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Ecological characteristics of areas naturally inhabited by Dolbae trees(*Pyrus pyrifolia*) on Mt. Kaya

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The ecological characteristics of Dolbae trees, a valuable genetic resource for native *Pyrus* fruit trees, were investigated at four naturally inhabited areas on Mount Kaya, Gyeongsangnam-Do. Most Dolbae trees were found on the southwest side of an old hiking path to a mountain valley at altitudes of 610~670 m. The surrounding flora consisted of 46 families, 69 genera, 75 species, and 10 varieties. The natural habitat of the Dolbae trees was basically a deciduous broad-leaved forest with a predominance of *Quercus serrata* and ligneous plants(xylophytes) from the Fagaceae and Betulaceae families. The habitat was also found to be in a second transition resulting from forest disturbance and exhibited a degree of diversity of 2.901-5.065, based on Shannon-Weiner's index. Examination of the Dolbae trees found in Mount Kaya revealed diameter breast heights(DBHs) ranging from 10 to 60 cm, including six old and large Dolbae trees with a DBH of 50~60 cm, which will be particularly valuable as a genetic resource. Accordingly, the current results suggest that the study areas are a secondary forest in a typical mid-temperate zone resulting from forest damage about 10 years earlier.

Key words : habitat, Dolbae tree, *Pyrus pyrifolia*, Plant resource, diversity

1. Introduction

Pear trees are the major deciduous fruit tree cultivated in the temperate zone around the world, and are commonly cultivated in South Korea, except for Jeju Island. In addition to their important fruit value, pear trees are also valuable as woody and ornamental plants, as their flowers and leaves are very beautiful. Several different *Pyrus* genera naturally populate many areas of Asia and Europe, and some areas of North Africa. According to Lee[1], 5 species and 8 varieties, including *Pyrus ussuriensis* and *Pyrus pyrifolia,* naturally grow in various habitats in Korea.

Naturally growing *Pyrus* trees, commonly called "Dolbae" in contrast to horticulturally cultivated trees, are known to be very strong and have a good germination rate, therefore, their seedlings have been cultivated for use as root stocks, grafting, and propagating cultivars[2]. As such, wild plant resources of naturally populated *Pyrus* species are important for developing good fruit trees and ornamental trees[3]. In Korea, many native *Pyrus* species have been cultivated as special to certain areas. However, native *Pyrus* plants are becoming more difficult to find due to the development of so many improved cultivars.

Generally, the cultivation of pear trees in Korea is expanding as they fruit early and are easy to grow compared to other fruit trees. Korean pears are very sweet and juicy due to their high sugar and water content. Consumed fresh or processed, Korean pears are exported to many countries in East Asia and North America. Most of the cultivars grown in Korea are the same as the cultivars grown in Japan, which have been developed from native "Dolbae" by Japanese breeders. Cultivars with a strong resistance to plant diseases that commonly occur in fruit trees, such as the Rosaceae family, are also required, as cultivated species are usually

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very weak against plant diseases, such as 'Rust' (*Gymnosporangium asiaticum*) or noxious insects. Furthermore, with the rapidly changing tastes of consumers, new cultivars are always needed. To develop a new cultivar from the wild plant resources of native *Pyrus* species, it is important to study the distribution state and characteristics of naturally growing "Dolbae"[4]. Consequently, based on the natural genetic resources of Dolbae trees, excellent fruit tree cultivars can be bred that produce pears with a good shape and taste.

The 21st century has heralded a plant resource war with most countries competing to study and secure their native genetic plant resources[5]. For the effective use of Korea's native genetic plant resources, studies are needed to identify the best wild genetic resources, their conditions, and the ecological characteristics of the populated areas, followed by proper management and control[6]. The taxonomical classification of plants native to Korea[7] and studies related to *in vitro* breeding[8] have already been conducted, however, there have been relatively few studies on the habitats of special plant species and little information collected on the actual condition of such plants[9,10]. Accordingly, the purpose of the current study was to collect useful information on the actual distribution conditions and ecological characteristics of Dolbae growing on Mount Kaya in Hapcheon-Gun, Gyeongsangnam-Do.

2. Materials and Methods

A search was made for old and large Dolbae trees in the area around Mount Kaya in Hapcheon-Gun, Gyeongsangnam-Do from July, 2001 to November, 2001. Information on the exact locations of naturally inhabited areas was provided by the Global Positioning System(GPS III, Plus, USA), then the actual ecological conditions of the areas were investigated.

A survey of the surrounding vegetation in the areas with naturally growing Dolbae was conducted using Braun-Blanquet's method[11]. The degree of cover and sociability of the specific plant genera growing within 10 x 10 m of the naturally populated areas on Mount Kaya were monitored. Each area was divided into a tree layer, subtree layer, shrub layer, and herb layer, then the percentage of vegetation in each layer was measured. The degree of diversity for each species in the plant community was analyzed based on the number of plant species and number of individual plants in the surveyed area. The degree of diversity[12] for each species was determined using Shannon-Weiner's index, plus for the species with the highest degree of diversity, the evenness and dominance index were also investigated. The cover degree and sociability of the specific plants populating the surveyed areas were analyzed using Braun-Blanquet's index[11]. The distribution of the plant species in the surveyed area was classified using Lee's method[12].

For each area, the altitude was determined using a digital altimeter(Pretel, Alti-D2, USA), the soil pH and humidity measured using a simple combined type of pH and hygrometer(Takemura Electro DM-15, Japan), the degree of soil hardness measured using a penetrative soil hardness meter (Yamanaka K-730, Japan), the light intensity measured using a portable photometer(Delta, OHM HD-8366, France), and the degree of the slope determined using a gradient detector(Suunto PM-5, Japan). The annual climatic changes in the Mount Kaya region between 1999 and 2001 were analyzed using climatic data on Hapcheon-Gun(Table 1).

To analyze the physical and chemical characteristics of the soil in the areas naturally populated with Dolbae, soil samples were collected and pretreated as follows. The soil samples were spread onto a clean vinyl sheet indoors and air dried for 10 days at 25~35 ℃ until the range of water content was 20~60 %. Each soil sample was filtered through a 2 mm-sieve to remove any sand or pebbles. The resulting samples were then analyzed for their pH, EC(electric charge), OM (organic materials), CEC(cation exchange capacity), and P_2O_5, K^+, Ca^+, Mg^{+2}, and Na^+ ion content. The EC values for the soil samples were determined based on the electric conductivity (Hanna, HI9033, France) after mixing and shaking the soil samples with 25 mL of H_2O. The cation contents in the soil samples were measured by combusting the filtered leaching liquid using ICP (ICP Atomic Emission Spectrometer, Liberty 100, Varian, USA). The phosphoric acid content in the soil samples was determined by measuring the optical absorbance at 720 nm using a colorimeter. The organic matter content was investigated by

Table 1. The climatological data of surveyed areas(Hapcheon-Gun : 1999-2001)

Month	1	2	3	4	5	6	7	8	9	10	11	12	Annual
Mean temp.(℃)	-0.7	1.4	6.4	12.9	17.7	21.7	25.0	25.3	20.3	13.9	7.2	1.3	12.7
Max. temp.(℃)	8.1	9.3	13.7	21.2	25.6	28.6	28.2	29.2	27.9	21.2	16.0	9.7	19.89
Min. temp.(℃)	-0.6	-4.5	0.2	6.3	10.8	16.7	19.8	20.8	18.6	8.5	1.7	-4.3	7.83
Relative humidity(%)	65.4	63.1	62.3	60.6	63.9	71.1	77.0	70.7	76.1	72.6	70.6	68.0	69.0
Precipitation(mm)	22.5	28.0	98.8	72.5	124.5	151.5	232.2	309.3	266.5	68.0	14.5	0.2	115.70
Duration of sunshine(hr)	199.1	197.7	233.9	234.3	250.2	204.9	183.5	206.1	194.8	212.8	182.0	193.8	207.75
Mean wind velocity(m/sec)	1.1	1.3	1.5	1.7	1.5	1.3	1.3	1.1	0.9	0.9	1.0	1.0	1.2

Table 2. Chemical properties of soil in surveyed areas on Mt. Kaya

Survey area number	Soil pH	EC (ds/m) 18.2℃	Organic matter (%)	Available phosphate (ppm)	Cation exchange capacity (mol/ ℓ)	Exchangeable cations(mg/ ℓ)			
						Ca	K	Mg	Na
I	5.45	4.9990	5.8	27.2419	11.0	111.0	16.77	15.81	0.9446
II	5.36	4.9946	8.0	144.5448	17.7	348.0	46.93	39.30	0.9600
III	5.21	4.9998	6.5	103.1416	24.4	388.0	52.24	39.34	1.4618
IV	6.00	4.9990	5.2	42.5415	7.5	129.7	11.29	9.52	0.6216

dissolving 0.1 g of the soil samples in 10 mL of 0.4 N potassium dicromate and heating on a heat-block at 200 ℃. After adding 5 mL of 58 % H_3PO_4 and 6~7 drops of an indicator, diphenyl amine, the samples were then titrated with a 0.2 N iron-[1]-ammonium sulfate solution to measure the organic matter content[13].

3. Results and Discussion

The old and large Dolbae trees were mostly found dotted across the mid-slopes of Mount Kaya, at an altitude of 610~670 m(Table 3). The surveyed areas were close to a valley and old hiking path through dense forest, as such, the atmosphere stayed relatively humid, yet quite sunny during the day. The surveyed areas were identified as gentle slope lands with an inclination of 5~18°. In the surveyed areas, *Quercus serrata* was the most abundant, and the tree layer was composed of Dolbae trees, *Ilex macropoda*, *Carpinus laxiflora*, *Quercus dentata*, and *Zelkova serrata*. The height and coverage of this layer were 7~9 m and 30~80 %, respectively. The sub-shrub layer was mostly composed of *Carpinus cordata*, *Acer mono*, *Acer pseudo-sieboldianum*, *Cornus controversa*, *Quercus variabilis*, *Morus bombycis*, *Lindera erythrocarpa*, *Euonymus oxyphyllus*, and *Celtis sinensis*, and the height and coverage of this layer were 7~9 m and 5~30 %, resepctively. The herb layer was mostly *Sasa borealis* at an average height of 1m and 40~80 % coverage. Fig. 1 shows the coverage and sociability of the plants typically found in the vegetative layer where the Dolbae trees were found growing naturally. The coverage value represents the degree of cover provided by the above-ground plant parts and was divided according to Braun-Blanquet's classes. As a result, the coverage of *Quercus serrata* in the tree layer was 2~3, whereas the coverage of Dolbae trees in the same tree layer was only 1~2, indicating that the tree crown of *Quercus serrata* covered up to one half or at least one tenth of each 10×10 m, while the Dolbae trees only covered one quarter of one tenth[14]. However, in the case of xylophyte, its tree crown coverage could not be determined as a fixed value due to

its irregular distribution, therefore, its degree of distribution was analyzed according to a sociability value. As a result, the *Quercus serrata* and Dolbae trees on Mount Kaya were found to be distributed in small groups in the same natural habitat and competing with each other.

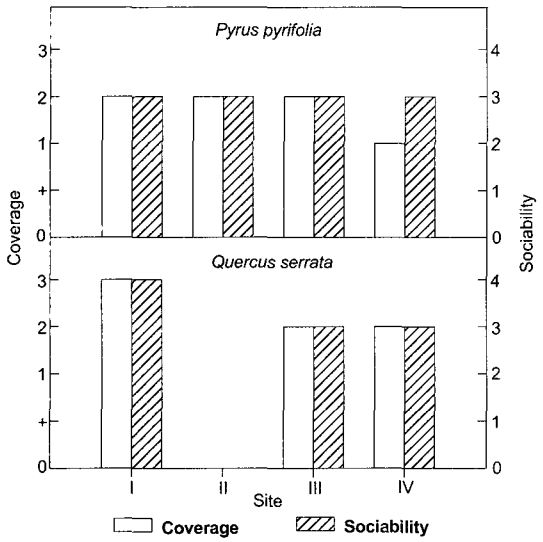

Fig. 1. Coverage and sociability of Pyrus pyrifolia and Quercus serrata in the habitat.

When surveying the natural habitats of the Dolbae trees found on Mount Kaya, a total of 85 taxa were identified, consisting of 46 families, 69 genera, 75 species, 2 formas, and 8 varieties. In particular, the flora was surveyed at 4 of the natural habitats and typically resulted in the identification of 4 genera, 5 species, and 1 variety of Betulaceae as a xylophyte, 5 genera, 5 species, and 1 variety of Rosaceae, and 5 genera, 5 species, and 1 variety of Compositae(refer Table 4). Among the xylophytes making up the tree layer, *Carpinus laxiflora* and *Carpinus cordata* were shade-loving plants, whereas *Alnus hirsuta*, *Quercus serrata*, *Quercus variabilis*, and *Quercus dentata* were heliophytes, which love sunshine. In addition, the Compositae plants, such as *Erieron annuus*, *Youngia sonchifolia*, *Artemisia princeps* var. *orientalis*, and *Aster ageratoides*, and Rosaceae plants, such as *Duchesnea chrysantha*, *Rubus crataegifolius*, *Potentilla fragarioides* var. *major*, and *Agrimonia pilosa* were also heliophytes with a high coverage and sociability in the natural habitat of the Dolbae trees. As such, a good light-interception was apparently maintained in the natural habitat of the Dolbae trees. Also, since the plants with high sociability are known to populat inter-mountain areas

Table 3. Physical features and stratum of each *Pyrus pyrifolia* habitat

Habitat number	I	II	III	IV
Latitude	N 35° 47′ 31.8″	N 35° 47′ 31.5″	N 35° 47′ 32.4″	N 35 °47'35.7″
Longitude	E 128° 04′ 48.5″	E 128° 04′ 48.2″	N 128° 05′ 47.7″	E 128 05'52.5″
Altitude(m)	625	629	670	610
Exposition	SE	SE	S	SW
Light intensity	Semi sunshine	Semi sunshine	Semi sunshine	Sunshine
Slop(°)	5	18	14	5
Condition of habitat	Roadside	Roadside	Roadside	Roadside
Height of tree layer(m)	13	11	12	18
Cover of tree layer(%)	80	30	50	80
Height of subtree layer(m)	9	7	8	8
Cover of subtree layer(%)	30	5	10	30
Height of shrub layer(m)	5	4	4	5
Cover of shrub layer(%)	30	10	40	20
Height of herb layer(m)	0.9	0.9	0.8	1.2
Cover of herb layer(%)	80	80	40	70
Depth of soil(Ao : cm)	25	25	30	20

that are relatively humid, it would appear that the natural habitat of the Dolbae trees included both good light-interception and adequate soil humidity.

Among second-growth forests, the existence of *Quercus acutissinafla* in *Quercus serrata* forests has been reported between the temperate and cool temperate zones in the northeast area of Japan, where the flora is basically the same as in Korea. *Quercus serrata* forests have also been appearing in low-land in mid-temperate zones[15]. In addition, Fagaceae xylophytes, such as *Quercus dentata*, Betulaceae xylophytes, such as *Betula davurica*, and deciduous broad-leaved xylophyte trees have all been found growing together in secondary forests of *Quercus serrata*[16]. As such, the natural habitat of the Dolbae trees found growing on Mount Kaya was identified as a typical second-growth forest formed by tree species with strong sprouts and a regenerative ability after the felling of trees and incidents of forest destruction. Furthermore,

Table 4. List of vascular plants in *Pyrus pyrifolia* habitats

Scientific name	Survey area	Scientific name	Survey area
Aspidiaceae	1. 2	**Caryophyllaceae**	
Athyrium yokoscense(FR. et SAV) H. CHRIST		*Pseudostellaria dawidii*	3
Taxaceae	4	**Ranunculaceae**	
Cephalotaxus koreana NAKAI		*Clematis apiifolia* DC	2
Pinaceae	2. 4	**Lardizabalaceae**	
Pinus densiflora S. et Z.		*Akebia quinata* DECNE.	1. 2
Gramineae	2. 3	**Menispermaceae**	
Stipa sibirica(L.) LAMARCK	1. 4	*Cocculus trilobus*	3
Sasa borealis(HACK.) MAKINO	3	**Magnoliaceae**	
Oplismenus undulatifolius(ARD.)		*Schisandra chinensis* BAILL.	1. 2
ROEM. et SCHULT.	2. 3	**Lauraceae**	
Cyperaceae	1. 2	*Lindera obtusiloba* BL.	1
Carex lanceolata BOOTT.		*Lindera erythrocarpa* MAKINO	4
Carex siderosticta HANCE	3	**Saxifragaceae**	
Liliaceae	1. 3	*Astilbe chinensis* var. *davidii* FR.	2
Hemerocallis fulva var. *kwanso* REGEL.	2. 3	**Rosaceae**	
Smilax sieboldii MIQ.		*Pyrus pyrifolia*(BURM.) NAKAI	1. 2. 3. 4
Smilax china L.	3	*Duchesnea chrysantha*(ZOLL. et MORR.) MIQ.	2. 3
Orchidaceae		*Rubus crataegifolius* BUNGE	2. 3
Cephalanthera longibracteata BL	2	*Potentilla fragarioides* var. *major* MAX.	2. 3
Betulaceae	1. 2. 3	*Rubus oldhamii* MIQ.	2. 3
Corylus heterophylla var. *thunbergii* BL.	4	*Agrimonia pilosa* LEDEB.	2. 3
Corylus sieboldiana BL.	1	**Leguminosae**	
Carpinus cordata BL	3	*Vicia venosissima* NAKAI	2
Carpinus laxiflora BL.	3	*Glycine soja* S. et Z.	2
Betula davurica PALL.		*Lespedeza bicolor* TURCZ.	2. 3
Alnus hirsuta(SPACH) RUPR.		*Pueraria thunbergiana* BENTH.	2
Fagaceae	3	*Lespedeza maximowiczii*	3
Quercus dentata THUNB.	1. 2. 3. 4	**Anacardiaceae**	
Quercus serrata THUNB.	3	*Rhus chinensis* MILL.	3
Quercus variabilis BL.		**Aquifoliaceae**	
Ulmaceae	1. 4	*Ilex macropoda* MIQ.	1
Celtis sinensis PERS.	4	**Celastraceae**	
Zelkova serrata MAKINO		*Celastrus orbiculatus* THUNB.	3
Moraceae	1. 3	*Euonymus oxyphyllus* MIQ.	3. 4
Morus bombycis KOIDZ.		*Euonymus alatus* for. *ciliato - dentatus* HIYAMA	1. 3. 4
Aristolochiaceae	3		
Asarum sieboldii MIQ.			

Table 4. (Continued)

Scientific name	Survey area	Scientific name	Survey area
Aceraceae		**Sympocaceae**	
Acer mono MAX.	1. 3	*Symplocos chinensis* for. *pilosa* (NAK.) OHWI	1. 3
Acer pseudo-sieboldianum(PAXTON) KOM.	1. 4	**Styracaceae**	
Rhamnacea		*Styrax obassia* S. et Z.	1. 3
Rhammus yoshinoi MAKINO	3	**Oleaceae**	
Vitaceae		*Ligustrum obtusifolium* S. et Z.	4
Vitis amurensis RUPR.	4	**Borraginaceae**	
Actinidiaceae		*Trigonotis peduncularis* BENTH.	1. 2. 3
Actinidia arguta PLANCH.	1. 2. 3	**Verbenaceae**	
Violaceae		*Callicarpa japonica* THUNB.	
Viola rossii HEMSL.	2. 3	**Labiatae**	1. 3
Viola collina BESS.	3	*Prunella vulgaris* var. *lilacina* NAKAI	
Viola acuminata LEDEB.	2. 3	*Isodon inflexus*(THUNB.) KUDO	2
Elaeagnaceae		**Plantaginaceae**	3
Elaeagnus macrophylla THUNB.	3	*Plantago asiatica* L.	
Onagraceae		**Rubiaceae**	2
Epilobium pyrricholophum FR. et SAV.	2	*Rubia akane* NAKAI	
Umbelliferae		**Caprifoliaceae**	2. 3
Angelica polymorpha MAX.	2	*Viburnum dilataum* THUNB.	
Cornaceae		*Weigela florida*(BUNGE) A. DC.	4
Cornus macrophylla WALL.	3	*Sambucus sieboldiana* var. *miquelii*(NAK.) HARA	2. 3
Cornus controversa HEMSL.	1. 2	*Lonicera subhispida* NAKAI	2
Pyrolaceae		**Compositae**	2. 3
Pyrola japonica KLENZE	4	*Erieron annuus*(L.) PERS.	
Ericaceae		*Youngia sonchifolia* MAX.	2
Rhododendron yedoense var. *poukhanense*(LEV.)	3	*Aster ageratoides* TURCZ.	2
NAKAI	1	*Artemisia stolonifera*(MAX.) KOM.	2
Rhododendron schlippenbachii		*Synurus deltoides*(AIT.) NAKAI	3
Primulaceae	2	*Artemisia princeps* var. *orientalis*(PAMPAN.)	3
Lysimachia acroadenia MAX.		HARA	2

since the current study area had similar climate conditions to Touhuku in Japan, which is a mid-temperate zone, the vegetation structure was also very similar to that of a *Quercus serrata* forest in Japan[17]. In a second-growth forest, the flora is expected to change considerably according to the environment and forest management. Consequently, rather than leave the forest alone, the current study would seem to indicate that the best way to preserve the growth of Dolbae trees is the effective management of plants that are vigorous in character or grow fast in the vicinity of Dolbae trees and the removal of climbing plants, such as *Pueraria thunbergiana*, *Vitis amurensis*, *Actinidia arguta*, and *Celastrus orbiculatus*.

The degree of diversity for each species in the natural habitat of the Dolbae trees, determined using Shannon-Weiner's Index[18], was within a range of 2.901 ~ 5.065(Table 5), which was relatively higher than that determined for the habitat of *Pyrus ussuriensis* around the Jindong valley, where the dense forest consists of xylophytes(Ahn *et. al.*[4]). According to Table 2, area 3 had an especially high degree of diversity, reflecting excellent conditions for the growth of various plants due to a high content of organic matter in the soil, high cation exchange capacity(CEC), and relatively deep layer of surface soil. In a previous paper on the distribution of naturally growing *Rhapontica uniflora* and the related ecological characteristics, Ahn and Choi[6] reported that soil conditions are closely related to the plant species that make up the vegetation. In area 4 in the current study, located in front of Haein temple, *Sasa borealis* dominated

Table 5. Species diversity in *Pyrus pyrifolia* habitats

Habitat area	Number of species	Number of total individual	Shannon-Weiner's diversity index (H')	Maximum of diversity index (H' Max)	Evenness (J')	Dominance (D)
I	24	161	3.750	1.380	2.717	0.880
II	42	222	4.845	1.623	2.985	0.952
III	50	161	5.065	1.698	2.982	0.959
IV	16	112	2.901	1.204	2.409	0.761

under a tree layer of deciduous broad-leaved forest, including *Quercus serrata* and *Zelkova serrata*. As a result, the degree of diversity for each species was relatively low in this area, as a simple herb layer was formed by colonies of *Sasa borealis*, in spite of very good sunshine conditions.

Fig. 2 shows the DBHs for the Dolbae trees found growing naturally on Mount Kaya. Overall, the DBHs ranged from 10~60 cm. The DBHs for the Dolbae trees in area 1 included one at 50-60 cm, one at 40~50 cm, five at 20~30 cm, and one at 10~20 cm. Four old and large Dolbae trees with a DBH of 50~60 cm were examined in area 2 and recommended as an excellent genetic resource for the future. In area 3, eleven Dolbae trees were examined with DBHs ranging from 10~50 cm. Finally, area 4 included one Dolbae tree with a DBH of 50~60 cm and four with a DBH of 40~50 cm. Based on these results, it would appear that the Dolbae trees in the surveyed areas were at least 50 years old. Although it is difficult to determine the exact timing and type of disturbances experienced by the natural habitat of the native Dolbae trees growing on Mountain Kaya, the conditions would seem to suggest the emergence of a second-growth forest in a typical mid-temperate zone after forest damage about 10 years earlier. As such, the surveyed areas exhibited severe competition and selectivity among various plant species[19]. Accordingly, to preserve the naturally growing Dolbae trees as a valuable genetic resource, proper management of the forest is needed, for example, the periodic removal of climbing plants and xylophytes to secure light for the crown of the Dolbae trees and reduce competition with other species.

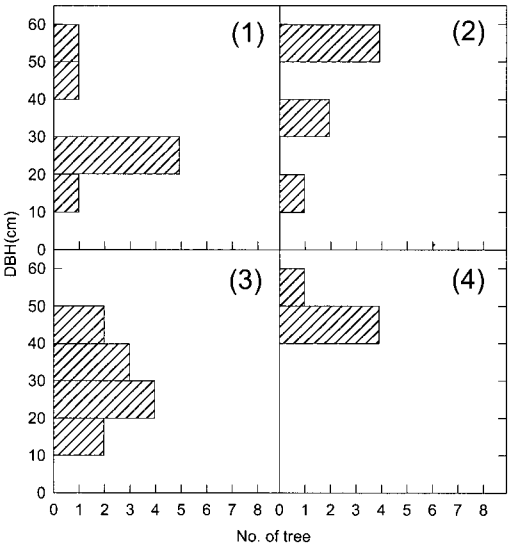

Fig. 2. Distribution of DBH classes of *Pyrus pyrifolia* in surveyed areas.

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