For Soc 64: 52-63
Park KW, Kim SS (1984b) A study on the wood identification of the genus *Acer* in Korea. -Especially on the method by thin layer chromatography of lipid in heartwood. J Korean For Soc 65: 60-67
Pickett TA, White PS (1985) The Ecology of Natural Disturbance and Patch Dynamics. Academic Press, New York
Ross MA, Harper JL (1972) Occupation of biological space during seedling establishment. J of Ecol 60: 77-88
Runkle JR (1990) Gap dynamics in an Ohio *Acer-Fagus* forest and speculations on the geography of disturbance. Canadian J of Forest Research 20: 632-641
Runkle JR, Stewart GH, Veblen TT (1995) Sapling diameter growth in gaps for two *Nothofagus* species in New Zealand. Ecology 76: 2107-2117
Sasaki S, Mori T (1981) Growth responses of dipterocarp seedlings to light. Malayan Forester 44: 319-345
Schupp EW (1988) Seed and early seedling predation in the forest understory and in treefall gaps. Oikos 51: 71-78
Schupp EW (1995) Seed-seedling conflicts, habitat choice, and patterns of plant recruitment. American J of Bot 82: 399-409
Seiwa K (1998) Advantages of early germination for growth and survival of seedlings of *Acer mono* under different overstorey phenologies in deciduous broad-leaved forests. J of Ecol 86: 219-228
Seiwa K, Kikuzawa K (1996) Importance of seed size on the establishment of five deciduous broad-leaved tree species. Vegetatio 123: 51-64
Silvertown JW (1982) Introduction to Plant Population Ecology. Longman, London
Sipe TW, Bazzaz FA (1994) Gap partitioning among maples (*Acer*) in central New England: shoot architecture and photosynthesis. Ecology 75: 2318-2332
Streng DR, Glitzenstein JS, Harcombe PA (1989) Woody seedling dynamics in an east Texas floodplain forest. Ecol Monogr 59: 177-204
Suh Y, Cho H-J, Kim S, Park C-W (1996) Comparative analysis of ITS sequences from *Acer* species (Aceraceae) in Korea. J Plant Biol 39: 1-8
van der Pijl L (1972) Principles of Dispersal in Higher Plants, Ed 2. Springer-Verlag, Berlin
Wilson MV (1991) Age structure patterns in *Abies amabilis* stands of the Cascade Mountains. Amer Midl Nat 125: 331-339
Zobel DB, Antos JA (1991) Growth and development of natural seedling of *Abies* and *Tsuga* in old-growth forest. J of Ecol 79: 985-998