Studies on the Seed Production of Japanese Red and Black Pine (2)

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アカマツとクロマツの種子の生産量に関する研究 (2)

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目　　次

要　　旨

この研究はアカマツの種子生産量に関する一連の研究として，アカマツの種子の生産量を京都市岩倉のアカマツ林で調査した結果をとりまとめたものである。1973年10月に 20×20m の方形区を設け毎木調査した後，6本の試料木を伐採し各部分の量や球果の数を測定した。そして Seed Trap による調査を1973年10月から1974年6月まで行なった。その結果は次のようであった。

アカマツの球果の数と技乾重との間にはもっとも高い相関関係が認められた。

一方球果の数と葉乾重との間には一定の関係が認められたが，その相関係数は低い値を示した。球果の全数は樹令が高くなるに従いおおむね増加する傾向が認められた。球果の生産量は年によって大きく変化するようであった。またその年の球果を多くつけている個体は翌年度の球果生産量も多くなる傾向が認められるようであった。

Seed Trap を用いた場合アカマツ種子の生産量は 710,000 粒 / ha と推定された。一方種子数—D^2H 関係から推定された種子生産数は 1,300,000 粒 / ha となり Seed Trap の場合より著しく過大な値を示した。枝葉単位（kg）あたりの球果数は個体の上部ほど増加する傾向が見受けられた。アカマツの種子は12月以前に68%以上が落下するようであった。

Abstract

This study was carried out to estimate seed production in the Japanese red pine stand, a private forest located at Iwakura, northeastern part of Kyoto, during the period from October 1973 to June 1974. Analysis was made for 6 trees, sampled from the above mentioned forest, and seed trap method was applied as a supplementary experiment. The results are as follows;

1) Among several factors, the correlation between cone number and branch weight was high.
2) Total cones, disseminating cones, and conelets increase with age, but the points along the regression line were scattered widely.
3) The relation between total cone number and leaf weight seemed to be comparativley low.
4) A large annual variation was observed in cone crop at the Iwakura pine forest.
5) A significant correlation between cone and conelet was observed ($r=0.93$ at Iwakura, $r=0.82$ at Kamigamo).
6) Trapping seed number was 710,000/ha, while estimation by $D^2 \cdot H$ factor was 1,300,000 /ha. The estimation by $D^2 \cdot H$ factor seems to be overestimated compared with the seed trap method.
7) Viewing the vertical distribution of cones the higher part of the tree crown, the larger cone numbers when cone number is counted in terms of cone number per unit weight ofleaf and branch.
8) More than 68 per cent of seeds fell before December at the experiment stand.

Introduction

It is well known that to estimate cone crop is fundamental to foresters as well as for effective natural regeneration. In general, foresters have judged the cone crop good, average or bad only by looking at cones of pine trees. All cones of a tree may show a reproductive capacity. Sometimes old cones have been attached to mother tree for several years, and only some of them are responsible for disseminating seeds. Cones responsible for disseminating seeds are available for estimating seed crop. In Japanese red pine and black pine, the serotinous problem[17] is not so serious as in lodgepole pine in America. So cone counting is supposed to be a reasonable method.

It is necessary to find a reasonable way of estimating cone crop. Inoue[18] observed cone crop by climbing individual pine trees in Japanese red pine stands. A similar method by means of Swedish ladder was adopted to count individual cones.[20] As already noted by Four Universities' report,[8] comparison study of cone production between good and bad pine forests was carried out as a production survey.

With a view to obtaining an insight into possible factors which may be used to estimate cone crop, several workers have attempted to find suitable methods. But a conclusion seems to be very difficult. This study is an attempt to estimate cone crop for a given red or black pine stand. Seed traps were used as a supplementary experiment for estimating seed crop.

Description of Sample Plot and Methods

The experimental site is located near Iwakura, northeastern part of Kyoto and belongs to a private forest. It is supposed that a red pine forest was invaded by Japanese cypress

Table 1. Plant species seen in the sample plot and its immediate vicinity area

Plant species	stem No / 20×20m
Vaccinium var glabrum	14
Rhus verniciflua	15
Chamaecyparis obtusa (seedlings and saplings)	57
Smilax china	12
Ilex pedunculosa	9
Quercus glauca	4
Viburnum erosum	5
Rhododendron macrocepalum	24
Castanea crenata	1
Rhododendron reticulatum	66
Acer crataegifolium	10
Eurya japonica	5
Quercus serata	7
Euonymus Sieboldianus	3
Clethra barbinervis	2
Edoviopanax innovans	4
Rhododendron nudipes	5
Cinnamomum japonicum	5
Alnus firma	11

through natural regeneration. The sample plot is not a pure forest but a mixed one composed of red pine and Japanese cypress. As in typical red pine forests in Japan, various undergrowth trees are well developed and ground flora is dominated by Rhododendron spp. Plant species seen in the sample plot and its vicinity are listed in Table 1. The identifications were checked by the members of Lab. of Forest Ecology, Kyoto University. Rhododendron spp. occurs at a density of 9 stems/10m^2 and a number of Japanese cypress seedlings are found on the forest floor at random. A few pine seedlings with seed coat are found on the forest floor but saplings of red pine are not found.

The pine trees were 17 to 64 years old in 1973, ranged from 5.6 to 16 meter in tree height and from 6.9 to 28.8 cm in diameter of DBH. Thirtyeight trees of red pine were observed within the sample area. Six pine trees of different sizes of DBH were selected and cut at an interval of one meter except 30 cm of bottom trunk, and then each part was divided into three ; stem, branch, and leaves. At the same time dead cones, cones responsible for disseminating, and conelets were sampled from the cut. Each sample of stem, branch, and leaf was kept at 80°C in the dry oven for one week and their dry matter was obtained. Seeds of each cone disseminating was counted. As a supplementary estimation of seed crop, 16 seed traps, sized 40×40 cm with a cover, were set up in lines approximately 3 m apart. Trap contents were collected at monthly intervals.

Results and Discussion

The allometric correlation between trunk weight and DBH sometimes differs in different

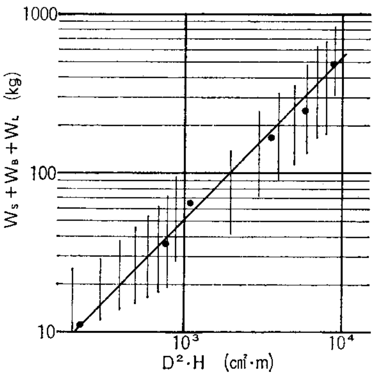


Fig. 1. Upper ground part-D^2. H allometry in red pine forest of Iwakura near Kyoto.

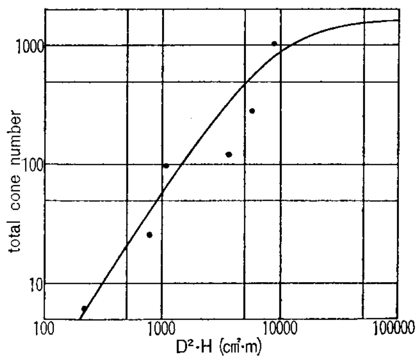


Fig. 2. The relation between cone number and D^2. H

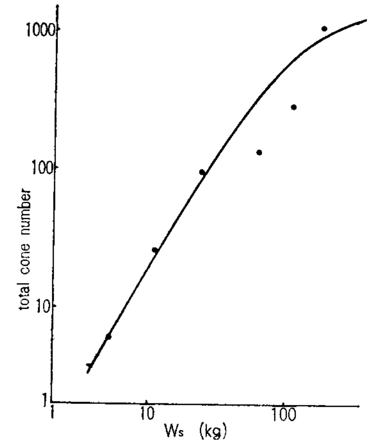
stands of the same species according to their age and habitat. This problem can be avoided by simply introducing tree height (H) as the second parametric.[1]

In this study $D^2 \cdot H$ instead of DBH was applied to estimate biomass of upper ground parts.

Considering only P. densiflora, dry weight of upper ground part reached 259 tons and those of branch and leaf were 24.8 and 10.1 tons per ha. Basal area in this study was 28 m²/ha. Comparing with Miyake's[2] results, the value of basal area was very low, while those of branch and leaf weight were similar.

In general, the number of cones may increase with tree size, with several exceptions. In this study six trees were sampled and these trees were supposed not to be sufficient because of annual or site variation. The relationship between total cone number and $D^2 \cdot H$ showed a reasonably strong one(Fig. 2). This result agreed with those of Shidei's and Miyake's. But in case of the relationship between cone and $D^2 \cdot H$ or conelet and $D^2 \cdot H$, the points along the regression line were widely scattered. The relation between total cone number and dry stem weight, dry branch weight, and dry leaf weight is shown in Fig.3, 4, and 5 respectively. Among these three factors, dry branch weight was the most reliable. Several workers[3,4,5,6,7,20] have found a relationship between fruitfulness and DBH of the tree. It has been suggested that height may influence cone production. The correlation coefficient is a valuable figure in cone production studies. It measures the degree of association between two variables, such as DBH and number of cones. This study showed that size of tree, regardless of how expressed, was significantly related to the average number of cones produced. Tree height, although associated to a highly significant degree with cone-producing ability, gives much variation (Fig. 6). There are many variables such as DBH (or $D^2 \cdot H$), height, branch, and leaf for estimation of cone crop. Among above variables, DBH which is so easy to measure, is one of the better indicators of cone producing capacity. But variation among individual trees is so large that it would be difficult to estimate cone production with accuracy. The relation between $D^2 \cdot H$ and cone number can be expressed by means of following formula ; $\log C_N = 1.24 \log D^2 \cdot H - 2.10$....(1) or

$$\frac{1}{C_N} = \frac{8854}{(D^2 \cdot H)^{1.5}} + 0.05 \cdots\cdots (2)$$



F g. 3. The relation between cone number and stem weight

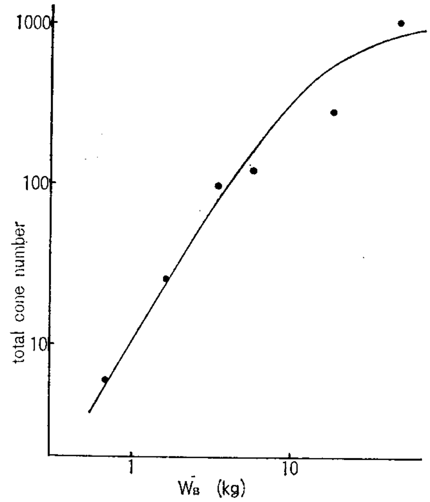


Fig. 4. The relation between cone number and branch weight.

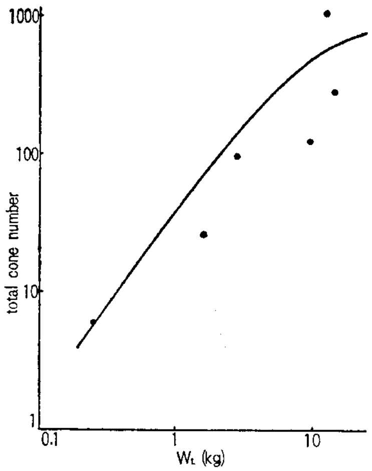


Fig. 5. The relation between cone number and leaf weight

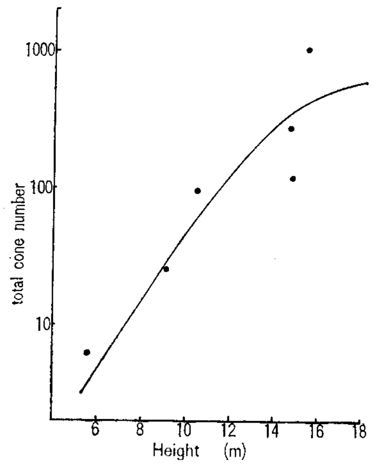


Fig. 6. The relation between cone number and tree height

The cone number obtained from formula (1) was 47450/ha, while the cone number from formula (2) was 35150. Seed number, was 1,775,000 seeds and 1,300,000/ha respectively. Compared with the estimation by seed trap, formula (2) is recommended. This result agreed approximately with those of Shidei,[3] Miyake,[2] and Asakawa.[9]

Both male and female strobili may be produced in P. densiflora and P. thunbergii at a very young age. For example, P. densifjora and P. thunbergii grown in the nursery of Faculty of Agriculture, Kyoto University, produced conelets at an early age of two years. This phenomenon of such an early conelet production has not been observed under natural conditions. Such precocious flowering is not common, and will not be found in the forest, where consistently dependable production begins only after the first period of rapid juvenile height growth is over and the trees approach the young mature stage. In this experi-

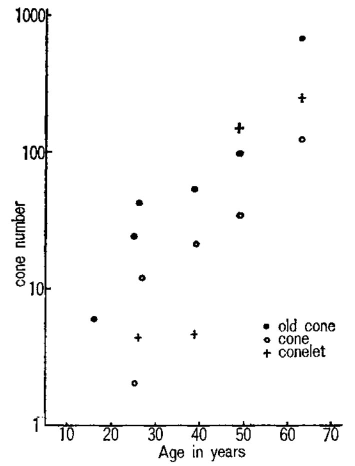


Fig. 7. The relation between cone number and tree ages

mental stand, the number of cones increased with the age ot tree and this result coincided with Garman's.

But in case of same age, isolated trees are notoriously heavy cone producers, while suppressed trees in the forest produce virtually few cones. It is supposed that such differences are certainly tied with the direct stimulus of light on the formation of flower buds, together with the general thrift and character of the tree crown. Garman[10] noted that in an earlier report on this study, the ability to bear cone increased with age up to at least 100 years. He found differences in cone bearing resulting from isolation of the crown and site quality. Dianthus prolifer in cultivated ground, practically free from competition, bore many capsules, while the plant under severe competition bore few capsules.[11] Thus herbaceous plants as well as woody plants need sufficient space to bear much fruits.

On the individual branches there are short branches which are several times as numerous as the main branch tips and the main side branches. However, these short branches supported a small amount of cones. The tips of the main branches supported comparatively a number of cones, and half or more of the cones were located on main side branches according to binocular observations.

In case of vertical distribution of branches, leaves and cone number, the relationship between cone number and unit weight of branch or leaf at each vertical layer is shown in Fig. 8. and Fig. 9.

No. 6 tree as a sample, was 15.5 meter in height, 24.01 cm in DBH, and 63 years old. This tree had the most branches and leaves at an interval of 11.3–12.3 meter above ground. Toward above and under portion of the layer, branches and leaves decreased. The layer had the most old cones and conelets. Miyake N.[2] reported that a significant relationship between F/C ratio and cone crop was observed. At each vertical layer, cone number per unit weight(kg) of leaves or branches increased toward top crown. It is supposed that this phenomenon may be related to light conditions and the ability to bear cones may be high near top crown.

Pomery[12] states that crown development does not provide a consistent value of future

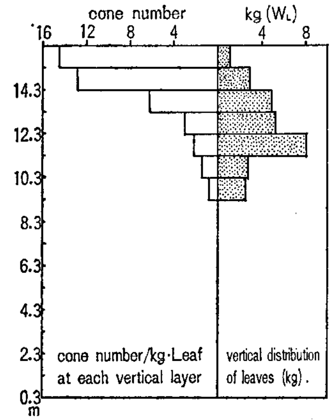


Fig. 8. Vertical distribution of cones and leaves.

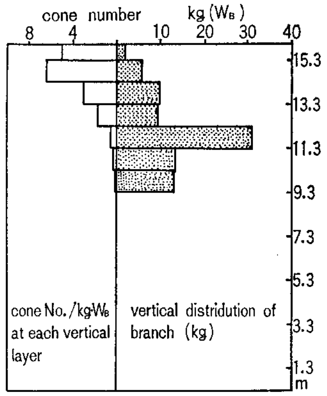


Fig. 9. Vertical dstribution of cones and branches.

cone crop. But Grano[13] reports a relationship between cone production and crown volume, that was better than the relationship between cone production and tree diameter, while Goddard[4] observed in a seed production area that the trees with large crowns were not necessarily the heaviest cone producers. These results have usually been based on subjective estimate alone, rather than on actual measurements.

Plotting the number of conelets in fall 1973 against the number of cones of Iwakura and Kamigamo stand clearly indicates considerable variation between trees. But a considerable significant positive correlation between number of old cones and new cones was observed. Some workers[3,4,5,6,7] recommend using old cones as an indicator of the degree of future cone crop. In both study area, Kamigamo and Iwakura, an ocular investigation showed that trees with many old cones bore comparatively many new cones. The correlation coefficient was comparatively high ($r=0.93$ at Iwakura, $r=0.82$ at Kamigamo). But the number of sample trees was not sufficient. The presence or absence of old cones will provide the foresters or observers a valuable clue to cone or conelet crop of a tree. This phenomenon shows that cone crop may be related to heritability of a tree. It has been repeatedly observed that certain trees are consistently heavy seed producers, while others are rather consistently barren.[15] Among the pines, for example, heavy-bearing trees are marked by the accumulations of cones of many years beneath the tree, while the clean forest floor under similar neighboring trees indicates small cone production. A similar result was observed at Hino Town pine forest. Similar behaviour has been noted in hardwoods, as the tulip tree.[13] Such differences can be rather unconvincingly ascribed to local soil vegetation or to factors causing distress cones, but it is commonly felt that genetic differences offer the only plausible explanation. Whatever the cause may be, it is reasonably certain that the production pattern of the past will be continued into the future.

In P. densiflora and P. thunbergii, it is very easy to find out two-years' cone crop at any time. In general above two pine species have cone and conelet on a same tree. The observation of conelet in Kamigamo Forest, showed that new conelets formed in April or May scarcely decrease in number in the course of time. But D.T. Lester[14] noted that a

Table 2. Annual variation in cone crop

tree No.	1	2	3	4	5	6
DBH (cm)	6.3	9.3	10.3	15.7	20.0	24.0
height (m)	5.6	9.2	10.5	14.9	14.9	15.6
cone	0	2	12	21	34	125
conelet	0	0	44	47	154	253

summary of average counts of 2nd-year cones in relation to average counts of 1st-year cones in the previous year shows a decrease of 60 %. In view of these losses, a central point in his study was the degree to which counts of 2nd-year cones reflected variation in cone initiation of red pine (P. resinosa). Annual variation in P. densiflora is shown in Table 2. Even though short period's observation, annual variation was clear fact.

According to Lester's report,[14] most coniferous tree species show marked variation in the production of cones from year to year. This variation is presumably attributable to variation in environmental influences acting upon an endogenous component of cone induction, and to variable losses of cones as a consequence of frost, poor pollination. Variation in reproductive potential is commonly measured in terms of numbers of cones near maturity. Garman,[10] in an earlier report on this study, stated that in pine, several years may pass with no cones produced, but flowers may be initiated in abundance while conelets, cones, or both are on a tree.

Associations between annual variation in cone production and variation in certain weather factors have been widely reported. In a comprehensive review of literature on factors affecting the production of seed by forest trees, Mathews[15] reported that a certain minimum degree of heat is apparently necessary for initiation of cones, while water supply may be either positively or negatively associated with cone formation. And Wenger[18] noted that a number of environmental factors may cause the large annual variation in cone production

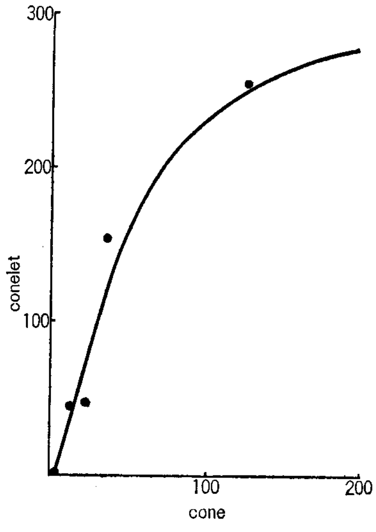


Fig. 10. The relation between cone and conelet at Iwakura

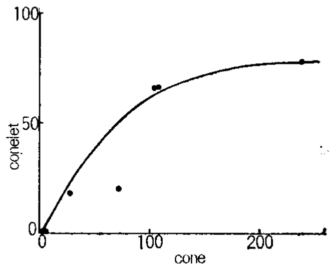


Fig. 11. The relation between cone and conelet at Kamigamo

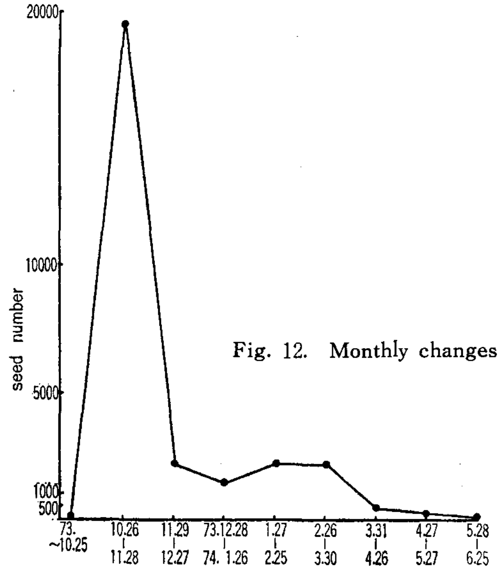


Fig. 12. Monthly changes in seed fall

as clearly evident in loblolly pine (P. taeda). Considering the above observations, $D^2 \cdot H$ or D^2 is not always recommendable for cone crop estimation. It is supposed that it will be necessay to investigate cone crop on sample tree every year to adopt $D^2 \cdot H$ or D^2 as factors.

There are two methods to estimate seed fall. One is the seed trap method and the other is to investigate remaining seeds in cones from many trees.[17] Seed fall is influenced by weather conditions. A combination of low precipitation, low humidity and high temperature and less resin content seems to be necessary to cause the cones open. During the period from Nov. 1973 to June 1974, seed fall investigated is shown in Fig. 12. About 68 per cent of seeds fell before December. This result showed different value comparing with the result of 1972-1973. It is supposed that this is due to annual variation in seed fall and locality. Seed crop estimation by seed trap showed 710,000 seeds per hectare, on the other hand that by $D^2 \cdot H$ showed 1,300,000 seeds. In the same stand seed crop estimation between seed trap and $D^2 \cdot H$ method revealed a great difference. This means that one of two above methods is not reliable. Considering propriety of seed trap method, cone crop estimation by $D^2 \cdot H$ factor has some problems, such as annual and site variation. Supposing that it is the simplest and most convenient to measure tree height and DBH for cone crop estimation among several factors, more detailed methods should be obtained through various investigations.

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