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原 著

COMPARISON OF SEEDLING GROWTH BETWEEN EVERGREEN CHESTNUTS AND DECIDUOUS CHESTNUTS IN SECONDARY FORESTS

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ABSTRACT

The secondary forest of Misaoyama in Okayama city is a mixture of deciduous and evergreen oak, and is at an interesting stage of succession: the evergreens are slowly replacing the deciduous trees. To investigate why one type of oak is taking over from another, we examined how the different species of chestnut germinate and grow. Four species of chestnut, *Quercus variabilis, Quercus serrata, Quercus glauca*, and *Castanopsis cuspidata* collected in the forest were planted in vinyl pots with the same type of soil. After seven months, the stems and leaves of seedlings were measured, and the roots, stems, leaves, and chestnuts were weighed.

The germination times and growth patterns were different among the four species. The deciduous germinated earlier than the evergreens. As for seedling growth, the nutrients of the chestnut species were rapidly consumed in all the plants, except *Quercus variabilis* (about 20 % of the chestnut weight remained). Above the ground (T), *Quercus serrata* developed a taller stem and more leaves than the others. Below the ground (R), the evergreens' roots were heavier than the deciduous. We compared the T/R ratio (the ratio of parts above ground to those below) with the height of the stem: *Quercus variabilis* achieved a coefficient of 0.096, *Quercus serrata* 0.252, *Quercus glauca* 0.106 and *Castanopsis cuspidata* 0.061. These results show that the species allocate chestnut nutriment differently, and that is changing the forest.

These results suggest another explanation for the replacement of one species with another, usually attributed to photosynthesis. This may be useful in understanding the succession of secondary forests and recovering forests from major environmental disturbances.

Key word : Replacement of deciduous oak with evergreen oak, Seedling of chestnut, T/R ratio.

Introduction

In southwest Japan, until the 1960s, red pine trees were predominant in secondary forests. In former times people would use the forests' resources for their everyday needs and the pine would regenerate naturally. However, about thirty years ago our fuel sources changed – instead of using wood we began to use oil. Consequently, the forests also began to change: they regenerated as deciduous and evergreen Oak trees.

The hill called Misaoyama (latitude 34° 39' N,

Figure 1. Vegetation of Misaoyama: The picture shows the forest in the stage of succession between deciduous and evergreen.

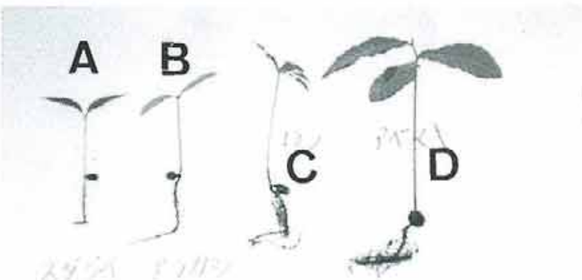

Figure 2. Plants of the different species after seven months' growth: A: *Castanopsis cuspidata*, B: *Quercus glauca*, C: *Quercus serrata*, D: *Quercus variabilis*. The organs are weighed and measured separately after the plants are dried.

longitude 133°57' E, elevation 140m) in Okayama city (Fig. 1), which is a mixture of both deciduous and evergreen Oak after pine died, but slowly the deciduous broad leafed trees are being replaced by broad leafed evergreen trees. So we became interested in finding out *why* one Oak is taking over from another by examining how the different species germinate and grow.

Material and Method

We collected four kinds of chestnut from Misaoyama, where the mean annual temperature and total precipitation during the last 30 years has been 15.8°C and 1160mm, respectively.

Two are deciduous, the *Quercus serrata* and *Quercus variabilis*. The others are evergreen, *Quercus glauca* and *Castanopsis cuspidata*. These oaks dominate the forest in the high tree layer. Those chestnuts that were not worm-eaten, were checked by

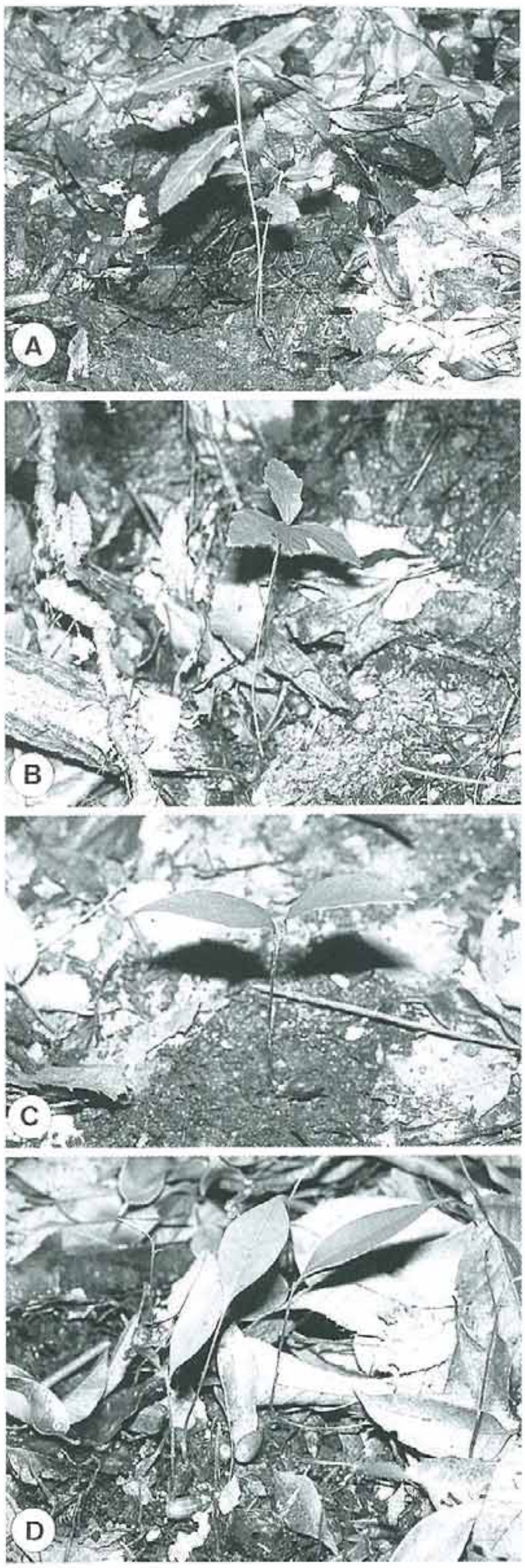

Figure 3. Seedlings of the different species in the floor of the forest: A: *Quercus variabilis* had several leaves, B: *Quercus serrata* had four leaves, C: *Quercus glauca* had two leaves, D: *Castanopsis cuspidata* had a leaf.

sinking them in water. Next the chestnuts were planted in separate vinyl pots with the same type of soil, 30 pots for each species. Then we placed them near the south face of the school building where they grew for seven months.

After that time, more than 70% of the 120 chestnuts germinated. The seedlings were carefully removed by washing the soil away with water (Fig. 2) and then dried in an oven at 100°C for 24 hours, until the weight became constant.

Then each organ (root, stem, leaf and chestnut) was dissected, and measured and weighed on an electric scale.

We analyzed the similarities and differences of these measurements by using computer analysis software, in order to understand the growth characteristics of each species.

Results and Discussion

Time of germination

The plants germinated at different times. The first to germinate was *Q. variabilis* without a dormant period, followed by *Q. serrata*, then *Q. glauca* about two months after planting, and the last was *Castanopsis cuspidata* about five months after planting. So we concluded that the deciduous species germinate earlier than the evergreen. Interestingly, the seedlings in the pots were approximately the same size as those that can be found naturally on the floor of the forest (Fig. 3).

The germination times were different. The deciduous germinated earlier than the evergreen.

Seedlings of four species

Each species displayed the following distinctive characteristics (Table 1 and Fig. 4).

Quercus variabilis: it grew to be the biggest and heaviest among the four species. On average, it developed four leaves that had the widest area among the four species. The weight of its leaves accounted for 33 % of the whole plant's weight, and the root accounted for 46 %.

Quercus serrata: it was taller than the evergreen. The weight of one plant was the lightest among the four species. On average, it developed three leaves that had the widest leaf area per 1g of leaves. The ratio of the leaf weight in proportion to the whole plant was highest (38%).

Quercus glauca: the ratio of the leaf weight in proportion to the whole plant was 21 %, and the

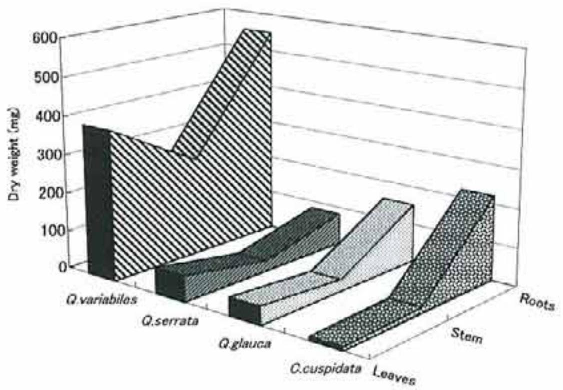

Figure 4. Dry weight of the four species seven months after planting: A: *Quercus variabilis* (average of 6 plants), B: *Quercus serrata* (average of 10 plants), C: *Quercus glauca* (average of 6 plants), D: *Castanopsis cuspidata* (average of 9 plants).

Table 1. Characteristics of leaves of four species seven month after plant.

Characteristics / Species		Hight of stem (cm)	Number of leaves	Leaf area of a plant (cm²)	Leaf area per 1 g (cm²)
Decidous					
Quercus variabiles	(n = 6)	22	4.7	138	285
Quercus serrata	(n = 7)	11.9	3	33	303
Evergreen					
Quercus glauca	(n = 4)	9.3	3.3	27	208
Castanopsis cuspidata	(n = 2)	6.6	2	21	172

weight of the root was 66 % of the whole weight. On average, it developed two leaves that were smaller in area per gram.

Castanopsis cuspidata: It germinated so late that it had the shortest shoot, and developed leaves that had the smallest area per 1g of leaves among the four species. Its root weighed 89% of the whole plant's weight. It is possible that the roots stored nutriment at the seedling stage for later use.

Form of seedling growth

We also examined *how* the plants grew. We compared several different factors (the weight of the roots, the weight of the leaves, the height of the shoots) with the total weight of each plant, then analyzed the results of these comparisons. If there was a coefficient relationship between one and the other then the correlation coefficient was higher than 0.6. It was found that the dry weight of whole plant had a positive relation to the weight of the roots and leaves, but had a negative relation to the weight of the chestnuts. That is, if the dry weight of the whole plant increased then the weight of the roots and leaves also increased, but the weight of the chestnut decreased.

As the weight of the seedling increased, each organ grew. In the relationship between the tree height and the weight (Fig. 5), *Q. serrata* achieved the highest rate, and next was *Q. glauca*. These species displayed a far superior stem growth compared to the others. In terms of leaf weight (Fig. 6), *Q. serrata* achieved the highest constant, and next was *Q. variabilis*. The deciduous trees displayed superior leaf development to the evergreen trees. At the same leaf weight the deciduous had so many more leaves that they were able to get much more sunshine.

In terms of root weight (Fig. 7), *C. cuspidata* achieved the highest coefficient, and next was *Q. glauca*. The evergreen trees had heavier dry root weight (in relation to the whole plant weight) than the deciduous trees, and would develop roots in order to absorb nutrition and water from the soil.

As for seedling growth, investment of nutriment in the organs was different among four species. Above

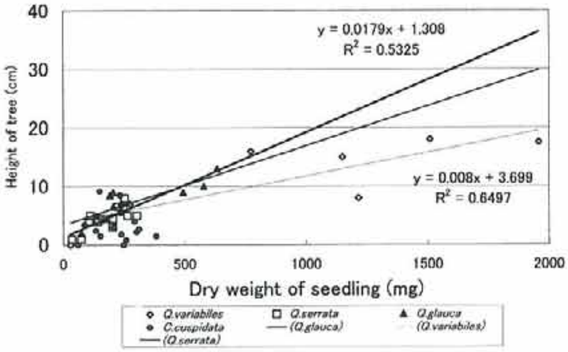

Figure 5. Tree height in relation to growth: *Quercus serrata* has the highest coefficient; next is *Quercus glauca*.

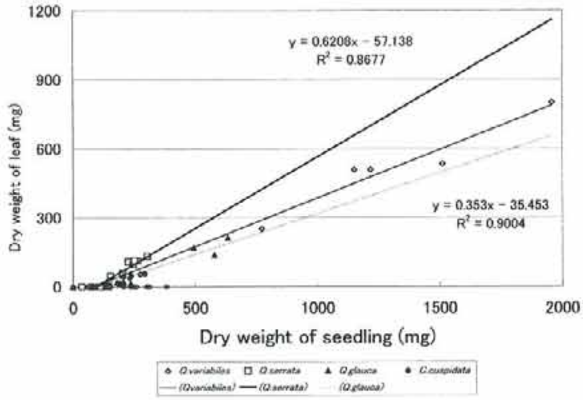

Figure 6. Leaf weight in relation to growth: *Quercus serrata* has the highest coefficient; next is *Quercus variabilis*.

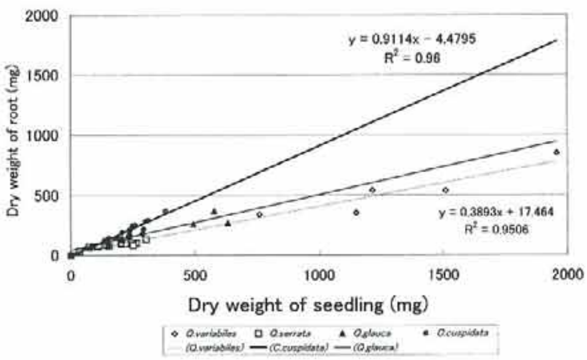

Figure 7. Root weight in relation to growth: *Castanopsis cuspidata* has the highest coefficient; next is *Quercus glauca*.

the ground, it was apparent that the *Q. serrata* developed a taller stem and more leaves than the others did. Below the ground, it was apparent that the evergreens' roots were heavier than the deciduous. These results indicate that sun trees invested their nutriment above the ground and shade trees invested

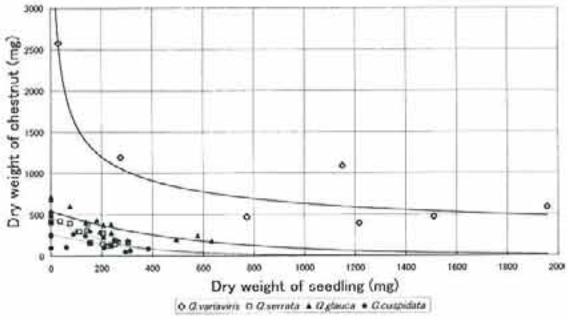

Figure 8. Chestnut weight in relation to growth: The nutriment of the chestnut was rapidly consumed in all the plants except *Quercus variabilis* (in which about 20 % of the weight of the chestnut remained).

their nutriment below the ground.

Consumption of chestnut

Next we determined how much nutriment remained in the chestnut (Fig. 8). The dry weight of the chestnut was different among the four species. *Q. variabilis* was the biggest at about 2600 mg. *Q. serrata* and *Q. glauca* were about same size and weight at 600 mg. *C. cuspidata* had the smallest size and weight at 300 mg. As for seedling growth, as the dry weight of the plant increased, the nutriment of the chestnut was rapidly consumed in all the plants, except *Q. variabilis*. It did not completely consume the nutriment, which remained at about 20% of the weight of the chestnut.

As the chestnuts were consumed after the seedlings grew, we concluded that they had stored the nutriment for the germination and growth of the seedling. The chestnuts of *Q. variabilis* suggested another function of the chestnut. We considered the possibility that the chestnut not only provided nutriment for germination, but also stored nutriment for the juvenile plant. It may save the extra nutriment for use next spring to expand leaves or regenerate damaged seedlings.

T/R ratio

Finally, we analyzed the way in which each plant allocated nutriment between its above ground and below ground parts. We compared the T/R ratio (the proportion of above ground (T:g) to below ground (R:g) parts) with the height of the stem, and then analyzed the relationship between them by calculating a formula which showed us how the plant allocates nutriment to its individual organs.

The relationship between the T/R ratio and the height of the stem varied depending on the species. The values of the T/R ratio were smaller during the early stages of germination and increased gradually as the plant grew. This showed us which plants' shoots grew higher: *Q. variabilis* was given a coefficient of 0.096, *Q. serrata* 0.252, *Q. glauca* 0.106 and *C. cuspidata* 0.061. Among the deciduous trees (Fig. 9) it was much higher in the *Q. serrata* than the *Q. variabilis*. Among the evergreens (Fig. 10) it was higher in the *Q. glauca* than the *C. cuspidata*. *Q. glauca* had a slightly higher ratio than *Q. variabilis*.

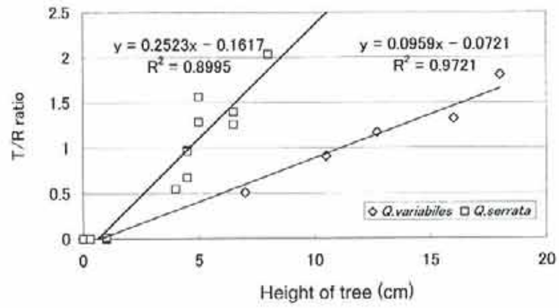

Figure 9. T/R ratio in relation to tree height among the deciduous trees: *Quercus serrata* has a higher coefficient than *Quercus variabilis*. Higher rates of T/R than 1.0 mean there is a higher allocation of nutriments for stem and leaves.

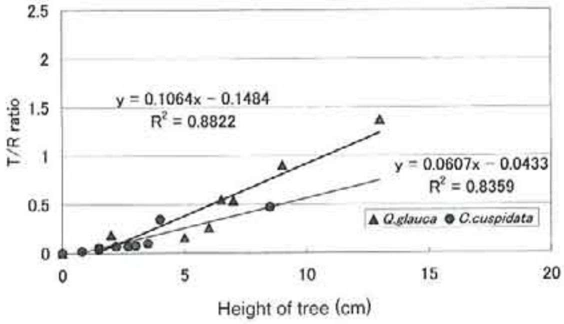

Figure 10. T/R ratio in relation to tree height among the evergreen trees: *Quercus glauca* has a higher coefficient than *Castanopsis cuspidata*.

T/R rates higher than 1.0 mean a higher allocation of nutriment for stem and leaves.

Most interestingly, deciduous trees had higher coefficients than evergreen trees. It is commonly accepted that deciduous trees appear at an earlier stage of succession than evergreen trees, which appear at a late stage. So from our study it seems that *Q. glauca* appears at the same stage of succession as *Q. variabilis*, and we can therefore conclude that the variations in the coefficients are a factor in the sere in the secondary forest .

Our results suggest that the different times of germination and the different ways in which the plants allocate nutriment to their organs has transformed the forest. The results can provide another explanation for the replacement of one species with another, which is usually attributed only to photosynthetic production. This knowledge will be useful not only in helping to recognize the effects of the phenomenon of succession over a long period, but also to aid the recovery of mature forest from major environmental disturbances, such as burning and clearing. However, further research is necessary into the relationship between growth of seedlings and different types of soil. It will also be useful to study these phenomena over a 1-2 year period after planting. This will help us to fully understand the nature of the changes occurring on the secondary forest.

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ドングリの背比べから身近な二次林の遷移を考える

高橋　和成・小河原　明恵

朝日高校の背後にある操山の森は,落葉樹と常緑樹のドングリの樹が混生する混交林である。この森で採集した4種類のドングリをビニールポット（12.5cm深×15cm直径）に植え，それらの発芽と初期成長を7ヶ月後に比較し，森の遷移について考えた。

ドングリは種類別に1個ずつポットに植えた（1997年12月)。発芽時期は種類により異なった。アベマキ（*Quercus variabilis*）とコナラ（*Quercus serrata*）は1ヶ月後から芽生え始めたが，アラカシ（*Quercus glauca*）は3ヶ月後，スダジイ（*Castanopsis cuspidata*）は5ヶ月後から芽生え始めた。

芽生えの乾燥重量が2000mgになったとき，コナラやアラカシ，スダジイはドングリの貯蔵栄養分をほとんど消費していたが，アベマキでは約20%が残されていた。

樹高が約8cmに成長した個体間で根，幹，葉への投資の割合を比較した。葉への投資は，コナラ45.6%，アベマキ41.8%と高くなったが，アラカシ23.2%，スダジイ16.7%となり，常緑樹は落葉樹よりも低い値であった。一方，根への投資は，アラカシとスダジイで高く，コナラで最も低くなった。このように，落葉樹は葉への投資割合が高く，常緑樹は根への投資割合が高いという傾向がみられた。

発芽後の樹高の伸長にともなう地上部重量／地下部重量の比（T/R比）は，直線的に増加した。その回帰式の係数は，種によって異なった。コナラ（0.252）が最大で，次にアラカシ（0.106），アベマキ（0.096），スダジイ（0.061）の順であった。陽樹であるコナラは地上部に多く投資していたが，極相林を構成するスダジイでは地上部への投資は低いことがわかった。

裸地にこれらの樹種が同時に侵入した場合には，落葉樹が先に成長し，その後に常緑樹のアラカシやスダジイが育ってくるだろう。今日，操山の森で見られる階層構造は，アベマキやコナラが高木層に優占し，その下層にアラカシやスダジイが混生する。それはドングリの成長様式を反映した姿と考えられる。