PROBLEMS RELATING TO THE RESEARCH ON FOREST FERTILIZATION IN THE TROPICAL RAIN FOREST OF BALIKPAPAN, KALIMANTAN TIMOR, INDONESIA

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Japan's wood consumption amounts to about 1 m^3 per capita as against 0.6 m^3 that in the world. The supply of wood is hardly keeping the balance with the production from tropical rain forests and the preservation of the wood from tropical rain forest resources is problematical for the future generations.

As the world population which presently totals 4 billion people is expected to double in the next century, agricultural activities will expand, and large areas covered with forests will have to be cleared.

The consumption of wood will decrease below twice the present level as it will be difficult to secure the actual world level of 0.6 m^3 per capita. Unlike cultivated soil, forest soil may undergo degradation as a result of clearance for the creation of fields needed to grow crops.

For example the land of the Mayas and of the Aztecs in Central America or that of the Khmers in Indochina, deteriorated into jungles as compared with the soil of Borobudur near Jogjakarta. The former areas could not produce food for long years to maintain large populations, because of the rapid degradation of soils while the latter was able to produce food for many years owing to the presence of rich new volcanic soil whose fertility was enhanced under tropical conditions, including anaerobic condition of paddy fields.

Thirty percent of the land of the globe is covered with forests and in many cases people cannot live in these areas. This applies to the forests in Japan which are located on steep slopes, to the swampy areas of Finland, to the cold zones of Siberia, or to poor soils in some of the tropical rain forests. There are 200-300 ton/ha of organic matter in the forests, of which more than half is being stored in the soil of the temperate forests while less than twenty percent remains in the soil of tropical rain forests.

If harvesting or shifting cultivation encroaches upon the tropical rain forests, soil degradation takes place at once, and these will change to grasslands. For example it is said that one fourth of the forest land in the Philippines or half of it in Sumatra is occupied by grassland. The report entitled "Research on forest fertilization in Balikpapan, Kalimantan Timor, Indonesia" is presented here.

The Sotek area, (0°—1° south, 117° east) in Kalimantan Timor, Indonesia belongs to the tropical rain forest zone. The average annual precipitation between the years 1899-1941 was approximately 2,200 mm. There is plenty of rain from October through March, but the precipitation is low from April through September. It is however, difficult to draw a clear line between a dry and a wet season. The average daytime temperature is 30.2° and the temperature during the night is 24.4°C. The maximum temperature recorded so far is 32.2° and similarly, the minimum 23.0°C. The humidity is 99% at the highest and 35% at the lowest. Its average is around 85%. The direction of the constant wind is south during the dry season and north during the wet season. The wind velocity reaches around 10m/sec, but there is no fear of typhoon.

Geologically, the area is made up of Tertiary sand rock, and the soil is primarily composed of volcanic ash ranging from Miocene series to Pliocene series in the Tertiary. The soil is undergoing podzolization. The research area is 40—50 m above sea level, and the slopes have 10—30° inclination.

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Balikpapan Forest Industry (BFI) and International Timber Corportion of Indonesia (ITCI) are developing the forests in this area for the purpose of harvesting timber and regenerating forests. They are also making artificial plantations over a considerably large area, in accordance with the agreement made with the Government of Indonesia.

The soil in this area shows signs of laterization in some parts, but most of the surveyed area is undergoing podzolization. (Fig. 1) A close examination into the soil profile shows that there are different series of colors in the profile of the soil which was turned over from different sites. The sites are namely, virgin forest, second growth forest, shifting cultivation field and grassland. The grassland soil shows a 10Y-R series of color (Table 1). The other sites show 7.5Y-R series. Further experiments need to be done in order to classify the results analytically.

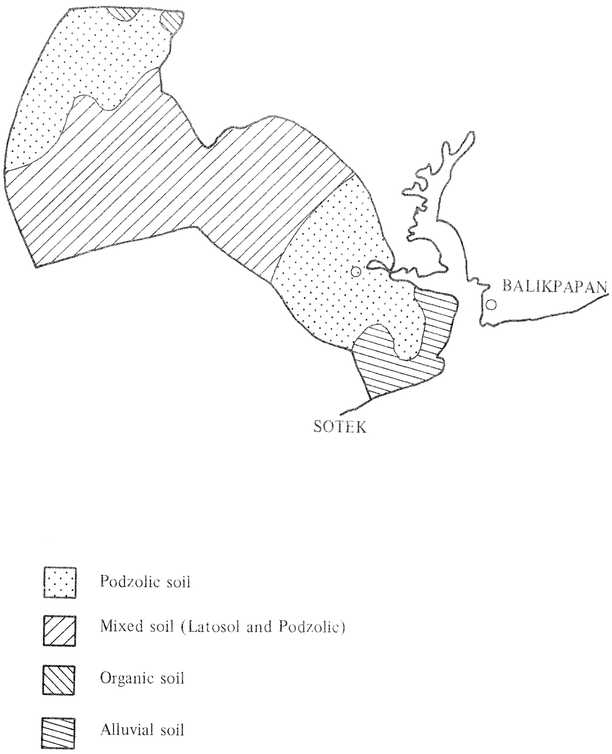

Fig. 1 Soil Map of B.F.I's Concession

Table 1 Colour of the Sotek soil

Soil Layer		Virgin Forest			Second Growth Forest			Shifting Cultivation Field			Grassland		
	7.5												
A		5/3	4/3	5/3	4/3	4/3	4/3	5/1	4/3	1.7/1	$2/2^{10}$	2/3	4/4
B_1		5/6	5/6	6/6	6/6	5/6	4/6	5/6	5/6	5/6	5/4	5/6	5/6
B_2		6/6	5/8	5/6	8/6	6/6	5/6	5/6		8/6	6/6	8/6	5/6
B_3–C					6/4	5/8	5/8	$5/8^{5}$	5/6	$5/8^{5}$	6/8	6/8	5/8

X-ray identification of clay and minerals in the soil was also performed, but there was no notable difference between the sites. Similar parent materials which are fairly old, were also found. The three types of diffraction curves obtained by X-ray are shown in Figure 2. A difference in the curves was noted between a clear Montmorillonite and a non-clear Montmorillonite, and a clear Chlorite.

There was also no marked difference in pH, y_1, concentration of nitrogen and phosphorus, and in C/N ration, in these plantations (Table 2). There was a difference however, in the concentrations of nitrogen, phosphorus, carbon and other elements when the soil samples were taken from representative types of a virgin forest, second growth forest and shifting cultivation field. (Figures 3 to 8). The profile of the podzolic soil is, in most parts, massive. On the upper horizon, it is very thin. Topography of the previous land condition may have an influence on the thickness of the soil layer, especially that of the upper horizon. For instance, the soil layer found in the grassland was thicker and heavier than in the other sites, and it contained carbonized organic matter and resin blocks. The grassland also lacked in basic volcanic grass and had a higher fixation value of phosphorus than the other sites. Nitrogen and carbon were found in lower percentage. The C/N ratio was also somewhat low.

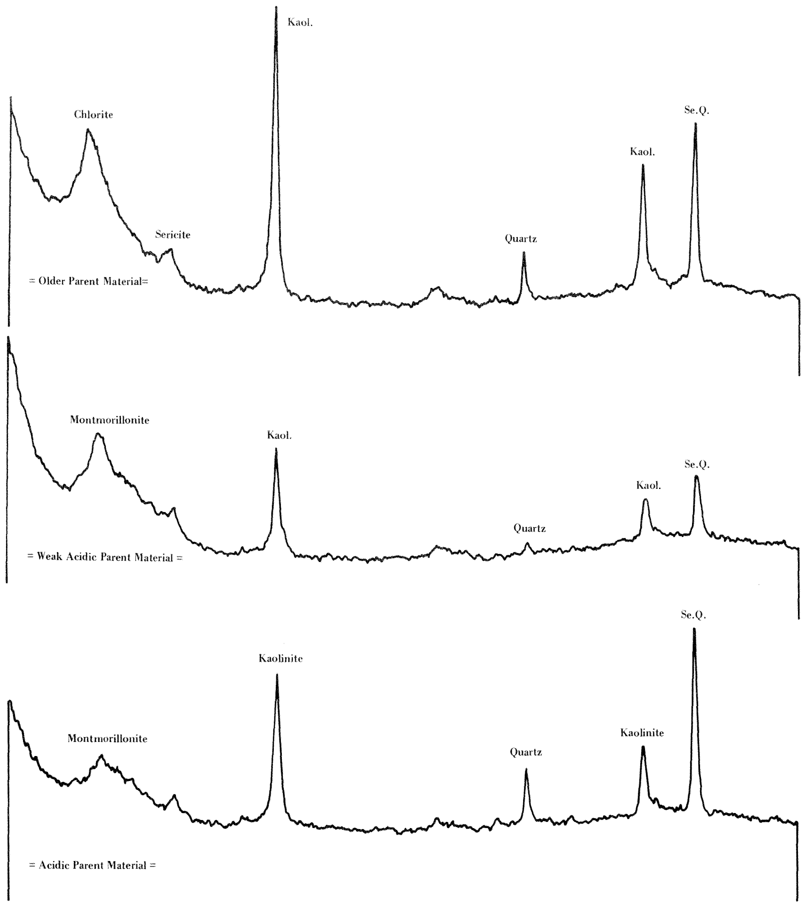

Fig 2 X-Ray identification of the soil

Table 2 Chemical properties of the soil in the plantations

Soil	Plot	Horizon	Thickness	pH(H_2O)	pH(KCl)	y_1	C (%)	Total N (%)	C/N	Total P (%)	Total K (%)
Plantation after Virgin Forest	1	A	4	5.1	4.5	3.0	2.66	0.18	14.8	0.020	0.47
		B_1	16	4.8	4.0	23.1	0.87	0.10	8.8	0.018	0.81
		B_2	30	5.0	4.0	40.6	0.50	0.08	7.0	0.025	0.90
	2	A	3	5.6	4.6	3.4	3.48	0.21	16.6	0.012	0.54
		B_1	13	4.6	4.0	30.4	0.85	0.06	14.2	0.012	0.51
		B_2	25	4.7	3.9	37.4	0.33	0.03	11.0	0.010	0.59
	3	AB	3	4.4	3.8	27.2	2.13	0.15	14.2	0.015	0.57
		B_1	14	4.5	3.8	40.4	1.16	0.08	14.5	0.011	0.59
		B_2	26	5.0	3.9	44.3	0.66	0.05	13.2	0.009	0.56
		C_1	10+	5.3	3.9	48.3	0.27	0.03	9.0	0.011	0.98
Plantation after Second Growth Forest	1	A_2	6	6.2	5.8	1.2	3.66	0.25	14.6	0.019	0.62
		B_1	30	5.7	4.2	22.5	0.82	0.08	10.0	0.011	0.71
		B_2	25	5.6	4.1	43.2	0.62	0.06	10.3	0.013	0.96
		C	10+	5.7	4.1	52.9	0.35	0.06	5.8	0.014	0.54
	2	A_2	4	5.4	4.3	12.0	2.37	0.23	10.3	0.010	0.26
		B_1	8	5.5	4.3	21.4	0.81	0.12	6.8	0.007	0.27
		B_2	10	5.3	4.3	24.7	0.64	0.10	6.4	0.005	0.27
		B_3	33	5.3	4.2	29.2	0.47	0.06	7.8	0.004	0.25
		C_1	25	5.3	4.1		0.34	0.07	4.8	0.001	0.43
	3	A	7	5.3	4.2	22.9	2.65	0.22	12.0	0.012	0.32
		B_1	35	4.8	3.8	32.3	0.76	0.09	8.4	0.006	0.34
		B_2	32	5.0	3.9	38.8	0.34	0.05	6.8	0.008	0.38
		C_1	20+	5.1	4.1	47.6	0.27	0.05	5.4	0.006	0.35
Plantation after Shifting Cultivation	1	A	3	6.1	4.5	2.3	3.21	0.27	11.9	0.019	0.50
		B_1	11	5.5	4.0	27.4	1.17	0.15	7.8	0.013	0.51
		B_2	30	5.2	4.0	44.3	0.45	0.10	4.5	0.010	0.56
		C_1	10+	5.2	3.9	51.7	0.34	0.06	5.7		
	2	A_2	3	6.3	5.8	0.9	3.34	0.24	14.3	0.019	0.60
		B	43	6.3	3.9	28.4	0.62	0.04	15.5	0.002	0.09
		C	20	5.4	4.1	52.6	0.44	0.04	11.0	0.009	0.76
	3	A	6	5.5	4.3	15.4	4.58	0.35	13.1	0.014	0.41
		B_1	30	5.1	4.0	38.9	0.86	0.13	6.6	0.008	0.45
		B_2	20	5.4	4.1	45.7	0.47	0.08	5.9	0.007	0.51
		C_1	10+	5.5	4.1	54.0	0.42	0.09	4.7	0.008	0.60
Plantation after Grassland	1	A	4	5.7	3.9	10.2	2.53	0.19	13.3	0.012	0.37
		B_1	32	5.3	4.0	29.8	1.05	0.11	9.5	0.008	0.43
		B_2	15	5.2	4.0	36.5	0.48	0.07	6.9	0.006	0.39
		C	15+	5.3	4.0	40.6	0.36	0.06	6.0	0.006	0.37
	2	A	2	5.8	4.2	4.6	3.11	0.26	12.0	0.013	0.45
		B_1	18	5.1	3.9	34.3	0.89	0.11	8.1	0.008	0.31
		B_2	20	5.2	3.9	42.2	0.45	0.07	6.4	0.007	0.34
		C	50+	5.3	3.9		0.33	0.07	4.7	0.007	0.50
	3	A	8	5.4	3.9	19.4	2.23	0.18	12.4	0.012	0.47
		B_1	20	5.4	3.9	31.2	0.73	0.10	7.3	0.011	0.58
		B_2	25	5.5	4.0	38.1	0.45	0.08	5.6	0.012	0.48
		B_3	13+	5.7	4.0	50.6	0.39	0.08	4.9	0.013	0.52

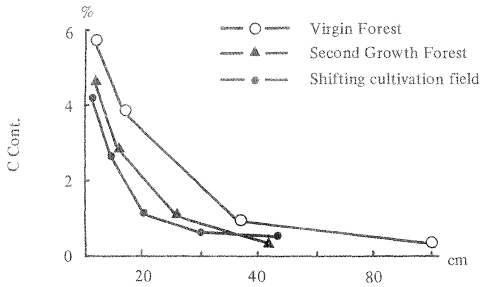

Fig. 3. Vertical Distribution of C

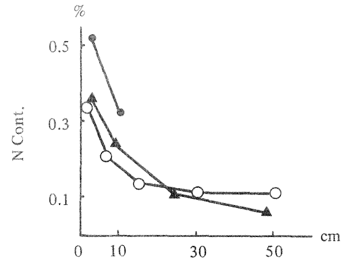

Fig. 4. Vertical Distribution of N

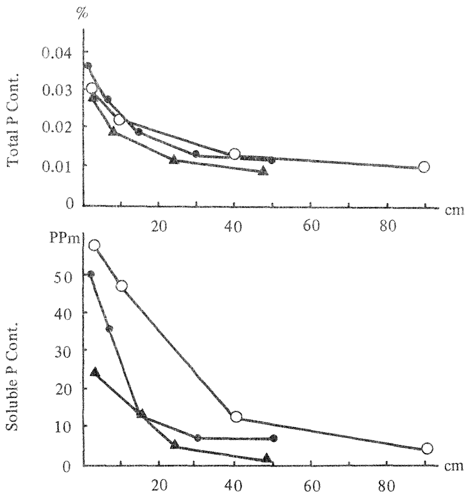

Fig. 5. Vertical Distribution of P

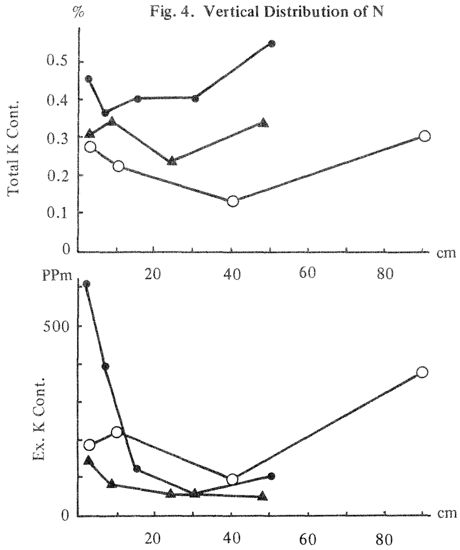

Fig. 6. Vertical Distribution of K

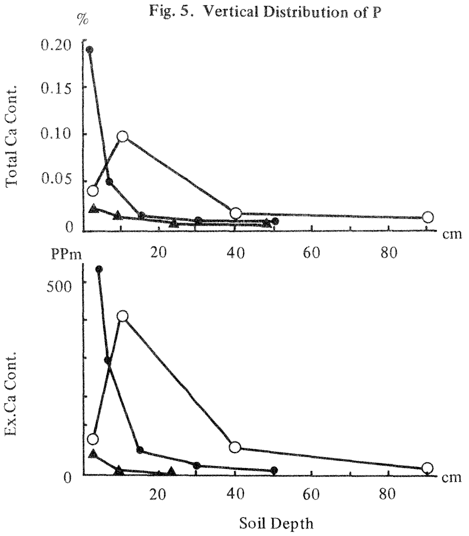

Fig. 7. Vertical Distribution of Ca

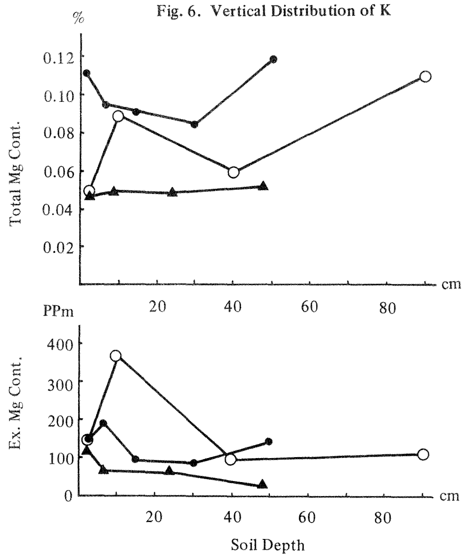

Fig. 8. Vertical Distribution of Mg

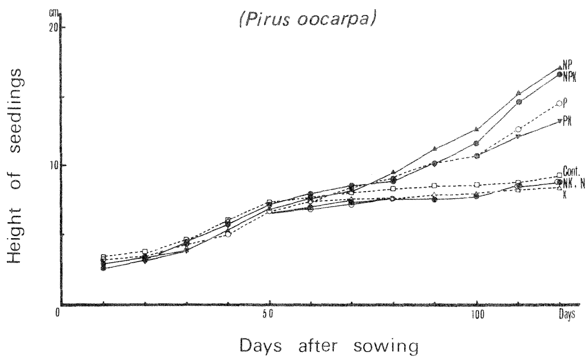

Fig. 9 Fertilization Research in the Nursery

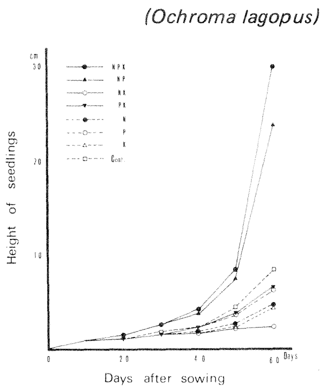

Fig. 10 Fertilization Research in the Nursery

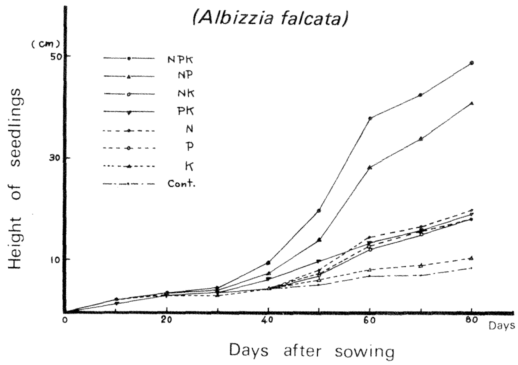

Fig. 11 Fertilization Research in the Nursery

Further fertilization experiments were carried out in the nursery of BFI. In these experiments, three sample species *Pinus oocarpa, Albizzia falcata* and *Ochroma lagopus* were selected (Table 3). The outline of the experiment is shown in Table 3. The purpose was to demonstrate the importance of the presence of nitrogen, phosphorus and potassium in the soil. The results for *Pinus oocarpa* are shown in Figure 9. They indicate that NP, NPK, P or PK, promotes growth of seedlings. An experiment with *Ochroma* tree (Figure 10) shows that NPK and NP are excellent growth promoters but the application of P, PK, N, or NK results in less growth than in the control. The *Albizzia* trees gave good growth response to NPK and NP applications, but the effects of NK, P, and PK were only slight (Figure 11). These results imply that phosphorus is very effective for pine trees, whereas nitrogen has little effect. In a letter of Dr. Dykstra, who had carried out the same type of experiment at ITCI nursery, it was pointed out that nitrogen might even exert a reverse effect on the growth of the pines.

Another BFI experiment, in which the mycorrhiza injection test was carried out on the pine seedlings bed, gave the following results (Table 4).

Table 3 Treatment and amounts fertilizer applied in the research nursery

Fertilizer / Species	Amount of Element g/m^2	Amount of Fertilizer g/m^2			
	N : P : K	Urea	Bound Phosphate	Super Phosphate	Potassium Chloride
Albizzia falcata	20 : 20 : 20	48	71	54	40
Pinus oocarpa	40 : 20 : 20	96	71	51	40
Ochroma lagopus	40 : 20 : 20	96	71	51	40

Treatment: NPK, NP, NK, PK, N, P, K, Control

Element content (%): Urea (43–0–0)
Bound phosphate (0–17–0)
Super phosphate (0–15–0)
Potassium chloride (0–0–50)

Table 4 Height measured 3 months after treatment

Plots	Average Height
NPK	20.5cm (15.0cm – 31.1cm)
Mycorrhiza injection in unfertilized plot	19.6cm (13.8cm – 27.7cm)
Unfertilized plot	10.3cm (8.4cm – 15.0cm)

The above results seem to suggest that mycorrhiza may stimulate nitrogen uptake and/or promote growth. The difference in the growth response of the three species is outlined below. Nitrogen and phosphorus are found to be effective for the pine trees. In fact, phosphorus seems to exert a considerable effect by itself. *Albizzia* trees respond well to nitrogen and phosphorus, but the application of one agent without the other only affects growth to a lesser extent. The growth of balsa tree is also promoted by nitrogen and phosphorus application, but a lack of either of them reduces growth to less than that of the control. A lack of growth indicates a deficiency in either one or the other.

The tropical podzolic soils are very poor due to the development process which reduces the amount of organic matter, nitrogen and other nutrients. Nitrogen and phosphorus in the soil are found only in very small amounts, under natural conditions. Thus, if one wants to reproduce forest resources, it will be difficult to do so by natural means, such as selection cutting. Sometimes, the line planting system, enrichment planting or the clearcutting system including bed grass system and tumpangsari are being carried out, instead of the selection cutting. It is preferable to plant fast growing species such as balsa, gmerina, eucalyptus and pine. Because of poor soil, useless tree species, bushes, vines and various damages, it is difficult to establish a good plantation by either selection or line planting system. Normally, the first growth of the fast growing species is adequate in the younger stages, but there may be a retardation of growth in the later stages, or in the second growth. Not only fast growing species, but various tree species may also be planted as undergrowth.

In many places, tropical virgin forests are found intact due to lower production. Even if they were used to make an agricultural field, the farmers could only use the field for shifting agriculture, without any special treatment.

In the plantations, the fertility of the soil must be maintained. The content of nitrogen, carbon and other organic matter should always be at a high level, and if the nutrients are insufficient, they should be supplemented by nitrogen and phosphorus fertilizers. The forest fertilization is a good solution to the problem. Fertilization was undertaken in the plantations as a part of the experiment, and the project is shown in Table 5.

Table 5 Treatment and amounts of fertilizer in the research forest

Treatment	Fertilizer	Amount of Fert. (kg/tree) IB Compound	Urea
Fertilization (Twice a year)	Cultivation	1.02	0.20
	Absence of cultivation	1.02	0.20
Absence of fertilization	Cultivation	0	0
	Absence of cultivation (Control)	0	0

Element Content (%): IB (10–10–10)
Urea (43–0–0)

Amount of Element (g): N 190 g/Tree
P 102 g/Tree
K 102 g/Tree

Isobutyridene diurea fertilizer is used in abundance. It is one of the slow releasing fertilizers, which was developed by a Japanese chemical company. Formerly, it was thought that in a tropical humid region, an adequate supply of fertilizers had to be kept constantly in the soil throughout the year.

The experiment is still under way, but the author is convinced that fertilization, and not cultivation, is suitable for the tree growth. It is hoped that the efficiency of IB fertilizer will be demonstrated in the near future (Figure 12). An experiment with balsa tree has resulted in an average tree height increment of 7 m for the fertilized trees as compared to 5.7 m in the control, within a year. With oocarpa pine, the effects are not as clearly demonstrated due to the short duration of the experiment and to the difficulty in weeding.

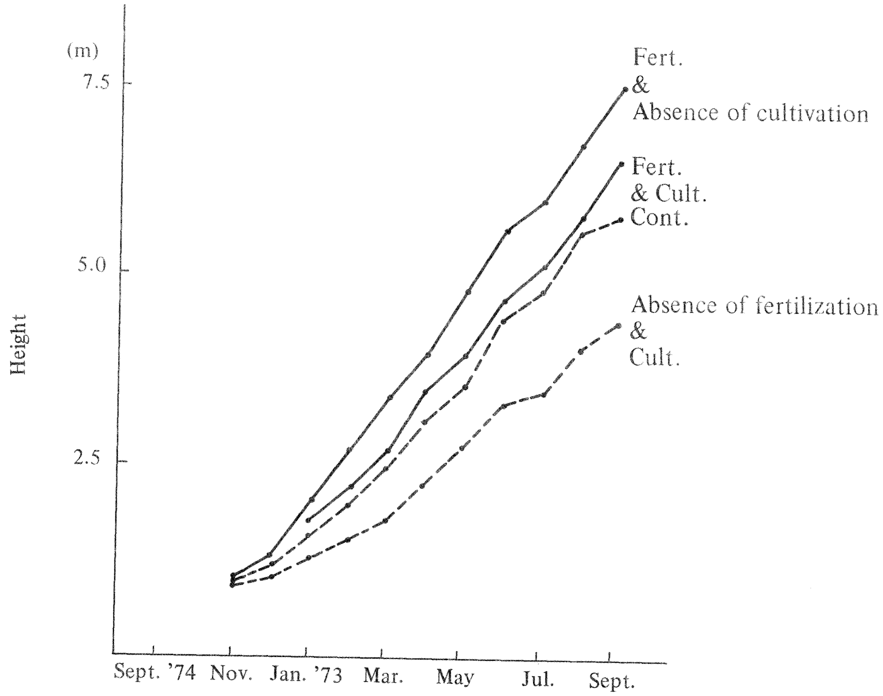

Fig. 12 Forest fertilization (Balsa)

Data and information on isobutyrydene diurea are presented by Dr. Hamamoto of the research department of Mitsubishi chemical company.

The experiments seem to strongly suggest that forest fertilization is an effective method of promoting growth of trees in the tropical forest plantations. Various methods of soil survey and the means of detecting the deficiency in certain elements in the soil are presented in the report. The experiment using the nursery stock was fruitful in outlining these deficiencies.

In any case, the land of tropical rain forests is poor, and fertilization may be effectively put to use as a way of increasing organic matter in the soil and of promoting tree growth.

The results strongly support the view that forest fertilization is effective in some areas of tropical rain forests.

We have to consider that the policy of selective cutting, as far as harvesting is concerned, is helpful for conserving the forest environment and also for ensuring continuous production of wood. But, as the technique originated in the northern European forests, it cannot be applied to the tropical zone.

The conifer forests have only a few tree species and the vegetation on the ground is not tall. Sometimes there is active growth under the canopy. But, the tropical rain forests, abound in tree species although only a few are useful economically. The forests harbour vines, weeds and shrubs making afforestation difficult to carry out. These differences clearly depict variations in regeneration between forests. Moreover, as selective cutting along with the development of shifting cultivation or fires deplete forest resources, the soil fertility sometimes deteriorates or the forests are replaced by grasslands.

We have to develop techniques for wood harvesting which would enable to preserve the soil conditions. Sometimes selective cutting should not be performed and it is preferable to proceed to forest fertilization in the artificial forests.

Discussion

Liew, T.C. (Malaysia): Why do you recommend fertilizer application to *Albizzia falcata*? This species which is widely planted in Sabah does not show any evidence of nutrient deficiency and a height growth of 35 feet in 10 months has even been documented in Sabah in 1975. Moreover, this species can withstand a large range of soil conditions and weeding can be kept minimal.

Answer: Although fertilizer application is not essential, it is preferable to supply phosphorus, in particular. One should take into account the soil conditions and the area.

Glori, A. (The Philippines): Why not carry out loosening or cultivation of soil so as to promote aeration instead of applying fertilizers?

Answer: Such practice may be favourable in sandy soils but in poor soils organic matter tends to leach out. It is then preferable to apply nitrogen fertilizers or organic matter which will enable cultivation in loosened soil.

Glori, A. (The Philippines): What are the soil nutrients which are most needed and often found deficient?

Answer: The main nutrient which is often deficient is phosphorus followed by nitrogen and boron.

Sasaki, S and Osumi, Y. (Japan): The soil nutrient conditions appear to differ depending on the nature of the soil parent rock material. For example, requirements are less in the case of areas on basic volcanic rock (basalt), metamorphic rock (serpentine) than in those on granite soils. Also, in the nursery, nutrient requirements are less in the case of seedlings growing in the shade than for those in the open. Moreover, nutrient requirements vary depending on the nature of the species. For example in the nursery, *Shorea talura* requires 120 mg N and 50 mg P/seedling while *Shorea ovalis* needs 450 mg N/seedling and traces of phosphorus.

Answer: I have mentioned that fertilizer requirements vary depending on the nature of the soil. Also nutrient requirements depend on a series of conditions such as nature of the soil, amount of light and moisture, tree species and age.

Glori, A. (The Philippines): Why is it necessary to apply nitrogen fertilizer to *Albizzia falcata* which, as a legume, is able to fix nitrogen from the soil?

Answer: Although such application is not essential it is usually followed by improved tree growth.