Korean J. Ecol., 24(2): 111~116, 2001

Vegetation Analysis Along Elevational and Topographical Gradients in Mt. Jumbong in Central Korea

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ABSTRACT: Vegetational changes along elevational and topographical gradients were studied in Mt. Jumbong which is located at the core area of the Mt. Sorak Biosphere Reserve in Kangwon-do Province in central Korea. Two 500 m north-south transects crossing two valleys and a small ridge were laid out, and fifty-one 10 m X 10 m permanent quadrats were systematically set up. All trees bigger than 2.5 cm DBH were marked with numbered aluminum tags, and their DBH measured and the species identified. Coverage of plant species in the herb layer were determined in two 2 m X 2 m subquadrats in each of the permanent quadrats. Thirty-two species of woody plants occurred in the tree layer in the permanent quadrats studied. *Quercus mongolica* was the dominant species across the study site, and *Acer pseudosieboldianum* and *Carpinus cordata* were also important. *Quercus mongolica* occurred on the ridges and south-facing slopes, and *Acer pseudosieboldianum* occurred extensively except for valleys. In contrast, *Fraxinus mandshurica, Acer mono, Acer triflorum,* and *Ulmus laciniata* were common in valleys. At the herbaceous layer, 112 species were identified. Dominant species were *Ainsliaea acerifolia* and *Sasa borealis* on the ridges, *Meehania urticifolia* on north-facing slopes, and *Deutzia glabrata* on valleys. Soil environmental factors were compared among the quadrats. pH was lower in the quadrats located on ridges and south-facing slopes, and organic matter was lowest on south-facing slopes. Quadrats located on valleys were generally higher in pH, organic matter, N, P, K, Ca and Mg. DCA ordinations for tree layer and herb layer were carried out in order to identify the dominant environmental factors affecting the distribution of plant species along the environmental gradients. Correlation analysis between ordination axis scores and environmental factors showed that axis one was negatively correlated with elevation and positively correlated with soil organic matter, pH, Ca, Mg, and P, but that axis two was positively correlated with elevation. These results indicate that vegetation responds very sensitively to elevational and topographical gradients although the study area is relatively small with about 100 m in elevational variation.

Key Words: Deciduous hardwood forest, Environmental gradient, Mt. Jumbong, Ordination, *Quercus mongolica*

INTRODUCTION

Topographic differences such as elevation, slope degree, and slope aspect can create microenvironmental changes. These topographic differences and the environmental factors associated with them affect distribution pattern of plants and biodiversity (Hamilton and Limbard 1982, Titus 1990, Ware *et al.* 1992). Mountainous terrain predominating Korean landscape contains ridges and valleys, and these microtopography affects the occurrence of plant species and their biomass due to variation in water content, nutrients and soil texture (Gauch and Stone 1979, Huenneke and Sharitz 1986).

In the biodiversity conservation, conservation of rare and endangered species are very important, and they usually require habitats with special microenvironments. The results of this study can be applied to the biodiversity conservation program in such sites as Mt. Jumbong which has high biodiversity and is subjected to human interference.

Mt. Jumbong (128 °22′E and 38 °02′E) has well-preserved old-growth hardwood forests within the core area of Mt. Sorak Biosphere Reserve designated by UNESCO in 1982. Flora and vegetation classification have been studied (Park *et al.* 1983, Lee *et al.* 1983, Lee 1993), but studies on vegetation structure and vegetation dynamics are lacking in Mt. Jumbong.

This study was conducted as a part of the three year research project titled "Analyses of ecological structure and function of natural forest reserve in Mt. Jumbong for conservation of biodiversity" (Lee *et al.* 1997). The purpose of the current study is 1) to

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determine the distribution pattern of plant species in tree and herb layers in permanent quadrats, 2) to determine the major environmental factors affecting the species distribution, and 3) to provide basic data for future long-term changes in vegetation composition and structure.

METHODS

Distribution of tree and herb species along environmental gradients

Two 500 m north-south transects were set up in 1997 to see the distribution pattern of trees on different elevation, slope and aspect. The transects contained a small central ridge and two valleys within two major east-west ridges (Fig. 1). In each transect, 10 m X 10 m permanent quadrats, which are 10 m apart from each other, were laid out. All trees with DBH (diameter at breast height) bigger than 2.5 cm were attached with numbered aluminum tag (diameter 2.3 cm) at 130 cm height. DBH of trees within the quadrats were measured and the species identified in 1997. All trees will be reexamined every three to five years to see any change in mortality, growth, and ingrowth. Within each permanent quadrat, two 2 m X 2 m subquadrats were set up to determine the coverage of plant species in the herb layer. Trees and shrubs with height less than 50 cm were regarded as herbs.

Ordination analysis

DCA ordinations (Hill and Gauch 1980) were carried out in order to see the distributional pattern of plant species for herb layer and tree layer. Ordination axis scores were examined for correlation with environmental factors of each quadrat, including elevation and soil environmental factors. Based on the result of correlation analysis, factors important for plant species distribution were determined.

Soil environmental factors

As physico-chemical characteristics of soils, pH, organic matter, total nitrogen, available phosphorus, Ca, Mg, and K were determined. In each quadrat, about 400 g of soils of A horizon (5 - 10 cm depth) were collected and mixed for soil chemical analysis. Soil pH was determined by shaking a mixture of soil: distilled water = 1 : 5 (g/g) for an hour and the filtered solution was tested with pH meter. Soil organic matter was determined by the loss on ignition after ashing the air-dried soil at 600°C for 4 hours. Total nitrogen was determined by the microkjeldahl method, and available phosphorus was by the chlorostannous-reduced molybdophosphoric blue color method (Jackson 1967). Exchangeable potassium, calcium, and magnesium were determined by atomic absorption spectrophotometer (Shimadzu AA-6601F) after extraction by 1N ammonium acetate and filtration (Chapman 1976).

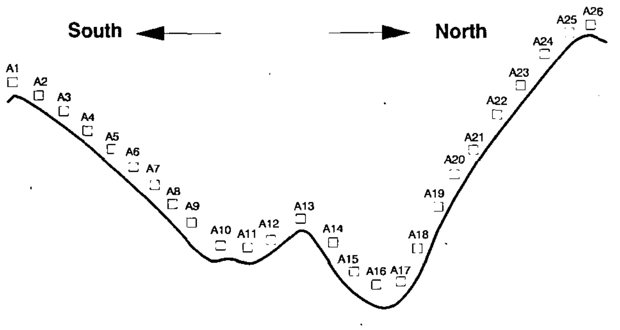

Fig. 1. Location of permanent quadrats on transect A in Mt. Jumbong. Transect B is close to and parallel with transect A.

RESULTS AND DISCUSSION

Thirty-two species of woody plants were recorded in the tree layer in the 51 permanent quadrats studied in 1997. *Quercus mongolica* was the dominant species across the whole study site, and *Acer pseudosieboldianum* and *Carpinus cordata* were also important (Table 1). At the genus level, oaks (*Quercus*), maples (*Acer*) and ashes (*Fraxinus*) were dominant plants. *Quercus mongolica* occurred on the ridges and south-facing slopes, and *Acer pseudosieboldianum* occurred extensively except for valleys. In contrast, *Fraxinus mandshurica, Acer mono, Acer triflorum*, and *Ulmus laciniata* were common in valleys. The occurrence of late successional species such as *Carpinus cordata* and *Acer mono* indicates that the study site is relatively well preserved and that it is more or less mesic. *Fraxinus* species did not occur on the ridges. While *Fraxinus rhynchophylla* occurred mostly on north-facing slopes, *Fraxinus mandshurica* occurred only on valleys.

At the herbaceous layer, 112 species were identified (Table 2). Dominant species were *Ainsliaea acerifolia* and *Sasa borealis* on the ridges, *Meehania urticifolia* on north-facing slopes, and *Deutzia glabrata* on valleys. In contrast, *Astilbe chinensis* occurred extensively on all the sites. Spring ephemerals were not included in the data because herb layer were surveyed in the summer.

Lee and Cho (2000) showed that litter depth was the most important factor for herb distribution in Mt. Jumbong, and that litter depth was correlated with slope aspect and elevation. Thus the distribution of herbs as well as trees can be affected indirectly by elevational and topographical gradients, although other microtopographical factors are also important for herb distribution (Lee and Cho 1999).

These distribution patterns of species can be closely related to environmental factors of the quadrats (Tables 3 and 4). pH was lower in the quadrats located on ridges and south-facing slopes,

Table 1. Tree species distribution at the study site in Mt. Jumbong. Species are listed in the order of importance values. Numbers are in percentages. RD, RC, RF, and IV indicate relative density, relative cover, relative frequency and importance value, respectively

Species acronym	Scientific name	RD	RC	RF	IV
QUMO	*Quercus mongolica*	10.37	42.47	10.69	21.18
ACPS	*Acer pseudosieboldianum*	25.49	6.00	14.16	15.22
CACO	*Carpinus cordata*	13.39	5.28	10.98	9.88
TIAR	*Tilia amurensis*	10.26	4.42	8.67	7.78
ACMO	*Acer mono*	6.26	6.35	7.23	6.61
FRMA	*Fraxinus mandshurica*	4.54	6.86	4.62	5.34
KAPI	*Kalopanax pictus*	3.13	7.93	3.76	4.94
FRRH	*Fraxinus rhynchophylla*	4.21	5.01	4.62	4.62
ULLA	*Ulmus laciniata*	3.56	3.52	4.91	4.00
SOAL	*Sorbus alnifolia*	3.24	1.17	4.91	3.11
ACTR	*Acer triflorum*	2.48	2.1	3.18	2.62
ABHO	*Abies holophylla*	1.94	1.55	3.18	2.22
RHSC	*Rhododendron schlippenbachii*	2.92	0.04	2.89	1.95
COCO	*Cornus controversa*	0.97	1.68	1.73	1.46
PRSA	*Prunus sargentii*	0.86	1.4	2.02	1.45
EUSA	*Euonymus sachalinensis*	1.30	0.06	2.89	1.41
ACMA	*Acer mandshuricum*	0.76	0.86	1.16	0.92
PIKO	*Pinus koraiensis*	0.65	1.18	0.87	0.90
SYWO	*Syringa wolfii*	0.76	0.24	1.45	0.81
POMA	*Populus maximowiczii*	0.43	0.37	0.87	0.56
ACAR	*Actinidia arguta*	0.65	0.04	0.87	0.52
ACTS	*Acer tschonoskii*	0.32	0.03	0.87	0.41
BECO	*Betula costata*	0.43	0.20	0.58	0.40
PIDE	*Pinus densiflora*	0.11	0.41	0.29	0.27
SOCO	*Sorbus commixta*	0.22	0.01	0.58	0.27
ULDA	*Ulmus davidiana*	0.11	0.11	0.29	0.17
SAHU	*Salix hulteni*	0.11	0.05	0.29	0.15
CALA	*Carpinus laxiflora*	0.11	0.04	0.29	0.15
MASI	*Magnolia sieboldii*	0.11	0.04	0.29	0.15
AREL	*Aralia elata*	0.11	0.03	0.29	0.14
SYCH	*Symplocos chinensis*	0.11	0.00	0.29	0.13
JUMA	*Juglans mandshurica*	0.11	0.00	0.29	0.13

Table 2. Herb species distribution at the study site in Mt. Jumbong. Species are listed in the order of importance values. Numbers are in percentages. RD, RC, and IV indicate relative density, relative cover, and importance value, respectively

Species acronym	Scientific name	RD	RC	IV
AIAC	*Ainsliaea acerifolia*	8.34	2.53	5.44
MEUR	*Meehania urticifolia*	7.53	3.31	5.42
SABO	*Sasa borealis*	8.69	1.85	5.27
ASCH	*Astilbe chinensis*	6.36	3.51	4.93
DEPA	*Deutzia parviflora*	7.75	1.36	4.55
MEON	*Melica onoei*	6.32	2.53	4.43
PSHE	*Pseudostellaria heterophylla*	4.33	3.02	3.67
PIBR	*Pimpinella brachycarpa*	3.63	2.63	3.13
ASSC	*Aster glaber*	2.39	3.70	3.05
DRCR	*Dryopteris crassirhizoma*	3.92	1.75	2.84
CASI	*Carex siderosticta*	2.81	2.34	2.57
RHSC	*Rhododendron schlippenbachii*	3.59	1.46	2.52
ACPS	*Acer pseudosieboldianum*	2.38	2.04	2.21
FIMU	*Filipendula multijuga*	2.75	1.27	2.01
SYNI	*Symplocarpus nipponicus*	0.80	2.82	1.81
ISEX	*Isodon excisus*	1.59	1.95	1.77
ARAM	*Arisaema amurense*	0.45	2.92	1.69
HYVE	*Hylomecon vernale*	1.47	1.75	1.61
HAAS	*Hanabusaya asiatica*	0.90	2.24	1.57
LABA	*Lamium album* var. *barbatum*	1.09	1.75	1.42
LYCO	*Lychnis cognata*	0.87	1.95	1.41
EUOX	*Euonymus oxyphylla*	0.88	1.85	1.37
CIHE	*Cimicifuga heracleifolia*	1.02	1.46	1.24
STIN	*Stephanandra incisa*	0.70	1.75	1.23
VEPA	*Veratrum patulum*	0.88	1.56	1.22
GAKI	*Galium kinuta*	0.38	1.95	1.16
POTR	*Polystichum tripteron*	1.15	1.07	1.11
ASSI	*Asarum sieboldii*	0.25	1.95	1.10
PERE	*Pedicularis resupinata*	0.96	1.17	1.06
ACJA	*Aconitum jaluense*	0.66	1.36	1.01
LIFI	*Ligularia fischeri*	0.45	1.56	1.01

and organic matter was lowest on south-facing slopes. Quadrats located on valleys were generally higher in pH, organic matter, N, P, K, Ca and Mg, and this can be explained by the fact that soil on the surface of rocks on valleys was mostly derived from organic debris.

DCA ordinations for tree layer (Figs. 2 and 3) and herb layer (Figs. 4 and 5) were performed in order to identify the dominant environmental factors affecting the distribution of plant species along the environmental gradients. Tree species ordination (Fig. 2) showed two groups of species: lower axis one was occupied by species typical on ridges such as *Quercus mongolica* and *Rhododendron schlippenbachii* and higher axis one was occupied by species typical on valleys such as *Fraxinus mandshurica* and *Juglans mandshurica*. The distribution pattern of herbs (Fig. 4) closely followed that of trees due to lack of conspicuous pits and mounds (Lee and Cho 1999). Correlation analysis between axis scores of both tree and herb ordinations and environmental factors showed that axis one was negatively correlated with elevation and positively correlated with soil organic matter, pH, Ca, Mg, and P, and that axis two was positively correlated with elevation (Table 5). These results indicate that vegetation responds very sensitively to elevational and topographical gradients although the study area is relatively small with less than 100 m in elevational variation.

Table 3. Soil physical and chemical characteristics of the study site (Transect A) in Mt. Jumbong

Quadrat	Elevation (m)	Slope aspect(°)	pH	Organic matter (%)	Total-N (mgN/g)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)
A-1	1005	110	5.11	28.0	5.78	2.93	243.50	937.13	93.13
A-2	1002	110	4.77	34.5	3.13	2.93	290.75	1124.38	122.50
A-3	1000	60	5.05	29.3	11.92	2.95	295.88	1190.38	111.88
A-4	1000	50	5.18	27.8	10.00	3.18	227.68	1465.00	121.25
A-5	992	45	5.50	25.1	5.18	2.96	305.25	1303.75	140.63
A-6	983	60	5.41	22.9	2.41	4.27	304.88	1267.50	121.88
A-7	980	60	5.60	18.8	4.58	3.43	275.25	1241.00	110.63
A-8	974	60	5.62	18.7	5.42	7.05	334.38	1285.00	106.88
A-9	982	90	5.54	20.8	7.34	4.38	331.63	1300.00	132.50
A-10	980	110	5.87	43.8	4.21	8.25	425.88	2496.25	299.38
A-11	980	120	4.90	56.8	19.26	20.83	521.50	3047.50	367.50
A-12	988	200	5.36	20.2	1.81	3.27	519.25	684.38	63.13
A-13	992	200	4.74	30.1	16.49	3.63	347.88	378.25	66.88
A-14	990	50	5.50	26.4	5.06	2.74	749.38	133.75	100.00
A-15	980	60	5.30	26.0	2.89	5.31	550.25	1518.75	120.63
A-16	980	130	5.43	34.1	10.96	6.69	390.88	2121.25	243.13
A-17	980	130	5.05	68.0	27.57	31.45	583.25	3501.25	476.88
A-18	986	220	5.18	15.0	4.45	2.87	253.38	346.88	56.25
A-19	1000	200	4.89	15.1	3.25	2.69	229.75	393.75	60.63
A-20	1121	200	4.97	14.0	3.61	2.26	174.75	60.88	35.00
A-21	1128	180	4.56	16.7	5.30	2.27	116.63	84.38	36.25
A-22	1131	150	4.89	15.9	2.17	2.27	159.50	209.38	44.38
A-23	1140	160	5.11	19.0	2.89	2.68	264.88	507.75	64.38
A-24	1132	150	5.03	16.7	3.49	3.74	175.25	207.50	45.63
A-25	1145	150	4.54	25.5	10.47	3.07	196.13	367.88	70.63
A-26	1150	80	4.75	28.2	3.49	2.46	173.13	1147.88	106.88

Table 4. Soil physical and chemical characteristics of the study site (Transect B) in Mt. Jumbong

Quadrat	Elevation (m)	Slope aspect(°)	pH	Organic matter (%)	Total-N (mgN/g)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)
B-1	1030	190	4.74	24.7	5.78	2.25	218.75	206.50	53.75
B-2	1140	70	4.77	25.8	5.54	1.82	204.25	846.00	81.8
B-3	1130	70	4.70	29.3	9.87	2.90	212.00	1120.50	113.75
B-4	1120	75	4.83	18.8	9.63	4.76	149.00	462.63	56.25
B-5	1120	85	4.85	25.0	8.31	3.74	302.00	927.88	78.75
B-6	1020	90	4.96	24.7	9.75	3.54	213.88	950.75	81.25
B-7	1018	90	5.00	21.5	3.61	4.39	249.63	1103.25	79.38
B-8	1016	110	4.94	25.9	5.90	3.77	241.25	477.25	76.25
B-9	1100	95	5.54	22.7	6.50	4.47	495.25	1475.00	145.63
B-10	1091	110	5.31	23.6	3.85	9.94	304.75	1183.25	106.25
B-11	1100	120	5.32	33.9	6.02	8.35	371.63	2076.25	211.25
B-12	1100	200	5.01	21.9	2.77	3.94	3693.52	1087.75	80.00
B-13	1110	110	5.01	20.9	8.19	3.23	587.50	1202.13	82.50
B-14	1102	50	5.39	24.5	7.46	2.57	577.38	1870.00	135.50
B-15	1098	75	5.50	23.3	7.10	5.75	495.75	1603.75	125.63
B-16	1090	120	5.77	57.1	16.98	54.11	781.38	3198.75	491.25
B-17	1091	120	5.60	62.9	23.60	47.52	491.00	3811.25	446.25
B-18	1100	200	5.16	15.6	3.85	3.73	401.38	870.13	66.88
B-19	1106	200	4.84	13.0	3.61	3.58	144.00	176.25	43.75
B-20	1111	200	4.95	13.8	3.97	2.63	160.38	1132.38	21.25
B-21	1122	220	4.80	14.5	3.25	1.52	189.25	266.50	39.38
B-22	1132	210	4.92	13.9	3.49	3.13	145.13	120.25	41.25
B-23	1146	210	4.86	15.4	29.14	2.71	18.00	84.88	42.50
B-24	1148	170	4.81	15.5	2.53	1.95	216.25	114.38	45.00
B-25	1162	135	4.83	22.1	5.66	3.32	195.00	301.00	53.13

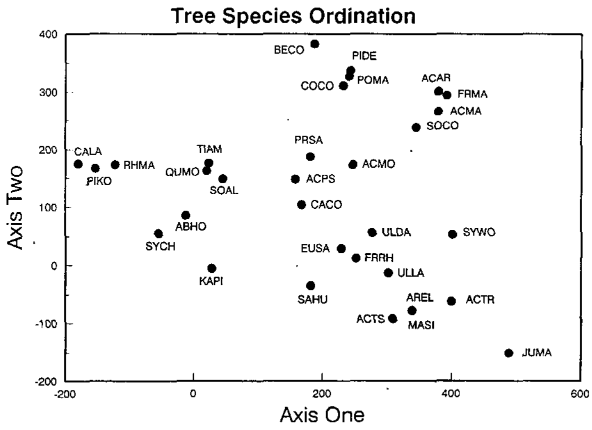

Fig. 2. DCA ordination for tree species in Mt. Jumbong. See Table 1 for acronyms of tree species.

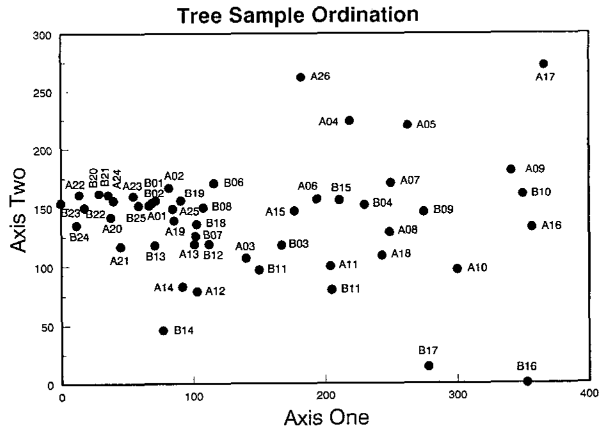

Fig. 3. DCA ordination for tree sample quadrats in Mt. Jumbong.

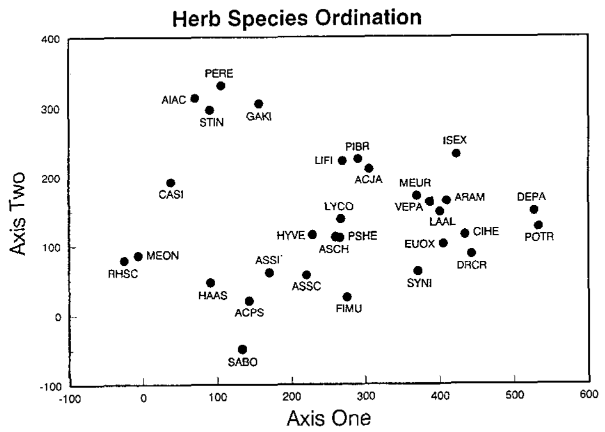

Fig. 4. DCA ordination for herb species in Mt. Jumbong. See Table 2 for acronyms of herb species.

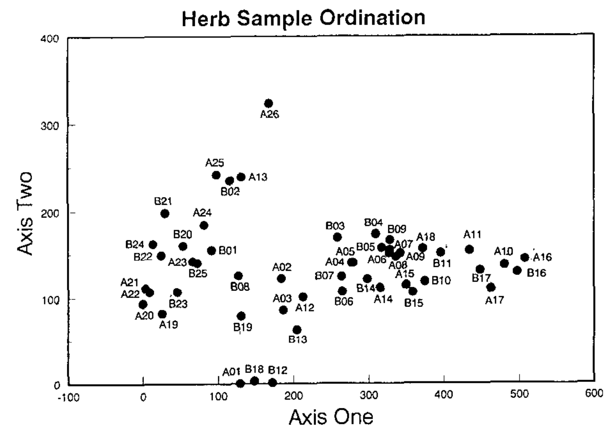

Fig. 5. DCA ordination for herb sample quadrats in Mt. Jumbong.

Table 5. Correlation coefficients between ordination axis scores and environmental factors

Ordination axis / Environmental factors	Tree ordination Axis one	Tree ordination Axis two	Herb ordination Axis one	Herb ordination Axis two
Elevation	-0.606***	0.357*	-0.706***	0.291*
Organic matter	0.571***	-0.215NS	0.652***	0.059NS
pH	0.641***	-0.308 *	0.696***	-0.201NS
N	0.300*	-0.110NS	0.337*	0.043NS
Ca	0.716***	-0.234NS	0.799***	-0.041NS
K	0.107NS	-0.204NS	0.170NS	-0.388**
Mg	0.690***	-0.270NS	0.741***	-0.006NS
P	0.527***	0.398**	0.543***	-0.040NS

(*: $p<0.05$, **: $p<0.01$, ***: $p<0.001$, NS: not significant)

Size-frequency distribution of trees can be used as an indicator of regeneration of tree species (Boerner and Cho 1987). Fig. 6 shows size distribution of the six most abundant tree species in the study site. The shade-intolerant *Quercus mongolica* showed relatively even distribution pattern with large emergent trees not uncommon, and *Fraxinus rhynchophylla* showed a similar pattern, too. In contrast, shade-tolerant tree species such as *Acer pseudosieboldianum* and *Carpinus cordata* showed typical

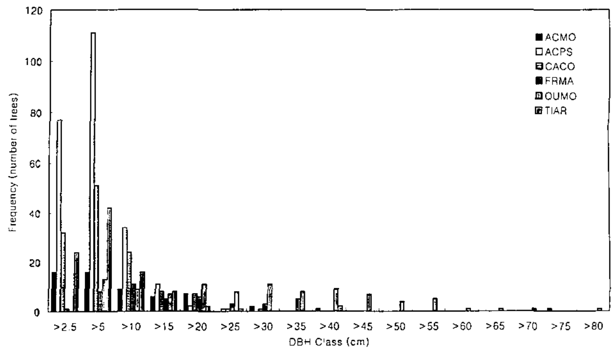

Fig. 6. Size-frequency distribution of six dominant tree species in Mt. Jumbong. See Table 1 for acronyms of tree species.

reverse-J shaped curve indicating fairly good regeneration. In well-preserved areas dominated by small scale disturbances, shade-intolerant trees usually show poor representation in smaller size trees (Cho and Boerner 1991, Cho 1992). In the study sites in Mt. Jumbong, however, tree regeneration might not be a problem possibly due to past human interference and current disturbance regime.

ACKNOWLEDGEMENTS

This research was supported by the Korea Science and Engineering Foundation grant KOSEF 94-9401-01-01-3 to DSC. Thanks are due to Si-Yearn Kim, Yong-Jin Bae, Sang-Kyu Park and Young-Han Yoo for field works.

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(*Received March 14,* 2001, *Accepted April 3, 2001*)