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Comparative Height Growth and Forest Structure of *Fraxinus Spaethiana* and *Pterocarya Rhoifolia* in Natural Reforestation Stands in Steep Valleys of Central Japan

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Height-growth analysis was used to examine forest structure and compare *Pterocarya rhoifolia* and *Fraxinus spaethiana* growth characteristics within and between each species in two *P. rhoifolia*-dominant and two *F. spaethiana* established contemporaneously in the sere, species vertical stratification 25 years after stand initiation was such that *P. rhoifolia* dominated the overstory but *F. spaethiana* the understory, including that *P. rhoifolia* grew about 4 times more rapidly. Similarly, *F. spaethiana* dominated the overstory but not the understory, in a stand where it established mainly by itself, 25 years after initiation. However, comparing the two different stands, *P. rhoifolia* overstory heights were about two times greater than *F. spaethiana*. This suggests that in a disturbance regime, forest regeneration is affected by height-growth patterns such that *P. rhoifolia*'s ability to achieverapid height growth allows it to dominate where lights growth allows it to dominate where light resources are continuously abundant.

Key Words : *Fraxinus spaethiana*, *Pterocarya rhoifolia*, Height-Growth Pattern, Natural Reforestation

1. Introduction

On large talus gravel sites in the steep valley region of the Chichibu Mountains, the main dominant trees are *Fraxinus spaethiana* Lingelsh (ash) and *Pterocarya rhoifolia* Sieb. et. Zucc (wignut)[1~3]. Characteristic of these sites is that *F. spaethiana* and *P. rhoifolia* dominance is interrupted in disturbance regimes which have led to significant variations between the two species in their density ratios and structure[4]. In the sere, *P. rhoifolia*is assumed to achieve more rapid height growth in large disturbance regimes; however, *F. spaethiana*has a higher degree of shade tolerance and a longer life span. These differences influence the regeneration process.

In this study an examination of individual success, as reflected in height-growth patterns, and as influenced by establishment time, would further our understanding of themechanisms driving secondary forest succession. Our objectives were to (i) describe species establishment patterns; (ii) compare height-growth rates between different-aged populations within individual species and between both species, (iii) compare and contrast the influence of height-growth rates on individual and species position in the height profile of each layer.

2. Study sites and methods

Research was conducted within young *F. spaethiana* and *P. rhoifolia*-dominated populations which regenerated naturally after harvesting (natural reforestation), on the steep valleys in the Chichibu Mountains, central Japan (36°00' to 36°04'N, 138°39' to 138°43'E). The study areas occurred at altitudes ranging from 920-1,390m, on the mainly bedrock but also including aqueous-rocks, sandstones, slates, quartziteand siliceous slates of the Chichibu-Paleozoic and Mesozoic-formations. The slopes were unstable, had gradients of 22-37, and contained large talus gravel on wet sites.

The general area around the research site, which was dominated by *F. spaethiana* and *P. rhoifolia*, experienced commercial logging whereby old growth populations were clear cut into "belt-shapes".

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Nevertheless, for purposes of natural reforestation seedling were not cut. At this sites, within the steep valleys that had undergone natural reforestation, forests of *P. rhoifolia*, *Pterostyrax hispida* Sieb. et. Zucc. *F. spaethiana* and *Cornus controversa*Hemsl. were mainly dominant, though other species existed, too. Incidentally, at the study sites, there was no evergreen dwarf bamboo, therefore its influence did not have to be taken into account regarding regeneration. Furthermore, coppice individual regimes were not included in the study plots. The region around the study area, located in the temperate zone, was occupied by deciduous broad-leaved forests. The research plots were studied in July to October of 1990 and August of 2000. Four stands were selected from young regenerated areas composed of the same surficial geology and soil characteristics. The four research plots chosen were 6- and 25-year-old *P. rhoifolia*-dominant stands (P-6, P-25), and 10- and 25-year-old *F. spaethiana* -dominant stands (F-10, F-25). These plot stands regenerated after clear cutting in 1984 (P-6), 1980(F-10) and 1965 (P-25, F-25). The area of plots P-6, F-10, P-25 and F-25 were 12, 24, 250, and 200m², respectively. In all plots, tree over 1.3m in height were measured for diameter at breast height (DBH) and height (H). Additionally, in plot P-6 all stems (H>0.1m) were measured for diameter at 0.1m height (D 0.1), and height. In plots P-25 and F-25, crown sizes were measured (H>1.3m).

For making clear characteristics on verticalstructure in these young forests, each plot was divided into three layers as follows. Tree heights in the first layer of P-6, P-25, F-10 and F-25 as measured from the ground were over 2, 15, 4, and 9m, in the second layer, 1-2, 5-15, 2-4, and 5-9m, and under 1, 5, 2, and 5m in the third layer, respectively. In each plot, detailed analyses of height-growth histories were done on *P. rhoifolia* and *F. spaethiana* stems in the three height-class layers. Two to seven stems were randomly selected from each of three layers in plots P-25, F-10 and F-25. Furthermore, all stems (H>0.1m, 79 *P. rhoifolia* and 41 F. *spaethiana*) were sampled in plot P-6. Annual height-growth measurements were taken using internodal methods and annual ring analysis.

3. Results

Tree heights frequencies are shown in Fig. 1. For P-6, all trees appears in an "L-shape" curve, the greatest number of *P. rhoifolia* (H>0.1m) are in the

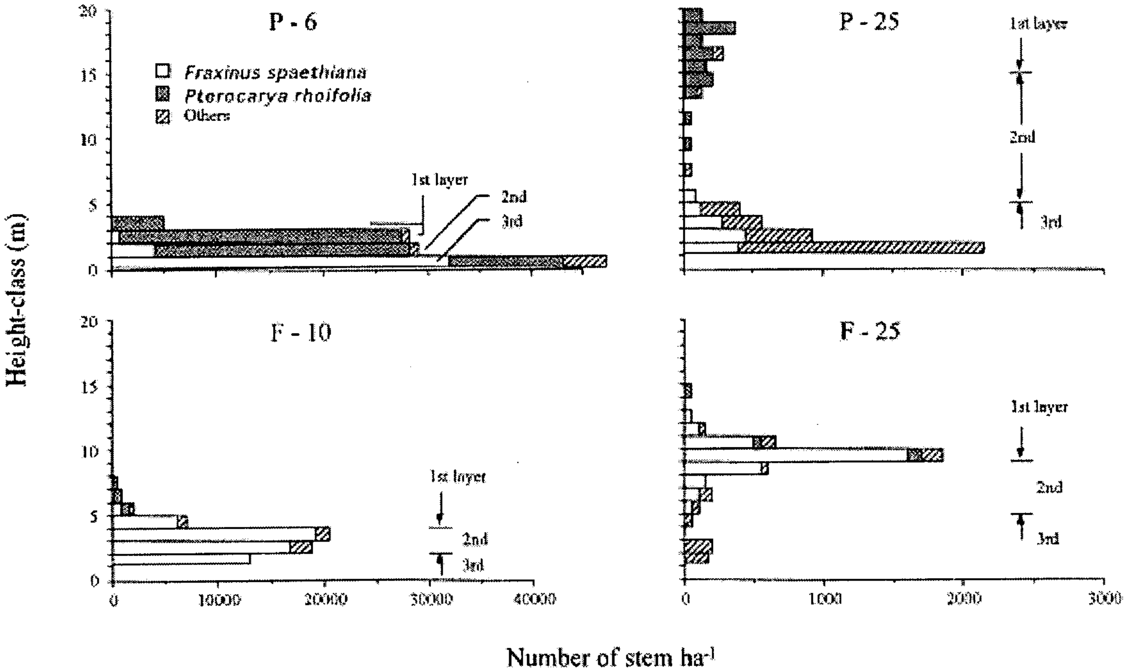

Fig. 1. Height-class distribution of stem (>0.1 m) in plot p-6, and stem (>1.3 m) in plots F-10, P-25 and F-25.

1.6-2.6m range. On the other hand, most *F. spaethiana* and others species were found in the range below 0.6m. As forP-25, the height-class distributions of all tree species (H>1.3m), when graphed, appear in a "L-shape" curve: *P. rhoifolia* individuals are found in the range above 9.3 m, while *F. spaethiana*individuals are found in the range below 7.3m. When graphed the overall height distribution pattern of *F. spaethiana* appears as a "bell-shape". In the *F. spaethiana*-dominant plots, that species dominated the overstory, but had undergone severe thinning in the understory. Furthermore, in stands where either of the two species was dominant in the overstory, that same species scarcely existed in the understory.

Various height growth curves between *P. rhoifolia* and *F. spaethiana*within the three layers of each plot are shown in Fig. 2. The mean average height of the first layer (canopy individuals) in each plot was 2.5m in P-26, 17.7m of P-25 individuals was sloe for the initial three years after germination *P. rhoifolia*annual height growth in P-6 from the 4th through the 6th years was calculated at an average of about 78.0cm (n = 38). The average annual height growth of *P. rhoifolia* in P-25 form 4th to 25th years reached 80.1cm (n = 3) (Fig. 2). In both plots, *P. rhoifolia* annual average height growth in the two year period from 1989 and 1990 was, in the first layers, 95.0±1.0cm in P-6 and 63.2±2.7cm in P-25. In the second layers, it was 53.8±1.3 cm (n =29), that of *P. rhoifolia* was 17.8±1.8 cm (n = 12) in third layer.

Moreover, maximum annual height growth of *P. rhoifolia* and *F. spaethiana* was 142cm for *P. rhoifolia* and 81cm for *F. spaethiana* in P-6, and 138cm for *P. rhoifolia* and 60.5cm *F. spaethiana* in P-25, respectively. Likewise, in plots F-10 and F-25, average annual height growth of *F. spaethiana* in the two year period is as follows (Fig. 3): the first layers were 40.1±1.9cm (n = 7) and 37.42.8cm (n = 2); the second layers were 18.6±2.2cm (n = 5) and 9.5±1.8cm (n = 3); and the second layers of F-10 only, was 2.6±0.8cm (n = 4). The mean annual height growth in the first layer of both F-plots was estimated using the same method about mean annual length form 4 to 10 and from 4 to 25 years stem age. Those of *F. spaethiana* and *P. rhoifolia* were about 43.9cm and 71.0 cm in F-10, 43.2cm and 54.0cm in F-25. The maximum annual height growths of stem were 75cm in *F. spaethiana* and 124cm in *P. rhoifo-*

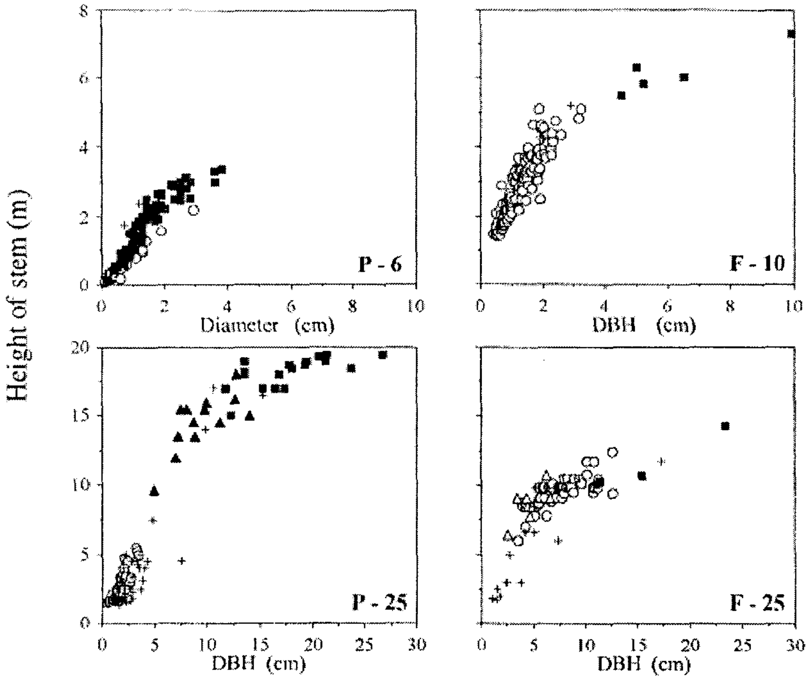

Fig. 2. Relationship between stem diameter of 0.1 m and stem height of over 0.1 m height in plot p-6, and stem height of 1.3 m height in plots F-10, P-25 and F-25.

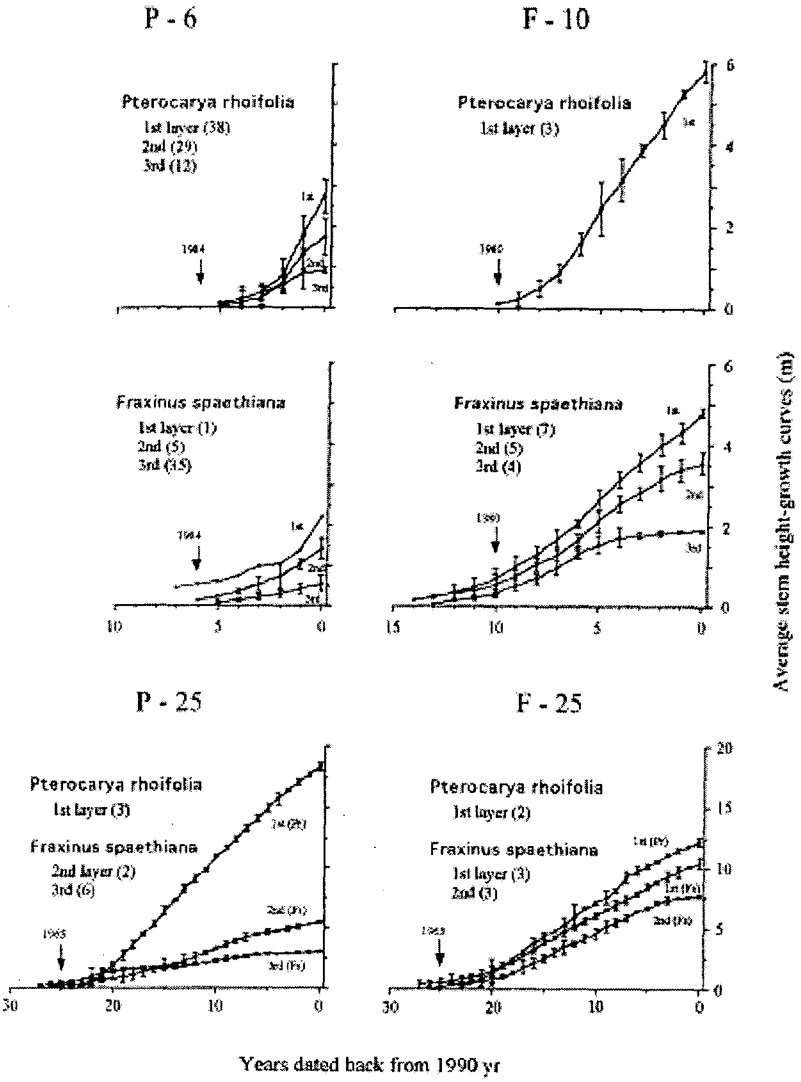

Fig. 3. Average height-growth reconstruction of individuals *Fraxinus spaethiana* and *Pterocarya rhoifolia*for three layers in four age groups.

lia for F-10, 72.5cm in *F. spaethiana* and 131cm in *P. rhoifolia* for F-25.

4. Discussion

Within the Uenomura valley forest stands natural forest, the co-existence of *F. spaethiana* and *P. rhoifolia* are seen in large numbers. Whereas *F. spaethiana* seedlings are seen in the sub layer, *P. rhoifolia* seedling cannot be found[1]. This is due to the difference in open growth patterns during the regeneration cycle that take place in the *F. spaethiana* and *P. rhoifolia*forests. This survey is an attempt to take a closer look at the reasons for this scattering, and to determine if the main reason has something to do with differences in forest structure and growth patterns that prevail within the young forest stands during the time they develop, after cutting and during natural reforestation.

Due to presence of seedlings, having fallen from the seed collecting trees before cutting, one could say that the natural reforestation of *F. spaethiana* and *P. rhoifolia* trees had successfully occurred. Observation reveals that in plots P-6 and furthermore, while plots F-8 and F-25 were dominated by *F. spaethiana* wasalso found in the first-layer of their canopies. However, even though *P. rhoifolia* was present in canopy-layers, it was absent under those layers. This fact suggests that with the continual growth of the *P. rhoifolia* tree, once it has reached the canopy-layer level, due to the coverage it incurs the species growth and cycle is reduced. Hence, it can be said that growth that takes place under the stable canopy-layer will be negatively affected. This might imply that the succession to the *P. rhoifolia* species is dependent on seeds falling during and cutting. This theory certainly deserves more attention in the future.

Two commonly used silvicultural practices, thinning and fertilization, offer similar potential benefits in forest stand management; both provide a residual stand with increased levels of nutrients, moisture, and sunlight. By mitigating factors that may be constraining growth, both allow the stand to develop larger trees sooner. To define stand growth response to fertilization and thinning, the effects of different levels of these treatments, applied singly and in combination, must be analyzed. The effects of fertilization, of thinning, and of both on growth response have been estimated in several research studies for a variety of species. Notable among those based in the Pacific Northwest of North America are the British Columbia Forest Productivity Committee study and the Shawnigan Lake studies in British Columbia; reports based on a poor-quality Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) site[5~8]. The overall objective of the work at Shawnigan Lake was to achieve a better understanding of the processes involved in tree growth to develop thinning and fertilization practices that would increase wood yields[9].

This report has observed that *P. rhoifolia*'s growth in elongation of was faster than *F. spaethiana.* And yet, *P. rhoifolia* could not really be seen growing in the under layers. Within the *F. spaethiana* dominant F-10 and F-25 forests, the first layer was found to have only a small number of *P. rhoifolia* trees. Furthermore, the *F. spaethiana* were found to be approximately 10m, thus forming a bell shape curve. Within plot P-6, due to a short elapse of time since the last cutting, the layer structures could not be clearly observed but the overstory was found to be dominant in *P. rhoifolia* and the understory in *F. spaethiana.* Within quadrant F-25, the average height was approximately 10m, with concentrated distributions of these trees dispersed around the area. It seems that this is due to an existing competition among the *F. spaethiana* trees themselves. Within the third layer, the *F. spaethiana* trees were few in number, whereas within the 4th-layer, *F. spaethiana* trees of less than 1.3m were dominant. Hence, in comparison with *P. rhoifolia*, had a slow growth elongation rate, hence a good shade-tolerance. In contrast, the *P. rhoifolia* had high growth elongation rates and thus a weak shade tolerance. Monshi and Oshima[10] analyzed standing trees with gaps for explanatory reasons and found that while those with wide gaps were low shade tolerant species, they did have the capability of achieving growth.

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