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学 位 論 文 内 容 の 要 旨/Dissertation Abstract

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学 位 論 文 題 名/Title of Dissertation

Potential of silvicultural practices focusing on wood properties of hardwood species in Hokkaido
（北海道における広葉樹の材質特性に着目した育林の可能性）

The use of hardwoods in Japan has generally been increasing. In particular, for species that have traditionally been used for high-value general purposes such as furniture, the demand for specialty products such as musical instruments and whiskey barrels has rapidly increased in recent years. In addition, species that had previously been limited to low-quality uses have seen an expansion in demand due to reassessment of wood quality, advances in processing technologies, and dramatic improvements in natural regeneration techniques that can greatly reduce silvicultural costs.

Despite this high demand, appropriate silvicultural systems and management practices for hardwood cultivation have not been fully established. One reason is that many hardwoods exhibit greater variability in tree form and require longer periods to reach harvestable size compared to conifers. Simply applying plantation systems developed for conifers often results in yields that do not justify the cost of cultivation, making sustainable forest management difficult. Therefore, hardwood silviculture requires an approach different from that used for conifers, one that allows both efficient production and high profitability.

One possible solution is to cultivate the wood properties that are key to price increases during the silvicultural process, and to match them with demand for specific uses so that the cost of cultivation can be recovered. However, compared with conifers, fundamental information on hardwood wood properties is limited, and little is known about their relationship with individual growth characteristics, site conditions, or whether these properties can be enhanced through forest management such as thinning.

This study focused on four representative hardwood species distributed in Hokkaido, Japan's largest hardwood-producing region: white birch (*Betula platyphylla*), Erman's birch (*Betula ermanii*), painted maple (*Acer pictum*), and Japanese oak (*Quercus crispula*). The objective was to clarify the relationships between key wood properties that determine the profitability of each species and their growth conditions and site characteristics. The specific wood properties addressed were: (Chapter 2) false heartwood, which is a defect in white birch; (Chapter 3) wood density, which is important for expanding new uses of Erman's birch; (Chapter 4) figured grain in painted maple, contributing to high-value products; and (Chapter 5) grain angle and tylose formation in Japanese oak, which are important indicators of suitability for barrel production. Individual studies were conducted for each species, and based on these results, Chapter 6 presents implications for hardwood forest management.

The study was conducted at the Uryu Experimental Forest of Hokkaido University (44°21'N, 142°15'E). A common approach was applied: first, a tree-by-tree survey was conducted to record individual tree size and visible characteristics, after which the trees were harvested, and wood samples were collected linked to the individual tree information. From these samples, growth indicators such as ring

number and ring width were recorded, and the samples were processed to a manageable size and shape. Key wood properties for each species were then measured, evaluated, and quantified. Direct and indirect relationships between individual growth conditions and wood properties were comprehensively analyzed using structural equation modeling.

Chapter 2 investigated false heartwood, a defect (irregular discoloration in the center of the wood) of white birch, which is increasingly used for furniture and flooring. False heartwood occurred in 80.3% (387/482) of the sampled trees. The proportion of false heartwood to cross-sectional area (false heartwood rate) was negatively affected by crown ratio and the topographic wetness index (TWI, representing local site moisture), and positively affected by branch scars and the density of surrounding trees. Among these factors, crown ratio had the strongest effect on false heartwood rate and was negatively correlated with the density of surrounding trees. These results indicate that suppressing false heartwood in white birch is compatible with growth promotion through thinning and density management.

Chapter 3 examined wood density in Erman's birch, which has attracted attention as a potential material for baseball bats. Wood density ranged from 491.0 to 810.6 kg/m³, with a mean of 666.2 kg/m³ (SD = 67.8). There was no clear relationship with ring width or tree size, but a negative association with TWI was observed. Significant positive spatial autocorrelation was detected, indicating that neighboring trees tended to have similar wood density, consistent with a strong influence of local site conditions. The lack of constraint of wood density by growth promotion through thinning suggests that active growth promotion can be compatible with maintaining wood quality.

Chapter 4 investigated figured wood in painted maple, which is highly valued for furniture and musical instruments, and the proportion of figured area to board surface area. Figured wood occurred in 87% of trees, ranging from 0 to 46.2% with a mean of 7.0% (SD = 9.8). The proportion of figured wood was strongly positively or negatively associated with tree form characteristics, such as stem crookedness and fork height, while its relationship with ring width or tree size was weak. Since tree form is generally related to surrounding tree density, thinning may promote figured wood formation via its effect on tree form. Selectively retaining trees with strong crookedness or low fork height, which are often removed as inferior during thinning, may help cultivate higher value stands in the long term.

Chapter 5 examined fiber inclination (deviation between the tree axis and grain direction) and tylose filling ratio (proportion of large vessels per unit area filled with tyloses) in Japanese oak, which has become increasingly demanded as whiskey barrel material. High suitability for barrel production depends on small grain angle and high tylose filling ratio. Grain angle ranged from –10.9% to 9.6%, with a mean of –0.7% (SD = 3.8), and was most positively influenced by stem eccentricity, followed by ring width. Tylose filling ratio ranged from 0 to 91.1%, with a mean of 26.8% (SD = 25.7), and was most negatively affected by ring width. Stem eccentricity is associated with crown asymmetry, and thinning generally opens the canopy, promoting growth and crown asymmetry. Therefore, intensive thinning may increase grain angle and reduce tylose filling ratio. These results suggest that cultivating Japanese oak suitable for barrel production requires long-term forest management that maintains moderate competition.

From these results, it was shown that for white birch and Erman's birch, which had previously been limited to low-quality use, efficient production of general-purpose wood can be achieved by combining natural regeneration with active thinning. In contrast, for painted maple and Japanese oak, both late-successional species, management strategies for producing high-value wood differ for each species. Thus, the recommendation for active tending to ensure both quantity and quality, the fact that high-value production does not necessarily align with increased yield depending on species, and the potential to recover overlooked opportunities for profitability through revising thinning selection criteria, all underscore the need for hardwood silviculture that focuses explicitly on wood quality—an aspect insufficiently considered in conventional conifer-oriented management. This study, which integrates silviculture and wood science while taking into account species-specific wood properties and growth conditions in predominantly natural hardwood forests, provides fundamental knowledge for realizing forest management that ensures both stable supply and high value of hardwood resources.