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A Study on Characteristics of Working of KARAMATSU (*Larix leptolepis* Gord.) Forests in Kyushu District

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Résumé

The present study was conducted for two purposes. First, the KARAMATSU forests formed in Kyushu District, where there is no natural distribution of KARAMATSU, are subject to different conditions of location from those in Shinshu District, homeland of KARAMATSU, such as abundant precipitation, high atmospheric humidity, windiness, etc. Therefore, by the comparison with the forests in Shinshu District and Hokkaido District where KARAMATSU's are grown under similar conditions to those in the homeland, the author aimed at the clarification of the influences of the conditions of location on the stand composition, standing volume, stand volume, volume growth, and utilized volume growth. Second, since most of the KARAMATSU forests in Kyushu District are considered to have been worked for production of timber for raw material, whereas the KARAMATSU forests in Shinshu and Hokkaido Districts where cleaning cutting, pruning and thinning are performed and the KARAMATSU forests in some parts of Kyushu District where tending is performed are considered to be the forests for production of timber for construction, the author aimed at the clarification of the influences of the differences of working methods when the target of production is set for timber for construction and for timber for raw material, on the stand composition, standing volume, stand volume, volume growth, utilized volume growth, weight growth and calory growth.

In line with the above purposes, considerations were made first on the form and quality of wood required of timber for construction and of timber for raw material, the working technique to produce required wood, the social and economic conditions for the formation of such forestry when the purpose of production is set for timber for construction and timber for raw material, and also considerations were made on the forest mensural characteristics of the forest for production of timber for construction and the forest for production of timber for raw material. And from the results of these considerations, it was clarified that most of the KARAMATSU forests in Kyushu District could be regarded as the forests for production of timber for raw material and the KARAMATSU forests in Shinshu and Hokkaido Districts and the tended forests in some parts of Kyushu District could be regarded as the forests for production of timber for construction.

Next, with all the KARAMATSU stands regarded as the forests for production of timber for raw material in Kyushu District, measurements of the above-mentioned factors of forest mensuration were made, and the relationship between the con-

ditions of location and the working method and the factors of forest mensuration was studied, from the comparison of those measurements with those for the forests for production of timber for construction. The results of the studies are summarized in the following.

I. Forests for Production of Timber for Construction and Forests for Production of Timber for Raw Material

i. Characteristics of Forests for Production of Timber for Construction

Since physical utilization of timber is aimed at, such characteristics as large diameter, soundness, straightness, fullness of bole, nodelessness, moderate and uniform annual ring spacing, ampleness of mature wood and heart wood parts are required of the timber for construction. Consequently, the following features are pointed out of the working technique for the forests for production of timber for construction.

The species of trees should have the characteristics required of the timber for construction, and be resistant to various damages, and it is desirable from the economic view point that the small diameter trees by thinning can be utilized.

The planting density should be determined from primary consideration of the characteristics of the tree species, with due thoughts on such natural conditions as climate and fertility of soil, on such social conditions as traffic convenience and wages for the workers, and on the target of management.

Weeding and vine cutting are indispensable in tending the stands, and cleaning cutting, pruning, thinning and such tending works should be carried out to remove physically inferior trees and poor growing trees and to help the growth of sound, nodeless, straight and full bole trees.

As the social conditions for the formation of forestry for production of timber for construction are counted favorable location and availability of labor, and as the economic condition large forestry capital is counted.

ii. Characteristics of Forests for Production of Timber for Raw Material

The timber for raw material is produced for the purpose of utilization of wood constituting substance, and consequently long fibers, large apparent specific gravity, low resin content, little color, ampleness of sap wood portion and high cellulose content are required, but the physical quality is not required so much as of the timber for construction.

The following features are pointed out of the working technique for the forests for production of timber for raw material. Tree species of large material mass, of easy chemical treatment, and of positive nature and speedy initial growth should be adopted. The planting density should preferably be high so that the stands may be canopied early and the substantial production may be large. It may be practical to fertilize the stand land in the early stage of growing to expedite the growth and

canopy. Weeding and vine cutting should be carried out in tending the forests, but it is advisable to limit pruning and thinning to a moderate degree to keep the soundness of the stand, because the purpose of production is more in the increase of the stem mass than in the quality growth.

As the social and economic conditions for the formation of forestry for production of timber for raw material are counted remote and inconvenient location and poor availability of labor, and such forestry is suited to the management with small areas and small capital.

II. KARAMATSU Forests in Kyushu District

The KARAMATSU forests formed in the national forests in Kyushu District are located inconveniently in deep mountains and their conditions of location are comparable to Shinshu District, homeland of KARAMATSU, in temperature and soil, but differ in that there is more precipitation, the humidity is higher and it is more windy. As practically no tending such as cleaning cutting, pruning and thinning has been performed, those KARAMATSU forests in Kyushu District have the characteristics of the forest for production of timber for raw material, such as high stand density formed of trees of uneven sizes and poor quality. Thus they can be regarded as the forests for production of timber for raw material. Contrary to this, the KARAMATSU forests in Shinshu and Hokkaido Districts and the tended forests as seen in private forests in Kyushu District have the characteristics of the forest for production of timber for construction in the stand composition and the process of growth, and they can be classified as the forests for production of timber for construction.

The KARAMATSU forests in Kyushu District were selected as the subject of the present study from these points of view.

III. Stand Composition

The distribution of stem number by diameter grade and the distribution of stem number by total height grade of the KARAMATSU forests in Kyushu District were studied with respect to the skewness and kurtosis, and no marked difference was observed from the stands for production of timber for construction in Shinshu District. However, the ranges of distribution were larger than those for the forests for production of timber for construction, the forests being formed of more uneven trees, which is regarded as the characteristics of the forests for production of timber for raw material.

Next, one plot each was selected from the forest for production of timber for construction and from the forest for production of timber for raw material under similar conditions of location in Kyushu District, and the quality of trees and the

progress of growth were compared. The characteristics of the forest for production of timber for raw material were seen in that there were many poor quality, uneven-sized trees, that the tree volume was extremely small but the stand volume was nearly equal to that of the forest for production of timber for construction, and that the time of the maximum annual growth and the maximum average growth appeared early.

IV. Standing Volume

First, the applicability of the standing volume tables for KARAMATSU forests in Shinshu and Kokkaido Districts were examined, and it was confirmed that those volume tables were not applicable to KARAMATSU forests in Kyushu District.

For KARAMATSU forests in Kyushu District, YAMAMOTO's formula applies and the standing volume table was prepared for KARAMATSU forests in Kyushu District by the formula,

$$\log V = -4.28047 + 1.76308 \log D + 1.14964 \log H$$

The comparison of this table with those for KARAMATSU forests in Shinshu and Hokkaido Districts reveals that KARAMATSU's in Kyushu District are of fuller bole. This was confirmed also by the comparison of the form factors computed by the regression equations between the form factor and the diameter at breast height and between the form factor and the total height,

$$F = 0.5090 - 0.1790/D + 2.7270/D^2$$

and $$F = 0.5161 - 0.4280/H + 3.8340/H^2$$

with those for KARAMATSU forests in Hokkaido District, and excepting small diameter trees of 10 cm and under, KARAMATSU's in Kyushu District are of fuller bole.

Next, the examination of the standing volume and the form factor of KARAMATSU forests for production of timber for construction in Kyushu District showed that they agreed better with those for the KARAMATSU forests in Shinshu and Hokkaido Districts than with those for the general KARAMATSU forests in Kyushu District. Therefore, the fullness of bole is considered to be due to the difference of stand density caused by the difference of working method rather than to the difference of the conditions of location.

The following regression equation holds between the thickness of bark and the diameter at breast height,

$$D = 0.245 + 0.061\ d$$

As compared with KARAMATSU's in Shinshu District, the thickness of bark is thinner. No correlation is observed between the bark ratio and either of age, diameter at breast height, total height or stem volume. Consequently, the bark ratio of KARAMATSU's in Kyushu District can be regarded as constant.

The thickness of bark and the bark ratio of the forests for production of tim-

ber for construction in Kyushu District agree better with those for forests in Shinshu District than with those for forests in Kyushu District as mentioned above. Therefore, the thin bark and the small bark ratio for small diameter trees are considered to be the characteristics of the forest for production of timber for raw material.

V. Stand Volume Table

The stand volume table prepared for KARAMATSU forests in Kyushu District was compared with that for KARAMATSU forests in Shinshu District, and it was observed that it did not agree with the volume table for the forests for production of timber for construction.

The stand volume is expressed by

$$V=11.99+0.49\ B\cdot H$$

The stand volume of KARAMATSU forests in Shinshu District is expressed by equations of the forms,

$$V=a+b\ B\cdot H \qquad \text{for } B\cdot H<300$$

$$\text{and}\quad V=a+b\ H+c\ B\cdot H \qquad \text{for } B\cdot H>300$$

and therefore, the stand volume of KARAMATSU forests in Kyushu District is expressed by the volume equation of different form from that for the forests in Shinshu District when the B·H is over 300, or the forests are canopied.

The stand volume of the forests for production of timber for construction in Kyushu District agrees better with the volume table for the forests in Shinshu District than the above-mentioned volume table for Kyushu District. Consequently, the difference of the forms of the stand volume formulas is considered to be due to the difference of stand composition caused by the difference of working mothod rather than due to the difference of the conditions of location.

VI. Stand Volume Yield Table

The stand volume yield table was prepared with the standard plot data collected from the KARAMATSU forests in Kyushu District. And the yield table was compared with those for the KARAMATSU forests in Shinshu and Hokkaido Districts and the KARAMATSU forests for production of timber for construction in Kyushu District, and the following points were observed as the characteristics due to the difference of the conditions of location and the characteristics as the forests for production of timber for raw material.

i. Characteristics due to Difference of Conditions of Location

Most of KARAMATSU forests formed in Kyushu District are not located favorably and the average total height of the superior stand is generally low. However, the average breast height diameter shows good growth for the poor height growth. The secondary stand is limited to suppressed trees and damaged trees, and thier ra-

tio to the total number of trees is large, and the basal area per ha is large partly due to the high stand density. Because of the poor site quality, the time when the annual and the average growths of the basal area per ha and the stem volume per ha of the superior stand get maximum is late in spite of the high stand density.

ii. Characteristics as the Forest for Production of Timber for Raw Material

The stand density of the superior stand is high because the secondary stand is limited to suppressed trees and damaged trees. As a result, the average diameter at breast height is small as compared with that of the forest for production of timber for construction. This is more pronounced in the younger period when the difference of stand density is larger, and the diameter growth is inferior to that of the forests for production of timber for construction.

As for the secondary stand, since they are limited to suppressed and damaged trees, their individual volumes are small and the ratio of the volume of the secondary stands to that of the total volume is small, and the time of the maximum total yield mean increment is late as compared with the superior stand, though the difference is very slight.

VII. Utilized Stand Volume Yield Table

For the purpose of studying the growth of the utilized stand volume, the taper table of the stem volume was prepared, and the utilized volume was computed by diameter grade and by total height grade, and the utilized volume table was prepared. Next, with the data used in the preparation of the stand volume yield table, the stand utilization factor was obtained by the ratio of the utilized stand volume to the standing volume, and the stand utilization factor by age grade was determined by the regression with age. And the utilized stand volume yield table was prepared by the multiplication of the figures in the stand volume yield table by the stand utilization factor.

The utilization factor of the individual trees is somewhat larger than that of KARAMATSU's in Shinshu District because of the fuller bole. The age at which the annual and the average growths of the utilized stand volume get maximum is a little higher than with the case of the volume growth, because the rate of increase of the stand utilization factor with the advancement in age is a little larger than the volume growth. However, the age difference is smaller than in the case of KARAMATSU forests in Shinshu District. These results are due to the high stand density and are considered to be the characteristics of the forests for production of timber for raw material.

VIII. Stand Weight Yield Table

The stand weight yield table was prepared for the purpose of clarifying the pro-

gress of growth when the weight was adopted as the scale of stand mensuration.

The mean specific gravity of the wood part excluding bark and the tree weight were measured with the trees subjected to the stem analysis, and high correlation was observed between the mean specific gravity and such factors as the age, the diameter at breast height and the total height with the superior stand, but practically no correlation was observed with the secondary stand. The correlation between the tree weight and the age and the diameter at breast height were different between the superior stand and the secondary stand, but with respect to the total height, the same correlation held with the superior stand and the secondary stand, and the following regression equations were obtained.

Age and tree weight

Superior stand $\log y=2.0299-3.8464 \log x+2.4483 (\log x)^2$

Secondary stand $\log y=3.7117-8.2060 \log x+4.4583(\log x)^2$

D. B. H. and tree weight

Superior stand $\log y=-1.8488+2.9847 \log x$

Secondary stand $\log y=-1.2936+2.4946 \log x$

Total height and tree weight

Superior and secondary stand

$\log y=-1.7365+3.1607 \log x$

Next, the average weight by age-gradation of the superior and the secondary stands were computed by the correlation between the various factors and the mean specific gravity and the tree weight, and the stand weight yield table was prepared by the multiplication of those figures by the number of trees per ha.

The age at which the annual growth of the stand weight gets maximum is 5 years higher than with the case of the volume growth, and the age is 2 years higher in the case of the average growth. The difference is smaller than with the case of AKAMATSU (*Pinus densiflora* Sieb. et Zucc.) and RYUKYUMATSU (*Pinus luchuensis* Meyr).

One reason for that is supposed to be due to the fact that the width of the annual rings is small because of the inferior growth in the diameter at breast height caused by the high stand density, and therefore, the above results can be considered to show the characteristics of the forest for production of timber for raw material. However, since the influences of the tree species and the conditions of location are considered to exist, this problem is to be studied further.

IX. Stand Calory Yield Table

The stand calory yield table was prepared for the clarification of the progress of gowth when the calory was adopted as the scale of measurement of the wood substance.

Fairly high correlation was observed between the mean volumetric calory and

such factors as the age, the diameter at breast height and the total height in the case of the superior stand, but practically no correlation was observed in the case of the secondary stand.

There was a high correlation between the mean volumetric calory and the mean specific gravity as shown by the following regression equation.

$$y=72+4{,}675\ x$$

The relation between the tree calory and the age and the D. B. H. with the superior stand differed from that with the secondary stand, but the same relation between the tree calory and the total height held with the superior and the secondary stands, and the following regression equations were obtained.

Age and tree calory

Superior stand $\log y=1.6646-3.7439 \log x+2.4000 (\log x)^2$

Secondary stand $\log y=-1.7291+0.2310 \log x+0.8515(\log x)^2$

D. B. H. and tree calory

Superior stand $\log y=-2.1487+2.9695 \log x$

Secondary stand $\log y=-1.5571+2.4328 \log x$

Total height and tree calory

Superior and secondary stand

$$\log y=-2.0183+3.1215 \log x$$

Next, the average calory by age-gradation was computed from the correlation between the various factors and the volumetric calory and the tree calory, and the stand calory yield table was prepared by the multiplication of those figures by the number of trees per ha.

The stand calory showed a similar progress of growth to that of the stand weight. The time at which the average growth of the stand calory gets maximum was one year later than that of the volume growth and the difference was shorter than with AKAMATSU. As one reason for that is counted the fact that the woking method suited for the forest for production of timber for raw material was adopted as in the case of the weight, as seen by the proportional relationship between the mean specifiic gravity and the mean volumetric calory. As it is supposed that the mode of change of the mean volumetric calory with the age differs with the tree species and the conditions of location, further studies are still to be made.

X. General Considerations

With the KARAMATSU forests in Kyushu District, the author has studied the relation between the conditions of location and the working methods for production of timber for construction and for production of timber for raw material and various factors of forest mensuration, and clarified the characteristics due to the difference of the conditions of location and the characteristics as the forest for production of timber for raw material. And now a general consideration is made on the

results of the study.

Since most of the KARAMATSU forests in Kyushu District are under the working method consequentially suited for the production of timber for raw material, the factors of forest mensuration are mostly of characteristics of the forest for production of timber for raw material as considered in Section I, and are quite different from those of the forest for production of timber for construction. Therefore, in case where the purpose of management is set for the production of timber for raw material from reasons of the labor, afforestation capital, location, etc., the standing volume table, the stand volume table, the stand volume yield table, the stand utilized volume yield table, the stand weight yield table, the stand calory yield table, etc., making the bases of management, should be prepared to suit the forest for production of timber for raw material.

As for the progress of growth, in spite of the fact that the central Kyushu mountain districts where the KARAMATSU forests are located have poor condition of location and are not suited for SUGI (*Crypotomeria japonica* D. Don), HINOKI (*Chamaecyparis obtusa* Sieb. et Zucc.) and AKAMATSU, the common species for afforestation in Kyushu District, the diameter at breast height of KARAMATSU's shows a rather good growth for the poor growth in total height, and as a result the stand volume shows a fairly good growth for the poor location. However, in the wind swept areas, the height growth is very poor and many trees are felled by the wind, — in the worst cases almost all the trees were felled by the wind, — and it is observed that the growth is markedly hindered where the under ground water level is high. These areas are better suited for the production of timber for raw material than for the production of timber for construction from the location and labor conditions, KARAMATHU's being utilized as timber for raw material as well as for construction. Therefore, in the light of conversion of the waste grassland and the poor natural forests in the central Kyushu mountain district into forests for production of timber for raw material, KARAMATSU would be a suitable species, if such precautions are taken as to avoid extremely windswept areas or too moist lands. Moreover, these areas are pressed for afforestation from the viewpoint of erosion control and flood control, and KARAMATSU that is easily forested and shows fairly good growth in poorly located mountain districts, is considered to be a useful species from the viewpoint of national land preservation.

Even in the central Kyushu mountain districts, KARAMATSU's planted in favorable locations and given intensive tending, as seen in the privately-owned forests, the growth is very good not only in the form and quality but also in the volume, and the volume growth is equal to those in the 2nd-3rd class lands of SUGI forests in Kumamoto Prefectue, the 2nd class land of HINOKI forests in Chugoku District and the 1st class land of AKAMATSU forests in the Island Sea District of Chugoku. Consequently, it is advisable to aim at the production of timber for construction

rather than at the production of timber for raw material in locations where intensive working is possible from the labor, location and investment considerations.

In view of the growth conditions of the existing stands, elevation of the areas suitable for KARAMATSU afforestation in central Kyushu mountain districts may be as follows. As most of the existing KARAMATSU stands are located at elevations 900～1,300 m, afforestation within this elevation range will practicable, unless the land is improperly selected. The only stand located above 1,300 m is the 30th Compartment of the Kuzu Working Unit of the National Forest (elev. approx. 1,450 m), where the growth, especially the height growth, is very poor because of the high wind and the lean soil. Since most of the lands located higher than 1,300 m are subject to high wind and are of lean soil, it may be advisable to avoid those lands in afforestation. As no forestation of KARAMATSU exists below elevation 900 m, it is difficult to determine the lower limit of elevation for KARAMATSU afforestation, but judging from the fact that the annual average temperature in KARAMATSU forests in Shinshu District is 7～9° C, and the annual average temperature at Ohara in Kuzu-gun, Oita Prefecture at 900 m is 10.8° C, 900 m may be considered to be the lower limit of elevation in the central Kyushu mountain districts from the temperature considerations, and it may be impractical to afforest below this limit.

Most of the KARAMATSU forests in Kyushu District are concentrated in the central mountain districts, but if it is possible to afforest in lands of volcanic ashes or similar soil and of the annual average temperature of 10° C or below, such high mountains along the border line between Miyazaki and Kumamoto Prefectures leading to Kirishima Volcanic Mountains and near the top of Mt. Unzen may be counted as the places suited for KARAMATSU afforestation.

And in places where intensive working is difficult from the conditions of location, labor and economy, it would be practical to aim at the production of timber for raw material, limiting such tending works as cleaning cutting, pruning and thinning to the very minimum necessary for keeping the stand in sound conditions, and in places where intensive tending work is possible, it would be advisable to study the method of growing KARAMATSU's for production of timber for construction aiming at the increase of quality growth, and adopt KARAMATSU in future, if it is found to be more advantageous than SUGI, HINOKI and AKAMATSU, the conventional species for afforestation.

In the foregoing, the author studied into the relation between the conditions of location and the working method and various factors of forest mensuration with KARAMATSU forests in Kyushu District, and at the same time considered the types of KARAMATSU forests as they should be in Kyushu District in future. The relation between the conditions of location and the working method and the factors of forest mensuration differs with the characteristics of species, and the relation with the conditions of location is still to be clarified under varied conditions. Since the

present study limited its subject to the KARAMATSU forests in Kyushu District, it is necessary to study further with different species and different conditions of location, for clarifying theoretically and practically the relationship between the purpose of production and the working, and also further studies should be made in the silvicultural and the wood utilization aspect. When these studies have progressed sufficiently, the relationship between the conditions of location and the working method and the factors of forest mensuration would be clarified, and the leading principle for the formation of KARAMATSU forests in Kyushu District and formation of the forests for production of timber for raw material in increasing demand would be established scientifically.