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Fundamental Studies on Pruning III

Difference of pruning method and subsequent variation of stand structure (1)

By

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Summary: As the growth of individual tree is controled by pruning operation, it is expected to be able to modify the development of stand structure in accordance with the object of forest management. Several kinds of pruning were examined on two experimental stands and subsequent effects were followed up on the development of stand structure.

From the results, the pruning methods in relation to this experiment were classified into two groups. As the effect of the pruning in one group, the range and the scattering in the distribution of tree size continued to widen and the fluctuation index in the order of tree size continued to decrease. In this group there are the pruning of up to the same height from the stand floor through the stand, and the pruning of up to the height where a certain external indication (criterion) is appointed in the crown.

On the other hand as the effect of the pruning in another group, the range and the scattering began to become smaller and the fluctuation index began to increase after the pruning operation. In this group there are the pruning of leaving the same length of tree crown through stand, and the other is the pruning where the rate of removal is large in large trees and small in small trees.

Finally, the application of these pruning methods to the practical forest management was discussed.

Introduction

The effect of pruning on tree growth has been well known and on the basis of this knowledge, it might be expected that if prunings are operated with different methods on the stands whose conditions are the same, the structure of each stand will develop into different types with the progress of tree growth after pruning operation. However, so far as my experience is concerned, the study which followed up such a phenomenon in association with pruning operation has not yet been reported. Only a similar study was reported by TADAKI and SHIDEI[4] who followed up the fluctuations in the order of tree size in relation to thinning. Although they added pruning treatment in part there, it was supplemental treatment as the contrast of thinning.

I examined the effect of several different kinds of pruning on the development of stand structure on two experimental stands. And on the basis of the results in this experiment, pruning method was classified and the application of them to the practical forest management were discussed in this paper.

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Method

Two experimental stands of Sugi (*Cryptomeria japonica*) were established for this study. One is the model stand on a nursery (Experimental Stand I) and the other is a young artificial stand in the field (Experimental Stand II).

Experimental stand I

In March 1968, 1-2 Sugi seedlings were planted at 80 cm intervals on the nursery in Kansai Branch, Government Forest Experiment Station, Kyoto. Two years later (in March 1970), four kinds of treatment including no pruning were carried out on the stand. Each treatment was carried out on each sub-plot involving $7\times8=56$ trees, and $3\times4=12$ trees without two outside rows were measured as the sample trees. Each treatment was replicated a second time, so one plot consists of two sub-plots. The outline of the sample plots are shown in Table 1 and Table 2. At the time of the pruning operation, ten sample trees were cut down in proportion to the frequency distribution of tree size in the plot for the direct measurement of leaf amount, and measurements were taken at every vertical stratum of 20 cm. These data were used for the estimation of the ratio of removed leaves in each tree or each plot. During the first two years after the planting, as the diameter of sample tree was too small to measure accurately, the comparison of tree growth was done with tree height. The shoots which spread after the pruning were removed as often as possible. The control plot closed during the third growing season after the planting, and all of the pruning plots closed during the fourth growing season.

Experimental stand II

The experimental stand was laid out on a 9-year-old artificial Sugi stand in Ujidawara located 30 kilometers from the Forest Experiment Station, Kyoto. The soil condition was good and the progress of the growth had been also. Thinning and pruning had not been conducted there. In March 1969, the experimental plots were laid out in the stand and in November 1969, pruning operation was carried out with three kinds of treatment including no pruning (control). As the tree density was so high (4600/ha) for this experiment a cosiderable number of trees were thinned in proportion to the frequency distribution of tree size there, then the tree density became 2900/ha. In each experimental plot, 11 sample trees were involved and they were surrounded by equally treated marginal trees. The outlines of the sample plots are shown in Table 1 and Table 2. At the same time of the pruning operation, 6 sample trees were selected in proportion to the frequency distribution of tree size from the cut trees for the direct measurement of leaf amount. It was measured at every vertical stratum of 50 cm. From these data, the ratio of removed leaves in each tree or each plot was estimated. In this experimental stand, tree size was expressed with D^2H (D denotes diameter at breast height and H denotes tree height).

In both experimental stand I and II, none of the experimental trees died during the experimental period.

The state of the scattering in the distribution of tree size in each plot was expressed with the standard deviation in this paper.

The degree of the fluctuations in the order of tree growth in each plot at every year was expressed in the following way[4]. Every year, each experimental tree in each treatment was numbered in accordance with the order of tree size. For example, in the case of a plot in the

Table 1. Outline of the experimental plots

Experimental stand	Symbol of the experimental plot	Treatment	Number of sample trees	Summary
Nursery at Gov't For. Exp. Sta., Kyoto	I —1	Control	12+12	No pruning
	I —2	Pruning of up to the same height through the plot	12+12	80 cm from the floor. The ratio of the removed leaves through the plot was 79%
	I —3	Pruning whose intensity is proportional to tree size	12+12	The larger the tree height was, the larger the ratio of pruning length to tree height was and the smaller the tree height was, the smaller it was (See Table 2). The ratio of removed leaves through the plot was 79%
	I —4	Pruning of leaving the same crown length	12+12	The crown length of all trees were 120 cm. The range of the ratio in removed leaves was from 95% to 23%. 80% of leaves was removed through the plot
Field at Ujidawara	II —1	Control	11	No pruning
	II —2	Pruning of up to the same height through the plot	11	4.2 m from the floor (Mean stem clear length was 1.68 m at that time). The ratio of removed leaves through the plot was 47%
	II —3	Pruning whose intensity is proportional to tree size	11	The larger the D^2H was, the larger the ratio of pruning length to crown length was and the smaller the D^2H was, the smaller it was (See Table 2) The ratio of removed leaves through the plot was 59%

experimental stand I, the highest tree is 1 and the lowest tree is 24. When the same order existed, smaller number was given to the tree whose original tree number is smaller on table. Then the difference of the order between adjacent years in each tree was obtained. In effect, the difference of the order in the tree whose order did not change in one year is 0, jumped over two places is +2, and came down two places is −2. In this paper, fluctuation index in the order of tree size was defined as the total absolute values of the difference in the order of tree size in each plot in one year.

Although most of the periodical measurements were made in November, some of them were not. But as the tree growth is regarded as not occuring from November to the following March, the month of periodical measurement were unified as November on the tables and figures in this paper.

Table 2. The details of the treatment in the experimental plots, I—3 and II—3

Experimental stand and plot	Sub plot	Order of tree height	Tree height	Pruning length	Ratio of pruning length to tree height
Nursery at Gov't For. Exp. Sta., Kyoto (I—3)	A	1	223	130	58
		2	200	100	50
		3	200	100	50
		4	195	90	46
		5	190	70	37
		6	180	50	28
		7	176	45	26
		8	169	35	21
		9	160	25	16
		10	140	0	0
		11	136	0	0
		12	135	0	0
	B	1	225	130	58
		2	225	130	58
		3	220	120	55
		4	219	120	55
		5	215	100	47
		6	215	100	47
		7	205	85	41
		8	205	85	41
		9	200	70	35
		10	192	60	31
		11	185	50	27
		12	177	40	23

Remarks: As the clearing of branches has not yet started in the stand, I—3, tree height was regarded as approximate crown length.

Table 3. Result of height growth

Time measured (Year, Month)		'67, 11		'68, 11
Experimental plot number	Value of height (m) / Treatment	Mean Min.~Max.	Standard deviation	Mean Min.~Max.
I —1	Control (No pruning)	0.152 0.065~0.245	5.8	0.700 0.585~0.860
I —2	Pruning of up to the same height	0.141 0.068~0.210	4.3	0.705 0.550~0.860
I —3	Pruning whose intensity is individually different	0.120 0.045~0.305	5.4	0.684 0.565~0.900
I —4	Pruning of leaving the same crown length	0.110 0.040~0.225	4.8	0.696 0.513~0.915

Table 2. (Continued)

Experimental stand and plot	Order of D^2H	D^2H	Crown length	Pruning length in crown	Ratio of pruning length to crown length
Field at Ujidawara (II—3)	1	817	579	400	69
	2	715	581	375	65
	3	684	566	365	64
	4	654	559	360	64
	5	606	572	345	60
	6	584	580	330	57
	7	582	546	310	57
	8	459	500	255	51
	9	454	545	240	44
	10	454	517	230	44
	11	430	556	170	31

Results

Experimental stand I

The progress of the growth and others during four growing seasons in each experimental plot are shown in Table 3~4 and Fig. 1~6. In Fig. 1~4, as it was difficult to express the progress in the growth of all trees in one plot on one graph, it was expressed at every sub-plot.

I—1 (No pruning): As the growth progressed, the range in the distribution of tree size widened (Table 3, Fig. 1), the standard deviation in the distribution of tree size continued to increase (Table 3, Fig. 5), and the mean fluctuation index in the order of tree size continued to decrease (Table 4, Fig. 6).

I—2 (Pruning of up to the same height): As the growth progressed, the range in the distribution of tree size widened (Table 3, Fig. 2), although it was not so large as that in I—1. The standard deviation in the distribution of tree size continued to increase (Table 3, Fig. 5), and the mean fluctuation index in the order of tree size continued to decrease (Table 4, Fig. 6) with the lapse of time before and after the pruning operation. The reason why

in the Experimental Stand I

	'69, 11		'70, 11		'71, 11	
Standard deviation	Mean Min.~Max.	Standard deviation	Mean Min.~Max.	Standard deviation	Mean Min.~Max.	Standard deviation
7.1	1.81 1.35~2.30	25.0	2.77 2.10~3.40	32.0	3.53 2.75~4.08	34.5
8.9	1.83 1.55~2.15	17.4	2.54 2.03~3.00	21.4	3.55 3.04~4.06	28.4
8.7	1.91 1.35~2.25	27.6	2.48 2.15~3.08	19.7	3.42 2.82~3.84	22.9
8.9	1.87 1.44~2.32	25.3	2.31 1.99~2.63	17.4	3.28 2.75~3.73	25.3

Table 4. Mean fluctuation index in the order of tree height in the Experimental Stand I

Symbol of the experimental plot	Treatment	Period '67, 11 ～'68, 11	'68, 11 ～'69, 11	'69, 11 ～'70, 11	'70, 11 ～'71, 11
I —1	Control (No pruning)	6.50	5.16	2.91	2.08
I —2	Pruning of up to the same height through the plot	7.08	6.58	4.41	2.16
I —3	Pruning where the ratio of the removal is large in large trees and small in small trees	6.00	4.66	8.41	5.25
I —4	Pruning of leaving the same crown length	7.58	4.50	6.16	3.25

the range and the standard deviation in the distribution of tree size in I—2 did not become so large as those in I—1 after pruning operation must be the fact that those in I—2 were smaller than those in I—1 at the time of the pruning operation (Fig. 1, 2 and 5). As is evident from Fig. 5, increasing rate of the standard deviation in the distribution of tree size after the pruning operation in I—2 is rather larger than that in I—1. Generally speaking, the progress of the tree growth both in I—1 and I—2 can be said to be of a similar tendency.

I—3 (Pruning, with intensity proportional to tree size): Although the tendency in the progress of tree growth was the same as those in I—1 and I—2 before the pruning operation, it changed clearly after the pruning. The range in the distribution of tree size ceased to widen (Table 3, Fig. 3), the standard deviation in the distribution of tree size decreased in one year after pruning (Table 3, Fig. 5) and the mean fluctuation index in the order of tree size increased in one year after pruning (Table 4, Fig. 6).

I—4 (Pruning, leaving the same length of tree crown): The tendency in the progress of the range, the standard deviation in the distribution of tree size, and the mean fluctuation index in the order of tree size were almost the same as those in I—3 (Table 3～4, Fig. 4～6).

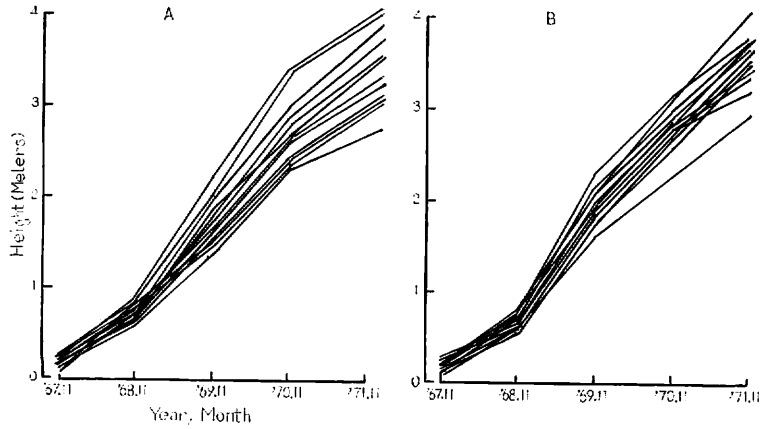

Fig. 1 Progress of the height growth in the control plot in the Experimental Stand I (I—1).
A and B denote the sub-plots.

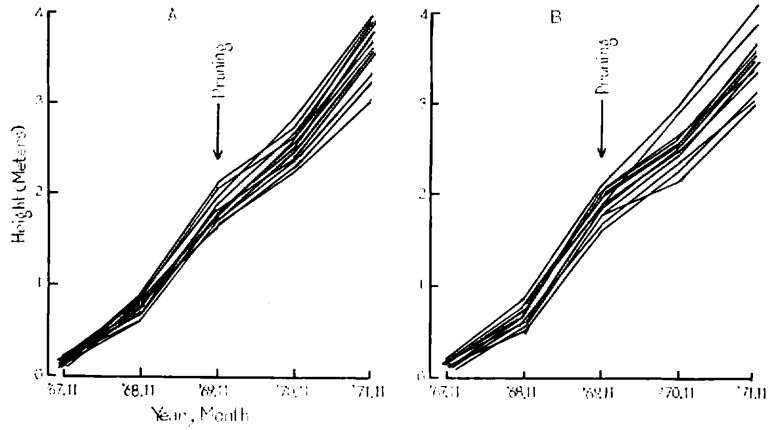

Fig. 2 Progress of the height growth in the plot for the pruning of up to the same height in the Experimental Stand I (I—2). A and B denote the sub-plots.

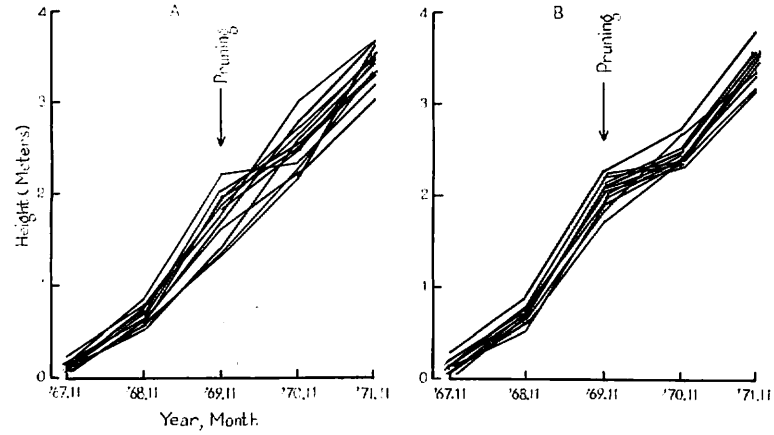

Fig. 3 Progress of the height growth in the plot for the pruning whose intensity is individually different in the Experimental Stand I (I—3).
A and B denote the sub-plots.

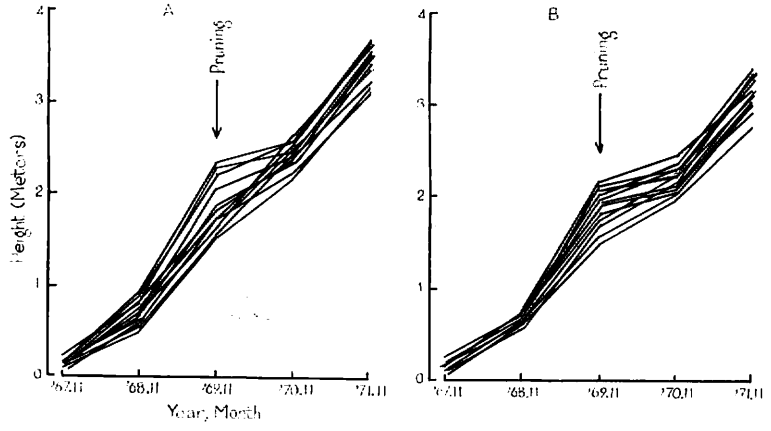

Fig. 4 Progress of the height growth in the plot for the pruning of leaving the same crown length in the Experimental Stand I (I—4). A and B denote the sub-plots.

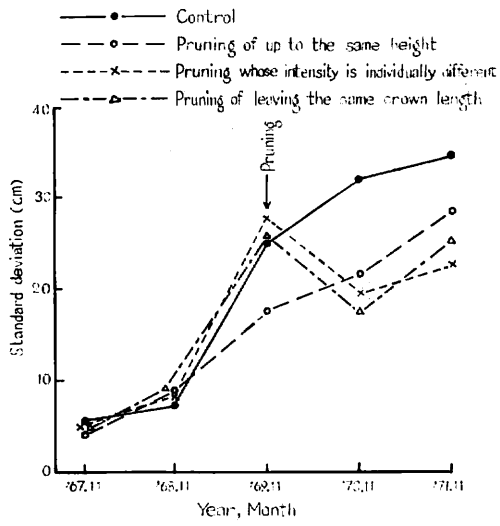

Table 5. Result of the

Time measured (Year, Month)	
Symbol of the experimental plot	Values of D^2H (cm^2m) / Treatment
II—1	Control (No pruning)
II—2	Pruning of up to the same height
II—3	Pruning where the ratio of removal is large in large trees and small in small trees

Fig. 5 State of the scattering in the distribution of tree height in each plot in the Experimental Stand I.

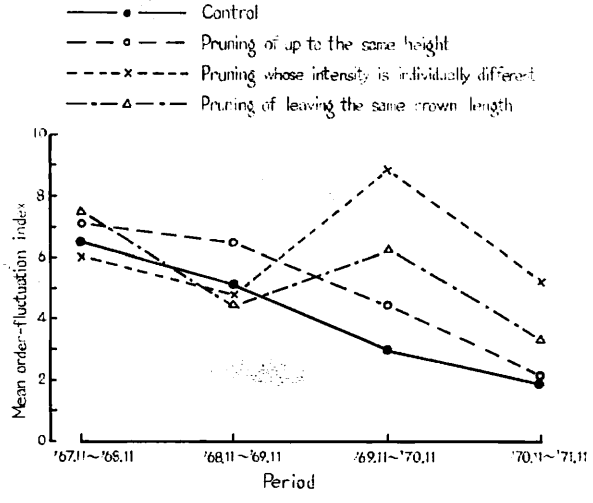

Fig. 6 Mean fluctuation index in the order of tree height in each plot in the Experimental Stand I.

But the mean fluctuation index in the order of tree size in I—4 did not increase so much as that in I—3 after the pruning operation (Table 4, Fig. 6).

Experimental stand II

The progress of growth and others during three growing seasons are shown in Table 5~6 and Fig. 7~9.

II—1 (No pruning): As the growth progressed, the range in the distribution of tree size continued to widen (Table 5, Fig. 7), the standard deviation in the distribution of tree size continued to increase (Table 5, Fig. 8), and the mean fluctuation index in the order of tree size kept small values (Table 6, Fig. 9).

II—2 (Pruning of up to the same height): Although the growth rate decreased after the pruning operation, the range in the distribution of tree size continued to widen (Table 5, Fig. 7). The standard deviation kept small values (Table 5, Fig. 8) and the mean fluctuation

D^2H growth in the Experimental Stand II

'68, 11		'69, 11		'70, 11		'71, 11	
Mean Min.～Max.	Standard deviation	Mean Min.～Max.	Standard deviation	Mean Min.～Max.	Standard deviation	Mean Min.～Max.	Standard deviation
480 320～650	108	560 377～770	128	677 467～980	156	852 584～1184	195
441 280～627	116	525 328～755	141	576 362～860	159	680 415～1032	193
501 367～677	99	585 430～817	127	613 472～834	117	693 564～843	93

Table 6. Mean fluctuation index in the order of D^2H in the Experimental Stand II

Period		'68, 11～'69, 11	'69, 11～'70, 11	'70, 11～'71, 11
Symbol of the experimental plot	Treatment			
II—1	Control (No pruning)	0	0	0.18
II—2	Pruning of up to the same height through the plot	0.18	0	0.18
II—3	Pruning where the ratio of the removal is large in large trees and small in small trees	0.18	0.36	0.55

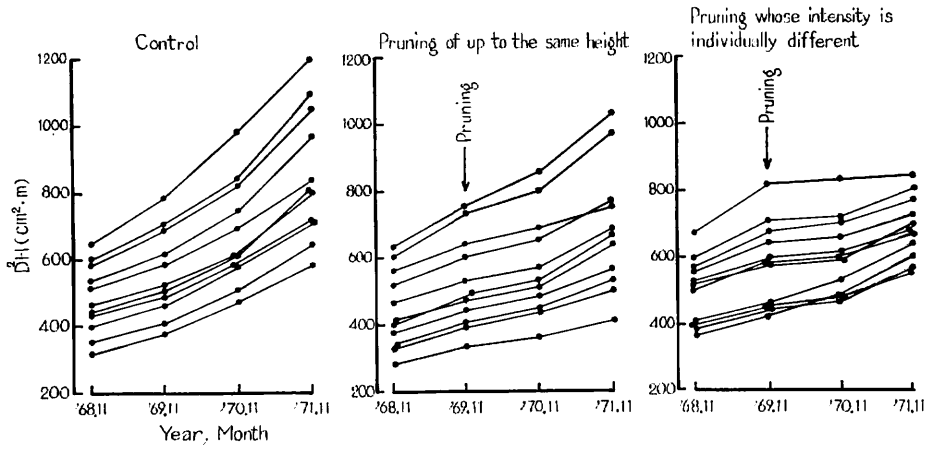

Fig. 7 Progress of the D^2H growth in each plot in the Experimental Stand II.

index in the order of tree size continued to increase (Table 6, Fig. 9) before and after the pruning operation.

II—3 (Pruning, with intensity proportional to tree size): The growth rate decreased after the pruning operation and that was remarkable in large trees, although the growth rate in small trees did not decrease so much (Table 5, Fig. 7). Then the range in the distribution of tree size began to reduce after the pruning operation. The standard deviation began to

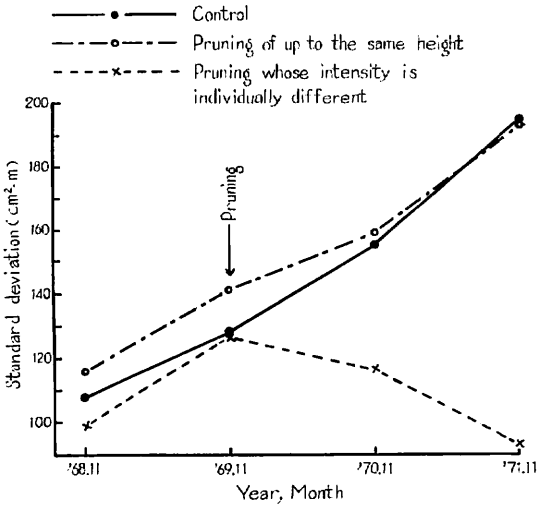

Fig. 8 State of the scattering in the distribution of the D^2H in each plot in the Experimental Stand II.

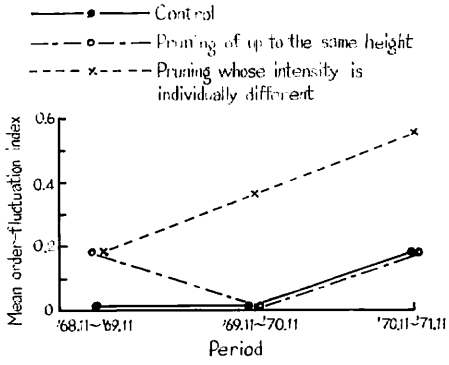

Fig. 9 Mean fluctuation index in the order of the D^2H in each plot in the Experimental Stand II.

decrease (Table 5, Fig. 8) and the mean fluctuation index in the order of tree size increased after the pruning operation (Table 6, Fig. 9).

Discussion

The experimental stand I is younger than the experimental stand II. In effect, at the time of the last measurement, the experimental stand I was 4th year and the experimental stand II was 12th year after they were planted. So the effects of pruning and the recovery from the effects occurred more intensively in the experimental stand I. Even so, the results of the same treatment showed the same tendency through both experimental stands I and II.

Judging from the results in this experiment, pruning methods could be classified into two groups in association with the subsequent effect on the development into different types of forest structure. The characteristic of the first group is as follows: As the effects of pruning operation, the range in the distribution of tree size is maintained or widening is promoted, the standard deviation in the distribution of tree size increases, and the mean fluctuation index in the order of tree size decreases with the lapse of time. The pruning of up to the same height and no pruning belong to this group.

On the other hand, the characteristic of the second group is as follows: As the results of the pruning operation, the rate of the development in the range in the distribution of tree size decreases or the range reduces, the standard deviation in the distribution of tree size decreases, and the mean fluctuation index in the order of tree size keeps high values. In this group there are the pruning whose intensity is severe in large trees and it is mild in small trees, and the pruning of leaving the same length of tree crown through stand.

Application of the results in this experiment to the practical forest management

There are several objectives of pruning, and the following will be enumerated as general objectives[2].

1) Control of tree growth and the modification of forest structure.
2) Production of good quality timber.
3) Distribution of sun-light to understories.
4) Prevention of disease, fire, and others.
5) Improvement of forest condition for the efficiency of the work in forest.

Among these, this experiment was focussed on 1), but 1) has close relation to 2) and 3) at the same time. From the results of this experiment, pruning method was classified into two groups above mentioned, and here I will discuss the application of the pruning methods in both groups to the practical forest management.

For the forest management whose objective is the production of uniform logs, the following may be enumerated. One is the management of the even-aged forest where the production of the crops and regeneration are performed simultaneously, and the other is the compound forest where each story is yielded at a time. The objective production in this management is mainly knotless boxed-heart pole for pillars and this type of forest management usually belongs to short rotation forest management.

The pruning methods which are adapted to such forest management as these are as follows: one is the pruning of leaving the same length of tree crown through stand, and the other is the pruning whose intensity is individually different; that is, the rate of the removal is large in large trees and small in small trees. Generally in these pruning methods, the trees in the large class are pruned from an earlier time than those in the small class, and the latter or at least the last pruning is carried out at one time in all trees. The reason is that in the pruning of leaving the same length of tree crown, pruning is not made on the trees in the small class until their crown length reaches a marginal length, and in the pruning whose intensity is individually different, mildest pruning is often no pruning. When the aim is to get uniform trees earlier, the pruning in which the rate of the removal is large in large trees and small in small trees shall be adopted, but in general, the pruning of leaving the small trees shall be adopted, but in general, the pruning of leaving the same length of tree crown seems to be more easy to practice and after the stand structure has become uniform, this method more or less equals the pruning of up to the same height.

Meanwhile, in the forest management under which it is immaterial or required that the range in the distribution of tree size widens, the following will be enumerated. The first is the management of even-edged forest from which the production of logs for many-sided demand are expected. In this management, large trees on the first growing stage are made the subject for the supply of large-size logs of good quality, while small trees are made the subject for the thinned pole of knotless boxed heart. This is relatively a long rotation forest management for many-sided objects. And also in this management, first pruning is carried out on all of the trees at a time, but the pruning on small trees ends earlier than that on large trees. The same thing is expected in each story of the compound forest, and when its management is pushed forward, the final aspect of forest management becomes selection

forest management. So it might be said that the pruning method which maintains or promotes widening of the range in the distribution of tree size can be adopted in the forest management which is on the process of the development from simple forest to compound and finally selection forest.

As the pruning methods which can be adapted to the forest management above mentioned, the following will be enumerated. The first is the pruning of up to the same height from stand floor through the stand; the second is the pruning of up to the height determined by a certain external indication in crown, and the third is the pruning only for dead branches. In the second pruning method, external indications (criteria) in crown are as follows: the stratum with a certain clearing ratio in a branch from its base to the tip, the stratum with the largest branch amount, or others[1]. When the second pruning method is adopted, the effect of its pruning on tree growth is regarded as being similar in tendency to the effect of the pruning of up to the same height from stand floor through stand[1]. From the viewpoint of the pruning effect on the tree growth, there is no difference between the pruning only for dead branches and no pruning[3)5)]. So the result of no pruning in this experiment can be regarded as the same as the result which would have been obtained from the experiment of pruning dead branches.

The pruning method above discussed must be most practical and general, but other pruning methods also may be devised in accordance with other situations.

Acknowledgement

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Literature cited

1) Fujimori, T.: Fundamental studies on pruning I. Discussion about pruning on the basis of an ecological research. Bul. Gov't For. Exp. Sta., 228, 1～38, (1970)*

2) Fujimori, T. and O. Waseda: Fundamental studies on pruning II. Effects of pruning on stem growth (1). Bul. Gov't For. Exp. Sta., 244, 1～15, (1972)

3) Henman, D. W.: Pruning conifers for the production of quality timber. Forestry Commission Bul. 35, Edinburgh: Her Majesty's Stationary Office, 55pp., (1963)

4) Tadaki, Y. and T. Shidei: Studies on competition of forest trees (IV). The order-fluctuation of individuals in stand with progress of growth. J. Jap. For. Soc. 44, 203～212, (1962)*

5) Takahara, S.: Influence of pruning on the growth of Sugi and Hinoki. Bul. Tokyo Univ. For., 46, 1～24, (1954)*

Remarks: The mark, * denotes that the literature is written in Japanese with English summary.

枝打ちに関する基礎的研究 III*

枝打ち方法の違いによる林分構造の変化について（1）

藤森隆郎(1)

摘　要

枝打ちによつて林木の成長が影響されることはよく知られている。そのことを応用して，林分構造を調節するための枝打ち試験を行なった。

苗畑に設けた植栽後2年目のスギのモデル林分と，京都府下にあるスギ9年生の現実林分にいくつかの異なった方法で枝打ち処理を行ない，その前後の生育経過を追跡した。生育にともなう個体の大きさの分布の範囲とそのバラツキ方およびその個体の順位変動の起こり方を解析し，その結果をもとにして枝打ち方法を分類した。そして森林の経営目標に応じたそれらの枝打ち方法の適応について考察した。

筆者の試験した4種類の枝打ち方法はその結果によって2つのグループに分けられた。1つは生枝打ちなし（枯れ枝打ちも含まれる）と林分をとおして地上からの高さを一定にして打つ枝打ち方法である。このグループの作業を行なうと個体の分布範囲は拡がり，個体分布の標準偏差も大きくなり，個体の順位変動指数は小さくなった。

第2のグループは，大きな木ほど強く，小さな木ほど弱い枝打ちを行なう方法と，樹冠長を同じ長さに残して打つ枝打ち方法である。このグループの作業を行なうと個体の大きさの分布範囲の拡がる率と個体分布の標準偏差は小さくなり，個体の順位変動指数は増加した。

皆伐一斉更新した林分から長期間に多岐にわたる目的材の収穫を目指す経営のための施業，多段林において逐次収穫を得ようとするための施業，あるいは択伐林施業などにおいては，林木の個体差が拡大してもさしつかえないか，むしろその方が好ましい場合が多い。そのような場合には第1のグループに属する枝打ちの採用が考えられる。本試験には用いなかつたが，一定の外観的指標，たとえば枝の一定枯れ上り長率までの高さや力枝層までの枝打ちなどは第1のグループに属する。また単層林から複層林へもっていこうとすれば，その過程で第1のグループに属する枝打ちを行なうことはその促進の大きな助けとなろう。

一斉更新して一斉に収穫する施業と，間断収穫を行なう多段林施業においては個体差の小さな均質な材をそろえて収穫できることが望まれる。そのためには第2のグループに属する枝打ちを用いることが考えられよう。

（前報訂正　研報第244号，p. 15，下から4行目　誤：葉量最大量　正：枝量最大量）

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