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Author(s)	UJIIE, Masao; 氏家, 雅男; MAEDA, Yutaka et al.
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# Properties of Larch-Plantation Soils and Larch Trees Grown in Tomakomai Experiment Forest\*

By

Masao UJIE\*\* and Yutaka MAEDA\*\*

苫小牧地方演習林におけるカラマツ  
造林地の土壌と林木の性質\*

氏家雅男\*\* 前田 豊\*\*

## CONTENTS

Introduction . . . . .	463
Experiments . . . . .	466
1. Methods of Soil Survey . . . . .	466
2. Analyses . . . . .	466
2.1. Soils and their Chemical Elements . . . . .	466
2.2. Growth of Trees . . . . .	467
2.3. Woods and Needle-leaves . . . . .	467
Results and Discussion . . . . .	468
1. Circumstances and Soil Properties under Natural Conditions . . . . .	468
2. Physical and Chemical Properties of Soils . . . . .	471
3. Stem Analysis . . . . .	476
4. Chemical Composition of Woods . . . . .	479
5. Foliar Nutrients . . . . .	479
6. Accumulation of Organic Matters and Nitrogen Compounds . . . . .	485
Conclusion . . . . .	485
Summary . . . . .	485
Literature . . . . .	486
摘 要 . . . . .	488
Appendix: Climatological Data . . . . .	489

## Introduction

Tomakomai Experiment Forest, Hokkaido University, established in 1904, is located on the coastal terrace, having an area of 2,720 ha in the suburbs of Tomakomai City, where a great industrial base has recently been constructed (Fig. 1). As the Experiment Forest lies only 70 km south of Sapporo City, the location of Hokkaido University Campus, a lot of activities on field training for the students and researches of forestry and forest products have been done using the forest.

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\*\* Experiment Forest, Faculty of Agriculture, Hokkaido University.  
北海道大学農学部演習林

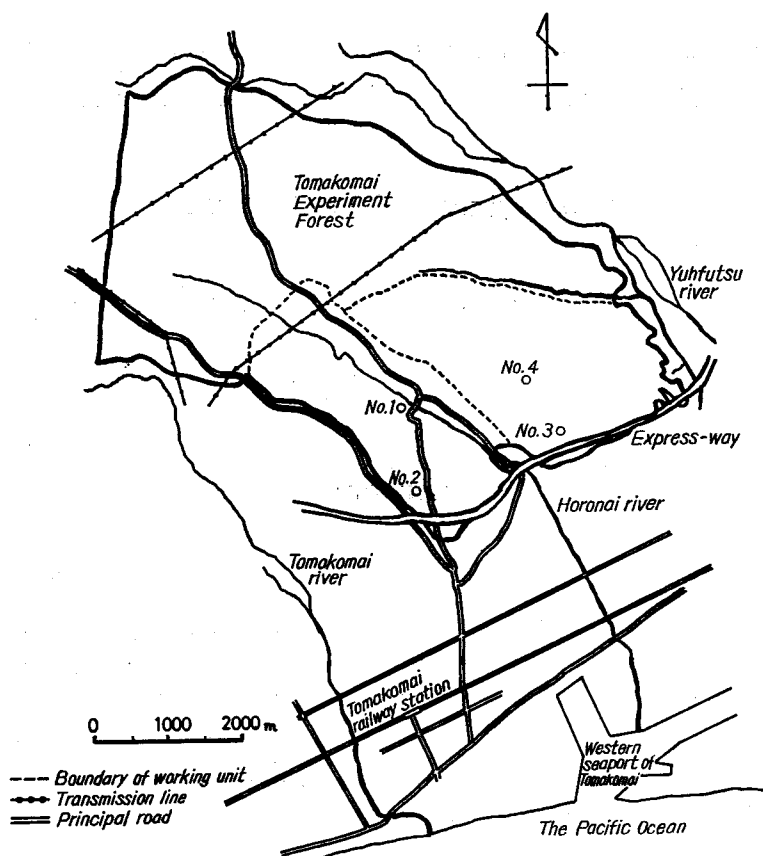


Fig. 1. Location of Tomakomai Experiment Forest and experiment plots.

It belongs to the northern Temperate Forest Zone composed of broad-leaved trees such as *Quercus mongolica* var. *grosseserrata*, *Ostrya japonica*, *Betula* spp., *Tilia japonica*, *Fraxinus* spp., *Ulmus davidiana* var. *japonica*, *Kalopanax pictus*, *Cercidiphyllum japonicum*, *Acer* spp., *Carpinus cordata*, etc. The studies have been chiefly made on the plantation of various tree species. Since the Forest Museum and the Forest Observation Tower were built in 1977, the studies have been expanded to urban forestry, wild life and air pollution.

However, the forestland consists of the deposits from recent volcanic ejecta (erupted in 1739 and 1667 from Mt. Tarumae)<sup>2,3,36,39</sup> and has only a thin soil-layer containing a considerable amount of humus. Concerning climatic condition, temperatures are comparatively low during the period of vegetation growing by a sea wind as well as a dense sea-fog, and in winter are lowered to the minimum of  $-25^{\circ}\text{C}$ . The snow cover is not so thick that the soils are frozen as deeply as 60 cm below surface during the season. Late frosts visiting sometimes in the latter part of spring, give rise to sprout injury of planted juvenile trees. Besides, air pollutants derived from the large factories of pulp and paper, aluminum refine, electric power industries, etc. and the express way passing through the Experiment Forest, may be

fearful of damaging vegetation life.

On account of these bad conditions the growth of plantation trees is so poor that in the lapse of the 30-year period the trees gradually seem to lose their vitality and among the 50-year trees the withered or wind-fallen begin to be often seen. For the last 30 years the forest was attacked twice by violent typhoons in 1954 and 1981, the former of which was the severest ever experienced, and caused a great damage corresponding to 40% of all the growing stock, while the latter injured mainly the plantation trees such as Japanese larch (*Larix kaempferi*), Todomatsu-fir (*Abies sachalinensis*) and Korean pine (*Pinus koraiensis*), estimating the wind-fallen at 15,000 m<sup>3</sup>.

Afforestation is an urgent problem for the Experiment Forest to recover the fields for education and research, but it is pretty difficult to succeed in the plantation as described before. Nevertheless, forests are increasingly becoming important in such viewpoints as the gain of natural recreation site and the other multiple beneficial roles in Japan, a highly urbanized country.

The plantation has been done with emphasis in the Experiment Forest since the foundation. Total of the plantation area amounts to about 30% of the forests, in which Japanese larch (*Larix kaempferi*) man-made forest is the largest.

Among the tree species planted in Tomakomai Experiment Forest, it is said that the larch trees have been most favorable.<sup>41)</sup> However, compared with the other districts in Hokkaido the growth is far fallen behind.<sup>4,27)</sup> Moreover, the injury of larch trees in Hokkaido by infections of *Guignardia laricina* spread in early 1960's and could be barely stopped with earnest efforts by sprinkling an antibiotic chemical, cycloheximide.<sup>10~12)</sup>

Physiological studies<sup>13,15,31,32,48)</sup> of larch trees planted in the Forest and the investigations of physical properties,<sup>7,8,14,25)</sup> chemical properties<sup>40,42)</sup> and utilizations<sup>5,9,51)</sup> of their woods have been hitherto carried out in detail. On the other hand, the studies on the soils<sup>33,52~55)</sup> and volcanic deposits<sup>29)</sup> by geological means in the Forest have been comparatively few, including the ones in the vicinities of it,<sup>18,30,50)</sup> though the researches on the black soils composed of weathered volcanic ashes have considerably done.<sup>22,24,29,34~38,44)</sup> Recently, the studies on biomass and production structures have been actively made using various forests.<sup>46~48)</sup> Larch forestlands have been also investigated in Honshu under detailed surveys.<sup>16,17,49~49)</sup> The biomass produced by some *Abies sachalinensis*-plantation lands in Tomakomai Experiment Forest has been studied,<sup>6)</sup> but not by larch forestlands.

This study was carried out from 1970 to 1973, in the 4 plots of typical larch plantation site and the laboratory of the Forest. After the surveys of circumstances and soil profiles were made, soils collected individually from each layer were examined on physical and chemical properties. The larch trees felled in autumn, 1970, were furnished to the stem analysis, and chemical analysis. The specimens divided into heartwood, sapwood and barks were analyzed by TAPPI standards, while the investigation of needle-leaves was made by an elementary analysis method. Besides, accumulation and fixation of organic matters and nitrogen compounds on

the larch forestland were estimated.

The authors are deeply indebted and would like to express their gratitude to the members of Tomakomai Experiment Forest for kind helps in the experiments.

## Experiments

### 1. Method of Soil Survey

Soil surveys were carried out in autumn, 1970. The stands chosen from among larch plantations were four, i. e. No. 1, 2, 3 and 4 planted in compartment No. 120 in 1960, No. 106 in 1952, No. 308 in 1939 and No. 314 in 1931, respectively, as shown in Fig. 1. Before the survey, the tree growth was measured in each plot (10×10 m), then two trees of a mean (average in diameter at breast height) and a typical (normally growing) one were cut, the former of which was used for chemical analyses of woods and needle-leaves, while the latter for a stem analysis.

The pit was made in each plot by digging up to 60 to 100 cm in accordance with the appearance of fine roots of the trees. The soil profile observed was divided into 5 or 6 layers according to the color or texture by naked eye, then the Roman numerals and horizontal marks were given to each layer. After the thickness and color by Munsell's notation were individually examined, the soils under natural condition were taken for the measurement of apparent specific gravity, moisture and three phases, using a core sampler with a 100-ml cylinder, in the field. At the same time the samples of each layer including Ao-layer were collected and taken for the investigation of physical and chemical properties in the laboratory, where the percentage of gravels was determined on the occasion of an acquisition of air-dried fine soils by passing through a 2-mm sieve. Cored samples were weighed and heated to absolute dryness, then the proportion of solid, liquid and gas phases as well as the porosity were calculated by a volumetric percentage after measuring a real specific gravity of fine soils.

### 2. Analyses

#### 2.1. Soils and their Chemical Elements

The soils brought into the laboratory were air-dried for 2 weeks. The investigation of fine soil obtained by passing through the sieve were mainly carried out by standard procedures.<sup>20,21,45)</sup> The physical examinations used were as follows: mechanical analysis, by a pipet method after pretreating with H<sub>2</sub>O<sub>2</sub> and HCl; Maximum water holding capacity and bulk density, by Yamanaka's method; Real specific gravity, with a Beckman air comparison pycnometer. The chemical examinations of the soils and the Ao were as follows: pH in water and N-KCl, with a pH-meter; Exchange acidity (Y<sub>1</sub>), by the titration of N-KCl-soil-extract with 0.1 N NaOH; Loss on ignition, in a 650°C-muffle for 8 hours; Carbon and total organic matter, by the wet oxidation method; Total nitrogen, by Kjeldahl method; Free R<sub>2</sub>O<sub>3</sub>, by precipitating the filtrate obtained on pretreatment of mechanical analysis with NH<sub>4</sub>OH; CEC, by Schollenberg method with an ionmeter (ORION 407)

using an ammonium electrode; Exchangeable cations (Ca, Mg, K and Na) treated with 1 N  $\text{NH}_4\text{OAc}$  at pH 7, with an atomic absorption spectrophotometer (SEIKO SAS 721); phosphate absorption, with 2.5%  $(\text{NH}_4)_2\text{HPO}_4$  and using the filtrate colored by a vanado-molybdate method with a spectrophotometer (440 nm).

Moisture content at various pF was determined with a KOKUSAN centrifuge using the following equation:

$$\text{pF} = \log \frac{r}{g} \left( \frac{\pi n}{30} \right)^2 = 2 \log n + \log r - 4.95$$

where  $r$  is 8.95 cm, the distance between the axis and the cup;  $g$  is  $980 \text{ cm} \cdot \text{s}^{-2}$ , the acceleration of gravity;  $n$  is revolutions per minute. The values of pF chosen were 1.6, 2.7, 3.09, 3.9 and 4.2 corresponding to field capacity, moisture equivalent, *lento* capillary point, temporary wilting point and permanent wilting point, respectively. The fully wetted samples were put in the cup and revolved for 30 min. at the prescribed speeds. Available water was determined by subtracting the moisture content at pF 4.2 from that at 1.6.

The chemical elements of IA layer soils and Ao were determined. Firstly 100 mg of the samples ignited and milled were put in a *Teflon*-covered acid-decomposition vessel with 1 ml of *aqua regia* and 3 ml of HF, then were perfectly dissolved by heating at  $110^\circ\text{C}$  for an hour.<sup>1,56,58)</sup> The solution obtained was treated with 2.8 g of boric acid and used for the element investigation with the atomic absorption spectrophotometer. Determination of Si, Al, Fe, Mg, Ca, K and Na was made with each corresponding hollow-cathode lamp and adequate wave length, using  $\text{C}_2\text{H}_2$  and air or  $\text{N}_2\text{O}$ , then they were calculated as oxides.

## 2.2. Growth of Trees

Growth of typical larch trees felled at a 30-cm height was investigated according to a stem analysis by Nakajima's method.<sup>20)</sup> The growth and annual as well as periodic increment of height, diameter at breast height, the sectional area and the volume were calculated. Based on the results, illustrations of the 4 tree stems were made.

## 2.3. Woods and Needle-leaves

Four mean larch woods were chemically analyzed by the standard procedures. Firstly, the each wood debarked was divided into 3 parts; lower, middle and top, then lower parts were further divided into heart- and sapwood. All the parts including barks were air-dried and milled. The portions of 40 to 60 meshes and 60 to 100 meshes were used for the analysis; the former, for holocellulose and the latter, for the other components. The analyses were done on ash, solubilities in alcohol-benzene, cold and hot water as well as 1% NaOH, pentosan and methyl pentosan, holocellulose,  $\alpha$ -cellulose, lignin and total nitrogen.

Needle leaves air-dried and milled were used for the analyses of nitrogen and minerals. After the samples were ignited and dissolved with *aqua regia* and HF, the elementary analysis except P was made on Si, Al, Fe, Mg, Ca, K and Na with the atomic absorption spectrophotometer by the same method as described before.<sup>1,56,58)</sup>

Phosphorus was photometrically determined. The elements were calculated as oxides.

## Results and Discussion

### 1. Circumstances and Soil Properties under Natural Conditions

Circumstances of 4 experimental plots in the larch forests are shown in Table 1.

Table 1. Description of plantation sites and results of growth

Plot No.	Location (compartment)	Year of plantation	Area of plantation (ha)	Slope and derection	Tending treatment	
					Weeding	Improvement cutting
1	120	1960	1.28	NE 10°	4 times	once
2	106	1952	2.09	W 7°	4 times	times
3	308	1939	5.91	flat	twice	4 times
4*	314	1931	2.94	S 6°	twice	6 times

Plot No.	Location (compartment)	Year of plantation	Result of growth					
			Date of inventory	Survived numbers per ha	Mean tree			
					Height (m)	Diameter at breast height (cm)	Stem volume (m <sup>3</sup> )	Stem dry-weight (kg)
1	120	1960	Oct., 1970	2,400	6.2	6.4	0.0099	5.8
2	106	1952	"	1,420	7.9	7.4	0.0185	9.3
3	308	1939	"	980	10.0	13.8	0.0849	33.3
4*	314	1931	"	980	12.1	14.8	0.1140	47.9

\* plantation mixed with *Picea abies*.

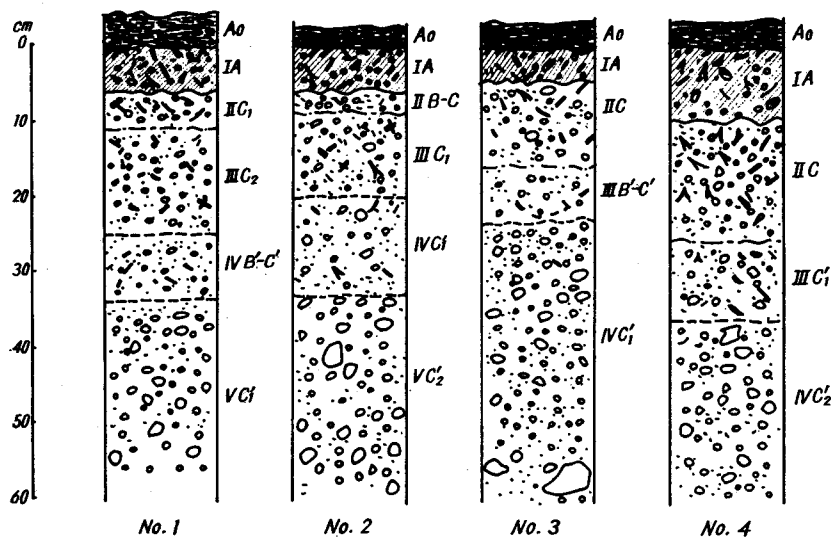


Fig. 2. Soil profiles surveyed.

Table 2. Properties of soils under natural conditions

Plot No.	Location (compartment)	Layer	Depth (cm)	Thickness (cm)	Color		
					Description of fresh soil by naked eye	Fresh soil by Munsell	Dried soil by Munsell
1	120	I A	0-6	6	brownish black	5Y R2/2	5Y R3/2
		II C <sub>1</sub>	6-11	5	brown	7.5Y R4/4	7.5Y R4/3
		III C <sub>2</sub>	11-25	14	dark brown	7.5Y R3/4	7.5Y R4/3
		IV B'-C'	25-33.5	8.5	"	7.5Y R3/3	7.5Y R4/3
		V C'	33.5-	>25	grayish brown	7.5Y R4/2	7.5Y R5/1
2	106	I A	0-5.5	5.5	brownish black	7.5Y R2/2	7.5Y R3/2
		II B-C	5.5-10	4.5	dark reddish brown	5Y R3/4	7.5Y R5/3
		III C	10-20	10	reddish brown	5Y R4/6	7.5Y R5/3
		IV C <sub>1</sub>	20-33	13	brown	7.5Y R4/4	7.5Y R5/3
		V C <sub>2</sub>	33-	>25	grayish brown	7.5Y R4/2	7.5Y R5/1
3	308	I A	5-0	5	brownish black	7.5Y R3/2	7.5Y R3/2
		II C	5-16	11	dull reddish brown	5Y R4/4	5Y R5/3
		III B'-C'	23-23.5	7.5	dark reddish brown	5Y R3/4	5Y R4/2
		IV C <sub>1</sub>	23.5-	>30	grayish brown	7.5Y R5/2	7.5Y R4/1
4	314	I A	0-10	10	very dark reddish brown	5Y R2/3	7.5Y R3/2
		II C	10-26	16	dark brown	7.5Y R3/4	7.5Y R4/3
		III C <sub>1</sub>	26-41	15	"	7.5Y R3/4	7.5Y R4/3
		IV C <sub>2</sub>	41-	>25	grayish brown	7.5Y R4/2	7.5Y R5/2

Plot No.	Location (compartment)	Layer	Apparent specific gravity		Moisture content based on		Gravel (%)	Distribution of three phases in soil (Vol. %)			Porosity (Vol. %)
			Fresh soil	Dried soil	Fresh soil (%)	Dried soil (%)		Solid	Liquid	Gas	
1	120	I A	0.99	0.69	30.7	44.2	17	26	30	44	74
		II C <sub>1</sub>	1.11	0.92	16.8	20.2	33	29	19	52	71
		III C <sub>2</sub>	1.06	0.89	16.2	19.3	25	30	17	53	68
		IV B'-C'	1.00	0.83	17.5	21.3	17	29	18	53	71
		V C'	1.16	0.99	14.4	16.8	40	34	17	49	66
2	106	I A	0.85	0.39	54.7	120.7	18	15	47	38	85
		II B-C	1.11	0.82	26.6	36.2	27	28	30	42	72
		III C	1.25	1.05	16.1	19.1	24	37	20	43	63
		IV C <sub>1</sub>	1.40	1.18	15.5	18.4	9	42	22	36	58
		V C <sub>2</sub>	1.21	1.05	13.0	14.9	38	36	16	48	64
3	308	I A	0.96	0.69	28.3	39.4	21	25	27	48	75
		II C	1.30	1.14	12.3	14.0	20	37	16	47	63
		III B'-C'	1.40	1.20	14.2	16.5	13	41	20	39	59
		IV C <sub>1</sub>	1.16	1.00	14.2	16.5	41	34	17	49	66
4	314	I A	0.90	0.57	36.9	58.6	12	22	33	45	78
		II C	1.05	0.83	21.3	27.1	27	28	22	50	72
		III C <sub>1</sub>	1.24	0.98	20.4	25.6	22	35	25	40	65
		IV C <sub>2</sub>	1.21	1.04	14.0	16.3	40	35	17	48	65

Ages of the larch trees planted in the compartment No. 120, 106, 308 and 314 were 12, 19, 32 and 42 years, respectively. The inventory of the trees grown on the flat or gentle slope lands were carried out using the areas of  $10 \times 10$  m, the results of which showed that the survived numbers per ha were 2,400, 1,420, 980 and 980, while growing stocks 23.8, 26.3, 83.2 and 111.7  $m^3/ha$  in the above-mentioned order estimating from the volumes of the mean trees. The main vegetations on the forest lands are as follows:

No. 1 (compartment No. 120)...*Dryopteris crassirhizoma*, *Aruncus dioicus* var. *kamtschaticus*, *Artemisia montana*, *Polygonatum odoratum* var. *maximowiczii*, *Anaphalis margaritacea* var. *angustior*, *Cacalia hastata* var. *orientalis*, *Spiraea salicifolia*, *Aralia elata*.

No. 2 (comp. No. 106)...*Artemisia montana*, *A. japonica*, *Erigeron annuus*, *Lasterea thelypteris*, *Carex* spp., *Rubus* spp., *Spiraea salicifolia*, *Schisandra chinensis*.

No. 3 (comp. No. 308)...*Dryopteris crassirhizoma*, *Phryma leptostachya* var. *asiatica*, *Agrimonia pilosa*, *Artemisia montana*, *Trillium kamtschaticum*, *Pachysandra terminalis*, *Aralia elata*, *Vitis coignetiae*.

No. 4 (comp. No. 314)...*Lilium cordatum* var. *glehnii*, *Maianthemum dilatatum*, *Lysimachia vulgaris* var. *davurica*, *Polygonatum odoratum* var. *maximowiczii*, *Carex* spp., *Euonymus alatus*, *Schisandra chinensis*, *Hydrangea paniculata*.

Table 3. Particle-size distribution of gravel (%)

Location	Slope	Direction	Layer	Thickness (cm)	Particle-size (mm)					
					>20	20-10	10-4	4-2	Total gravel	2>
Northern edge of the Exp. Forest, fir-plantation of compartment No. 203.	15°	S	I A	8	0	1	3	1	5	95
			II B-C	18	0	3	1	0	4	96
			III C <sub>1</sub>	19	1	16	28	35	80	20
			IV C <sub>2</sub>	26	0	4	8	2	14	86
			V B'-C'	6	1	6	22	0	29	71
			VI C <sub>1</sub>	>20	5	11	29	38	83	17
Southern part of the Exp. Forest, larch-plantation of compartment No. 117.	flat	—	I A	8	0	1	8	1	10	90
			II C <sub>1</sub>	7	0	2	10	0	12	88
			III C <sub>2</sub>	10	1	9	12	0	22	78
			IV C <sub>3</sub>	12	0	0	6	20	26	74
			V C <sub>4</sub>	45	1	9	24	0	34	66
			VI C <sub>5</sub>	>20	4	7	21	13	45	55
Center of the Exp. Forest, natural forest of compartment No. 405.	flat	—	I A	6	0	1	12	1	14	86
			II B-C	5	0	2	8	1	11	89
			III C	24	1	7	11	0	19	81
			IV B'-C <sub>1</sub>	5	0	1	5	0	6	94
			V C <sub>2</sub>	>25	1	8	31	0	40	60

Ao-layers composed of organic matters were mostly F-layer, and could be distinctly distinguished from the surface soils. The thickness of the Ao-layer in No. 1, 2, 3 and 4 was 4.0, 2.5, 3.0 and 3.0 cm, respectively.

Illustrations of the soil profiles surveyed and soil properties under natural conditions are given in Fig. 2 and Table 2, respectively. The soils consisting of recent volcanic ejecta from Mt. Tarumae belong to Regosol and are called immature soils (Im) because of not fully developing the differentiation of the horizons, according to the classification of the forest soils by the Forestry Agency, Japan. The soils investigated were divided into 5 or 6 layers by naked eye, the upmost layer of which is 5- to 10-cm thick, and somewhat soft and mellow soils containing a considerably rich humus. However, the soils located lower than the first layer are hardly weathered and composed of coarse sands and gravels. Table 3 reveals the distribution of gravels by the particle-size, which is different with the place and direction in the Forest. The gravels more than the diameter of 20 mm are extremely a little. It is also clear the lowest layer surveyed has generally a large amount of gravels in the relation between the quantity and the layer.

## 2. Physical and Chemical Properties of Soils

Table 4 shows the physical and chemical properties of the fine soils. The textures of I-layer are sandy loam (SL), but those of the subsoils are all sand (S) by the mechanical analysis. Accordingly, it is natural that they have a low moisture in the air-dried state as well as a low maximum water holding capacity, on the contrary, a high real specific gravity.

As for the chemical properties, any subsoils derived from the deposits, are high in pH and low in the values of  $Y_1$ , carbon and nitrogen as well as low in CEC and the absorption of phosphorus. It must be said from the results only I-layer forms the just correct soils called A-horizon and the others do not form the soils in the strict and literal sense.

The relation between the moisture content and the various pF is shown in Table 5. The water retention ability and available water of the soils are extremely low except I-layer compared even with other subsoils studied.<sup>29,56,58</sup> Fig. 3 indicates the pF curves of some soils, including newly pF-values of 7.0, 5.7 and 0, corresponding to the moisture contained in the samples of the oven-dry, air-dry and the maximum water holding capacity. The soil of natural forest IA graphed here is seemingly one of the best quality-soils in the Experiment Forest. It can be also understood that the moisture state in soils under natural conditions is considerably excessive, in the comparison of Table 5 with Table 2.

The chemical properties of Ao layers are summarized in Table 6. The oven-dry samples have such very low specific gravities as the value of 0.05 to 0.08, and low pH on account of the organic acid produced. The organic matters which range from 42 to 66%, indicate the samples contain fairly ample minerals. Cation exchange capacity of Ao is high. It is, however, shown from the base saturation that only half of it is the base essential for growing the tree, when Ao is reduced to the soils.

**Table 4.** Physical and chemical properties of fine soils

Plot No.	Location (compartment) No.	Layer	Mechanical analysis (%)				Soil texture	Air-dried moisture (%)	Maximum water holding capacity (water ratio %)	Bulk density	Real specific gravity	pH		Exchange acidity
			Coarse sand	Fine sand	Silt	Clay						H <sub>2</sub> O	N-KCl	
1	120	I A	70	10	7	13	SL	2.73	80.4	0.92	2.65	5.6	4.8	1.1
		II C <sub>1</sub>	96	1	2	1	S	0.39	24.2	1.46	3.19	6.1	5.4	0.6
		III C <sub>2</sub>	94	2	2	2	S	0.47	23.6	1.41	2.96	6.2	5.5	0.3
		IV B'-C'	91	3	3	3	S	0.76	26.2	1.38	2.89	6.1	5.2	0.4
		V C <sub>1</sub>	97	1	1	1	S	0.16	23.1	1.44	2.90	6.2	6.0	0.4
2	106	I A	71	9	8	12	SL	5.04	83.6	0.81	2.60	5.3	4.3	1.7
		II B-C	82	8	4	6	S	1.67	34.3	1.26	2.89	5.6	4.7	1.4
		III C	92	3	3	2	S	0.63	23.6	1.45	2.87	5.9	5.1	0.4
		IV C <sub>1</sub>	85	9	2	4	S	0.79	25.0	1.39	2.78	5.9	5.0	0.5
		V C <sub>2</sub>	96	3	1	1	S	1.19	24.4	1.41	2.90	6.1	5.6	0.3
3	308	I A	70	14	8	8	SL	1.59	50.5	1.16	2.77	5.6	4.7	1.2
		II C	92	4	1	3	S	0.27	23.1	1.44	3.08	6.1	5.2	0.3
		III B'-C'	89	6	1	4	S	0.56	28.1	1.38	2.94	5.9	4.9	0.7
		IV C <sub>1</sub>	97	1	0	2	S	0.12	22.9	1.39	2.97	6.1	5.6	0.4
4	314	I A	71	11	6	12	SL	2.04	63.0	1.07	2.61	5.6	4.6	2.0
		II C	91	4	1	4	S	0.72	25.6	1.41	2.98	5.8	4.8	1.0
		III C <sub>1</sub>	91	3	2	4	S	0.88	32.2	1.19	2.80	5.8	4.7	1.0
		IV C <sub>2</sub>	98	1	0	1	S	0.26	24.2	1.43	2.96	6.2	5.6	0.2

Plot No.	Location (compartment) No.	Layer	Loss on ignition (%)	C (%)	N (%)	C-N ratio	Total organic matter (%)	Isolated R <sub>2</sub> O <sub>3</sub> (%)	CEC (me/100 g)	Exchangeable cations (me/100 g)				Degree of base saturation (%)	Absorption coefficient of P <sub>2</sub> O <sub>5</sub> (mg/100 g)
										Ca	Mg	K	Na		
1	120	I A	13.1	5.77	0.315	18	10.6	0.00	18.09	7.83	1.10	0.22	0.10	51	530
		II C <sub>1</sub>	0.8	0.34	0.023	15	0.6	0.45	1.87	0.75	0.06	0.03	0.01	46	140
		III C <sub>2</sub>	1.1	0.40	0.018	22	0.7	0.36	2.16	1.03	0.08	0.04	0.03	55	190
		IV B'-C'	2.0	0.63	0.049	13	1.2	0.78	4.14	1.30	0.09	0.03	0.05	36	420
		V C <sub>1</sub>	0.2	0.06	0.006	10	0.1	0.35	0.69	0.26	0.03	0.01	0.06	52	40
2	106	I A	12.3	6.50	0.331	20	11.9	0.00	20.77	3.56	0.73	0.15	0.07	22	660
		II B-C	4.2	1.70	0.126	14	3.1	0.84	6.27	1.18	0.15	0.03	0.05	23	490
		III C	1.1	0.74	0.035	21	1.4	0.42	3.35	0.48	0.06	0.01	0.05	18	190
		IV C <sub>1</sub>	1.5	0.76	0.043	18	1.4	0.78	3.72	0.58	0.07	0.28	0.05	26	200
		V C <sub>2</sub>	0.2	0.03	0.000	—	0.1	0.32	0.89	0.16	0.03	0.03	0.03	28	110
3	308	I A	7.0	3.68	0.175	21	6.7	0.43	17.50	5.16	0.83	0.14	0.09	36	380
		II C	1.1	0.70	0.022	32	1.3	0.34	2.11	0.57	0.08	0.03	0.02	33	80
		III B'-C'	2.1	1.21	0.040	30	2.2	0.70	5.54	0.82	0.11	0.05	0.03	18	200
		IV C <sub>1</sub>	0.3	0.16	0.006	27	0.3	0.23	0.62	0.21	0.03	0.01	0.03	45	30
4	314	I A	10.3	4.21	0.292	14	7.7	0.00	17.54	3.47	0.64	0.12	0.07	25	620
		II C	1.5	0.80	0.039	21	1.5	0.42	3.02	0.54	0.08	0.04	0.03	23	130
		III C <sub>1</sub>	2.5	0.95	0.046	21	1.7	0.57	3.74	0.58	0.08	0.03	0.02	19	370
		IV C <sub>2</sub>	0.7	0.15	0.012	13	0.3	0.24	0.74	0.38	0.04	0.03	0.06	69	70

Table 5. Water ratio in various pF of fine soils

No.	Location (compartment)	Layer	pF					Available moisture (points)
			1.6	2.7	3.09	3.9	4.2 (%)	
1	120	I A	43.1	31.0	26.4	16.9	13.8	29.3
		II C <sub>1</sub>	5.1	3.8	3.0	2.0	1.2	3.9
		III C <sub>2</sub>	7.5	5.3	4.4	2.4	1.9	5.6
		IV B'-C'	7.7	5.3	4.3	2.5	1.6	6.1
		V C <sub>1</sub>	5.2	3.7	3.0	1.8	1.1	4.1
2	106	I A	52.7	35.0	28.0	18.3	15.8	37.9
		II B-C	14.7	9.3	7.9	4.6	3.5	11.2
		III C	6.4	4.8	3.8	2.2	1.7	4.7
		IV C <sub>1</sub>	10.2	7.2	6.3	3.7	2.6	7.6
		V C <sub>2</sub>	5.2	3.7	3.0	1.7	1.2	4.0
3	308	I A	22.4	14.7	11.5	7.5	6.2	16.2
		II C	6.4	4.5	3.8	2.2	1.6	4.8
		III B'-C'	9.7	6.9	5.5	3.0	1.9	7.8
		IV C <sub>1</sub>	4.6	3.5	2.8	1.8	1.1	3.5
4	314	I A	30.7	21.0	17.5	10.0	8.9	21.8
		II C	11.6	8.0	6.6	3.8	2.7	8.9
		III C <sub>1</sub>	7.4	5.2	4.2	2.6	1.7	5.7
		IV C <sub>2</sub>	4.2	2.9	2.3	1.3	1.1	3.1

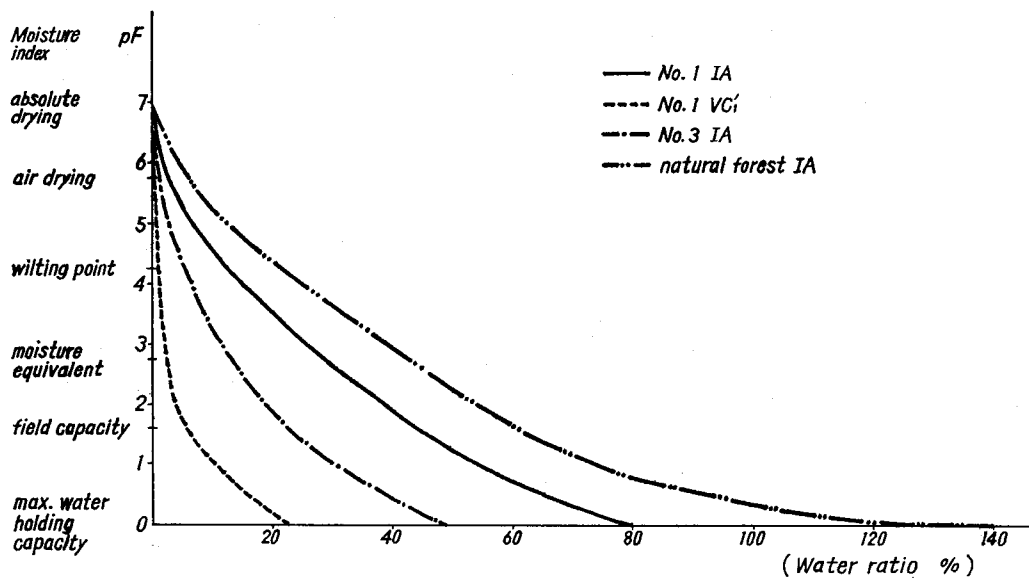


Fig. 3. Relation between moisture content and pF in various fine soils.

**Table 6.** Physical and chemical properties of Ao-layer

Plot No.	Location (compartment) No.	Thickness (cm)	Moisture (%)		Apparent specific gravity		Real specific gravity	pH	
			Fresh	Air-dried	Fresh	Oven-dried		H <sub>2</sub> O	N-KCl
1	120	4.0	81.2	7.47	0.45	0.08	1.70	3.91	3.68
2	106	2.5	78.2	7.49	0.23	0.05	1.58	4.38	3.99
3	308	3.0	75.3	7.41	0.30	0.07	1.80	4.78	4.36
4	314	3.0	76.1	8.07	0.24	0.06	1.89	4.94	4.64

Plot No.	Location (compartment) No.	C (%)	N (%)	C/N ratio	Total organic matter (%)	CEC (me/100 g)	Exchangeable cations (me/100 g)				Degree of base saturation (%)
							Ca	Mg	K	Na	
1	120	26.7	1.42	19	46.0	73.5	24.5	5.6	1.6	0.5	43.8
2	106	38.2	1.82	21	65.9	61.9	26.3	7.6	1.7	0.5	58.3
3	308	24.1	1.17	21	41.5	67.9	24.6	7.0	2.0	0.3	49.9
4	314	29.0	1.25	23	50.0	78.5	26.3	9.5	3.7	0.5	50.9

**Table 7.** Inorganic chemical composition of Ao-and I-layer (A-horizon)

Plot No.	Location (compartment) No.	Layer	Thickness (cm)	Apparent specific gravity (dried)	Organic matter (%)
		IA	6.0	0.69	10.6
2	106	Ao	2.5	0.05	65.9
		IA	5.5	0.89	11.9
3	308	Ao	3.0	0.07	41.5
		IA	5.0	0.69	6.7
4	314	Ao	3.0	0.07	50.0
		IA	10.0	0.57	7.7

Plot No.	Location (compartment) No.	Layer	Components contained as oxides (%)								
			SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	MgO	CaO	K <sub>2</sub> O	Na <sub>2</sub> O	P <sub>2</sub> O <sub>5</sub>	total
1	120	Ao	32.3	6.0	5.6	1.8	3.1	0.3	0.6	0.19	49.89
		IA	53.5	12.7	11.4	1.7	4.0	0.4	1.0	0.06	84.76
2	106	Ao	20.1	4.0	3.4	1.4	1.9	0.5	0.5	0.14	31.94
		IA	51.4	11.1	11.2	1.9	3.7	0.6	1.2	0.10	81.20
3	308	Ao	34.9	6.8	5.5	2.6	2.6	0.5	0.7	0.13	53.73
		IA	56.2	13.1	12.0	1.8	4.0	0.4	1.0	0.05	88.55
4	314	Ao	29.7	5.8	4.7	2.2	2.3	0.6	0.8	0.19	46.29
		IA	56.7	12.1	10.5	2.3	4.1	0.4	1.0	0.06	87.16

Inorganic chemical composition of Ao and the soil of I-layer is given in Table 7. Naturally, the content of  $\text{SiO}_2$  is the highest. That of  $\text{Al}_2\text{O}_3$  and  $\text{Fe}_2\text{O}_3$  is similar to each other and followed by the content of  $\text{CaO}$ . That of  $\text{P}_2\text{O}_5$  is very low.

### 3. Stem Analysis

Growth and increment of the typical larch trees are given by the lump in Figures 4 to 11. Though the growth of the young tree is fairly good, that which

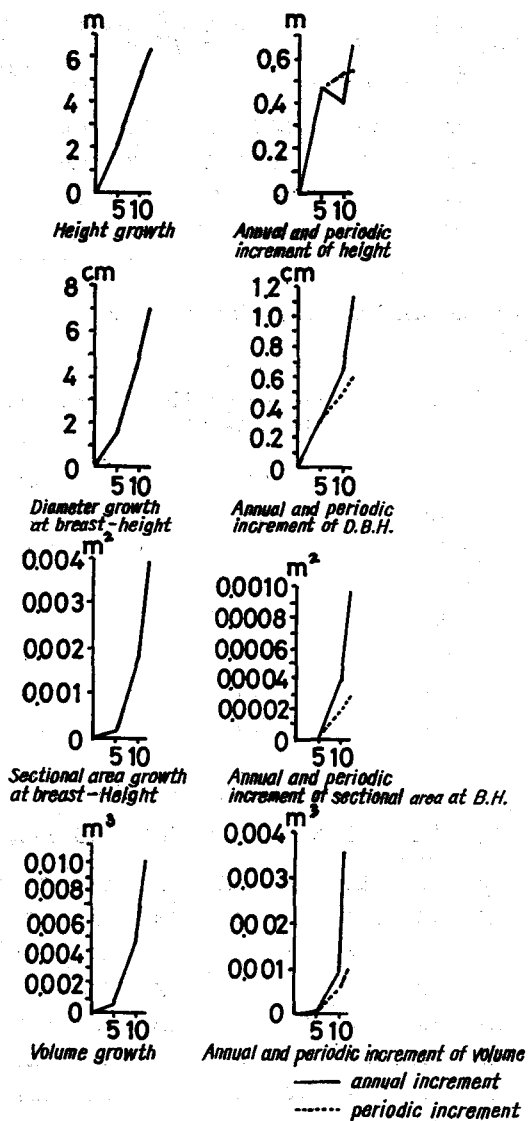


Fig. 4. Growth increment of a typical larch tree planted in compartment No. 120.

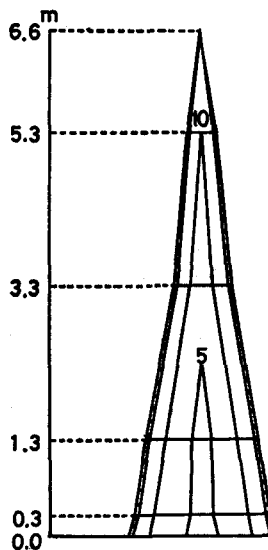


Fig. 5. Stem analysis of a typical larch tree planted in compartment No. 120.

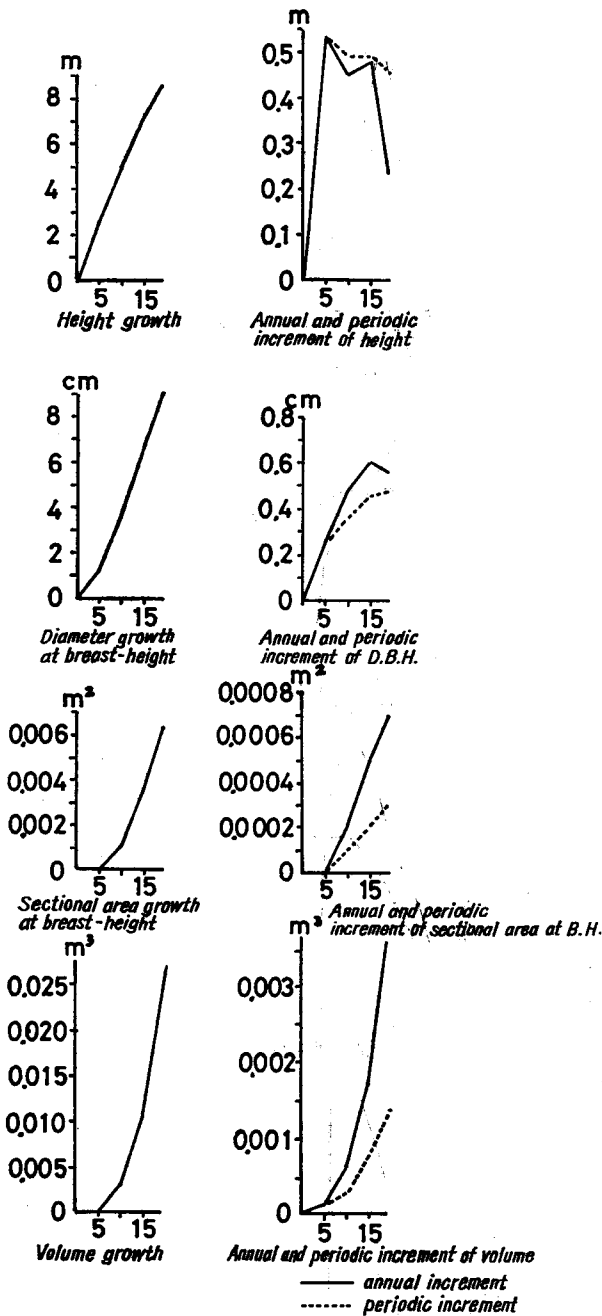


Fig. 6. Growth increment of a typical larch tree planted in compartment No. 106.

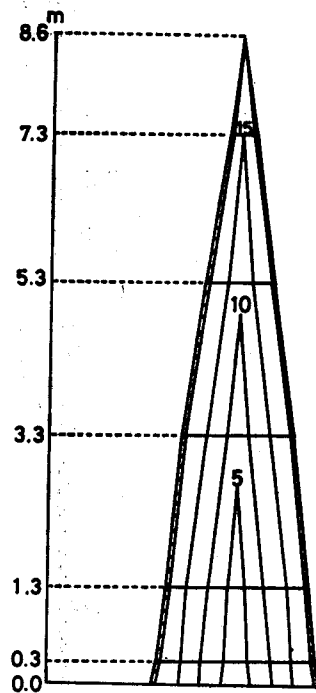


Fig. 7. Stem analysis of a typical larch tree planted in compartment No. 106.

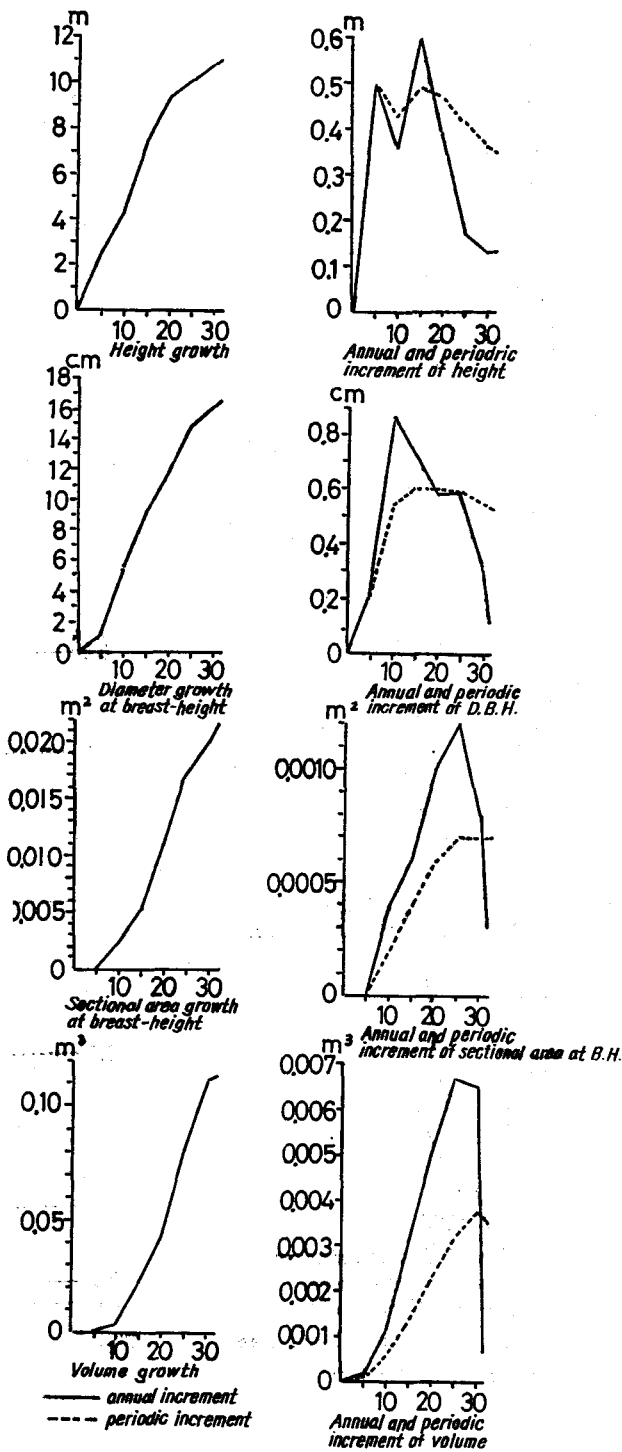


Fig. 8. Growth increment of a typical larch tree planted in compartment No. 308.

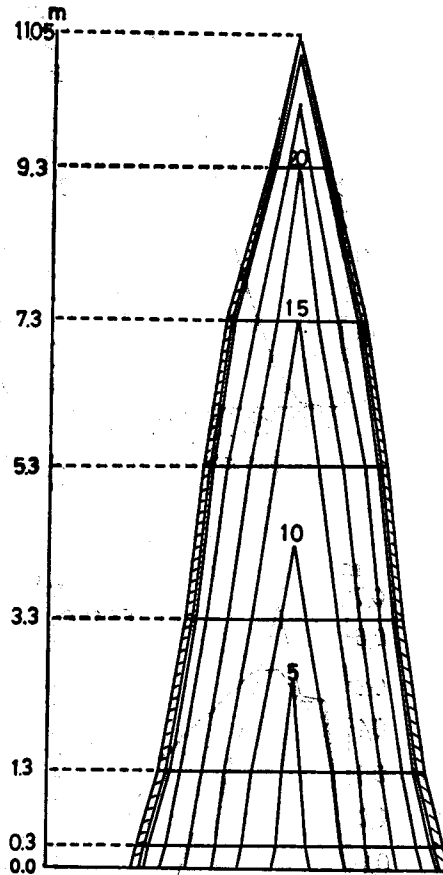


Fig. 9. Stem analysis of a typical larch tree planted in compartment No. 308.

exceeds by some 20 years old reveals a little retardative growth. It should be noted that even the 42-year-old tree is only 14.2 m high and 22.5 cm in diameter at breast height. Examining with a stand yield table of larch plantation, these forests cannot help belonging to the worst site-class in Hokkaido.<sup>4)</sup>

#### 4. Chemical Composition of Woods

Table 8 shows the results of proximate analyses of the various parts of the wood and bark. It is notable that, compared with the woods, the barks contain high percentages of ash, solubility, lignin and nitrogen, while the woods are high in the cellulosic components. Among the parts of the wood, the sapwood of lower parts have high holocellulose and  $\alpha$ -cellulose contents. Variations of the component with the difference of the age are not seen.

#### 5. Foliar Nutrients

Chemical elements of the needle-leaves are shown in Table 9. The nitrogen content ranging between 1.4 and 1.8%, is generally low. As a matter of course,

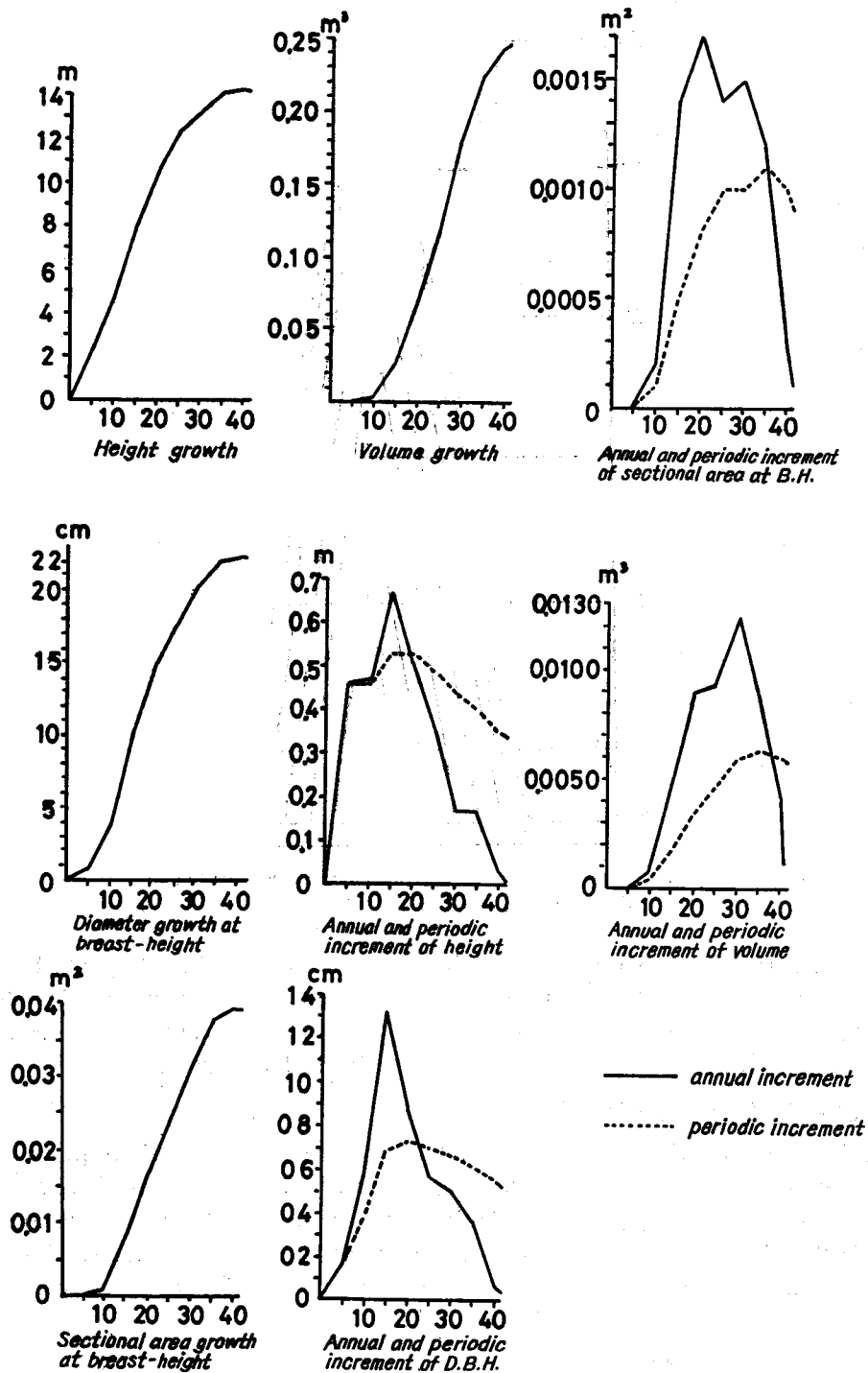


Fig. 10. Growth increment of a typical larch tree planted in compartment No. 314.

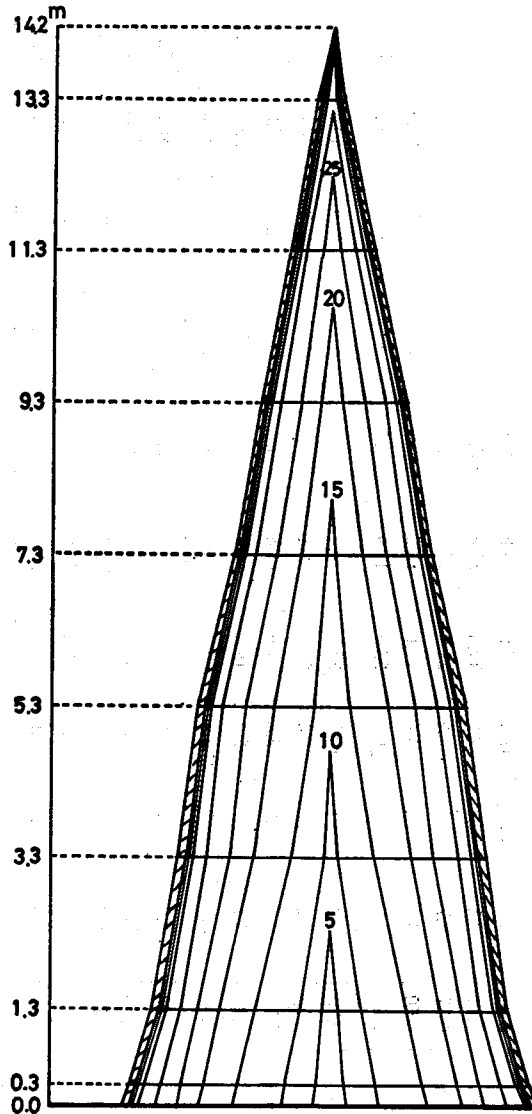


Fig. 11. Stem analysis of a typical larch tree planted in compartment No. 314.

the content varies with the season, and is least in autumn. Comparatively speaking, the low content is natural, as the samples were collected in the late October, but it is a little higher than its leaf-falls.<sup>20)</sup> The data also indicate that the younger trees have a high nitrogen content than the older ones. On the other hand, the ash content is in the reversed relation. It should be noted that the ash content of the larch leaves is considerably high and that the main component is  $\text{SiO}_2$ , which seems to be characteristic of the larch trees.<sup>19, 27)</sup> Among the foliar nutrients contained in the larch leaves, nitrogen is the highest and followed by  $\text{CaO}$ ,  $\text{K}_2\text{O}$  and  $\text{P}_2\text{O}_5$  in sequence.

Table 8. Proximate chemical composition of larchwoods

Plot No.	Tree age (years)	Sample	Ash	Solubility in				Total pentosan (%)	Methyl pentosan	Holo-cellulose	Alpha cellulose	Lignin	Total N
				Alcohol benzene	Cold water	Hot water	1%-NaOH						
1	12	Bark	1.89	13.7	20.2	20.7	48.2	10.9	2.5	53.7	26.7	31.0	0.59
		Lower part sapwood	0.45	4.7	4.8	10.8	25.5	11.6	4.1	64.0	41.2	26.5	0.32
		Lower part heartwood	0.36	5.3	9.3	13.1	24.3	13.2	5.4	59.1	35.9	26.9	0.16
		Middle part	0.33	3.9	3.7	5.6	19.3	15.3	4.5	62.3	37.8	29.0	0.19
		Top part	0.49	4.6	5.9	6.6	20.8	14.5	5.8	61.7	35.2	29.1	0.20
2	19	Bark	0.94	9.1	11.2	16.1	48.5	9.8	2.8	54.5	26.2	40.9	0.33
		Lower part sapwood	0.14	3.1	2.7	7.8	17.4	12.8	5.9	66.4	42.1	26.7	0.22
		Lower part heartwood	0.17	5.7	8.4	9.2	21.9	12.4	4.4	61.0	37.8	26.8	0.13
		Middle part	0.50	3.1	4.1	4.6	17.6	15.5	4.8	65.1	39.8	27.8	0.17
		Top part	0.68	4.7	7.4	9.9	23.8	14.9	4.7	60.4	33.6	27.3	0.24
3	32	Bark	0.72	8.0	8.1	12.7	35.7	9.4	1.8	55.1	26.9	40.5	0.38
		Lower part sapwood	0.18	3.1	3.0	5.4	20.1	13.1	5.3	65.2	42.7	26.6	0.19
		Lower part heartwood	0.11	4.8	5.8	8.8	21.6	11.4	3.4	63.7	41.0	26.8	0.13
		Middle part	0.12	3.4	2.7	5.0	19.4	14.7	5.0	65.7	42.4	28.7	0.17
		Top part	0.60	3.4	3.0	5.9	19.2	14.6	3.8	66.5	40.3	30.1	0.21
4	42	Bark	0.83	7.3	5.2	7.7	36.0	11.0	2.6	57.1	26.7	40.5	0.28
		Lower part sapwood	0.16	3.6	3.8	6.0	16.6	12.3	6.0	69.2	46.8	26.7	0.18
		Lower part heartwood	0.12	5.2	7.3	9.9	21.8	12.6	3.8	63.0	39.8	26.9	0.13
		Middle part	0.09	2.8	3.8	5.6	15.1	14.5	4.4	65.7	42.1	29.7	0.16
		Top part	0.75	4.9	7.5	10.6	24.4	18.3	4.1	64.8	35.7	29.2	0.19

Table 9. Chemical elements of needle-leaves in larch trees

Plot No.	Tree age (years)	N (%)	Ash (%)	Components as oxides (%)								
				SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	MgO	CaO	K <sub>2</sub> O	Na <sub>2</sub> O	P <sub>2</sub> O <sub>5</sub>	total
1	12	1.76	5.93	2.62	0.11	0.12	0.25	1.21	0.96	0.07	0.30	5.64
2	19	1.42	6.60	3.56	0.32	0.05	0.29	1.08	0.69	0.07	0.20	6.26
3	32	1.54	8.02	4.06	0.19	0.07	0.50	1.28	1.01	0.20	0.20	7.51
4	42	1.37	8.27	4.04	0.17	0.17	0.51	1.93	0.81	0.09	0.23	7.95

Table 10. Organic matters and nitrogen fixed by larch trees

Plot No.	1	2	3	4
Tree age (years)	12	19	32	42
Mean tree				
Height (m)	6.2	7.9	10.0	12.1
Diameter at breast height (cm)	6.4	7.4	13.8	14.8
Crown height (m)	1.3	3.4	6.0	6.6
Crown diameter (m)	2.9	2.5	2.7	3.2
Stem volume (m <sup>3</sup> )	0.0099	0.0185	0.0849	0.1140
" green weight (kg)	10.4	16.2	60.2	79.5
" moisture (%)	43.9	42.5	44.7	39.8
" dry weight (kg)	5.8	9.3	33.3	47.9
Living branches number	42	50	38	52
" green weight (kg) (including needle-leaves)	7.2	6.8	15.3	23.0
Rate of branches (%)	60.7	69.3	82.2	83.5
" needle-leaves (%)	39.3	30.7	17.8	16.5
Branches moisture (%)	45.9	46.5	47.3	47.1
" dry weight (kg)	2.4	2.5	6.6	10.2
Needle-leaves moisture (%)	59.7	61.0	59.4	59.7
" dry weight (kg)	1.1	0.8	1.1	1.5
Dead branches number	25	32	18	12
" dry weight (kg)* <sup>1</sup>	(0.7)	(1.9)	(1.2)	(2.6)
Total of dry weight (kg)	9.3	12.6	41.0	59.6
T-R ratio assumed* <sup>2</sup>	2.6	3.0	3.8	4.0
Root weight (kg)	3.6	4.2	10.8	14.9
Grand total of dry weight in tree (kg)	12.9	16.8	51.8	74.5
Nitrogen in wood* <sup>3</sup> (%)	0.22	0.20	0.19	0.18
" needle leaves (%)	1.76	1.42	1.54	1.37
Total nitrogen of wood (kg)	0.026	0.032	0.096	0.131
" needle leaves (kg)	0.019	0.011	0.017	0.020
Grand total of nitrogen in tree (kg)	0.045	0.043	0.113	0.151
Tree number per ha	2,400	1,420	980	980
Growing stock (m <sup>3</sup> /ha)	23.8	26.3	83.2	111.7
Fixation of organic matter (tons/ha)	31.0	23.9	50.8	73.0
Fixation of nitrogen (kg/ha)	108.0	61.1	110.7	148.0
Reduction of nitrogen to forest land by leaf-fall a year (kg/ha)	45.6	15.6	16.7	19.6

\*<sup>1</sup> excluded from total dry weight.\*<sup>2</sup> applied from Karizumi's data.\*<sup>3</sup> weighted average of nitrogen in individual parts.

**Table 11.** Organic matters and nitrogen compounds accumulated in larch-plantation sites (till 60-cm depth)

Plot No.	Location (compartment) No.	Layer	Thickness (cm)	Apparent specific gravity	Dry weight (tons/ha)	Gravel (%)	Gravel-removed weight (tons/ha)	Organic matter		Nitrogen compounds as N	
								(%)	(tons/ha)	(%)	(kg/ha)
1	120	A <sub>0</sub>	4	0.08	32	0	32	46.0	14.7	1.42	454
		I A	6	0.69	414	17	344	10.6	36.5	0.315	1,084
		II C <sub>1</sub>	5	0.92	460	33	308	0.6	1.8	0.023	71
		III C <sub>2</sub>	14	0.89	1,246	25	935	0.7	6.5	0.018	168
		IV B'-C'	8.5	0.83	705	17	585	1.2	7.0	0.049	287
		V C <sub>1</sub>	22.5	0.99	2,250	40	1,350	0.1	1.4	0.006	81
		Total			5,107		3,554		67.9		2,145
2	106	A <sub>0</sub>	2.5	0.05	13	0	13	65.9	8.6	1.82	237
		I A	5.5	0.39	214	18	175	11.9	20.8	0.331	579
		II B-C	4.5	0.82	369	27	269	3.1	8.3	0.126	339
		III C	10	1.05	1,050	24	798	1.4	11.2	0.035	279
		IV C <sub>1</sub>	13	1.18	1,534	9	1,396	1.4	19.5	0.043	600
		V C <sub>2</sub>	25	1.05	2,625	38	1,628	0.1	1.6	0.000	0
		Total			5,805		4,279		70.0		2,034
3	308	A <sub>0</sub>	3	0.07	21	0	21	41.5	8.7	1.17	246
		I A	5	0.69	345	21	273	6.7	18.3	0.175	478
		II C	11	1.14	1,254	20	1,003	1.3	13.0	0.022	221
		III B'-C'	7.5	1.20	900	13	783	2.2	17.2	0.040	313
		IV C <sub>1</sub>	33.5	1.00	3,350	41	1,977	0.3	5.9	0.006	119
		Total			8,870		4,057		63.1		1,377
4	314	A <sub>0</sub>	3	0.06	18	0	18	50.0	9.0	1.25	225
		I A	10	0.57	570	12	503	7.7	38.7	0.292	1,466
		II C	16	0.83	1,328	27	969	1.5	14.5	0.039	378
		III C <sub>1</sub>	15	0.98	1,470	22	1,147	1.7	19.5	0.046	528
		IV C <sub>2</sub>	16	1.04	1,664	40	998	0.3	3.0	0.012	120
		Total			5,050		3,634		84.7		2,717

The results of the organic matters and nitrogen contents per ha, estimated from the fixation by the mean larch trees are summarized in Table 10. The dry weight of the stems was calculated from the weighted average of the moisture contents in the bark, sap and heartwood, while that of the branches and leaves, similarly from the moisture in the each part. As the roots could not be measured, the quantity was presumed by the results of T-R ratio investigated in detail by KARIZUMI.<sup>46,47)</sup> The organic matters fixed by the trees in the experimental plots No. 1, 2, 3 and 4 are 31.0, 23.9, 50.8 and 73.0 tons/ha, respectively. They show to increase nearly in parallel with the tree-age of the plantations, but their fixation generally very low. Dry weight of the needle-leaves calculated as 1.1 to 2.6 tons/ha, is also low.<sup>46,48)</sup> The nitrogen fixed by the leaves ranges between 17 and 46 kg/ha, with the high content of the young plantation. These amounts of nitrogen are supposed to be reduced to the larch forestland every year.

#### 6. Accumulation of Organic Matters and Nitrogen Compounds

The results of organic matters and nitrogen compounds (determined as total N) accumulated in each larch plantation site are shown in Table 11. The organic matters determined per ha range from 63 to 85 tons, while the weight of nitrogen, between 1.4 and 2.7 tons. It is clear the oldest plantation is the richest in these substances.

#### Conclusion

The research of Japanese larch plantation have been long carried out in Tomakomai Experiment Forest, where the sites consist of sterile immature soils and do not always have a good climatic condition. Accordingly, the soils prove to be sand and lack the nutrients and water holding capacity, except those of I-layer. Although the growth of the larch planted is normal in such young ages as 20 years or so by an uptake of the nutrients contained in Ao and I-layer (A-horizon) the trees passing over their juvenile periods show an obvious decline in the growth. The typical 42-year-old tree is only 14.2 m in height and 0.11 m<sup>3</sup> in its stem volume.

The chemical composition of the wood, however, is not so different from that of the other larch woods. The amounts of the needle-leaves calculated from the mean trees per ha are gradually decreased with the long lapse of the plantations. Accordingly the nutrients reduced to the forest land are also low.

It seems to be hard to accomplish the plantation in Tomakomai Experiment Forest.

#### Summary

Properties of Japanese larch (*Larix kaempferi*) plantation soils and the larch trees grown in Tomakomai Experiment Forest, Hokkaido University, were investigated and summarized as follows:

1. The forest lands consist almost of immature soils piled up with recent volcanic ejecta.

2. The thickness of Ao layer on the forest soils was 2.5 to 4.0 cm, while the surface soils of 5 to 10 cm thickness classified as first layer (I) have been gradually forming A-horizon by mingling with humus. But the layers other than IA were still composed of the very deposits of the ejecta. It is, therefore, seen that they have less nutrients and lower water holding capacity. The larch trees are barely growing by the use of these nutrients contained in Ao and the surface soils.

3. Stem analyses of the typical larch trees showed that the tree growth was normal till some 20 years but the trees older than the age lose their vitality by slow degrees. The typical 42-year-old tree was only 14.2 m high and 22.5 cm in diameter at breast height.

4. Chemical composition of the wood, did not give much differences from the other larch woods.

5. There were not a great quantity of the leaves estimated from the mean trees, which was a little short of nitrogen and contained an excessive ash composed mainly of  $\text{SiO}_2$ . Accordingly, the nutrients such as N,  $\text{K}_2\text{O}$ ,  $\text{P}_2\text{O}_5$  and CaO reduced to the forest lands are naturally low.

6. Accumulation of Ao on the surface soils was increasing with the age of trees planted, but the organic matters amounted at the most to 85 tons/ha including all the soils, (60-cm depth) while the nitrogen, 2.7 tons/ha.

From these results, it would be very difficult to grow successfully the forest trees in Tomakomai district situated under those soil and climatic conditions.

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## 摘 要

北海道大学苫小牧地方演習林に植栽された林齢の異なるカラマツの造林地4カ所を対象に、その土壌の理化学的性状を調べ、さらに各調査地より、平均的な大きさの林木と比較的生長の良好な林木をそれぞれ伐採して、前者よりその化学的な成分を分析し、後者を用いて、樹幹析解を行なった。これらの結果は、次のとおりである。

1. その林地は新期の火山放出物からなる未熟土壌である。

2. Aoの厚さは2.5 cmから4.0 cm程度であり、その直下のI層は5ないし10 cmの厚さを有し、腐植と混合しながら、A層を形成している。しかしII層以下の土壌は砂土からなる火山堆積物そのものの形態を示し、栄養分は少なく、水保持力も低い。そのような土地に植栽されたカラマツは、このAo及びI層の養分を利用して生育している。

3. 比較的生育の良好なカラマツの樹齢別の樹幹析解から、その生長は植栽後20年程度までは順調であるが、それを越えると次第に劣えを見せていることが判った。今回解析した42年生のカラマツは樹高がわずかに14.2 mで胸高直径は22.5 cmであった。

4. 木材分析の結果このカラマツは、他の地域に植栽されたカラマツと比較して、成分的には大差がないことを示している。

5. 平均木からha当りに換算して算出した葉量は少ない。またこの葉は窒素が他とくらべて僅かに少ないが、灰分は多く、その主要なものは珪酸である。従って土壌へ還元される窒素、リン酸、カリ、石灰等の栄養分は少ない。

6. 栄養のもととなるAoの堆積量は植栽年の経過とともに増加するが、有機物の量は各層すべてを合せても、せいぜい85 ton/haで窒素の量は2.7 ton/haであった。

このように、苫小牧地方は、土壌、気象条件ともに悪く林木の生育に適する場所ということとはできない。

**Appendix**

Climatological data observed from 1966 to 1975 at the height of 19 m above sea level in Tomakomai  
Experiment Forest (42°40'N. lat., 141°36'E. long.)

1. Temperatures (°C)

		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	yearly Mean
Air temperature	Mean	- 6.3	- 5.8	- 1.9	4.4	9.8	14.2	18.6	20.8	15.8	9.0	3.1	- 3.5	6.5
	Mean maximum	0.0	0.2	3.1	9.4	15.0	17.6	21.8	24.5	20.9	15.1	8.8	2.5	11.6
	Mean minimum	- 9.5	-11.0	- 6.9	- 1.5	3.9	10.0	15.0	17.2	10.3	2.1	- 1.9	- 8.9	1.6
	Maximum	10.1	7.9	12.5	21.0	27.0	28.4	32.3	33.1	26.5	24.3	18.3	15.1	—
	Minimum	-25.5	-25.5	-23.9	-17.0	- 7.8	- 0.6	2.2	6.4	0.1	- 6.5	-12.5	-23.0	—
Underground temperature	0.5 m below surface	0.7	- 0.2	- 0.6	0.3	6.3	13.7	17.7	20.1	18.7	13.6	7.7	3.0	8.4
	1.0	4.2	2.9	1.9	1.6	4.3	10.1	14.3	17.6	17.9	15.1	10.7	6.6	8.9
	2.0	7.4	6.0	4.9	4.0	4.2	7.3	11.0	13.6	15.5	14.7	12.4	9.5	9.2

2. Precipitation, humidity, sunshine and snowcover

		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total or mean
Precipitation	(mm)	80.4	67.0	61.1	91.5	136.7	135.4	164.4	200.2	221.2	128.4	92.5	47.8	1426.6
Mean relative humidity	(%)	73.6	71.1	72.2	71.7	75.4	82.4	81.9	84.1	80.9	77.0	74.5	74.0	76.5
Rate of sunshine	(%)	41.0	40.9	41.0	41.1	35.4	26.4	23.6	26.0	36.9	40.1	35.1	40.1	35.6
Average depth of snow cover	(cm)	18	35	22	1	0	0	0	0	0	0	0	5	

## 3. Prevailing wind direction

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
1966	W	NW	NW	SSE	SSE	SSE	SSE	SSE	SSE	SSE	W	W
1967	W	W	SE	SSE	S	S	S	SSE	NNW	NNW	NW	NW
1968	NW	NNW	S	N	—	S	SSE	SE	SSE	SE	SE	NW
1969	NW	NW	NW	N	SSW	SSE	SSW	S	N	NNW	NW	NW
1970	N	N	NW	N	S	N	SSE	—	SSE	N	N	NNW
1971	N	N	N	—	N	SSW	S	S	N	NW	N	NNW
1972	N	N	N	S	N	SE	SE	S	SE	NW	NNW	NNW
1973	NNW	NNW	NNW	SE	NNW	SSE	SSE	SSE	NW	NW	NW	NW
1974	NNW	NW	N	SE	NW	S	S	SE	SE	NW	NW	NW
1975	N	N	N	S	NE	N	SSE	SSE	SSE	N	N	NNW
mean	N	N	N	N	NW	SSE	SSE	S	SSE	NW	N	NW

## 4. Snow and frost

	Date of snow melt		Last spring frost		First autumn frost		Date of first snow fall		Date of snow cover		Duration of snow cover	
1966	April	11	June	12	Oct.	25	Nov.	22	Dec.	1	127 (days)	
1967	Mar.	25	May	8	Oct.	20	Nov.	24	Nov.	30	115	
1968	Mar.	22	May	11	Oct.	8	Oct.	12	Dec.	15	114	
1969	April	13	May	22	Nov.	5	Nov.	4	Dec.	8	120	
1970	April	13	May	24	Oct.	3	Nov.	15	'71 Jan.	13	127	
1971	Mar.	26	May	20	Oct.	1	Nov.	8	'72 Jan.	16	73	
1972	Mar.	16	May	7	Oct.	8	Nov.	16	'73 Jan.	8	61	
1973	April	5	May	24	Oct.	6	Nov.	20	Dec.	5	88	
1974	Mar.	25	May	7	Oct.	1	Nov.	1	Dec.	10	103	
1975	April	2	April	24	Oct.	30	Nov.	9	Dec.	17	114	