Properties of Soils and Japanese Cedar Planted in Hiyama Experiment Forest*

By

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桧山地方演習林の土壌とスギ造林木の性質*

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Introduction

Japanese cedar (Sugi, *Cryptomeria japonica* D. DON) is the greatest tree species planted throughout the country excluding Hokkaido, because of the production of superior timber for the Japanese wooden house. Though a lot of varieties are bred in the different regions, the tree is peculiar to Japan, consisting of only one species of one genus and is energetically growing in the artificial forests, fitting for the Japanese climate.

Meanwhile, in Hokkaido situated under very cold circumstances in winter such trees as *Abies sachalinensis, Picea glehnii, Larix kaempferi* etc. have been generally

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afforested. The cedar seedlings, however, have been considerably planted in the southern part of Hokkaido including Hiyama Province, where the climatic condition is similar to northern Honshu.

According to the latest Hokkaido Forestry Statistics[10] it is reported that the area where the cedar was planted in 1982 was 223 ha, or 1% of the entire afforestation in Hokkaido, and that the cumulative cedar plantation area amounted to 31,000 ha, while 70% of it was contained in 5th age-class (25 years old of stand age) or less. It seems the cedar is the most promising in southern Hokkaido from the viewpoint of growth and wood quality. In Hiyama Experiment Forest of Hokkkaido University, the species has been also planted since 1957, and the area occupied by the artificial forests attains to 44 ha, in which the pruning and thinning are being gradually practiced for the production of valuable knottless timbers.

The studies hitherto reported on the cedars have almost dealt with those produced in Honshu, Shikoku or Kyushu, but hardly in Hokkaido.[9,12,13] In present study the authors investigated the artificial forests in Hiyama Experiment Forest, relating the site to the growth and quality of the Japanese cedar. First of all the soils of several stands including the natural secondary forest were surveyed and analyzed on physical and chemical properties. After 4 experimenral plots of the cedar forests were chosen and surveyed on both soils and trees, the each average and typical tree was felled and used for the stem analysis as well as the examinations of physical property. Furthermore, biomass of these stands was estimated under consideration of the utilization of the branches and needle leaves, which are now neglected after timber cutting.

A part of this study has been already announced at the Meeting of Hokkaido Branch of the Japanese Forestry Society.[14]

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

Outlines of Hiyama Experiment Forest[2]

Hiyama Experiment Forest, Hokkaido University, was founded in 1956 with the forest of a 100-ha area contributed by Kaminokuni Town after main trees had been cut. It is situated in 140°11′ east longitude and 41°50′ north latitude, the southern part of Hokkaido as shown in Fig. 1, and lies in the cool temperate forest zone. The forest consists of broad-leaved trees such as dominating *Fagus crenata*, *Quercus mongolica* var. *grosseserrata*, *Tilia japonica*, *Acer* species, *Betula* species etc. with a little of *Thujopsis dolabrata* and *Abies sachalinensis* var. *mayriana* which grows at high altitudes with a south limit in Japan. Meanwhile, *Cryptomeria japonica* which does not originally grow, is now widely planted in this district, on account of similar climatic conditions to northern Honshu. In terms of the topography, it is on the east slope of Mt. Taiheizan (alt. 365 m) and generally steep. The geological features show it belongs to the Paleozoic Strata classified into Mera Formation, which is composed of sandstone, clayslate, shale and chert.[5] Concerning the climate, mean monthly climatological data recorded at the Experiment Forest

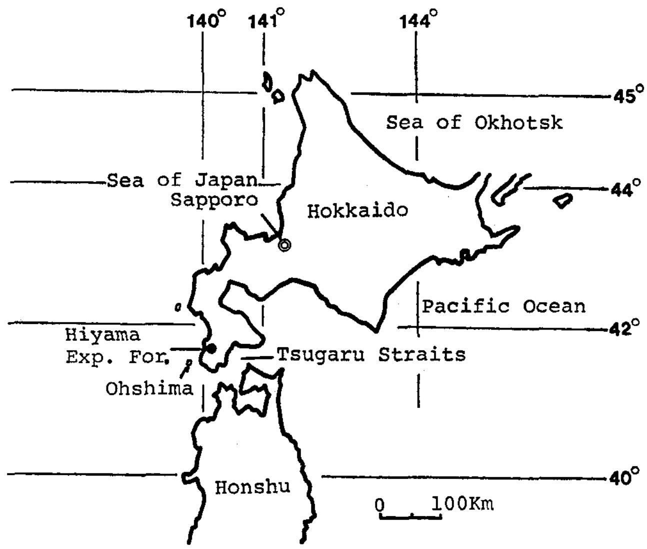

Fig. 1. Location of Hiyama Experiment Forest.

Table 1. Climatological data of Hiyama Experiment Forest

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
Mean temperature (°C)	−2.1	−2.6	0.8	6.6	11.2	15.6	20.4	22.2	17.9	11.4	5.5	1.4	9.0
〃 max. 〃 (°C)	0.5	0.1	4.4	10.9	15.4	19.2	23.6	25.6	22.0	15.9	9.2	4.1	12.6
〃 min. 〃 (°C)	−5.2	−5.2	−2.7	2.4	7.0	12.0	17.3	18.9	13.8	6.8	1.7	−1.8	5.4
Precipitation (mm)	113.6	82.6	97.4	89.8	71.0	70.6	95.5	165.2	187.2	130.0	90.4	123.4	109.7 (1316.7)*1
Mean wind force (m/s)*2	8.1	7.3	7.5	6.0	6.7	6.1	5.1	5.1	—	6.9	7.5	6.7	6.6

*1 The figure in parenthesis is the yearly precipitation.
*2 Observed at Kaminokuni Station of National Railway Board.
Observed period: 5 years from 1980 to 1984.

Station are shown in Table 1. The annual mean temperature is 9.0°C, while the mean maximum and minimum are 25.6°C and −5.2°C, respectively, and the difference between cold and warmth is not so remarkable. Total yearly precipitation is 1,317 mm which comes down almost equally by month, having a little much rain in autumn corresponding to "the typhoon season". Mean wind force is strong, 6.6 meters per second, which blows over the mountains from the Tsugaru Straits in spring and blows from the Sea of Japan during winter. Accordingly, the forests are always exposed to the strong wind throughout a year, which gives an injurious effect on the growth of trees.

The forest management has been concentrated on the afforestation of the Japanese cedar since the foundation. The other studies now investigated are as follows: 1) Tending of secondary forests of *Fagus crenata.* 2) Underplanting by cutting of *Thujopsis dolabrata* in the beech or cedar forests. 3) Silvicultures on the slope constantly suffered by snowslide or on the coastal side constantly suffered by windblow.

Experiments

1. Experimental Plots and Surveys of Soils

The surveys of soils widely distributed in the Experiment Forest were carried out in 1972. The stands chosen were: 1) Natural secondary forest (compartment 7, designated as H 7-1) consisting of such broad-leaved trees as *Fagus crenata* and *Quercus mongolica* var. *grosseserrata* occupied at 88% of total stem numbers in the experimental plot after main trees were clearly cut in 1955 (before the property). 2) Artificial forest of *Larix kaempferi* (compartment 7, designated as H 7-2) planted in 1957, and now replanted with *Cryptomeria japonica*, because the former trees had been drastically suffered by *Guignardia laricina*. 3) Artificial forest of *C. japonica* mixed with *Abies sachalinensis* (compartment 4, designated as H 4) planted in 1957.

Each pit was made in the plots by digging till some 60 cm depth, corresponding with the appearance of fine roots of the trees. In the profile obtained, the soils were divided into 2 to 4, composed of A and B horizons. The observation and description of the features were done by the standard method, while the soils under natural condition were collected from each horizon for the measurements of

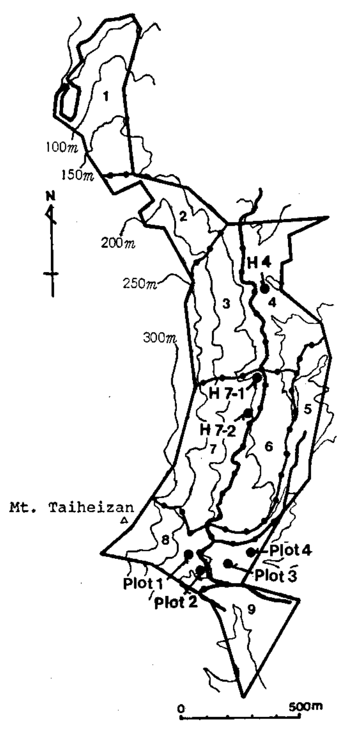

Fig. 2. Experimental plots surveyed in Hiyama Experiment Forest.

apparent specific gravity, moisture content and volumetric distribution of threee phases using a core sampler with a 100-ml cylinder.

Meanwhile, the surveys of soils in the stands chosen for the comparison of the cedar growth were carried out in 1984 in 4 plots (designated as Plots 1-4 in the order from the upper site) as shown in Fig. 2, in the compartments 8 and 9, where the trees were planted in 1967 and 1966, respectively. After each profile was made with some 1-m depth, the soils were minutely divided into A, B and C horizons with subindex number by the difference of color and texture with naked eye, and examined in detail in the same manner as above-mentioned.

2. Analysis of Soils

The soils surveyed in 1972 were brought in the laboratory and air-dried. The fine soils obtained by passing through a 2-mm sieve were analyzed by the standard procedures with an exception of the following measurements: Real specific gravity with a Beckman air comparison pycnometer, carbon and nitrogen contents with a Yamagimoto CN corder, CEC with an Orion ionmeter using an ammonium electrode, and exchangeable cations (Ca, Mg, K and Na) with a Seiko atomic absorption spectrophotometer.[15,16]

3. Surveys of Trees in Plantation Stands

The 4 cedar plantation stands were surveyed on the number of the trees, their diameter at breast height and their height in each plot of a 10×10 m^2 area, including the observation of the undergrowth. Each average typical tree was felled at a 30-cm height and measured exactly on the diameter, length, crown height etc. The branches trimmed off were all collected by 1-m interval from the bottom of the crown and examined on the number, length and weight including needle leaves. Then samples selected from the branches in each interval were divided into the real branch and the leaf which was distinguished with coloring in green, and the both were weighed and determined on their moisture content in the laboratory. The each stem was cut to obtain the wood discs in accordance with the method of stem analysis, together with the extra discs at the same position, which were used for the examinations of the physical property.

4. Stem Analysis and Examinations for Wood Quality

The stem analysis of the 4 typical cedars were carried out using the discs by Nakajima's method. The growths and annual as well as periodic increments were calculated by every 5-annual ring on height, diameter at breast height, the sectional area and volume. Meanwhile, the extra discs were cut by about 3-cm width including the pith and also rectanglarly cut into blocks with every 5 annual rings from the pith. The physical property was examined using them on moisture content, basic density, annual ring width and the rate of heartwood.

Results and Discussion

1. Soil Properties

The properties of soils surveyed in 1972 are shown in Table 2. The soils

Table 2. Properties of Soils under natural

Exp. site	Stand	Horizon	Depth (cm)	Color by Munsell
H 7-1	Natural secondary forest	A	12	7.5 YR 2/2
		B	20	10 YR 3/3
		A′	29	7.5 YR 3/2
		B′		10 YR 4/4
H 7-2	*L. kaempferi* plantation	A	20	7.5 YR 2/1
		B		10 YR 3/4
H 4	*C. japonica* plantatioa	A_1	15	7.5 YR 2/1
		A_2	11	10 YR 2/2
		B		10 YR 4/4

Table 3. Physical and chemical properties of

Exp. site	Hori-zon	Mechanical analysis (%) Coarse sand	Fine sand	Silt	Clay	Soil class	Air-dried moisture (%)	Maximum water holding capacity (%)	Bulk density	Real specific gravity	pH H_2O	pH KCl
H 7-1	A	69	6	10	15	SL	9.4	160	0.56	2.30	5.3	4.6
	B	45	17	16	22	SCL	7.2	103	0.78	2.53	5.7	4.6
	A′	57	7	16	20	SCL	8.3	98	0.78	2.58	5.9	4.7
	B′	66	8	9	17	SCL	9.6	86	0.90	2.73	5.6	4.9
H 7-2	A	15	28	18	39	LiC	6.9	109	0.78	2.37	5.9	4.7
	B	49	17	21	13	SL	9.6	86	0.89	2.73	6.2	4.5
H 4	A_1	48	17	11	24	SCL	7.6	172	0.53	2.26	5.5	4.8
	A_2	37	16	14	33	LiC	8.3	123	0.70	2.35	6.1	4.5
	B	62	9	9	20	SCL	8.5	85	0.92	2.71	6.1	5.0

designated as H 7-1 under natural secondary forest consist of 4 horizons, the surfaces of which seem to be colluvial soils mixed with volcanic ashes. The volcanic ashes seen on the upland in the Experiment Forest are supposed to derive from the eruption of an active volvano in Ohshima (a small island distant 50 km west from Kaminokuni Town) in 1741.[6] Below B horizon being 20 cm thick, there lies a brownish black A′ horizon which was temporarily a top-soil. The whole soils are generally rich in gravels and have a high value in apparent specific gravity. However, the permeability of air also relatively high even in B′ horizon, as presented at 29% of gaseous phase in volume rate. The soils of *L. kaempferi* plantation designated as H 7-2 consist of 2 horizons, a 20-cm thick and black A horizon and a dull yellowish brown B horizon. The soils of the A horizon have high apparent specific gravity and the rate occupied with solid is as considerably high as 22%, compared with the value of an average A horizon. The soils of *C. japonica* plantation designated as H 4 have such a thick A horizon as 26 cm divided into A_1

condition in different stands

Apparent specific gravity		Moisture content based on (%)		Gravel	Distribution of three phases (vol. %)			Porosity (vol. %)
Fresh soil	Dried soil	Fresh soil	Dried soil	(%)	Solid	Liquid	Gas	
0.73	0.34	54.0	117.3	27	15	39	46	85
0.99	0.61	38.1	61.4	44	24	38	38	76
1.04	0.64	38.9	63.7	63	24	41	35	76
1.14	0.68	40.3	67.6	32	25	46	29	75
0.96	0.53	45.4	83.2	3	22	44	34	78
1.05	0.62	41.5	71.1	22	23	44	33	77
0.94	0.37	60.7	154.8	0	16	57	27	84
1.03	0.45	56.6	130.3	4	19	58	23	81
1.20	0.58	51.6	106.7	21	21	62	17	79

fine soils obtained in different stands

Exchange acidity	Loss on ignition (%)	C (%)	N (%)	C/N	Total organic matter (%)	CEC (me/100 g)	Exchangeable cations (me/100 g)				Degree of base saturation (%)	Absorption coefficient of P_2O_5 (mg/100 g)
							Ca	Mg	K	Na		
0.28	26.8	11.1	0.64	17	20.3	40.4	11.8	5.6	1.6	2.1	51	1,640
0.47	13.9	4.7	0.26	18	8.7	28.5	1.7	1.0	1.0	1.4	18	1,500
0.43	16.4	5.9	0.31	19	10.8	31.0	2.0	0.9	0.5	1.3	15	2,230
0.15	9.9	1.3	0.17	8	2.4	17.7	1.5	0.8	2.1	0.6	28	2,170
0.13	18.2	7.1	0.50	14	13.0	28.4	10.9	5.6	3.8	1.9	78	1,260
0.15	9.9	1.3	0.18	7	2.4	22.1	1.5	1.6	1.2	2.0	29	1,930
0.26	26.9	12.6	0.78	16	23.1	35.0	17.7	8.2	0.9	3.4	86	1,030
0.54	19.1	6.9	0.39	18	12.6	29.5	3.5	2.0	1.0	2.0	29	2,170
0.13	11.8	2.5	0.23	11	4.5	29.2	1.7	1.8	1.1	1.8	22	2,140

and A_2 by color. The moisture content of these soils are extremely high.

In addition, the thickness of A_0 layer measured at H 7-1, H 7-2 and H 4 was 3.7, 3.0 and 2.5 cm, respectively.

The properties of the fine soils are shown in Table 3. The whole soils generally are composed of loam classified by mechanical analysis, showing partly light clay in the A horizon soils of H 7-2 and H 4, which probably contain fine volcanic ashes. Bulk density determined by YAMANAKA's method and real specific gravity are low in the topsoils of H 7-1 and H 4, which have greater water holding capacity as well as high humus content. The soils are weakly acidic as shown at 5 to 6 of pH with pure water, coinciding with low exchange acidity. Cation exchange capacity is high, especially in the topsoils which hold mainly calcium ion. Based on these results, it can be mentioned that the soils belong to typical brown forest soils corresponding to B_D type of properly moist condition at H 7-1 and -2 and B_E type of weakly wet condition at H 4, and that the soil properties in Hiyama Experiment

Table 4. Properties of soils under natural

Plot	Site			Horizon	Depth	Thickness	Color		Hardness	
	Height (m)	Slope (°)	Direction		(cm)	(cm)	by Munsell	with naked eye	Tester (mm)	Consistency
1	228	16	W60°S	A_1	0– 3	3	7.5YR2/3	very dark brown	12	soft
				A_2	3–11	8	〃 3/3	dark brown	18	hard
				A_3	11–21	10	〃 〃	〃	15	slightly hard
				B_1	21–30	9	10YR3/3	〃	16	〃
				B_2	30–50	20	〃 4/3	dull yellowish brown	14	〃
				B_3	50–63	13	〃 5/4	〃	15	〃
				C	63–	41–	7.5YR6/4	dull orange	24	very hard
2	205	17	W20°S	H–A_1	0– 7	7	10YR1.7/1	black	7	loose
				A_2	7–15	8	7.5YR2/3	very dark brown	14	slightly hard
				B_1	15–26	11	〃 3/3	dark brown	17	〃
				B_2	26–39	13	10YR3/4	〃	16	〃
				C_1	39–74	35	〃 5/4	dull yellowish brown	17	〃
				C_2	74–	20–	〃 〃	〃	19	hard
3	178	25	W	A_1	0– 7	7	7.5YR2/2	bownish black	13	soft
				A_2	7–15	8	10YR4/3	brown	17	slightly hard
				B_1	15–30	15	〃 4/4	〃	18	hard
				B_2	30–44	14	〃 5/4	dull yellowish brown	16	slightly hard
				C_1	44–69	25	〃 〃	yellowish brown	26	solid
				C_2	69–	70–	7.5YR5/8	bright brown	22	very hard
4	162	0	W20°S	H–A_1	0–10	10	7.5YR2/1	black	7	loose
				A_2	10–17	7	〃 3/2	brownish black	12	soft
				A_3	17–27	10	〃 3/3	dark brown	13	〃
				B_1	27–38	11	〃 4/4	brown	13	〃
				B_2	38–49	11	〃 3/4	dark brown	15	slightly hard
				C	49–	65–	〃 4/4	brown	18	hard

condition in *Cryptomeria japonica* plantations

Structure	Soil class	Humus content	Gravel content (%)	Apparent specific gravity		Moisture content based on (%)		Distribution of three phases (vol. %)			Porosity (vol. %)
				Fresh soil	Dried soil	Fresh soil	Dried soil	Solid	Liquid	Gas	
crumby	C L	rich	2	0.98	0.46	52.7	111.4	18	51	31	82
blocky	S C L	slightly rich	5	0.99	0.52	48.1	92.7	21	48	31	79
〃	S i L	〃	5	0.91	0.41	54.8	121.2	16	50	34	84
crumby	〃	slightly containing	24	0.97	0.44	54.9	122.0	17	54	29	83
massive	C	scare	33	1.03	0.53	48.5	94.4	20	50	30	80
〃	S L	〃	54	1.34	0.96	28.5	39.8	36	38	26	64
〃	G	no	90	1.37	1.00	46.0	85.2	36	55	9	64
loose-granular	S i L	very rich	2	0.86	0.32	62.9	169.2	13	54	33	87
crumby	S L	rich	3	1.00	0.45	54.9	121.9	18	55	27	82
〃	S i L	slightly rich	14	1.01	0.46	54.8	121.3	18	55	27	82
coarse-crumby	C L	containing	49	1.13	0.68	40.1	66.8	26	45	29	74
massive	C	scare	70	1.32	0.83	37.3	59.5	31	49	20	69
〃	G	no	97	1.39	0.76	45.5	83.4	29	63	8	71
crumby	S i L	rich	27	1.02	0.51	50.2	100.9	20	51	29	80
coarse-crumby	S L	containing	54	1.06	0.66	37.9	61.1	25	40	35	75
blocky	C L	slightly containing	79	1.32	0.86	34.6	52.9	32	46	22	68
〃	G	〃	84	1.04	0.66	36.7	58.0	25	38	37	75
massive	G	no	91	1.04	0.72	31.0	44.8	28	33	39	72
〃	G	〃	92	1.33	0.89	34.3	52.1	33	42	25	67
loose-granular	S i L	very rich	3	0.56	0.25	56.0	127.0	10	31	59	90
fine-crumby	S L	rich	1	1.10	0.58	47.7	91.1	22	53	25	78
crumby	L	〃	1	0.98	0.47	51.7	107.0	19	51	30	81
〃	C L	containing	1	1.09	0.60	45.3	82.8	23	50	27	77
coarse-crumby	C	slightly containing	17	1.03	0.50	51.7	106.9	19	53	28	81
massive	G	scare	80	1.38	0.89	35.5	55.1	33	49	18	67

Photo 1. Circumstances of *C. japonica* plantation in Plot 1.

Photo 2. Circumstances of *C. japonica* plantation in Plot 2.

Pohto 3. Cricumstances of *C. japonica* plantation in Plot 3.

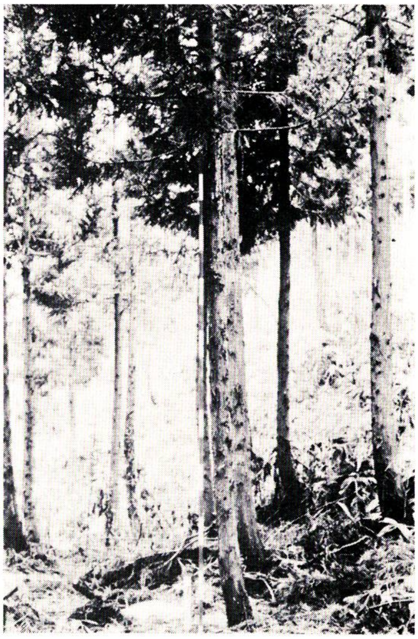

Photo 4. Circumstances of *C. japonica* plantation in Plot 4.

Forest are suitable for the silviculture.

Meanwhile, the properties of soils in the cedar plantations surveyed in 1984 are shown in Table 4. The soils in Plots 1, 2, 3 and 4 are on the whole divided into 6 or 7 horizons, on which the A_0 layer covered at 2, 6, 6 and 3-cm thickness, respectively. The soils in Plot 1 located at the upmost height have an A horizon of 21-cm thickness divided into 3 subhorizons A_1, A_2 and A_3 which are a little mixed with volcanic ashes. The soils of the A horizon show loamy textures consisting of different rate of sand, silt and clay, and are rich or slightly rich in humus but hardly contain gravels. The topsoils are said to be excellent in term of physical property, because they are not only moist but also high in air permeability. Though the soils of B horizon are rich in gravel, they contain also much water. On the other hand, the soils of C horizon underlying below the B_3 horizon at 63-cm depth or more are composed of parent material considerably weathered and very hard. Accordingly, the rate occupied with air is only 9% by volume.

The soils in Plot 2 consist of 6 horizons, the topsoil of which is mingled with humus layer and designated as H–A_1 of the horizon. It is black and naturally enriched with much humus. And it shows, accordingly, high moisture content and low apparent specific gravity, as well as low solid rate determined at 13%. The C horizon composed of gravel appears from a 39-cm depth.

The soils in Plot 3 lying on a steep slope of 25° are generally rich in gravels even in the A horizon, on account of the flow-out of the soils. On the contrary, the soils in Plot 4 under a flat land are colluvial ones, the consistency of which is loose or soft corresponding to 7 to 15 mm by a hardness gauge in the A and B horizons. The topsoils having a total 27-cm thickness show the crumby structures and hardly contain gravels. Generally speaking, the soils in Plot 4 are the most excellent. Thus the results would give the type of B_C, B_D, B_D and B_E to the soils in Plots 1, 2, 3 and 4, respectively.

2. Circumstances of Plantation Stands

According to the silvicultural ledger of the Japanese cedar plantations in the Experiment Forest, the 3-year-old seedlings bred at a private nursery from the seeds produced in Akita Prefecture were planted at the rate of 3,000 and 4,000 per hectare in the compartments 8 and 9 in the spring 1967 and 1966, respectively. Since then, the tending treatments have been carried out: Weeding for 5 years after planting, pruning of 4 times, and improvement cutting including thinning of 5 times. The present circumstances are shown in Photos 1 to 4. The tree inventory measured in each experimental plot of a 10×10 m^2 area in 1984, is shown in Table 5. In Plot 1 planted at the highest site the average tree height is 5.6 m and the average diameter at breast height is 9.9 cm, while the average tree planted at the lowest site or Plot 4, has such high values as 11.9 m and 19.3 cm in the above order. The each tree volume estimated by the volume table[3] was totaled, and the growing stock in Plots 1, 2, 3 and 4 calculated by conversion to a hectare, is 52.2, 131.5, 218.7 and 266.0 m^3, respectively. These figures show that the lower the plantation site is, the greater the growing stock is, and that the value obtained

Table 5. Tree inventory of *Cryptomeria japonica* plantations

Plot	Location (compartment)	Year of plantation	Land height (m)	Slope and direction	Planted number (stems/ha)	Survived number (stems/ha)	Height mean (m) / min.-max.	Diameter at breast height (cm) mean / min.-max.	Growing stock (m³/ha)
1	8	1967	228	16° W60°S	4,000	2,000	5.6 / 4.5–7.0	9.9 / 7–12	52.2
2	8	1967	205	17° W20°S	4,000	2,000	7.9 / 5.0–9.0	13.7 / 9–17	131.5
3	9	1966	178	25° W	3,000	1,800	10.9 / 7.5–12.0	16.1 / 11–20	218.7
4	9	1966	162	flat W20°S	3,000	1,400	11.9 / 10.0–14.0	19.3 / 15–23	266.0

in Plot 4 is 5 times as large as that in Plot 1.

Meanwhile, the undergrowth consisted mainly of *Sasa senanensis*, which was about 1 m high and grew at the rate of some 20 culms per square meter, together with some kinds of shrub such as *Celastrus orbiculatus* and *Benzoin umbellatum*.

3. Tree Growths

The description of the typical trees used for the stem analysis is shown in Table 6. The trees selected from Plots 1 and 2 were 20 years old and had the crown height of 2.8 and 3.4 m, respectively, while the trees selected from Plots 3 and 4 were 21 years old and had the crown height of 4.2 m due to the pruning. The results of the stem analysis by 5 years are shown in Tables 7 to 10 and Figs. 4 to 7. Height growth in the first 10 years is not so different from each other as estimated at 3.63 m of the sample in Plot 1 and at 4.19 m in Plot 4, the most excellent site. However, the 20-year lapse indicates a large difference, i. e. the former attains to 5.40 m and the latter to 11.0 m. Similarly, the volume at the age of 10 years is 5.71×10^{-3} and $4.42\times10^{-3}\,m^3$ in Plots 1 and 4, respectively, and afterwards, the one of the former shows to increase slowly to $2.54\times10^{-2}\,m^3$, at the 20-year end, while that of the latter shows to increase rapidly to $10.5\times10^{-2}\,m^3$, corresponding to 4 times as large.

Table 6. Typical trees used for stem analysis

Plot	Age	Tree height (m)	Crown height (m)	Crown diameter (m)	D. B. H. (cm)
1	20	5.4	2.8	2.8	10.7
2	20	7.8	3.4	3.6	12.7
3	21	9.8	4.2	5.6	15.9
4	21	11.3	4.2	4.8	18.2

Table 7. Description of growths in a typical tree selected in Plot 1

Age class	Height: Growth (m)	Height: Periodic increment (m)	Height: Annual increment (m)	Height: Mean increment (m)	Height: Growth rate (%)	Diameter at breast height: Growth (cm)	Diameter at breast height: Periodic increment (cm)	Diameter at breast height: Annual increment (cm)	Diameter at breast height: Mean increment (cm)	Diameter at breast height: Growth rate (%)
5	0.97	0.97	0.19	0.19	—	—	—	—	—	—
10	3.63	2.66	0.53	0.36	30.2	5.17	5.17	1.03	0.52	—
15	4.87	1.24	0.25	0.32	6.1	8.10	2.93	0.59	0.54	9.4
20	5.40	0.53	0.11	0.27	2.1	9.95	1.85	0.37	0.50	4.2
(20)*						(10.54)				

Age class	Sectional area at breast height: Growth (m^2)	Sectional area at breast height: Periodic increment (m^2)	Sectional area at breast height: Annual increment (m^2)	Sectional area at breast height: Mean increment (m^2)	Sectional area at breast height: Growth rate (%)	Volume: Growth (m^3)	Volume: Periodic increment (m^3)	Volume: Annual increment (m^3)	Volume: Mean increment (m^3)	Volume: Growth rate (%)
5	—	—	—	—	—	5.42×10^{-5}	5.42×10^{-5}	1.08×10^{-5}	1.08×10^{-5}	—
10	2.10×10^{-3}	2.10×10^{-3}	4.20×10^{-4}	2.10×10^{-4}	—	5.71×10^{-3}	5.65×10^{-3}	1.13×10^{-3}	5.71×10^{-4}	153.8
15	5.15×10^{-3}	3.05×10^{-3}	6.10×10^{-4}	3.43×10^{-4}	19.7	1.55×10^{-2}	9.79×10^{-3}	1.96×10^{-3}	1.03×10^{-3}	22.1
20	7.78×10^{-3}	2.63×10^{-3}	5.30×10^{-4}	3.89×10^{-4}	8.6	2.54×10^{-2}	9.90×10^{-3}	1.98×10^{-3}	1.27×10^{-3}	10.4
(20)*	8.73×10^{-3}					2.95×10^{-2}				

* Including bark.

Table 8. Description of growths in a typical tree selected in Plot 2

Age class	Height: Growth (m)	Height: Periodic increment (m)	Height: Annual increment (m)	Height: Mean increment (m)	Height: Growth rate (%)	Diameter at breast height: Growth (cm)	Diameter at breast height: Periodic increment (cm)	Diameter at breast height: Annual increment (cm)	Diameter at breast height: Mean increment (cm)	Diameter at breast height: Growth rate (%)
5	0.80	0.80	0.16	0.16	—	—	—	—	—	—
10	3.30	2.50	0.50	0.33	32.8	3.42	3.42	0.68	0.34	—
15	6.30	3.00	0.60	0.42	13.8	8.73	5.31	1.06	0.58	20.6
20	7.80	1.50	0.30	0.39	4.4	12.09	3.36	0.67	0.60	6.7
(20)						12.85				

Age class	Sectional area at breast height: Growth (m^2)	Sectional area at breast height: Periodic increment (m^2)	Sectional area at breast height: Annual increment (m^2)	Sectional area at breast height: Mean increment (m^2)	Sectional area at breast height: Growth rate (%)	Volume: Growth (m^3)	Volume: Periodic increment (m^3)	Volume: Annual increment (m^3)	Volume: Mean increment (m^3)	Volume: Growth rate (%)
5	—	—	—	—	—	2.23×10^{-5}	2.23×10^{-5}	4.46×10^{-6}	4.46×10^{-6}	—
10	0.92×10^{-3}	0.92×10^{-3}	1.84×10^{-4}	9.20×10^{-5}	—	2.77×10^{-3}	2.75×10^{-3}	5.50×10^{-4}	2.77×10^{-4}	162.3
15	5.99×10^{-3}	4.07×10^{-3}	8.14×10^{-4}	3.99×10^{-4}	45.5	2.09×10^{-2}	1.81×10^{-2}	3.62×10^{-3}	1.39×10^{-3}	49.8
20	1.14×10^{-2}	5.41×10^{-3}	1.08×10^{-3}	5.70×10^{-4}	13.7	4.65×10^{-2}	2.56×10^{-2}	5.12×10^{-3}	2.33×10^{-3}	17.3
(20)	1.30×10^{-2}					5.26×10^{-2}				

Table 9. Description of growths in a typical tree selected in Plot 3

Age class	Height: Growth (m)	Height: Periodic increment (m)	Height: Annual increment (m)	Height: Mean increment (m)	Height: Growth rate (%)	Diameter at breast height: Growth (cm)	Diameter at breast height: Periodic increment (cm)	Diameter at breast height: Annual increment (cm)	Diameter at breast height: Mean increment (cm)	Diameter at breast height: Growth rate (%)
5	0.63	0.63	0.13	0.13	—	—	—	—	—	—
10	3.30	2.67	0.53	0.33	39.3	3.20	3.20	0.64	0.32	—
15	7.30	4.00	0.80	0.49	17.2	9.93	6.73	1.35	0.66	25.4
20	9.30	2.00	0.40	0.47	5.0	14.32	4.39	0.88	0.72	7.6
21	9.80	0.50	0.50	0.47	5.4	15.51	1.19	1.19	0.74	8.3
(21)						16.10				

Age class	Sectional area at breast height: Growth (m^2)	Sectional area at breast height: Periodic increment (m^2)	Sectional area at breast height: Annual increment (m^2)	Sectional area at breast height: Mean increment (m^2)	Sectional area at breast height: Growth rate (%)	Volume: Growth (m^3)	Volume: Periodic increment (m^3)	Volume: Annual increment (m^3)	Volume: Mean increment (m^3)	Volume: Growth rate (%)
5	—	—	—	—	—	5.74×10^{-5}	$5.74\times{}^{-5}$	1.15×10^{-5}	1.15×10^{-5}	—
10	0.80×10^{-3}	0.80×10^{-3}	1.60×10^{-4}	8.00×10^{-5}	—	4.78×10^{-3}	$4.72\times{}^{-3}$	9.44×10^{-4}	4.78×10^{-4}	142.2
15	7.74×10^{-3}	6.94×10^{-3}	1.39×10^{-3}	5.16×10^{-4}	57.4	2.86×10^{-2}	$2.38\times{}^{-2}$	4.76×10^{-3}	1.91×10^{-3}	43.0
20	1.61×10^{-2}	8.36×10^{-3}	1.67×10^{-3}	8.05×10^{-4}	15.8	7.86×10^{-2}	$5.00\times{}^{-2}$	1.00×10^{-2}	3.93×10^{-3}	22.4
21	1.89×10^{-2}	2.80×10^{-3}	2.80×10^{-3}	9.00×10^{-4}	17.4	9.16×10^{-2}	$1.30\times{}^{-2}$	1.30×10^{-2}	4.36×10^{-3}	16.5
(21)	2.04×10^{-2}					1.00×10^{-1}				

Table 10. Description of growths in a typical tree selected in Plot 4

Age class	Height: Growth (m)	Height: Periodic increment (m)	Height: Annual increment (m)	Height: Mean increment (m)	Height: Growth rate (%)	Diameter at breast height: Growth (cm)	Diameter at breast height: Periodic increment (cm)	Diameter at breast height: Annual increment (cm)	Diameter at breast height: Mean increment (cm)	Diameter at breast height: Growth rate (%)
5	0.97	0.97	0.19	0.19	—	—	—	—	—	—
10	4.30	3.33	0.67	0.43	34.7	4.19	4.19	0.84	0.42	—
15	7.97	3.67	0.73	0.53	13.1	10.75	6.56	1.31	0.72	20.7
20	11.00	3.03	0.61	0.55	6.7	16.05	5.30	1.06	0.80	8.3
21	11.30	0.30	0.30	0.54	2.7	16.80	0.75	0.75	0.80	4.7
(21)						17.53				

Age class	Sectional area at breast height: Growth (m^2)	Sectional area at breast height: Periodic increment (m^2)	Sectional area at breast height: Annual increment (m^2)	Sectional area at breast height: Mean increment (m^2)	Sectional area at breast height: Growth rate (%)	Volume: Growth (m^3)	Volume: Periodic increment (m^3)	Volume: Annual increment (m^3)	Volume: Mean increment (m^3)	Volume: Growth rate (%)
5	—	—	—	—	—	3.64×10^{-5}	3.64×10^{-5}	7.28×10^{-6}	7.28×10^{-6}	—
10	1.38×10^{-3}	1.38×10^{-3}	2.76×10^{-4}	1.38×10^{-4}	—	4.42×10^{-3}	4.38×10^{-3}	8.76×10^{-4}	4.42×10^{-4}	161.1
15	9.08×10^{-3}	7.70×10^{-3}	1.54×10^{-3}	6.05×10^{-4}	45.8	3.62×10^{-2}	3.18×10^{-2}	6.36×10^{-3}	2.41×10^{-3}	52.3
20	2.02×10^{-2}	1.11×10^{-2}	2.22×10^{-3}	1.01×10^{-3}	17.3	1.05×10^{-1}	6.88×10^{-2}	1.38×10^{-2}	5.25×10^{-3}	23.7
21	2.22×10^{-2}	2.00×10^{-3}	2.00×10^{-3}	1.06×10^{-3}	9.9	1.19×10^{-1}	1.40×10^{-2}	1.40×10^{-2}	5.67×10^{-3}	13.3
(21)	2.41×10^{-2}					1.31×10^{-1}				

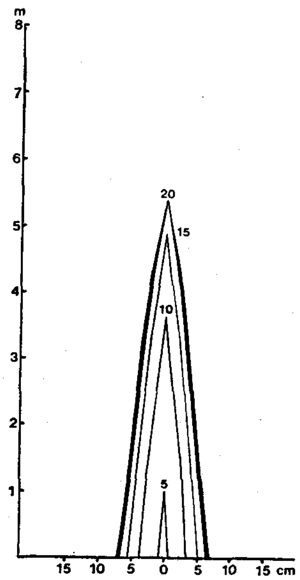

Fig. 3. Stem analysis of a typical tree selected in Plot 1.

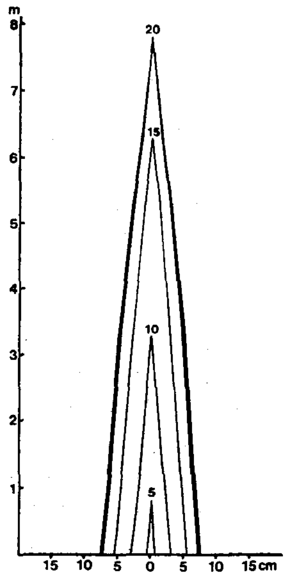

Fig. 4. Stem analysis of a typical tree selected in Plot 2.

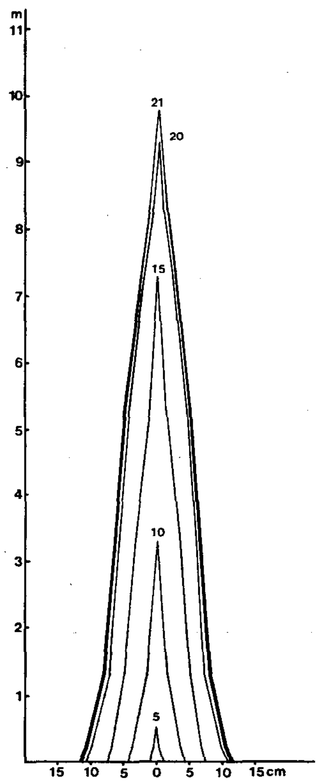

Fig. 5. Stem analysis of a typical tree selected in Plot 3.

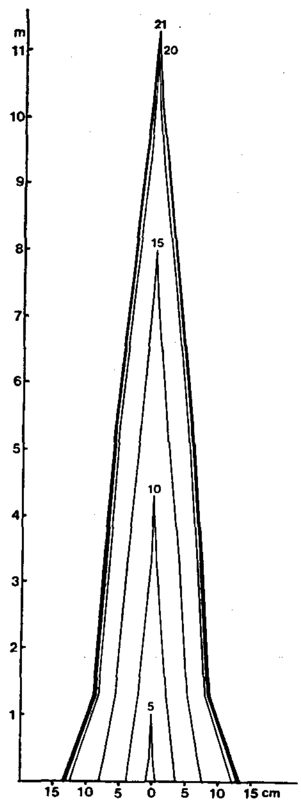

Fig. 6. Stem analysis of a typical tree selected in Plot 4.

4. Physical Properties of Woods

The results of the physical properties in the typical tree woods are shown in Tables 11 to 14, using the blocks having each 5-annual ring which were prepared from another wood disc collected at the same position as the stem analysis.

Table 11 shows that the distribution of moisture content naturally reveals the low value at the inner wood consisting mainly of heartwood as well as the high value at the outer wood consisting of sapwood. The average moisture content is 127, 150, 106 and 118% in the samples obtained from Plots 1, 2, 3 and 4, respectively. Meanwhile, the basic density is generally high at the inner wood, especially as indicated at 435 kg/m^3 for the sample collected in Plot 1, while the lowest is shown at 247 kg/m^3 for the outer wood cut at the 0.3 m stem height of the sample in Plot 4. The average basic density is low in general, measured at 382, 299, 318 and 308 kg/m^3, respectively. And this each value is converted to 0.439, 0.376, 0.401 and 0.388 in air-dry specific gravity by calculation of volume shrinkage and a weight increase of 15% moisture.[1] And these figures do not attain to the lowest value of 0.43 proposed for the higher structural timber grade for the building,[11] excluding the sample obtained from Plot 1. As regards the basic density of several kinds of *C. japonica* grown in Honshu, the average was also so low

Table 11. Distributions of moisture content in the wood of typical trees (%)

Plot	Height (m)	Section of ring number from pith 1–5	6–10	11–15	16–	Average
1	0.3	81	107	193	—	106
	1.3	98	192	—	—	134
	3.3	142	—	—	—	142
						(127)
2	0.3	129	168	273	—	175
	1.3	104	144	221	—	142
	3.3	63	209	—	—	135
	5.3	146	—	—	—	146
						(150)
3	0.3	49	70	205	—	95
	1.3	81	112	201	—	114
	3.3	72	162	—	—	108
	5.3	86	166	—	—	108
						(106)
4	0.3	52	54	166	303	100
	1.3	53	75	205	—	88
	3.3	54	134	262	—	104
	5.3	78	212	—	—	129
	7.3	169	—	—	—	169
						(118)

Table 12. Distributions of basic density in the wood of typical trees (kg/m³)

Plot	Height (m)	Section of ring number from pith 1–5	6–10	11–15	16–	Average
1	0.3	435	387	377	—	414
	1.3	363	338	—	—	353
	3.3	378	—	—	—	378
						(382)
2	0.3	356	279	275	—	331
	1.3	290	258	253	—	267
	3.3	301	267	—	—	285
	5.3	312	—	—	—	312
						(299)
3	0.3	353	296	278	—	323
	1.3	316	283	266	—	296
	3.3	394	292	—	—	346
	5.3	307	295	—	—	305
						(318)
4	0.3	369	280	255	247	293
	1.3	331	292	296	—	307
	3.3	332	274	257	—	295
	5.3	335	327	—	—	331
	7.3	312	—	—	—	312
						(308)

Table 13. Distributions of annual ring width in the wood of typical trees (mm)

Plot	Height (m)	Section of ring number from pith 1–5	6–10	11–15	16–	Average
1	0.3	5.4	3.4	3.0	—	3.9
	1.3	5.5	2.8	—	—	4.1
	3.3	3.6	—	—	—	3.6
						(3.9)
2	0.3	5.5	4.8	3.6	—	4.9
	1.3	4.3	3.7	3.2	—	3.9
	3.3	4.3	4.4	—	—	4.3
	5.3	3.6	—	—	—	3.6
						(4.2)
3	0.3	5.2	5.7	4.9	—	5.2
	1.3	6.2	6.0	4.6	—	5.6
	3.3	6.4	4.7	—	—	5.6
	5.3	5.6	3.8	—	—	5.0
						(5.4)
4	0.3	4.2	7.7	6.7	6.5	5.9
	1.3	6.6	5.7	4.7	—	5.9
	3.3	5.9	5.7	5.0	—	5.7
	5.3	5.0	5.8	—	—	5.2
	7.3	4.9	—	—	—	4.9
						(5.5)

Table 14. Distributions of rate of heartwood in the wood of typical trees

Plot	Height (m)	Annual ring number of heartwood	Rate of diameter (%)	Rate of area (%)
1	0.3	7	41	17
	1.3	5	30	9
	3.3	2	14	2
2	0.3	8	40	16
	1.3	7	41	17
	3.3	4	31	9
	5.3	1	6	0.4
3	0.3	9	45	20
	1.3	7	39	15
	3.3	5	30	9
	5.3	4	19	4
4	0.3	12	55	30
	1.3	8	53	25
	3.3	6	42	18
	5.3	5	27	7
	7.3	2	6	0.4

as 308 kg/m^3 in 13 trees collected from Chubu Province[4] as well as 333 and 340 kg/m^3 in 4 and 7 trees, respectively, from Kanto Province.[7,8] Meanwhile, the average annual ring width is so broad as 3.9, 4.2, 5.4 and 5.5 mm in the order as shown in Table 13, indicating the broader width in the samples of the more excellent growth. The width, however, does not exceed the upper limit of 6 mm standardized for the above mentioned grade for the building.[11] As presented in Table 14, the rate of heartwood is greater in the large stem disc or the wood of remarkable growth, indicating over 50% at the rate of the diameter and 25 to 30% at that of the area in the lower part of the sample selected from Plot 4.

5. Biomass in Plantation Sites

The distributions of the branches collected from the typical tree in each plot are shown in Tables 15 to 18 and in Fig. 7. Table 15 indicates a total of the branch from Plot 1 is 48 excluding 20 twigs composed only of the leaves. The greatest branch is 120 cm long whose weight is 1,400 g. Naturally, the branches of the lower part in the crown are generally long. The dried weight of the real branches and leaves is 1,045 and 5,916 g, respectively. Meanwhile, the largest number of the branch is given at 145 including 50 of the short twig in the tree from Plot 3, as shown in Table 17, which also indicates this tree has the heaviest leaf quantity of all the four selected. The tree from Plot 4, possessing the largest growing stock, spreads 100 branches and twigs, excluding 3 of the withered branch.

Table 15. Length and weight of branches including needle leaves collected from a typical tree in Plot 1

Location in crown	Number	Length (cm)		Green weight (g)					Moisture content (%)		Dried weight (g)		
		mean min.–max.	standard deviation	mean min.–max.	standard deviation	total	real branch	leaf	real branch	leaf	total	real branch	leaf
First section (2.8–3.8 m high)	18	81 60–120	15.4	444 200–1,400	291	8,000	1,220	6,780	49.4	58.5	3,431	618	2,813
Second 〃 (3.8–4.8 m high)	24 (10)	60 20–90	18.8	319 50–600	159	7,650 (100)	880	6,770 (100)	51.6	56.9	3,388	427	2,961
Third 〃 (4.8–5.4 m high)	6 (10)	30 20–40	5.8	47 20–60	12	280 (50)	0	280 (50)	—	57.2	142	0	142
Total	48 (20)	—	—	—	—	15,930 (150)	2,100	13,830 (150)	—	—	6,961	1,045	5,916

( ): Short twigs composed only of leaves.

Table 16. Length and weight of branches including needle leaves collected from a typical tree in Plot 2

Location in crown	Number	Length (cm)		Green weight (g)					Moisture content (%)		Dried weight (g)		
		mean min.–max.	standard deviation	mean min.–max.	standard deviation	total	real branch	leaf	real branch	leaf	total	real branch	leaf
First section (3.4–4.4 m high)	16	99 50–140	20.0	525 100–1,100	264	8,400	1,490	6,910	51.3	54.8	3,849	726	3,123
Second 〃 (4.4–5.4 m high)	13 (5)	87 80–100	8.2	481 300–700	114	6,250 (50)	930	5,320 (50)	49.8	56.4	2,809	467	2,342
Third 〃 (5.4–6.4 m high)	19 (3)	67 40–80	11.3	271 100–400	83	5,150 (50)	440	4,710 (50)	51.7	54.8	2,365	213	2,152
Fourth 〃 (6.4–7.4 m high)	13 (9)	45 30–80	13.4	120 100–250	42	1,560 (100)	40	1,520 (100)	53.3	56.8	719	19	700
Total	61 (17)	—	—	—	—	21,360 (200)	2,900	18,460 (200)	—	—	9,742	1,425	8,317

Table 17. Length and weight of branches including needle leaves collected from a typical tree in Plot 3

Location in crown	Number	Length (cm)			Green weight (g)						Moisture content (%)		Dried weight (g)		
		mean	min.–max.	standard deviation	mean	min.–max.	standard deviation	total	real branch	leaf	real branch	leaf	total	real branch	leaf
First section (4.2–5.2 m high)	14	126	80–160	38.4	775	150–1,600	369	10,850	2,660	8,190	51.3	53.0	5,144	1,295	3,849
Second 〃 (5.2–6.2 m high)	20 (4)	110	40–140	22.0	627	100–1,250	307	12,540 (50)	2,510	10,030 (50)	49.9	55.3	5,764	1,258	4,506
Third 〃 (6.2–7.2 m high)	27 (16)	85	40–120	24.2	393	100–800	215	10,600 (200)	1,690	8,910 (200)	45.7	54.7	5,045	918	4,127
Fourth 〃 (8.2–9.2 m high)	22	71	50–100	12.4	255	150–400	82	5,600	580	5,020	47.9	59.0	2,360	302	2,058
Fifth 〃 (8.2–9.2 m high)	12 (17)	60	40–90	10.8	163	100–350	65	1,950 (300)	0	1,950 (300)	—	57.9	947	0	947
Sixth 〃 (9.2–9.8 m high)	0 (13)	—		—	—		—	(200)	0	(200)	—	59.0	82	0	82
Total	95 (50)	—		—	—		—	41,540 (750)	7,440	34,100 (750)	—	—	19,342	3,773	15,569

Table 18. Length and weight of branches including needle leaves collected from a typical tree in Plot 4

Location in crown	Number	Length (cm)			Green weight (g)						Moisture content (%)		Dried weight (g)		
		mean	min.–max.	standard deviation	mean	min.–max.	standard deviation	total	real branch	leaf	real branch	leaf	total	real branch	leaf
First section (4.2–5.2 m high)	7 ((3))	161	140–190	13.6	871	600–1,150	192	6,100 ((950))	1,710	4,390	50.3 ((30.0))	58.1	2,689 ((665))	850	1,839 ((665))
Second 〃 (5.2–6.2 m high)	7 (3)	147	120–180	20.5	950	600–1,500	322	6,650 (100)	1,740	4,910 (100)	53.9	58.5	2,881	802	2,079
Third 〃 (6.2–7.2 m high)	15 (3)	119	50–180	33.2	740	150–2,300	552	11,100 (100)	2,670	8,430 (100)	50.7	58.2	4,882	1,316	3,566
Fouth 〃 (7.2–8.2 m high)	18	87	50–140	30.4	331	100–700	191	5,950	990	4,960	49.2	59.0	2,537	503	2,034
Fifth 〃 (8.2–9.2 m high)	17 (5)	98	40–120	16.6	415	100–700	133	7,050 (100)	1,130	5,920 (100)	53.8	58.6	3,014	522	2,492
Sixth 〃 (9.2–11.3 m high)	15	69	60–100	11.2	173	100–300	54	2,600	0	2,600	—	60.1	1,037	0	1,037
Seventh 〃 (10.2–11.3 m high)	2 (8)	40	40–40	0	50	50–50	0	100 (150)	0	100 (150)	—	59.5	101	0	101
Total	81 ((3)) (19)	—		—	—		—	39,550 (450)	8,240	31,310 (450)	—	—	17,141 ((665))	3,993	13,148 ((665))

(( )): Withered branch.

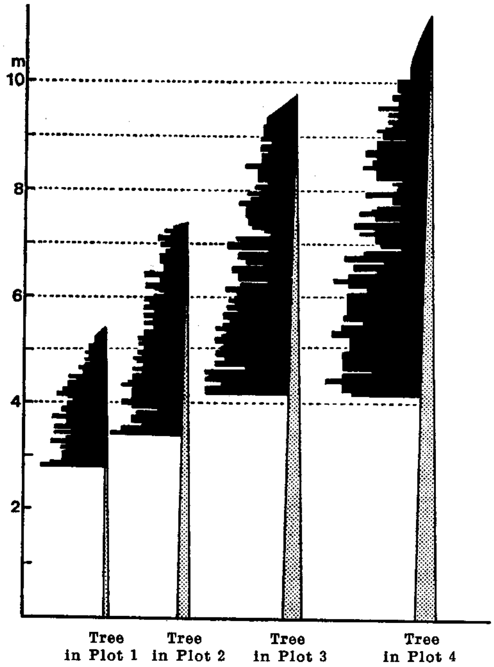

Fig. 7. Illustrated distributions of branches in typical trees.

Table 19. Biomass calculated from a typical tree and undergrowth growing in each plot

Plot		1	2	3	4
Typical tree volume (m^3)	stem	2.54×10^{-2}	4.65×10^{-2}	9.16×10^{-2}	11.9×10^{-2}
	bark	0.41×10^{-2}	0.61×10^{-2}	0.84×10^{-2}	1.2×10^{-2}
green weight (kg)	stem	9.7	13.9	29.1	36.7
	bark	1.6	2.4	3.4	4.8
	branch	2.1	2.9	7.4	8.2
	leaf	14.0	18.7	35.9	31.8
dried weight (kg)	stem	4.3	5.6	14.1	16.8
	bark	0.9	1.4	2.0	2.8
	branch	1.0	1.4	3.8	4.0
	leaf	5.9	8.3	15.6	13.1
Undergrowth green weight (tons/ha)		11.0	7.0	5.5	7.0
Stem density per ha		2,000	2,000	1,800	1,400
Biomass (tons/ha)	stem	8.6	11.2	25.4	23.5
	bark	1.8	2.8	3.6	3.9
	branch	2.0	2.8	6.8	5.6
	leaf	11.8	16.6	28.1	18.3
	undergrowth	5.3	3.5	2.5	3.5
	total	29.5	36.9	66.4	54.8
Available biomass (bark+branch+leaf) (tons/ha)		15.6	22.2	38.5	27.8

The greatest is 190 cm long and the heaviest is 2,300 g, obtained from the 6.2～7.2 m section. Table 18 reveals the amount of the branches including the leaves is estimated at 17,141 g in the tree selected from Plot 4, the second figure next to the tree from Plot 3. As the pruning has been often properly carried out, it should be considered the typical tree does not always show the amount of the branches and leaves representing exactly the whole trees growing in each plot.

Biomass was calculated by multiplying the survived tree number by the weight of the typical tree which was divided into the stem, barks, branches and leaves, and by the hectare-weight of the undergrowth as shown in Table 19. The biomass in Plots 1, 2, 3 and 4 was estimated at 29.5, 36.9, 66.4 and 54.8 tons per hectare, respectively. The greatest given in Plot 3 might happen to account for the remarkable amount of the leaves and the stem density of the site. However, the lower height site has generally a greater biomass, while the upper height site has a lower one. The biomass of the natural secondary forest investigated earlier was estimated at 124.4 tons per hectare which contain the roots of broad-leaved trees and the undergrowth consisting mainly of *S. senanensis.*[14] The data showed that the roots was considerably much and that the stem density was 2,460 per hectare.[14] Therefore, the Japanese cedar forests planted in good site would be believed to be a match for the natural forests in a near future.

Available biomass composed of barks, branches and leaves which have been hitherto neglected is unexpectedly a remarkable quantity. The greater parts are left in the forests after timber felling and can be surely turned to the soils as a fertilizer. But the branches and leaves fall every year and are sufficiently accumulated on the soils enough to supply the matters necessary for the tree growth. Accordingly, these waste residues should be transported to the mill with the logs and effectively utilized as a new forest biomass.

Conclusion

Summarized through these results, the soils in Hiyama Experiment Forest are generally good on the physical and chemical properties, especially the soils obtained in Plot 4 are excellent for the tree growth, possessing the highest growing stock in the 20-year lapse. However, the trees planted in the upper site such as Plots 1 and 2, do not show the good growth probably on account of the effect of wind, though the vitality in the earlier stage is energetic. Wind force of the different windy districts facing to the Sea of Japan in Hokkaido is shown in Table 20, compared with that of Kaminokuni Town. This indicates Kaminokuni Town is understandable to be a most windy district, where the strong wind blows even in the summer, the growing season of vegetation, at the average speed of 6.6 meters per second through a year. Accordingly, the top of the trees planted in the upper site is always exposed to the strong wind, which is very harmful for height growth, showing 52.2 m^3 of growing stock and 29.5 tons of biomass per hectare in Plot 1, while Plot 4, the most excellent site from the viewpoint of both soils and wind, possesses 266.0 m^3 of growing stock, 5 times as large as that of the former. These

Table 20. Wind force in various districts facing to the Sea of Japan in Hokkaido*1 (m/sec)

District	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
Kaminokuni*2	8.1	7.3	7.5	6.0	6.7	6.1	5.1	5.1	—	6.9	7.5	6.7	6.6
Esashi	7.8	7.6	7.0	5.6	4.3	3.5	3.3	3.6	4.5	5.4	7.9	8.6	5.8
Wakkanai	5.2	4.9	4.7	4.7	5.1	4.4	4.0	3.9	4.2	4.9	4.9	5.0	4.7
Haboro	3.8	3.4	3.2	3.2	2.9	2.4	2.2	2.4	2.9	3.5	4.2	3.7	3.2
Rumoi	6.0	5.8	5.4	5.1	4.5	3.6	3.4	3.7	4.8	5.5	6.5	6.9	5.1
Otaru	3.0	2.8	2.8	2.6	2.2	1.7	1.6	1.9	2.2	2.6	2.7	2.8	2.4
Suttsu	6.2	6.0	5.8	5.9	5.6	5.8	5.4	5.0	4.8	4.9	5.4	5.5	5.6
Hakodate	2.6	2.6	3.0	3.1	2.7	2.4	2.1	2.4	2.4	2.6	2.8	2.6	2.6

*1 From the data of "Climate in Hokkaido" 19–40 (1982).
*2 Observed at Kaminokuni station of National Railway Board.

big trees, however, have generally low specific gravity and broad annual ring width, though the characteristics are to some extent natural because the trees are young, comprising relatively much juvenile wood.

It should be always considered to select the good site for tree growth and to tend the trees for good quality in the case of afforestation. Furthermore, the waste residues now neglected in timber harvesting should be also utilized as a new forest biomass.

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摘　　要

北海道南部の上の国町にある北海道大学桧山地方演習林の土壌と，スギ造林木の性質を立地別に調べた。桧山地方演習林は1956年の創設以来，スギの造林試験に努力を注いでいる。

本研究では，まず広葉樹の二次林を含む全般的な土壌の調査と分析を行なった。つぎに1984年，植栽後およそ20年を経過したスギ造林地から標高別に4カ所標準地を選定し，その毎木調査を行ない下草を調べ，さらに代表的な造林木を伐採した。各代表木について，樹幹解析をすると同時に，含水率・容積密度数・年輪幅・心材率等の材質を調べた。一方，それらの樹木の枝を葉の着いたまますべて集め，その数，長さ，重量をはかり，実験室にもちかえった種々のサンプルから褐色を呈している部分（枝）と，緑色からなる部分（葉）を分けて，それぞれの重さと水分を測定した。これらを総合して，各4カ所の立地毎の地上部現存量をヘクタール換算で算出した。またスギ造林地の立地毎の土壌についても，詳しく現地調査を行なった。以上の結果はつぎのとおりである。

1. 桧山地方演習林の土壌の理化学的性状は全般的に良好である。黒色または黒褐色のA層には1741年に噴火した大島の火山灰が混っている。斜面下部の土壌は崩積土で，A, B層の下にA′, B′層が存在している。一方，傾斜地では，礫が多いが，沢の中の平坦地では，礫のない膨軟な厚いA層が生成している (Table 2, 3)。

2. 標高別に分けた4カ所 (Plot 1-4) のスギ造林地の土壌は，肉眼で6ないし7層に分けられ，Plot 3を除き，厚いA層には礫がほとんど含まれていない。この土壌は一般に壌土質で，水分は高いが空気の流通もよい。その中でも，Plot 4の土壌は深くまで柔らかく，細粒状ないし団粒構造を呈して，とくに良好である (Table 4)。

3. 毎木調査の結果，標高の高いPlot 1では，ヘクタール当り立木蓄積が52.2 m^3であるのに対し，Plot 4ではわずか21年生で，実に266.0 m^3の蓄積を有している (Table 5)。

4. Plot 1ないし4の4本の代表木は，樹高5.4 mから11.3 m，胸高直径10.7 cmから18.2 cmの範囲にあり，Plot 1と4の材積の違いは，同一樹齢で4倍にものぼっている (Table 6-10)。

5. 樹幹解析の試料を採取する際，同一高で同時に採った円板について，髄から5年毎にサンプリングして，ブロックを調製し，その含水率を定量すると，心材ばかりからなる試料では50%前後，辺材からなるものでは300%に達するものもある。平均含水率は106～150%の範囲である (Table 11)。

6. 容積密度数は, 一般に低く, Plot 1, 2, 3 および 4 から採取した代表木ではそれぞれ平均 382, 299, 318 および 308 kg/m^3 (Table 12) であり, 15% 水分の気乾比重に換算すると, 0.439, 0.376, 0.401 および 0.388 となる。

7. 年輪幅は全般的に広く, Plot 1 の試験材のみ平均 3.9 mm であるが, Plot 4 のものは, 5.5 mm にもなっている。しかし, この樹木は未成熟材の占める割合が高い若齢木なので, 当然かもしれない (Table 13)。

8. 心材率は, 大きな樹木ほど大であり, Plot 4 でえられた代表木の 1.3 m 以下の部位では, 直径比ですでに 50% をこえている (Table 14)。

9. 各代表木より採取した枝を測定すると, その数は Plot 3 のものが最大で葉ばかりからなる小枝を含めると 145 本にも達する。また, これらの乾重量も Plot 3 の木が最大で, 枝と葉を合せて約 20 kg にもなる。一方, Plot 1 からえられた代表木では約 7 kg である (Table 15-18)。

10. 樹幹解析, 含水率, 比重から, 立地別にスギ造林地のヘクタール当りの地上部現存量を算出すると, Plot 1 から 4 まで, それぞれ 29.5, 36.9, 66.4 および 54.8 トンとなり, Plot 3 の立地が最高であった。Plot 3 の代表木の葉の量が最大であったことと, 立木本数が比較的多いことが, その理由である。しかし, 各立地においては, これまで枝打ちや除間伐が何度か行われており, これは飽くまでも代表木から推定した値である。

けれども一般に標高の低い立地では現存量が多く, 逆に高いところはその量は少ないといえよう。また葉の量はいずれも多く, とくに生長の悪い樹木での幹材に対する割合が高い。これ等の枝葉は伐倒の際ほとんど棄てられており, 今後は素材と一緒に工場に運び, 森林バイオマスとして有効に利用することが望ましい (Table 19)。

11. 以上の結果から, スギの造林に当っては常に立地や植栽本数を考慮することが必要である。この地方は北海道でも最も風力の強い地域 (Table 20) であり, 風当りの激しい場所に植えられたスギは, 10 年も経過すると著しく生長が衰えてくる。また植栽後の手入れも十分に行なって, 材積ばかりでなく材質についても考慮することが重要である。