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Stand Structures of Coniferous Forests on Serpentinite Zone in Teshio Experiment Forest

By

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天塩地方演習林における蛇紋岩地帯の針葉樹林の林分構造

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Abstract

Forest surveys were carried out to clarify the stand structures and their change in virgin coniferous forests consisting doninantly of Akaezomatsu (*Picea glehnii*) on the serpentinite zone of Teshio Experiment Forest, Hokkaido University, both in 1972 and 1986. The results of 1972-survey showed the Akaezomatsu forests appearing uniformly at a glance were diverse and divided by tree-height grade into such three types as a canopy consisting of Akaezomatsu, that consisting mainly of Todomatsu (*Abies sachalinensis*), and that of the two species. The stand of the upper story occupied with Akaezomatsu was generally poor in these young trees, while the stand of Todomatsu upper story was naturally rich in Todomatsu young ones. The results of 1986-survey showed that though the canopy of the stand where the disaster by wet snow had occurred in the 14-year lapse was yet formed with Akaezomatsu, the average tree height considerably lowered owing to the loss of the over-matured trees and that Todomatsu became dominant in the number and growth of the stand.

Key words: Serpentinite, *Picea glehnii* (Akaezomatsu), *Abies sachalinensis* (Todomatsu), stand structure, soil analysis.

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Introduction

Akaezomatsu (*Picea glehnii* MASTERS) is a tall forest tree belonging to *Pinaceae* and distributes in northern Hokkaido. The tree, the logs of which have been already used even in Honshu since the Edo Period (18th century)[2] is one of the most important in Japan, and now widely planted.

TATEWAKI[11] has reported that natural Akaezomatsu forests are divided by the land condition into six types: 1) moor, 2) serpentinite, 3) volcanic deposits, 4) sand dune, 5) detritus, and 6) land attacked by forest fire. The Akaezomatsu forests having come out into the moor land and the serpentinite zone in the College Experiment Forests, Hokkaido University, were investigated by many researchers.[3~9,12]

The authors have long dealt with them. In present study, the virgin forests consisting dominantly of Akaezomatsu on the serpentinite zone were surveyed in Teshio Experiment Forest in 1972 including soil analysis and in 1986 together with stem analysis of the typical trees including Todomatsu (*Abies sachalinensis* MASTERS) to clarify the stand structures and to investigate the change in the 14-year lapse, in which the disaster by wet snow had occurred, and the injury of insects had broken out in connection with the disaster.

The authors are deeply indebted and would like to express their gratitude to the member of the Teshio Experiment Forest for kind helps in the surveys, and to Misses Y. KOBAYASHI and A. SATO in drawing up the figures.

Experimental Sites

The experimental sites are situated in the Teshio Experiment Forest, belonging administratively to Toikanbetsu (142° east longitude and 45° north latitude), Horonobe Town, Teshio County. The surveys were carried out both in the compartments Okuchi 38 and Kato 53 in 1972 (*cf.* Fig. 2. Sample plots: the former, Nos. 1~22 and the latter, Nos. 28~30) and in 1986 (the former, Nos. 23~27 and the latter, Nos. 31 and 32).

It is geologically in the serpentinite zone, near a source of the Toikanbetsu River and on the slope or the flat of the gentle hill locating between 60-and 180-m altitudes. Concerning the stand condition, the forests are nearly occupied with big Akaezomatsu trees, the seeds of which are collected as a seed stand of Nayoro Tree Breeding Station. The forest floor is mainly covered with Chishimazasa (*Sasa kurilensis*) and partially with such young broad-leaved trees as *Sorbus commixta, Acanthopanax sciadophylloides, Acer mono* etc. Though the upper story

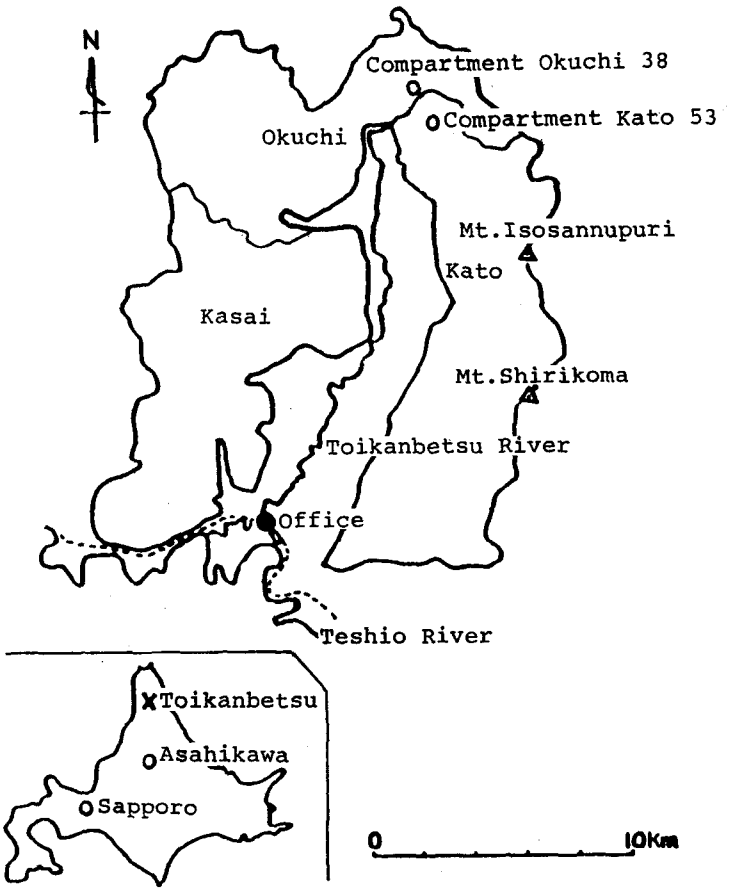


Fig. 1. Location of experimental sites in Teshio Experiment Forest.

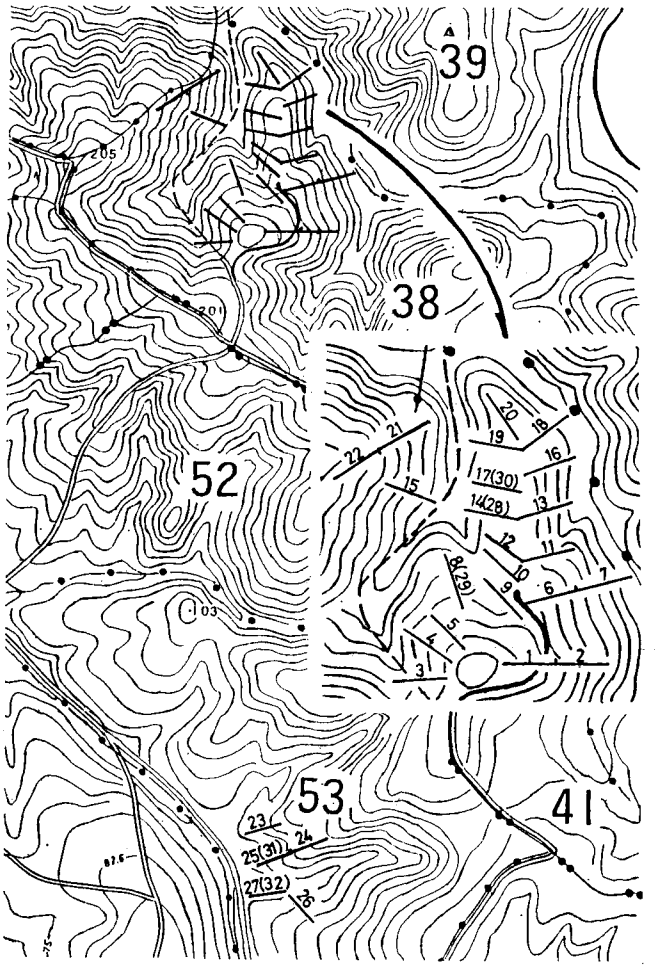
of the forests was composed of Akaezomatsu and partially of Todomatsu in the 1972-survey, the stand composition was considerably changed by the disaster of wet snow attacked in December, 1972, showing the uprooting or stem break and the injury by *Ambrosia*-beetles which occurred immediately after the disaster. However, the site was not so directly suffered as surrounding forests, which were gradually affecting on the condition of this experimental site.

As for the climate, the annual average temperature is 5.7°C and the wind force is 3.4 m per second, while the precipitation is 980 mm a year, which leads to the maximum snow depth of 128 cm in winter, as shown in Table 1.

Experimental Methods

1. Soil survey and analysis

Surveys of the soils were practiced in 1972 at two plots in the compartment Okuchi 38; the one situated at a 160-m height on the 5° slope of southeastern direction (Okuchi-38-I) and the other situated at a 100-m height on the flat of the



Foot note: Large figures are compartment numbers.
Small figures are plot numbers surveyed in 1972.
Small figures in parenthesis are plot numbers surveyed in 1986.

Fig. 2. Situation of experimental plots.

hill (Okuchi-38-II), and at one plot of a 60-m height on the flat in the compartment Kato 53 (Kato-53), together with one plot in the forest land derived from Neogene strata in the compartment Kasai 27 done for the comparison (Kasai-27). The soil profiles were made by digging till a 1-m depth, and the soils were observed and described by standard procedures.[13,14] The soils, furthermore, were taken for the measurements of apparent specific gravity, moisture content and three phases including porosity under natural condition, using a core sampler with a 100-mℓ cylinder. Those were also collected from each horizon including A_0 layer for the analysis in the laboratory.

The soils brought in the laboratory were air-dried and passed through a 2-mm

Table 1. Climatological data of Teshio Experiment Forest

	Mean temperature (°C)	Precipitation (mm)	Mean wind force (m/s)	Max. snow depth (cm)
Jan.	−9.2	60.5	3.2	119
Feb.	−9.6	39.9	3.6	126
Mar.	−3.9	42.0	3.7	128
Apr.	3.0	56.4	3.9	104
May	9.7	58.0	4.4	3
Jun.	15.3	74.8	3.5	—
Jul.	19.9	92.5	2.9	—
Aug.	19.5	103.0	2.7	—
Sep.	15.5	111.4	2.7	—
Oct.	9.1	120.4	3.4	6
Nov.	2.5	134.4	3.6	30
Dec.	−3.3	86.7	3.4	74
Mean	5.7	(980.4)	3.4	128

Observed period: 5 years from 1976 to 1980.
The figure in parenthesis is the yearly precipitation.

sieve. Fine soils thus obtained were analyzed by standard methods,[13,14] in which following items were included: Real specific gravity with Beckman air comparison pycnometer; Carbon and nitrogen with Yanagimoto CN Corder (MT 500); Cation exchange capacity (CEC) with an ionmeter (Orion 407) using an ammonium electrode; Calcium, magnesium, potassium and sodium in exchangeable cations with an atomic absorption spectrophotometer (Seiko 721); Phosphate absorption by vanado-molybdate method with a spectrophotometer at 440 nm. The moisture contents at various pF values made with Kokusan centrifuge were also determined.[13,14]

2. Surveys of stands

The surveys of the forest stands were practiced in 1972 by sample plot method, in which the area was fixed by 0.2 ha (20×100 m), totaling 22 plots (Nos. 1～22) equivalent to 10% of the whole seed stand area in the compartment Okuchi 38, and totaling 5 plots (Nos. 23～27) in the compartment Kato 53, while in 1986 the surveys were done, by selecting 3 plots (Nos. 28～30) in the former compartment and 2 plots (Nos. 31 and 32) in the latter, so as to overlap them with some plots surveyed in 1972.

All the living trees over 6-cm DBH (diameter at breast height) were counted by each species and measured on the height according to a relative ocular estimation and DBH with 1-cm-rounding calliper. The coniferous trees were classified in quality by Yanagisawa's tree-form method[15] (Table 2). Those below 6-cm DBH counted were only divided into coniferous or broad-leaved tree, while the dead standing trees were recorded in the number. Furthermore, the quality of trees surveyed in 1986 were classified also according to Terasaki's specification[10] (Table 3).

Table 2. Guide description for the classification of tree-form by Yanagisawa's method

	First class (Plus tree)	Second class (Normal tree)	Third class (Minus tree)
Growth	good, especially in early stage	moderate	bad, especially in early stage
Width of crown	narrow	moderate	wide
Straightness of stem	straight	a little bent	remarkably bent
Smoothness of bark	smooth and unconspicuous branch-scar	a little branch-scar	unsmooth and conspicuous branch-scar
Size of branch	slim	moderate	big
Fall-off of branch	good	moderate	bad
Defects of stem including insect or fungus damage	undefected, or sound	a little defective, or uninfected	defective or remarkably infected
Fruiting	vital and fruitful	vital or moderate and fruitful by cut-over of environs	withered and unfruitful

3. Stem analysis

Both two typical Akaezomatsu trees occupying the canopy and the middle story, and two typical Todomatsu trees grown in middle and lower story groups, respectively, were felled at 30 cm high in the compartment Okuchi 38 in 1986. The trees were cut and measured according to a stem analysis procedure by Nakajima's method.[13] The growth, annual and periodic increments as well as growth rate were calculated by every 10-annual ring on height, DBH, its sectional area, and

Table 3. Guide description for the classification of tree-form by Terasaki's method

1. Dominant tree:	Trees composing a canopy
First class:	Trees of widely and unbiasedly developed crown and non-defects in trunk
Second class:	Biased trees prevented in the development of crown by neibourings or of defective trunk
a:	Excessively developed or flat crown (wolf tree)
b:	Weakly developed crown and slim trunk
c:	Growth biased by neibourings
d:	Remarkably bent or forked trunk
e:	Damaged or infected
2. Recessive tree:	Trees composing lower story
Third class:	Trees of declined growth but unsuppressed
Fourth class:	Suppressed living trees
Fifth class:	Withered, dead or fallen trees

volume.

Results and Discussion

1. Soil properties

The soil properties examined under natural condition are shown in Table 4. The soils of the Okuchi-38-I are colluvial lithosol consisting of hard sandstone presumably called "Greywacke", derived from Sorachi formation in the serpentinite zone. Their humeous A horizon, the thickness of which is as extremely thin as 1 cm, is described as H-A, while the upper subsoils are classified into C_1 horizon because of the gravel content of 87% and the lower ones described as C_2 horison, consist of weathered gravel. The soils of the Okuchi-38-II are a little gley-podozolic brown forest soils divided into 5 horizons under the thick A_0 layer. The soils of A horizons (H-A_1 and A_2) are mellow and gravel-free, while those of B horizons (B_1 and B_2) are hard, especially in B_2 horison containing 52% of gravels consisting of the serpentine. However, the soils of C horizon coloured in grayish olive are composed of all brittle gravels crushed easily down with fingers. Though the soils of the Kato-53 are similar to the ones in the Okuchi-38-II, the topsoils of A horizons (A_1 and A_2) are hard, while the subsoils contain as much gravels as 45 to 54% and the solid rate occupied in the three phases is also high in volume percentage. Meanwhile, the soils of the Kasai-27, investigated for the comparison are typical properly-wet forest soils derived from Neogene strata, which widely distribute in Hokkaido. The soils are generally low in apparent specific gravity and gravel-free, in which the rate of solid phase is also as low as below 30% even in the subsoils.

The physical and chemical properties of fine soils sieved out from gravel are shown in Table 5. The mechanical analysis shows they are composed of clay by soil class. The soils obtained from lithosol (Okuchi 38-I) are strongly acidic owing to insufficient decomposition of litters, and show high cation exchange capacity and absorption of phosphate. However, in despite of the strongly acidic topsoils owing to high humus content, the soils derived from the serpentine (Okuchi 38-II and Kato-53) are yet rather neutral in the subsoils because of maitaining its characteristics, which show a higher magnesium content in exchangeable cations, compared with calcium etc. The soils of Kasai-27 reveal the typical properties of forest soils observed in Hokkaido, such as low pH and high absorption of phosphate.

The moisture contents at various pF values are shown in Table 6. The contents at pF 0, 1.6, 2.7, 3.1, 3.9, 4.2, and 5.7 correspond to the ones at maximum water holding capacity, field capacity, water equivalent, *lento* capillary point, temporary and permanent wilting points, and air dry, respectively. Generally speaking, the soils are relatively strong in water holding force due to clayey characteristic or high humus content. Accordingly, the available moisture calculated by subtracting the moisture content at pF 1.6 from the one at pF 4.2 is also low in the subsoils except those of the Kasai-27.

Table 4. Properties of soils

Sample	Situation			Horizon	Depth	Thickness	Color	
	Height (m)	Slope (°)	Direction		(cm)	(cm)	by Munsell	with naked eye
Okuchi-38-I	160	5	SW	A_0		3	7.5YR2/1	black
				H-A	0~ 1	1	7.5YR2/3	very dark brown
				C_1	1~95	94	10YR3/4	drak brown
				C_2	95<	—	10YR4/4	brown
Okuchi-38-II	100	flat		A_0		7	10YR2/2	brownish black
				H-A_1	0~10	10	7.5YR2/3	very dark brown
				A_2	10~19	9	10YR2/2	brownish black
				B_1	19~29	10	2.5Y4/3	olive brown
				B_2	29~53	24	2.5Y4/4	olive brown
				C	53<	—	5Y4/2	grayish olive
Kato-53	60	flat		A_0		8	7.5YR2/2	brownish black
				A_1	0~ 7	7	7.5YR3/2	brownish black
				A_2	7~15	8	10YR4/2	grayish yellow brown
				B_1	15~42	27	10YR4/4	brown
				B_2	42<	—	2.5Y4/4	olive brown
Kasai-27	100	10	W	A_0		7	7.5YR2/2	brownish black
				A	0~ 8	8	10YR3/3	dark brown
				B_1	8~27	19	10YR4/4	brown
				B_2	27<	—	10YR5/6	yellowish brown

Table 5. Physical and chemical

Sample	Horizon	Mechanical analysis (%)				Soil class	Air-dried moisture (%)	Maximum water holding capacity (%)	Bulk density	Real specific gravity
		Coarse sand	Fine sand	Silt	Clay					
Okuchi-38-I	A_0	—	—	—	—	—	19.8	482	0.21	1.66
	H-A	13	5	28	54	HC	15.0	342	0.35	1.96
	C_1	20	19	26	35	LiC	9.9	80	0.87	3.01
	C_2	31	33	15	21	SCL	12.2	79	1.04	3.01
Okuchi-38-II	A_0	—	—	—	—	—	21.0	556	0.20	1.75
	H-A_1	10	26	26	38	LiC	9.1	200	0.41	2.22
	A_2	2	23	38	37	LiC	6.2	116	0.63	2.61
	B_1	9	15	36	40	LiC	3.9	76	0.87	3.08
	B_2	40	32	12	16	SCL	5.9	61	1.01	3.06
	C	27	21	14	39	LiC	9.4	101	0.83	3.31
Kato-53	A_0	—	—	—	—	—	20.6	464	0.22	1.73
	A_1	5	39	40	16	CL	6.6	144	0.57	2.57
	A_2	24	18	24	34	LiC	5.6	76	0.93	3.00
	B_1	29	29	8	34	SC	3.0	50	1.12	2.92
	B_2	16	22	4	58	HC	3.5	55	1.07	2.96
Kasai-27	A_0	—	—	—	—	—	16.4	385	0.23	1.59
	A	1	14	42	43	LiC	5.9	103	0.70	2.34
	B_1	1	10	36	53	HC	6.7	106	0.71	2.57
	B_2	0	13	43	44	LiC	7·5	110	0.73	2.81

under natural condition

Hardness		Apparent specific gravity		Moisture content based on (%)		Gravel content	Distribution of three phases (vol. %)			Porosity
Tester (mm)	Consistency	Fresh soil	Dried soil	Fresh soil	Dried soil	(%)	Solid	Liquid	Gas	(vol. %)
—	—	0.35	0.23	67.8	210.9	0	6	24	70	34
1	loose	0.61	0.38	61.7	154.4	0	6	38	56	94
15	slightly hard	1.63	1.39	14.6	17.1	87	46	24	30	54
19	hard	1.88	1.47	21.9	28.0	40	49	41	10	51
—	—	0.39	0.10	73.4	276.5	0	5	29	66	95
2	loose	0.52	0.13	74.9	298.0	0	11	39	50	89
7	loose	1.18	0.50	58.0	138.0	0	19	69	13	81
19	hard	1.69	1.16	31.4	45.8	5	38	53	9	62
19	hard	1.48	0.93	37.6	60.1	52	30	56	14	70
18	hard	1.71	1.25	26.9	36.8	0	38	46	16	62
—	—	0.56	0.14	74.3	289.1	0	8	42	50	92
10	soft	1.29	0.69	46.4	86.5	0	26	60	14	74
19	hard	1.38	0.99	28.0	38.9	0	33	39	28	67
24	very hard	1.59	1.32	14.0	16.3	45	45	27	28	55
25	very hard	1.91	1.64	16.8	12.7	38	54	27	19	46
—	—	0.44	0.18	58.0	138.1	0	12	25	63	88
12	soft	1.02	0.63	36.0	56.3	0	27	42	31	73
21	hard	1.16	0.74	38.5	62.5	0	29	39	32	71
20	hard	1.43	0.85	40.6	68.4	0	30	58	12	70

properties of fine soils

pH		Exchange acidity	Loss on ignition	C	N	C/N	Total organic matter	CEC	Exchangeable cations (me/100 g)				Degree of base saturation	Absorption coefficient of P_2O_5
H_2O	KCl		(%)	(%)	(%)		(%)	(me/100 g)	Ca	Mg	K	Na	(%)	(mg/100 g)
3.9	3.3	2.0	79.3	46.4	1.68	28	80	87.8	18	9	3	2	35	1,070
3.8	3.2	6.3	60.3	32.1	1.29	25	55	61.1	11	7	1	0.9	33	2,270
5.2	4.2	4.3	11.0	2.6	0.13	20	4	20.6	0.5	0.3	0.1	0.4	6	2,670
4.7	3.5	10.0	6.6	0.4	0.03	13	0.6	58.0	12	7	0.1	0.8	33	2,570
4.5	3.7	1.7	81.2	46.3	2.52	18	80	69.2	7	5	0.7	0.9	19	1,080
4.0	3.5	3.4	35.7	18.4	1.03	18	32	40.3	4	6	0.6	1	29	1,130
5.6	4.7	0.5	13.1	6.4	0.57	11	11	29.6	3	8	0.9	1	43	1,270
5.6	4.7	0.2	4.2	1.2	0.12	10	2	16.0	3	7	0.3	0.4	66	1,420
6.7	6.0	0.1	9.7	0.1	0.01	10	0.2	13.0	0.6	8	0.1	0.3	70	1,030
6.6	5.6	0.1	9.4	0.6	0.02	30	1	35.3	3	7	0.3	0.5	29	1,730
4.4	3.9	1.6	74.4	43.3	1.57	28	75	70.5	12	6	3	0.9	29	1,900
5.5	4.6	0.4	16.3	9.4	0.45	21	16	45.5	5	8	0.5	0.4	31	1,640
6.2	6.0	0.2	8.3	1.3	0.05	26	2	19.3	2	8	0.2	0.3	53	1,510
6.8	6.7	0.1	5.5	0.1	0.01	10	0.2	8.8	0.5	6	0.1	0.2	71	570
7.3	6.8	0.1	10.1	0.1	0.01	10	0.2	6.0	0.4	5	0.1	0.2	97	1,200
4.1	3.7	1.4	80.3	46.7	2.04	23	80	63.7	19	5	1	0.8	40	1,690
3.8	3.5	1.7	11.5	6.7	0.40	17	12	28.8	7	2	0.3	0.4	35	2,740
4.8	3.5	7.9	9.4	4.2	0.26	16	7	22.4	2	2	0.3	0.3	20	2,070
5.2	4.0	10.6	6.5	1.0	0.06	17	2	23.9	1	2	0.2	0.3	13	2,950

Table 6. Moisture contents at various pF values of fine soils (Water ratio %)

Sample	Horizon	pF							Available moisture (points)
		0	1.6	2.7	3.1	3.9	4.2	5.7	
Okuchi-38-I	A_0	482	122	98	94	80	78	28	44
	H-A	342	112	92	87	75	71	18	41
	C_1	80	52	38	34	23	21	11	31
	C_2	79	56	42	39	32	31	14	25
Okuchi-38-II	A_0	556	134	108	103	93	90	27	44
	H-A_1	200	86	65	61	50	48	10	38
	A_2	116	77	53	46	29	27	7	50
	B_1	76	55	39	35	21	19	4	36
	B_2	61	41	30	27	24	23	6	18
	C	101	73	61	57	47	44	10	29
Kato-53	A_0	464	137	109	100	81	78	26	59
	A_1	144	74	44	40	30	28	7	46
	A_2	76	57	45	42	30	28	6	29
	B_1	50	37	28	26	19	17	3	20
	B_2	55	39	29	25	20	19	4	20
Kasai-27	A_0	385	120	113	99	94	93	20	27
	A	103	69	50	44	28	24	6	45
	B_1	106	65	49	43	27	25	7	40
	B_2	110	83	63	57	38	35	8	48

2. Stand structures

The sample plots of Nos. 1 to 22 surveyed in the compartment Okuchi 38 in 1972 were integrated according to the topographical features and stand condition as stands I to VI, while those of Nos. 23 to 27 in the compartment Kato 53 were also integrated as stand VII. Similarly, the plots of Nos. 28 to 30 in the Okuchi 38 and Nos. 31 and 32 in the Kato 53 examined in 1986 were integrated as VIII and IX, respectively.

The forests situated at 100-to 180-m altitudes, divided into 6 stands, vary in the tree number, species or growing stock, though appearing uniformly at a glance. As shown in Table 7, the average number is 44 (220 trees per ha) in the 0.2-ha plot, ranging between 31 (plot 22) and 65 (plot 20). The distribution of species shows the rate of coniferous trees is 84%, ranging from 98% (plot 4) to 52% (plot 22) which means a mixed forest with broad-leaved trees. Such a difference is also shown in the stand like the stands II and III composed of 91% and 67% of coniferous trees, respectively. The composition of tree species is as follows on the average : 38% of Akaezomatsu, 40% of Todomatsu, 6% of Ezomatsu (*Picea jezoensis*) and 16% of others, including the maximums of 89% of Akaezomatsu (plot 20) and

Table 7. Tree number and its percentage at plots 1~22

Stand	Plot	Tree number							Percentage (%)						
		Coniferous tree				Broad-leaved tree	Total	Dead tree	Coniferous tree				Broad-leaved tree	Total	Dead tree
		Akaezo-matsu	Todo-matsu	Ezo-matsu	Sum				Akaezo-matsu	Todo-matsu	Ezo-matsu	Sum			
I	1	28	10	1	39	1	40	10	69	25	3	97	3	100	20
	2	22	15	0	37	4	41	3	54	36	0	90	10	100	7
	3	7	14	1	22	11	33	10	21	43	3	67	33	100	23
	4	28	15	1	44	1	45	16	62	34	2	98	2	100	26
	5	17	21	0	38	6	44	9	38	48	0	86	14	100	17
	Average	20.4	15.0	0.6	36.0	4.6	40.6	9.6	50	37	2	89	11	100	19
II	6	12	32	6	50	3	53	7	23	60	11	94	6	100	12
	7	15	17	1	33	3	36	3	42	47	3	92	8	100	8
	8	23	10	1	34	5	39	3	59	25	3	87	13	100	7
	9	7	18	6	31	3	34	7	20	53	18	91	9	100	17
	10	18	23	2	43	5	48	7	38	48	4	90	10	100	13
	Average	15.0	20.0	3.2	38.2	3.8	42.0	5.4	36	48	7	91	9	100	11
III	11	0	18	14	32	16	48	4	0	38	29	67	33	100	8
	12	2	26	10	38	18	56	3	4	46	18	68	32	100	5
	Average	1.0	22.0	12.0	35.0	17.0	52.0	3.5	2	42	23	67	33	100	6
IV	13	13	33	5	51	8	59	3	22	56	8	86	14	100	5
	14	11	21	2	34	8	42	8	26	50	5	81	19	100	16
	15	0	26	2	28	13	41	3	0	63	5	68	32	100	7
	Average	8.0	26.7	3.0	37.7	9.7	47.3	4.7	17	56	6	80	20	100	10
V	16	15	11	2	28	13	41	5	36	27	5	68	32	100	11
	17	26	15	0	41	7	48	7	54	31	0	85	15	100	13
	18	28	16	0	44	4	48	4	58	34	0	92	8	100	8
	19	11	24	1	36	3	39	6	28	61	3	92	8	100	13
	20	58	5	0	63	2	65	5	89	8	0	97	3	100	7
	Average	27.6	14.2	0.6	42.4	5.8	48.2	5.4	57	30	1	88	12	100	10
VI	21	23	11	2	36	4	40	3	57	28	5	90	10	100	7
	22	2	11	3	16	15	31	1	6	36	10	52	48	100	3
	Average	12.5	11.0	2.5	26.0	9.5	35.5	2.0	35	31	7	73	27	100	5
Total average		16.6	17.8	2.7	37.1	7.0	44.1	5.8	38	40	6	84	16	100	12

63% of Todomatsu (plot 15), as well as the minimums of 0% of Akaezomatsu (plots 11 and 15) and 8% of Todomatsu (plot 20). The coefficient of correlation of Akaezomatsu percentage to Todomatsu one in the whole trees is -0.7245 (significant at 1% level), which means that the Akaezomatsu-rich stand is scarce

Table 8. Tree number below 6-cm DBH and growing stock at plots 1~22

Stand	Plot	Tree number				Growing stock (m^3)			Percentage (%)					
			Below 6-cm DBH						Below 6-cm DBH			Growing stock		
		Total	Coniferous tree	Broad-leaved tree	Sum	Coniferous tree	Broad-leaved tree	Total	Coniferous tree	Broad-leaved tree	Sum	Coniferous tree	Broad-leaved tree	Total
I	1	40	7	5	12	84.3	0.3	84.6	13	10	23	100	0	100
	2	41	7	2	9	95.6	1.0	96.6	14	4	18	99	1	100
	3	33	4	13	17	26.8	3.7	30.5	8	26	34	88	12	100
	4	45	15	9	24	54.1	0.2	54.3	22	13	35	100	0	100
	5	44	26	6	32	50.2	1.7	51.9	34	8	42	97	3	100
	Average	40.6	11.8	7.0	18.8	62.2	1.4	63.6	20	12	32	98	2	100
II	6	53	6	5	11	61.2	1.6	62.8	9	8	17	97	3	100
	7	36	8	3	11	59.5	2.6	62.1	17	6	23	96	4	100
	8	39	8	2	10	59.7	2.0	61.7	16	4	20	97	3	100
	9	34	5	2	7	57.0	1.3	58.3	12	5	17	98	2	100
	10	48	13	5	18	55.1	1.7	56.8	20	7	27	97	3	100
	Average	42.0	8.0	3.4	11.4	58.5	1.8	60.3	15	6	21	97	3	100
III	11	48	7	12	19	38.0	46.6	84.6	10	18	28	45	55	100
	12	56	14	16	30	61.4	23.4	84.8	16	19	35	72	28	100
	Average	52.0	10.5	14.0	24.5	49.7	35.0	84.7	14	18	32	59	41	100
IV	13	59	13	1	14	61.6	3.0	64.6	18	1	19	95	5	100
	14	42	15	7	22	53.1	6.0	59.1	23	11	34	90	10	100
	15	41	10	6	16	40.1	37.8	77.9	18	10	28	51	49	100
	Average	47.3	12.7	4.7	17.3	51.6	15.6	67.2	21	7	28	77	23	100
V	16	41	7	2	9	60.0	4.4	64.4	14	4	18	93	7	100
	17	48	13	8	21	79.7	1.1	80.8	19	11	30	99	1	100
	18	48	16	7	23	79.2	4.2	83.4	22	10	32	95	5	100
	19	39	16	7	23	60.5	0.9	61.4	26	11	37	99	1	100
	20	65	38	6	44	112.3	0.5	112.8	35	5	40	100	0	100
	Average	48.2	18.0	6.0	24.0	78.3	2.2	80.5	25	8	33	97	3	100
VI	21	40	25	8	33	72.4	2.6	75.0	34	11	45	97	3	100
	22	31	10	10	20	29.9	37.6	67.5	20	19	39	44	56	100
	Average	35.5	17.5	9.0	26.5	51.2	20.1	71.3	28	15	43	72	28	100
Total average		44.1	12.8	6.5	19.3	58.6	12.7	71.3	20	10	30	82	18	100

in Todomatsu and *vice versa*, and that the Akaezomatsu plot having been attacked by a typhoon etc. has been changed to a new forest intruded with Todomatsu trees. The difference of the composition is revealed also in each stand; the rates of Akaezomatsu to Todomatsu are diverse like 57% to 30%, 35% to 31%, and 2% to 42% in the stands V, VI and III, respectively. Namely, the stand V is the richest in Akaezomatsu, situated in the low land, while the stand III is relatively rich in Ezomatsu. As for the dead trees, the average rate is 12%, ranging between 26% in the highest altitude (plot 4) and 3% (plot 22).

As shown in Table 8, the growing stock is as high as 71.3 m^3 (357 m^3 per ha) on the average, ranging from 112.8 m^3 to 30.5 m^3 in the different plots. The higher altitudes such as the stands I and II give generally the low growing stock, and *vice versa*. The rate of coniferous tree stock is as remarkably high as 82%. Meanwhile, the tree number below 6-cm DBH is 19 (95 trees per ha) on the average, indicating the maximum of 44 at the plot 20 and the minimum of 7 at the plot 9, while the average rate of the coniferous tree to broad-leaved one is 20% to 10% in the whole tree number. The coefficient of correlation of the below 6-cm DBH trees to the whole number is 0.4227 (significant at 5% level), which

Table 9. Tree number, growing stock and their percentage at plots 23~27

Stand	Plot	Tree number										Growing stock (m^3)		
		Coniferous tree				Broad-leaved tree	Total	Dead	Below 6-cm DBH					
		Akaezomatsu	Todomatsu	Ezomatsu	Sum				Coniferous tress	Broad-leaved tree	Sum	Coniferous tree	Broad-leaved tree	Sum
VII	23	36	14	0	50	3	53	4	23	6	29	86.5	0.6	87.1
	24	36	9	0	45	1	46	5	17	5	22	72.8	0.2	73.0
	25	39	4	0	43	3	46	2	18	10	28	92.7	0.4	93.1
	26	4	13	1	18	3	21	0	6	7	13	10.9	0.5	11.4
	27	48	0	0	48	1	49	3	11	2	13	61.9	0.1	62.0
	Average	32.6	8.0	0.2	40.8	2.2	43.0	2.8	15.0	6.0	21.0	65.0	0.3	65.3

Percentage (%)

Coniferous tree				Broad-leaved tree	Total	Dead	Below 6-cm DBH			Growing stock		
Akaezomatsu	Todomatsu	Ezomatsu	Sum				Coniferous tree	Broad-leaved tree	Sum	Coniferous tree	Broad-leaved tree	Sum
68	26	0	94	6	100	7	28	7	35	99	1	100
78	20	0	98	2	100	10	25	7	32	100	0	100
85	8	0	93	7	100	4	24	14	38	100	0	100
19	62	5	86	14	100	0	18	20	38	96	4	100
98	0	0	98	2	100	6	18	3	21	100	0	100
76	19	1	95	5	100	6	24	9	33	99	1	100

means that the stand of high tree density is also rich in the trees below 6-cm DBH.

In the compartment Kato 53 (stand VII), situated topographically on the land less wind-beaten in comparison with the former, the average tree number is 43 (215 trees per ha) ranging from 53 to 21, as shown in Table 9. The forest is mainly composed of coniferous trees, consisting almost of Akaezomatsu, except the plot 26. The rate of dead tree is generally low. As for the number of trees below 6-cm DBH, the average is 21, indicating less difference and higher rate of coniferous trees among the plots. The coefficient of correlation of the below 6-cm DBH trees to the whole number is 0.5904 which is not significant at 5% level. The average growing stock is as high as 394 m^3 per ha, excluding the plot 26 of 11.4 m^3 (57 m^3 per ha) having an extremely low stock and consisting dominantly of Todomatsu.

The frequencies in the numbers of Akaezomatsu and Todomatsu surveyed in 1972 by tree height grade and DBH grade are shown in Figs. 3 to 8. The frequency is converted to the tree number per hectare. The distribution is divided by the height grade into 3 types: 1) The type of Akaezomatsu centered at the higher tree height such as the stands V and VI, where the forests show also the high density of Akaezomatsu (138 trees per ha); 2) The type of Todomatsu centered such as III and IV, where the canopy is occupied with Todomatsu as comparatively low as 22 m, showing some Akaezomatsu trees of higher height; 3) The type of the

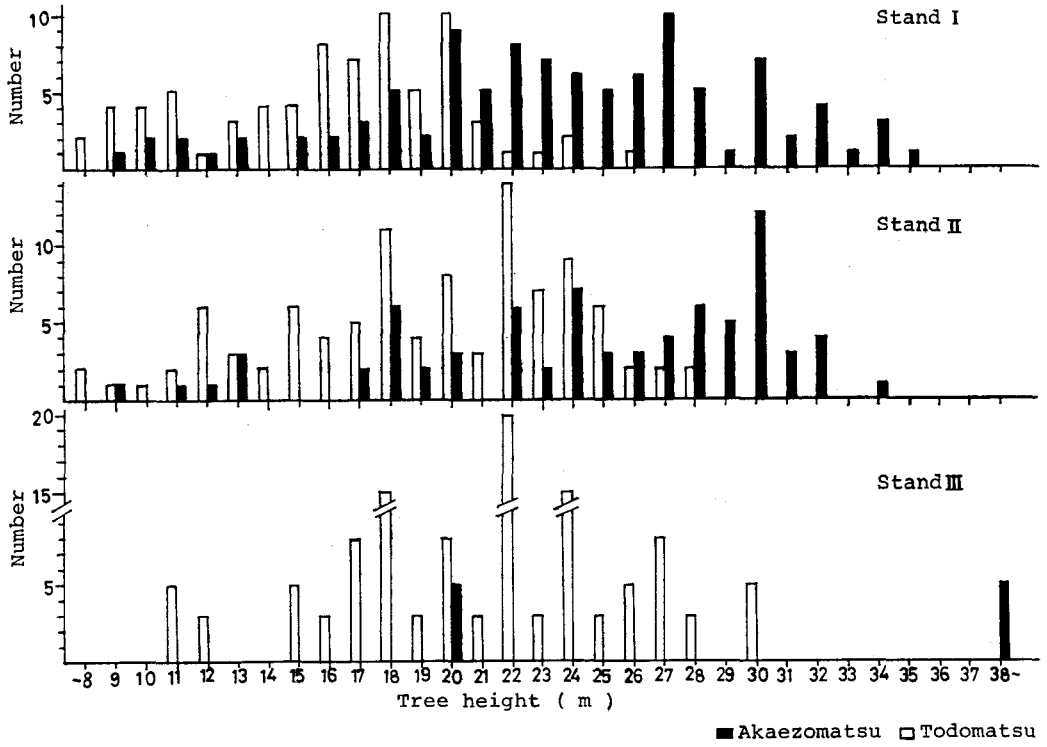


Fig. 3. Frequencies in the numbers of Akaezomatsu and Todomatsu in the stands I-III by height grade.

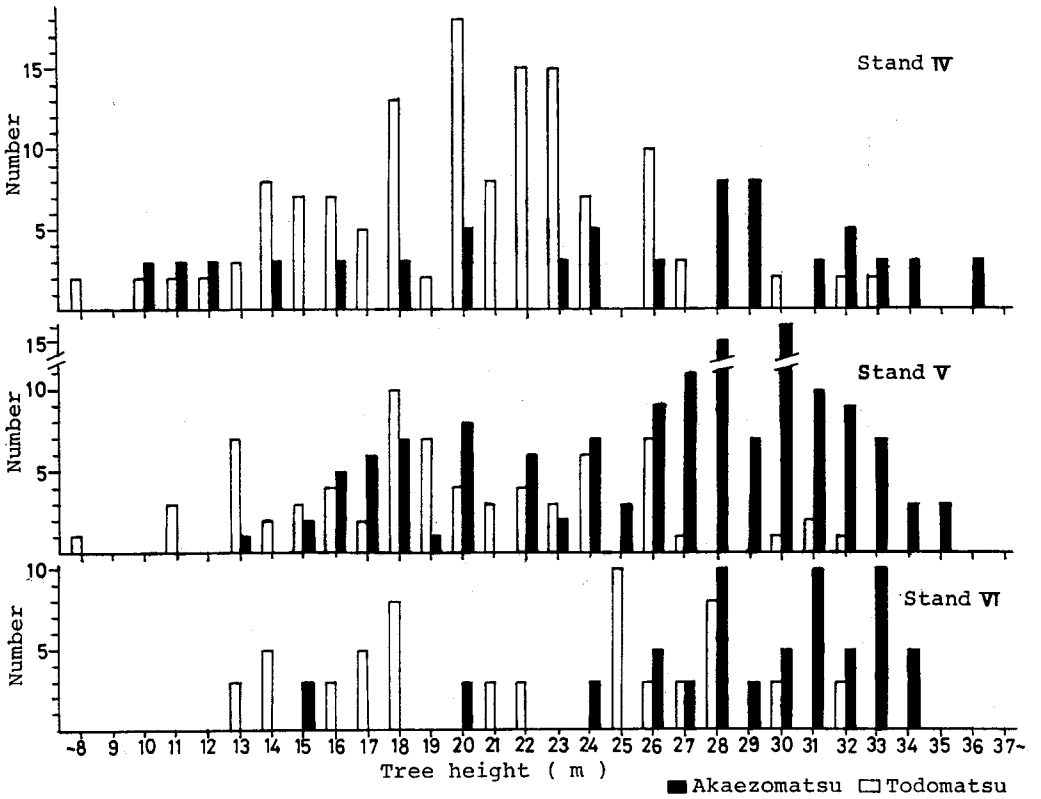


Fig. 4. Frequencies in the numbers of Akaezomatsu and Todomatsu in the stands IV–VI by height grade.

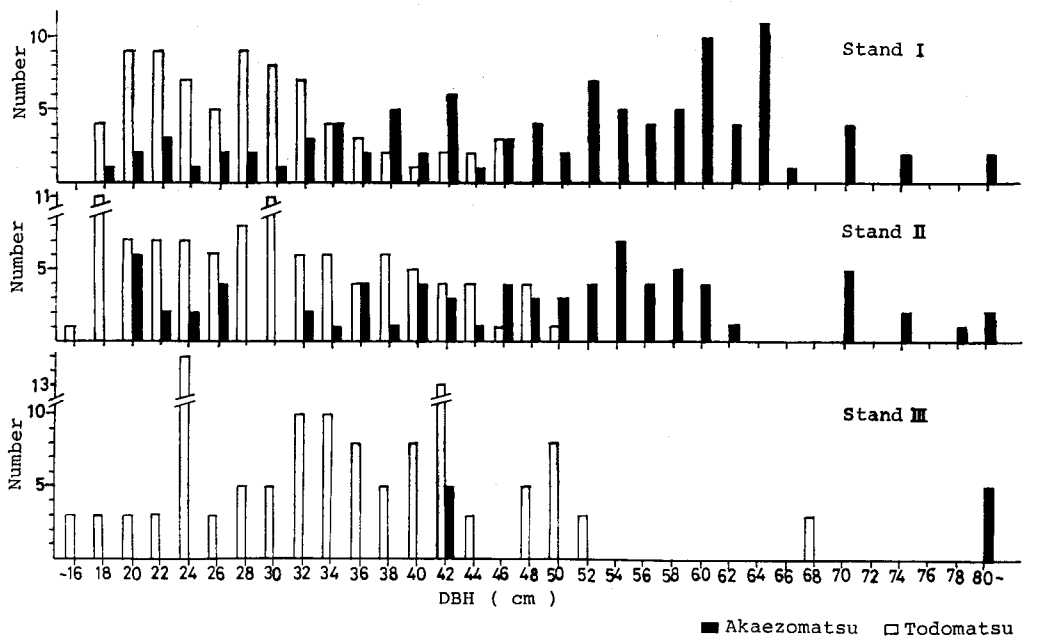


Fig. 5. Frequencies in the numbers of Akaezomatsu and Todomatsu in the stands I–III by DBH grade.

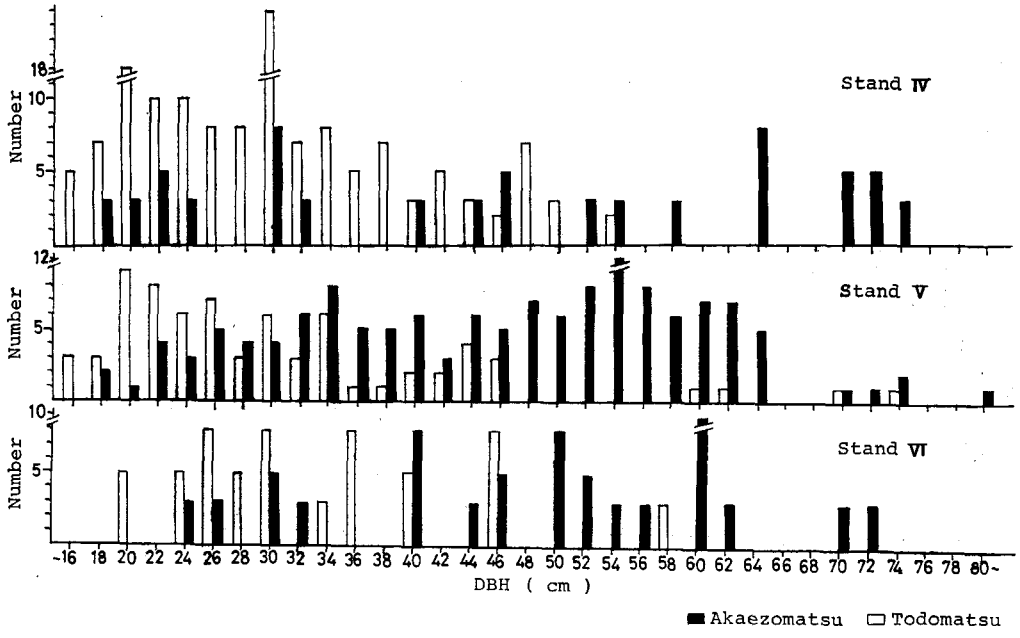


Fig. 6. Frequencies in the numbers of Akaezomatsu and Todomatsu in the stands IV-VI by DBH grade.

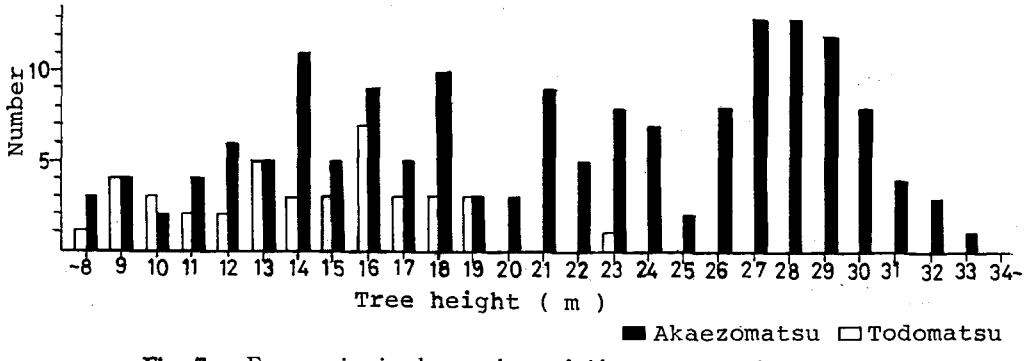


Fig. 7. Frequencies in the numbers of Akaezomatsu and Todomatsu in the stand VII by height grade.

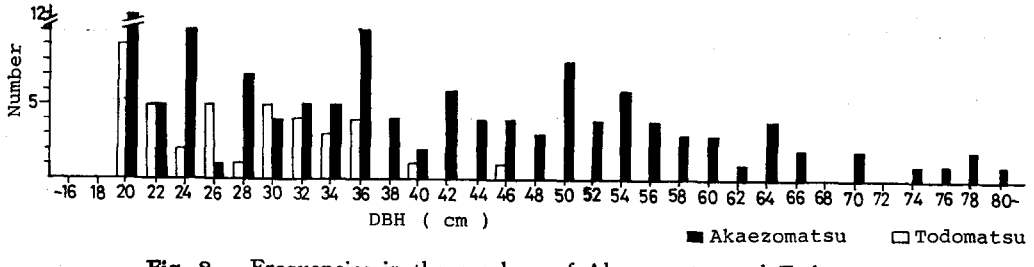


Fig. 8. Frequencies in the numbers of Akaezomatsu and Todomatsu in the stand VII by DBH grade.

Table 10. Averages and CV in height of coniferous trees at plots 1~22

Stand	Plot	Akaezomatsu				Todomatsu				Ezomatsu			
		Number	Average height	Standard deviation	CV	Number	Average height	Standard deviation	CV	Number	Average height	Standard deviation	CV
			m	m	%		m	m	%		m	m	%
I	1	28	24.7	4.24	17	10	16.9	3.73	22	1	12.0	0	
	2	22	28.1	5.38	19	15	17.4	3.27	19	0	—		
	3	7	23.1	3.82	17	14	18.2	4.93	27	1	12.0	0	
	4	28	18.0	4.02	22	15	13.1	3.46	26	1	17.0	0	
	5	17	24.2	5.91	24	21	16.0	3.92	25	0	—		
	Average	20.4	23.4	5.91	25	15.0	16.2	4.18	26	0.6	13.7	2.89	21
II	6	12	23.0	7.25	32	32	19.6	4.86	25	6	23.0	3.52	15
	7	15	25.8	4.09	16	17	17.5	4.03	23	1	22.0	0	
	8	23	23.8	5.42	23	10	15.6	3.53	23	1	13.0	0	
	9	7	27.4	6.48	24	18	19.7	4.88	25	6	21.8	6.27	29
	10	18	24.6	6.34	26	23	21.5	4.35	20	2	15.0	1.41	9
	Average	15.0	24.6	5.83	24	20.0	19.3	4.76	25	3.2	20.9	5.33	26
III	11	0	—			18	21.0	3.88	18	14	21.5	4.78	22
	12	2	29.5	13.44	46	26	21.2	5.22	25	10	25.1	4.51	18
	Average	1.0	29.5	13.44	46	22	21.1	4.67	22	12.0	23.0	4.92	21
IV	13	13	23.8	77.3	32	33	20.4	3.57	18	5	23.0	7.28	32
	14	11	25.3	7.98	32	21	17.1	4.70	27	2	24.5	77.8	32
	15	0	—			26	22.1	5.13	23	2	36.5	0.71	2
	Average	8.0	24.5	7.71	31	26.7	20.1	4.78	24	3.0	26.3	8.23	31
V	16	15	26.2	5.24	20	11	22.2	4.31	19	2	20.0	2.83	14
	17	26	26.0	4.06	16	15	21.7	6.11	28	0	—		
	18	28	27.7	5.11	18	16	18.3	5.16	28	0	—		
	19	11	30.5	2.81	9	24	18.5	4.59	25	1	14.0	0	0
	20	58	24.9	6.09	24	5	17.4	5.86	34	0	—		
	Average	27.6	26.2	5.44	21	14.2	19.6	5.28	27	0.6	17.0	4.00	24
VI	21	23	29.0	4.56	16	11	20.9	5.94	28	2	27.5	0.71	3
	22	2	30.3	4.24	14	11	23.4	5.54	24	3	25.7	7.51	29
	Average	12.5	29.1	4.46	15	11.0	22.1	5.74	26	2.5	26.4	5.41	20
Total average		16.6	25.2	5.98	24	17.8	19.3	5.06	26	2.7	22.5	6.16	27

Table 11. Averages and CV in DBH of coniferous trees at plots 1~22

Stand	Plot	Akaezomatsu				Todomatsu				Ezomatsu			
		Number	Average DBH	Standard deviation	CV	Number	Average DBH	Standard deviation	CV	Number	Average DBH	Standard deviation	CV
			cm	cm	%		cm	cm	%		cm	cm	%
I	1	28	52.5	15.39	29	10	30.5	7.79	26	1	22.0	0	
	2	22	60.0	15.91	27	15	27.1	6.25	23	0	—		
	3	7	45.3	11.81	26	14	33.8	8.59	25	1	22.0	0	
	4	28	24.2	5.91	24	15	16.0	3.92	25	1	42.1	0	
	5	17	47.5	13.66	29	21	28.1	5.53	20	0	—		
	Average	20.4	50.7	15.34	30	15.0	28.5	7.46	26	0.6	28.7	11.55	40
II	6	12	43.4	20.80	48	32	30.7	9.17	30	6	38.5	10.46	27
	7	15	53.7	17.82	33	17	28.2	11.89	42	1	35.0	0	
	8	23	48.3	13.27	27	10	27.2	5.43	20	1	26.0	0	
	9	7	56.0	16.00	29	18	34.0	10.24	30	6	43.8	25.79	59
	10	18	40.8	14.57	36	23	31.2	8.28	27	2	24.0	2.83	12
	Average	15.0	47.4	16.58	35	20.0	30.5	9.41	31	3.2	37.5	17.32	46
III	11	0	—			18	34.1	11.14	33	14	36.1	15.10	42
	12	2	71.0	41.01	58	26	35.9	9.42	26	10	40.4	11.03	27
	Average	1.0	71.0	41.01	58	22.0	35.0	10.10	29	12.0	37.6	13.34	35
IV	13	13	40.8	17.76	44	33	29.4	10.07	34	5	43.2	22.08	51
	14	11	54.0	19.92	37	21	27.2	7.28	27	2	43.0	18.38	43
	15	0	—			26	33.2	10.09	30	2	70.0	0.00	0
	Average	8.0	46.6	19.33	41	26.7	30.0	9.66	32	3.0	48.9	20.98	43
V	16	15	50.8	17.77	35	11	35.9	13.64	38	2	30.5	20.51	67
	17	26	45.9	13.29	29	15	34.7	18.82	54	0	—		
	18	28	46.6	12.16	26	16	28.1	7.85	28	0	—		
	19	11	58.9	15.86	27	24	28.0	8.63	31	1	22.0	0	
	20	58	42.0	12.33	29	5	24.8	6.10	25	0	—		
	Average	27.6	45.9	14.07	31	14.2	30.5	12.23	40	0.6	27.3	14.74	54
VI	21	23	47.5	13.31	28	11	29.3	8.26	28	2	40.0	0	
	22	2	57.0	7.07	12	11	37.1	9.81	26	3	47.3	22.03	47
	Average	12.5	48.2	13.16	27	11.0	33.2	9.71	29	2.5	44.4	16.09	36
Total average		16.6	47.6	15.34	32	17.8	30.7	9.92	32	2.7	38.9	16.3	42

intermediate consisting of the two species mixed such as the stands I and II. The trend is shown also by the DBH grade, not so remarkable as the former. Though the tree number of the two species becomes almost equal, if totaling the numbers counted in all the sample plots of the compartment Okuchi 38, the stand VII (Kato 53) is markedly rich in Akaezomatsu trees and is classified in the type of centered Akaezomatsu, occupying the upper story with this species as shown in Figs. 7 and 8.

Meanwhile, Tables 10 and 11 show the averages and coefficients of variation (CV) in height and DBH of coniferous trees at the sample plots 1 to 22, respectively. The tree height of Akaezomatsu is 25.2 m on the average, having CV of 24%, in which the highest is 30.5 m at the plot 19 and the lowest is 18.0 m at the plot 4. On the contrary, the average tree height of Todomatsu is 19.3 m, ranging from 23.4 m to 13.1 m, showing considerably lower height than the former. Compared by the stand integrated, the distribution of Akaezomatsu height in the stands V and VI indicates 21% and 15% CV, respectively, lower than the average (24%), showing the type of centered Akaezomatsu. Then that in the stands III and IV indicates 46% and 31%, while CV of Todomatsu is given at 22% and 24%, respectively, showing the type of centered Todomatsu (dispersed Akaezomatsu). Furthermore, as the distribution in the stands I and II gives the CV of both the two species near to the whole average, they can be said to belong to the intermediate type. It is certain that the upmost story of the stands is almost occupied with Akaezomatsu through every stand, although the species composing the lower story are different. As for DBH, by which the competitive effect is more clearly indicated than the height,[1] the big difference of growth affected by the tree density or the circumferences is also shown in Table 11. Namely, the average CV is 32%, more than that of the height (24%). Similarly, the types above mentioned, is also recognized by the DBH grade, but not so conspicuous. The average DBH of Akaezomatsu is 47.6 cm, ranging from 71.0 cm to 24.2 cm, while that of Todomatsu is 30.7 cm, ranging from 37.1 cm to 16.0 cm.

As regards the individual, the biggest trees in the Okuchi 38 are in the 1972-

Table 12. Averages and CV in height of coniferous trees at plots 23~27

Stand	Plot	Akaezomatsu				Todomatsu				Ezomatsu			
		Number	Average height	Standard deviation	CV	Number	Average height	Standard deviation	CV	Number	Average height	Standard deviation	CV
			m	m	%		m	m	%		m	m	%
VII	23	36	21.8	6.02	28	14	14.1	4.28	30	0	—		
	24	36	21.4	7.47	35	9	12.3	3.08	25	0	—		
	25	39	25.3	5.58	22	4	15.3	2.87	19	0	—		
	26	4	14.8	4.50	30	13	15.2	2.42	16	1	24.0	0	0
	27	48	18.3	6.13	33	0	—			0	—		
	Average	32.6	21.3	6.78	32	8.0	14.2	3.49	25	0.2	24.0	0	0

Table 13. Averages and CV in DBH of coniferous trees at plots 23~27

Stand	Plot	Akaezomatsu				Todomatsu				Ezomatsu			
		Number	Average DBH	Standard deviation	CV	Number	Average DBH	Standard deviation	CV	Number	Average DBH	Standard deviation	CV
			cm	cm	%		cm	cm	%		cm	cm	%
VII	23	36	40.6	17.47	43	14	27.5	7.72	28	0	—		
	24	36	42.8	16.84	39	9	25.8	5.02	19	0	—		
	25	39	47.2	13.36	28	4	27.8	7.41	27	0	—		
	26	4	23.5	6.35	27	13	29.7	6.17	21	1	48.0	0	0
	27	48	38.4	12.87	34	0	—			0	—		
	Average	32.6	42.6	15.53	36	8.0	27.7	6.34	23	0.2	48.0	0	0

Table 14. Tree number, growing stock and their percentage at plots 28~32

Stand	Plot	Tree number							Growing stock (m^3)		
		Coniferous tree				Broad-leaved tree	Total	Dead	Coniferous tree	Broad-leaved tree	Sum
		Akaezomatsu	Todomatsu	Others	Sum						
VIII	28	40	20	0	60	17	77	3	47.3	0.6	47.6
	29	40	26	4	70	10	80	6	22.1	0.4	22.5
	30	52	14	2	68	8	76	0	58.7	0.2	58.9
	Average	44.0	20.0	2.0	66.0	11.7	77.7	3.0	42.7	0.4	43.0
IX	31	66	9	0	75	35	110	5	96.7	1.3	98.0
	32	31	22	0	53	11	64	4	54.8	0.2	55.0
	Average	48.5	15.5	0	64.0	23.0	87.0	4.5	75.8	0.8	76.5

Percentage (%)

Coniferous tree				Broad-leaved tree	Total	Dead	Growing stock		
Akaezomatsu	Todomatsu	Others	Sum				Coniferous tree	Broad-leaved tree	Sum
52	26	0	78	22	100	4	99	1	100
50	33	5	88	12	100	7	98	2	100
68	18	3	89	11	100	0	100	0	100
57	26	4	85	15	100	4	99	1	100
60	8	0	68	32	100	4	99	1	100
49	34	0	83	17	100	6	100	0	100
56	18	0	74	26	100	5	99	1	100

survey: Height, DBH and species; The 39-m and 100-cm Akaezomatsu, the 31-m and 75-cm Todomatsu, the 32-m and 93-cm Ezomatsu, and the 23-m and 150-cm Mizunara (*Quercus mongolica* var. *grosseserrata*) in all the broad-leaved trees.

As shown in Tables 12 and 13, the canopy of the stand VII (Kato 53) is occupied with Akaezomatsu, but the size is fairly smaller than the stands of the Okuchi 38, indicating the average tree heights like 21.3 m of Akaezomatsu and 14.2 m of Todomatsu. The height distribution is also so wide as 32% of CV in Akaezomatsu. However, the tree density is so high that the stand can be called the Akaezomatsu pure forest, in which the biggest tree is the 30 m high and 92-cm DBH one.

To sum up the above-mentioned, the low and hollowed stand like V and VI is rich in Akaezomatsu, which is generally big, having less CV. As the altitude goes up, the range of Akaezomatsu height is expanded and the density is lowered, designated as Akaezomatsu-dispersed type (Todomatsu-centered type) or the intermediate type. It is proved that the virgin Akaezomatsu forests appearing uniformly, is diverse if minutely examined.

Table 14 shows the tree number, growing stock and their percentage in the stands VIII (Okuchi 38) and IX (Kato 53) surveyed in 1986. The average number and growing stock in the stand VIII are 389 trees and 215 m^3 per ha, respectively, in which coniferous trees are indicated at 85% in the number and 99% in the stock. The average number of Akaezomatsu is 220 trees per ha occupied at 57%, while that of Todomatsu is 100 occupied at 26%, revealing the similar trend even in the plot each. In the stand IX, the average number is as many as 435 trees and the growing stock is as much as 383 m^3 per ha. Coniferous trees are indicated at 74% in the number and 99% in the stock. Especially, the stand is relatively rich in broad-leaved trees, growing at 26% in the whole tree number, together with 56% of Akaezomatsu. The rate of dead standing tree is low both in the stands.

Figs. 9 and 10 show the frequencies in the numbers of Akaezomatsu and Todomatsu in the stands VIII and IX by tree height grade and DBH grade, respectively. Table 15 reveals that the average heights are generally low, shown at 17.2 m (stand VIII) and 18.7 m (stand IX) of Akaezomatsu and 8.5 m and 10.2 m of Todomatsu, and that CV is high, which means the dispersed type of the two species, although occupying the canopy with Akaezomatsu. The distribution by the DBH grade (Table 16) proves also the same trend, exceeding CV of 50% in the two species.

The classification of coniferous trees surveyed in the Okuchi 38 and Kato 53 in 1972 by Yanagisama's method[15] is shown in Tables 17 and 18, respectively. This method is usually used for the classification of the seed-collecting stand into first or second class. As for Akaezomatsu, both the I_a or II_a-ranked trees were the most at 33% in the Okuchi 38, where the forest is designated as the first-class Akaezomatsu seed stand. On the contrary, most Todomatsu trees are ranked to II_a, II_b and III_b at about 24% each, which means that the lower story is occupied with Todomatsu.

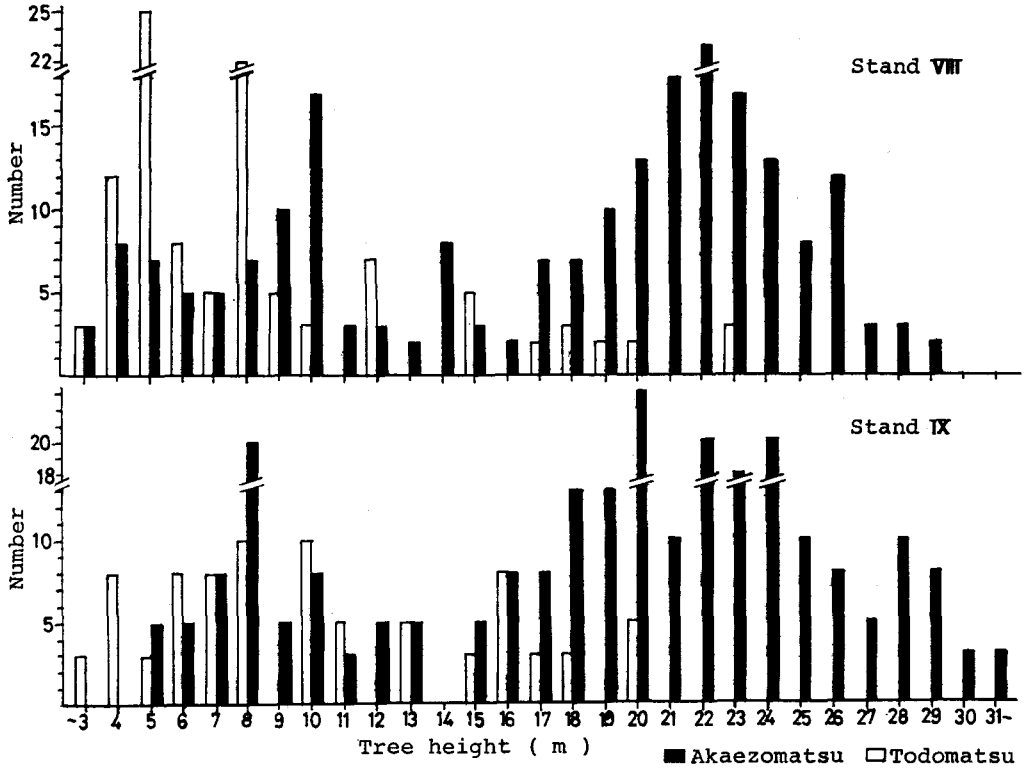


Fig. 9. Frequencies in the numbers of Akaezomatsu and Todomatsu in the stands VIII and IX by height grade.

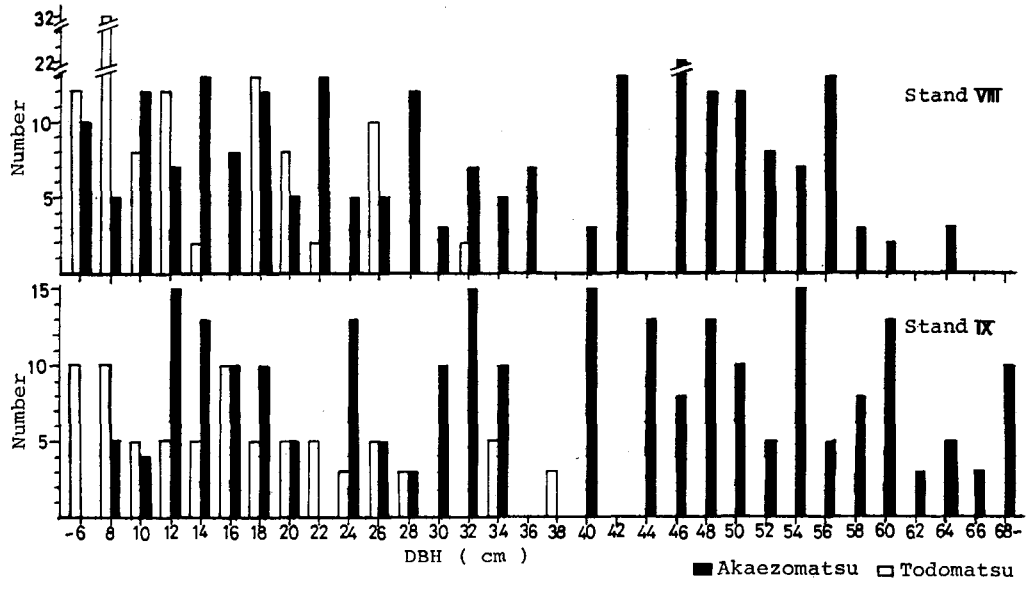


Fig. 10. Frequencies in the numbers of Akaezomatsu and Todomatsu in the stands VIII and IX by DBH grade.

Table 15. Averages and CV in height of coniferous trees at plots 28~32

Stand	Plot	Akaezomatsu				Todomatsu			
		Number	Average height	Standard deviation	CV	Number	Average height	Standard deviation	CV
			m	m	%		m	m	%
VIII	28	40	18.8	7.35	39	20	8.3	5.07	61
	29	40	15.9	6.99	44	26	10.1	5.41	54
	30	52	16.3	7.11	44	14	5.6	1.90	34
	Average	44.0	17.2	7.16	42	20.0	8.5	5.08	60
IX	31	66	18.6	7.63	41	9	8.0	3.74	47
	32	31	17.4	5.93	34	22	12.0	5.18	43
	Average	48.5	18.7	6.92	37	15.5	10.2	4.96	49

Table 16. Averages and CV in DBH of coniferous trees at plots 28~32

Stand	Plot	Akaezomatsu				Todomatsu			
		Number	Average DBH	Standard deviation	CV	Number	Average DBH	Standard deviation	CV
			cm	cm	%		cm	cm	%
VIII	28	40	32.8	16.29	50	20	12.9	6.66	52
	29	40	30.0	17.81	59	26	15.9	7.14	45
	30	52	33.8	17.21	51	14	10.0	4.00	40
	Average	44.0	32.2	16.86	52	20.0	13.3	6.85	52
IX	31	66	36.5	18.37	50	9	15.1	7.42	49
	32	31	39.8	20.19	51	22	20.1	10.68	53
	Average	48.5	37.4	18.80	50	15.5	16.8	8.94	53

The same trend is revealed in the stand VII (Kato 53), in which the I_a and I_b-ranked Akaezomatsu tree are occupied at 42% added up, while Todomatsu is ranked to I_b, II_b and III_b, totaling 82%.

Tables 19 and 20 show the classifications of coniferous trees surveyed in 1986 by Yanagisawa's method[15] and Terasaki's method,[10] which is widely used for the thinning of plantation trees in Japan. In the 1986-survey, the rate of the I_a and II_a-ranked Akaezomatsu trees likewise are as high as 61% both in the stands VIII and IX, while most Todomatsu trees are ranked to I_b, II_b and III_b, totaling over 80%. It means that the stands are dominant in the plus and ordinary Akaezomatsu trees, in spite that the disaster have occurred. The Terasaki's method also proves the same trend, like 36% and 42% of the first class Akaezomatsu trees in the stands VIII and IX, resectively.

Though the tree number increases to 180% in the stand VIII to the whole average of the stands I to VI in the Okuchi 38, the average height is lowered to 70% in Akaezomatsu and 40% in Todomatsu. Namely, Tables 21 and 22 show

Table 17. Classification of coniferous tree form at plots 1~22 by Yanagisawa's method

Species	Stand	I							II							III				IV					V							VI				Total	
	Plot / Tree form class	1	2	3	4	5	Sum	%	6	7	8	9	10	Sum	%	11	12	Sum	%	13	14	15	Sum	%	16	17	18	19	20	Sum	%	21	22	Sum	%	Number	%
Akaezomatsu	Ia	12	9	2	9	4	36	35	6	5	8	2	8	29	39					5	2		7	29	3	10	12	3	8	36	26	14		14	56	122	33
	Ib	1			6		7	7			2		3	5	7					1			1	4					1	1	1	1		1	4	15	4
	IIa	8	9	2	6	8	33	32	3	7	7	2	3	22	29		1	1	50	5	4		9	38	10	7	9	5	16	47	34	6	1	7	28	119	33
	IIb	4	1		4	2	11	11	2	1				3	4					1	1		2	8	2	5			3	10	7	1		1	4	27	7
	IIIa	3	1	2	1	2	9	9		2	5	2	1	10	13		1	1	50		3		3	13		4	4	3	20	31	23	1	1	2	8	56	15
	IIIb		2	1	2	1	6	6	1		1	1	3	6	8					1	1		2	8			3		10	13	9					27	8
	Sum	28	22	7	28	17	102	100	12	15	23	7	18	75	100		2	2	100	13	11		24	100	15	26	28	11	58	138	100	23	2	25	100	366	100
Todomatsu	Ia		2	4	1		7	9	1			1	2	4	4	3		3	7	1		3	4	5	1			1		2	3	2	2	4	18	24	6
	Ib		1		2	3	6	8				1	1	2	2	1	2	3	7		2	5	7	9		2	3	2	1	8	11	1	2	3	14	29	7
	IIa	1	1	1		2	5	7	16	1		3	11	31	31	9	9	18	41	14	2	4	20	25	5	6	1	5		17	24	2	3	5	22	96	24
	IIb	6	7	3	8	8	32	43	7	6	3	2		18	18	2	3	5	11	13	6	2	21	26	1	4	2	2		9	13					85	23
	IIIa	1		5		4	10	13	2	3	2	6	2	15	15		5	5	11	2	4	7	13	16	2	1	5	3	2	13	18	4	3	7	32	63	16
	IIIb	2	4	1	4	4	15	20	6	7	5	5	7	30	30	3	7	10	23	3	7	5	15	19	2	2	5	11	2	22	31	2	1	3	14	95	24
	Sum	10	15	14	15	21	75	100	32	17	10	18	23	100	100	18	26	44	100	33	21	26	80	100	11	15	16	24	5	71	100	11	11	22	100	392	100
Ezomatsu	Ia								3			1		4	25	7	2	9	38	2		2	4	45												17	28
	Ib	1					1	33				3		3	18						1		1	11	1			1		2	67					7	12
	IIa				1		1	33		1				1	6	5	1	6	25	2	1	2	3	33	1					1	33	2	2	4	80	16	26
	IIb			1			1	34	1		1		2	4	25	2		2	8																	7	12
	IIIa								1			1		2	13		6	6	25	1			1	11												9	15
	IIIb								1			1		2	13		1	1	4														1	1	20	4	7
	Sum	1		1	1		3	100	6	1	1	6	2	16	100	14	10	24	100	5	2	2	9	100	2			1		3	100	2	3	5	100	60	100

Footnote: I (plus tree) II (normal tree) III (minus tree), a: Upper story b: lower story *cf.* Table 2.

Table 18. Classification of coniferous tree form at plots 23~27 by Yanagisawa's method

Species	Stand	Ⅶ						
	Tree form class \ Plot	23	24	25	26	27	Total	%
Akaezomatsu	Ⅰa	9	12	18		8	47	29
	Ⅰb	4	8	3	2	4	21	13
	Ⅱa	5	5	10	1	10	31	19
	Ⅱb	5	4		1	9	19	11
	Ⅲa	7	4	6		9	26	16
	Ⅲb	6	3	2		8	19	12
	Sum	36	36	39	4	48	163	100
Todomatsu	Ⅰa							
	Ⅰb	4	1	1	4		10	25
	Ⅱa	1		1	2		4	10
	Ⅱb	1	3	1	4		9	22
	Ⅲa	1		1	1		3	8
	Ⅲb	7	5		2		14	35
	Sum	14	9	4	13		40	100
Ezomatsu	Ⅰa							
	Ⅰb							
	Ⅱa							
	Ⅱb							
	Ⅲa				1		1	100
	Ⅲb							
	Sum				1		1	100

Footnote: Symbols of tree form is the same as Table 17.

clearly the facts by the comparison in almost the same plots (not exactly) of the 1986-survey as the 1972-one. The Akaezomatsu trees of higher height are extinguished, while those of the low height increase. The same trend is also recognized by the DBH grade. From the results, the 14-year lapse indicates the process of regeneration; the increase of tree number and the appearance of young trees.

3. Tree growths

The results of stem analysis are shown in Fig. 11 and Tables 23 to 26. The Akaezomatsu tree (1) occupying the canopy was 566 years old, 28.2 m high, and 62 cm in DBH. It took about 30 years to reach at the breast height. The growth was very slow but proceeded steadily and constantly at 1 to 2% of the rate after the 80-year age. The present volume amounted to 4.19 m^3. The Akaezomatsu tree (2) selected from the middle story group was 336 years old, 21.5 m high and 38 cm in DBH. This tree was also slow in the early growth and took similarly about 30 years to reach at the breast height, but it grew normally afterward at more than 2% of the growth rate of the volume even between 200 and 260 years.

Table 19. Classification of coniferous tree form at plots 28~32 by Yanagisawa's method

Species	Tree form class	Ⅷ					Ⅸ			
		28	29	30	Total	%	31	32	Total	%
Akaezomatsu	Ⅰa	21	18	22	61	46	33	12	45	46
	Ⅰb	1	2		3	2	4	5	9	9
	Ⅱa	3	6	10	19	15	5	9	14	15
	Ⅱb	4	6		10	8	11	3	14	15
	Ⅲa	2		2	2	2	2	1	3	3
	Ⅲb	9	8	18	35	27	11	1	12	12
	Sum	40	40	52	132	100	66	31	97	100
Todomatsu	Ⅰa		2		2	3		1	1	4
	Ⅰb	2	2	6	10	17	1	11	12	39
	Ⅱa	1	2		3	5		2	2	6
	Ⅱb	5	2	2	9	15	6	3	9	29
	Ⅲa		6		6	10		2	2	6
	Ⅲb	12	12	6	30	50	2	3	5	16
	Sum	20	26	14	60	100	9	22	31	100

Footnote: Symbols of tree form is the same as Table 17.

Table 20. Classification of coniferous tree form at plots 28~32 by Terasaki's method

Species	Tree form class	Ⅷ					Ⅸ			
		28	29	30	Total	%	31	32	Total	%
Akaezomatsu	Ⅰ	19	14	16	49	36	30	12	42	42
	Ⅱa	2	2	2	6	4	2	1	3	3
	Ⅱb	2	4		6	4	7		7	7
	Ⅱc	3	4	12	19	14	3	7	10	10
	Ⅱd	2		4	6	4	3	2	5	5
	Ⅱe			2	2	2	1		1	1
	Ⅲ	6	8		14	10	9	8	17	17
	Ⅳ	6	6	16	28	21	11	1	11	11
	Ⅴ	3	4		7	5	4	1	4	4
	Sum	43	42	52	137	100	70	32	102	100
Todomatsu	Ⅰ		2		2	3		1	1	3
	Ⅱa		4		4	6		1	1	3
	Ⅱb		2		2	3		1	1	3
	Ⅱc						1	2	3	9
	Ⅱd	1	2		3	5		1	1	3
	Ⅱe	2			2	3				
	Ⅲ	11	4	8	23	36	6	13	19	54
	Ⅳ	5	12	6	23	36	2	3	5	14
	Ⅴ	1	4		5	8	1	3	4	11
	Sum	20	30	14	64	100	10	25	35	100

cf. Table 3.

Table 21. Comparison of numbers at almost the same plots in the 1972-and 1986-surveys by tree height grade

Plot	Species \ Tree height (m)	~3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35~	Total	Average
8	Akaezomatsu											2				1	1	2			4			2	2	3	2	2	1				1		23	23.8
	Todomatsu						(1)					(1)		(3)	(2)	(1)	(1)				(1)														(10)	(15.6)
29	Akaezomatsu		2	2			2	2	4	2			2	2		4			2	2	6	2	4		2										40	15.9
	Todomatsu		(4)	(4)			(4)	(2)	(2)		(4)			(2)		(2)						(2)													(26)	(10.1)
14	Akaezomatsu								1				1			1						1					1	3		1		1	1		11	25.3
	Todomatsu						(1)			(1)	(1)	(1)	(3)	(2)	(2)	(1)	(2)		(2)		(1)	(2)	(1)		(1)										(21)	(17.1)
28	Akaezomatsu		1	2	1	1			2		2	1	3		1				2	1	6	4	2	3	3	2	2	1							40	18.8
	Todomatsu		(1)	(7)	(3)	(3)	(1)	(1)						(1)		(1)		(1)	(1)																(20)	8.3
17	Akaezomatsu															1	2		1		1	1	2			2	2	3	4	3	2	2		2	28	26.0
	Todomatsu									(1)		(2)	(1)		(2)	(1)	(1)	(2)	(1)				(1)		(2)	(1)									(15)	(21.7)
30	Akaezomatsu	2	2		2	2	2	4	4							4		6	4	8	2	4	2	2	2										52	16.3
	Todomatsu	(2)	(2)	(4)	(2)		(4)																												(14)	5.6

Table 22. Comparison of numbers at almost the same plots in the 1972-and 1986-surveys by DBH grade

Plot	Species \ DBH (cm)	~6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72~	Total	Average
8	Akaezomatsu								1	1							2	1	2		1	2	1	1	1	3	2	2	2						1	23	48.3
	Todomatsu							(1)	(1)		(1)	(1)	(2)	(2)	(1)		(1)																			(10)	(27.2)
29	Akaezomatsu	2		4	2	2	2	2	2	4		2			2					2		2	6			2	2	2								40	30.0
	Todomatsu	(2)	(8)		(2)			(4)	(4)			(6)																								(26)	(15.9)
14	Akaezomatsu							1						1	1						1					1				2			2	2		11	54.0
	Todomatsu							(2)	(3)	(4)		(2)	(2)	(3)			(2)	(1)	(2)																	(21)	(27.2)
28	Akaezomatsu	2	1	1	2		1	5	1		3	1	3	2		1	2			2		3	1	3	1	2	2		1							40	32.8
	Todomatsu	(3)	(5)	(3)	(3)	(1)		(2)	(1)	(1)					(1)																				(20)	(12.9)
17	Akaezomatsu								1			1	1			4	2				2		2	2	2	3	4	1			3					28	45.9
	Todomatsu								(2)	(3)	(2)	(1)	(1)		(1)	(2)		(1)	(1)		(1)															(15)	(34.7)
30	Akaezomatsu	2	2	2		6	2			4			4		2	2	2		2	4		4		4	4		4				2					52	33.8
	Todomatsu	(2)	(6)	(2)	(2)			(2)																												(14)	(10.0)

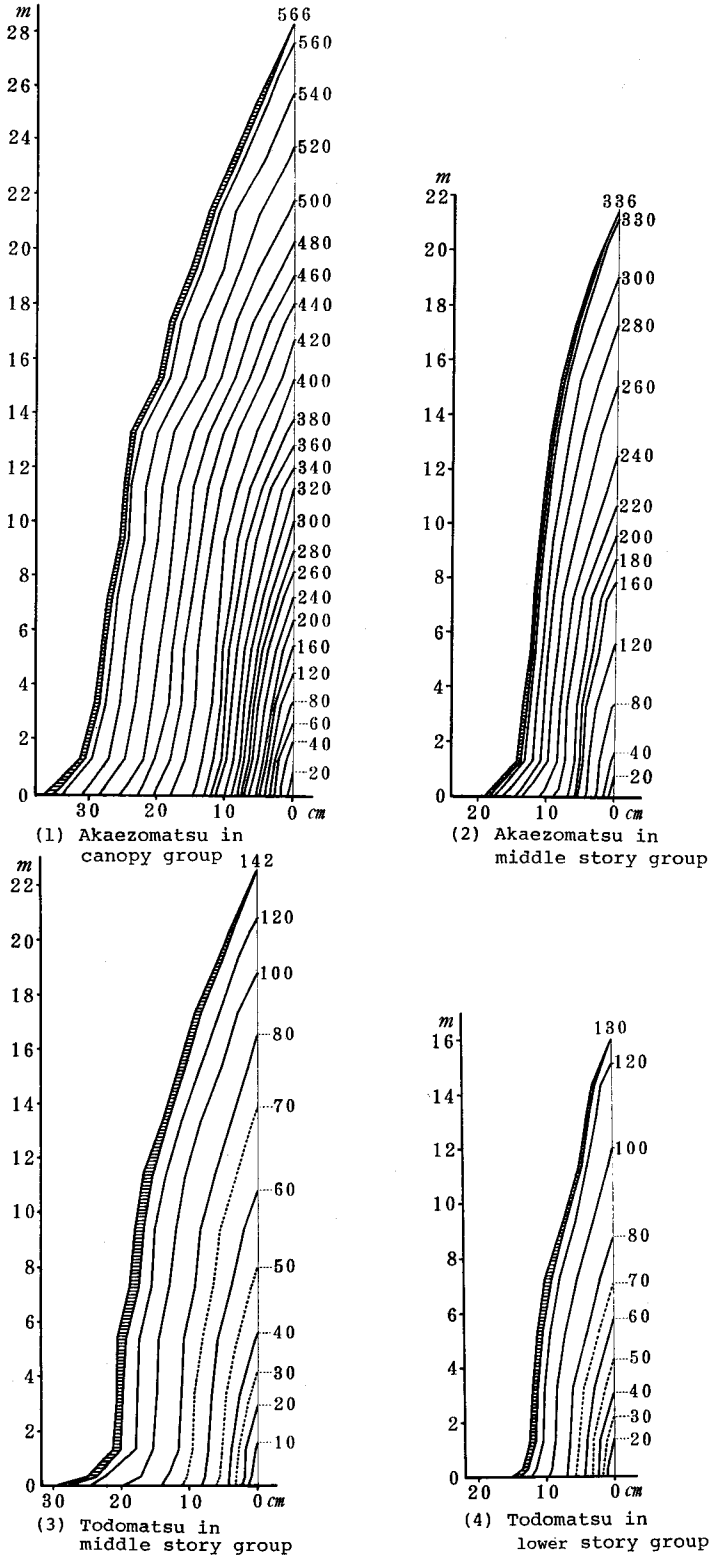


Fig. 11. Diagrams of typical trees occupying different story groups.

Table 23. Volume growth of a typical Akaezomatsu tree occupying a canopy

Age class	Growth (m^3)	Periodic increment (m^3)	Annual increment (m^3)	Mean increment (m^3)	Growth rate (%)
10	2.0×10^{-7}	2.0×10^{-7}	2.0×10^{-8}	2.0×10^{-8}	—
20	6.3×10^{-5}	6.3×10^{-5}	6.3×10^{-6}	3.2×10^{-6}	41.2
30	3.19×10^{-4}	2.6×10^{-4}	2.6×10^{-5}	1.1×10^{-5}	17.6
40	9.87×10^{-4}	6.7×10^{-4}	6.7×10^{-5}	2.5×10^{-5}	12.0
50	3.08×10^{-3}	2.1×10^{-3}	2.1×10^{-4}	6.2×10^{-5}	12.0
60	4.61×10^{-3}	1.5×10^{-3}	1.5×10^{-4}	7.7×10^{-5}	4.1
70	6.08×10^{-3}	1.5×10^{-3}	1.5×10^{-4}	8.6×10^{-5}	2.8
80	6.95×10^{-3}	0.9×10^{-3}	0.9×10^{-4}	8.7×10^{-5}	1.3
90	7.72×10^{-3}	0.8×10^{-3}	0.8×10^{-4}	8.6×10^{-5}	1.1
100	8.70×10^{-3}	1.0×10^{-3}	1.0×10^{-4}	8.7×10^{-5}	1.2
110	9.90×10^{-3}	1.2×10^{-3}	1.2×10^{-4}	9.0×10^{-5}	1.3
120	1.11×10^{-2}	1.2×10^{-3}	1.2×10^{-4}	9.3×10^{-5}	1.2
130	1.25×10^{-2}	1.4×10^{-3}	1.4×10^{-4}	9.6×10^{-5}	1.2
140	1.38×10^{-2}	1.3×10^{-3}	1.3×10^{-4}	9.9×10^{-5}	0.8
150	1.53×10^{-2}	1.5×10^{-3}	1.5×10^{-4}	1.0×10^{-4}	1.0
160	1.70×10^{-2}	1.7×10^{-3}	1.7×10^{-4}	1.1×10^{-4}	1.1
170	1.82×10^{-2}	1.2×10^{-3}	1.2×10^{-4}	1.1×10^{-4}	0.7
180	1.95×10^{-2}	1.3×10^{-3}	1.3×10^{-4}	1.1×10^{-4}	0.7
190	2.09×10^{-2}	1.4×10^{-3}	1.4×10^{-4}	1.1×10^{-4}	0.7
200	2.28×10^{-2}	1.9×10^{-3}	1.9×10^{-4}	1.1×10^{-4}	0.9
210	2.48×10^{-2}	2.0×10^{-3}	2.0×10^{-4}	1.2×10^{-4}	0.8
220	2.78×10^{-2}	3.0×10^{-3}	3.0×10^{-4}	1.3×10^{-4}	1.1
230	3.17×10^{-2}	2.9×10^{-3}	2.9×10^{-4}	1.4×10^{-4}	1.3
240	3.69×10^{-2}	5.2×10^{-3}	5.2×10^{-4}	1.5×10^{-4}	1.5
250	4.60×10^{-2}	9.1×10^{-3}	9.1×10^{-4}	1.8×10^{-4}	2.2
260	5.58×10^{-2}	9.8×10^{-3}	9.8×10^{-4}	2.1×10^{-4}	2.0
270	6.39×10^{-2}	8.1×10^{-3}	8.1×10^{-4}	2.4×10^{-4}	1.4
280	7.08×10^{-2}	6.9×10^{-3}	6.9×10^{-4}	2.5×10^{-4}	1.0
290	7.92×10^{-2}	8.4×10^{-3}	8.4×10^{-4}	2.7×10^{-4}	1.1
300	9.14×10^{-2}	1.2×10^{-2}	1.2×10^{-3}	3.0×10^{-4}	1.4
310	1.05×10^{-1}	1.4×10^{-2}	1.4×10^{-3}	3.4×10^{-4}	1.4
320	1.20×10^{-1}	1.5×10^{-2}	1.5×10^{-3}	3.8×10^{-4}	1.3
330	1.36×10^{-1}	1.6×10^{-2}	1.6×10^{-3}	4.1×10^{-4}	1.2
340	1.60×10^{-1}	2.4×10^{-2}	2.4×10^{-3}	4.7×10^{-4}	1.6
350	1.92×10^{-1}	2.8×10^{-2}	2.8×10^{-3}	5.5×10^{-4}	1.8
360	2.29×10^{-1}	3.7×10^{-2}	3.7×10^{-3}	6.4×10^{-4}	1.8
370	2.62×10^{-1}	3.3×10^{-2}	3.3×10^{-3}	7.1×10^{-4}	1.4
380	2.97×10^{-1}	3.5×10^{-2}	3.5×10^{-3}	7.8×10^{-4}	1.2
390	3.30×10^{-1}	3.3×10^{-2}	3.3×10^{-3}	8.5×10^{-4}	1.1

Age class	Growth (m^3)	Periodic increment (m^3)	Annual increment (m^3)	Mean increment (m^3)	Growth rate (%)
400	3.73×10^{-1}	4.3×10^{-2}	4.3×10^{-3}	9.3×10^{-4}	1.2
410	4.31×10^{-1}	5.8×10^{-2}	5.8×10^{-3}	1.1×10^{-3}	1.5
420	5.18×10^{-1}	8.7×10^{-2}	8.7×10^{-3}	1.2×10^{-3}	1.9
430	6.38×10^{-1}	1.2×10^{-1}	1.2×10^{-2}	1.5×10^{-3}	2.1
440	7.77×10^{-1}	1.4×10^{-1}	1.4×10^{-2}	1.8×10^{-3}	2.0
450	9.10×10^{-1}	1.3×10^{-1}	1.3×10^{-2}	2.0×10^{-3}	1.6
460	1.04	1.3×10^{-1}	1.3×10^{-2}	2.3×10^{-3}	1.3
470	1.19	1.5×10^{-1}	1.5×10^{-2}	2.5×10^{-3}	1.4
480	1.37	1.8×10^{-1}	1.8×10^{-2}	2.9×10^{-3}	1.4
490	1.57	2.0×10^{-1}	2.0×10^{-2}	3.2×10^{-3}	1.4
500	1.79	2.2×10^{-1}	2.2×10^{-2}	3.6×10^{-3}	1.3
510	2.03	2.4×10^{-1}	2.4×10^{-2}	4.0×10^{-3}	1.3
520	2.34	3.1×10^{-1}	3.1×10^{-2}	4.5×10^{-3}	1.4
530	2.64	3.0×10^{-1}	3.0×10^{-2}	5.0×10^{-3}	1.2
540	2.99	3.5×10^{-1}	3.5×10^{-2}	5.5×10^{-3}	1.2
550	3.34	3.5×10^{-1}	3.5×10^{-2}	6.1×10^{-3}	1.1
560	3.70	3.6×10^{-1}	3.6×10^{-2}	6.6×10^{-3}	1.0
566	3.92	2.2×10^{-1}	3.7×10^{-2}	6.9×10^{-3}	1.0
(566)*	4.19				

* including bark.

Table 24. Volume growth of a typical Akaezomatsu tree occupying a middle story

Age class	Growth (m^3)	Periodic increment (m^3)	Annual increment (m^3)	Mean increment (m^3)	Growth rate (%)
10	7.4×10^{-6}	7.4×10^{-6}	7.4×10^{-7}	7.4×10^{-7}	—
20	6.6×10^{-5}	6.9×10^{-5}	6.9×10^{-6}	2.3×10^{-6}	24.5
30	2.37×10^{-4}	1.7×10^{-4}	1.7×10^{-5}	7.9×10^{-6}	13.6
40	4.68×10^{-4}	2.3×10^{-4}	2.3×10^{-5}	1.2×10^{-5}	7.0
50	8.20×10^{-4}	3.5×10^{-4}	3.5×10^{-5}	1.6×10^{-5}	5.8
60	1.44×10^{-3}	6.2×10^{-4}	6.2×10^{-5}	2.4×10^{-5}	5.8
70	2.54×10^{-3}	1.1×10^{-3}	1.1×10^{-4}	3.6×10^{-5}	5.8
80	3.95×10^{-3}	1.4×10^{-3}	1.4×10^{-4}	4.9×10^{-5}	4.5
90	6.07×10^{-3}	2.1×10^{-3}	2.1×10^{-4}	6.7×10^{-5}	4.4
100	9.08×10^{-3}	3.0×10^{-3}	3.0×10^{-4}	9.1×10^{-5}	4.1
110	1.25×10^{-2}	3.4×10^{-3}	3.4×10^{-4}	1.1×10^{-4}	3.2
120	1.61×10^{-2}	3.6×10^{-3}	3.6×10^{-4}	1.3×10^{-4}	2.6
130	1.97×10^{-2}	3.6×10^{-3}	3.6×10^{-4}	1.5×10^{-4}	2.0
140	2.42×10^{-2}	4.5×10^{-3}	4.5×10^{-4}	1.7×10^{-4}	2.0
150	2.87×10^{-2}	4.5×10^{-3}	4.5×10^{-4}	1.9×10^{-4}	1.7

Age class	Growth (m^3)	Periodic increment (m^3)	Annual increment (m^3)	Mean increment (m^3)	Growth rate (%)
160	3.31×10^{-2}	4.4×10^{-3}	4.4×10^{-4}	2.1×10^{-4}	1.4
170	3.73×10^{-2}	4.2×10^{-3}	4.2×10^{-4}	2.2×10^{-4}	1.2
180	4.31×10^{-2}	5.8×10^{-3}	5.8×10^{-4}	2.4×10^{-4}	1.4
190	4.99×10^{-2}	6.8×10^{-3}	6.8×10^{-4}	2.6×10^{-4}	1.5
200	6.55×10^{-2}	1.6×10^{-2}	1.6×10^{-3}	3.3×10^{-4}	2.7
210	8.58×10^{-2}	2.0×10^{-2}	2.0×10^{-3}	4.1×10^{-4}	2.7
220	1.09×10^{-1}	2.3×10^{-2}	2.3×10^{-3}	4.9×10^{-4}	2.4
230	1.38×10^{-1}	2.7×10^{-2}	2.7×10^{-3}	6.0×10^{-4}	2.4
240	1.69×10^{-1}	3.1×10^{-2}	3.1×10^{-3}	7.0×10^{-4}	2.4
250	2.06×10^{-1}	3.7×10^{-2}	3.7×10^{-3}	8.2×10^{-4}	2.0
260	2.51×10^{-1}	4.5×10^{-2}	4.5×10^{-3}	9.6×10^{-4}	2.0
270	3.04×10^{-1}	5.3×10^{-2}	5.3×10^{-3}	1.1×10^{-3}	1.9
280	3.59×10^{-1}	5.5×10^{-2}	5.5×10^{-3}	1.3×10^{-3}	1.7
290	4.23×10^{-1}	6.4×10^{-2}	6.4×10^{-3}	1.5×10^{-3}	1.7
300	4.75×10^{-1}	5.2×10^{-2}	5.2×10^{-3}	1.6×10^{-3}	1.2
310	5.35×10^{-1}	6.0×10^{-2}	6.0×10^{-3}	1.7×10^{-3}	1.2
320	5.95×10^{-1}	6.0×10^{-2}	6.0×10^{-3}	1.9×10^{-3}	1.1
330	6.52×10^{-1}	4.3×10^{-2}	4.3×10^{-3}	2.0×10^{-3}	0.9
336	6.82×10^{-1}	3.0×10^{-2}	5.0×10^{-3}	2.0×10^{-3}	0.8
(336)	7.51×10^{-1}				

Table 25. Volume growth of a typical Todomatsu tree occupying a middle story

Age class	Growth (m^3)	Periodic increment (m^3)	Annual increment (m^3)	Mean increment (m^3)	Growth rate (%)
10	4.3×10^{-4}	4.3×10^{-4}	4.3×10^{-5}	4.3×10^{-5}	—
20	2.74×10^{-3}	2.3×10^{-3}	2.3×10^{-4}	1.4×10^{-4}	20.3
30	7.04×10^{-3}	4.3×10^{-3}	4.3×10^{-4}	2.3×10^{-4}	9.9
40	1.43×10^{-2}	7.3×10^{-3}	7.3×10^{-4}	3.6×10^{-4}	7.3
50	4.08×10^{-2}	2.7×10^{-2}	2.7×10^{-3}	8.2×10^{-4}	11.0
60	1.01×10^{-1}	6.0×10^{-2}	6.0×10^{-3}	1.7×10^{-3}	9.5
70	2.15×10^{-1}	1.1×10^{-1}	1.1×10^{-2}	3.1×10^{-3}	7.8
80	3.87×10^{-1}	1.7×10^{-1}	1.7×10^{-2}	4.8×10^{-3}	6.1
90	5.87×10^{-1}	2.0×10^{-1}	2.0×10^{-2}	6.5×10^{-3}	4.3
100	7.90×10^{-1}	2.0×10^{-1}	2.0×10^{-2}	7.9×10^{-3}	3.0
110	1.00	2.1×10^{-1}	2.1×10^{-2}	9.1×10^{-3}	2.4
120	1.21	2.1×10^{-1}	2.1×10^{-2}	1.0×10^{-2}	1.9
130	1.41	2.0×10^{-1}	2.0×10^{-2}	1.1×10^{-2}	1.5
140	1.56	1.5×10^{-1}	1.5×10^{-2}	1.1×10^{-2}	1.0
142	1.58	0.2×10^{-1}	1.0×10^{-2}	1.1×10^{-2}	0.6
(142)	1.80				

Table 26. Volume growth of a typical Todomatsu tree occupying a lower story

Age class	Growth (m^3)	Periodic increment (m^3)	Annual increment (m^3)	Mean increment (m^3)	Growth rate (%)
10	3.0×10^{-5}	3.0×10^{-5}	3.0×10^{-6}	3.0×10^{-6}	—
20	2.2×10^{-4}	2.9×10^{-4}	2.9×10^{-5}	1.1×10^{-5}	22.0
30	1.00×10^{-3}	7.8×10^{-4}	7.8×10^{-5}	3.3×10^{-5}	16.3
40	3.20×10^{-3}	2.2×10^{-3}	2.2×10^{-4}	8.0×10^{-5}	12.3
50	7.11×10^{-3}	3.9×10^{-3}	3.9×10^{-4}	1.4×10^{-4}	8.3
60	1.61×10^{-2}	9.0×10^{-3}	9.0×10^{-4}	2.7×10^{-4}	8.5
70	3.60×10^{-2}	2.0×10^{-2}	2.0×10^{-3}	5.1×10^{-4}	8.4
80	6.43×10^{-2}	2.8×10^{-2}	2.8×10^{-3}	8.0×10^{-4}	6.0
90	1.08×10^{-1}	4.4×10^{-2}	4.4×10^{-3}	1.2×10^{-3}	5.3
100	1.54×10^{-1}	4.6×10^{-2}	4.6×10^{-3}	1.5×10^{-3}	3.6
110	2.09×10^{-1}	5.5×10^{-2}	5.5×10^{-3}	1.9×10^{-3}	3.1
120	2.73×10^{-1}	6.4×10^{-2}	6.4×10^{-3}	2.3×10^{-3}	2.7
130	3.51×10^{-1}	7.8×10^{-2}	7.8×10^{-3}	2.7×10^{-3}	2.5
(130)	4.15×10^{-1}				

However, the growth at the recent stage was rapidly declined, showing the present volume of 0.751 m^3. The Todomatsu tree (3) selected from the same story group as the former was 142 years old, 22.5 m high and 42.7 cm in DBH. This tree was normally growing, taking ten years to reach at the breast height. The process of the volume growth is said to be satisfactory, as proved at 1.80 m^3 of the present volume. Meanwhile, the Todomatsu tree (4) selected from the lower story group was 130 years old, 16 m high and 30 cm in DBH. Though the age was not so different from the former, this was suppressed and remarkably worse in the early growth for Todomatsu, taking 20 years to reach at the breast height. However, the growth was recovering at 2 to 3% of the rate even in the recent stage, though the present volume was only 0.415 m^3.

Conclusion

The virgin coniferous forests consisting dominantly of Akaezomatsu are not uniform but rather diverse in the stand structure. The Akaezomatsu trees are generally bigger in the average height and DBH than Todomatsu trees except the plot 26. However, from the fact that the low story of the stand is nearly occupied with Todomatsu and relatively few in the number of the Akaezomatsu succeeding trees, it is possible that when the Akaezomatsu of the upper story is decreased by a certain cause, the forest is changed to Todomatsu one, with which the lower story was occupied, as shown in the stand III, where such disaster is supposed to have occurred in the past. Though the stands VIII and IX were not so directly suffered as surrounding forests owing to the topography by the wet snow disaster having broken out in December, 1972, the big trees were gradually weakened by invisible

damage such as cutting of fine roots and the insect injury having attacked immediately afterward. The authors often observed the fallen decayed Akaezomatsu trees in the 1986-survey. Although such calamity would visit once in a hundred years at least, the long-life Akaezomatsu means to encounter it several times through the whole life. The canopy of the forests surveyed in 1986 are yet formed dominantly with Akaezomatsu, partially extinguishing their bigger and over-matured trees, and increasing the number of young trees including mainly Todomatsu.

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摘　　要

アカエゾマツ (*Picea glehnii* MASTERS) はマツ科トウヒ属の高木で，北海道の北部に分布し，古くから建築材等に用いられている重要な樹木である。舘脇はアカエゾマツ天然林を立地によって，6系に区分しているが，本研究では北海道大学天塩地方演習林の蛇紋岩系といわれ

るアカエゾマツを主とする天然林について，1972年の調査により土壌と林分構造を解析した。さらに，その直後に起った湿雪による被害を比較的まぬがれた同天然林を1986年に再度調査し，代表的なアカエゾマツとトドマツ (*Abies sachalinensis* MASTERS) の樹木について樹幹解析を行った。この研究の目的は，天然林の林分構造を明らかにするとともに，その後の変化を調べ，天然林の自然の推移を推測するものである。

調査地は，同大学天塩地方演習林奥地38林班と河東53林班で，1調査地の大きさは0.2 ha (20×100 m) 合計32カ所で，プロット調査法により樹種，樹高，胸高直径等を測定し，柳沢および寺崎の樹型級区分によってアカエゾマツとトドマツを分類した。

1972年の調査においては，この土壌は一部空知層に由来すると思われるリソゾルと，大部分は蛇紋岩からなるややグライポドゾル化した褐色森林土であることが明らかになった。一方その林相は，一見一様のアカエゾマツ林と見えるが，詳細に調べると極めて多様であった。すなわち，全体の本数平均では，針葉樹が80% 以上占めているが，調査地によっては，90%，60% と変化があり，アカエゾマツが上層に集中する場合，トドマツが上層に集中する場合，両者の中間型などに区分された。しかし，アカエゾマツに富む林分はトドマツが少なく，トドマツが多いプロットはアカエゾマツが少ないという負の有意な相関が成立し，何らかの原因で，アカエゾマツ上層木が減少すると，トドマツが増加するものと思われる。全成木数と胸高直径6 cm 以下の樹木本数の間にも正の有意な相関が成立し，立木密度の高い調査地は，後継樹の数も多いことが判った。1972年の調査に比較して，1986年の調査結果では，全本数の平均は，1.8～2倍に増加したが，平均樹高はアカエゾマツで0.7～0.9，トドマツでは0.4～0.7と減少した。柳沢の樹型級区分による，上層を占めるアカエゾマツのプラス木，普通木の全本数に対する百分率は，約60% で，1972年と1986年の調査では変化がなく，14年を経過しても，アカエゾマツが上層を優占していることに変りはない。1986年調査の寺崎式樹型級区分でもアカエゾマツI級木が40% と同様の結果が得られているが，後継樹となるべきIII級木は，トドマツが約45% を占め，アカエゾマツは10数 % に過ぎない。さらに樹幹解析の結果，林冠を占めるアカエゾマツは樹齢500年以上，樹高30 m 近くの巨木であり，その生長は極めて遅い。一方，中・下層を占めるトドマツの樹齢は130～140年であり，たとえ初期に被圧をうけていても，次第にその生長力を回復している。

これらの事実から，次のように総括される。1972年と1986年の調査では，この天然林はいずれもアカエゾマツが上層を優占していたが，この14年の間に起った湿雪害とその直後におこった虫害の影響をうけて構造は大きく変化している。つまり，老齢過熟のアカエゾマツの一部が失われて平均樹高が低下し，主としてトドマツからなる下層木本数の増加が認められた。

1) Okuchi 38 (1) in 1986.

2) Okuchi 38 (2) in 1986.

3) Kato 53 in 1986.

Photo 1. Present circumstances in the compartments Okuchi 38 and Kato 53.