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Comparison of the Initial Demographies of Pine and Oak Populations in Rural Pine Forests in Korea and Japan

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In order to understand the human impact upon demographic change in plant population in rural forests, we examined the population trends of *Pinus densiflora* and *Quercus serrata* in *P. densiflora* forests viewing their seedlings and saplings in rural Korea and Japan. The most prominent factor affecting the regeneration of the pine and oak was the intensity of management activity which controlled the vegetation stratification and its light environment. Open spaces, such as graveyard or cleaned area that allow the long-term direct daylight in dry season to accelerate the surface heat of soil, were unfavorable habitats for germination and growth of both species. The negative effects of the presence of litter and evergreen trees were related to the failure of early seedling and sapling growth of pine. Cover of litter is, especially, another factor related to the growth of pine saplings. It is considered that successful germination and sapling growth of pine and oak in early successional stages is determined by vegetation structures and light condition.

Keywords: germination, initial demography, light condition, mosaic vegetation landscape, *Pinus densiflora* forest

INTRODUCTION

Pinus densiflora is a light-demanding species which regenerates in the early successional phases such as open bare land or post-fire sites (Nakagoshi *et al.*, 1987). *Pinus densiflora* forest is a representative secondary vegetation in rural regions in Korea and Japan. Its ecological function has been established and maintained by natural and human disturbances in community and landscape scales (Hong *et al.*, 1993, 1995).

The ecological characteristics of human impact on the rural forest are, however, not yet clear. A rural forest has many ecological roles, for instance, wood supply, providing habitats for local biota, and environmental purification between urban and agricultural areas. At present, many studies on secondary forests in the relationships between man and vegetation might provide reliable information necessary for a management strategy for both sustainable forest use and agriculture in world countries (Gonzáles-Espinosa *et al.*, 1991; Iida and Nakashizuka, 1995; Hong, 1998). For this purpose, the current regeneration strategies of *Pinus densiflora* and some oaks as major species of secondary forest was examined through an organism-environment integrated demographic approach (Harper, 1977; Beatty, 1984; Collins and Good, 1987).

Species comparisons were made using the pine, and some oaks which were probably changed from the pine as canopy species in the succession process in both countries. In the present study, comparison of emergence and survival success of seedlings and saplings of both genera under different intensity of anthropogenic conditions were examined in an attempt to find the "favorable habitats" (Harper, 1977; Fowler, 1988).

There are many environmental factors on germination performance of plants. Light and soil moisture, in specially, is significantly important factors on early germination and seedling growth (Grime and Jeffrey, 1965; Grime, 1979; Canham *et al.*, 1990). Differ with natural condition like natural forest, these factors are unstable in the rural forest extremely susceptible to human impact. Therefore,

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regeneration strategy of pine occurring at early successional stage should be depending on the constant supply of light and soil moisture. Human activity, however, always disturbs the forest structure, and creats vegetation heterogeneity by forest management. In recent, many ecological studies are focusing on the succession process and regeneration mechanism of human-influenced vegetations for keeping sustainable ecosystem and usable energy resource (Gonzáles-Espinosa *et al.*, 1991; Iida and Nakashizuka, 1995; Hong and Nakagoshi, submitted). Under this idea, we carried out the population level comparing of co-occuring pine and oak in both rural pine forests of Korea and Japan with recent different anthropogenic disturbance intensity.

The first aim of this study is to verify the relationships between germination and establishment dates, and seedling success. The second is exploring the factor affecting failure of seedling performance and its mortality types. Finally, we wish to know the Status Quo of rural forests in both countries by comparing the initial demographies of pine and oak as major plant vegetations composed of rural forest.

MATERIALS AND METHODS

Investigated Sites and Species

This study was carried out in Yanghwa-ri (YH, lat. 36° 23' N, long. 127° 12'E) in Korea and Miwa-cho (MW, lat. 34° 32'-34° 43'N, long. 132° 46'-132° 52'E) in Japan (Fig. 1). The vegetation landscape of the study areas have been described in *bis* Hong *et al.*, 1993-1995. The secondary pine forest covers two sites. Yanghwa-ri is a hamlet in Mt. Kyeryong National Park, Korea. The soil is derived from granite and most of the Yanghwa-ri forest area is privately owned.

Miwa-cho is in a basin in the central part of Hiroshima Prefecture, Japan. The geology in Miwa-cho consists of granite and the soil of the study area is generally yellowish-brown forest soil and immature soil (Hong *et al.*, 1995). The vegetation in both areas is mostly *Pinus densiflora*. Both regions belong to the temperate forest zone (Box, 1995). The two regions have no remarkable differences regarding annual mean temperature and precipitation (12.2°C and 1,319 mm in YH and 12.4°C and 1,471 mm in MW), though there were weak differences in the monthly mean precipitation.

Two genera, *Pinus* and *Quercus*, were examined

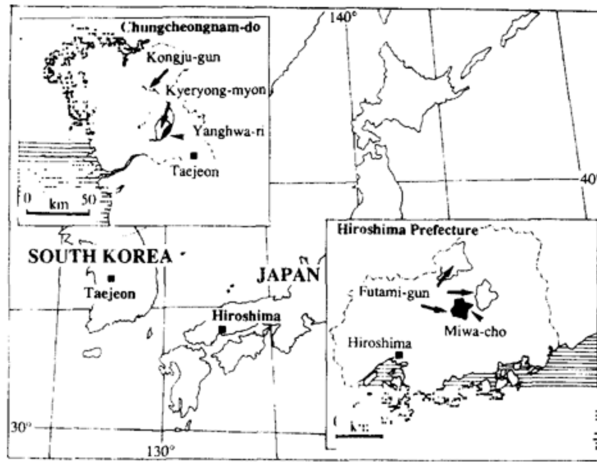

Fig. 1. The locations of study areas.

in this study. *Pinus densiflora* and *Quercus* species like *Q. variabilis* and *Q. accutissima* including *Q. serrata* are the representative species maintaining rural forest in a agricultural landscape system. Specifically, the following species were studied: *Pinus densiflora* and *Quercus serrata* are co-occuring at pine forests in both countries (referred to as pine and oak). A few seedlings of the alien *Pinus rigida* were present in the unexploited forest in Yanghwa-ri, however those were removed from this study. Pine seedlings were aged by counting terminal bud scale scars. Individuals over two years old were treated as saplings. Juveniles smaller than 1.3 m in height were also selected as saplings (Hong *et al.*, 1993).

Experimental Design and Analysis

Two pairs of 20×50 m^2 permanent quadrats were set up in two areas where a preliminary survey including tree census for all woody stems had been carried out. Each quadrat was placed in a series of heterogeneous vegetations in the managed forest (Fig. 2); an open forest with graveyards (GY) and a herb-layer cleared forest around graveyard (UM) were selected in Yanghwa-ri, while in Miwa-cho, heterogeneous pine forests consisting of cleared area (CU), plantation (PL) and natural pine regeneration area (RE) were chosen. Unexploited forest stands (non-managed, abandoned forests) away from the managed forest stand were carefully selected as controls; Yanghwa-ri unexploited forest (YU) and Miwa-cho unexploited forest (MU).

Eighteen circular subplots (90-cm in radius) were located in both unexploited plots. Due to the

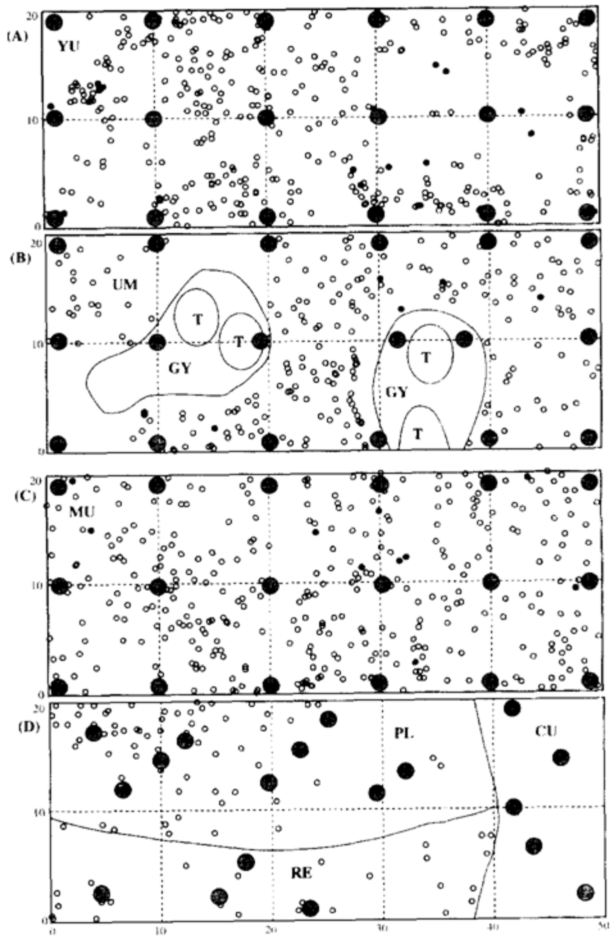

Fig. 2. Spatial distribution maps of *Pinus densiflora* and oak over 1.3 m height and circular subplots in study stands (each 20 m×50 m) in Yanghwa-ri, Korea and Miwa-cho, Japan. Hatched circle; subplot with 1.8m in diameter. Open circle; the pine stem, and dot; oak stem. (A) Unexploited and (B) managed forests in Yanghwa-ri and (C) unexploited and (D) managed forests in Miwa-cho. YU: unexploited forest, UM: a herb-layer cleared forest around graveyard, GY: an open forest with graveyard, T: soil mounded tomb in Yanghwa-ri, MU: unexploited forest, RE: natural pine regeneration area, PL: plantation area of *Chamaecyparis obtusa*, CU: cleared area in Miwa-cho.

different sizes of heterogeneous managed stands, circular subplots (90-cm in radius) distributed by size of patches (Fig. 2). Current seedlings (first-year seedlings) of the pine and oak were counted in these subplots between early April 1992 and April 1993.

Counting of presence and absence of seedlings and saplings of the pine and oak was carried out. Seedlings and established saplings were marked and their survival followed. Mortality factors were placed in four categories; withering, breaking-off, predation, and others. Chemical properties of soil, relative light intensity and structure of vegetation were measured. Two hundreds grams of soil samples, excluding O horizon, were taken from all subplots. Organic carbon was determined by loss on ignition; total nitrogen content was determined by the micro-Kjeldahl method. The pH was measured in a 1:2.5 volume ratio (soil-water suspension) using a glass electrode assembly. Total nitrogen and carbon content were determined by C/N coder. Carbon was considered as organic carbon because of the acidic soil property of pine forests in Miwa-cho and Yanghwa-ri (Fig. 2).

The relative light intensities of the subplots were measured by using a fisheye camera lens (Nikkor Auto Lens 8mm, f=2.8 Camera body: Nikkon F4) at the height of 30 cm from the floor (Madgwick and Brumfield, 1968). Total illuminance was counted using a grid on each hemispherical photograph of the forest canopy. The percentage reduction of illuminance was estimated by counting the segments which were clear and those which were obstructed (Anderson, 1964). The circular subplots were helpful for measuring relative light intensity by hemispherical photography and other habitat factors of sites located in each subplot.

Vegetation structures surrounding seedlings and saplings were noted. Cover (%) of each forest understory, tall-tree (>8 m in vegetation height), sub-tree (3~7.99 m), shrub (1.3~2.99 m) and herb layer (<1.29 m) were recorded. The cover (%) of litter of each subplot was measured. Total plant species identified in the stands were placed in woody, herb, and evergreen plant classes to investigate the efficiency of seedling survival and maintenance under vegetation succession. Data analyses in this study were carried out using statistics-graphic software StatView (ver 4.02) for Macintosh.

RESULTS

Habitat Structures

Vegetation characteristics and several habitat variables measured in surveyed plots are described in Table 1. Tall-tree and sub-tree forests were mostly pines in YU with a mean cover of 69.9%. Under the tall-tree and sub-tree layers, nitrogen-fixing plants such as *Robinia pseudo-acacia* and *Alnus* spp. commonly comprised the shrub layer. *Lespedeza* spp., *Carex* spp., *Robinia pseudo-acacia*, *Miscanthus sinensis* and pine saplings frequently appeared at the open bareland were dominant in the herb layer. Cover of litter was 76.4%. Except for tall-tree pines, all layers are harvested by forest management in UM. Harvested forest by-products have been used for fuel for heating and organic fertilizer by nearly farm household. Cover of litter, mostly fallen pine leaves, was 48.5%. GY is an open area without vegetation canopy. Coverage of the herb layer was 50.8% mainly owing to *Zoysia japonica*. Coverage of litter was smaller (5.5%) than that of other two plots in Yanghwa-ri (Table 1). The relative light intensity inside the forest was the lowest of all surveyed plots in MU. As a result of long-term forest abandonment (Hong *et al.*, 1995), the shade-tolerant plants such as *Ilex* spp., *Eurya japonica* and *Pieris japonica* rigorously colonised the pine forest (mean cover of all layers is 77.8%). Woody plants were covered with 90.5% of the cover of ground surface and a ratio of 35.6% was by evergreen plants. Acidic soil and high C/N ratio were likely to be caused by decay of fallen pine leaves (Table 1). Under the canopy pines, juvenile pines younger than 10 years old composed the sub-tree layer in RE. Coverage of shrub and herb layers were poor due to management. Specially, *Miscanthus sinensis* was a characteristic grass plant in this plot. Plantation of Japanese cypress, *Chamaecyparis obtusa* often occurred in Miwa-cho. In PL, juvenile *Chamaecyparis obtusa* was planted under the canopy pine. Cover of shrub layer was also poor due to periodic management like RE. The highest ratio of woody plants among other plots was examined. Vegetation structure of CU was similar to GY. After cutting the pine trees, juvenile *Chamaecyparis obtusa* smaller than 30-cm in height was planted. Regrowth of some phanerophytes *Rhododendron* spp., *Ilex* spp., *Eurya japonica*, *Quercus* spp. and *Rubus* spp. remained in the herb layer (coverage 80.7%) in the cleared area. Evergreen shoots beneath the young plantation of *Chamaecyparis obtusa* (45.8%) were particularly important. Litter was, mainly, composed of evergreen shrub leaves, and their coverage showed 25.7%.

Germination Performances of the Pine and Oak

Table 2 shows the monthly dynamics of current seedlings and saplings of the pine and oak which were counted at each subplot during the period of one year. Germination of pine of Yanghwa-ri took place in April, earlier than that of Miwa-cho. Almost all seedlings of pine in Miwa-cho were recruited from late spring to early summer at all plots. Germination of pine continued to July, and decreased from early fall at RE and PL. Virtually no seedlings emerged after early fall. All pine seedlings

Table 1. Means of 13 habitat variables of surveyed plots. RLI*p* is relative light intensity measured by hemispherical photography. YU: unexploited forest, UM: a herb-layer cleared forest around graveyard, GY: an open forest with graveyard in Yanghwa-ri, Korea. MU: nuexploited forest, RE: natural pine regeneration area, PL: plantation area of *Chamaecyparis obtusa*, CU: cleared area in Miwa-cho, Japan

Variable	Yanghwa-ri			Miwa-cho			
	YU	UM	GY	MU	RE	PL	CU
Light intensity RLI*p* (%)	39.3	42.2	54.2	28.3	51.8	43.6	72.4
Vegetation structure							
Cover (%) of tall-tree layer	88.5	60.5	0	90.3	35.7	75.6	0
sub-tree layer	53.3	20.6	0	70.2	71.6	0	0
shrub layer	72.5	15.4	0	58.5	18.7	22.5	0
herb layer	65.0	31.7	50.8	92.2	53.5	50.0	80.7
mean	69.8	32.1	12.7	77.8	44.9	37.0	20.2
Cover of ground surface by litter	76.4	48.5	5.5	90.5	38.5	40.3	25.7
Height of herb layer (m)	0.7	0.5	0.1<	1.4	0.5	0.5	0.7
Ratio (%) of woody plants	74.7	84.5	1.5	90.5	76.4	95.0	85.7
herbaceous plants	25.3	15.5	98.5	9.5	23.6	5.0	14.3
evergreen plants	4.5	2.5	0	35.6	15.5	30.1	45.8
Soli properties							
pH	4.3	5.1	5.7	4.7	5.2	4.8	4.8
C/N (%)	31.8	39.1	28.8	43.6	34.6	28.7	28.9

Table 2. The monthly variations of a mean number of current seedlings and saplings of *Pinus densiflora* and oak. Each number indicates mean number of each subplot. Number of parentheses shows mean number of established sapling per subplot

Plots (Number of subplots)	Time spans (Calender month)						
	Apr. '92	May	June	July	Oct.	Nov.	Apr. '93
Pine							
YU(18)	3.0(9.0)	3.5(10.2)	–	3.7(10.1)	2.8(5.9)	–	1.9(4.0)
UM(14)	<1(7.4)	1.5(7.7)		<1(7.9)	<1(4.9)		<1(4.6)
GY(4)	0(6.0)	1.2(9.0)	–	<1(9.0)	<1(5.0)		0(<1)
MU(18)	0(4.0)	3.7(4.5)	3.2(4.5)	3.1(4.4)	–	2.0(3.2)	1.4(2.7)
RE(4)	0(9.7)	2.5(13.5)	4.7(13.5)	8.0(13.5)	–	5.0(11.5)	4.7(10.5)
PL(9)	0(13.8)	11.1(20.8)	13.0(20.8)	15.0(20.8)	–	11.4(14.5)	8.2(11.4)
CU(5)	0(13.2)	<1(14.4)	<1(14.4)	<1(14.4)	–	<1(13.6)	0(5.4)
Oak							
YU(18)	<1(1.5)	<1(1.6)	<1(1.6)	<1(1.6)	<1(1.6)	–	<1(1.3)
UM(14)	<1(7.1)	<1(7.6)	<1(7.6)	<1(7.5)	<1(4.1)	–	<1(3.2)
GY(4)	0(2.2)	<1(2.2)	<1(2.2)	1<(2.2)	<1(1.5)	–	0(0)
MU(18)	0(0)	<1(<1)	<1(<1)	<1(<1)	–	0(0)	0(0)
RE(4)	0(0)	0(1.0)	0(1.0)	<1(1.1)	–	<1(1.0)	<1(<1)
PL(9)	0(0)	1(1.0)	0(1.0)	0(0)	–	0(1.0)	0(1.1)
CU(5)	<1(0)	1.1(0)	1.1(0)	1.1(0)	–	<1(0)	0(0)

disappeared until next April at GY in Yanghwa-ri and at CU in Miwa-cho where the total germination was less than the other plots. Saplings of pine were found at YU in Yanghwa-ri, but at MU there were fewer than in the other three plots of Miwa-cho. Saplings show a similar trend at the sites where seedlings emerged. In the monthly variations of seedlings and saplings, clear distinction between unexploited plot (MU) and managed plots (RE and PL) was observed in Miwa-cho. The number of seedlings and saplings of pine of Yanghwa-ri was not significantly different between unexploited plot (YU) and the two managed plots (UM and GY).

The total oak germination was less than that of pine and the germination date was different, because it was delayed about one month at YU and UM in Yanghwa-ri and CU in Miwa-cho. Fertility was poor in all plots in Yanghwa-ri and Miwa-cho. Both pine and oak seedlings once recruited safely, were decreased from early fall. Seedlings were notably absent at GY in Yanghwa-ri and two plots, MU and CU, in Miwa-cho in next April. Germination of oak at GY could not be monitored next April, but the germinated oak of PL has been survived till next spring. Saplings of oak were recorded at all plots in Yanghwa-ri, but most of them disappeared from fall to winter.

Survivorships

Figure 3 shows the survival curves for seedlings and saplings of the pine and oak. After successful germination, the seedling survival varied widely in space and time. Germination of the pine and oak continued from April to early October 1992 in YU and UM. At the same time, mortality began in May in the dry season in 1992. A sharp decline occurred at UM and GY in Yanghwa-ri and CU of Miwa-cho where human disturbance are frequent. Seedlings which emerged early show a higher survival rate than that of later-recruited seedlings. But in CU, germination in all plots in Miwa-cho was one month later than those of Yanghwa-ri. These plots, show a higher survival rate of pine than those of Yanghwa-ri. Pine seedlings, except for those in GY and CU, maintained their high survival rates until the following spring.

MU contained few oak seedlings because it was not favorable for their germination. Mortality in YU and UM began earlier than in MU and RE in Miwa-cho. Except for PL which had no oak seedlings, survival rates in all plots in Miwa-cho were rather lower than those of YU and UM in Yanghwa-ri. GY and CU had the highest mortality of both pine and oak seedlings. They may be severe habitats for germination success although their relative light intensities were high.

Pine saplings of CU show significantly higher survival rate than those of GY. There is considerable oak regrowth in CU, but no saplings. Both pine and oak saplings in RE and PL in Miwa-cho and UM in Yanghwa-ri show a moderate

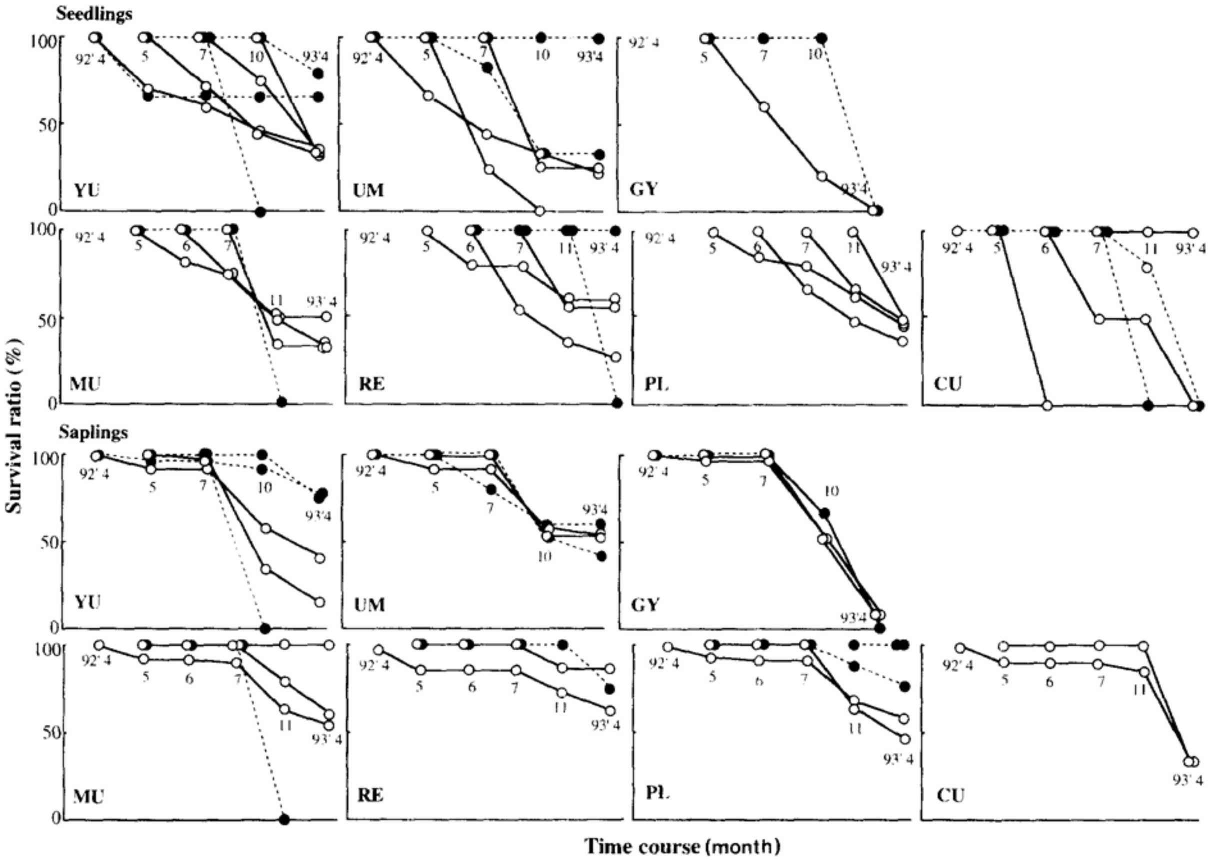

Fig. 3. Survivorship curves of seedlings and saplings of the pine and oak in each stand. Open circle and line; pine, closed circle and dot line; oak.

reduction of their survival rates. MU with the lowest relative light intensity of all plots may not suitable for establishment and growth of deciduous oaks. The survival rates of some pine and oak saplings in YU decreased from July 1992.

Mortality

Mortality rates and variation of mortality factors in pine seedlings were examined during the period of one year. Mortality by annual drought is the most important factor in all plots in Yanghwa-ri, especially in the open space of graveyard (GY) (Fig. 4). Breaking-off and trampling occurred during management activity at UM and GY in the fall. Trampling was a major factor from early fall in all plots in Yanghwa-ri, suggesting that forest managers may move towards the managed forest such as UM and GY through this unexploited forest. Damage by animals was not identified in Yanghwa-ri.

In Miwa-cho, drought is also a main cause of mortality. Human disturbance, such as breaking-off and trampling, were identified in late fall in three managed forests. An interesting damage factor is predation by animals. In PL where juvenile *Chamaecyparis obtusa* were planted, grazing livestock removed the understory of shrubs and herbs. This damage was rarely found in either RE or CU. Damage was also caused by field mice and insects on pine seedlings, but it was not possible to trace those animals. There were other unknown factors which caused seedling damages in Miwa-cho (Fig. 4). Considering the small forest animals and insects, it may also related to their predation without leaving the feed trace. In the pine forests in Yanghwa-ri, apparent field mice or insect damages were not identified. In this study, disappearance of seedlings may be, however, related to predation movement of field animals like *Sciurus vulgaris* and *Tamias sibiricus* (Hong, personal observation). According to the field predation test (Hong and Rim, 1997), forest small animals like *Sciurus vulgaris* and *Tamias sibiricus* frequently had leave their feed traces in the seedling. However, these damaged seedlings were

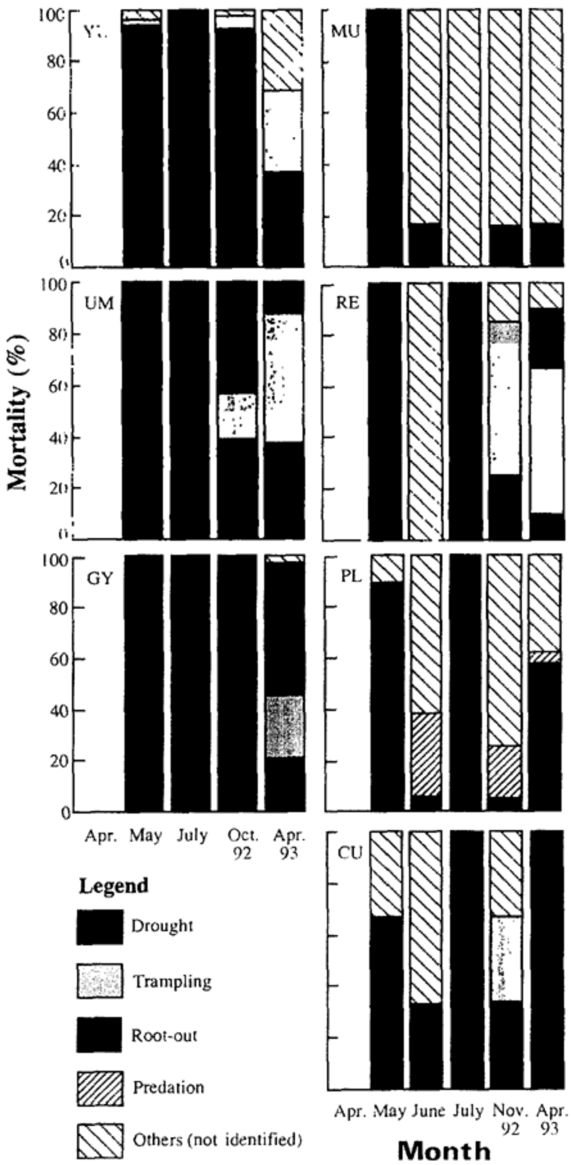

Fig. 4. The composition spectrum of mortal factors of the pine seedlings in different months.

easily root-out and disappeared by soil erosion and rain fall. Disappearance of seedlings, therefore, was considered as one of the mortality factors. As a result of this study, it is certain that the mortality factors such as breaking-off and trampling are direct indicators of human disturbance on forests. Unlike old natural forests, the drought factor in human-disturbed forest may be greater upon the forest floor.

Light Effects on Seedling and Sapling Growth

In order to understand the effect of the light conditions on survivorship and natural mortality of seedlings and saplings in each subplot, the correlation analysis between relative light intensity and the cumulative number of seedlings and saplings was examined (Table 3). The correlation coefficient between emerged and dead seedlings of pine and relative light intensity were significantly high at GY in Yanghwa-ri (Pearson's correlation coefficient $r = 0.869$, $p < 0.01$ and $r = 0.661$, $p < 0.01$) and CU in Miwa-cho ($r = 0.835$, $p < 0.01$ and $r = 0.854$, $p < 0.01$). Seedlings of oaks also showed a similar result at GY in Yanghwa-ri and RE and CU in Miwa-cho. In the case of GY, the light conditions influenced on germination performance of oak seedlings and had an effect on successful sapling growth or failure ($r = 0.691$ in saplings emerged, $r = 0.701$ in sapling dead). While CU in Miwa-cho, the higher relative light intensity seems to offer good conditions for seedling establishment, but other factors affected on the mortality of the seedlings. The mortality of oak saplings at GY, despite high relative light intensity, was also high ($r = 0.701$, $p < 0.01$) and there was a significant relationship between dead pine seedlings and relative light intensity ($r = 0.661$). Even once emerged, most pine seedlings were killed by early summer drought or run-off with soil in the rainy season. Some of the grown seedlings and saplings were however removed by forest management in the graveyard during the fall.

Heterogeneous Human Effect on Rural Pine Forest

In order to identify the human impact on germination and seedling growth, the ratio of human-induced mortal factors (such as breaking-off and trampling) to the total mortal factors was quantified. Figure 5 shows human impact on each stand in Yanghwa-ri and Miwa-cho. The black part (over than 81%) in Yanghwa-ri indicates a completely disturbed stand because of clear-cutting of forest for the construction of a graveyard during the investigation period. The human impact in Yanghwa-ri, GY and its surroundings, is caused by intensive management activities (41~60% in GY and 21~40% in surroundings of GY, UM). Moreover, these human activities extend to a long distant unexploited forest along pathway toward the managed forest. Human disturbance was rarely found at MU in Miwa-cho. The most affected area was CU which showed more damage than other plots in a

Table 3. Correlation coefficients between relative light intensity (RLI*p*) and mean number of seedlings and saplings of the pine and oak

Variable	Yanghwa-ri			Miwa-cho			
	YU	UM	GY	MU	RE	RL	CU
Pine							
Emerged seedlings		0.151^{ns}	0.869**	0.105^{ns}	0.310*	0.096^{ns}	0.835**
Dead seedlings	0.010^{ns}	0.057^{ns}	0.661**	0.322*	0.023^{ns}	0.130^{ns}	0.854**
Emerged saplings	0.148^{ns}	0.577*	0.207^{ns}	0.303*	0.011^{ns}	0.266^{ns}	0.316*
Dead saplings	0.042^{ns}	0.569*	0.039^{ns}	0.264^{ns}	0.370*	0.090^{ns}	0.495*
Oak							
Emerged seedlings	0.147^{ns}	0.323*	0.869**	0.137^{ns}	0.857**	–	0.702**
Dead seedlings	0.093^{ns}	0.088^{ns}	–	0.210^{ns}	0.890**	–	0.750**
Emerged saplings	0.027^{ns}	0.306*	0.691**	0.284^{ns}	0.820**	0.188^{ns}	–
Dead saplings	0.099^{ns}	0.164^{ns}	0.701**	0.258^{ns}	0.370*	0.438*	–

**; significant at $p<0.01$ (bold type), *; $p<0.05$, ns; non-significant, Bar; a result not recorded.

heterogeneous managed forest in Miwa-cho.

DISCUSSION

Cause of Heterogeneous Patch of the Rural Pine Forests

Human impact is one of the important factors which changes the original structure, composition and pattern of vegetation. Traditional forest management such as tree cutting, grazing or slash-and-burn farming have a direct effect upon the species composition and vegetation structure, including the succession process, in woody and herbaceous vegetation of the forest floor (Andersson, 1991; Hong *et al.*, 1995). Such human disturbance upon vegetation landscape fosters the occurrence of spatially heterogeneous man-made vegetation (Burgess and Sharpe, 1981). One of the traditional uses of private rural pine forests in Korea is the construction of graveyards. They are built in cleanings within pine forests. Plants around the constructed graveyards are cut by the owners of graveyards once or twice a year. In Korea, construction of graveyards in pine forests is one of the important management regimes in the rural landscape (Hong *et al.*, 1993, 1995). Practical forest management is carried out in pine forests around graveyards. Phyto-materials such as cut twigs, branches, coppice stems and litter in forests have been used as a fuel for heating and as organic composts for agriculture (Kim *et al.*, 1981). Such periodic utilization has influenced the regeneration processes and productivity of rural pine forests in Korea (Hong and Nakagoshi, 1996).

Tall-tree layer is virtually dominated by the pine. Subtree and shrub layers are oaks such as *Quercus serrata, Q. variabilis and Q. acutissima*. Nitrogen-fixing shrubs like *Alnus firma, Robinia pseudo-acacia* are mixed with juvenile *Pinus densiflora* in unexploited forests in Yanghwa-ri. The undergrowth of a managed forest is controlled by traditional management such as litter scraping and weeding by scythe. This traditional management interfered with the vegetation development (Burgess and Sharpe, 1981; Gonzáles-Espinosa *et al.*, 1991). Only small saplings in the shrub and herb layers were established in the managed forest. These saplings were composed of oaks and alien pitch pine (*Pinus rigida*) which has a large quantity of seed and more vigorous regeneration than that of *Pinus densiflora*. When intensive management of undergrowth around a graveyard is stopped, the forest floor of the graveyard may be invaded by pitch pines.

Pine-dominated vegetation of Miwa-cho is similar to that of Yanghwa-ri. Pine forest is also a representative landscape element. Due to the development of a substitute energy resource since 1960s, the traditional forest exploitation became defunct in rural Japan (Nakagoshi and Ohta, 1992; Hong *et al.*, 1995). Except for some commercial pine forests managed for timber, plantation and edible mushroom production, most pine forests are drastically changing to broad-leaved forests by vegetation succession. Evergreen shrub-layer, such as *Ilex crenata, I. macropoda, Eurya japonica* and *Pieris japonica* which commonly occurred at the late successional stages, have invaded underneath the tall pine trees. Moreover, the accumulated fallen leaves of pine foster acidification of forest soil (see Table 1). According to Bormann and Likens (1979), the revegetation of open bare land formed by clear-

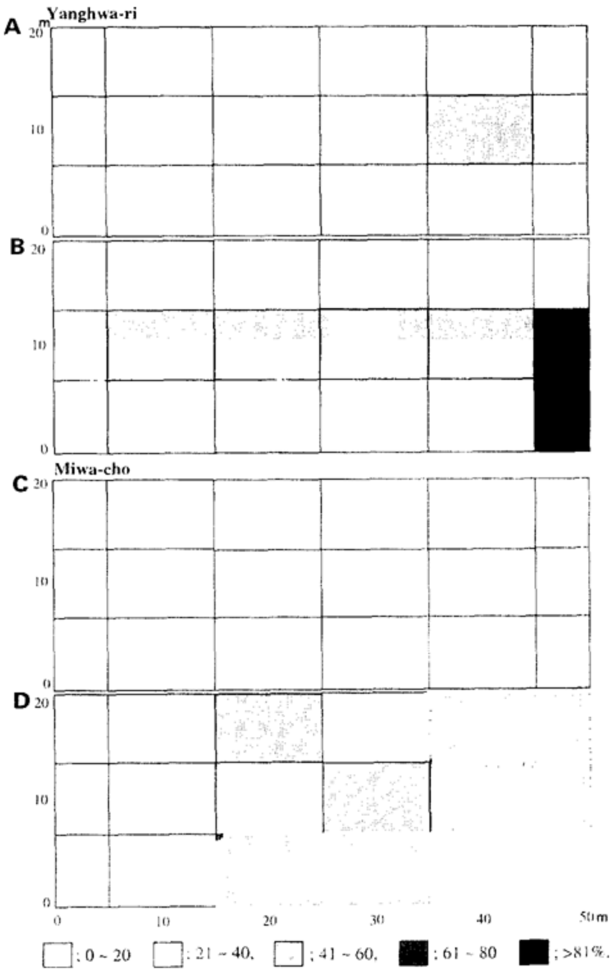

Fig. 5. Anthropogenic effect on heterogeneous habitats on pine forests investigated (A) unexploited and (B) managed forests in Yanghwa-ri and (C) unexploited and (D) managed forests in Miwa-cho. Each category represents spatially appearing human disturbance caused by forest management. It was quantified by calculating the ratio of human-induced mortality factors (such as root-out and trampling) to the total mortality factor in each subplot. The higher percentage means the more human disturbances. The area of 61~80% was absent in Yanghwa-ri, Korea.

cutting is usually accompanied by the increase of biomass accumulation. The biomass of undergrowth is, however, poor around graveyards in Yanghwa-ri because of intensive periodic collecting for fuel and organic fertilizer.

Mosaic Effects on Population Dynamics of the Pine and Oak

The germination of seed in GY, with a sunny light condition, did not coincide with that of other plots in Yanghwa-ri. In all plots, moreover, seedlings of the pine and oak started to die from early summer. It was certain that their germination failures were caused by drought in a dry season in the late spring. Furthermore, direct sunlight on seedlings would cause their germination failure. This means that once seedlings of pines and other plants in the sunny graveyard emerged in the early spring, seasonal factors inhibited their successful establishment (Table 3). The annual mean precipitation of Yanghwa-ri is similar to that of Miwa-cho and there is a little difference in monthly precipitation. Extremely low precipitation from spring to early summer, and a period of drought, continued in Korea.

After the dry season, about forty percent of annual precipitation came down in the middle of summer. Pine seedlings which had hardly established in the dry season were carried off by the run-off of soils. This trend appeared in the graveyard of Yanghwa-ri. The graveyard (GY) which was constructed after clear cutting of pine forest, is composed of several soil-mounted tombs (Fig. 2). People manage its surrounding by planting grass (*Zoysia japonica*) and removal of above-ground vegetation by weeding and livestock grazing. Community stratification of the graveyard, which is similar to an artificial meadow, can be sustained by intensive management regimes (Fig. 5). Being different from YU in Yanghwa-ri, saplings of oaks in CU also completely died as well as pine seedlings. Therefore, the decreasing survivorship curves of sapling and seedling from early October indicate human disturbance during the management season. Such an artificial environment was extended to UM surrounding GY, even though human disturbance was less severe than that of GY.

Plot CU in Miwa-cho had similar patterns of survivorship curves in pine seedlings (Fig. 3). Survivorship curves of pine seedlings at CU declined drastically from the late summer. It is especially characteristic that the pine seedlings in direct sunlight at CU died after the first investigation term. This was caused by drought sunlight (Fig. 4). Tall trees with large crowns usually stabilize the surface soil temperature by intercepting direct sunlight. Plot CU the same as GY in Yanghwa-ri, therefore, may be a severe habitat for establishing seedlings. Once seedlings are established successfully, the light condition in CU has a positive effect on tree growth (Fig. 3). Considering that the pine immediately invades disturbed places after clear-cutting or forest fire

(Nakagoshi *et al.*, 1987; Gonzáles-Espinosa *et al.*, 1991), both GY and UM in Yanghwa-ri and CU in Miwa-cho might be favorable for the rehabilitation of vegetation but this phenomenon was not observed.

All the oak saplings in Miwa-cho were smaller in number than in Yanghwa-ri. Even in RE, where the undergrowth under the tall pine canopy is managed regularly and so provides proper environment for germination of oak seedlings. As might have been expected, oak seedlings were rarely identified in PL where *Chamaecyparis obtusa* is planted under the canopy pine.

In the closed forests such as MU or PL, with luxuriant understory of evergreen shrubs, it is impossible to maintain the germination and growth of oak seedlings properly. Physiological characteristics of oak seedlings in light conditions (Takenaka, 1986; Matsuda, 1989) suggested that both habitats of MU and PL would have been too dark for the germination and growth of seedlings of oak (Table 3).

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