

壮齡林肥培に関する研究(IV)

スギ壮齡林に対する生育相別施肥試験

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 論 文

Studies on Fertilization in Established Stands (IV) Examination of Fertilization Periods According to Different Growing Phases of Sugi (*Cryptomeria japonica*) Stands

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壮齡林肥培に関する研究 (IV) スギ壮齡林に対する生育相別施肥試験

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要 旨: この試験は、スギ壮齡林における施肥適期を知るために、29年生スギ林の各生育相に応じた時期ごとに施肥して、その施肥効果を、葉の栄養分析と、生長量測定との両面から検討したものである。実際に施肥されたのは、1月、4月、6月、8月、11月の各月で、施肥量は、haあたりの要素量で、N-P₂O₅-K₂O がそれぞれ 300-160-160kg であった。

なお、試験成績は4生育期間についてのものである。

1. 4年間の材積生長量では、いずれの施肥区も無肥料区にくらべて、haあたり 29m³以上の増収となり、とくに6月施肥区は 68m³とすぐれた肥効を示した。競争による自然枯死木のものであるような密度の高い林分で、しかも年生長量 22m³もの優良な林分で、なおこのような肥効をみたことは注目されるべきであろう。

2. 施肥によって葉のリンとカリ含有率は変わらなかったが、チッソ含有率は高まった。

3. チッソ含有率の高まり方は、生育休止期ではややおくれ、生育期では施肥後間もなく高まった。しかしながら施肥後の葉のチッソ含有率は、施肥時期のちがいににもかかわらず、似たような値となり、そのままの高いレベルで翌年も持続した。

4. 2年連続施肥区のチッソ含有率も、1回施肥区のそれと変わらなかったことから、チッソについての施肥量は十分であったように思われる。そして2%前後の値は、この地域でのスギ壮齡林分が、十分な生育をするのに必要なひとつの指標値のように考えられた。

5. 以上のような肥効による材積増加量と、葉の養分含有率による栄養生理学的検討とから、スギ壮齡林での施肥適期は、幅が広く、どの季節でも相当の肥効がみられたが、とくに新葉の展開の終了する初夏、6月ころのように思われた。

6. 施肥後の年々の材積にみられる肥効の経過は、気候の変化にも対応するので、いちがいにはいえないが、施肥年よりも翌年以降に大きくなり3年目に最大に達し、少なくとも4年以上は続くようであった。このことから、主伐期のスギ壮齡林での施肥は、少なくとも主伐の4年以上前が適当のように考えられた。

7. 施肥による材積生長量増大は、優勢木ほど大きかった。また肥効のいちじるしい優勢木ほど、樹冠の内部すなわち幹の上部と根元との肥大生長が顕著であった。

Summary: This work was carried out to find the suitable period for the fertilization of Sugi stands. The fertilization was done in several growing phases of sugi forest trees. The fertilizer efficiency was determined by the chemical analysis of needles and the measurement of growth. The fertilizer was broadcasted in the forests in Jan., Apr., Jun., Aug., and Nov., from 1963 to 1965. Each fertilizer application contained 300kg of N, 160kg of P₂O₅, and 160kg of K₂O per hectare. The measurements were taken during the four growing periods.

1) At the end of the four year test period, the fertilizer produced a 29~68 cubic meter per hectare increase in stem volume when compared to the control plot. Especially, in the plot fertilized in Jun., the largest growth increase of 68m³/ha was observed. A high efficiency of fertilizers is remarkable in such a high density forest under natural thinning.

2) The concentration of potassium and phosphorus in the needles did not change significantly after each fertilization, but the increase in nitrogen concentration was consistent.

3) The increase in the nitrogen concentration in the needles after each fertilization

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appeared soon in the growing period and a little later in the dormant period. In spite of the difference in fertilizing periods, the nitrogen concentration was approximately at the same level in all needles taken from the six test plots. The high nitrogen concentration persisted until the next year.

4) Judging from the fact that the nitrogen concentration of the needles in the plot fertilized consecutively in April 1964 and April 1965 was not different from that of nitrogen concentration of needles in the plot fertilized only in April 1964, the amount of nitrogen in the latter case is supposed to be sufficient for the stand. These tests indicated the value of 2% nitrogen content in the current year needles is a sufficient growth indicator in established Sugi stands in the sample forest.

5) The results obtained from the increase in volume growth and in nitrogen content of the needles gave us some significant information as to the best fertilization period. The suitable period for fertilization in the established Sugi stand is wide, because good efficiency was given whenever fertilization was done. In the early summer, at the end of the elongation of the spring buds, the fertilizer efficiency was especially good.

6) The total volume growth varies annually in direct relation to the climate of the season. The effect of fertilization on volume growth seems to be greater in the year after the initial application. The greatest volume increase was seen in the third year with a possible fertilization effect in the fourth year. The fertilizer efficiency indicates that fertilization should be carried out at least four years prior to the final cutting.

7) The volume increase of the stems by fertilization is largest in the more dominant trees. The trees which had the largest response showed a particular increase of growth in the diameter of the stems in the crown and butt portion.

1. Foreword

The practice of forest fertilization in established stands has been developed in foreign countries¹⁻³. The necessity of fertilization in Japan was suggested by Kawana in 1960⁴. The practice has since been spreading step by step^{5,6}. Among the individual techniques applicable to forest fertilization, the suitable period for fertilizer application has not been determined. As we are limited in the basic data in the experimental results in the quantitative efficiency of forest fertilization in established stands, we have to push the experiments forward. This report publishes the results of fertilization test made for the purpose of determining suitable fertilization periods.

During selected growing periods, the established Sugi stands were fertilized in order to determine the variation in fertilizer efficiency. The 29-year-old Sugi stand experimental plots were located in the Yamizo National Forest of the Daigo District. Unfortunately, we had to fell all of the experimental plots in 1966. The stand was suddenly selected for clear cutting on account of a change in the Forest Office Planning. We believe that four years were not long enough for a complete analysis of the fertilizer efficiency. However, some valuable data were collected.

We would like to thank the Japan Ammonium Sulphate Industry Association for their support in part; Mr. H. KATAOKA, ex-Chief of the Daigo District Forest Office; Mr. T. KANAI, Chief of the Daigo District; Mr. S. UCHIDA, Chief Ranger; some of the

members of his office for their kindness offered in the use of the forest and the help in the final measurement of the clear cutting and again we would like to thank Dr. Yoshinori AIBA for his help in organizing and publishing this study.

2. The Outline of the Experimental Field

The experimental field was selected in Nov. 1963, and its outline is presented in Table 1.

Table 1. Outline of the Experimental Field

Location	Yamizo, Kaminomiya, Daigo town, Kuji, Ibaraki Pref. Sub-compartment 18, Compartment 93, Daigo District.
Land Description:	
Area	4,162m ²
Tree species	<i>Cryptomeria japonica</i> (Sugi)
Stand age	29 at the beginning of the experiment
Topography	Equilibrium slope at the basal part of the hill-side
Altitude	600m
Inclination angle	25°
Bearing	WSW
Parent material of soil	Schistous sandstone, clay slate in Yamizo palaeozoic strata
Soil type	Bd-BE, clay loam, creeping or colluvial soil, rich in gravel
Climatological data:	
Average temperature	Annual: 12.9°C Summer: 19.8°C Winter: 6.0°C
Precipitation	Annual: 1,449mm Summer: 1,005mm Winter: 444mm
Warmth index	95
Rain factor	112
Stand condition:	Average tree height: 18.4m Average D.B.H.: 20.1cm Total basal area: 57.0 m ² /ha Tree density: 1,670/ha

The topography of the experimental field is an equilibrium slope, characteristic to palaeozoic strata. The soil is a creeping or colluvial soil containing many large and small gravels showing Bd or Be type. Soil horizons are thick; physical and chemical properties of the soil are good. Moreover, as the warmth index and rain factor show, the site is very suitable for Sugi stands. In fact, the value of 18.4m in average tree height and 20.1cm in average D.B.H. are well over the first class growth standards as shown in the Ibaraki District Field Table for Sugi⁸⁾. The stand density of 1,670 per hectare exceeds the field index of Ry 0.9, according to the Ando's Stand Density Control Diagram⁹⁾ for all Japanese forests.

3. Method of the experiment

1) Experimental treatment

Experimental plots were treated according to selected growing periods as shown in Table 2.

The fertilizer used was Sumitomo No. 1 (15-8-8). Application was by broadcasting with the amount of 2,000kg per hectare. Chemical content of the fertilizer was 300kg of N, 160kg of P_2O_5 , and 160kg of K_2O .

2) Experimental Method

a) Measurement of Growth

The measurement of D.B.H. of all the trees in the stand was carried out in January each year. The tree height was obtained by applying the height curve method. The standard for the height curve method was four standard trees and ten selected trees from the diameter grade in each plot. At the end of the experiment, 14 trees in each plot, 98 in total, were selected for stem analysis by proportional allotment.

b) Chemical Analysis of Needle.

Four specimen trees, more dominant than the average trees in each plot, were selected for needle analysis. The needles were taken in the dormant period each year. The analytical values presented are the average of four trees. The sample needles of each specimen tree were the current year needles on the branch which was directed toward the down hill slope. The sample needles were taken from the terminal end of the branch and 1.5 meters below

the top of the stem. The one year old needles in the fertilized plots of June and August were analyzed for the purpose of reference. The analytical methods were as follows:

Nitrogen; Semi micro-Kjeldahl method

Phosphorus; Measured by photoelectric colorimetry indicated by molybdenum blue color after wet ashing with sulphuricnitric acid.

Potassium; Measured with flame photometer after needle extraction with 1/5N-HCl solution.

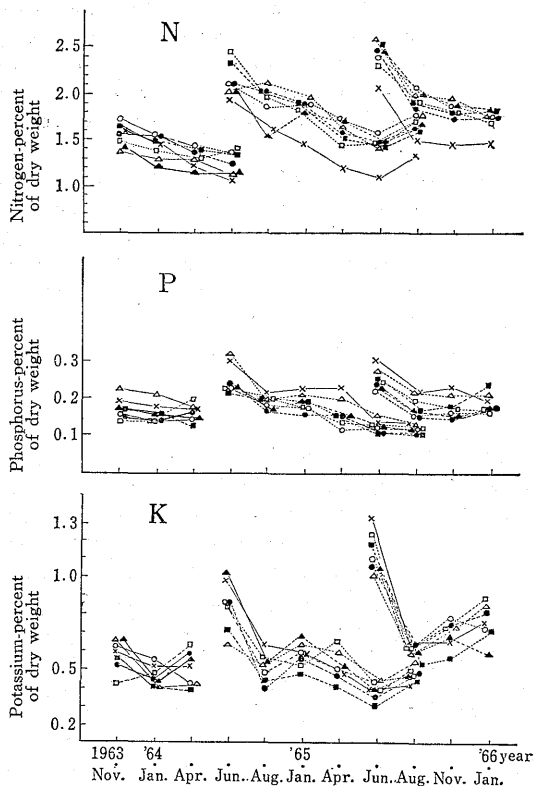


Fig. 1. Seasonal variation in the foliar nutrient contents with fertilizer application

Introductory remarks

-: Fertilized Plots
- : Non-fertilized Plots
- : Fertilized in Nov.
- : Fertilized in Jan.
- : Fertilized in Apr.
- : Fertilized in Apr. (two applications)
- △: Fertilized in June
- ▲: Fertilized in Aug.
- ×: Non-fertilized

Table 2. The Experimental treatment

Sampling plot	Growing phase of Sugi	Fertilized date	Area (m ²)	Number of trees
Nov.	Opening of the ripe corn	12 Nov., 1963	400	63
Jan.	Dormant period	12 Jan., 1964	405	73
Apr.	Spring buds as large as grain of rice	12 Apr., 1964	592	103
Apr. (two applications)	ibid. two consecutive years	12 Apr., 1964 12 Apr., 1965	448	73
Jun.	End of elongation of spring buds	12 Jun., 1964	437	78
Aug.	Flower buds as large as grains of rice	12 Aug., 1964	493	80
Control	Non-fertilization		492	75

4. Experimental Results

1) Influence of Fertilization on the Nutrient Concentration of Needles (Fig. 1).

a) Nitrogen

The concentration of nitrogen was found to increase immediately after fertilization in the vigorous growth periods, i.e. June and August, but the increase in the nitrogen concentration appeared later when application was made in the dormant periods, i.e. November and January. In all cases, the concentration of nitrogen in the needles increased after fertilization and the increased concentration continued into the next year. The same increased concentration of needle nitrogen was also seen in the plot which was fertilized for two consecutive years. Also a remarkable difference in nitrogen concentration appeared between the current year needles and the one-year old ones.

b) Phosphorus

Fertilization did not affect the phosphorus concentration in the needles. The seasonal fluctuations of the phosphorus concentration were not found. The concentration order was not changed continuous through the period of the treatment.

c) Potassium

In general, the concentration of potassium in the needles was unchanged in most treatments, as was the case with phosphorus. However, the concentration of potassium in the current year needles was always higher than in the one year needles.

Nitrogen and phosphorus contents were also higher in the current year needles when compared

to the one year needles.

2) Measurement of Stand Growth by Tree Height and D.B.H. (Table 3).

In this forest the periodic thinning was not done for several years. The stand showed such a high density that the yield index (Ry value) was over 0.9 as shown in Ando's Stand Density Control Diagram⁹⁾. By comparing the fertilized and the non-fertilized plots, the four-year growth in the fertilized plot was found to be higher than the non-fertilized plot by an average of thirteen percent (6~19%) in height. The D.B.H. increased by 4~23% and the total basal area by 8~44%. Among these plots the greatest effect was shown in the plot fertilized in June: i.e. tree height by 19%, D.B.H. by 23%, total basal area by 44%.

3) Increase in Volume Growth by Fertilization

The total volume growth of each plot was calculated by the breast height factor. The breast height factor was determined by stem analysis of the trees selected from each diameter class and by the grada-

Table 4. Volume Growth in sample plots (m³/ha)

Plot	Total volume at the onset of the treatment	Total volume after four years	Total volume increase in four years	Affected volume increase after four years
Nov.	538.8	665.8	127.0	39.0
Jan.	578.0	708.0	130.0	42.0
Apr.	631.6	753.9	122.3	34.3
Apr. (two applications)	543.9	680.9	136.6	48.6
Jun.	593.1	749.1	156.0	68.0
Aug.	563.2	680.4	117.2	29.2
Control	558.3	646.3	88.0	—

Table 3. Stand Growth

Plot	Nov.	Jan.	Apr.	Apr. (two applications)	Jun.	Aug.	Control
Tree Density (tree/ha)							
At the beginning	1578	1808	1746	1632	1790	1627	1527
After four years	1578	1759	1729	1632	1767	1627	1527
Natural thinning	0	49	17	0	23	0	0
Average height (m)							
At the beginning	17.5	17.7	19.5	16.8	17.6	18.9	20.1
After four years	19.3	19.6	21.2	18.6	19.5	20.6	21.7
Growth	1.8	1.9	1.7	1.8	1.9	1.7	1.6
Ratio to control	113	119	106	113	119	106	100
Average diameter breast height (cm)							
At the beginning	20.4	19.2	20.5	20.3	19.6	19.4	20.6
After four years	23.1	22.1	23.2	23.3	22.8	22.2	23.2
Growth	2.7	2.9	2.7	3.0	3.2	2.8	2.6
Ratio to control	104	112	104	115	123	108	100
Total basal area (m ² /ha)							
At the beginning	53.91	57.24	61.79	55.81	57.38	51.76	53.25
After four years	68.58	73.46	77.00	72.49	76.97	66.42	66.83
Growth	14.67	16.22	15.21	16.68	19.59	14.66	13.58
Ratio to control	108	119	112	123	144	108	100

tion method. From Table 4, it can be seen that the greatest volume increase over the control (increment of yield) for the four-year period is 68m^3 per hectare, for the June fertilization plot. The smallest increment of 29m^3 was in the Aug. fertilization plot.

From the comparison of volume growth against the crown classes (Table 5) and from the finite difference curves (Fig. 2) obtained by stem analysis, the efficiency of fertilization is considered greater in the dominant trees than in the suppressed trees.

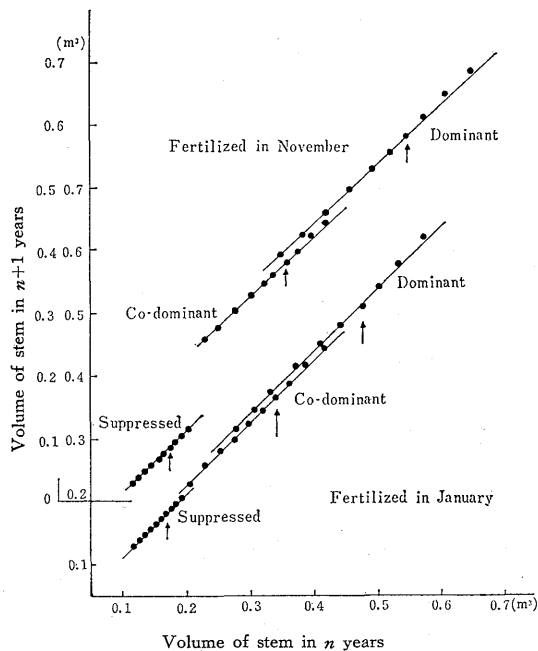


Fig. 2-1.

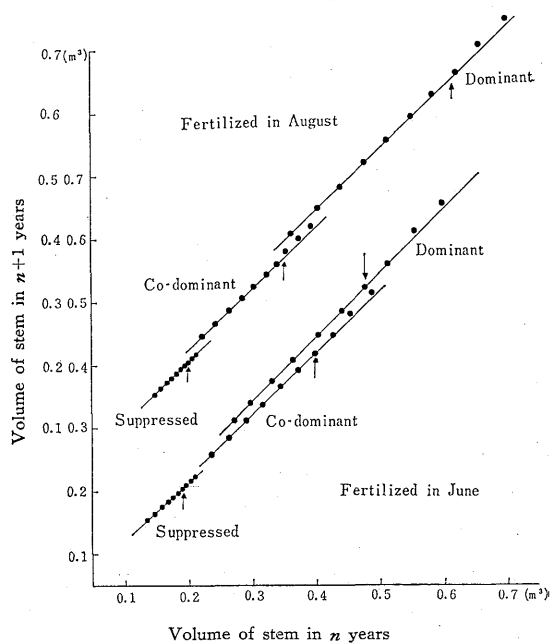


Fig. 2-3.

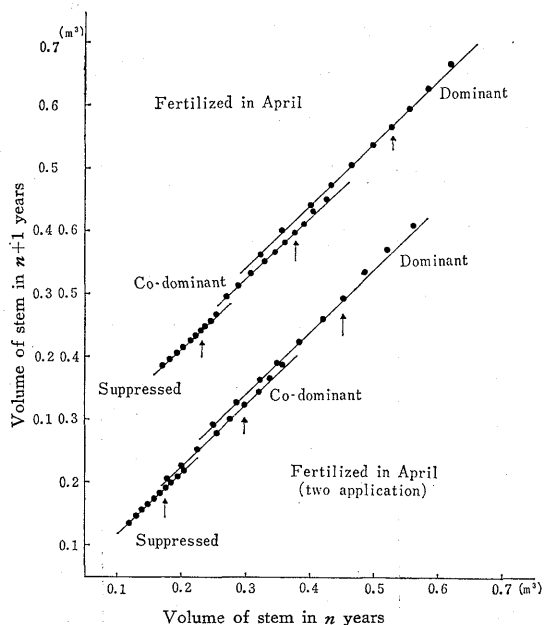


Fig. 2-2.

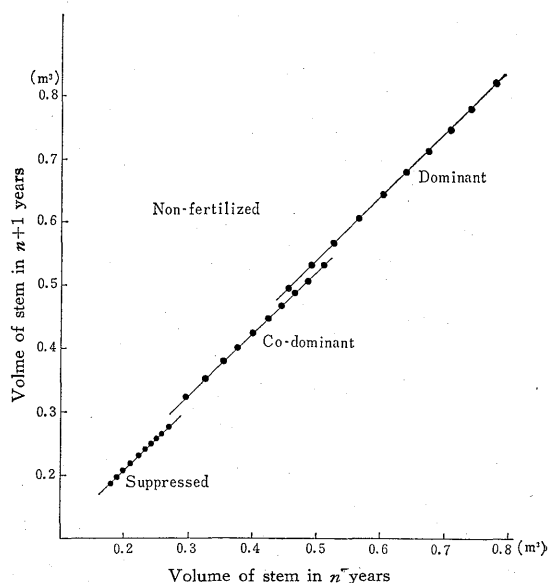


Fig. 2-4.

Fig. 2. Finite difference curves in volume of stems

↑: Time of fertilization

Table 5. Comparison of Volume Growth by Crown Classes

Treatment	Crown Class	Growth in four years before fertilization	Growth in four years after fertilization	Ratio of volume increment before and after fertilization	Ratio to control
Fertilized plot	Dominant	0.132m ³	0.141m ³	107	108
	Codominant	0.090	0.097	108	111
	Suppressed	0.035	0.034	95	102
Non-fertilized plot	Dominant	0.149	0.147	99	100
	Codominant	0.095	0.092	97	100
	Suppressed	0.042	0.039	93	100

4) Annual Difference in Volume Growth

The annual fluctuation in volume growth after fertilization was shown by the finite difference curve¹⁰⁾ of volume growth as shown in Fig. 2. The quotient of increment volume growth after fertiliza-

tion divided by the average volume growth in four years before fertilization was presented in Fig. 3. These figures show that the efficiency of fertilization appears in the second year, comes to a maximum in the third year and continues into the fourth year.

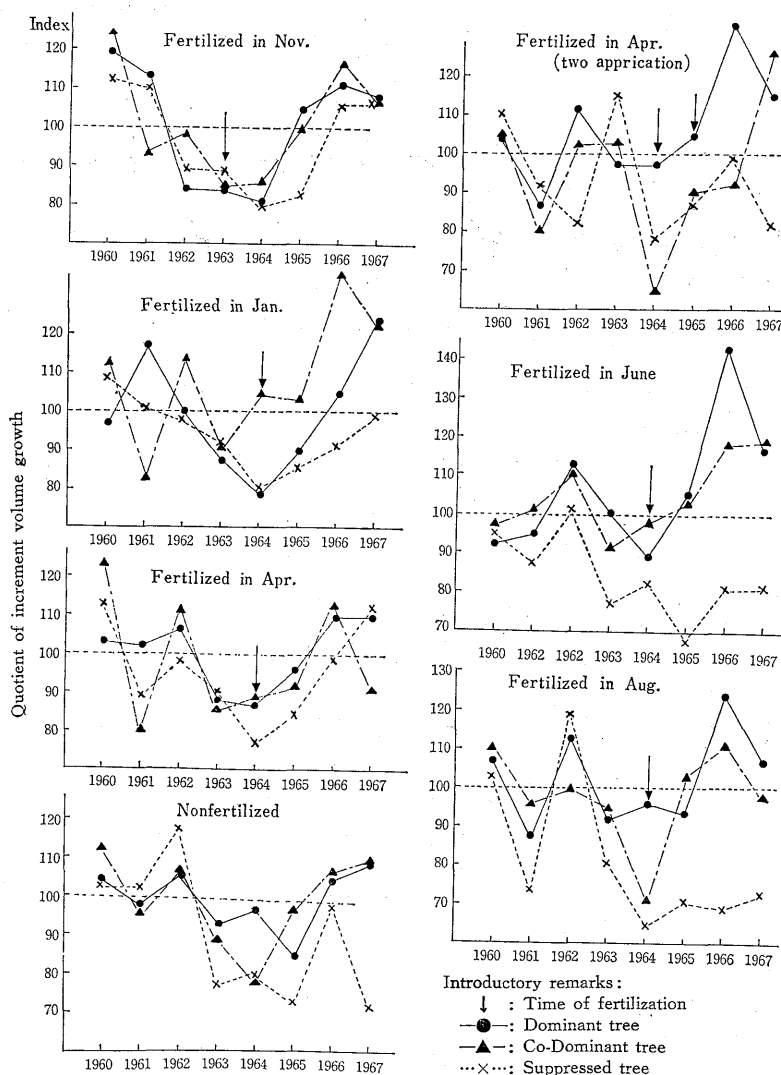


Fig. 3. Annual difference in volume growth

Notes: The quotient of increment volume growth after fertilization divided by average volume growth of four years before fertilization

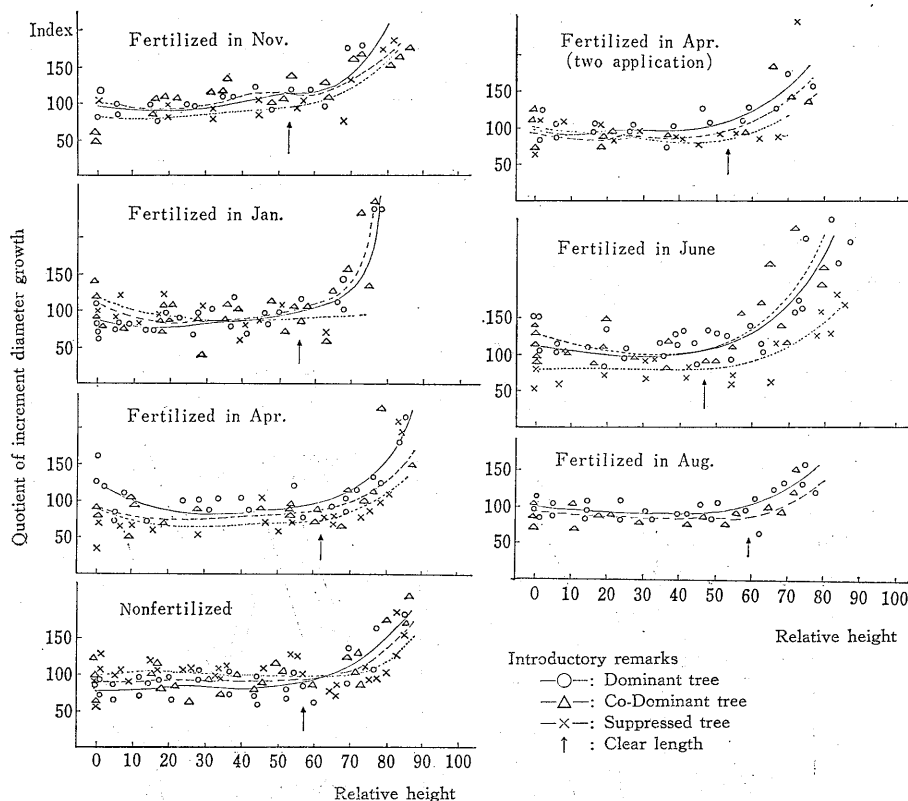


Fig. 4. The distribution of diameter growth in the trunks was surveyed according to the relative length height

Notes: The vertical distribution of the index of cross sectional growth in four years after fertilization to that of before

5) Vertical Distribution of Diameter Growth in the Stems

The vertical distribution quotient of cross sectional growth, before and after fertilization is compared to relative height in Fig. 4. It is recognized that the growth was better in the crown and butt portion of the stems, as reported before^{4,7,11~13}. The difference in growth compared with the relative height was small in the non-fertilized trees for both dominant and suppressed trees. Among the fertilized trees the greatest difference in growth occurred at the upper part of the stem. However, this was influenced by the individual clear length of trees.

5. Discussion

Nitrogen concentration of the needles increased steadily after fertilization. The increase in the nitrogen concentration of the needles after each fertilization appeared soon in the growing period and a little later in the dormant period. In spite of the difference in fertilizing periods the nitrogen concentration was approximately at the same level

in all needles taken from the six test plots. The high nitrogen concentration persisted until the next year. Judging from the fact that the nitrogen concentration of the needles in the plot fertilized consecutively in April, 1964 and April, 1965 was not different from that of the nitrogen concentration of needles in the plot fertilized only in April, 1964, the amount of nitrogen in the latter case is supposed to be sufficient for the stand. A needle nitrogen concentration of 2.5% in June and 1.8~1.9% in the dormant periods of November and January may be the standard value for the established Sugi stands in this forest. The phosphorus and potassium contents in the needles were not different after fertilization. Other examples of no increase in concentration were presented in previous reports^{12,14,15}, although the reason was not confirmed.

Generally, the efficiency of fertilizers on the established stands may be caused by the area and/or weight increase of needles and by the accelerated photosynthesis. Under the condition of the high density stands in this experimental forests, the

efficiency of fertilization was probably caused by the acceleration of photosynthesis with some increase of needles. Correlation of nitrogen concentration in the plants with photosynthesis activities¹⁶⁻¹⁹⁾ has been reported. A relationship between nitrogen fertilization and photosynthesis activities³³⁾ is also known. Other researchers suggest that the efficiency of fertilization is not shown in established forests because the increase in the amount of needles is not expected²⁰⁾. On the other hand the weight of needles increased on fertile sites²⁴⁾.

Data from our studies^{7,11,12,26)} reveal significant efficiency. Although no difference was noted among the respective needle concentration of nitrogen, phosphorus and potassium during different fertilization periods, a high efficiency in the June fertilization plot was observed. The June fertilization was timed to coincide with the end of the elongation of the spring buds. ISHIZUKA¹⁷⁾ and MURAYAMA²²⁾ studied the age of leaves and the movement of nitrogen in the rice plant. They reported that the requirement of nitrogen is the highest in the growing phase in June and July. SHIBAMOTO²³⁾, KAWANA²⁴⁾, and TANGE²⁵⁾ also reported that the absorption of nitrogen and fertilization with nitrogen in the seedlings of Sugi was best in June and July. Thus it can be said that the requirements for nitrogen were high, and the quantity of dry matter production increased rapidly in this growing phase.

In connection with the above-described facts, further examination of established Sugi stands are indicated.

Review of the foreign literature by KAWANA²⁷⁾, SHIBAMOTO²⁸⁾, and TSUTSUMI²⁹⁾ introduced to the Japanese foresters the value of fertilizer. Research in our country by KAWANA et al^{7,11,12,26)}, WATANABE¹³⁾, TAKESHITA et al³⁰⁾, IWATA et al³¹⁾ established the importance of fertilizer efficiency. However, the literature has no evidence for fertilizer response in closed stands^{13,20,32)}. Consequently many experiments on the relation of fertilization and density in established stands are in progress. In this experiment it is noticeable that the increased volume growth of 68m³/ha was shown in the fertilized plot compared with the control plot, which occurred under the unfavorable condition of high density competition under natural thinning. The combination of artificial thinning with the increased growth rate after fertilization is expected to yield a total volume in excess of the 117~156m³/ha value shown in this four years' experiment. When choosing the best period for fertilization of the established forest, the forest age and the season must be considered. To solve this problem, studies of the continuation of fertilizer efficiency must be encouraged. In this study,

the effect appeared in the next year after fertilization, reached the maximum in the third year and continued into the fourth year. Therefore, the last fertilization must be performed more than four years before the final cutting. We must repeat many experiments to determine the best season for fertilization of the established forests.

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抄 録

○菌類覚え書・その2 (Deuxième bloc-notes mycologique) MORELET, M.: Bull. Soc. Sci. Nat. et Archéol. Toulon et Var 180: 3~4, 1969

1. 1968年8月フランス Côte-d'Or の Dijon と Meurthe-et-Moselle の Cercueil でイタリア改良系ポプラ上にマルゾニナ落葉病の発生を認めた。病原菌はオランダの GREMMEN 博士からの標本と比較対照の結果 *Marssonina brunnea* (EU. et EV.) MAGN. と同定された。これが本病菌のフランスにおける最初の記録である。

2. Var 県の Saint-Raphaël の海岸石礫地に生育する *Pinus halepensis* に 1964 年以来 *Sirococcus strobilis* (DESM.) PETR. (= *Ascochyta piniperda*) の発生を認めている。本菌は毎年5月頃枝曲りをおこし、ついで若枝

の枯損をひきおこす。同じ地域の *Pinus pinaster* には本病の被害を認めない。

3. 日本で T. KOBAYASHI が林試研報に報告した3種の *Rhizosphaera* 属菌のうち、種名未決定の *Rhizosphaera* sp. は明らかに *Rhizosphaera pini* (CDA.) MAUBL. より胞子が大きいの。したがってこれを *Rhizosphaera pini* の変種と認めてもさしつかえないと考えたので、次の名を与えて正式に新変種として登録した。*Rhizosphaera pini* (CDA.) MAUBL. var. *kobayashii* MORELET, var. nov.

(抄者注: 抄者がすす葉枯病菌の所属について林試研報に発表したとき、第3番目の種をあえて未決定のまま *Rhizosphaera* sp. としたのはそれ相当の理由があることをのべておいたのであるが、ここに紹介したように正式に手続きをとられた以上、ハイマツやオオシラビソのすす葉枯病菌の学名は以後 *R. pini* var. *kobayashii* MORELET を使用することになる) (小林 享夫)