NUTRITIONAL STUDIES ON THE SEEDLING OF *ABIES SACHALINENSIS* MAST. WITH LAMMAS SHOOTS.

By

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トドマツ二次生長苗の栄養的研究

玉利長三郎

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Introduction

It has been observed that the *Abies sachalinensis* MAST. (Todomatsu) seedling in the nursery, generally, has the most rapid growth of stem during the period from mid-May to mid-June and begins to form its current-year buds in early July

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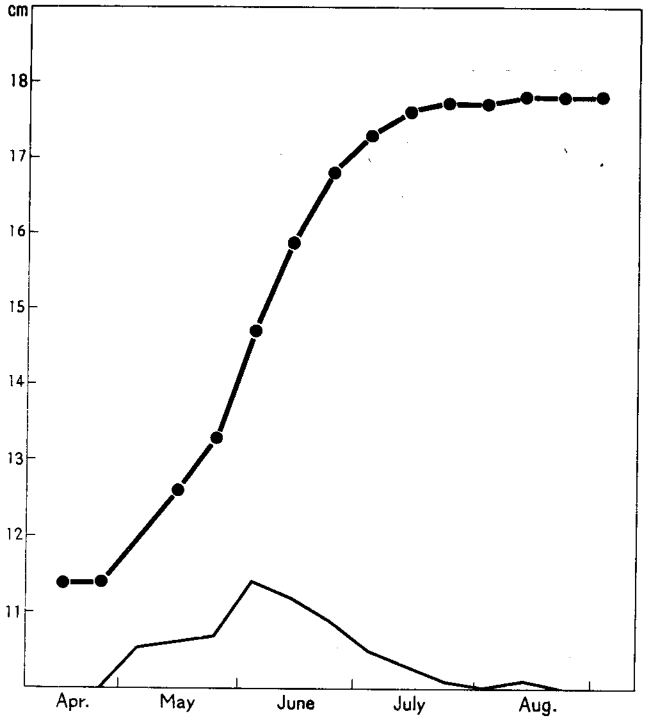

Figure 0-1. Height growth of *Abies sachalinensis* MAST. (Todomatsu) 3-year-old seedlings in Sapporo plotted as cumulative growth over a period of time (above), and as actual growth during the same period of the growing season. (1957)

(Figure 0–1), but thereafter, some seedlings show the secondary growth of stem immediately after bursting their current-year buds[5,19,42,46,50,63,70,155,158]. ASAHI et al.[5] reported that one-year seedlings of Todomatsu in Yamabe began to burst their buds in mid-May, formed the terminal buds in the period before and after June 30th, then burst again, and began to form the second terminal buds finally in late August having the complete buds about September 11th. Furthermore, IWAMOTO and SHIBATA[42] obtained the same pattern on 5-year-old seedlings also in Yamabe. This shows that such late growth, that is to say, lammas shoot growth in Todomatsu occurs commonly in some nurseries in Hokkaido. Lammas shoots are formed not only by Todomatsu but also by other evergreen species[30,70,149]: *Picea jezoensis* CARR. (Jezomatsu), *P. Glehnii* MAST. (Akajezomatsu), *Cryptomeria japonica* D. DON (Sugi) and by the deciduous species[70,95]: *Quercus serrata* THUNB. (Konara), *Q. crispula* BLUME. (Mizunara), *Zelkova serrata* MAKINO (Keyaki) and also, in America[13,18,22,38,48,53,54,58,66,171,172], commonly, by oaks, hickories, alders, elders, and elms. Furthermore, it was reported that with lemons, oranges, cacao, tea, etc. the recurrent flushes[9,10,58,165] of shoot growth occur during this vegetative season. KRAMER recognized the recurrent flushes for 2-year-old loblolly pine seedlings in the open[56], and also under a constant environment in the EARHART Laboratory[57], and then he and KOZLOWSKI[58] pointed out that the lammas shoot is really an example of this type of growth.

In Todomatsu, lammas shoot growth produces an abnormally formed seedling[46,136,1[illegible]5], for example, the dichotomous seedling, the forked stem seedling, and the seedling which, because of the new main stem was produced by one of the lateral shoots, has disarranged branches. The dormancy of lateral buds usually is broken more easily than the dormancy of terminal buds, and accordingly, its lateral buds open, while its terminal bud remains closed in the budding stage. What is worse, the length of the growing season, which the seedling with lammas shoots has, is longer than that which the normal one has. Hence, the period of preparation for (winter) dormancy after the cessation of growth; i.e. hardening period of the former is shorter than that of the latter. Especially, the hardening period of the lammas shoot is very short. Then, they often suffer from abnormal weather, insects, epidemic bacilli, and other things[44,103,113,115]. In the writer's preceding observations[50,51,137] and that of other on the so-called "cold-damage" to Todomatsu, such seedlings suffered worse damage than the normal seedlings.

Although there is the particular case in which lammas shoot growth is accelerated for the production of the big seedlings as a means to keep out the frost-damage or to shorten the nursery stage, there is essentially no difference in the shortening of the hardening period. Setting apart the nursery stage, trees in the forest land suffer more from extensive management than the cultivated plants in agriculture. Consequently, it need scarcely be said, such seedlings with lammas shoots are poor nursery stock for shipping purposes.

Lammas shoots are often observed in a fixed and densely planted bed and scarcely ever in a transplanted bed[70]. Also, they are produced as a result of an abundance of available water in a year when it is warm and rains much, particularly, in early autumn[171]. However, the environmental factor cannot explain satisfactorily how the lammas shoot growth occurs or does not occur, and why it differs among different seedlings. Besides such conditions of environment, the luxual absorption of nitrogen nutrition is favorable to the production of lammas shoots[18,30,32,70], and it is reported that lammas shoot growth is accelerated by the use of nitrogen rich compounds[19,30,129]. Whether lammas shoot growth occurs or not differs among different tree species and different strains in a species. However the cause of lammas shoot growth is not yet clearly explained in spite of he presence of some evidence suggesting that accumulation of inhibitors is a factor in the development of dormancy[33,34]. The clarification of this problem may be important for the study of the nutritional reality of the seedling; that is, for the appreciation of the nutritional metabolism of the seedling. And then the bursting from the buds in lammas after the perfection of the current-year buds may be interesting in consideration of the dormancy[162]. And the temporary summer dormancy in lammas seedling lasted from a few days to a few weeks, while the winter dormancy has the long winter season of low temperature.

Already KLEBS[49], WAREING[161], and KRAMER[56,57] studied this temporary summer dormancy, but they did not form any definite conclusion.

From such a view point, the writer wished to examine physiologically lammas shoot growth, and to investigate its quality due to the seasonal variation of the nutrients in the seedling.

The study of the mineral nutrition of tree species in Japan was begun by TSUDA in 1909[154], and, in recent years, there are number of reports[2,3,4,23,25,28,29,52,65,69,71,72,73,74,89,90,91,116,118,122,123,156] on studies of the relation of absorption of each nutrient element by different species at different rates at different times. Particularly, there are ISHIHARA et al.'s report[33], UCHIDA et al.'s[158], MIZUTA's[63], ASAHI's[5,6], and TSUDA's[150~153] for such studies of Todomatsu seedlings. Those investigations have been carried out concerning the fertilization with mineral nutrients, mainly, nitrogen, phosphorous, potassium, calcium, magnesium, and other micro-nutrients in the water or soil cultures, and concerning the seasonal variation of these nutrient contents in trees. But, in consideration of the balance in the nutrient metabolism, we can not pass by carbohydrates which are the main reserve food and the first products by photosynthesis besides the preceding elements[96,97,128,130]. This is well known from KLEBS' theory of carbohydrates to nitrogen ratio in the flowering, namely, the environmental condition favorable for flowering (reproductive growth) accelerates simultaneously with the photosynthesis and, accordingly, with the assimilative products — reserve carbohydrates. On the other hand, mineral nutrient, especially, nitrogen accelerates vegetative growth, while, at the same time, tends to control the flowering. Therefore, the flowering occurs at the time when the reserve carbohydrates predominate over nitrogen compounds in the plant tissues. This theory was negated thereafter, but such consideration of the relation among the mineral nutrients and carbohydrates may be essential for the knowledge of the nutrient metabolism.

Hitherto, the top to root ratio, the top length to diameter (at base) ratio[102], the antitoxic reaction of the seedlings to potassium or sodium chlorate[40,45,47,75,98,119,127], and contents of organo solutes[167] were examined as the method which indicates qualitatively the slenderness of the seedlings, and, recently, BAKER[7] made a proposition to establish an index of slenderness; i.e. top length to top dry weight ratio. Also, in the study of the frost-hardiness, carbohydrates[16,31,37,43,64,80~82,84~86,101,105~107,109,110,112,125~127] (mainly, sugars), water soluble protein[83,105,106,124], polyhydric alcohols[111], anthocyanins[36,83], sulfhydryls (SH)[59,120], and others in addition to the osmotic pressure[107,142], the antitoxic reaction of seedlings to chlorate, the dehydration resistance in hypertonic balanced salts[107], and the dye adsorption degree[17], which indicates the frost resistance, were measured. There is no proof that the above-mentioned elements increased directly the frost-hardiness, but it is well known that these elements increase with the increment of the frost-hardiness. Above everything else, sugars are most favorable in these studies.

Hence, the writer investigated the seasonal variations of nitrogen (the essential role as a constituent of amino acids, which are the building blocks of proteins), phosphorous (a constituent of nucleoproteins and phospholipids, and the high-energy bonds associated with phosphate groups which seem to constitute the chief medium for energy transfer in plant), and carbohydrates for the clarification of physiological quality in the seedling. And he inquired into the relationships between nitrogen, phosphorous, and carbohydrates.

The writer wishes to express his deep appreciation to Emeritus Professor K. KONDA for his encouragement throughout the course of this work for a thesis of Agricultural degree, Hokkaido University, to Professor Y. SAITO and Assistant Professor K. MUTO for their continued guidance and cordial revision and to Assistant Professor A. SAKAI, Research Institute of Low Temperature Science, who gave him kind guidance in the determination of carbohydrate contents.

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Experimental part

General method and material

The experiment concerning the seasonal variations of each element was carried out in the period from September, 1961 to April, 1963, excepting the determination of the height growth curve of 3-year-old seedlings in 1957.

In the dormant season from late September to early February, only carbohydrates (total sugars, reducing sugars, and starch) were investigated as follows: Samples were used from 5-year-old seedlings. The length of the lammas shoots varied, but, in this experiment, 5 malformed seedlings without terminal shoot, and 5 normal seedlings were selected at random. The lateral shoots which were removed by razor from each seedling, were placed immediately in tarred weighing bottles in the field; their fresh weights were measured on a chemical balance in the laboratory; and they were put into the oven (2 hrs. at 110°C). After determination of dry weights, moisture contents were expressed on a dry or a fresh weight basis. Samples were taken generally at 10 days intervals with several exceptions, as exact weighing can not be expected in a wet-leaf condition. Fresh weights were determined in the period from 14:00 to 15:00.

This procedure was performed at approximately 20 days intervals for the comparison of moisture contents between the part of lammas shoot and the part of current shoot in the same seedlings.

All of the lateral shoots which were taken at random for the determination of reducing sugar concentration were placed in an oven (1 hr. at 100°C)[79] and then in another oven (24 hrs. at 60°C). Determination of reducing sugar concentrations was performed by OKAZAKI's improved micro-BERTRAND method[78]), and expressed as a ratio on the basis of the value obtained when the residue weight was taken away from a dry, or a fresh weight.

The experimental methods in the period from March, 1962 to April, 1963 were performed following the procedure of TAGAWA and his assistant[131] on fresh potato material. Determinations of moisture contents were the same as the preceding method, and, in this experiment, samples were taken at 9 : 00 in accordance with TAGUCHI's report[125]. The 7-year-old fixed seedlings were used as the material.

In part I of the experiment, the seedlings were 35.8 cm in average height, 1.0 cm in average diameter at the base, and the first sample was taken on May 29th, 1962, and the last sample on April 28th, 1963. In this nursery, some seedlings, en masse, strongly suggested symptoms of malnutrition ; that is, apparently, the growth of the new shoot was greatly reduced. This was due to damage to the root by cutworms, but at least they grew somewhat and there was no seedling which was presumed to die. By adding such seedlings to the material, we could compare simultaneously the nutritional differences among the seedlings which have different growth stages from each other. Immediately after digging up carefully the material seedling in the field, it was brought into the laboratory, and the roots steeped in water. Then, the seedling was carefully washed to remove the soil from the roots, and the water on the surface of the roots was absorbed by filter paper before the determination of their formal factors.

For chemical analysis in the period from April, 1962 to April, 1963, the fresh material was used intact as in figure 0-2. The shoots removed from the seedling were whittled again finely by a new razor blade and then mixed. A part of them (about 1 g) was put into the oven (2 hrs. at 110°C) for determination of moisture content, and about 4 g material was ground in the presence of a

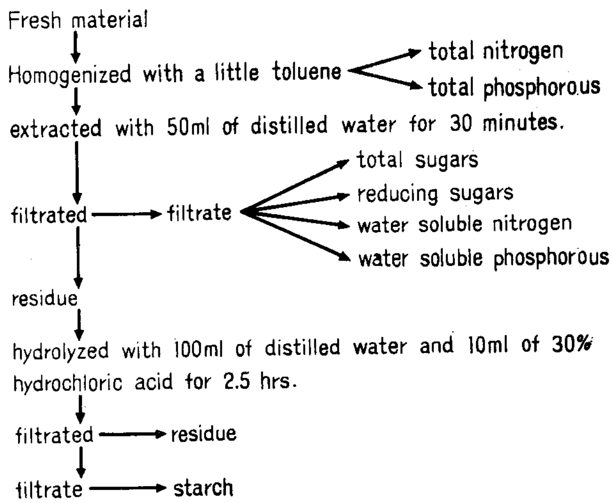

Figure O-2. Chemical analysis of the shoots of Todomatsu seedlings.

little toluene by a mortar and pestle, and then a material solution was made up to total 20 mℓ with distilled water. This sample solution was used for the estimation of total nitrogen and total phosphorous. Furthermore, the balance, approximately 4 g of material was ground up in the same way ; then the water soluble fractions were extracted during a period of 30 minutes ; after that the residue was made up to a total of 50 mℓ with distilled water. The extracted solution was separated from the residue by centrifugal separator, and the washings left after cleaning the residue 3 times was added to the filtrate and then made up to a total of 100 mℓ with distilled water for the estimation of water soluble nitrogen, water soluble phosphorous, and total sugars.

A semi-micro-Kjeldahl procedure was adopted for total and water soluble nitrogen analysis.

Estimation of phosphorous was carried out by the phosphorous-vanadous-molybdic acid method[121,163] as follows ; after 2 mℓ of 60% perchloric acid was added to 5 mℓ sample solution in 100 mℓ Kjeldahl flask, the flask was put in a draft for oxidation decomposition. The colourless decomposition solution was cooled and made up to 15 mℓ with distilled water. Then, after 30 minutes, 5 mℓ of this solution was taken, and shaken with 10 N perchloric acid 0.6 mℓ, 0.02 M ammonium vanadate 1.5 mℓ, 0.2 M ammonium molybdate 3.0 mℓ, and distilled water 4.9 mℓ in a 15 mℓ measuring flask. The phosphorous content was estimated by the SHIMAZU-KOTAKI photoelectric colorimeter at 470 mμ.

A deproteinized extract solution made by the use of zinc sulfate and barium hydroxide was diluted with distilled water until it was found to contain 10-70 μ g sugars per 2 mℓ and used for total sugar determination in accordance with the phenol-sulfric acid method[15] as follows ; 10 minutes after a 2 mℓ dilute solution was taken in test tube with 80% refined-phenol 0.05 mℓ and conc. sulfric acid, 5 mℓ. The test tube was well shaken and put in a water bath at 20–30°C for 10–20 minutes, and total sugar concentration was colorimetered at 490 mμ. The residue after extracting water soluble fractions was simmered for 2.5. hrs. in a reflux condenser to hydrolyze starch to glucose by 30% hydrochloric acid 10 mℓ with distilled water 100 mℓ, filtered, and washed. The filtrate and the washing in this treatment were made up to a total of 200 mℓ with distilled water. Starch content of this solution was determined by either OKAZAKI's improved micro-Bertrand[78] method or phenol-sulphuric acid method[121].

The residue after washing was put in the oven (2 hrs. 110°C) for determination of its dry weight.

These results were expressed by the percentage of each element in milligrams on the basis of the values obtained when the residue weight was taken away from a dry or a fresh weight, as in the preceding description ; and on a dry or a fresh weight, however, in part I, the two formers were omitted because of time limitation.

Part I. Growth grades and nitrogen, phosphorous, carbohydrate contents in the seedling during the early growing stage.

The relation between growth pattern and nutrient metabolism in a tree may differ among different tree species, different environment conditions, and different hereditary factors, as in a cultivative plant[41]. And the present studies on this problem suggest that diameter growth is apparently due largely to the expenditure of current photosynthate and is sensitive to environmental conditions, especially water supply, and current-year growth of trees with short growing seasons, after bursting their buds, is mostly influenced by the previous-year photosynthate[64,90], but those of trees with longer growing seasons use the products of current-year photosynthesis for at least the latter part of their height growth[58]. In any case, reserve food accumulated during the previous-year acts in the early stage of current-year growth, and also the decrease of reserve food is generally larger in the root than in the stem. This is also observed very much in the sprouting after cutting[163].

It is well known that the largest part of the reserve food in trees is in the form of carbohydrates, chiefly starch, and that fats are an important storage form in some species. BAUER's study[8] in 4-year-old fir seedlings shows that the organic substance decreases 7% in the stem, 6% in the root from May 2nd to May 14th, and the contents of nitrogen, phosphorous, and potassium decrease, remarkably in current leaves, in the period from mid-May to mid-July as compared with other elements. Todomatsu[70], usually, makes about 60% of the shoot growth within a 30 day period, beginning 10- or 15-days after bursting their buds, as well as Jezomatsu. Then, it seems that the early shoot growth of Todomatsu is influenced mostly by reserve food. Here, the writer investigated the general relation between growth and reserve food of the Todomatsu seedling in the early stage of its growth, because this relation is important in comparison to that in the lammas growing stage.

Chapter 1. Growth grades in the seedling.

Although height growth patterns themselves differ from each other according to hereditary potentiality, current weather condition, size of seedling, either transplanted or not, and other conditions. An example of the trend in Sapporo was shown graphically in figure 0–1. These values were measured on 3-year-old seedlings at 10 day intervals during the growing season of 1957. Namely, they budded in early May, and completed a large part of their height growth in the period from May till early or mid-June; and then their growth rate decreased in late June. Thereafter, they grew slightly in the period from early July to late July and, in late August, their growth could not be recognized. The sample seedlings in the present experiment were collected and examined for their formal factors and nutrient contents in the period from May 29th to June 22nd. Then, sample seedlings contained seedlings in the first height growth stage, and those

Table I-1. Formal factors of seedlings (7-year-old, 1962)

Seedling No.	Date	Stem height (cm)	Length of new stem shoot (cm)	Diameter at base (cm)	L. of root (cm)	Fresh weight of stem (g)	F. W. of root (g)	F. W. of new shoots at top (g)	Top: root ratio	Index of slenderness	Remarks
1	May 29	44.0	7.6	1.3	49.5	98.5	31.0	7.5	3.2	2.4	damaged by cutworm
2	June 1	37.8	9.2	0.9	31.0	30.8	13.5	4.8	2.3	7.3	
3	〃 5	20.9	4.9	0.8	20.8	23.8	9.0	2.4	2.6	4.5	damaged heavily by cutworm
4	〃 7	44.0	13.3	1.5	48.0	118.9	58.0	9.5	2.1	2.3	
5	〃 9	33.0	5.7	0.9	25.0	43.3	14.3	3.9	3.0	3.7	damaged slightly by cutworm
6	〃 11	42.2	6.2	1.2	55.0	87.6	30.4	—	2.9	2.6	
7	〃 14	29.0	9.8	1.0	29.5	35.6	14.0	4.5	2.5	4.3	
8	〃 15	34.5	2.2	1.0	16.0	40.4	17.3	3.6	2.3	4.3	damaged heavily by cutworm
9	〃 19	29.0	3.8	0.9	28.0	25.5	9.5	2.6	2.7	6.9	
10	〃 19	17.5	7.0	0.8	21.0	15.9	11.5	2.4	1.4	5.5	damaged slightly by cutworm
11	〃 22	56.0	22.0	1.2	42.0	101.2	45.0	12.2	2.3	2.0	
12	〃 22	42.0	12.3	1.2	45.0	63.7	31.0	10.7	2.1	2.7	
13	〃 22	35.5	19.5	0.9	45.0	40.4	23.6	5.8	1.7	3.4	
Mean		35.8	9.5	1.0	35.1	55.8	23.7	5.4	—	—	

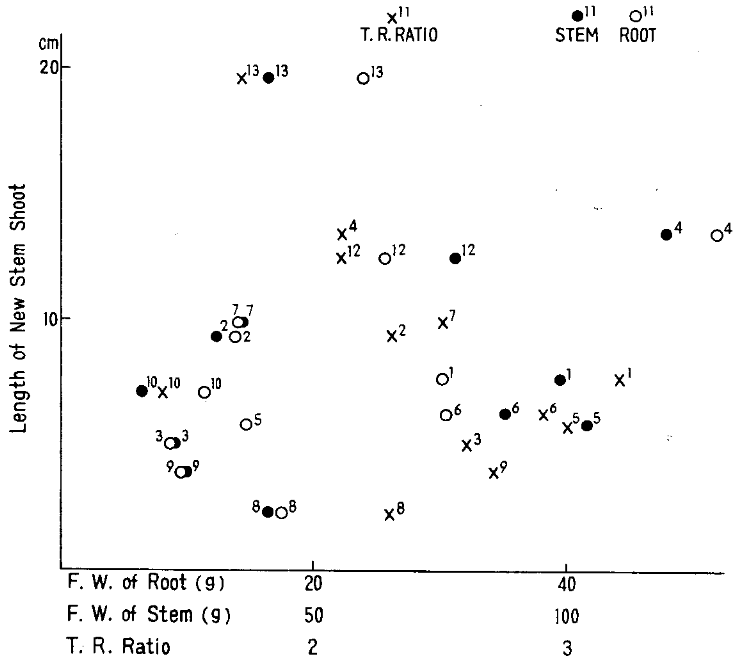

Figure I-1. Relationships among length of new stem shoot and fresh weight of stem, fresh weight of root, and top to root ratio.

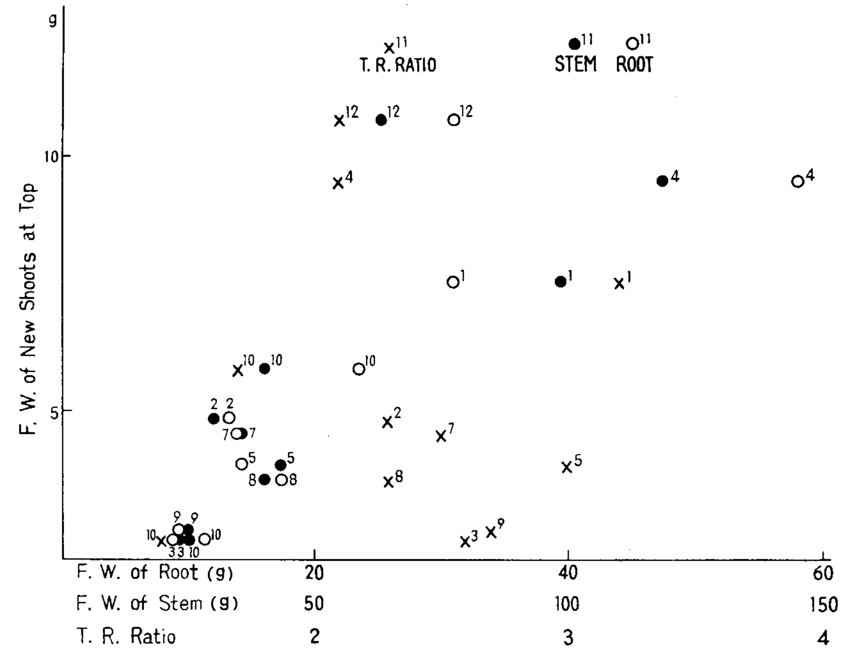

Figure I-2. Relationships among fresh weight of new shoots at top, of stem, of root, and top to root ratio.

in the decreasing stage of their growth.

Table I-1 presents the growth grades of sample seedlings. The growth grade of each seedling was indicated as "Length of new stem shoot" and "Fresh weight of new shoots at top" (containing new terminal and lateral shoots), and relationships among these growth grades and other formal factors was presented graphically in figure I-1 and I-2. Growth grades of the seedlings damaged by cutworm were less as compared with those of normal seedlings, and the growth grades of those damaged by cutworm were shown in lower fresh weights of roots, and in abnormally large values of top to root ratios in comparison with normal seedlings. There was a positive trend in the relation of growth grades as compared with fresh weight of stem and root, and this trend was more distinct in relation to fresh weights of new shoots at the top (Figure I-2) than those of the length of the new stem shoot as compared to the fresh weight of stem and root (Figure I-1). And also, growth grades of normal seedlings had more deep positive relation to fresh weight of root than to that of stem, but the seedling damaged by cutworm and sampled on June 22nd had a rather contrary relation. The top to root ratio of normal seedling in the present experiment showed the increasing tendency till mid-June and thereafter gradually decreased. The negative trend in relation of grades of top to root ratios was shown strikingly in figure I-1, but, in figure I-2, could not be determined clearly. The seedling damaged heavily by cutworm and sampled on June 22nd showed exceptional values in these relations.

The index of slenderness of the seedlings was presented in the ratio of stem height per dry weight and was very variable, and that of damaged seedlings, except No. 1 seedling, was larger than normal seedlings in top to root ratio. Moisture contents ranged from 72% to 84% and the seedlings collected on June 22nd were lower in particular.

Chapter 2. Nitrogen contents and growth grades[100].

The seasonal variation in nitrogen content was shown in figure II–2. 1 and II–2. 2.

Concerning the present experimental term, total nitrogen concentration decreased greatly during May and slightly in early to mid-June, and began to increase slowly after mid-June, but water soluble nitrogen kept a constant low level from early to mid-June and showed a distinct tendency to increase in late June. Accordingly, present seedlings were collected in the slow decreasing stage of total nitrogen content and the constant concentration stage of water soluble nitrogen. The increasing tendencies in total and water soluble nitrogen after mid-June coincided with the decreasing stage of first height growth. Those trends were well shown in the normal seedlings in table I–2; total nitrogen decreased to about 0.40%, and water soluble nitrogen to about 0.10% in concentration until mid-June, and the amount of increment after mid-June was more remarkable in the latter than in the former quarter. But the damaged seedlings had higher concentrations than the normal at any stage.

The relations between nitrogen contents and growth grades were shown in

Table I–2 a. Nitrogen, phosphorous, and reserved carbohydrate contents in shoots of Todomatsu seedlings on a dry weight basis. (7-year-old, 1962)

Seedling No.	Nitrogen		Phosphorous		Carbohydrates		
	Total N.	Water soluble N.	Total P.	Water soluble P.	Total C.	Sugars	Starch
1	4.27	1.72	—	—	4.14	1.13	3.01
2	3.03	1.60	—	—	3.47	1.05	2.42
3	3.63	1.53	0.30	0.16	4.84	1.42	3.42
4	3.00	0.80	0.21	0.06	2.54	1.12	1.42
5	3.12	1.46	0.33	0.10	3.37	1.11	2.26
6	4.42	1.35	0.42	0.16	4.67	2.15	2.52
7	2.90	1.12	0.25	0.06	2.70	1.20	1.50
8	4.00	1.12	0.25	0.10	3.43	1.86	1.57
9	4.52	1.49	0.34	0.11	3.07	1.24	1.83
10	3.22	0.53	0.23	0.12	4.26	1.86	2.40
11	2.45	0.95	0.20	0.08	5.56	1.29	4.27
12	2.09	0.62	0.15	0.06	4.65	1.56	3.09
13	1.60	0.57	0.18	0.07	4.19	1.05	3.14

Table I-2 b. Nitrogen, phosphorous, and reserved carbohydrate contents in shoots of Todomatsu seedlings on a fresh weight basis. (7-year-old, 1962)

Seedling No.	Moisture	Nitrogen		Phosphorous		Carbohydrates		
		Total N.	Water soluble N.	Total P.	Water soluble P.	Total C.	Sugars	Starch
1	81.7	0.78	0.32	—	—	0.76	0.21	0.55
2	83.0	0.51	0.27	—	—	0.59	0.18	0.41
3	80.8	0.70	0.29	0.06	0.03	0.94	0.28	0.66
4	84.1	0.47	0.13	0.03	0.01	0.41	0.18	0.23
5	79.4	0.64	0.30	0.07	0.02	0.70	0.23	0.47
6	81.3	0.83	0.25	0.08	0.03	0.87	0.40	0.47
7	81.3	0.54	0.21	0.05	0.01	0.49	0.23	0.26
8	79.9	0.80	0.23	0.05	0.02	0.70	0.38	0.32
9	83.7	0.74	0.24	0.06	0.02	0.51	0.20	0.31
10	80.1	0.64	0.10	0.05	0.02	0.78	0.37	0.41
11	72.3	0.68	0.26	0.06	0.02	1.54	0.36	1.18
12	75.7	0.51	0.15	0.04	0.01	1.13	0.38	0.75
13	74.6	0.41	0.14	0.05	0.02	1.08	0.27	0.81

figure I-3, I-4, and I-5. Nitrogen concentrations and growth grades in first height growing stage had a negative relation, nitrogen concentration decreases with developing growth, except for the seedlings severely damaged by cutworm (No. 8, No. 9) and the normal seedlings collected in late June (No. 11, No. 13), and also these trends were clearer in the relation of nitrogen concentration to length of new stem shoot than that of fresh weight of new shoots at top. These exceptional values were more distinguishable in the relation between water soluble nitrogen and the growth grade than in that between total nitrogen and growth

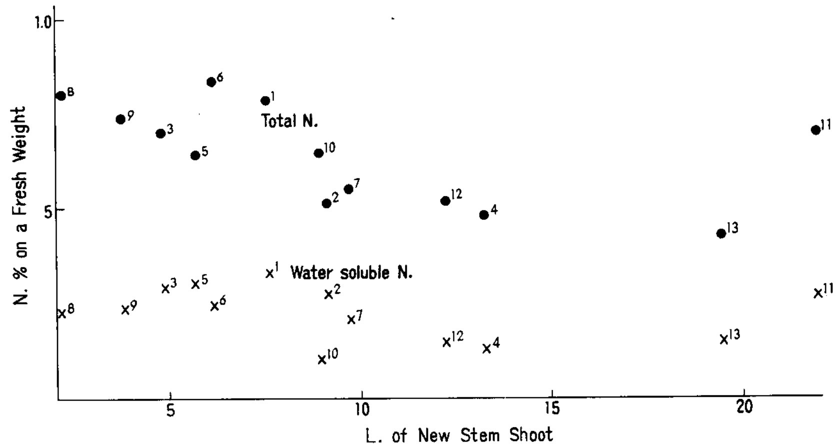

Figure I-3. Nitrogen concentration and length of new stem shoot.

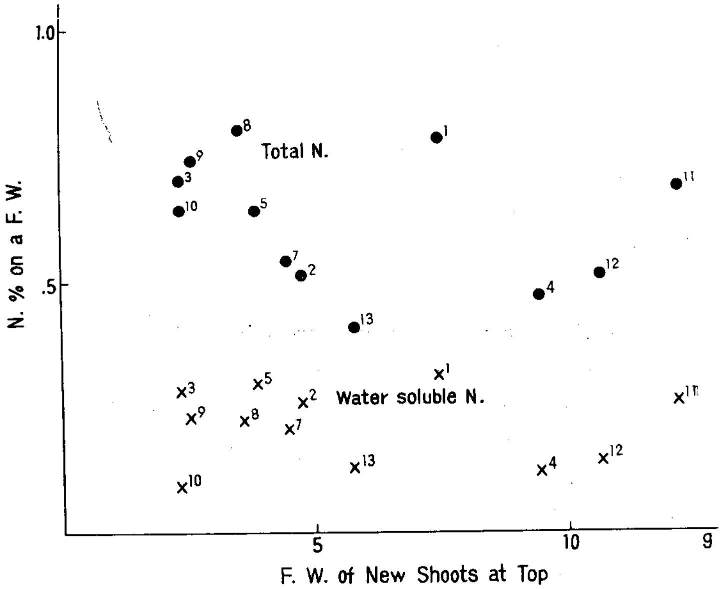

Figure I-4. Nitrogen concentration and fresh weight of new shoots at top.

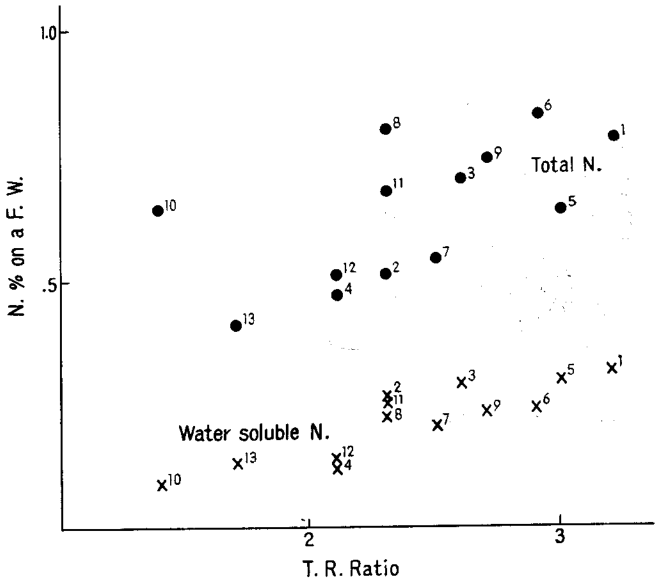

Figure I-5. Nitrogen concentration and top to root ratio

grade. Precisely, nitrogen concentrations in the seedlings damaged by cutworm were lower than the normal seedlings particularly, No. 8 and No. 9 seedlings, damaged heavily, showed markedly low concentration in water soluble nitrogen, and normal seedlings increased in this respect in late June. The smallest seedling slightly damaged by cutworm presented a lowered value of water soluble nitrogen concentration. The over-all curve of the present investigation in the relation between total nitrogen contents and length of new stem shoots strongly corresponded with the seasonal variation during the period from late May to late June in total nitrogen concentration as shown in figure II–2. 1. Nitrogen concentrations and top to root ratios were in positive relation, containing the seedlings damaged by cutworm and collected in the stage of decreasing first height growth. Especially, the relation between water soluble nitrogen and top to root ratio was positive linearly.

Chapter 3. Phosphorous contents and growth grades.

Phosphorous content, generally, was very indistinctive as compared with nitrogen or carbohydrates. According to figure II–3. 1 and II–3. 2, the general variation of phosphorous concentration from May to July resembled that of nitrogen, but the minimum concentration of water soluble phosphorous was obtained in mid-June, while that of water soluble nitrogen was obtained in early June. The total phosphorous content of sample seedlings ranged within 0.15–0.42% on a dry weight basis (and 0.03–0.08% on a fresh weight basis), and water soluble phosphorous of the same ranged within 0.06–0.16% on a dry weight basis and within 0.01–0.03% on a fresh weight basis as in table I–2.

Figure I–6 and I–7 are the graphs showing relations between phosphorous concentrations and growth grades in the seedlings. The negative relation of

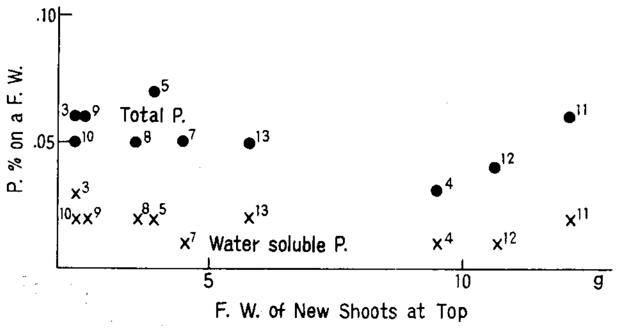

Figure I–6. 1. Phosphorous concentration and fresh weight of new shoots at top.

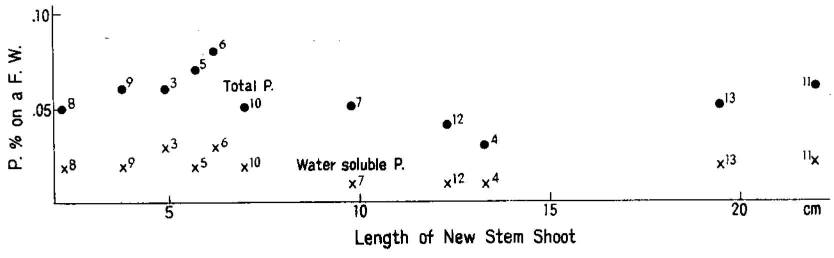

Figure I–6. 2. Phosphorous concentration and length of new stem shoot.

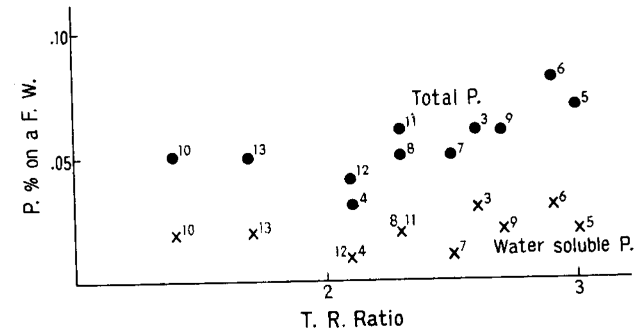

Figure I-7. Phosphorous concentration and top to root ratio.

phosphorous concentration to length of new stem shoot or fresh weight of new shoots at top; the positive relation of the former to the top to root ratio; the exceptional lower values in the seedlings damaged heavily by cutworm, and the higher values in those collected in late June follow the pattern of nitrogen concentration. The lower values in the seedlings damaged heavily by cutworm were more remarkable in the relation of phosphorous concentration to the length of new stem shoot than in the relation of fresh weight of new shoots at top to nitrogen. And such abnormal values in the seedlings heavily damaged were spotted not only in relation of water soluble phosphorous concentration but also in that of total phosphorous concentration to length of new stem shoot. This was different from nitrogen.

In the relation between phosphorous concentration and top to root ratio, abnormally higher values were obtained not only in the smallest seedling No. 10 damaged slightly by cutworm but also in the seedling No. 13 collected on June 22nd, and these seedlings had the lowest top to root ratio.

Chapter 4. Carbohydrate contents and growth grades.

Generally, total sugars and starch contents continued to decrease till late May, but increased rapidly in the period from late May to mid-June and then dropped again till late June and increased thereafter until early July. The first increasing trend was more remarkable in starch than in total sugars, and the latter, on the contrary, in total sugars than in starch. Also the starch content decreased in mid-June as soon as the first height growth declined (Figure II-4. 1 and II-4. 3). Total reserve carbohydrate contents of the seedlings in the present experiment ranged within 0.41-1.54% on a fresh weight basis and 2.34-5.56% on a dry weight basis, and also, on the whole, was much less in the seedling damaged by cutworm than in the normal one collected in the same stage (Table I-2). The seedling collected in late June showed a higher value, and this value was larger than that of the seedling collected in late May. However, the total sugar concentration showed a minimum of 0.18% and a maximum of 0.40%. Hence, the aforesaid differences in total carbohydrate concentrations were due

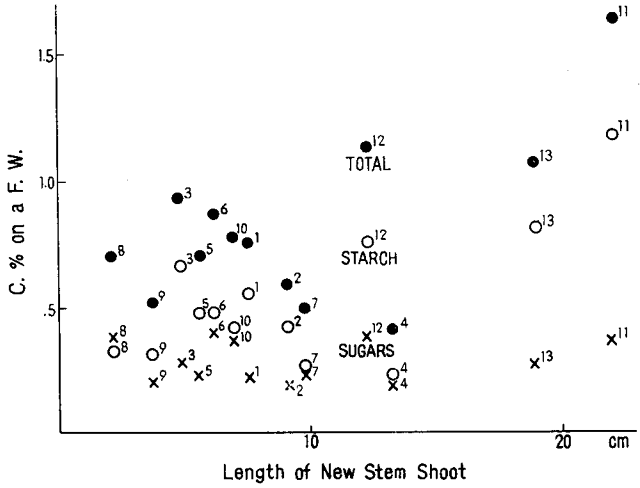

Figure I-8. Carbohydrate concentration and length of new stem shoot.

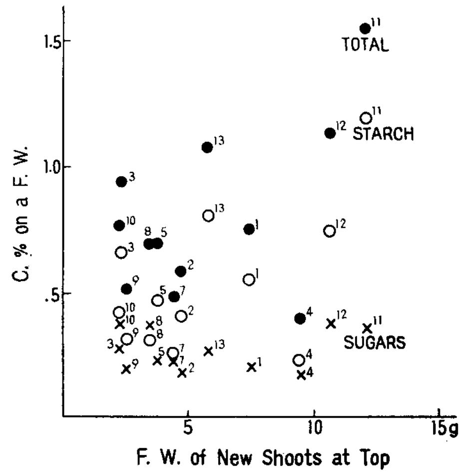

Figure I-9. Carbohydrate concentration and fresh weight of new shoots at top.

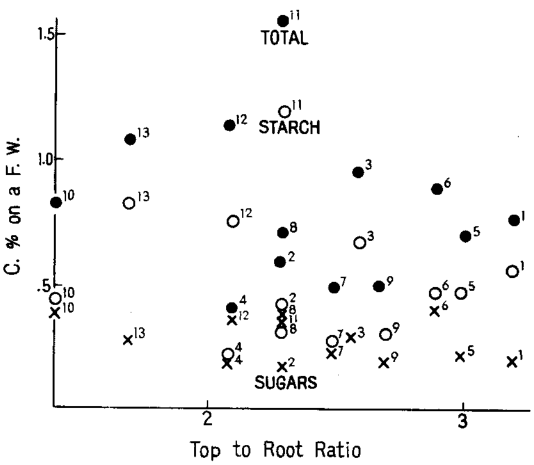

Figure I-10. Carbohydrate concentration and top to root ratio.

largely to the differences in starch contents. The relations among carbohydrate concentrations and growth grades were presented in figure I-8, I-9, and I-10. Excepting the seedlings collected in the increasing stage of starch (No. 11–No. 13), other seedlings showed a negative relation of starch to length of new stem shoot, and to fresh weight of new shoots at top. However, other seedlings showed a positive relation of starch to top to root ratio. This trend was similar to the relation of total carbohydrate to growth grades of seedlings. But total sugars had no clear relation to the growth grades of seedlings. No. 10 seedling took a remarkable higher value in relation of starch or total carbohydrates to top to root ratio. The relations of the seedlings damaged heavily (No. 8, No.

Table I-3 Relationships among nitrogen, phosphorous, and carbohydrate concentrations in shoots of Todomatsu seedlings.

Seedling No.	Water soluble N/Total N	Water soluble P/Total P	Sugars/ Total C	N/P	C/P	C/N
1	0.40	—	0.27	—	—	1.0
2	0.53	—	0.31	—	—	1.1
3	0.42	0.53	0.30	12.2	16.1	1.3
4	0.27	0.29	0.44	14.1	12.1	0.8
5	0.47	0.29	0.33	9.3	10.2	1.1
6	0.31	0.37	0.46	10.3	11.1	1.1
7	0.39	0.24	0.47	11.5	10.8	0.9
8	0.28	0.44	0.54	15.9	13.7	0.9
9	0.33	0.32	0.39	13.4	9.0	0.7
10	0.17	0.52	0.47	13.8	18.5	1.3
11	0.39	0.38	0.23	11.9	27.8	2.3
12	0.30	0.40	0.34	13.9	31.0	2.2
13	0.36	0.44	0.25	8.9	23.3	2.6

9) dropped to markedly low points as in those of water soluble nitrogen, total phosphorous, and water soluble phosphorous concentrations to top to root ratios.

Chapter 5. Interrelations among nitrogen, phosphorous, and carbohydrate contents.

In table I-3, are shown the interrelations among the above-mentioned elements.

Water soluble nitrogen to total nitrogen (n/N) ratio was 0.17 (No. 10) in minimum and 0.53 (No. 2) in maximum. The turning point from the decreasing to the increasing trend was early June in water soluble nitrogen, while it was mid-June in total nitrogen (Figure II-2. 1 and II-2. 2) and, accordingly, n/N ratio in normal seedling had a minimum value in early June (No. 4) and then increased till mid-June (No. 7). Furthermore, the next decreasing trend began in late June simultaneously in both concentrations, and this trend was more marked in total nitrogen than in water soluble nitrogen. Therefore, n/N ratio, in average, decreased somewhat in the normal seedlings collected in late June. In the seedling damaged by cutworm, it was shown that the changing stage in these ratios dropped behind.

Total and water soluble phosphorous concentrations changed simultaneously from the decreasing trend to the increasing trend in mid-June (Figure II-3. 1 and II-3. 2). The seedlings in this experimental period were a minimum of 0.24 and a maximum of 0.53 in water soluble to total phosphorous (p/P) ratio, and this range was more narrow than that of n/N ratio. The value in the normal seedling had a minimum in mid-June and then increased to late June, and thereafter dropped again. These ratios of the seedlings damaged by cutworm changed later, as in nitrogen.

According to figure II–4. 1 and II–4. 2, generally, the ratio of total sugars to total reserve carbohydrates (Su/C) ought to reach a maximum in late April, thereafter decreasing until mid-June and then begin to increase in late June. Then, in the sample seedlings of this experiment, the seedling damaged heavily by cutworm (No. 8, collected on June 15th) reached a maximum of 0.54 and the normal seedling collected on June 22nd (No. 11) showed a minimum of 0.23, and, generally, a higher ratio was obtained in damaged seedlings.

The relation of starch to total carbohydrates (St/C) increased in inverse ratio as compared to the ratio of total sugars to the latter (Su/C) throughout the experimental period, because total carbohydrates were made up of total sugars plus starch contents.

The variation in total nitrogen to total phosphorous (N/P) ratios was largely influenced by the changes in total nitrogen contents, because the total phosphorous content was lower, in quantity, than total nitrogen content. In the same way, the relation of total reserve carbohydrates to total phosphorous (C/P) were influenced by the total carbohydrates. Each ratio ranged from 8.9 to 15.9 in the former and from 9.0 to 31.0 in the latter, and also it was noticed that the former was variable and the latter, apparently, increased in mid-June.

The ratio of reserve carbohydrates to total nitrogen (C/N) in normal seedlings showed a minimum value in early June (No. 4–0.8) and thereafter increased from 2.2 to 2.6 in the seedlings collected on June 22nd. The seedling damaged by cutworm, No. 3 (collected on June 5th) had a 1.3 value in this ratio, and this was much larger when compared with normal seedlings, No. 4–0.8. And also, the heavily damaged No. 9 seedling showed a lower value of 0.7 on June 19th.

Chapter 6. Discussion.

If the reserve foods of the seedlings are indicated on the basis of their fresh weights, their concentrations may be slightly different from each other according to their moisture contents. And the investigation of the expenditure of reserve food was carried on not only in assimilation, but also considerably in respiration. So far as, however, the moisture contents of the seedlings did not differ much, we can deduce the approximate amount of reserve food contained in them from their fresh weights. The expenditure of food for respiration, in evergreen trees during the early growing stage, was compensated for to a certain extent, by new food manufactured by photosynthesis.

The results in the present experiment under such an assumption show the growth grades of Todomatsu seedlings, on the whole, tended in proportion to their fresh weights. Whether or not the new tissues were really produced by the expenditure of reserve food was well shown in the relations of carbohydrate concentrations, occupying the largest part of the reserve food, to growth grades in these seedlings. In the period till mid-June, the higher the growth grade of the seedling, the lower was the total carbohydrate concentration, especially starch content[164]. And the seedlings sampled on June 22nd showed more remarkable concentrations of total carbohydrates, this being due to the increase in starch content. Nitrogen and phosphorous concentrations had a similar relation, on a small scale, to the growth grades in these seedlings, as mentioned above. Accordingly, from the two above-mentioned results, it is clear that the early height growth of Todomatsu seedlings depended mostly on the reserve food.

In Sapporo, the roots of the Todomatsu seedlings elongate in early March[141], but their development progresses very slowly, even in the vigorous stage of shoot growth, till their active growth beings in late June. The results obtained by IWAMOTO and SHIBATA[42] on 5-year-old Todomatsu seedlings in Yamabe also presented a distinct pattern of root development. Then, the top to root ratio of the seedling increases during the active shoot growing season. The present data also showed that the sample seedlings taken till mid-June increased in this ratio during advancing growth grades, and the seedling collected on June 22nd showed a lower ratio than that of the seedling collected in mid-June (about 3.0). Then, the trend of early height growth of Todomatsu development on the reserves, ceases in mid-June.

RAMANN and BAUER[90] reported that the fir decreased 7.1% in weight of dry matter in the stem, 5.9% in the root as against a decrease in the case of norway spruce of 6.0% in the stem, and 23.0% in the root, in the early growing stage. As in figure II–1 and II–2, the growth grades of Todomatsu took a slightly similar relation to both fresh weights of stem and root; and the seedling damaged by cutworm showed a lower growth grade as compared with the normal one at any stage. In spite of these results the writer could not establish exactly that the expenditure of reserve food in Todomatsu seedling is much larger in either stem or root part, because heavy cutting of roots by cutworm may have resulted in reducing growth function with loss of reserve food.

It is commonly assumed that there is a striking relation between the amount of growth and the expenditure of nitrogen[11,12,14,130,134,145]. A deficiency seriously reduces growth owing to the demand for nitrogen largely for the production of protein used in formation of protoplasm for new cells and for the formation of chlorophyll. MURNEEK[68] reported that of total nitrogen in an 18-year-old apple tree, 75% was in the shoots, and nearly 20% was in the leaves in October. And also, in ARMSON's study[4] on the 2-year-old white spruce seedlings, there was a much larger nitrogen concentration in the secondary needles than in any other part of the seedling. Thus, the most vigorous growth part has the highest concentration of nitrogen; hence, the difference in nitrogen concentration between the same vigorous parts of two seedlings in a strain may correspond mostly with that in their growth grades. This relation is clear in the present results (Figure I–3 and I–4). Moreover, it was shown that the expenditure of nitrogen in the early growth stage of Todomatsu was based largely on the reserves in the tree, since, in the relation between growth grades and nitrogen concentration, the higher the growth grade was, the less the nitrogen concentration was, and the seedlings whose roots were damaged by cutworm had a similar concentration of total nitrogen as that of the normal seedlings.

Of all the seedlings sampled in early June, No. 4 seedling showed a higher growth grade. However, the other seedlings sampled at the same time showed a lower growth grade and had a much higher value in water soluble nitrogen concentration and in n/N ratio than those sampled at other times of the year. And also, those damaged heavily in mid-June showed low growth grades and different values in their water soluble nitrogen concentrations corresponding to the damaged state of their roots; the higher the top to root ratio was, the larger the value of total, water soluble nitrogen concentration, and n/N ratio were. Through the early growth stage, the total nitrogen decreased in both the apple[117] and Todomatsu trees[152,153]. However, TAGAWA and SAKAI[132,133] reported that, in the potato, the total and water soluble nitrogen contents reached a maximum in early June owing to the increased amount of the latter, due to the amount absorbed from the soil, because the reserve protein is available for the formation of new tissues as soon as it is hydrolized in water soluble fraction, amino and amide nitrogen. Such a trend was presented by the heavily damaged seedlings (No. 8, No. 9) and was spotted in the abnormally low relation of water soluble nitrogen to growth grades as compared with normal relation of total nitrogen concentrations to growth grades, but, the maximum stage of nitrogen concentration could not be determined in the present experiments.

As described previously, phosphorous contents decrease with advancing growth grades in the early stage of growth as same as nitrogen. It seems that the much lower concentration in the seedings damaged heavily by cutworm was found not only in water soluble, but also in total phosphorous, because phosphorous compounds occur in both organic and inorganic forms and are readily translocated, probably in both forms, and that the increase of phosphorous concentration begins in a later stage than that of nitrogen.

In the relations of nitrogen, phosphorous, and carbohydrate concentration to top to root ratios in these seedlings, excepting those collected on June 22nd, and the smallest seedlings, on the whole, the former were in proportion to the latter. If the early growth is influenced largely by the nutrients absorbed from the soil, each concentration must decrease in proportion to the increase of top to root ratio; hence, in the early growth stage of the Todomatsu seedling, its growth also progressed probably at the expense of the reserves. And, it has been presumed that the root at that time is under unfavorable condition, low soil temperature, for absorption of the nutrients from the soil. ULRICH[159] reported that, in barley, K-absorption in 5°C water was 1/4 of that in 35°C water.

The change of n/N ratio, from decreasing to increasing, occurred in early June, that of p/P ratio in mid-June, that of C/N ratio in early June. N/P and

C/P ratios were largely influenced by the values of nitrogen and carbohydrates alone, because phosphorous content was much less, in quantity, in comparison with the other elements. In the seedlings damaged by cutworm, these changes begin later as compared with normal ones, because, probably, the onset of their growth begins later than the latter.

Chapter 7. Summary.

In order to compare the variations of nitrogen, phosphorous, and carbohydrate contents in the lammas growing stage with that in early spring, the writer examined these contents in new shoots of 7-year-old Todomatsu seedlings in the early growing stage with their growth grades in the same stage and obtained the following results;

1. Growth grades were in proportion to the fresh weights of stems and roots, and nitrogen, phosphorous, and carbohydrate concentrations, particularly remarkable in starch, decreased with developing growth.
2. As soon as mid-June was gone, each concentration began to increase, markedly in starch and water soluble nitrogen, in contrast with the decreasing trend in top to root ratio.
3. The seedling whose roots were damaged by cutworm showed much less growth grade, and higher value, in each concentration as compared with the normal one at any stage. And also, the changing point from decreasing to increasing in n/N, p/P, and C/N ratios of the damaged seedlings began later than those of the normal seedlings.

Part II. Seasonal variations in nitrogen, phosphorous, and carbohydrate contents.

Chapter 1. Moisture and residue.

Many investigators reported the seasonal cyles in tree moisture contents. In general, tree moisture contents increase in the vigorous growing stage and decrease with the differentiation of the tissues followed by the cessation of its growth in the period from autumn to winter.

Moisture contents of Todomatsu seedlings (Figure II–1. 1) increased rapidly in late April and showed a maximum value, in late May after bursting, of 83.4%. Thereafter, they decreased to 70.6% in early July and then increased to the second peak (78.5%) in mid-August, having a small peak in mid-July. Namely, they had two big peaks in the growing season. Concerning the period from the second peak in mid-August to early February, they decreased gradually to 53.4%, and this decreasing trend was more remarkable in late summer than in the dormant season, and the former resembled that in the period from late May to early July. The values of 5-year-old seedlings in the dormant season of 1961 showed a trend similar to that of 1962. In the period from early February to early April, they showed variable curves. This was presumably due to the climatic condition,

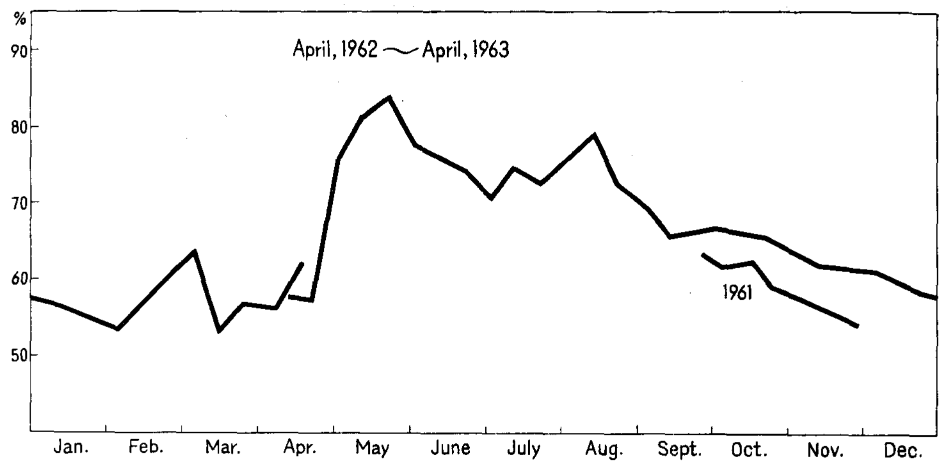

Figure II-1. 1. Seasonal variation of moisture contents in *Abies sachalinensis* MAST. (Todomatsu) seedlings (5-year-old in 1961, 7-year-old in 1962–1963) on a fresh weight basis.

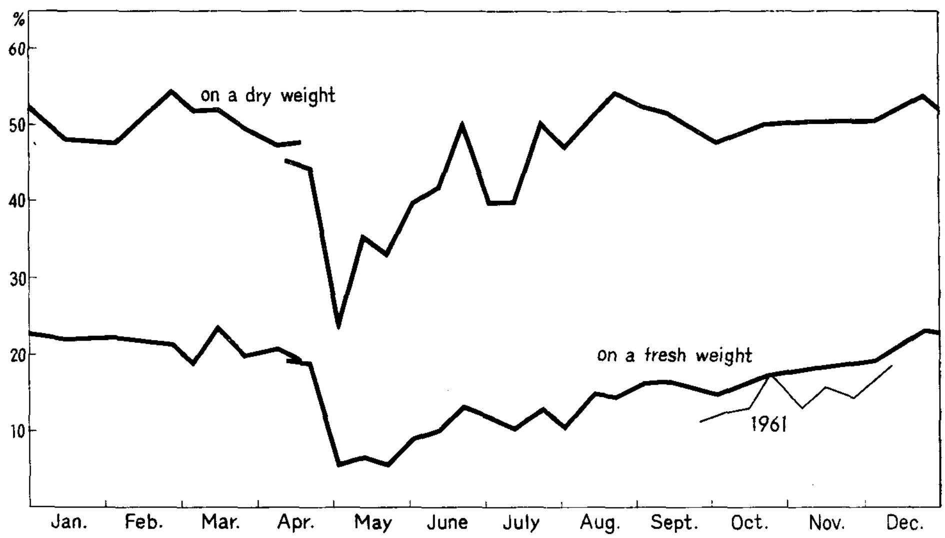

Figure II-1. 2. Seasonal variation of residue contents in *Abies sachalinensis* MAST. (Todomatsu) seedlings (5-year-old in 1961, 7-year-old in 1962–1963) on a dry or a fresh weight basis.

because, in the dormant season from 1962 to 1963, the weather was abnormal. In particular, the snow melted for a while in early February to below the seedling height and then it snowed again until it covered the seedling. The minimum value was 53.1% in mid-March, but, in early February, moisture contents were 53.4% in 1963 and 53.7% in 1962 (5-year-old seedling). The different values obtained in mid-April between 1962 and 1963 also seemed to be because of different weather conditions.

Residue (Figure II–1. 2) ranged from 5.6% to 23.4% throughout the experimental period, and the maximum content was reached in mid-March, and the minimum content in late May on a fresh weight basis. On a dry weight basis, its maximum content was reached in late February (54.3%) and its minimum content in early May (23.7%).

Generally, they took an inverse curve to moisture contents. This phase was observed in sharp decreasing trend of residue as compared with rapid increment of moisture, though at times there were slight exceptions. The increasing trend after early May reached 22.9% in late December and thereafter decreased slightly until mid-April by about 5% on a fresh weight basis. The fluctuations from late June to mid-Augst corresponding to moisture changes were on a small scale in comparison with those from mid-April till early May. It seemed that the changes during March corresponding to moisture changes were due to abnormal weather, and then, usually residue contents scarcely varied from December to mid-April.

The curve on a dry weight basis had more flexible variation than that on a fresh weight basis.

Chapter 2. Nitrogen.

1) Total nitrogen.

Seasonal variation of total nitrogen was graphed in figure II-2. 1 on a dry (B) or a fresh (D) weight basis and on a dry (A) or a fresh (C) weight basis

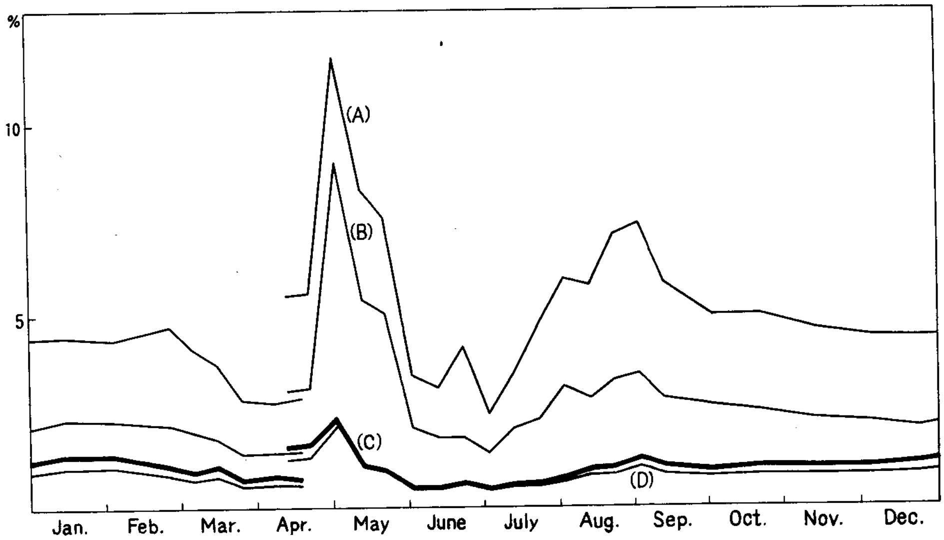

Figure II–2. 1 Seasonal variation of total nitrogen in *Abies sachalinensis* MAST. (Todomatsu) seedling (7-year-old) on a dry (B) or a fresh (D) weight basis and on a dry (A) or a fresh (C) weight basis after removal of residue weight.

after removal of residue through starch-hydrolysis. The same applies to the other elements that follow, and the writer, mainly, explained these results in concentration (C).

The distinct increasing trend of total nitrogen concentration (Figure II-2. 1) in late April resembled that of moisture contents, and the maximum concentration was 2.30% in early May. However, total nitrogen concentration decreased rapidly as soon as May set in and continued to decrease until about early or mid-June. Such changes from increasing to decreasing concentration were observed 5 times throughout this work, namely, in early May, late June, September, ealy February, and mid-March. Above all, the change in early May was most apparent, and others were on a smaller scale as compared with former. They remained fairly constant during June and began to increase slowly about early July and had the second peak in early September. The decrease during September was small (0.34 %). The general increase after early October continued until early February, but the amount of increment in concentration was limited to 0.44%. Their concentration in mid-April was 1.59% in 1962 and 0.76% in 1963, and the former was about twice as large as the latter.

2) Water soluble nitrogen.

Water soluble nitrogen varied more flexibly than total nitrogen in the latter

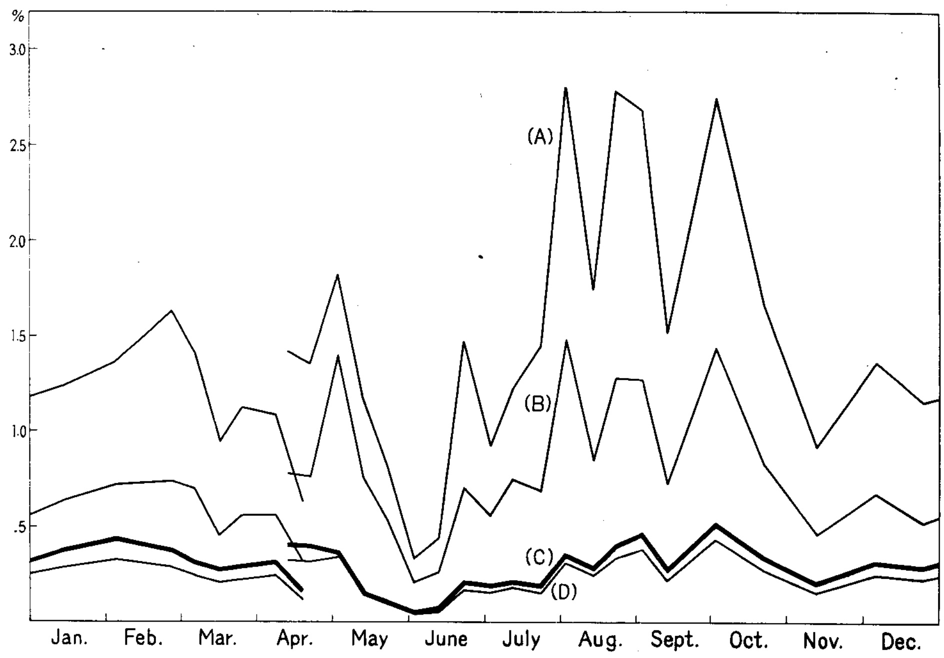

Figure II-2. 2. Seasonal variation of water soluble nitrogen in *Abies sachalinensis* MAST. (Todomatsu) seedling (7-year-old) on a dry (B) or a fresh (D) weight basis and on a dry (A) or a fresh (C) weight basis after removal of residue weight.

part of the growing season. The maximum value of water soluble nitrogen concentration was measured in early October (0.51%), while that of total nitrogen was measured in early May; but the minimum value of the former was 0.05% in early or mid-June about the same as that of the latter. The rapid decrease of water soluble nitrogen in early May, and then, the gradual decrease until early June corresponded to that of total nitrogen. Increment in late April could not be detected on a fresh weight basis but it was observed on a dry weight basis in about 0.5%. The decreasing phase in the growing season was shown strikingly in early August and early September, and also in early May. But the second decreasing trend of water soluble nitrogen differed from that of total nitrogen. In the dormant season, they decreased to 0.2% from early October to mid-November and thereafter increased gradually to 0.43% in early February. In the latter part of the dormant season, they showed a fairy constant concentration in comparison with the variable curve for total nitrogen. Over the entire year, water soluble nitrogen content was much greater in the developmental stage of the root than the others. This was indicated more clearly in a dry matter than in concentration.

Chapter 3. Phosphorous.

1) Total phosphorous.

A maximum content of total phosphorous was 0.17% in concentration and

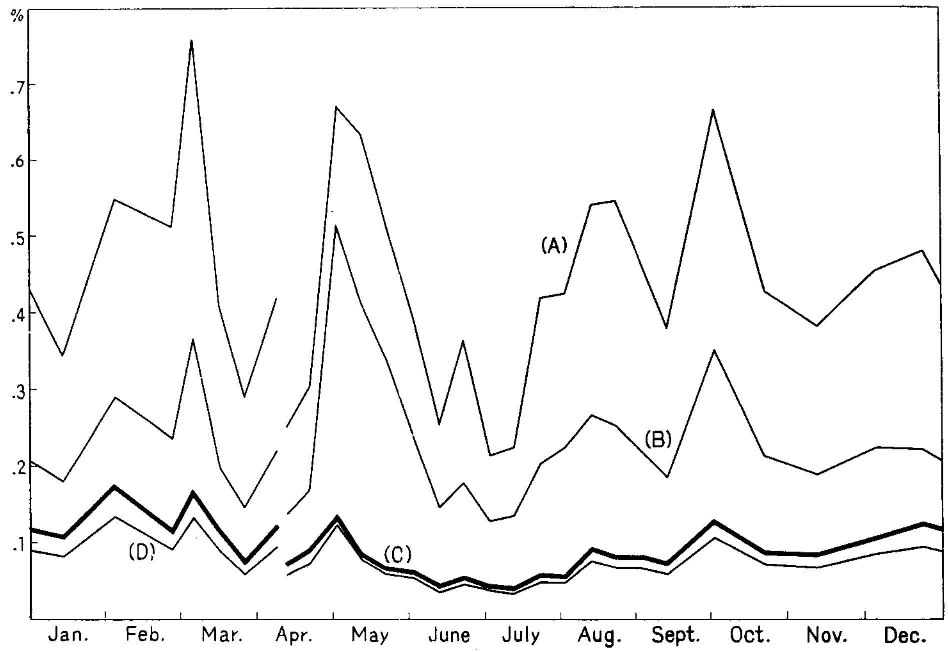

Figure II-3. 1. Seasonal variation of total phosphorous in *Abies sachalinensis* MAST. (Todomatsu) seedling (7-year-old) on a dry (B) or a fresh (D) weight basis and on a dry (A) or a fresh (C) weight basis after removal of residue weight.

0.76% in dry matter. Accordingly, phosphorous concentration was indicated less variation the year through, as compared with the variation of the other elements.

The curve of total phosphorous concentration varied much more than that of nitrogen does, and these indications were remarkable in the periods from the latter part of dormant season to May and from late summer to autumn. They decreased sharply in early May the same as nitrogen, continued to decrease during May and then showed an approximately similar low concentration from late May to late July. They reached a minimum about mid-July but, in mid-June, they showed a low concentration approximately the minimum. Except for the domant season, a maximum value was obtained in early May, and also, in early October, a close concentration similar to that in early May occurred. In dormant season, they kept about 0.1% concentration and reached a maximum concentration throughout this work in early February. The extreme variations in the latter part of the dormant season could not be observed for the curves of total and water soluble nitrogen, and water soluble phosphorous concentrations.

2) Water soluble phosphorous.

In comparison with total phosphorous, the curve of water soluble phosphorous concentration varied little with time. This relation between total and water soluble phosphorous concentrations differed from that between total and water soluble nitrogen. Water soluble phosphorous concentrations were limited to from 0.01% to 0.06% (Figure II–3. 2). The phase in early spring differed from that of other

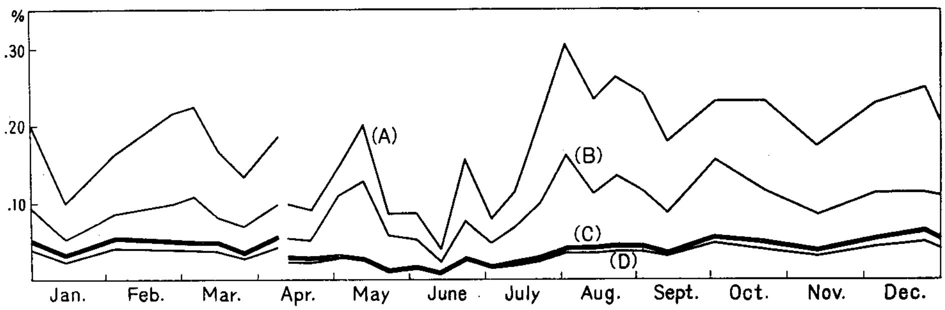

Figure II–3. 2. Seasonal variation of water soluble phosphorous in *Abies sachalinensis* MAST. (Todomatsu) seedling (7-year-old) on a dry (B) or a fresh (D) weight basis and on a dry (A) or a fresh (C) weight basis after removal of residue weight.

elements. Namely, their concentration indicated no rapid increase in late April and the clear and also sharp decreasing trend was shown in mid-May, while that of others was in early May.

Chapter 4. Carbohydrates.

1) Total carbohydrates.

Total carbohydrates in figure II–4. 1 are the values obtained by adding total sugars to starch.

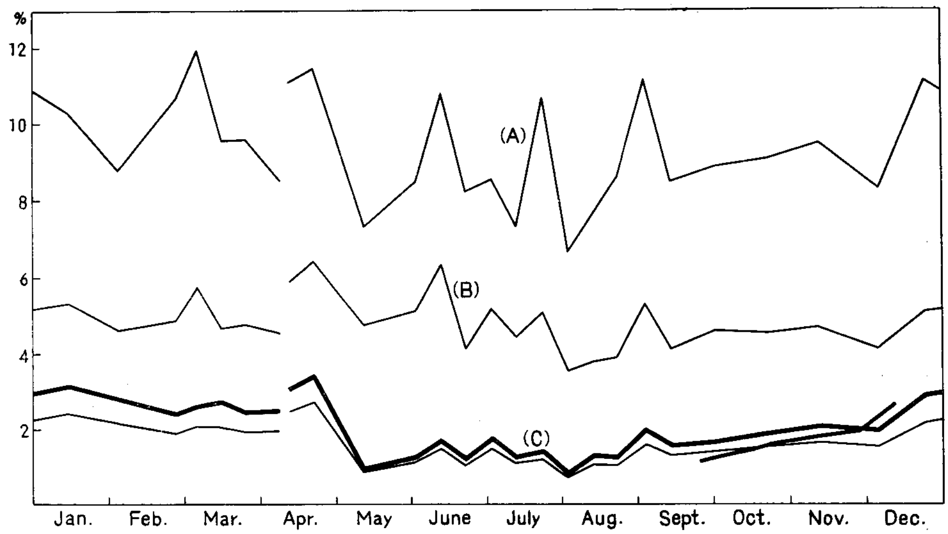

Figure II-4. 1. Seasonal variation of total carbohydrates in *Abies sachalinensis* MAST. (Todomatsu) seedling (7-year-old) on a dry (B) or a fresh (D) weight basis and on a dry (A) or a fresh (C) weight basis after removal of residue weight.

The special features in seasonal variation of total carbohydrate concentration were that their concentration decreased sharply in the period from mid-April to mid-May after reaching a maximum (3.10%) at about mid-April and that they had a more variable curve in the growing season as compared with a steady curve in the dormant season. The values measured in 1962 for 5-year-old seedlings in the dormant season showed a similar and steady curve. The decreasing trends in early spring were shown in early May not only for nitrogen but also for phosphorous concentrations. However, this phase in total carbohydrate concentrations corresponded to the sharp increase in moisture contents and decrease in residue contents in the same period. The slow increasing trend accelerated suddenly in late November in 1961 and in early December in 1962.

2) Total sugars.

Total sugar concentration was 0.27% at a minimum in early August and 2.10% at a maximum in mid-January. In early spring, total sugar concentration had no increasing trend as did water soluble nitrogen. The decrease of total sugar concentration before setting in of the growing season was indicated already in mid-April, 1962 and in mid-January, 1963. The increase of total sugar concentration after cessation of growth accelerated markedly in late November, 1961, and in early December, 1962. Accordingly, the sudden increase of total carbohydrate concentration in mid-winter was mainly due to total sugar increment. And also, in the other stages, total carbohydrates fluctuated in a manner similar to that of total sugars.

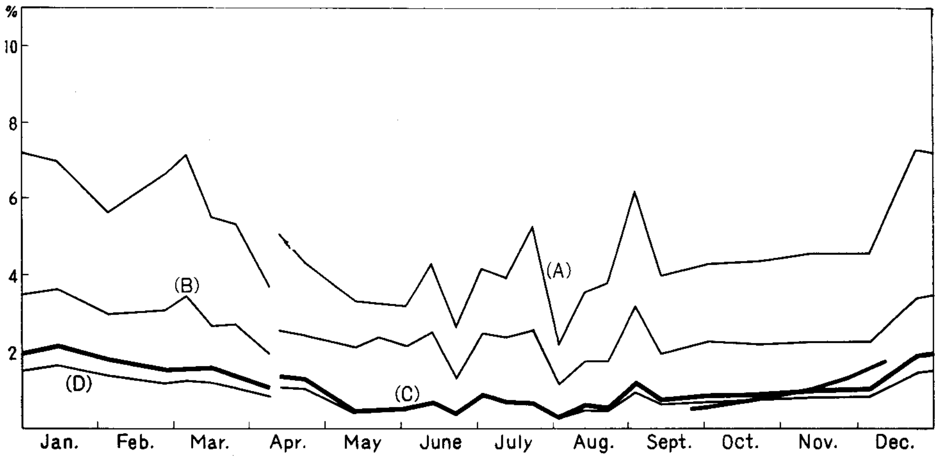

Figure II-4. 2. Seasonal variation of total sugars in *Abies sachalinensis* MAST. (Todomatsu) seedling (7-year-old) on a dry (B) or a fresh (D) weight basis and on a dry (A) or a fresh (C) weight basis after removal of residue weight.

3) Reducing sugars.

The curve of reducing sugar concentration with time resembled that of total sugars, excepting late April, 1962, when reducing sugars began to decrease, though the former has smaller fluctuations. And also, they increased gradually in the former part of the dormant season. In both peaks, in early September and in mid-January, of total sugars, the differences between total and reducing sugar concentrations showed higher (0.72%, 0.65%).

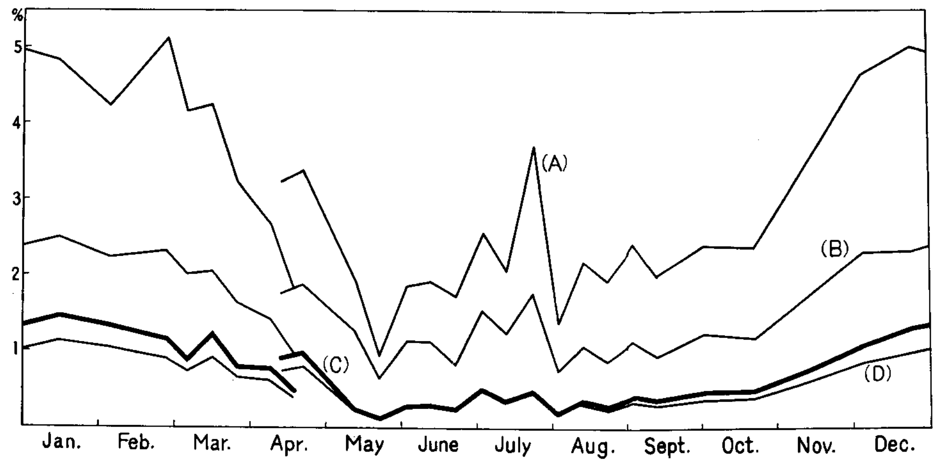

Figure II-4. 3. Seasonal variation of reducing sugars in *Abies sachalinensis* MAST. (Todomatsu) seedling (7-year-old) on a dry (B) or a fresh weight (D) basis and on a dry (A) or a fresh (C) weight basis after removal of residue weight.

4) Starch.[101]

Starch contents in the growing season tended to resemble reducing sugar concentration rather than total sugars, but, in the dormant season, they progressed in different ways. As soon as the setting in of late March, starch contents increased markedly and decreased immediately after reaching the maximum (2.09 %) in late April, and showed a sharper curve than the increasing curve in the

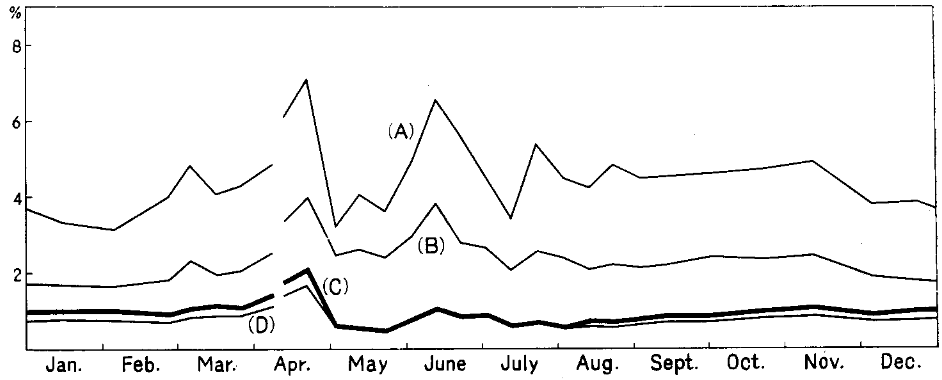

Figure II-4. 4. Seasonal variation of starch in *Abies sachalinensis* MAST. (Todomatsu) seedling (7-year-old) on a dry (B) or a fresh (D) weight basis and on a dry (A) or a fresh (C) weight basis after removal of residue weight.

preceding period. Increment of starch contents preceded the increasing trend of moisture contents. This phase was observed not only in starch but also in total and reducing sugars. Except for this change from increasing to decreasing in April and low concentration in May, starch contents kept about 1,0% from June to March of the following year. In the second experiment, a minimum content for the whole year was 0.43% on a fresh weight basis (3.60% on a dry weight basis) in late May.

Chapter 5. Interrelations among nitrogen, phosphorous, and carbohydrate contents.

These ratios were presented in table II-1.

The n/N ratio kept the decreasing trend after bursting in mid-May till late May and changed into the increasing trend slowly in early June, and then increased markedly in mid-June. These behaviors were in reverse proportion to the pattern of early height growth. Thereafter, there were small changes until reaching a maximum value (0.55) about early October, and showed a continuous decreasing trend as like as in the period before and after bursting stage. The minimum value in early June was 0.1, and the values kept over 0.25. The maximum stage in these ratios was the same as that of water soluble nitrogen concentration. In the dormant season, the dropping of n/N ratio in the period from early October to mid-November was very noticeable.

Table II-1 Interrelations among nitrogen, phosphorous, and carbohydrate contents-1.

Date		St/C		Su/C		RS/C		Su/St		RS/St		RS/Su	
		N.	L.	N.	L.	N.	L.	N.	L.	N.	L.	N.	L.
1961	IX 26	0.54	0.57	0.46	0.43	0.28	0.22	0.87	0.77	0.53	0.39	0.60	0.51
	X 4	0.57	0.61	0.43	0.39	0.27	0.22	0.78	0.67	0.47	0.36	0.60	0.54
	X 16	0.54	0.58	0.46	0.42	0.29	0.25	0.86	0.71	0.54	0.42	0.63	0.59
	X 24	0.54	0.57	0.46	0.43	0.31	0.25	0.84	0.74	0.57	0.43	0.68	0.53
	XI 6	0.45	0.48	0.55	0.52	0.34	0.26	1.23	1.09	0.76	0.55	0.62	0.50
	XI 16	0.41	0.51	0.59	0.49	0.35	0.31	1.41	0.97	0.83	0.60	0.59	0.62
	XI 27	0.35	0.38	0.65	0.63	0.33	0.33	1.83	1.67	0.94	0.87	0.52	0.52
	XII 12	0.35	0.37	0.65	0.63	0.41	0.38	1.89	1.73	1.19	1.05	0.63	0.61
1962	II 8	0.32	0.39	0.68	0.61	0.36	0.37	2.13	1.54	1.12	0.94	0.53	0.61
	IV 12	0.57	0.57	0.43	0.43	0.30	0.29	0.76	0.77	0.53	0.51	0.69	0.66
	IV 21	0.62	0.61	0.38	0.39	0.30	0.28	0.61	0.64	0.48	0.46	0.78	0.72
	V 2	—	0.48	—	0.52	—	0.36	—	1.09	—	0.75	—	0.69
	V 12	0.55	0.58	0.45	0.42	0.26	0.29	0.81	0.73	0.47	0.50	0.58	0.69
	V 22	—	—	—	—	—	—	—	—	0.28	—	—	—
	VI 2	0.58	—	0.42	—	0.23	—	0.72	—	0.39	—	0.54	—
	VI 12	0.60	—	0.40	—	0.18	—	0.66	—	0.29	—	0.45	—
	VI 22	0.68	—	0.32	—	0.21	—	0.46	—	0.30	—	0.66	—
	VII 2	0.51	0.49	0.49	0.51	0.30	0.35	0.94	1.04	0.58	0.72	0.61	0.69
	VII 12	0.46	0.54	0.54	0.46	0.28	0.25	1.22	0.86	0.60	0.47	0.52	0.54
	VII 23	0.51	0.61	0.49	0.39	0.35	0.26	0.97	0.63	0.69	0.42	0.71	0.67
	VIII 2	0.69	0.77	0.32	0.23	0.21	0.21	0.47	0.31	0.32	0.27	0.67	0.89
	VIII 13	0.54	0.58	0.46	0.42	0.29	0.29	0.84	0.74	0.53	0.51	0.63	0.69
	VIII 23	0.56	0.54	0.44	0.46	0.23	0.26	0.80	0.86	0.41	0.49	0.51	0.57
	IX 3	0.40	0.32	0.60	0.68	0.22	0.20	1.48	2.10	0.55	0.63	0.37	0.30
	IX 13	0.53	0.49	0.47	0.51	0.24	0.32	0.89	1.03	0.45	0.66	0.50	0.63
	X 2	0.52	0.53	0.49	0.47	0.28	0.25	0.94	0.89	0.55	0.48	0.58	0.54
	X 22	0.52	0.47	0.48	0.53	0.26	0.29	0.92	1.14	0.49	0.61	0.54	0.54
	XI 12	0.52	0.56	0.48	0.44	0.36	0.39	0.93	0.80	0.69	0.70	0.75	0.87
	XII 5	0.42	0.46	0.58	0.54	0.51	0.64	1.39	1.16	1.23	1.38	0.89	—
	XII 24	0.35	0.31	0.65	0.69	0.45	0.43	1.89	2.22	1.31	1.39	0.69	0.63
1963	I 14	0.32	0.31	0.68	0.69	0.47	0.44	2.12	2.24	1.46	1.42	0.69	0.64
	II 4	0.36	0.31	0.64	0.69	0.49	0.41	1.79	2.28	1.35	1.36	0.76	0.60
	II 25	0.38	0.33	0.63	0.67	0.48	0.43	1.67	2.06	1.28	1.33	0.77	0.64
	III 5	0.40	0.36	0.60	0.64	0.35	0.37	1.47	1.78	0.87	1.02	0.59	0.57
	III 15	0.42	0.36	0.58	0.64	0.44	0.45	1.37	1.74	1.05	1.24	0.77	0.71
	III 25	0.45	0.43	0.55	0.57	0.33	0.35	1.24	1.31	0.75	0.80	0.60	0.61
	IV 8	0.57	0.49	0.43	0.51	0.31	0.26	0.76	1.06	0.55	0.53	0.72	0.50
	IV 18	0.63	0.58	0.37	0.42	0.18	0.21	0.59	0.73	0.28	0.36	0.48	0.49

Table II-1 Interrelations among nitrogen, phosphorous, and carbohydrate contents-2.

Date		n/N		C/N		St/N		Su/N		RS/N	
		N.	L.	N.	L.	N.	L.	N.	L.	N.	L.
1962	IV 12	0.26	0.28	1.95	1.72	1.11	0.97	0.84	0.75	0.58	0.49
	IV 21	0.24	0.20	2.05	1.61	1.27	0.98	0.78	0.63	0.61	0.45
	V 2	0.16	0.30	—	0.49	0.27	0.23	—	0.26	—	0.18
	V 12	0.14	0.10	0.89	0.69	0.49	0.40	0.40	0.29	0.23	0.20
	V 22	0.11	—	—	—	0.47	—	—	—	0.13	—
	VI 2	0.10	—	2.48	—	1.44	—	1.04	—	0.56	—
	VI 12	0.14	—	3.45	—	2.08	—	1.37	—	0.61	—
	VI 22	0.34	—	1.97	—	1.34	—	0.62	—	0.41	—
	VII 2	0.40	0.20	3.56	2.28	1.83	1.11	1.73	1.16	1.06	0.80
	VII 12	0.36	0.19	2.12	2.30	0.98	1.23	1.13	1.06	0.59	0.57
	VII 23	0.30	0.22	2.19	2.42	1.11	1.49	1.08	0.93	0.76	0.62
	VIII 2	0.47	0.27	1.12	1.08	0.76	0.83	0.36	0.25	0.24	0.23
	VIII 13	0.30	0.28	1.34	1.66	0.73	0.95	0.61	0.70	0.39	0.48
	VIII 23	0.38	0.31	1.19	1.58	0.66	0.85	0.53	0.73	0.27	0.42
	IX 3	0.36	0.33	1.50	2.13	0.61	0.69	0.90	1.44	0.33	0.43
	IX 13	0.26	0.22	1.47	1.43	0.78	0.70	0.69	0.72	0.35	0.46
	X 2	0.55	0.31	1.80	1.72	0.92	0.91	0.87	0.81	0.51	0.44
	X 22	0.33	0.41	1.82	2.14	0.95	1.00	0.87	1.14	0.47	0.61
	XI 12	0.20	0.24	2.06	2.02	1.07	1.13	0.99	0.90	0.74	0.78
	XII 5	0.31	0.24	2.06	1.79	0.86	0.83	1.21	—	1.06	—
	XII 24	0.26	0.19	2.53	2.45	0.88	0.76	1.65	1.69	1.14	1.06
1963	I 14	0.27	0.13	2.29	2.31	0.73	0.71	1.56	1.60	1.07	1.02
	II 4	0.31	0.24	2.01	2.44	0.72	0.84	1.29	1.69	0.98	1.01
	II 25	0.35	0.33	2.24	2.66	0.84	0.87	1.40	1.79	1.07	1.15
	III 5	0.34	0.34	2.86	3.10	1.16	1.11	1.70	1.99	1.00	1.14
	III 15	0.25	0.25	2.54	2.85	1.07	1.04	1.47	1.81	1.13	1.29
	III 25	0.40	0.29	3.36	2.88	1.50	1.25	1.86	1.64	1.13	1.00
	IV 8	0.39	0.22	2.59	2.87	1.75	1.40	1.34	1.48	0.96	0.73
	IV 18	0.22	0.27	3.61	3.68	2.26	2.13	1.34	1.55	0.64	0.76

Table II-1 Interrelations among nitrogen, phosphorous, and carbohydrate contents-3.

Date		St/n		Su/n		RS/n		n/p	
		N.	L.	N.	L.	N.	L.	N.	L.
1962	IV 12	4.29	3.53	3.27	2.72	2.27	1.79	14.14	14.33
	IV 21	5.23	4.83	3.20	3.10	2.50	2.24	14.81	9.35
	V 2	1.75	0.79	—	0.87	—	0.60	12.41	9.85
	V 12	3.53	4.00	2.87	2.90	1.67	2.00	5.77	4.76
	V 22	4.30	—	—	—	1.20	—	10.00	—
	VI 2	14.40	—	10.40	—	5.60	—	3.85	—
	VI 12	14.57	—	9.57	—	4.29	—	11.67	—
	VI 22	3.90	—	1.81	—	1.19	—	9.13	—
	VII 2	4.63	5.67	4.37	5.92	2.68	4.08	11.88	6.32
	VII 12	2.76	6.44	3.19	5.56	1.67	3.00	11.05	3.46
	VII 23	3.68	6.70	3.58	4.20	2.53	2.80	7.04	6.67
	VIII 2	1.63	3.11	0.77	0.95	0.51	0.84	9.21	12.67
	VIII 13	2.41	3.39	2.03	2.50	1.28	1.72	7.63	8.18
	VIII 23	1.73	2.71	1.38	2.33	0.70	1.33	9.52	7.00
	IX 3	1.67	2.11	2.48	4.43	0.91	1.32	11.22	7.00
	IX 13	2.96	3.21	2.64	3.32	1.32	2.11	8.48	4.04
	X 2	1.69	2.96	1.59	2.63	0.92	1.42	9.27	5.71
	X 22	2.85	2.44	2.62	2.79	1.41	1.50	7.23	6.18
	XI 12	5.35	4.71	4.95	3.76	3.70	3.29	5.41	4.12
	XII 5	2.75	3.38	3.81	—	3.38	4.67	6.04	3.48
	XII 24	3.38	4.05	6.38	9.00	4.41	5.64	4.60	2.97
1963	I 14	2.68	5.31	5.68	11.88	3.92	7.56	12.33	8.00
	II 4	2.30	3.10	4.12	7.07	3.12	4.21	8.27	4.75
	II 25	2.43	2.67	4.05	5.50	3.11	3.53	7.55	4.92
	III 5	3.53	3.23	4.94	5.77	2.90	3.30	6.46	5.88
	III 15	4.26	4.16	5.81	7.24	4.48	5.16	5.74	3.21
	III 25	3.72	4.36	4.62	5.73	2.79	3.50	8.53	4.89
	IV 8	4.52	6.32	3.45	6.68	2.48	3.32	5.74	3.17
	IV 18	10.12	7.76	6.00	5.65	2.88	2.76	3.47	3.21

Table II-1 Interrelations among nitrogen, phosphorous, and carbohydrate contents-4.

Date		p/P		C/P		N/P		St/P	
		N.	L.	N.	L.	N.	L.	N.	L.
1962	IV 12	0.40	0.43	43.06	38.43	22.08	22.29	24.44	21.71
	IV 21	0.30	0.40	37.87	29.49	18.43	18.33	23.48	17.95
	V 2	0.22	0.48	—	7.87	17.56	16.03	4.81	3.76
	V 12	0.31	0.24	11.57	7.84	13.01	11.36	6.39	4.55
	V 22	0.16	—	—	—	14.92	—	7.05	—
	VI 2	0.22	—	21.38	—	8.62	—	12.41	—
	VI 12	0.15	—	42.25	—	12.25	—	25.50	—
	VI 22	0.43	—	22.64	—	11.51	—	15.47	—
	VII 2	0.37	0.37	39.77	26.73	11.16	11.73	20.47	13.08
	VII 12	0.50	0.57	32.89	23.48	15.53	10.22	15.26	12.61
	VII 23	0.49	0.36	25.09	25.95	11.45	10.71	12.73	15.95
	VIII 2	0.70	0.28	15.56	14.26	13.89	13.15	10.56	10.93
	VIII 13	0.42	0.42	14.33	20.00	10.67	12.08	7.78	11.51
	VIII 23	0.53	0.54	15.70	18.93	13.16	11.96	8.73	10.18
	IX 3	0.52	0.59	24.18	26.91	16.08	12.65	9.75	8.68
	IX 13	0.47	0.66	22.43	17.46	15.29	12.25	11.86	8.59
	X 2	0.44	0.46	13.36	14.57	7.44	8.48	6.88	7.72
	X 22	0.55	0.65	21.36	21.19	11.86	9.88	11.28	9.88
	XI 12	1.45	0.59	25.12	20.46	12.20	10.11	13.05	11.38
	XII 5	0.51	0.59	20.19	1.509	9.81	8.45	8.46	6.98
	XII 24	0.52	0.59	23.39	22.96	9.26	9.36	8.10	7.12
1963	I 14	0.29	0.19	29.43	26.44	12.86	11.44	9.43	8.17
	II 4	0.30	0.45	15.95	21.85	7.92	8.96	5.72	6.67
	II 25	0.43	0.58	20.87	23.33	9.30	8.76	7.83	7.62
	III 5	0.29	0.45	15.67	23.89	5.49	7.70	6.34	8.58
	III 15	0.40	0.49	23.25	18.04	9.15	6.33	9.83	6.58
	III 25	0.47	0.43	33.15	21.14	9.86	7.33	14.79	9.14
	IV 8	0.45	0.48	20.58	19.60	6.67	6.83	11.67	9.52
	IV 18	0.45	0.49	25.14	20.92	6.97	5.69	15.78	12.11

Table II-1 Interrelations among nitrogen, phosphorous, and carbohydrate contents-5.

Date			Su/p		RS/p		St/p		Su/p		RS/p	
			N.	L.	N.	L.	N.	L.	N.	L.	N.	L.
1962	IV	12	18.61	16.71	12.92	11.00	60.69	50.67	46.21	39.00	32.07	25.67
	IV	21	14.38	11.54	11.24	8.33	77.41	45.16	47.41	29.03	37.04	20.97
	V	2	—	4.11	—	2.84	21.72	7.79	—	8.53	—	5.88
	V	12	5.18	3.30	3.01	2.27	20.38	19.05	16.54	13.81	9.62	9.52
	V	22	—	—	1.97	—	43.00	—	—	—	12.00	—
	VI	2	8.97	—	4.83	—	55.38	—	40.00	—	21.54	—
	VI	12	16.75	—	7.50	—	170.00	—	111.67	—	50.00	—
	VI	22	7.17	—	4.72	—	35.65	—	16.52	—	10.87	—
	VII	2	19.30	13.65	11.86	9.42	55.00	35.79	51.88	37.37	31.88	25.79
	VII	12	17.63	10.87	9.21	5.87	30.53	22.31	35.26	19.23	18.42	10.38
	VII	23	12.36	10.00	8.73	6.67	25.93	44.67	25.19	28.00	17.78	18.67
	VIII	2	5.00	3.33	3.33	2.96	15.00	39.33	7.11	12.00	4.74	10.67
	VIII	13	6.56	8.49	4.11	5.85	19.42	27.73	15.53	20.45	9.74	14.09
	VIII	23	6.95	8.75	3.54	5.00	16.43	19.00	13.10	16.33	6.67	9.33
	IX	3	14.43	18.24	5.32	5.44	18.78	14.75	27.80	31.00	10.24	9.25
	IX	13	10.57	8.87	5.29	5.63	25.15	12.93	22.42	13.40	11.21	8.51
	X	2	6.48	6.85	3.76	3.70	15.64	16.90	14.73	15.00	8.55	8.10
	X	22	10.35	11.31	5.58	6.07	20.64	15.09	18.94	17.27	10.21	9.27
	XI	12	12.07	9.08	9.02	7.93	28.92	19.41	26.76	15.49	20.00	13.53
	XII	5	11.73	—	10.38	9.66	16.60	11.74	23.02	—	20.38	16.23
	XII	24	15.29	15.84	10.58	9.92	15.56	12.03	29.37	26.76	20.32	16.76
1963	I	14	20.00	18.27	13.81	11.63	33.00	42.50	70.00	95.00	48.33	60.50
	II	4	10.23	15.19	7.75	9.04	19.04	14.75	34.04	33.61	25.77	20.00
	II	25	13.04	15.71	10.00	10.10	18.37	13.11	30.61	27.05	23.47	17.38
	III	5	9.33	15.31	5.49	8.76	21.67	19.02	31.88	33.92	18.75	19.41
	III	15	13.42	11.46	10.34	8.16	24.47	13.33	33.40	23.21	25.74	16.54
	III	25	18.36	12.00	11.10	7.33	31.76	21.33	39.41	28.00	23.82	17.11
	IV	8	8.92	10.08	6.42	5.00	25.93	20.00	19.81	21.17	14.26	10.50
	IV	18	9.36	8.11	4.50	4.31	35.10	24.91	20.82	18.11	10.00	8.87

Remarks;

St: Starch, C: Total carbohydrates, Su: Total sugars, RS: Reducing sugars, N.: Normal shoot, L.: Lammas shoot, n: Water soluble nitrogen, N: Total nitrogen, P: Total phosphorous, p: Water soluble phosphorous.

The p/P ratios fluctuated in the range from 0.15 in mid-June to 0.70 in early August. These fluctuations were more extreme as compared with that of n/N ratios and the small changes occurred repeatedly even in the period before and after bursting stage. There was a remarkable decrease to the extent of 0.3 from early to mid-August and a constant value of about 0.50 in the period from late August to mid-December, and then the decreasing trend of over 0.2 from mid-December to mid-January, while there was a constant value in n/N ratios in that period.

St (Starch)/C and Su/C ratios kept 0.5 on the average throughout the year. These two ratios exhibited fairy large changes in the growing season and kept a nearly constant value of 0.5 from mid-September to mid-November. Then, the former's ratio decreased slowly to a minimum of 0.31 in mid-January in correspondence with the increase of the latter's ratio, because of the increase of total sugar concentration in comparison with the constant starch content. The increasing trend in the former's ratio after mid-January was gradual and took a value of over 0.50 when April began.

RS (Reducing sugars)/Su ratios were over 0.5 throughout the year, excepting the low ratios in mid-June (0.45) and in early September (0.37), and a maximum (0.89) in early December. Reducing and total sugar concentrations in the dormant season showed a value about twice as high as those in the growing stage ; hence, RS/C and Su/C ratios increased from autumn to winter, particularly the RS/C ratio nearly double. RS/C ratios progressed nearly in parallel to Su/C ratios, on the whole, but was inversely symmetrical to the curve of St/C ratio.

As mentioned previously, starch content increased temporarily before bursting. Accordingly, RS/St ratio dropped rapidly at that time. And also, this ratio increased in the former part of the dormant season, this being mostly due to the increasing of reducing sugar concentration. Su/St ratio had sharp fluctuations in mid-July and in early September.

C/N ratio varied in correspondence with the variation of starch contents ; it showed fairly large changes in the early growing season and kept increasing gradually from early August to early March in accord with starch contents. The minimum value was 0.89 in mid-May. Su/n ratio, in any stage, varied more than the changes in C/N ratio and their pattern resembled the height growth curves in the growing period. Because total sugars increased markedly in the early part of dormancy, this pattern was swayed by the changes in total sugars. And also, the Su/n ratio changed, on a small scale, in resemblance to the variation in RS/n ratios.

The ratios of C/P showed much higher values in the vigorous stage of growth than those of C/N ratios, because total carbohydrates had an increasing trend in spite of the decrease of total phosphorous at that time. These trends were also shown more noticeably in Su/p ratios.

The variation in N/P ratios was influenced mostly by the seasonal cycle of nitrogen concentration because nitrogen was much larger in quantity than phosphorous, and ranged within the values from 5.49 to 22.08. In the growing season, their ratios took a value of approximately 10. However, they had the largest value in April, 1962, and had the lowest value at that time in 1963. The n/p ratio was estimated usually under 15, and tended to keep the value at approximately 10 in the growing stage, though it repeated the fluctuations.

Chapter 6. Discussion.

GIBBS[27] stated that the deciduous species had a minimum moisture content in September or October and an increasing trend after leaf-fall, while the evergreen species showed a decreasing trend in winter, and that the latter was more variable than the former in the seasonal variation of moisture contents. And also, he reported that a maximum moisture content was recorded in late September for *Pinus Strobus*, in late June for *Larix laricina*, and in November for *Tsuga canadensis*. Thus, seasonal variations of moisture contents differs by species[55], varieties and strains[104]. In Todomatsu, it was shown that they obtained a higher value in the growing season, a maximum in mid-May, and decreased in winter. In addition to these trends, there were two particular phases. The first phase is that, in the growing season, two peaks were obtained in mid-May and in mid-August. ACKLEY's results[1] for Bartlett pear trees from May 15th to August 28th and also SAKAI's study[106] for *Morus bombysis* KOIDZ. (Kuwa) made no statement of this phase, while OKAZAKI[76] figured the second peak in mid-September for *Cryptomeria japonica* D. DON (Sugi). Root elongation of Todomatsu seedlings began vigorously in late June, decreased slowly in late July, and developed again in late August of early September. Then, the second peak in moisture contents corresponded to the latter's root development, as well as the beginning of early rapid growth. It seems that, in Sugi, its second peak occurs later than that of Todomatsu, because the former has a longer growing season than the latter.

Another particular phase is that the rapid increase of moisture contents before bursting was presented in late April in 1962, but, in 1963, occurred temporarily in early February. It is presumed that the rapid increase of moisure contents in February, 1963 was caused by the abnormal weather conditions as shown in table II-2. Concerning the seasonal variations of the other elements, the influence of the weather was observed in the dormant season from 1962 to 1963. And also, according to the variations of maximum, and minimum temperatures, and snowfall in the seedlings sampled in the nursery as shown in figure II-6, the second particular phase was caused mostly by snowfall instead of temperature.

Residue contents progressed reversely, on the whole, in correspondence to moisture contents.

As mentioned in the experiment, part I, the demand for nitrogen was in close relation to growth ; hence, nitrogen concentration varied in accordance with growth cycle. A maximum value of nitrogen concentration was in late April

Table II-2 The average temperatures, minimum and maximum snowfall in every ten days in Sapporo.

Month	Decade	1941–1950 Mean (°C)	1962–1963 Mean (°C)	Snowfall (1952–1963) Minimum (cm)	Snowfall (1952–1963) Maximum (cm)
October	early	12.4	11.2	—	—
〃	middle	10.8	10.1	—	—
〃	late	8.1	7.9	—	—
November	early	6.0	9.0	—	—
〃	middle	2.8	3.9	—	—
〃	late	1.4	−2.1	29	35
December	early	−1.5	0.4	9	25
〃	middle	−3.1	−0.1	11	19
〃	late	−4.8	−2.9	9	30
January	early	−5.8	−3.5	9	19
〃	middle	−4.8	−4.4	16	48
〃	late	−5.0	−6.0	35	53
February	early	−5.1	−4.0	34	43
〃	middle	−5.3	−3.9	37	69
March	early	−2.6	−1.4	26	45
〃	middle	−1.3	2.0	—	24
〃	late	0.2	2.6	4	8

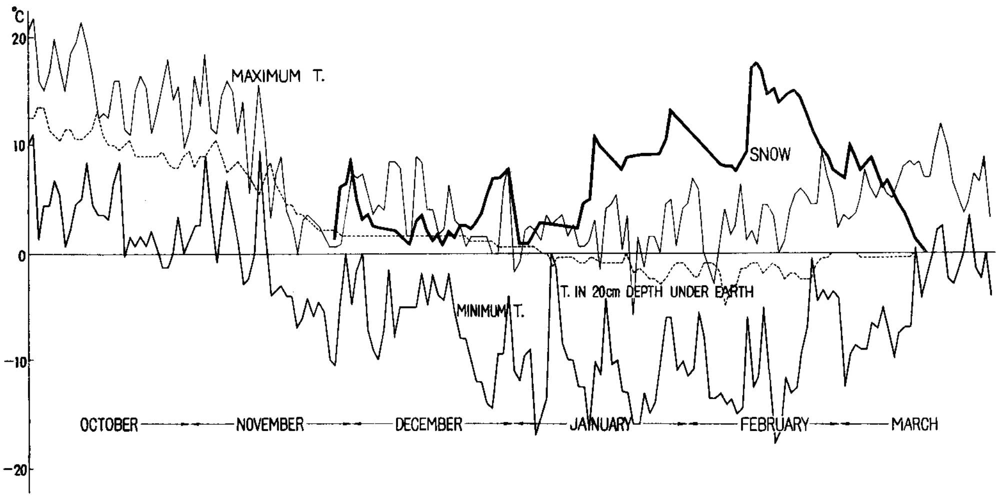

Figure II-6. Variation of maximum temperature, minium T., T. in 20 cm depth underearth, and height of snowfall in the period from October, 1962 to March, 1963 at the Sapporo Nursery of the College Experimental Forests, Hokkaido University.

for Todomatsu, at the same time for apple leaves[147], and for white spruce 2-year-old seedlings[4], while it was in early June for potato [133], on a dry weight basis. TSUDA's studies[152,153] for Todomatsu and TOCHIAKI's experiment[148] for *Abies homolepis* (Urajiromomi) resulted in a phase similar to the writer's pattern. However, these results were examined for total nitrogen contents, except for that of the potato. In the seasonal variation of water soluble nitrogen concentration of Todomatsu seedling, a maximum occurred in early October, and any rapid increment in the period before bursting was not presented. It seems that, in Todomatusu, nitrogen is reserved in insoluble forms and therefore water soluble nitrogen is kept under 0.50% concentration throughout the year.

Total nitrogen increased gradually from early September to early February. TSUTSUMI[157] reported that, in Akamatsu (*Pinus densiflora*), 70–80% of the current growth was produced during the period from April to May, and the expenditure of nitrogen during that time was covered by the reserves in the previous year, especially in the period from October to November. This behavior was similar in Todomatsu. LEYTON[60] examined the relation between height growth and nitrogen concentration of new leaves of sitka spruce and reported that the optimum concentration of nitrogen to growth was 1.6% on a dry weight basis. This optimum value for sitka spruce corresponded almost to the value in the vigorous growing stage of Todomatsu seedling, at a minimum level.

From May to June, water soluble nitrogen concentration took the lowest value (0.10%), and fluctuated more extremely in the growing season in contrast to the narrow range of variation of total nitrogen. SIMINOVITCH & BRIGGS[124] stated that water soluble protein contents of Black Locust tree increased remarkably in winter, and SAKAI[105], for Kuwa, and PARKER[83], for *Hedera helix*, also signified this trend. Although Todomatsu had often values over 1.0% of water soluble nitrogen content in the former part of the dormant season, thereafter they decreased during October and kept about 0.5%, and presented no increasing trend.

According to the results in phosphorous concentrations, total phosphorous varied more repeatedly than water soluble phosphorous in contrast to the relation of water soluble nitrogen to total nitrogen. Namely, inorganic phosphorous was kept constant. As most substances can be utilized only in phosphate compound forms by the plant and are changed into other forms by enzymes as soon as they became a phosphate compound, it seems that the extreme changes of total phosphorous concentrations were caused by organic phosphorous variation. The decreasing trend of phosphorous concentration in spring begans more lately than the other nutrient elements, and also phosphorous concentration increased lately than those as stated in part I. MÁRRE et al[61] recognized this phase in tomato ovaries. Their patterns resembled those of seasonal variation in nitrogen concentration, and they nearly agreed with ASAHI's[6] and TSUDA's[152,153] results for Todomatsu, and TOCHIAKI's result[148] for Urajiromomi, though, in the latter's result, the decrease in the growing season proceeded till early July. Phosphorous concentration was much lower in quantity as compared with nitrogen. Generally, the phosphorous removal from the soil was the lowest, nitrogen the highest, and potassium the intermediate for most species[170]. But, phosphorous concentrations were influenced slightly by weather conditions.

Seasonal variation of carbohydrates have two important significations, one in the early growing stage and the other in the hardening process. In the former, as stated in experiment, part I, early growth of Todomatsu depends on either reserve foods in the previous year, or the products by photosynthesis at that time, and in the latter, according to whatever pattern carbohydrates behave, Todomatsu, with advancing hardiness, reacts also.

Of course, the amount of carbohydrates varies with parts, ages, and growing stages of trees, hence the seasonal variation of the carbohydrate concentration differs in accordance with the parts of a tree used as the experimental material. For example, HEPTING[35] reported that, in April the reserve carbohydrate amount of shortleaf pine (*Pinus echinata* MILL.), including starch, sugars, and their intermediate products, was 16.6% in the needles, 12.4% in the stem bark, and 2.4% in the stem wood on a dry weight basis. And also, the soluble carbohydrates, after hydrolysis by 3% hydrochloric acid, in TAGUCHI's study[135], using Kuwa graft-seedling, was 190.6 in the bark and 129.2 in the wood of the shoots, 250.8 in the bark and 152.3 in the stem wood of the root stock, 328.9 in the root-bark and 185.9 mg/cm^3 in the root-wood. In this experiment, the writer determined simultaneously the reducing sugars, total sugars, and starch contents of one year's lateral shoot containing needles and buds. He could not use the terminal shoot as the material, becauses, in most cases, the seedling with lammas shoots has none.

In the preceding HEPTING's paper, the carbohydrate fluctuations were limited within about 2% in stem wood and 7% in stem bark on a dry weight basis. The writer's experiment in Todomatsu showed that the fluctuations of carbohydrate contents during the dormant season from 1961 to 1962 were within 3.1% in total carbohydrates, 2.8% in total sugars, 1.8% in reducing sugars, and 0.9% in starch on a dry weight basis. On a fresh weight basis, each fluctuation was within 1.5, 1.2, 0.8, and 0.3%. Furthermore, during the period from April, 1962 to April, 1963, these values were 4.8, 5.1, 4.2, and 4.0% on a dry weight basis, 2.5, 1.7, 1.3, and 1.7% on a fresh one. In PARKER's study[81] in the bark of *Pinus Strobus*, sugar concentration increased nearly 1.5% in the period from August to December, and this increment value agreed approximately with that of Todomatsu.

HEPTING's result indicated that reserve carbohydrate contents in the stem showed a small number of fluctuations; they showed higher contents from March to June that at any other stage, and were nearly constant from July to March of the following year. On a dry weight basis, Todomatsu (Figure II-5. 1 (B)) tended to follow a pattern similar to the seasonal variation of shortleaf pine in carbohydrates, but the former's concentration increased noticeably from autumm to winter. SIMINOVITCH et al.[125] pointed out maximum carbohydrate contents in the period from October to November for Black Locust tree, and SABRON[94] stated that a maximum of total reserve carbohydrate contents was obtained in the leaf-fall stage for a deciduous species and in spring before bursting for an evergreen species. Todomatsu had a maximum in mid-April in agreement with SABRON's result for an evergreen species.

Increasing trend of total carbohydrates before budding was largely due to the increase of starch as stated in experiment, part I, and that, in the dormant season, it was mostly due to total sugars. RUTTER[93] stated that, in *Pinus sylvestris*, starch content was high in April and early May, fell during late May and June to a low level, recoverd somewhat in August, and fell again in September. But, in Todomatsu, the recovering of starch in the growing season began already in June, probably due to the difference in the onset of its growing period.

Total and reducing sugar concentrations varied approximately in parallel, and they took lower values in the growing season and higher in the dormant season. They increased from September to mid-December, particularly, from late November to mid-December, and it was difficult to recognize the peak of starch fluctuation at that season on a fresh weight basis. But, on a dry weight basis, the starch fluctuation reached a peak in late October and took a decreasing trend in the period when sugar increased and thereafter, in mid-December, increased somewhat again. Though this pattern varied more or less according to the weather conditions of different years, similar behavior was shown in the secondary experimental period, and starch contents kept nearly constant. It is well known that the increment of sugars, especially sucrose, from autumn to winter is due to starch hydrolysis; hence starch decreases with the increasing trend of sugar in that season. For example, WORLEY[168] reported that the relative amount of starch decreased with a decrease in temperature and increased again with a return to the higher temperature for *Pinus ponderosa* and *Pseudotsuga taxifolia*. Concerning the 1961–1962 dormant season in this experiment, the fluctuations in total sugars and reducing sugars were larger than that in starch, but the decrease of starch was much smaller in quantity as compared with the sugar increasing ratio, and thereafter starch increased again to the maximum level. Moreover, the results of Todomatsu seedling in the 1962–1963 dormant season indicated that, under favorable conditions, the evergreen tree species is able to cover the expenditure of the reserves, especially starch, by the products of photosynthesis at that time. GIBBS[26] claimed that the winter increase in sucrose does not account for all the missing starch, and WILCOX[166] suggested that this fraction is used in phloem differentiation. It seems that, if the products by photosynthesis in winter is equal to the expenditure for respiration, the decrease of starch content may mostly correspond to the increase of sugars and that the relation between sugars and starch in a living tree is liable to vary with the weather conditions, and the writer could not confirm clearly any such results from preceding reports.

According to OKAZAKI [75], sugar concentration in one year's leaves of Todomatsu seedling increased more remarkably in winter than in summer and especially mono-saccharide concentration was much higher in winter in comparison with Jezomatsu (*Picea Jezoensis* CARR.). On the other hand, SAKAI[110] established three fundamental types; viz. reducing sugar, sucrose, and intermediate types according to the ratios of the carbohydrate constitution to the woody plants in winter, and he found that Todomatsu belongs to the sucrose type. In SAKAI's experiment, the leaves were also used as samples. In this experiment of one year's shoot, total and reducing sugars showed a similar increasing trend from autumn to winter, and this increasing trend was more remarkable in total sugars than in reducing sugars, and also differences between both sugars grew much larger from late October in 1961 or early December in 1962. Namely, the remaining sugars (=non-reducing sugars), deducting reducing sugars from total sugars, (SAKAI recognized a large amount of this remainder as sucrose)[109], went up markedly with the advancing hardiness though the amount of reducing sugars was much larger than that of the remainder.

According to FABRICIUS' study[20] on Norway spruce (*Picea excelsa*) and PRESTON and PHILLIPS' statement[87] on the shortleaf pine, it was shown that the transformation of starch in the older stem is not so great as in the younger stem. Moreover, SATOO and TAKEGOSHI[114] reported that starch fluctuation in the new shoot of *Quercus acutissima* (Kunugi), a deciduous species, was six or seven times as large as that of *Q. myrsinaefolia* (Shirakashi), an evergreen species, throughout the year. These results show that one year's shoot of the evergreen species has a very narrow range in the variation of starch contents. Starch contents of the new shoot in Todomatsu seedling varied within 0.3% on a fresh weight basis in the first dormant season from 1961 to 1962 and, in the next dormant season, was nearly constant. Black Loust tree had two peaks of starch contents in early May and October[125], and also Kuwa showed two peaks similar to those in late April and mid-September[105]. However, in Todomatsu, the second peak after September could not be recognized distinctly. Thus, there were clearly different modes in the variations of starch contents between deciduous and evergreen species. KRAMER and KOZLOWSKI[58] presumed that the evergreen species was more dependent on current photosynthesis for shoot growth in the spring than on stored food, because the seasonal changes of carbohydrate concentration in the evergreen species generally show much smaller fluctuations than in the deciduous species, and that the latter accumulates them during the summer, but the former accumulates them during winter, because of reduced respiration and cessation of growth at that saason.

In Todomatsu, as stated previously, nitrogen, phosphorous, and carbohydrate concentrations increased distinctly in winter, and, at least, its early growth was mostly dependent on the reserves from the previous year.

Su/St ratios varied in correspondence to the growth curve. In carbohydrate metabolism, the relation between growth and reserve food was presented in the balance between photosynthesis and expenditure resulting from respiration and assimilation. The above ratio kept mostly under 1.00 in the growing season and, in most cases, it was influenced by fluctuation of total sugars, because starch was kept changeless. The decreasing trend in the growing season was also presented in ratios of RS/C, Su/C, n/N, and p/P.

N/P ratio took 22.08 at a maximum and 5.49 at a minimum and was nearly 10 in the growing season. And also n/p ratio was 3.47 at a minimum and did not exceed 14.81. PREVOT and OLLAGNIER[83] obtained 16 as N/P ratio in leaves for maximum growth on oil palm, and LEYTON[60] examined the relation between growth and N/P ratio in water culture and got 10 as the optimum value for sitka spruce. The values of Todomatsu in N/P ratio during the growing season agreed fairly with Leyton's result for sitka spruce. As n/p ratio between two more active element than total nitrogen and phosphorous tended to keep approximately 10 in the growing season, it is presumed that this ratio suggests the optimum value for growth of Todomatsu seedling, and, accordingly, that the balance ratio among nutrient elements contained in normal growth seedling can be applied for the determination of the balance among fertilization materials.

The p/P ratio dropped largely in mid-January as well as in the vigorous growing stage though n/N ratio had a small fluctuation at this time. It seems that the p/P ratio in dormant stage was mostly due to respiration in accord with the abnormal metabolism in trees because, in this period, it is impossible that photosynthesis and assimilation increase as they do in the vigorous season.

It was interesting that C/N ratio varied mostly in correspondence to the variation of starch contents though the writer could not confirm that in this paper. And also, the larger amount of C/N ratio was obtained in the period from June to July, because, at that time, the products by photosynthesis increased greatly in spite of the following decrease in nitrogen concentration. SAITO et al.[93] reported that C/N ratio in the optimum grafting stage of Sugi was 2.0 (N-0.8, C-1.6). In 1962, a similar ratio was also given for Todomatsu in mid- or late April before bursting but not at that time in 1963, since it was an abnormally warm winter.

Chapter 7. Summary.

In the period from September, 1961 to April, 1963, the typical pattern of the variation in moisture, residue, total and water soluble nitrogen, total and water soluble phosphorous, total carbohydrates, total and reducing sugars, and starch contents was sought for 5- or 7-year-old seedlings of Todomatsu, and the following results were obtained;

1. Moisture contents increased rapidly in late April, reached a maximum at bursting stage, then kept their values over 70% till the second peak in August

and decreased slowly in the dormant season. Residue contents took a minimum at the maximum stage of moisture contents and increased gradually until they reached 23.4%.

2. Total nitrogen concentration had a maximum in late April before bursting as same as moisture, kept approximately 0.5% in the growing season and increased slowly after October. Water soluble nitrogen concentration tended to show a phase similar to total nitrogen but it changed rather more severely than the latter and, in the dormant season, did not increase as much as the latter.

3. Total and water soluble phosphorous concentrations were 0.17% and 0.06% even at a maximum. Generally, their change was similar to that of nitrogen, but, in detail, total phosphorous varied more severely than water soluble phosphorous.

4. A maximum value of total carbohydrate concentration obtained in mid-April was due mainly to the increase of starch. On the whole, the variation of total and reducing sugar concentrations showed a depressed curve; they were larger in dormant and lesser in the growing season. Starch kept about 1.0%, excepting the fluctuation in early spring.

5. From autumn to winter, sugars increased; reducing sugar concentration increased remarkably in autumn and non-reducing sugar concentration went up rapidly from November to December or mid-January. However, the reducing sugars usually account for a large part of sugars all the year round.

6. Increasing trend of sugar concentration was related largely by the weather conditions, especially the snowfall.

7. In the balances among the nutrient elements, it was shown that n/N ratio took about 0.10 at the minimum in growing stage and the decreasing pattern in spring was also distinctly presented in p/P and Su/St ratios.

8. N/P ratio took approximately 10 in the growing season in agreement with Leyton's result for sitka spruce. And also, n/p ratio held the value under 15 the year through and tended to keep about 10 in the growing season.

Part III. Physiological quality of the seedling with lammas shoots.

Chapter 1. Special features in lammas season.

1) Variation of each element.

Sampling and chemical analysis of lammas shoot began in early July, when the sympton of lammas shoot growth could be recognized clearly as distinguished from the normal shoot growth. Variations of all elements of lammas shoot were presented graphically in figure III–1. 1~III–1. 9 in comparison with those of normal shoot in the growing season.

Moisture content of lammas shoot in lammas stage, excepting that in mid-August, kept much higher ratio than that of normal shoot. Increasing trend of moisture contents in lammas stage started from early July in both shoots, and continued till early August in lammas shoot while the normal shoot showed

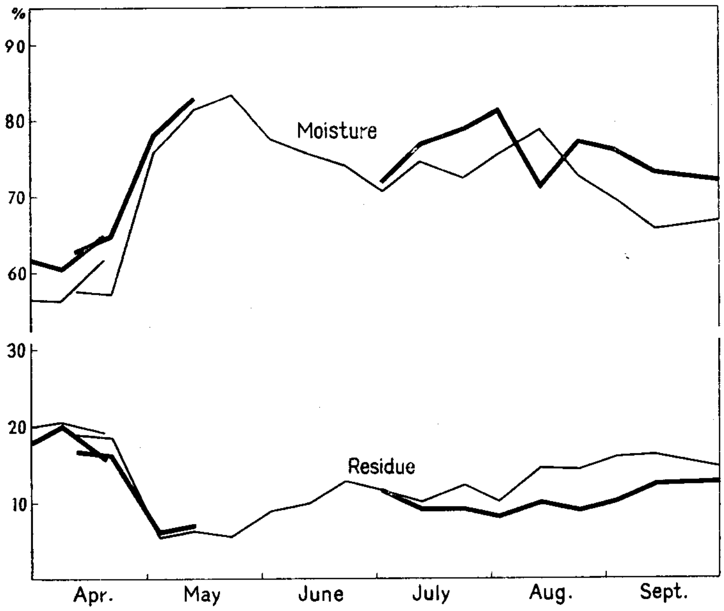

Figure III-1. 1 Variations of moisture (on a fresh weight basis) and residue (on a dry weight basis) contents of one year's shoots in *Abies sachalinensis* MAST. (Todomatsu) seedlings with lammas shoots (thick line) in comparison with normal seedlings (thin line) during growing season. (7-year-old, 1962)

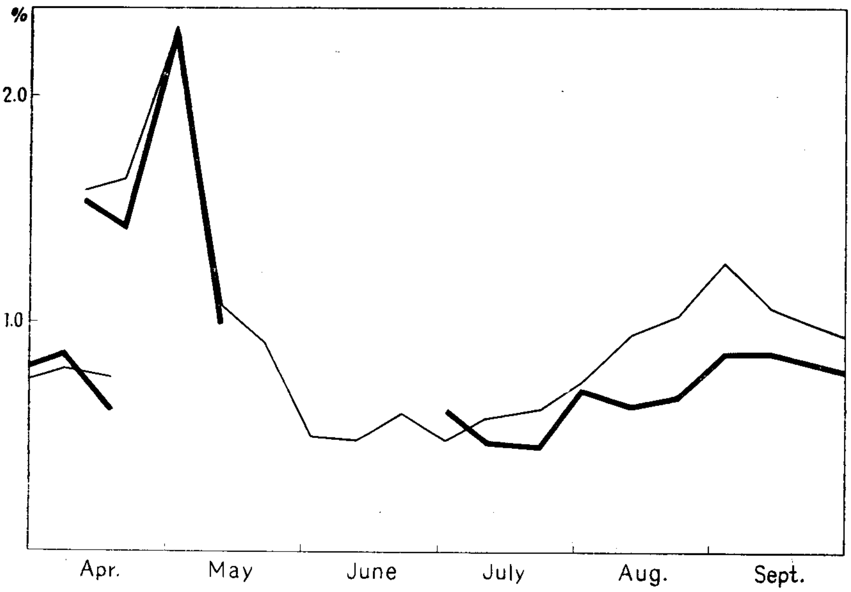

Figure III-1. 2 Variations of total nitrogen concentrations of one year's shoots in *Abies sachalinensis* MAST. (Todomatsu) seedlings with lammas shoots (thick line) in comparison with normal seedlings (thin line) during growing season. (7-year-old, 1962) a temporary decrease in mid-July. The maximum value in early August was nearly as large as that in early growing stage. Concerning the period from late summer to autumn, moisture content changed into the decreasing trend from the above-mentioned maximum value in early August, reached a minimum in mid-August, and, after a slight increase of 5% in late August, continued the decreasing trend. On the other hand, normal shoot reached a second higher peak in mid-August and thereafter decreased till mid-September.

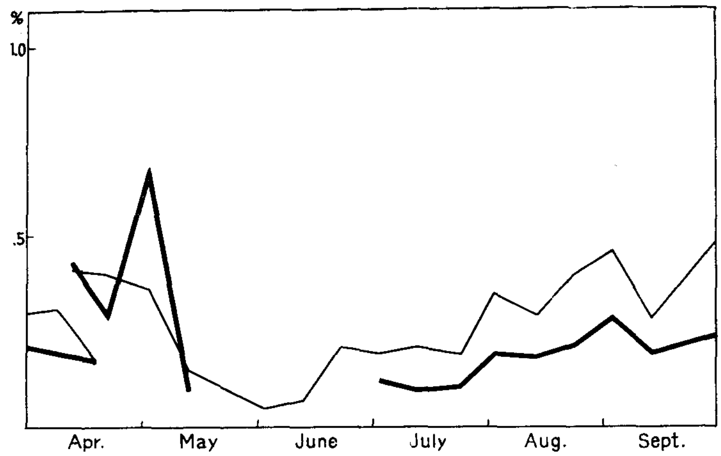

Figure III-1.3 Variations of water soluble nitrogen concentrations of one year's shoots in *Abies sachalinensis* MAST. (Todomatsu) seedlings with lammas shoots (thick line) in comparison with normal seedlings (thin line) during growing season. (7-year-old, 1962)

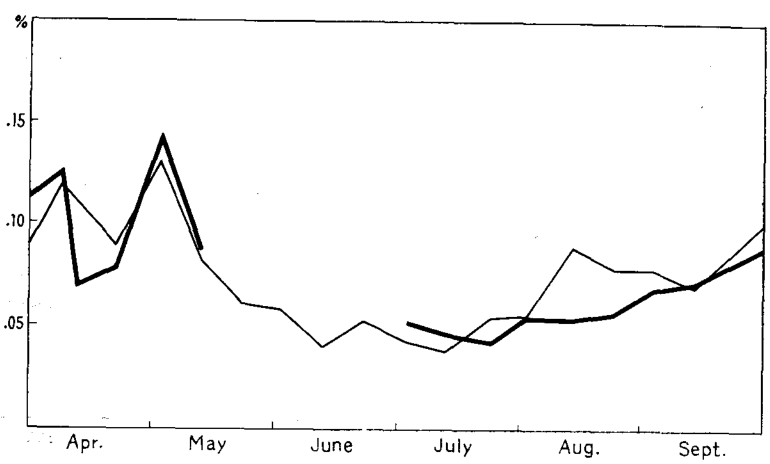

Figure III-1.4 Variations of total phosphorous concentrations of one year's shoots in *Abies sachalinensis* MAST. (Todomatsu) seedlings with lammas shoots (thick line) in comparison with normal seedlings (thin line) during growing season. (7-year-old, 1962)

Residue contents varied inversely to moisture contents showing a moderate curve. In early July, there was no difference between those of both shoots, their curve coincided in early July, and residue content of lammas shoot kept a lower value during lammas season approximately parallel with that of the normal one. The minimum level in that season was much higher than that in the early growing stage.

At the beginning of lammas growth, total nitrogen concentration was much higher in lammas shoot than that in normal one, but in mid-July, it was much less in the former than in the latter and this phase continued until the setting in of the dormant season. The total nitrogen concentration in normal shoot took a minimum value in early July and a slow increasing trend from that time on, while that of lammas shoot continued to decrease to a minimum in late July, and, in the period from late July to early August, showed a rapid increment, then kept almost changeless value during August, when the values were nearly

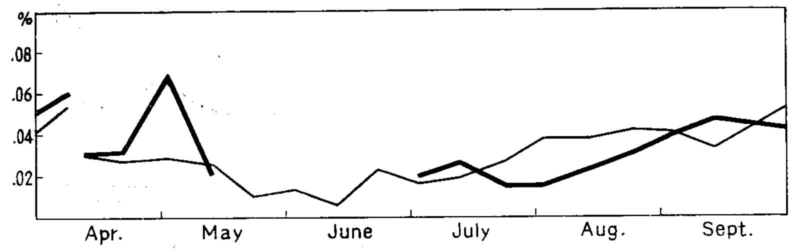

Figure III-1.5 Variations of water soluble phosphorous concentrations of one year's shoots in *Abies sachalinensis* MAST. (Todomatsu) seedlings with lammas shoots (thick line) in comparison with normal seedlings (thin line) during growing season. (7-year-old, 1962)

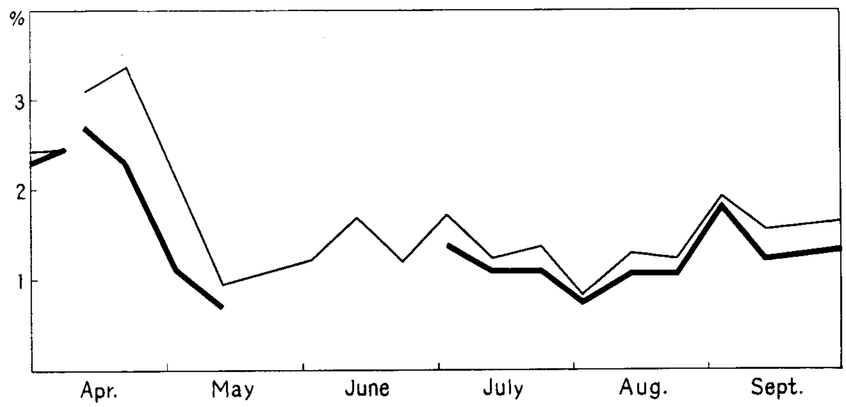

Figure III-1.6 Variations of total carbohydrate concentrations of one year's shoots in *Abies sachalinensis* MAST. (Todomatsu) seedlings with lammas shoots (thick line) in comparison with normal seedlings (thin line) during growing season. (7-year-old, 1962) the same as in the normal one, and thereafter took again an increasing trend till about mid-September. But, water soluble nitrogen concentration of lammas shoot was much lower (0.05%) than that of normal shoot already in early July, and the difference between both shoots remained about fixed during lammas season. Nitrogen concentration in lammas season had a different curve from those in the early growing stage; namely, the former changed on a small scale as compared with the latter, and at the beginning of the lammas growth, nitrogen concentration did not change so sharply as in the time before bursting in spring.

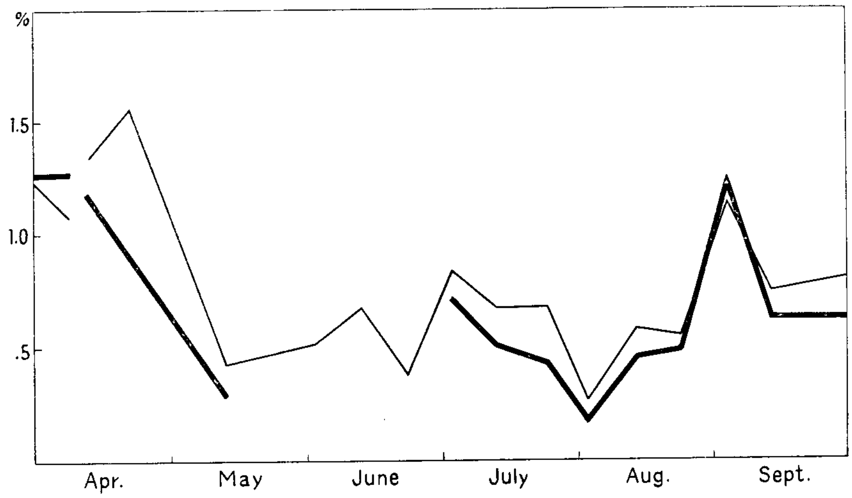

Figure III 1. 7 Variations of total sugar concentrations of one year's shoots in *Abies sachalinensis* MAST. (Todomatsu) seedlings with lammas shoots (thick line) in comparison with normal seedlings (thin l'ne) during growing season. (7-year-old, 1962)

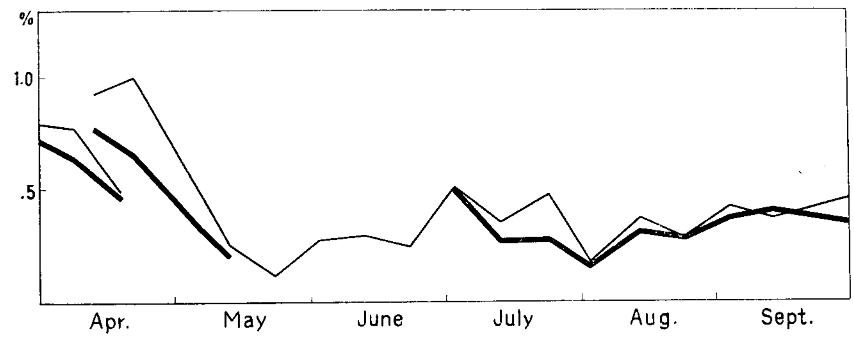

Figure III-1. 8 Variations of reducing sugar concentrations of one year's shoots in *Abies sachalinensis* MAST. (Todomatsu) seedlings with lammas shoots (thick line) in comparison with normal seedlings (thin line) during growing season. (7-year-old, 1962)

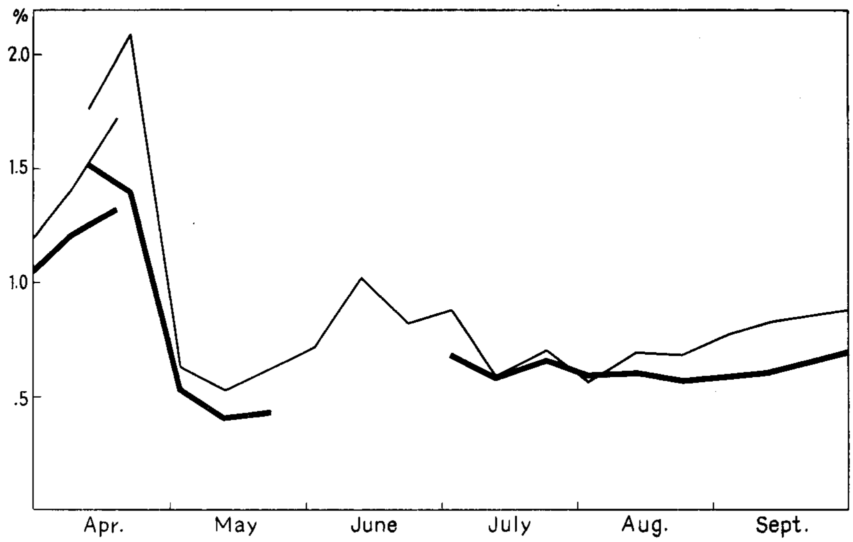

Figure III-1.9 Variations of starch contents of one year's shoots in *Abies sachalinensis* MAST. (Todomatsu) seedlings with lammas shoots (thick line) in comparison with normal seedlings (thin line) during growing season. (7-year-old, 1962)

Phosphorous concentration in that stage varied in a pattern similar to that of nitrogen concentration though it started to decrease in water soluble phosphorous concentration later (in mid-July) than soluble nitrogen, and the difference of total phosphorous and water soluble phosphorous concentrations between lammas and normal shoots started to occur in mid-July. The decreasing trend in water soluble phosphorous of lammas shoot turned to a moderately increasing trend in early August, while water soluble phosphorous of normal shoot began to increase about early July.

On the whole, total carbohydrate and total sugar concentrations in lammas shoot were more lower than those of the normal one, and they varied approximately parallel during the lammas season. It was a particularly noticeable that at that time, when totel sugars changed remarkably, starch remained changeless. Though reducing sugar concentration of the former took a much lower value than that of the latter, they progressed with similar values during August, and there was no difference between starch contents of both shoots during July. In early spring before bursting, total carbohydrates, total sugars, and starch of lammas shoot, in most cases, progressed at a lower level in parallel with those of the normal shoot, but these trends did not occur in lammas season.

2) Interrelations among nutrient elements.

Interrelations among nutrient elements were presented in table II-1. St/C ratio of lammas shoot showed an increasing trend already at the beginning of lammas season, and much higher value than that of normal shoot throughout that period, but the latter changed from decreasing to increasing in mid-July.

Then, Su/C ratios of both shoots had a nearly symmetrical value to St/C ratios. RS/C ratio of lammas shoot decreased more remarkably than the normal one in the pericd from early to mid-July, and Su/C ratio of the latter increased during that time while that of the former decreased. And then, in RS/C ratios, normal shoot varied rather more than lammas shoot, and St/C and Su/C ratios had much larger variation in the latter as compared with the former. The decreasing trend in Su/St and RS/St ratios occurred markedly in both shoots and began earlier in lammas shoot than in the normal one.

The n/N ratios of normal shoot reached the first peak in early July and then decreased during July, while, in early July, lammas shoot had 1/2 value of that of the normal one, and kept nearly constant till mid-July and then increased. This constant value of the latter in lammas season reached a much higher level than that of former in early growing season. Special features were that the values in p/P ratios of lammas shoot increased in a pattern similar to that of the normal one during about 15 days after bud swelling and that, in mid-July, they decreased rapidly in lammas shoot while the values of normal shoot were constant. Decrease of p/P ratio in lammas shoot followed during July and changed into increment as soon as the setting in of August, while that of normal shoot took a maximum value in early August. These objective changes in p/P ratios of both shoots in early August were shown in reverse phases in early May before bursting. The relation between p/P ratios of both shoots in early May resembled entirely that between n/N ratios of both shoots, but, in early April, these relations fitted only the normal shoot.

C/N ratio of lammas shoot had much lower values than that of the normal one at the beginning of lammas season, but this relation between both shoots changed reversely mid-July, because, presumably, the expenditure of nitrogen is much larger in the former as compared with the latter. Such difference between both shoots was also indicatd in the relation between Su/n ratios of those ; namely, Su/n ratio of lammas shoot kept much higher value than that of normal one during lammas season, especially at the beginning of that season.

In contrast to Su/n ratio, C/P and Su/P ratios in early July were much less in lammas shoot than that of normal shoot in resemblance to C/N and Su/n ratios in both shoots.

N/P ratio of lammas shoot held nearly 10 during lammas season the same as that in the early growing season while that of the normal shoot showed a much higher value during that time. Similarly, n/p ratio of the former in early July was approximately equal to that at the beginning of early growing season.

Chapter 2. Special features in dormant season.

1) Moisture, residue, nitrogen, and phosphorous contents (Figure III-2.1~III-2.5).

As stated previously, the seedlings with lammas shoots are damaged easily by abnormal weather and other causes, because their hardening periods are very

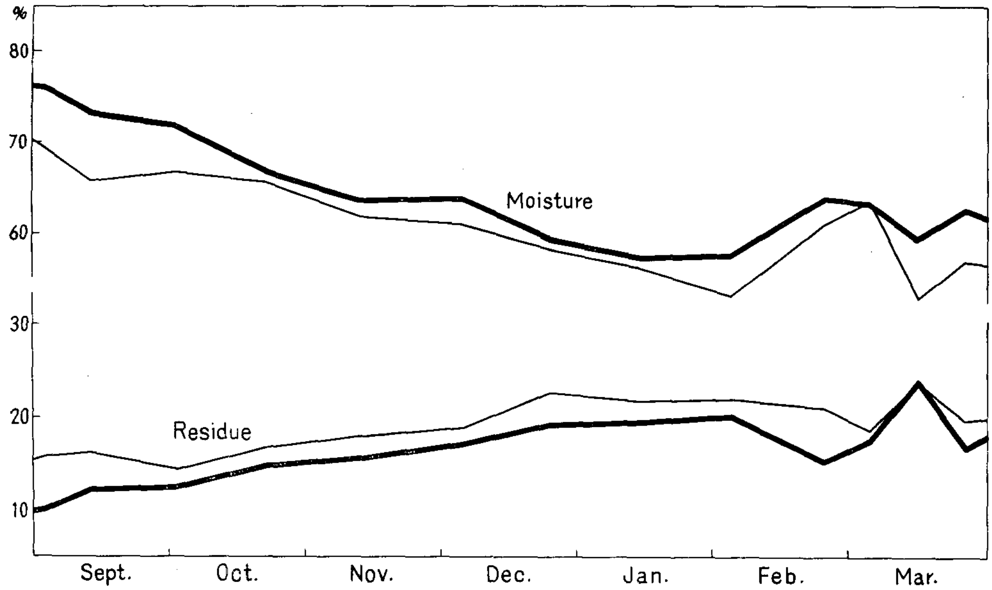

Figure III-2. 1 Variations of moisture (on a fresh weight basis) and residue (on a dry weight basis) contents of one year's shoots in *Abies sachalinensis* MAST. (Todomatsu) seedlings with lammas shoots (thick line) in comparison with normal seedlings (thin line) during dormant season. (7-year-old, 1962–1963)

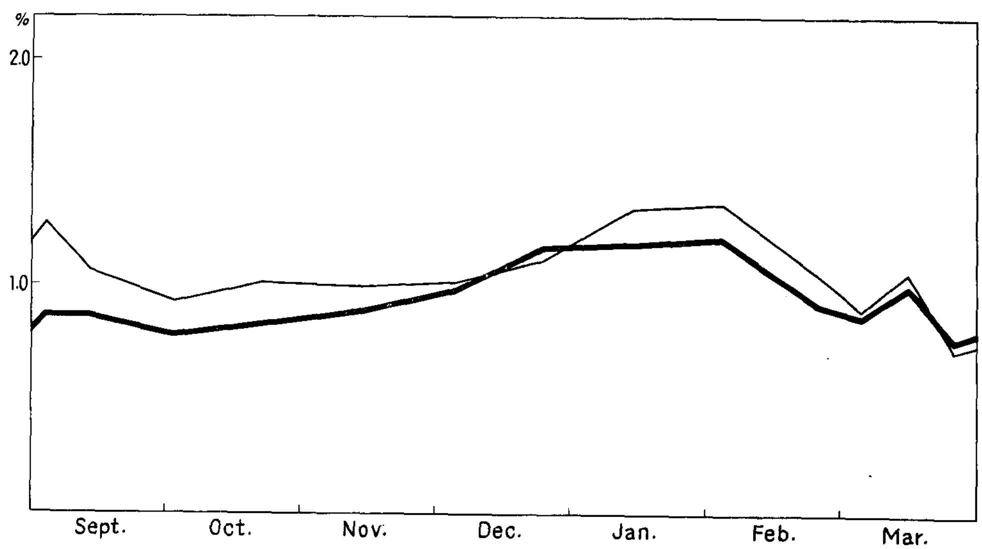

Figure III-2. 2 Variations of total nitrogen concentrations of one year's shoots in *Abies sachalinensis* MAST. (Todomatsu) seedlings with lammas shoots (thick line) in comparison with normal seedlings (thin line) during dormant season. (7-year-old, 1962–1963) short as compard with the normal seedlings. Such difference of resistance against damage in conformity with the different growing season between both seedlings is interesting in the study of tree breeding.

The decrease of moisture contents from autumn to winter was moderate in dormant season from 1962 to 1963 ; it began to decrease in late August, reached to the value under 60% in January, and began to increase in February. Lammas shoot had always much higher moisture contents than normal one. Differences

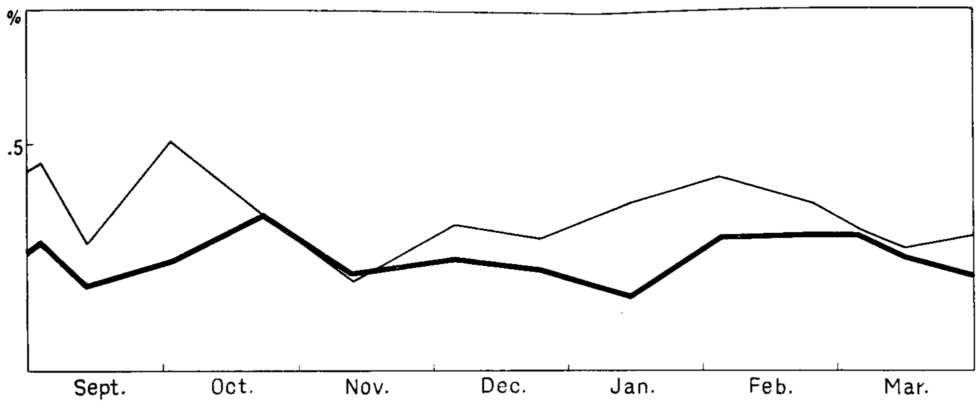

Figure III-2. 3 Variations of water soluble nitrogen concentrations of one year's shoots in *Abies sachalinensis* MAST. (Todomatsu) seedlings with lammas shoots (thick line) in comparison with normal seedlings (thin line) during dormant season. (7-year-old, 1962–1963)

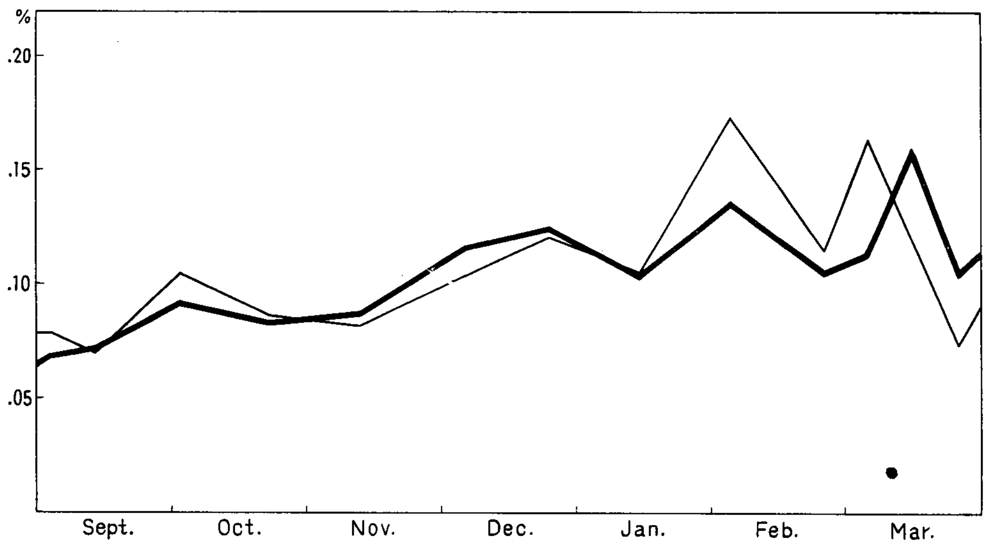

Figure III-2. 4 Variations of total phosphorous concentrations of one year's shoots in *Abies sachalinensis* MAST. (Todomatsu) seedlings with lammas shoots (thick line) in comparison with normal seedings (thin line) during dormant season. (7-year-old, 1962–1963)

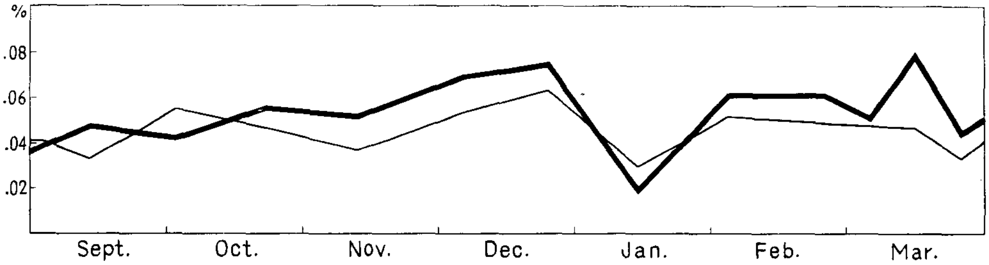

Figure III-2. 5 Variations of water soluble phosphorous concentrations of one year's shoots in *Abies sachalinensis* MAST. (Todomatsu) seedlings with lammas shoots (thick line) in comparison with normal seedlings (thin line) during dormant season. (7-year-old, 1962-1963)

between both shoots decreased to some extent with advancing hardiness. In the investigation from late Septmber to the season of snow fall in 1961, a similar pattern was presented, and the above-mentioned differences varied within the range from 2.9 to 6.4% and remained even in the time when the seedlings were covered with snow, and also this decreasing tendency was recognized clearly in the differences between both sort of shoots in the same seedling. On the contrary, residue contents of lammas shoot were at much higher level from autumn to early February than that of normal shoot. When February came, they decreased because of increment in moisture contents in both shoots. The maximum values in both shoots were, however, obtained in mid-March (24.0% in lammas shoot, 23.4% in normal one).

The increasing trends of total nitrogen concentrations in dormant season started from early October in both shoots and, in mid-December, reached temporarily similar concentrations. Thereafter, the nitrogen concentrations of lammas shoots kept nearly constant while those of normal shoots increased again nearly 0.1% till early February, when those of both sooots were at the maximum. Accordingly, total nitrogen concentrations of both shoots increased gradually with advancing hardiness and, in most cases, in lammas shoot was at a lower level during dormant season. However, water soluble nitrogen concentrations in dormant season changed more variably in comparison with those of total nitrogen concentrations in both shoot and the increasing trends of those were not shown distinctly, especially in lammas shoot. Moreover, their maximum concentrations in the period from September to March occurred in eaarly October for normal shoot and in late October for lammas shoot. Of course, the latter showed lower concentration as compared with the former.

Total phosphorous concentrations in both shoots kept increasing trends till late December and there was scarcely any difference between both shoots. During the period from January to March, those of both shoots were very insecure, and lammas shoot had a lower concentration than normal shoot from mid-January to mid-March. Water soluble phosphorous concentration was rather higher in lammas shoot during dormant season, excepted the periods from late September to mid-October and from early to late January. Although the great change during January was more remarkable in lammas shoot than in normal shoot, both shoots took the increasing trend in the former part of dormant season. Particularly, the change in mid-January was also indicated in water soluble nitrogen concentration of lammas shoot.

2) Carbohydrates[136,139].

The results obtained in dormant season from September 26th, 1961 to February 8th, 1962 were shown graphically in figurre III-2. 6, III-2. 7, and III-2. 11 and those from September, 1962 to March, 1963 in figure III-2. 8～III-2. 10 and III-2. 12.

As reported previously, reducing sugar concentration of the lammas shoot in the first experiment (from late September to the time when snow covers the seedling) was lower than that of the normal shoot, and it kept an increasing trend throughout the above-mentioned period in both shoots. Thereafter, according to the results measured during the time when the seedling is covered with snow, reducing sugar concentration went up remarkably from late November to mid-December, and then showed the decreasing tendency in early February, when the top of the seedling was covered over by snow. Therefore, reducing sugar concentration of Todomatsu seedling generally reaches the maximum level in mid-December, presumably, if the sonw protects the seedling, being constant thereafter till early February when the root begins to spread. In any way, reducing sugar of lammas shoot was lower than that of normal shoot in dormant season and

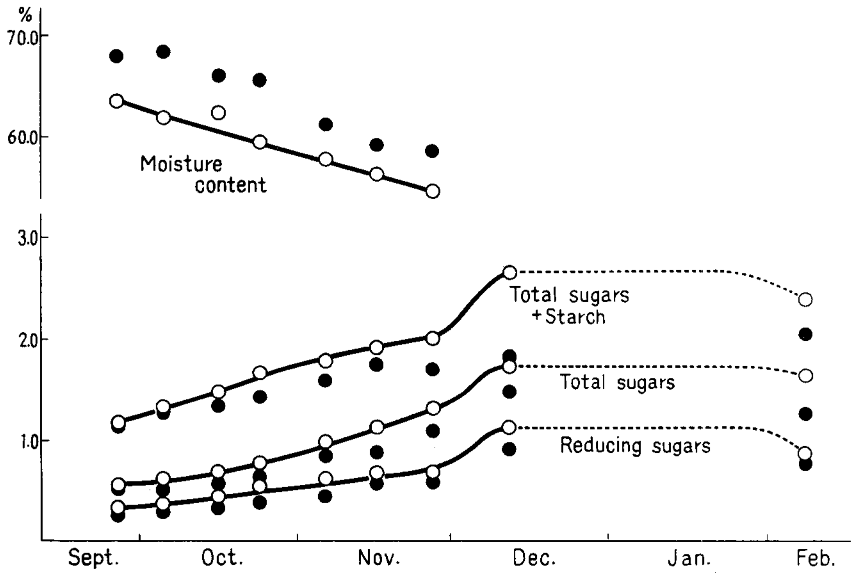

Figure III-2. 6 Variations in moisture and carbohydrate contents of lammas shoots (solid circles) and of normal shoots in *Abies sachalinensis* MAST. (Todomatsu) seedlings on a fresh weight basis. (5-year-old, 1961-1962)

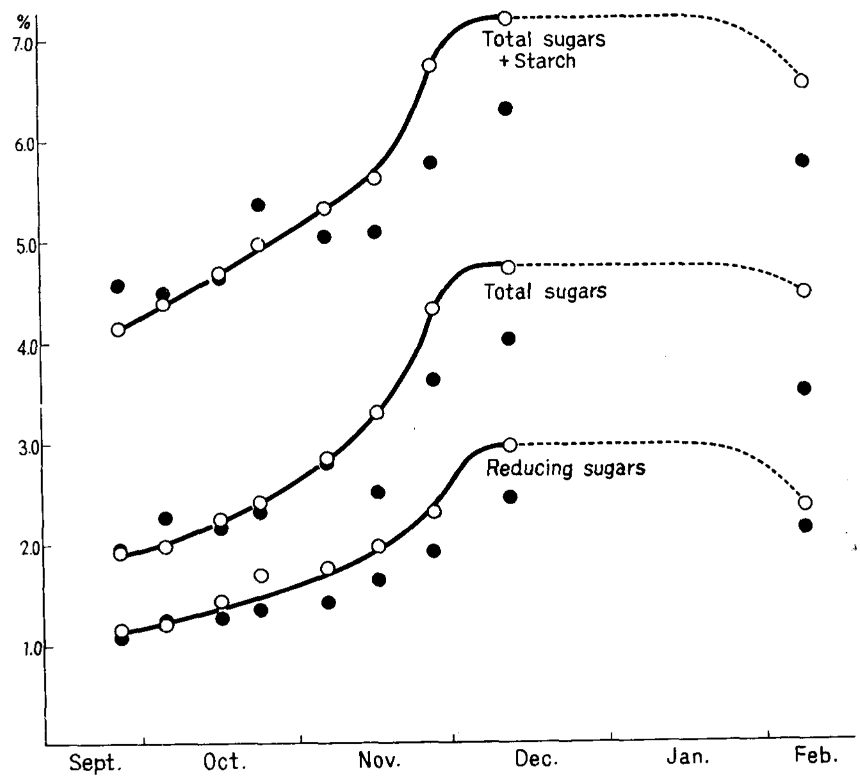

Figure III-2. 7 Variations in carbohydrate contents of lammas shoots (solid circles) and of normal shoots in *Abies sachalinensis* MAST. (Todomatsu) seedlings on a dry weight basis. (5-year-old, 1961–1962)

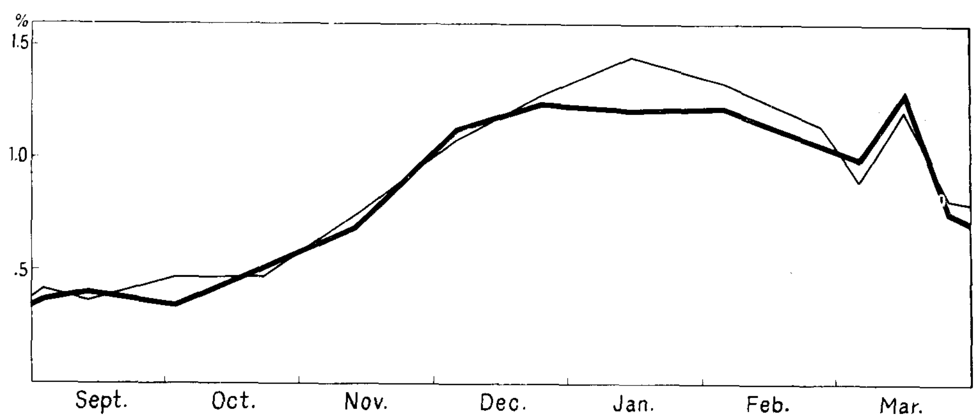

Figure III-2. 8 Variations of reducing sugar concentrations of one year's shoots in *Abies sachalinensis* MAST. (Todomatsu) seedlings with lammas shoots (thick line) in comparison with normal seedlings (thin line) during dormant season. (7-year-old, 1962–1963) the difference between both shoots developed from late September to mid-November and thereafter became somewhat less and remained constant until early spring. In the second experiment, the difference between the reducing sugars of both shoots began to develop clearly in late December, and lammas shoot showed lower concentration until late February but higher in the temporary flushing period from late February to mid-March than normal shoot. Furthermore, normal shoot reached a maximum in mid-January and thereafter kept a slight decreasing trend

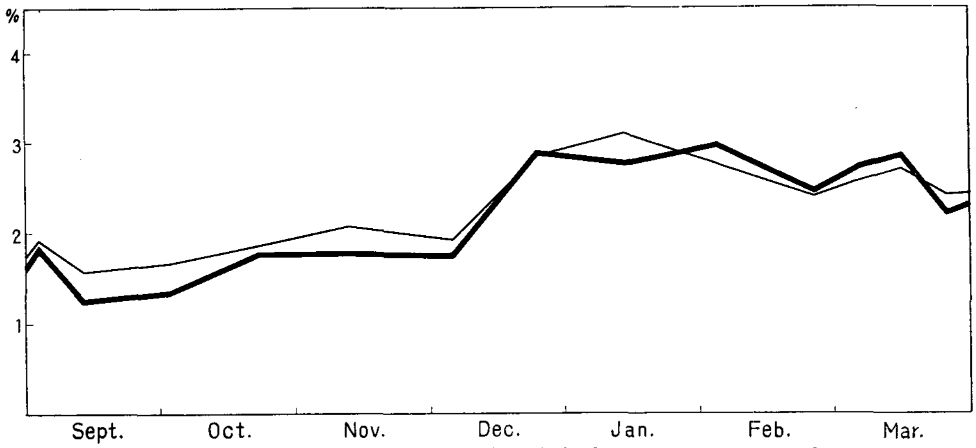

Figure III-2. 9 Variations of total carbohydrate concentrations of one year's shoots in *Abies sachalinensis* MAST. (Todomatsu) seedlings with lammas shoots (thick line) in comparison with normal seedlings (thin) line during dormant season. (7-year-old, 1962–1963)

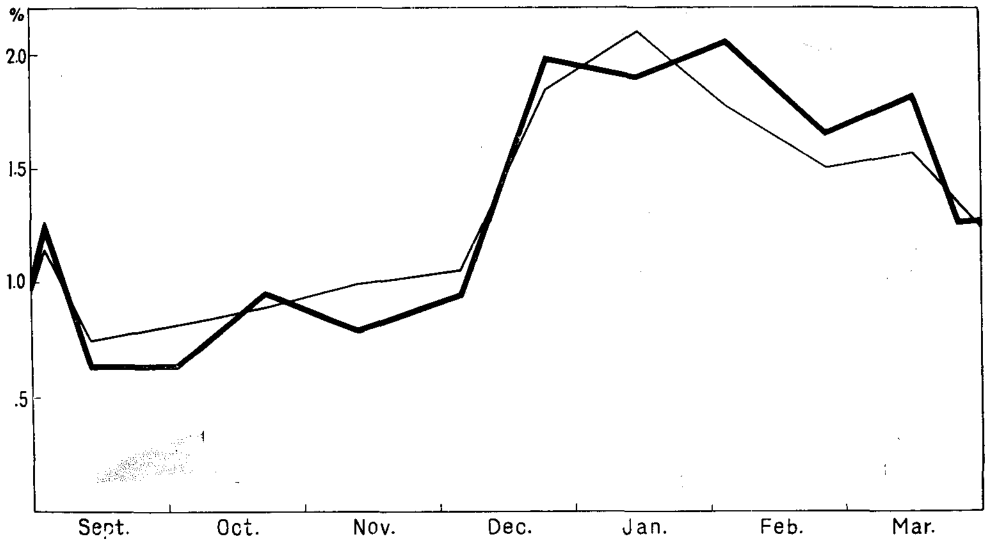

Figure III-2. 10 Variations of total sugar concentrations of one year's shoots in *Abies sachalinensis* MAST. (Todomatsu) seedlings with lammas shoots (thick line) in comparison with normal seedlings (thin line) during dormant season. (7-year-old, 1962–1963)

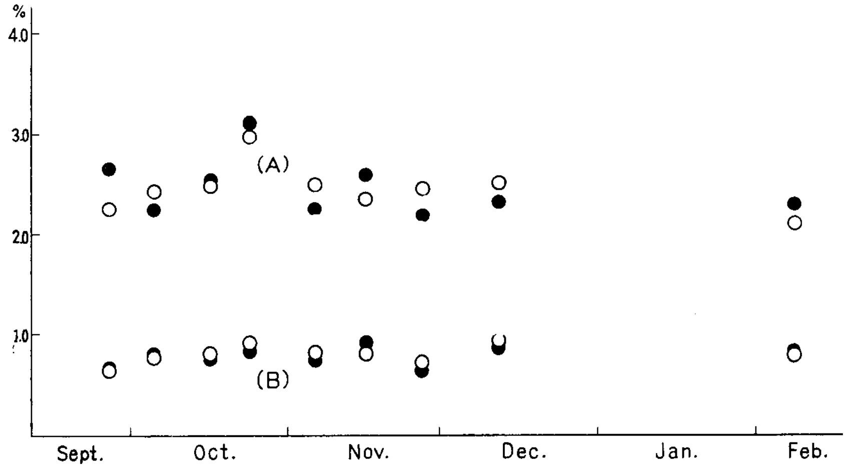

Figure III-2. 11 Variations in starch contents of lammas shoots (solid circles) and of normal shoots in *Abies sachalinensis* MAST. (Todomatsu) seedlings on a dry (A) and a fresh (B) weight basis (5-year-old, 1961-1962)

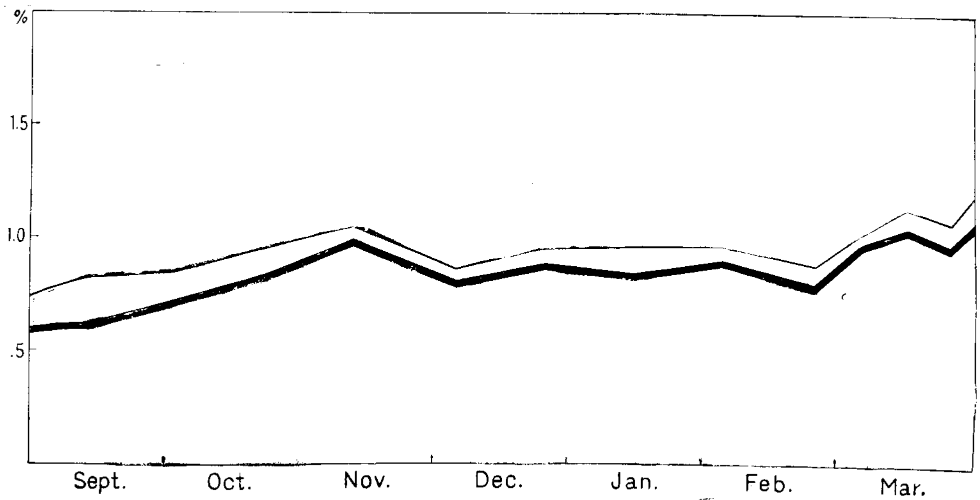

Figure III-2. 12 Variations of starch contents of one year's shoots in *Abies sachalinensis* MAST. (Todomatsu) seedlings with lammas shoots (thick line) in comparison with normal seedlings (thin line) during dormant season. (7-year-old, 1962-1963)

instead of the constant concentration. This particular variation of reducing sugars in 1962–1963 dormant season was due to abnormal weather, especially the lack of snow.

Seasonal variation of total sugar concentration from autumn to winter resembled that of reducing sugar; precisely, total sugar concentration began to increase in late September and its increasing trend accelerated remarkably from late November and reached a maximum concentration in mid-December. The increasing trend was more remarkable in total sugar concentration than in reducing sugar concentration alone, that is, the value obtained by deducting reducing sugar weight from total sugar weight increased noticeably. Total sugar concentration was lower in lammas shoot than in normal shoot throughout the experimental season like the results of reducing sugar. But, on a dry weight basis, there were no obvious differences between total sugar concentrations of both shoots till mid-October, and the fluctuation was sharp in lammas shoot. The differences appeared in early October and reached the maximum level in mid-December, and the maximum difference was much larger than that of reducing sugar. The decline in total sugar concentration in early February in lammas shoot was much more than that in normal shoot, though reducing sugar was much higher in the latter than in the former. During the dormant season from 1962 to 1963, lammas shoot showed very extreme changes in comparison with normal shoot as same as reducing sugar. And yet, in the former part of dormant, it was shown visibly that lammas shoot has much lower concentration of total sugar than normal one. Generally, lammas shoot obtained a higher position than normal shoot in total sugar concentration, and it was attributed to the fact that the latter was protected by snow, neverthless the former stood out of the snow because of abnormal weather in dormant season. In the latter part of dormant season, lammas shoot hastened its hardening process furthermore by such condition.

Starch content of normal shoot traced an increasing curve till late October and dropped from late October to late November in spite of the increment of sugars and then increased to the maximum level of late October in mid-December. In early February, starch value dropped somewhat below that in mid-December but this starch value was not the minimum. The variation range of starch content was less than reducing sugar and total sugar concentration, and the range was limited within 0.4% on a fresh weight basis (1.0% on a dry weight basis). And also they made more frequent changes than the other two and this flexibility was more remarkable in lammas shoot than in normal shoot. These extreme changes of lammas shoot as compared with normal shoot were presented not only in starch but also in moisture and total sugar. But, the results in the second experiment showed that lammas shoot had much lower content in starch than normal shoot throughout the dormant season, and, in the period from mid-November to late February, kept nearly 1.0% value.

3) Interrelations among nitrogen, phosphorous, and carbohydrate contents.

Su/C ratio in the dormant season was much higher in lammas shoot, while St/C ratio was much higher in normal shoot. These ratios in both shoots varied evenly in dormant season as compared with those in growing season. During the period from September, 1961 to February 1962, the maximum ratio of St/C was obtained in early October in both shoots, the minimum in mid-December for lammas shoot and in early February for normal one. Concerning 1962–1963 dormant season, St/C ratio of normal shoot was constant from mid-September to mid-November and then decreased to the minimum value in mid-January, while that of lammas one showed a similar pattern, accompanied with small fluctuations.

RS/C ratio started to increase rapidly from late October and attained the maximum value in early December and remained approximately constant till late February in both shoots. During the period when St/C ratio was constant, RS/C ratio of lammas shoot had much lower value than that of normal one. Generally, Su/St ratio in dormant season varied according to the variation of sugar content, because starch was constant, and lammas shoot had rather sharp variation. The n/N ratio of lammas shoot took a lower value throughout dormant season than normal shoot, excepting the period from mid-October to mid-November. On the contrary, p/P ratio was higher in the former though there was an inverse relation in mid-January.

C/N ratio continued to increase during dormant season, and variation of Su/n ratio was influenced largely by the pattern of total sugar concentration. However, Su/n and RS/n ratios kept much higher values in lammas shoot during dormant season with the exception of the period from mid-October to mid-November. Sugar contents affected not only the Su/n ratio but also the Su/p ratio for both shoots. It was a common feature between C/N and C/P ratios that they kept approximately constant in both shoots throughout dormant season and the difference between both shoots was inconspicuous. And also, it resembled closely the trend of Su/n ratio that Su/p ratio turned sharply from increasing to decreasing in mid-January, especially more sharply in lammas shoot.

Since nitrogen and phosphorous tended to follow as similar pattern both in the expenditure in the growing season and in the accumulation in the dormant season, N/P and n/p ratios in both shoots did not change very much. These ratios of lammas shoot usually showed lower values as compared with those of normal shoot.

Chapter 3. Discussion.

In lammas growth, Todomatsu seedlings began to burst their buds from early to mid-July at the earliest, continued to develop during 30 to 45 days, and almost ceased by the end of August. In that stage, especially in July, the root elongation was vigorous. The nutrient elements of lammas shoot generally showed a fluctuated curve in comparison with the smooth curve in the normal shoot and this was more remarkable on a dry weight basis than on a fresh weight basis. It seems that this is due to the deviation of the material collected and the sensibility of lammas shoot to weather condition. As the seedlings with lammas shoots differ from each other in the time of budding and cessation of growth, each lammas shoot has a different quantity of woody parts, therefore we used five lammas shoots at random at each sampling to keep down this deviation, but could not entirely exclude it.

Variation of nutrient concentrations of lammas shoot in lammas season progressed in a pattern similar to those in early growing season, but they were presented on a small scale in comparison with the latter. This was probably due to the fact that lammas growth was more dependent on the products of photosynthesis in current year, because lammas growth develops under favorable environmental condition, and the root activity is more vigorous at that time. Indeed, there was a striking difference in the changes of nutrient concentrations in bursting stages or thereabout between the two growth periods. And, in some cases, the lammas growth amount was higher than that of early growth in spring.[42,63,158]

At the starting stage of lammas growth, lammas shoot held much larger contents in total nitrogen, and total and water soluble phosphorous than normal shoot. These nutrient concentrations in the beginning of early growing stage were characterized by the fact that, just before bursting stage, total nitrogen and phosphorous in both shoots increased remarkably but water soluble nitrogen and phosphorous concentrations showed temporarily a higher increment only in lammas shoot. It has been assumed that the abnormally elongated seedling was caused by abundant fertilization of nitrogen compounds; that is the luxual absorption of those, but, so far as this investigation, lammas growth of Todomatsu occurred in the seedling containing much higher concentration of phosphorous with that of nitrogen. HARADA[30] investigated the relation between the growth and nutrient contents on the abnormally elongated seedling of Sugi and reported that it had more larger nitrogen and potassium contents in upper stem part as compared with normal seedling, while phosphorous contents of both seedlings did not differ from each other, and also, EGUCHI[19] obtained much less value of P_2O_5 concentration of leaves and stem top for abnormally elongated Todomatsu seedling than that for normal seedling in late October by the simple colorimetric method. Concerning phosphorous contents, the difference between the abnormally elongated seedlings of Sugi and Todomatsu was presumably due to the different sampling stages and the different sampling methods, because phosphorous had accumulated much in the vigorous growth part. Furthermore, Harada stated that the abnormally elongated seedling was characterized by much larger n/N ratio in upper stem part in comparison with normal seedling. In Todomatsu seedling, this relation between n/N ratios of both shoots was indicated only in the period from mid-October to mid-November and before bursting, and it was noticeable that p/P ratio of lammas shoot kept rather higher value throughout dormant season, excepting mid-January when it decreased temporarily. Of course, n/N and p/P ratios of lammas shoot decreased with advancing lammas growth though those showed increasing trend in normal shoot and progressed to a much higher level than those in early growing stage. And also, at the beginning of early growing stage, especially just before bursting, not only n/N ratio but also p/P ratio of lammas shoot increased markedly. TESHIMA et al.[143] produced the secondary growth of potato tuber by the treatment of 25 or 20 times of normal con. of culture solution (not only nitrogen) for 24, 48, and 72 hrs. and 15 times for 72 hrs. respectively, while scarcely in the plots of 15 times for 24 or 48 hrs. and 10 or 5 times for any hrs.. According to these results, lammas growth was caused by the large absorption ability of roots in the seedling with lammas shoots in essential agreement with the experimental fact that lammas shoots are often observed in a fixed bed and scarcely ever in a transplanted bed and, accordingly, that root cutting is a technical method to prevent lammas shoot growth in the nursery.

Carbohydrate contents, especially starch, of lammas shoots kept much lower the year through than those of normal shoots, as in abnormally elongated seedling of Sugi[130] and the secondary growth of potato tuber[141]. SAEKI and NOMOTO[95] stated also that the younger stage of leaf is characterized by a higher respiration and compensation point, and a lower chlorophyll content and photosynthetic activity, and those are clearly shown in the leaves of a lammas shoot of *Zelkova serrata* (Keyaki), which have generally higher activity than those of ordinary shoot. According to TAZAKI[140], the mulberry leaves unfolded in spring showed at first strong negative net assimilation, being due to the high amount of respiration, low chlorophyll content and inadequate stomatal movement, but, in the leaves unfolded in later season, the net assimilation increased far more rapidly that in those developed in spring and the former reached a maximum assimilation only ten days after unfolding. In Todomatsu, total carbohydrates, especially total sugars, in both shoots took a nearly similar value at maximum in early September.

Though the manifestation of increasing trend in starch content was distinctly recognized in early August for normal shoot, that of lammas shoot was belatedly shown in late August or early September. FLEMION and TOPPING[21] stated that the dwarf seedling from unchilled peach (*Prunus Pérsica* BATSCH.) seed rapidly stored starch relatively soon after germination and the amount resembled that which accumulated in the normal plants during the onset of dormancy many weeks later. These two results showed that the longer the growing period is, the later the onset of starch accumulation comes.

Concerning the relation between carbohydrates and nitrogen or phosphorous contents, every C/P, C/p, Su/n, RS/n, Su/p, RS/p ratios took a lower value in lammas shoot at the beginning of early growing stage, and, in the stage just before bursting of lammas buds, Su/n and RS/n ratios took characteristically higher value in lammas shoot. If these nutrient balances are influenced by the environmental or other conditions, they may differ more or less in different growing stages. In SUTO's study[130] on the relation between nitrogen and carbohydrates for Sugi, there was statement that the changes of photosynthesis caused by the absorption ability of nitrogen strikingly affected carbohydrate accumulation. However, in Todomatsu seedlings with lammas shoots, total and water soluble nitrogen took a lower value and water soluble phosphorous kept rather higher value the year through on the whole. Although HARADA and SUTO examined the nutrient contents after lammas growth, the question as to why a lammas shoot growth occurs or not must be answered directly by the conditions in the stage before and after bursting the lammas buds. Apparently, RS/n ratio of Todomatsu seedling took a higher value in early July, and this trend almost caused a lower concentration of water soluble nitrogen. Though nitrogen do not act always directly on carbohydrate accumulation[67], SUTO[128] explained the relation between reducing sugar, and water soluble nitrogen as a factor of the cause of abnormally elongated seedling in Sugi on the presumption that the absorption ability of water soluble nitrogen affects on photosynthesis and moreover on the accumulation of carbohydrates. On the other hand, MIYAZAKI[62] recognized that the increase of carbohydrates in tissues strongly and negatively correlated to photosynthetic ability throughout the seedbed and transplanting and considered that nitrogen contents of seedlings should be held at high level in order to avoid physiological decay of tissues throughout the seedbed period, the seedlings recover normal growth after transplanting, because the increase of carbohydrates and lowering of nitrogen levels in the tissues led to physiological decay in photosynthesis. In Todomatsu, total nitrogen of lammas shoot was much higher in this stage. Hence, the lammas shoot growth was not caused by nitrogen deficiency. Phosphorous deficiency results from the remarkable reduction of photosynthetic activity per unit leaf area ; the decrease in respiratory activity of each organ, and this phase was explained in the light of dry matter production.[146] So far as this invetigation is concerned, lammas shoot took a lower value in total carbohydrate concentration the year through, but its growth, of course, was superior and its phosphorous concentration was rather higher as compared with normal shoot. Accordingly, lammas shoot growth was not caused by phosphorous deficiency. Namely, from the results of nitrogen and phosphorous concentrations of Todomatsu seedling in lammas season, the statement of KLEBS[46], who attributed the cause of intermittent growth in both tropical and temperate zone plants to a temporary deficiency of mineral nutrients, can not be accepted.

REIFSYNDER[92] figured characteristically the difference between moisture contents of new- and old-growth leaves for mountain laurel (*Kalmia latifolia L.*), and OKAZAKI[77] found that, in Sugi, moisture content of one-year-shoot was much higher than that of a 2-year-shoot till late autumn, but there was little difference from autumn to winter. In the studies on Kuwa and Cha, the decrease in their respective moisture content concurrently with the differentiation of the tissues, followed the cessation of their growth[101,135]. According to the fact, the more the cessation of growth is delayed, the longer the period becomes during which moisture content decreases. The cessation of lammas shoot growth of Todomatsu comes later than that of normal shoot. Moisture contents of lammas and normal shoots did not trace a smooth decreasing curve during the former part of dormant season, and that of lammas shoots was always much higher than that of normal shoots, and also the relation between both shoots in the same seedling was similar. The difference of moisture contents between lammas and normal shoots showed a tendency to decrease, but it remained constant even in the time when the seedlings were covered with snow.

Reducing and total sugar concentrations in lammas shoot were much smaller than in normal shoot, and the difference between both shoots remained constant until early spring.

A cool temperature for plants did cause a greater average survival from freezing than with those grown at a warm temperature[17], but they can be hardened more only in the period after the completion of their development[103]. On the frost hardening process among varieties or strains, there are two types; one is that the stage when each variety becomes frost-hardy differs from each other, but each has the same maximum value in frost-hardiness; and the other is that each variety differs from each other not only in the stage when each variety becomes frost-hardy but also in the maximum frost-hardiness[103]. According to the variations of moisture content, reducing and total sugar concentrations (which were close in relation to frost-hardy) in this result, Todomatsu showed the latter type under favorable snowfall after late November in 1961. Concerning the dormant season 1962–1963, lammas shoot had temporarily rather higher concentration in carbohydrates than that of normal one, and then this phase was due to the condition that the latter was covered entirely with snow, neverthless the upper part of the former stood out of the snow in an abnormally warm winter. FREELAND[21] recognized the apparent photosynthesis in some conifers during the winter. The cold-damage of trees occurred often in such condition as stated previously[50], because they can not be hardened completely by subjection to severe low temperature. Growing season of the seedling with lammas shoots was longer than that of the normal seedling, and the former had a much larger moisture content and much less reducing and total sugar concentrations than the latter. Namely, among individuals of Todomatsu, it was shown that the later the cessation of growth came, the lower the grade of frost-hardiness and the maximum level were. This fact suggests that the shortening of the growing period is indispensable for the production of cold-hardy individuals[99,117,130], and also, SAKAI[103] stated that the developmental stage of twigs are important as an inner factor which is required for hardening by means of low temperatures according to his results for Kuwa varieties.

The lammas shoot varied more frequently in starch contents than normal one and, furthermore, starch decrease of the former in early February was much larger than that of the latter in 1962. In the latter part of 1962–1963 dormant season, St/C ratio of lammas shoot kept much lower but, in contrast, Su/C ratio remained much higher than that of normal shoot, and n/N and p/P ratios varied much more in lammas shoot. This trend indicates that lammas shoot is more easily influenced by the weather condition than normal one.

Chapter 4. Summary.

In the experiment, part III, the physiological features of lammas shoots were examined for variation of each nutrient content in comparison with that of normal shoots in order to clarify how the lammas shoot growth occurs and what their resistance against the various damages is.

1. In lammas shoot, the seasonal variation of each element during its lammas growing season was, though on a small scale, similar to that in early growing stage.

2. At the beginning of lammas growth, total nitrogen, total phosphorous, and water soluble phosphorous concentrations were much higher than those of normal shoot, but water soluble nitrogen was much less in lammas shoot.

3. Just before bursting in spring, the lammas shoot was characterized by the remarkable increasing trends of water soluble nitrogen and phosphorous concentrations while the values of normal shoot were nearly fixed. In this stage, total nitrogen and phosphorous concentrations increased distinctly together in both shoots.

4. The n/N ratio of lammas shoot, in most cases, kept a lower value and its p/P ratio had a higher value the year through as compared with that of normal shoot. Of course, these two ratios of lammas shoot decreased largely in lammas stage, while those of normal one increased.

5. Generally, the accumulation of carbohydrates in lammas shoot was inferior the year through to that of normal shoot.

6. Thus, it is possible to say that the lammas growth was characterized by their greater ability to absorb nitrogen and phosphorous compounds and by their inferior accumulation of carbohydrates.

7. In the former part of dormant season, the reserves of lammas shoot increased gradually in parallel with those of normal one, excepting water soluble nitrogen, but the former kept a lower value.

8. The nutrient concentrations of lammas shoot varied noticeably accordance with the temporary changes of environmental conditions.

9. Accordingly, it was indicated that, among individuals of Todomatsu seedlings, the later the cessation of growth, the lower the resistance against various damages are ; and then, the lammas shoot is more easily influenced actively by environmental conditions than normal shoot.

Conclusion

Lammas shoot growth in Todomatsu seedling occurs commonly in some nurseries in Hokkaido, but it produces an abnormally formed seedling. What is worse, the seedling with lammas shoots often suffer from abnormal weather or others because its hardening period is shorter than that of the normal one. Therefore, the seedlings with lammas shoots are unfavorable for shipping purposes. This trend has been explained mainly by the environmental conditions and the relations to the fertilizations. Recently, SUTO and HARADA studied physiologically this problem for Sugi, and KRAMER and others investigated the bursting from the buds in lammas after the perfection of the current-year buds in consideration of the dormancy. However, the cause of lammas shoot growth is not yet clearly explained in spite of the presence of some evidence suggesting that accumulation of inhibitors is a factor in the development of dormancy.

In order to clarify the physiological qualities of the seedlings with lammas shoots in Todomatsu, the writer examined fundamentally the seasonal variations of moisture, residue, nitrogen, phosphorous, and carbohydrate contents in lammas shoots in comparison with those of the normal shoots. Furthermore, he investigated the balances among the above-mentioned nutrients. The experiment was carried out during the period from September, 1961 to April, 1963 for 5- or 7-year-old seedlings, excepting the determination of the height growth curve for 3-year-old seedlings in 1957.

In the experimental part I, the general relation between growth and reserve food of Todomatsu seedling in the early stage of its growth was investigated, because the relation is important in comparison to that in the lammas growing stage. The writer examined the seasonal variations in moisture, residue, nitrogen, phosphorous, and carbohydrate contents of the normal seedlings in the experimental part II, and then, he compared the seasonal changes of the nutrients in lammas shoots with normal shoots in the experimental part III. From these investigations, the following results were obtained;

In early height growing stage of Todomatsu seedlings, the growth grades were in proportion to the fresh weights of stems and roots, and, inversely to nitrogen, phosphorous, and carbohydrate concentrations, particularly remarkable in starch. As soon as mid-June was gone, each concentration began to increase, markedly in starch and water soluble nitrogen, in contrast with decreasing trend in top to root ratio. And also, in that period, the seedlings which roots were damaged by cutworm showed lower growth grades and much higher values in every concentration as compared with normal seedlings at any stage.

Moisture content was higher in growing season, a maximum in late May and took a gradually decreasing pattern in dormant season after reaching the second higher peak, nearly equal to the maximum, in August. On the other hand, residue content changed inversely in correspondence to moisture content, from 5.7% in early May to 23.4% in mid-March of the following year on a fresh weight basis. A maximum value in nitrogen concentration was obtained in early May as same as that of phosphorous, and both concentrations took the concave patterns on the whole, little in growing season and large in dormant season. However, water soluble nitrogen and phosphorous concentrations did not increase much in the dormant season whereas total nitrogen and phosphorous did. There were also special features in what water soluble nitrogen had a more flexible fluctuation than total nitrogen and what, in contrast with nitrogen, total phosphorous changed more sharply than water soluble phosphorous. The rapid increase of total carbohydrate in early spring was mainly due to the increment of starch, and that in the dormant season was entirely due to the increase of sugars, because starch remained constant. The increasing trend of sugars in mid-winter was more remarkable in non-reducing sugars than that in reducing sugars, though, in most cases, the latter occupied the larger part of total sugars. Furthermore, there was a close relation between the increase of sugars and the snowfall.

In Todomatsu, it was indicated that the reserves, viz. nitrogen, phosphorous, and carbohydrates accumulated noticeably in the dormant season for the early height growth. In growing season, n/N and p/P ratios were less in comparison with the other season. N/P ratio tended to keep 10 at that time nearly in agreement with LEYTON's result, viz. the optimum nutrient balance of sitka spruce in water culture. And n/p ratio had usually a value under 15. In lammas season, lammas shoot had a change in the contents of each element similar (on a small scale) to that in the early growing stage, and, at the beginning of lammas growth, total nitrogen and phosphorous and water soluble phosphorous concentrations were much higher in lammas shoot than those in normal one, but water soluble nitrogen was much less in the former. And also, lammas shoot was characterized by the remarkable increasing phase of water soluble nitrogen and phosphorous concentrations in the time just before bursting in spring, while these concentrations of normal shoot were changeless. However, total nitrogen and phosphorous concentrations increased noticeably together in both shoots. Generally, carbohydate and nitrogen concentrations of lammas shoot kept lower the year through as compared with much higher concentration of water soluble phosphorous, excepting the vigorous growing season. In lammas shoot of Todomatsu, n/N ratio was much higher only in the period from mid-October to mid-November and before bursting in spring than in normal one, but p/P ratio was much higher the year through, excepting the period before bursting in spring, lammas shoot growing season, and mid-January. Thus it is possible to say that the lammas growth was caused by a greater ability to absorb nitrogen and phosphorous, and by its inferior accumulation of carbohydrates, and this suggested that, from a morphological view point, lammas shoot growth was caused by the imbalance between stem and root parts in the seedling.

The nutrient concentrations of lammas shoot changed more appreciably in accordance with the temporary changes of environmental condition in comparison with normal one. Accordingly, it was indicated that the later the cessation of growth comes, among individuals of Todomatsu seedlings, the lower the resistance to various injuries is and that lammas shoot is more easily influenced actively by the environmental condition.

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Reference table I-1 Seasonal variations of moisture and residue contents of *Abies sachalinensis* MAST. (Todomatsu) seedlings.

Date			Normal shoot				Lammas shoot			
			Moisture		Residue		Moisture		Residue	
			a	b	a	b	a	b	a	b
1961	IX	26	63.2	182.5	10.7	30.3	67.7	203.0	11.4	34.5
	X	4	61.6	160.4	12.2	31.8	68.0	212.5	12.6	39.3
		16	62.1	163.9	13.0	34.2	65.7	191.5	10.8	31.5
		24	59.1	144.5	15.2	37.3	65.2	187.4	11.4	32.7
	XI	6	57.4	134.7	12.8	30.0	60.8	155.1	14.0	35.8
		16	55.9	126.8	15.7	35.6	58.8	126.8	15.7	35.6
		27	54.2	118.3	14.3	36.5	58.2	139.2	11.1	29.9
	XII	12	53.2	113.7	16.0	34.1	55.8	126.2	12.2	27.6
1962	II	8	53.7	116.0	16.0	34.5	57.0	132.6	12.1	28.2
	IV	12	57.6	135.8	19.1	45.1	63.0	170.3	16.9	45.7
		21	57.3	134.2	18.8	44.1	64.8	184.1	16.1	45.8
	V	2	75.8	313.2	5.7	23.7	78.2	358.7	6.1	27.8
		12	81.2	431.9	6.6	35.3	82.5	471.4	6.9	39.4
		22	83.4	502.6	5.6	33.2	—	—	—	—
	VI	2	77.7	348.4	8.9	39.8	—	—	—	—
		12	75.9	314.9	10.0	41.6	—	—	—	—
		22	74.2	288.7	13.0	50.1	—	—	—	—
	VII	2	70.6	240.1	11.7	39.9	72.1	258.4	11.6	41.4
		12	74.6	293.7	10.1	39.8	76.9	332.9	9.2	39.6
		23	76.3	321.9	12.3	52.0	80.6	415.5	9.1	46.8
	VIII	2	78.5	365.1	10.1	47.2	80.8	420.8	8.2	42.9
		13	71.1	246.0	14.7	51.0	77.6	346.4	10.0	44.8
		23	73.2	273.1	14.4	54.1	78.7	369.5	9.2	43.1
	IX	3	69.6	228.9	16.0	52.4	78.1	356.6	10.1	42.0
		13	68.2	214.5	16.4	51.5	74.7	295.3	12.4	48.8
	X	2	69.5	227.9	14.5	47.5	75.1	301.6	12.7	51.0
		22	66.1	195.0	17.0	50.0	68.1	213.5	15.0	47.2
	XI	12	64.2	179.3	18.1	50.5	67.1	204.0	15.8	48.2
	XII	5	62.2	164.6	19.1	50.5	64.7	183.3	17.4	49.3
		24	57.5	135.3	22.9	53.8	58.7	142.1	19.4	47.1
1963	I	14	54.6	120.3	21.9	48.3	60.3	151.9	19.7	49.6
	II	4	52.1	108.8	22.1	47.4	58.9	143.3	20.2	47.7
		25	59.7	148.1	21.1	54.3	64.2	179.3	15.4	42.6
	III	5	63.7	175.5	18.8	51.9	64.0	177.8	17.7	49.2
		15	54.8	121.2	23.4	51.8	56.1	127.8	24.0	54.7
		25	59.9	149.4	19.8	49.5	61.6	160.4	16.7	43.4
	IV	8	56.5	129.9	20.6	47.3	58.7	142.1	20.1	48.8
		18	59.4	146.3	19.3	47.6	63.4	173.2	16.0	43.7

Remarks: a; % on a fresh weight basis.
b; % on a dry weight basis.

Reference table I-2 Seasonal variations of total nitrogen contents of *Abies sachalinensis* MAST. (Todomatsu) seedlings.

Date			Normal shoot				Lammas shoot			
			a	b	c	d	a	b	c	d
1962	IV	12	1.28	3.03	1.59	5.51	1.30	3.51	1.56	6.46
		21	1.33	3.12	1.64	5.58	1.20	3.40	1.43	6.27
	V	2	2.17	8.98	2.30	11.74	2.12	9.75	2.26	13.53
		12	1.01	5.38	1.08	8.30	0.93	5.33	1.00	8.79
		22	0.86	5.07	0.91	7.58	—	—	—	—
	VI	2	0.46	2.04	0.50	3.40	—	—	—	—
		12	0.44	1.83	0.49	3.12	—	—	—	—
		22	0.57	1.83	0.61	4.20	—	—	—	—
	VII	2	0.43	1.45	0.48	2.41	0.54	1.94	0.61	3.33
		12	0.53	2.08	0.59	3.45	0.43	1.87	0.47	3.10
		23	0.55	2.31	0.63	4.81	0.41	2.09	0.45	3.95
	VIII	2	0.68	3.15	0.75	5.94	0.66	3.42	0.71	5.97
		13	0.82	2.83	0.96	5.76	0.58	2.57	0.64	4.64
		23	0.89	3.31	1.04	7.16	0.61	2.85	0.67	5.02
	IX	3	1.07	3.50	1.27	7.40	0.78	3.55	0.86	6.59
		13	0.89	2.81	1.07	5.80	0.77	3.03	0.87	5.94
	X	2	0.80	2.61	0.93	4.98	0.68	2.73	0.78	5.57
		22	0.85	2.50	1.02	5.02	0.70	2.20	0.83	4.16
	XI	12	0.82	2.29	1.00	4.64	0.74	2.25	0.88	4.33
	XII	5	0.83	2.19	1.02	4.43	0.81	2.29	0.98	4.52
		24	0.87	2.04	1.12	4.42	0.94	2.28	1.17	4.30
1963	I	14	1.05	2.32	1.35	4.48	0.95	2.40	1.19	4.77
	II	4	1.07	2.29	1.37	4.36	0.96	2.28	1.21	4.37
		25	0.84	2.16	1.07	4.73	0.78	2.15	0.92	3.75
	III	5	0.73	2.01	0.90	4.18	0.72	2.00	0.87	3.93
		15	0.82	1.81	1.07	3.75	0.76	1.73	1.00	3.82
		25	0.57	1.43	0.72	2.83	0.64	1.67	0.77	2.96
	IV	8	0.63	1.46	0.80	2.77	0.68	1.66	0.86	3.23
		18	0.61	1.50	0.76	2.87	0.52	1.43	0.62	2.54

Remarks: a; % on a fresh weight basis.
b; % on a dry weight basis.
c; % on a value deducted residue weight from fresh weight.
d; % on a value deducted residue weight from dry weight.

Reference table I-3 Seasonal variations of water soluble nitrogen contents of *Abies sachalinensis* MAST. (Todomatsu) seedlings.

Date			Normal shoot				Lammas shoot			
			a	b	c	d	a	b	c	d
1962	IV	12	0.33	0.78	0.41	1.42	0.36	0.97	0.43	1.78
		21	0.32	0.76	0.40	1.35	0.24	0.68	0.29	1.26
	V	2	0.34	1.39	0.36	1.82	0.63	2.87	0.67	3.97
		12	0.14	0.75	0.15	1.16	0.09	0.51	0.10	0.84
		22	0.09	0.54	0.10	0.81	—	—	—	—
	VI	2	0.05	0.21	0.05	0.34	—	—	—	—
		12	0.06	0.27	0.07	0.45	—	—	—	—
		22	0.18	0.71	0.21	1.48	—	—	—	—
	VII	2	0.16	0.56	0.19	0.93	0.11	0.38	0.12	0.65
		12	0.19	0.75	0.21	1.24	0.09	0.37	0.09	0.61
		23	0.16	0.69	0.19	1.44	0.09	0.45	0.10	0.84
	VIII	2	0.32	1.48	0.35	2.80	0.18	0.92	0.19	1.62
		13	0.25	0.85	0.29	1.74	0.16	0.73	0.18	1.31
		23	0.34	1.28	0.40	2.78	0.19	0.88	0.21	1.55
	IX	3	0.39	1.27	0.46	2.68	0.25	1.16	0.28	2.15
		13	0.23	0.73	0.28	1.51	0.16	0.65	0.19	1.27
	X	2	0.44	1.44	0.51	2.75	0.21	0.85	0.24	1.73
		22	0.28	0.82	0.34	1.64	0.29	0.90	0.34	1.70
	XI	12	0.16	0.46	0.20	0.92	0.18	0.45	0.21	1.05
	XII	5	0.26	0.68	0.32	1.37	0.20	0.57	0.24	1.12
		24	0.23	0.53	0.29	1.16	0.17	0.42	0.22	0.79
1963	I	14	0.29	0.64	0.37	1.24	0.13	0.33	0.16	0.66
	II	4	0.33	0.72	0.43	1.36	0.23	0.54	0.29	1.03
		25	0.29	0.74	0.37	1.63	0.26	0.71	0.30	1.24
	III	5	0.25	0.70	0.31	1.45	0.24	0.68	0.30	1.33
		15	0.21	0.46	0.27	0.95	0.19	0.43	0.25	0.95
		25	0.23	0.57	0.29	1.13	0.19	0.48	0.22	0.85
	IV	8	0.25	0.57	0.31	1.09	0.15	0.36	0.19	0.70
		18	0.13	0.33	0.17	0.63	0.14	0.39	0.17	0.69

Remarks: a; % on a fresh weight basis.
b; % on a dry weight basis.
c; % on a value deducted residue weight from fresh weigat.
d; % on a value deducted residue weight from dry weight.

Reference table I-4 Seasonal variations of total phosphorous contents of *Abies sachalinensis* MAST. (Todomatsu) seedlings.

Date			Normal shoot				Lammas shoot			
			a	b	c	d	a	b	c	d
1962	IV	12	0.058	0.138	0.072	0.251	0.058	0.157	0.070	0.289
		21	0.073	0.170	0.089	0.304	0.066	0.187	0.078	0.344
	V	2	0.124	0.512	0.131	0.670	0.132	0.608	0.141	0.844
		12	0.077	0.411	0.083	0.633	0.082	0.466	0.088	0.770
		22	0.058	0.343	0.061	0.513	—	—	—	—
	VI	2	0.053	0.238	0.058	0.397	—	—	—	—
		12	0.036	0.148	0.040	0.253	—	—	—	—
		22	0.046	0.178	0.053	0.364	—	—	—	—
	VII	2	0.038	0.128	0.043	0.213	0.046	0.164	0.052	0.281
		12	0.034	0.135	0.038	0.223	0.042	0.181	0.046	0.300
		23	0.048	0.202	0.055	0.419	0.038	0.196	0.042	0.369
	VIII	2	0.048	0.224	0.054	0.423	0.050	0.258	0.054	0.450
		13	0.076	0.265	0.090	0.539	0.047	0.212	0.053	0.383
		23	0.067	0.252	0.079	0.544	0.051	0.239	0.056	0.421
	IX	3	0.066	0.219	0.079	0.462	0.061	0.279	0.068	0.517
		13	0.058	0.184	0.070	0.379	0.062	0.244	0.071	0.479
	X	2	0.107	0.350	0.125	0.666	0.081	0.324	0.092	0.661
		22	0.072	0.212	0.086	0.425	0.071	0.224	0.084	0.422
	XI	12	0.067	0.188	0.082	0.381	0.073	0.223	0.087	0.429
	XII	5	0.085	0.224	0.104	0.452	0.096	0.271	0.116	0.534
		24	0.094	0.220	0.121	0.478	0.101	0.243	0.125	0.459
1963	I	14	0.082	0.180	0.105	0.347	0.083	0.210	0.104	0.417
	II	4	0.135	0.289	0.173	0.549	0.108	0.254	0.135	0.487
		25	0.091	0.234	0.115	0.511	0.088	0.245	0.105	0.428
	III	5	0.133	0.366	0.164	0.760	0.093	0.258	0.113	0.507
		15	0.089	0.198	0.117	0.410	0.120	0.273	0.158	0.603
		25	0.059	0.147	0.073	0.290	0.087	0.228	0.105	0.403
	IV	8	0.096	0.220	0.120	0.417	0.101	0.244	0.126	0.476
		18	0.088	0.217	0.109	0.414	0.091	0.250	0.109	0.444

Remarks: a; % on a fresh weight basis.
b; % on a dry weight basis.
c; % on a value deducted residue weight from fresh weight.
d; % on a value deducted residue weight from dry weight.

Reference table I-5 Seasonal variations of water soluble phosphorous contents of *Abies sachalinensis* MAST. (Todomatsu) seedlings.

Date			Normal shoot				Lammas shoot			
			a	b	c	d	a	b	c	d
1962	IV	12	0.023	0.055	0.029	0.100	0.025	0.068	0.030	0.125
		21	0.022	0.052	0.027	0.093	0.026	0.073	0.031	0.134
	V	2	0.027	0.112	0.029	0.147	0.064	0.294	0.068	0.408
		12	0.024	0.129	0.026	0.199	0.019	0.111	0.021	0.182
		22	0.010	0.057	0.010	0.086	—	—	—	—
	VI	2	0.012	0.052	0.013	0.087	—	—	—	—
		12	0.006	0.024	0.006	0.041	—	—	—	—
		22	0.020	0.076	0.023	0.155	—	—	—	—
	VII	2	0.014	0.047	0.016	0.079	0.017	0.060	0.019	0.103
		12	0.017	0.069	0.019	0.114	0.024	0.102	0.026	0.169
		23	0.024	0.100	0.027	0.208	0.014	0.071	0.015	0.134
	VIII	2	0.034	0.159	0.038	0.300	0.014	0.073	0.015	0.127
		13	0.033	0.113	0.038	0.231	0.019	0.087	0.022	0.157
		23	0.036	0.134	0.042	0.261	0.027	0.129	0.030	0.226
	IX	3	0.035	0.114	0.041	0.239	0.036	0.164	0.040	0.304
		13	0.028	0.087	0.033	0.179	0.041	0.162	0.047	0.316
	X	2	0.047	0.154	0.055	0.229	0.037	0.147	0.042	0.299
		22	0.039	0.116	0.047	0.231	0.047	0.146	0.055	0.277
	XI	12	0.030	0.085	0.037	0.172	0.043	0.131	0.051	0.253
	XII	5	0.043	0.114	0.053	0.230	0.057	0.162	0.069	0.320
		24	0.049	0.115	0.063	0.249	0.059	0.144	0.074	0.271
1963	I	14	0.023	0.052	0.030	0.100	0.016	0.040	0.020	0.080
	II	4	0.041	0.087	0.052	0.166	0.049	0.116	0.061	0.221
		25	0.038	0.099	0.049	0.216	0.052	0.144	0.061	0.251
	III	5	0.039	0.108	0.048	0.224	0.042	0.117	0.051	0.230
		15	0.036	0.079	0.047	0.165	0.059	0.135	0.078	0.297
		25	0.027	0.068	0.034	0.135	0.037	0.097	0.045	0.171
	IV	8	0.043	0.099	0.054	0.187	0.048	0.117	0.060	0.228
		18	0.039	0.097	0.049	0.184	0.044	0.121	0.053	0.216

Remarks: a; % on a fresh weight basis.
b; % on a dry weight basis.
c; % on a value deducted residue weight from fresh weight.
d; % on a value deducted residue weight from dry weight.

Reference table I-6 Seasonal variations of total carbohydrate contents of *Abies sachalinensis* MAST. (Todomatsu) seedlings.

Date		Normal shoot				Lammas shoot			
		a	b	c	d	a	b	c	d
1961	IX 26	0.86	2.42	1.14	4.10	0.81	2.43	1.13	4.53
	X 4	1.04	2.72	1.30	4.35	0.83	2.58	1.25	4.45
	16	1.14	3.01	1.45	4.66	1.14	3.34	1.30	4.62
	24	1.25	3.06	1.64	4.94	1.03	2.97	1.41	5.33
	XI 6	1.57	3.70	1.76	5.28	1.27	3.22	1.57	5.01
	16	1.59	3.59	1.88	5.58	1.53	3.67	1.73	5.05
	27	1.70	4.34	1.98	6.70	1.49	4.02	1.68	5.74
	XII 12	1.99	4.25	2.63	7.16	1.81	4.10	2.29	6.27
1962	II 8	1.98	4.27	2.35	6.51	1.77	4.11	2.01	5.73
	IV 12	2.50	5.91	3.10	11.13	2.24	6.04	2.69	11.14
	21	2.73	6.40	3.37	11.44	1.93	5.48	2.30	10.12
	V 2	—	—	—	—	1.24	4.78	1.11	6.63
	12	0.89	4.75	0.96	7.34	0.64	3.66	0.69	6.04
	22	—	—	—	—	—	—	—	—
	VI 2	1.14	5.11	1.24	8.48	—	—	—	—
	12	1.52	6.31	1.69	10.80	—	—	—	—
	22	1.06	4.10	1.20	8.21	—	—	—	—
	VII 2	1.51	5.14	1.71	8.55	1.24	4.42	1.39	7.54
	12	1.12	4.42	1.25	7.34	0.98	4.23	1.08	7.01
	23	1.21	5.10	1.38	10.62	0.99	5.10	1.09	9.58
	VIII 2	0.76	3.52	0.84	6.66	0.71	3.70	0.77	7.48
	13	1.10	3.81	1.29	7.78	0.95	4.24	1.06	7.69
	23	1.06	3.95	1.24	8.61	0.95	4.48	1.06	7.88
	IX 3	1.60	5.27	1.91	11.09	1.65	7.53	1.83	13.94
	13	1.32	4.12	1.57	8.50	1.09	4.31	1.24	8.44
	X 2	1.43	4.66	1.67	8.92	1.16	4.69	1.34	9.55
	22	1.54	4.55	1.86	9.10	1.52	4.75	1.78	9.00
	XI 12	1.68	4.70	2.06	9.51	1.51	4.57	1.78	8.81
	XII 5	1.70	4.48	2.10	9.07	—	—	—	—
	24	2.18	5.13	2.83	11.12	2.31	5.60	2.87	10.58
1963	I 14	2.42	5.31	3.09	10.29	2.21	5.58	2.75	11.06
	II 4	2.15	4.61	2.76	8.76	2.34	5.55	2.95	10.61
	25	1.89	4.87	2.40	10.65	2.07	5.74	2.45	10.01
	III 5	2.09	5.75	2.57	11.97	2.23	6.19	2.70	12.17
	15	2.08	4.63	2.72	9.55	2.16	4.92	2.85	10.86
	25	1.94	4.74	2.42	9.58	1.85	4.82	2.22	8.52
	IV 8	1.96	4.51	2.47	8.54	1.96	4.77	2.47	9.32
	18	2.21	5.45	2.74	10.50	1.92	5.25	2.28	9.33

Remarks: a; % on a fresh weight basis. b; % on a dry weight basis
c; % on a value deducted residue weight from fresh weight.
d; % on a value deducted residue weight from dry weight.

Reference table I-7 Seasonal variations of total sugar contents of *Abies sachalinensis* MAST. (Todomatsu) seedlings.

Date			Normal shoot				Lammas shoot			
			a	b	c	d	a	b	c	d
1961	IX	26	0.31	0.87	0.53	1.88	0.24	0.71	0.49	1.90
	X	4	0.51	1.33	0.58	1.95	0.44	1.36	0.50	2.24
		16	0.53	1.40	0.67	2.22	0.56	1.63	0.54	2.13
		24	0.50	1.22	0.75	2.38	0.31	0.90	0.60	2.25
	XI	6	0.84	1.98	0.97	2.82	0.71	1.80	0.82	2.80
		16	0.93	2.10	1.10	3.26	0.75	1.80	0.85	2.48
		27	1.10	2.80	1.28	4.28	0.93	2.51	1.05	3.59
	XII	12	1.45	3.09	1.72	4.69	1.27	2.88	1.45	3.98
1962	II	8	1.35	2.91	1.60	4.44	1.07	2.49	1.22	3.47
	IV	12	1.08	2.55	1.34	5.01	0.97	2.62	1.17	4.83
		21	1.04	2.43	1.28	4.34	0.75	2.14	0.90	3.95
	V	2	—	—	—	—	0.74	2.49	0.58	3.45
		12	0.40	2.12	0.43	3.28	0.27	1.52	0.29	2.51
		22	—	—	—	—	—	—	—	—
	VI	2	0.48	2.15	0.52	3.56	—	—	—	—
		12	0.60	2.50	0.67	4.27	—	—	—	—
		22	0.34	1.30	0.38	2.50	—	—	—	—
	VII	2	0.73	2.48	0.83	4.13	0.63	2.25	0.71	3.84
		12	0.60	2.36	0.67	3.92	0.46	1.97	0.50	3.26
		23	0.60	2.53	0.68	5.26	0.38	1.98	0.42	3.72
	VIII	2	0.25	1.14	0.27	2.16	0.17	0.87	0.18	1.53
		13	0.50	1.74	0.59	3.56	0.40	1.80	0.45	3.26
		23	0.47	1.74	0.55	3.79	0.44	2.07	0.49	3.64
	IX	3	0.96	3.15	1.14	6.63	1.12	5.11	1.24	9.46
		13	0.62	1.93	0.74	3.99	0.55	2.19	0.63	4.29
	X	2	0.69	2.26	0.81	4.30	0.55	2.21	0.63	4.50
		22	0.74	2.18	0.89	4.36	0.81	2.54	0.95	4.81
	XI	12	0.81	2.26	0.99	4.58	0.67	2.03	0.79	3.91
	XII	5	0.99	2.61	1.22	5.28	—	—	—	—
		24	1.43	3.36	1.85	7.28	1.59	3.86	1.98	7.29
1963	I	14	1.64	3.60	2.10	6.98	1.53	3.85	1.90	7.64
	II	4	1.38	2.96	1.77	5.62	1.63	3.86	2.05	7.38
		25	1.18	3.04	1.50	6.65	1.40	3.87	1.65	6.75
	III	5	1.24	3.42	1.53	7.12	1.43	3.97	1.73	7.80
		15	1.20	2.66	1.57	5.50	1.37	3.13	1.81	6.90
		25	1.07	2.68	1.34	5.30	1.05	2.74	1.26	4.85
	IV	8	0.85	1.95	1.07	3.69	1.01	2.46	1.27	3.69
		18	0.83	2.04	1.02	3.89	0.81	2.21	0.96	3.93

Remarks: a; % on a fresh weight basis. b; % on a dry weight basis.
c; % on a value deducted residue weight from fresh weight.
d; % on a value deducted residue weight from dry weight.

Reference table I-8 Seasonal variations of reducing sugar contents of *Abies sachalinensis* MAST. (Todomatsu) seedlings.

Date		Normal shoot				Lammas shoot			
		a	b	c	d	a	b	c	d
1961	IX 26	0.28	0.78	0.32	1.12	0.23	0.70	0.25	1.06
	X 4	0.30	0.79	0.35	1.16	0.24	0.74	0.27	1.22
	16	0.35	0.92	0.42	1.40	0.29	0.84	0.32	1.23
	24	0.43	1.05	0.51	1.67	0.31	0.88	0.35	1.31
	XI 6	0.52	1.22	0.60	1.74	0.35	0.89	0.41	1.38
	16	0.55	1.25	0.65	1.94	0.49	1.18	0.53	1.62
	27	0.57	1.44	0.66	2.27	0.49	1.33	0.55	1.89
	XII 12	0.91	1.94	1.08	2.94	0.77	1.74	0.88	2.41
1962	II 8	0.71	1.53	0.84	2.33	0.65	1.51	0.74	2.10
	IV 12	0.75	1.77	0.93	3.23	0.64	1.73	0.77	3.19
	21	0.81	1.89	1.00	3.39	0.54	1.55	0.65	2.85
	V 2	—	—	—	—	0.37	1.71	0.40	2.36
	12	0.24	1.26	0.25	1.94	0.19	1.07	0.20	1.76
	22	0.11	0.65	0.12	0.97	—	—	—	—
	VI 2	0.25	1.13	0.28	1.87	—	—	—	—
	12	0.27	1.13	0.30	1.93	—	—	—	—
	22	0.22	0.84	0.25	1.73	—	—	—	—
	VII 2	0.45	1.54	0.51	2.56	0.43	1.54	0.49	2.63
	12	0.32	1.25	0.35	2.08	0.24	1.04	0.27	1.73
	23	0.42	1.78	0.48	3.70	0.26	1.33	0.28	2.50
	VIII 2	0.16	0.74	0.18	1.39	0.14	0.74	0.16	1.30
	13	0.31	1.08	0.37	2.20	0.27	1.23	0.31	2.22
	23	0.24	0.89	0.28	1.94	0.26	1.21	0.28	2.13
	IX 3	0.35	1.15	0.42	2.43	0.33	1.51	0.37	2.80
	13	0.31	0.97	0.37	1.99	0.35	1.38	0.40	2.69
	X 2	0.38	1.25	0.41	2.39	0.30	1.20	0.34	2.45
	22	0.40	1.18	0.48	2.36	0.43	1.36	0.51	2.58
	XI 12	0.60	1.69	0.74	3.41	0.58	1.76	0.69	3.39
	XII 5	0.87	2.31	1.08	4.68	0.92	2.61	1.12	5.15
	24	0.98	2.32	1.28	5.02	1.00	2.43	1.24	4.58
1963	I 14	1.13	2.49	1.45	4.82	0.97	2.44	1.21	4.85
	II 4	1.04	2.23	1.34	4.24	0.97	2.29	1.22	4.39
	25	0.91	2.34	1.15	5.11	0.90	2.48	1.06	4.33
	III 5	0.73	2.01	0.90	4.17	0.81	2.26	0.99	4.45
	15	0.93	2.05	1.21	4.25	0.98	2.23	1.29	4.93
	25	0.65	1.63	0.81	3.22	0.64	1.67	0.77	2.95
	IV 8	0.62	1.41	0.77	2.69	0.50	1.21	0.63	2.37
	18	0.39	0.97	0.49	1.85	0.39	1.08	0.47	1.92

Remarks: a; % on a fresh weight basis. b; % on a dry weight basis.
c; % on a value deducted residue weight from fresh weight.
d; % on a value deducted residue weight from dry weight.

Reference table I-9 Seasonal variations of starch contents of *Abies sachalinensis* MAST. (Todomatsu) seedlings.

Date			Normal shoot				Lammas shoot			
			a	b	c	d	a	b	c	d
1961	IX	26	0.55	1.55	0.61	2.22	0.57	1.72	0.64	2.63
	X	4	0.53	1.39	0.74	2.40	0.39	1.22	0.75	2.21
		16	0.61	1.61	0.78	2.44	0.58	1.71	0.76	2.49
		24	0.75	1.84	0.89	2.94	0.72	2.07	0.81	3.08
	XI	6	0.73	1.72	0.79	2.46	0.56	1.42	0.75	2.21
		16	0.66	1.49	0.78	2.32	0.78	1.87	0.88	2.57
		27	0.60	1.54	0.70	2.42	0.56	1.51	0.63	2.15
	XII	12	0.54	1.16	0.91	2.47	0·54	1.22	0.84	2.29
1962	II	8	0.63	1.36	0.75	2.07	0.70	1.62	0.79	2.26
	IV	12	1.42	3.36	1.76	6.12	1.27	3.42	1.52	6.31
		21	1.69	3.97	2.09	7.10	1.18	3.34	1.40	6.17
	V	2	0.59	2.45	0.63	3.21	0.50	2.29	0.53	3.18
		12	0.49	2.63	0.53	4.06	0.37	2.14	0.40	3.53
		22	0.41	2.40	0.43	3.60	—	—	—	—
	VI	2	0.66	2.96	0.72	4.92	—	—	—	—
		12	0.92	3.81	1.02	6.53	—	—	—	—
		22	0.72	2.80	0.82	5.59	—	—	—	—
	VII	2	0.78	2.66	0.88	4.42	0.61	2.17	0.68	3.70
		12	0.52	2.06	0.58	3.42	0.52	2.26	0.58	3.75
		23	0.61	2.57	0.70	5.36	0.61	3.12	0.67	5.86
	VIII	2	0.51	2.38	0.57	4.50	0.54	2.83	0.59	4.95
		13	0.60	2.07	0.70	4.22	0.55	2.44	0.61	4.43
		23	0.59	2.21	0.69	4.82	0.51	2.41	0.57	4.24
	IX	3	0.64	2.12	0.77	4.46	0.53	2.42	0.59	4.48
		13	0.70	2.19	0.83	4.51	0.54	2.12	0.61	4.15
	X	2	0.74	2.42	0.86	4.62	0.62	2.48	0.71	5.05
		22	0.80	2.37	0.97	4.74	0.71	2.21	0.83	4.19
	XI	12	0.87	2.44	1.07	4.93	0.84	2.54	0.99	4.90
	XII	5	0.71	1.87	0.88	3.79	0.67	1.89	0.81	3.73
		24	0.75	1.77	0.98	3.84	0.72	1.74	0.89	3.29
1963	I	14	0.78	1.71	0.99	3.31	0.68	1.73	0.85	3.42
	II	4	0.77	1.65	0.99	3.14	0.71	1.69	0.90	3.23
		25	0.71	1.83	0.90	4.00	0.67	1.87	0.80	3.26
	III	5	0.85	2.33	1.04	4.85	0.80	2.22	0.97	4.37
		15	0.88	1.97	1.15	4.05	0.79	1.79	1.04	3.96
		25	0.87	2.06	1.08	4.28	0.80	2.08	0.96	3.67
	IV	8	1.11	2.56	1.40	4.85	0.95	2.31	1.20	4.52
		18	1.38	3.41	1.72	6.51	1.11	3.04	1.32	5.40

Remarks: a; % on a fresh weight basis. b; % on a dry weight basis.
c; % on a value deducted residue weight from fresh weight.
d; % on a value deducted residue weiget from dry weiget.

トドマツ二次生長苗の栄養的研究 (要約)

玉利長三郎

林木における二次生長は，針葉樹・広葉樹を通じて屢々みられる現象である。冬の寒冷な休眠期を経て春の生長が開始されるのに対して，二次生長は寒冷な気候を受けることなしに夏の休眠の後に起る。そこで両者を比較して研究することは林木の生長，器官の分化および休眠の生理等を解明する上に重要な手掛りを与える。特にトドマツにおいては春季の芽条伸長を終えると冬芽を形成するが，苗畑においては二次生長を始め易く，この場合頂芽より側芽の開芽が優先するため，側芽のみが二次生長することも多く，形質不良な苗木を生産する原因となる。またこのような苗木は遅くまで生長を続けるため，生長休止後冬季までの硬化期間が短くなり，寒害を受け易く，林地へ植栽しても成績不良をきたす一因となる。したがって，この現象の生理的解明は単に学術上のみでなく，造林技術上大きな意義を持つ。この論文では，トドマツの正常生長苗と二次生長苗のそれぞれの生長経過と窒素・燐酸および炭水化物の新主条の頂部における年間の濃度変化ならびにその相互の関係を検討し，両種の苗の栄養の変動経過の相違と二次生長発生の要因を明らかにしようとした。この実験は北海道大学農学部演習林の札幌の実験苗畑で行われたものである。

第一部において，７年生トドマツ苗について５月上旬から６月下旬までの間に苗木の個体別の生長と栄養の転移を調査し，大要次のような結果を得た。新主条の長さの生長と主新条の生重は苗木の地上部および地下部の生重と大体均衡がとれていた。春の生長開始期に集積した窒素・燐酸・炭水化物，特に澱粉は生長がすすむとともに減少した。６月下旬には生長は急に減退し，地上部生重/地下部生重の比 (T-R 率) が低くなるのと対照的に炭水化物，特に澱粉が著しく増大した。すなわち地上部の伸長生長が衰え，地下部の生長が盛となる。根がネキリムシの害を受けた苗は地上部の生長も劣り，養料の濃度は生長期に正常生長苗にくらべて高い。また，このような苗は水溶性窒素/全窒素，水溶性燐酸/全燐酸，全炭水化物/全窒素などの比の減少傾向から，増加えの転換が正常生長苗よりおくれて来た。

第二部と第三部においては，次のような事項を明らかにした。材料とした５年生正常生長苗の水分含量は５月下旬に最高を示し，その後減少して７月上旬に最低となり，再び増加して８月上旬に第二の高位を示し，さらに減少して休眠期に入った。二次生長苗も大体同じような傾向を示し，その濃度は常に正常生長苗より稍高かった。正常生長苗の炭水化物，窒素，燐酸を抽出した残滓の量は水分量と負の相関を示し，生長期にすくなくて休

眠期に多かった。二次生長苗でも大体同様な傾向が認められた。しかし7月中旬から8月上旬の二次生長期に正常生長苗よりも多く減少した。両種の苗とも窒素，燐酸の濃度の最高値はいずれも伸長生長の関始される5月上旬であった。そしてその濃度は生長期には減少し，6月から7月上旬にかけて低位にあった。水溶性窒素と水溶性燐酸の濃度も大体同様な状態にある。水溶性窒素は全窒素よりも変動が顕著であった。全炭水化物の量は冬期間に大であった。4月の生長開始前に澱粉は急増し，5月の生長期には急減した。冬の休眠期の炭水化物の増加は，澱粉量には大きな変化がないので，糖の増加による。特に非還元糖の増加が著しかった。還元糖は冬の休眠期に多かったが，5月生長開始とともに急減し，5月下旬に第一の低位があらわれ，二次生長期の8月上旬に第二の低位があらわれた。春の生長期に備えて炭水化物は4月に急増し，窒素，燐酸は稍おくれて5月上旬に吸収が急増することが知られた。

生長期には水溶性窒素/全窒素，水溶性燐酸/全燐酸，還元糖/全炭水化物の比は他の季節にくらべて少なかった。生長期間中の全窒素/全燐酸の比は6月上旬に最低になった。全炭水化物/全窒素は7月上旬に最大となり，また糖/水溶性窒素，還元糖/水溶性窒素は6月上旬に最大となった。

二次生長開始期には，二次生長苗は各養料の濃度について春季生長期に稍似た変化をした。しかしその変動の幅は小さい。これは春の生長が大きな養料の集積の後に始まり，生長も大きいのに，二次生長は集積も生長も小さいことによる。この時期の全窒素と全燐酸，および水溶性燐酸の濃度は正常生長苗のそれより二次生長苗に高かった。二次生長苗では春の開芽期の全窒素，全燐酸の増加に比較して，水溶性窒素と水溶性燐酸が顕著に大きな増加を示すことが特徴である。この時期の二次生長苗のそれぞれの濃度は，正常生長苗の約2倍まで増加した。このことは二次生長苗の根の吸収力が正常苗のそれより著しく大きいものと考えることができる。二次生長苗について水溶性窒素の量は9月上旬が第二の高位となり，多くの場合正常生長苗より低い値を保った。水溶性燐酸の濃度の高位も9月上旬であって，休眠期を通じて正常生長苗より高かった。これまでの考察では，二次生長の原因は当年度の窒素の過剰な吸収に主として基因するとされていたが，この研究によると水溶性燐酸の濃度も二次生長苗では夏の二次生長期を除いて，正常生長苗よりかなり高かった。すなわち燐酸の吸収も二次生長に有力に関与しているものとみられる。このことは水溶性窒素/全窒素，水溶性燐酸/全燐酸の比が，ともに二次生長期には正常生長苗で顕著に増大し，二次生長苗では消費により低位にあり，隔差の増大することからも知られる。二次生長苗について，水溶性窒素/全窒素は10月中旬から11月中旬の期間と開芽期前に正常生長苗より高かった。また水溶性燐酸/全燐酸の比も春の生長開始期，二次生長開始期，1月中旬，3月下旬などを除いて高かった。

以上のことから二次生長は，窒素および燐酸の吸収する能力の特に大きいこと，および6月中，下旬の澱粉増にみられる炭水化物の内部集積が有力な発生条件となるものと考えられる。これは二次生長が据置苗で多くみられ，床替苗で少ないこと，また根浮かし作業等の根の吸収力抑制の操作が，その防止に効果ある事実と一致している。また林木の栄養の季節的な年間を通しての報告は少ないのであるが，この研究によりトドマツ正常生長苗，二次生長苗の年間を通しての養料吸収の大きさ，およびその相互の関係が明らかとなり，その生長との関連が考察され，トドマツ苗木の取扱い方，特に施肥法，二次生長防止法等について参考となる重要な知見が得られた。