EXTRACTS

FROM THE

BULLETIN OF THE FOREST EXPERIMENT STATION,

MEGURO, TOKYO

BUREAU OF FORESTRY,
DEPARTMENT OF AGRICULTURE AND COMMERCE,
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PREFACE

The following pages are the extracts from the Bulletin of the Forest Experiment Station. At this Station, various researches are being carried on in Sylviculture, Forest Taxation, Forest Technology, Botany, Bacteriology, Entomology, Physics and Chemistry, and what is here published is the result of investigations made between the course of 1905–1914.

Care has been taken to select either articles of general interests to the public or those of special value to the practical forester; it is further hoped to publish similar works from time to time as the opportunity offers.

Bureau of Forestry.

Tokyo, Japan,
July, 1915.

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INVESTIGATION OF TREE SEEDS IN RELATION TO THE PRODUCING DISTRICTS OF THE MOTHER TREES AND THEIR DESCENT

By Dr. HOMI SHIRASAWA, Forest Expert

What influence has the descent of the mother tree upon the seeds? was a question which was proposed by late Prof. Mayr of Munich University at the occasion of third International General Meeting of the Forest Experiment Stations' Union held at Bern, 1900. The question so interesting to the industry was subsequently taken up by the conference to be fully investigated, and experiments were undertaken by different Forest Experiment Stations in Austria, Switzerland, Prussia, Bavaria and Belgium. The Stations in Austria and Switzerland already published their results in treating the growth of seedlings fully and accurately. The work of our Institute was naturally limited to the investigation of japanese seeds, extending over a period of 10 years from 1902 and gave remarkable results, a resume of which is now published in the general interest of the country.

I. Origin of Seeds Used

The tree species used in the experiment were Sugi *(Cryptomeria japonica)*, Akamatsu *(Pinus densiflora)* and Kuromatsu *(Pinus Thunbergii)*, distinguished by the locality of the mother tree and age.

The latitude and mean annual temperature shown in the following table were furnished by the adjacent Meteorological Stations.

LOCALITIES FROM WHICH SUGI SEEDS WERE OBTAINED

Locality	Latitude	Mean annual temperature, C°	Altitude above sea-level, M	Soil	Age of mother trees	Meteorological Station
Akita	39°41′	10.3	290		Old (70 Yrs.) Young (30 Yrs.)	Akita
Tokyo	35°41′	13.8	20	Tuffy loam, overlying soil rich in organic matter, light and soft.	Old (80 Yrs.) Young (30 Yrs.)	Tokyo
Kyoto	35°01′	13.6			Old (70 Yrs.) Young (30 Yrs.)	Kyoto
Owashi	34°31′	14.1			Old (70 Yrs.) Young (10 Yrs.)	Yagi
Kumamoto .	32°49′	15.5	300 150		Old (70 Yrs.) Young (30 Yrs.)	Kumamoto

LOCALITIES FROM WHICH AKAMATSU SEEDS WERE OBTAINED

Locality	Latitude	Mean annual temperature, C°	Altitude above sea-level, M	Soil	Age of mother trees	Meteorological Station
Miyagi	38°26′	10.8	60	Red sandy loam.	Old (100 Yrs.) Young (30 Yrs.)	Ishinomaki
Mito	36°23′	12.5	45	Black light soil, rich in organic matter.	Old (60 Yrs.) Young (10 Yrs.)	Mito
Nagano ..	36°40′	10.8	1,360	Volcanic ash.	Old (60 Yrs.) Young (10 Yrs.)	Nagano
Tokyo	35°41′	13.8	20	Tuffy loam overlying soil rich in organic matter, light and soft.	Old (100 Yrs.) Young (20 Yrs.)	Tokyo
Kochi	33°33′	15.7	55		Old (70 Yrs.) Young (30 Yrs.)	Kochi

LOCALITIES FROM WHICH KUROMATSU SEEDS WERE OBTAINED

Locality	Latitude	Mean annual temperature, C°	Altitude above sea-level, M	Soil	Age of mother trees	Meteorological Station
Akita	39°41′	10.3	25	Sandy	Old (80 Yrs.) Young (20 Yrs.)	Akita
Mito	36°23′	12.5	45		Old (80 Yrs.) Young (10 Yrs.)	Mito
Kochi	33°33′	15.7	55		Old (70 Yrs.) Young (30 Yrs.)	Kochi

II. Phisical Properties of the Seeds

The physical properties of the seeds so collected from the mother trees of different localities were as follows:—

AKAMATSU (*Pinus densiflora*)

Locality of production	Age of mother trees	Weight of 1 litre in gr.	No. of seeds in 1 litre	Size (mm)					Color	Remarks
					Large	Medium	Small	Average		
Miyagi	Old	—	—	Length	—	—	—	—	—	
				Breadth	—	—	—	—		
	Young	—	—	Length	—	—	—	—	—	
				Breadth	—	—	—	—		
Mito	Old	524.9	72,176	Length	5.7	5.0	3.5	—	Dark brown.	Grains comparatively small, not even.
				Breadth	2.6	2.5	2.0	—		
	Young	514.4	57,403	Length	6.0	5.1	4.4	—	Dark brown.	
				Breadth	2.7	2.5	2.3	—		
Nagano ..	Old	513.5	55,901	Length	6.0	5.0	4.4	—	Greyish brown.	
				Breadth	2.9	2.7	2.4	—		
	Young	513.5	43,902	Length	6.3	5.5	4.7	—	do.	
				Breadth	3.0	2.7	2.5	—		
Tokyo	Old	—	—	Length	5.1	5.0	4.0	—	do.	
				Breadth	2.7	2.5	2.4	—		
	Young	—	—	Length	6.4	5.2	4.8	—	Dark brown.	
				Breadth	3.2	2.8	2.6	—		
Kochi	Old	498.9	54,437	Length	6.1	5.5	4.5	—	Greyish brown.	
				Breadth	3.3	3.0	2.5	—		
	Young	—	—	Length	—	—	—	—	—	
				Breadth	—	—	—	—		

Seeds from young mother trees are always large in size.

KUROMATSU (*Pinus Thunbergii*)

Locality of production	Age of mother trees	Weight of 1 litre in gr.	No. of seed in 1 litre	Size (mm)					Color	Remarks
					Large	Medium	Small	Average		
Akita	Old	523.9	36,441	Length	6.5	5.9	5.2	5.9	Dark brown.	Both seeds from "old" and "young" are irregular in size, generally however plump.
				Breadth	3.5	3.3	2.6	3.0		
	Young	501.7	33,261	Length	7.0	6.3	5.2	6.2	Light dark brown.	
				Breadth	3.5	3.4	2.6	3.2		
Mito	Old	537.7	41,632	Length	6.5	5.5	4.3	5.4	Dark brown.	
				Breadth	3.4	3.0	2.6	3.0		
	Young	529.4	40,689	Length	6.5	5.5	4.6	5.5	Light dark brown.	Uniformly well sized grains.
				Breadth	3.4	3.0	2.5	3.0		
Kochi	Old	540.5	39,968	Length	6.4	5.3	4.6	5.4	Dark brown.	Indistinct in shape, small sized seeds generally.
				Breadth	3.4	3.1	2.6	3.0		
	Young	462.9	37,696	Length	6.4	5.4	4.9	5.6	Light dark brown.	Large grains mostly.
				Breadth	3.4	3.0	2.6	3.0		

Seeds from young mother trees are generally large and light in color.

SUGI (*Cryptomeria japonica*)

Locality of production	Age of mother trees	Weight of 1 litre in gr.	No. of seeds in 1 litre	Size (mm)					Color	Remarks
				Large		Medium	Small	Average		
Akita	Old	374.1	89,694	Length	6.2	5.9	5.2	5.8	Reddish brown, no lustre.	
				Breadth	3.2	2.6	2.5	2.8		
	Young	363.1	77,554	Length	6.5	6.0	5.5	6.0	do.	Uniform sized grains.
				Breadth	3.1	2.6	2.4	2.7		
Tokyo	Old	410.2	78,496	Length	7.0	6.4	5.1	6.2	Reddish brown with darktint, lustrous.	do.
				Breadth	3.1	2.7	2.5	2.8		
	Young	335.4	76,722	Length	7.2	6.5	5.0	6.2	Some as preceding but somewhat lighter in color.	
				Breadth	3.1	2.7	2.5	2.8		
Kyoto	Old	332.6	99,229	Length	6.9	6.1	4.5	5.8	Reddish brown with dark tint. Very lustrous.	do.
				Breadth	3.0	2.9	2.2	2.7		
	Young	332.6	82,044	Length	7.0	6.5	4.5	6.0	do.	
				Breadth	3.2	2.5	2.3	2.6		
Owashi....	Old	377.0	82,432	Length	7.5	6.5	5.5	5.5	do.	do.
				Breadth	3.7	2.8	2.5	3.0		
	Young	335.4	75,669	Length	7.5	6.6	5.5	6.5	do.	
				Breadth	3.7	3.5	2.6	3.1		
Kumamoto.	Old	342.0	113,087	Length	6.5	5.9	4.3	5.6	do.	Size unequal.
				Breadth	3.1	2.4	2.1	2.5		
	Young	332.6	94,683	Length	6.5	6.0	4.4	5.6	do.	
				Breadth	3.2	2.6	2.3	2.7		

Seeds from young mother trees in all localities are large. No distinction is observable with regard to locality.

The above table shows that seeds obtained from young mother trees were larger than those from old ones, regardless of locality. They had also well developed germs for every species.

III. The Growth of Seedlings in the First and Second Years

The seeds of different tree species referred to in the preceding article were sown in a bed, carefully ploughed, harrowed, at the rate of 0.11 litre per 1.6 sq. metre in the April of 1903. The bed was properly compacted and the necessary weeding and tending were done in due course. The seedlings so grown were measured toward the end of November with the following results:—

THE GROWTH OF SEEDLINGS IN THE FIRST YEAR

Species	Locality of mother trees	Age of mother trees	Days required for germination	Seedlings germinated	Growth (cm)			Remarks
					H't	Extension of the crown	Length of the principal root	
AKAMATSU (*Pinus densiflora*)	Miyagi..	Old	28	920	9.7	12.7	15.2	Shortage in germinated seedling was caused by the damage done by birds.
		Young	„	1,878	12.4	15.2	18.2	
	Mito	Old	„	3,115	9.1	10.9	21.2	Better growth of root observable in plants from seeds of young trees.
		Young	„	1,240	9.1	14.5	21.2	
	Nagano..	Old	24	2,922	11.5	10.0	18.2	
		Young	„	3,565	12.1	12.7	19.7	
	Tokyo ..	Old	40	1,675	12.7	11.5	19.7	
		Young	„	2,237	14.9	6.1	18.2	
	Kochi ..	Old	26	1,200	8.5	10.6	19.1	
		Young	„	1,070	9.4	12.4	19.7	
KUROMATSU (*Pinus Thunbergii*)	Akita ..	Old	26	1,840	9.4	9.4	19.7	do.
		Young	„	1,439	10.9	12.4	17.6	
	Mito	Old	37	792	6.1	13.0	16.7	Shortage of seedlings germinated due to damage done by birds. Roots of the "Young" showed fair development.
		Young	„	340	7.6	11.8	12.7	
	Kochi ..	Old	35	1,422	10.0	13.0	15.2	Root development in the "Young" is somewhat better.
		Young	„	1,077	11.5	13.3	20.0	
SUGI (*Cryptomeria japonica*)	Akita ..	Old	35	555	7.9	13.0	13.9	Roots of "Young" and "Old" showed no remarkable difference except "Young" ones had somewhat longer roots.
		Young	„	725	9.1	15.8	18.2	
	Tokyo ..	Old	42	3,800	10.9	13.6	16.7	
		Young	„	1,770	12.1	14.2	18.2	
	Kyoto ..	Old	35	260	7.6	13.9	13.6	
		Young	„	580	10.9	11.2	19.1	
	Owashi..	Old	32	1,092	9.1	10.7	16.4	
		Young	„	1,820	9.7	16.4	10.6	
	Kumamoto..	Old	37	730	9.1	9.1	11.8	
		Young	„	951	10.0	13.0	12.1	

In April of the following year, 1904, well grown sample seedlings were taken from every plot; they were transplanted at the rate of 12 cm sq. for a seedling, 6.6 sq. metres being allotted to each species. The growth of these seedlings at the end of the year is shown in the following table:—

GROWTH OF TRANSPLANTED SEEDLINGS IN THE SECOND YEAR

Species	Locality	Age of mother trees	H't of seedlings (cm)	Diameter (mm)	Average of old and young: H't (cm)	Average of old and young: Dia-meter (mm)	Remarks
AKAMATSU (*Pinus densiflora*)	Miyagi	Old	17.6	8.5	19.4	8.5	No autumnal buds appeared; appearance of buds in spring later than at Nagano.
		Young	21.2	8.5			
	Mito	Old	18.8	7.3	20.0	8.2	Autumnal buds appeared but little; spring buds came out after those at Miyagi; leaves rich in color. The "Young" produced more autumnal buds than the "Old."
		Young	21.2	9.1			
	Nagano	Old	13.6	7.3	13.9	7.3	No autumnal buds appeared; spring buds appeared ealier than in other places.
		Young	14.2	7.3			
	Tokyo	Old	20.6	7.9	20.9	8.2	Autumnal buds as well as spring ones appeared about the time of those of Mito.
		Young	21.2	8.5			
	Kochi	Old	22.7	9.0	26.5	7.4	Both "Old" and "Young" gave many autumnal buds; those of "young" 8.2 cm; the "old" 7.9 cm long. From late summer up to spring leaves turned somewhat yellow.
		Young	30.3	9.7			
KUROMATSU (*Pinus Thunbergii*)	Akita	Old	17.3	8.5	17.7	8.6	No autumnal buds appeared; leaves dark greyish green; spring buds appeared earliest.
		Young	18.1	8.8			
	Mito	Old	19.7	7.3	21.2	7.9	Only few autumnal buds appeared, spring buds came out next to those at Akita; leaves of lighter color.
		Young	22.7	8.5			
	Kochi	Old	21.2	8.5	23.9	8.3	Like Akamatsu, many autumnal buds appeared; which attained length of 9 cm with "Young" and 6 cm with "Old"; leaves yellowish green. Spring buds appeared latest of group. In "Old" buds still later than the "Young."
		Young	26.1	8.2			
SUGI (*Cryptomeria japonica*)	Akita	Old	28.8	5.8	29.5	5.9	
		Young	30.3	6.1			
	Tokyo	Old	39.4	6.7	38.6	6.8	Roots well developed next to those at Kumamoto. Growth of seedlings uniform. Roots of the "Young" showed better growth.
		Young	37.9	7.0			
	Kyoto	Old	47.0	6.7	49.2	6.8	do.
		Young	51.5	7.0			
	Owashi	Old	56.1	7.3	58.3	7.1	Growth of roots exceedingly good. The end of new branches suffered by frost. Roots of the "young" far better developed.
		Young	60.6	7.0			
	Kumamoto	Old	51.5	7.0	53.8	7.1	Roots developed fairly, next to the preceding in this respect; in other respects the same.
		Young	56.1	7.3			

The growth of seedlings above stated in the first and second years may be described as follows:—

(1) In the first year seedlings obtained from young mother trees showed better growth than those from old ones. As it was impossible to get the same number of seedlings on areas of the same size we could

not make the desired accurate comparison of their growth with regard to species and locality of mother trees.

(2) As shown in the above table, second year seedlings from young mother trees showed a better growth than those from old trees. With regard to locality, seeds obtained from warmer sections gave better growth than those from colder sections. Thus, Akamatsu seeds from Kochi took the lead, followed by those from Tokyo, Mito and Miyagi while seeds from Nagano, in the highest altitude, was most inferior. In the case of Kuromatsu, too seeds from Kochi showed the best result, followed by those from Mito while those from Akita, in the north, came last. Sugi seedlings likewise from seeds collected in Owashi grew best. Those from the seeds collected in Kyoto and Kumamoto came next and followed by those from seeds produced in Tokyo and Mito. Those obtained from seeds produced in Akita showed the poorest growth. Taking the temperature of Tokyo as the standard, the farther south the seeds come from is better the growth while the farther north they come from is the worse the growth.

(3) When seedlings put out the earliest spring buds? In the case of Akamatsu, seedlings from Nagano put out buds first every spring, followed by those from Miyagi, Tokyo and Mito in order of time, with those from Kochi coming last. As for Kuromatsu, seedlings from Akita were foremost, followed by those from Mito and Kochi in order but the seedlings from Kochi gave better in autumn than the others.

IV. The Growth of Seedlings in General

In the spring of the third year after sowing in April, 1905, well grown seedlings distinguished according to species, locality, age of mother tree, etc., were chosen to be used as typical specimens and were transplanted in the Station's ground. During eight successive years that have passed since then, these plants were properly cared for and the mode of inflorescence, fructification, etc., registered. The results may be summarised as follows:—

Reference to the above table will lead the following conclusions as to Akamatsu and Kuromatsu:—

(1) Growth of the Stem.

Seedlings obtained from the seeds of colder localities are in their early stages slower in growth; later, however, such a similarity disappears and seedlings from seeds of cold and warm sections become alike in development.

(2) Number of Trees bearing Flowers.

There is no distinction with regard to number of flowers borne according to localities from which seeds are obtained. Young mother trees, however, give rise to more seedlings that bear flowers, and this is especially remarkable in the case of Sugi.

In general, the result of the experiment on these species, Akamatsu and Kuromatsu, did not give such a marked distinction as was expected, and this may be attributed to the fact that their growth was not in normal state.

Sugi, however, unlike the other two conifers, showed distinctions which may be summed up as follows:—

1. RELATION BETWEEN AGE OF MOTHER TREES AND SUGI SAPLINGS OBTAINED THEREFROM.

In the case of seedlings that have been transplanted several years in the forest, no such marked distinction is observable as existed in the younger days between those from young and those from old mother trees. In Tokyo, saplings originating in young trees showed a somewhat better growth than those from old trees while in Owashi this superiority was very clearly marked.

2. GROWTH OF SAPLINGS FROM SEEDS OF DIFFERENT LOCALITIES COMPARED.

In proportion to the differences of the climates of the producing districts saplings keep the distinctions shown in their seedling days and these become still more striking with the advance of years so that no uniformity is arrived at. Especially in colder districts such as Akita, the growth is every slow and it cannot be said how long such slowness in growth will continue.

GROWTH AND INFLORESCENCE OF AKAMATSU, KUROMATSU AND SUGI

Mother trees			1907						1908						1909						1910						1911						1212						
				Number of flowered seedlings						Number of flowered seedlings						Number of flowered seedlings						Number of flowered seedlings						Number of flowered seedlings						Number of flowered seedlings					
Locality	Age.	No. of seedlings tried	Total h't., m	Female flower	Male flower	Both male and female flower	Total	Per cent	Total h't., m	Female flower	Male flower	Both male and female flower	Total	Per cent	Total h't., m	Female flower	Male flower	Both male and female flower	Total	Per cent	Total h't., m	Female flower	Male flower	Both male and female flower	Total	Per cent	Total h't., m	Female flower	Male flower	Both male and female flower	Total	Per cent	Total h't., m	Female flower	Male flower	Both male and female flower	Total	Per cent	Total average
AKAMATSU (*Pinus densiflora*)																																							
Kochi....	Old	27	1.4	20	—	—	20	74	1.6	27	—	—	27	100	1.9	27	—	—	27	100	2.3	19	—	—	19	70	2.5	19	—	—	19	70	—	19	—	—	19	70	81
	Young	28	1.5	—	—	—	—	—	1.9	27	—	—	27	96	1.9	2	—	—	2	7	2.4	—	—	—	—	—	2.7	2	—	—	2	7	—	5	—	—	5	18	21
Mito	Old	28	1.4	4	—	—	4	14	1.6	11	—	—	11	39	1.9	24	—	—	24	86	2.5	1	—	—	1	4	2.8	3	—	—	3	11	—	4	—	—	4	14	28
	Young	29	1.0	7	—	—	7	24	1.5	17	—	—	17	59	2.1	28	—	—	28	97	2.5	1	—	—	1	3	2.8	9	—	—	9	31	—	14	—	—	14	48	44
Tokyo ..	Old	31	1.0	23	—	—	23	74	1.5	28	—	—	28	90	2.0	30	—	—	30	97	2.5	13	—	—	13	42	2.8	17	—	—	7	55	—	21	—	—	21	69	71
	Young	32	1.0	7	—	—	7	22	1.4	12	—	—	12	38	1.9	22	—	—	22	69	2.5	3	—	—	3	9	—	4	—	—	4	13	—	4	—	—	4	13	28
Miyagi ..	Old	33	1.0	4	—	—	4	12	1.4	9	—	—	9	27	1.9	13	—	—	13	39	2.4	3	—	—	3	9	—	2	—	—	2	6	—	3	—	—	3	9	17
	Young	33	1.1	30	—	—	30	91	1.6	33	—	—	33	100	2.0	33	—	—	33	100	2.5	24	—	—	24	73	—	24	—	—	24	73	—	26	—	—	26	79	86
Nagano..	Old	29	0.8	7	—	—	7	24	1.3	17	—	—	17	59	1.7	21	—	—	21	72	2.2	4	—	—	4	14	—	4	—	—	4	14	—	4	—	—	4	14	32
	Young	30	1.0	18	—	—	18	60	1.4	22	—	—	22	73	1.7	30	—	—	30	100	2.4	14	—	—	14	47	—	12	—	—	12	40	—	11	—	—	11	37	59
KUROMATSU (*Pinus Thunbergii*)																																							
Kochi....	Old	33	0.8	—	—	—	—	—	1.2	—	—	—	—	—	1.7	—	—	—	—	—	2.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Young	35	1.0	—	—	—	—	—	1.4	—	—	—	—	—	1.9	—	—	—	—	—	2.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Mito	Old	35	0.9	—	—	—	—	—	1.4	—	—	—	—	—	1.8	25	—	—	25	71	2.3	2	—	—	2	6	—	5	—	—	5	14	—	5	—	—	5	14	16
	Young	36	0.9	2	—	—	2	6	1.3	—	—	—	—	—	1.7	18	—	—	18	50	2.5	1	—	—	1	3	—	1	—	—	1	3	—	9	—	—	9	25	15
Akita....	Old	37	—	—	—	—	—	—	—	—	—	—	—	—	—	16	—	—	16	43	—	1	—	—	1	3	—	4	—	—	4	11	—	4	—	—	4	11	11
	Young	37	—	3	—	—	3	8	—	—	—	—	—	—	—	22	—	—	22	59	—	5	—	—	5	14	—	8	—	—	8	22	—	11	—	—	11	30	21
SUGI (*Cryptomeria japonica*)																																							
Owashi..	Old	19	—	8	1	1	10	53	—	2	1	16	19	100	—	—	2	16	18	95	—	7	1	7	15	79	—	—	1	17	18	95	—	1	0	17	18	95	86
	Young	19	—	9	—	—	9	47	—	3	1	14	18	95	—	2	2	14	18	95	—	4	2	8	14	74	—	3	2	14	19	100	—	5	1	13	19	100	85
Kumamoto..	Old	21	—	8	—	1	9	43	—	7	1	6	14	67	—	7	1	4	12	57	—	7	1	3	7	33	—	9	0	2	11	52	—	10	—	2	12	57	52
	Young	22	—	9	1	6	16	73	—	7	1	12	20	91	—	9	1	10	20	91	—	10	1	—	11	50	—	7	2	10	19	86	—	12	—	7	19	86	79
Kyoto ..	Old	23	—	5	—	4	9	39	—	5	—	6	11	48	—	6	—	4	10	43	—	5	1	—	6	26	—	4	1	2	7	30	—	5	1	2	8	35	37
	Young	24	—	14	—	2	16	67	—	8	1	8	17	71	—	4	—	5	9	38	—	3	2	1	6	25	—	6	1	5	12	50	—	8	1	4	13	50	51
Akita....	Old	20	—	1	—	—	1	5	—	1	—	—	1	5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
	Young	23	—	—	8	—	—	—	—	1	—	—	1	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Tokyo ..	Old	20	—	7	—	—	7	35	—	10	—	1	11	55	—	4	—	1	5	25	—	2	—	—	2	10	—	9	1	1	11	55	—	7	—	—	7	35	63
	Young	20	—	8	—	—	8	40	—	9	3	3	15	75	—	10	2	1	13	63	—	1	—	—	1	5	—	8	1	2	11	55	—	8	1	1	10	59	48
	Youngest (6 Yrs.)	20	—	14	—	—	14	70	—	7	—	12	19	95	—	8	1	11	20	100	—	12	—	1	13	63	—	6	—	13	19	95	—	14	1	5	20	100	87

3. AGE OF MOTHER TREES IN RELATION TO INFLORESCENCE AND FRUCTIFICATION OF SAPLINGS

(1) More saplings bearing flowers originate from young mother trees than from old mother trees, regardless of locality.

(2) This difference is more conspicuous when saplings from the seeds of a certain locality are grown in the same or another locality of similar climate.

(3) Regardless of the age of the mother trees, when saplings, originating in a warmer place, planted in a colder locality they bear more inflorescence at an earlier age. On the contrary, when saplings originating in a relatively colder climate, grown in a warmer district they have very little inflorescence.

(4) Saplings originated in localities of similar climate show slightest difference in growth and inflorescence when replanted another place.

The inflorescence and fructification of saplings are influenced by the locality of the mother trees and their ages as already explained in a previous chapter. This inflorescence and fructification of a tree must also be affected by the locality, nature of soil and method of tending. Further experiments were made on the subject with regard to the following points.

1. TRAINING OF SEEDLINGS IN RELATION TO INFLORESCENCE AND FRUCTIFICATION.

That the inflorescence and fructification of a plant can be forced is well known to horticulturists in relation to garden plants. Such forcing has, however, never known to have been tried on tree seedlings grown in the nursery until we carried out experiments during the years 1905 and 1907.

Method of the trial:—Several lots of equally grown two feet Sugi seedlings, such as are generally able for transplantation, were put in nursery beds in similar surroundings. The seedlings of each lot were cut at their root ends at various intervals respectively, by means of a scooper-scythe, as follows:—

Once cutting: 15th, May.
Twice cuttings: 15th, May; 15th, June.
Thrice cuttings: 15th, May; 15th, June; 15th, July.
Four times cuttings: 15th, May; 15th, June; 15th, July; 15th, Sept.

The seedlings so cut at their root ends at various intervals were left to grow in the same place. The cuttings again were made on the same date, the next year, and the inflorescence were fully studied. The results were as follows, the number of seedlings for each lot was taken as 100:—

No. of root cuttings	1905		1906		Remarks
	No. of seedlings that bore flowers	No. of flowers borne	No. of seedlings that bore flowers	No. of flowers borne	
Seedlings left uncut..	—	—	7	301	More female flowers than male were borne.
Once cutting	6	149	54	3,134	
Twice cuttings	28	514	71	2,904	
Thrice cuttings	59	1,904	80	2,746	
Fourtimes cuttings ..	84	3,389	45	1,810	

From the above statement, one notes that the inflorescence of Sugi seedlings depends upon the growth of roots and subsequently the nutrition. For example, in rich soil with ample water supply, where roots grow freely, the seedlings use most of the nutriment assimilated for the construction of leaves and stems, and make a luxuriant growth of crowns. On the contary, where nutrition is scanty with but a poor supply of water, the roots develope but poorly and most of the nutrition is used forming flowers and fruits, the plant itself being but poorly developed.

When seedlings that once bore numerous flowers are planted in other places, they continue to bear numerous flowers for several years in the replanted place.

2. SURROUNDINGS AND INFLORESCENCE.

With the view of studying the effect of the surroundings and soil upon flower bearing, experiments were made at our Station on various plots.

(1) Sunny Plot.

Land flat; surface soil 0.7 m about; sub-soil underneath.

Surroundings: The plot is open on the south and east. On the west and north, Shirakashi *(Quercus myrsinaefolia)* and Sugi trees grow and make a wood at the distance of some 15 m. The plot is exposed to sunshine all the year round.

(2) Shady plot.

Land even with surface soil measuring 0.6 m.

Surroundings: The plot is open on the east and north. On the south, big Keyaki *(Zelkowa acuminata)* and Shirakashi, 14 m high, are found at a distance of 7 m; on the west, Shirakashi and norway spruce *(Picea excelsa)* make a perfect screen so that excepting in summer no direct sunshine falls on the place.

(3) Wet Plot.

Land sloping to east; surface soil 0.6 m deep; subterranean water at a depth of 1 m causing dampness throughout the year.

Surroundings: The place is open in every direction exposed to full sunshine all the day long.

(4) Dry Plot.

Land sloping somewhat to the north. Subdivided into three plots:—

No. 1. Previous to this trial, the place was used as a field, with the soil 0.5 m deep.

No. 2. The same as No. 1, except that the soil was enriched with humus to a depth of 0.6 m.

No. 3. The surface soil was entirely removed leaving only the subsoil beneath.

Surroundings: Open in every direction and exposed to sunshine throughout the year and all day long.

In April, 1905, well grown Sugi seedlings were planted 1.5 m apart on the spots above mentioned. Except weeding the trees were left to grow naturally. The growth was as follows:—

Those marked *manured* were given night soil in the spring of 1906 and 1907; *not manured* received no manure.

GROWTH OF SUGI SAPLINGS (OLD AND YOUNG MOTHER TREES) AND NUMBER OF TREES THAT BORE FLOWERS

Years on which researches were done	OLD MOTHER TREES														YOUNG MOTHER TREES													
	Manured							Unmanured							Manured							Unmanured						
		Number of flowered seedlings							Number of flowered seedlings							Number of flowered seedlings							Number of flowered seedlings					
	No. of trees tested	Female flower	Male flower	Both male and female flower	Total	Per cent	Average h't., m	No. of trees tested	Female flower	Male flower	Both male and female flower	Total	Per cent	Average h't., m	No. of trees tested	Female flower	Male flower	Both male and female flower	Total	Per cent	Average h't., m	No. of trees tested	Female flower	Male flower	Both male and female flower	Total	Per cent	Average h't., m
(1) Sunny Plot																												
1907	18	2	1	—	3	17	0.70	36	4	—	—	4	11	0.55	18	1	1	5	7	39	0.79	36	1	3	3	7	19	0.64
1908	18	5	1	10	16	89	1.76	36	20	1	12	33	92	1.03	18	4	2	11	17	94	1.88	36	7	4	17	28	87	1.21
1909	18	—	—	18	18	100	2.58	36	8	—	27	35	97	1.42	18	1	2	15	18	100	2.58	36	7	2	27	36	100	1.79
1910	18	10	—	4	14	78	3.00	36	23	—	9	32	89	1.97	18	9	1	6	16	89	3.06	36	13	3	18	34	94	2.39
1911	18	7	—	11	18	100	3.45	36	7	—	29	36	100	2.58	18	—	1	17	18	100	3.58	36	2	3	31	36	100	3.03
1912	18	10	1	5	16	86	4.00	36	10	—	21	34	94	3.55	18	3	2	13	18	100	4.15	36	9	5	19	33	91	3.79
Average	—	—	—	—	—	76	—	—	—	3	—	—	81	—	18	—	—	—	—	87	—	—	—	—	—	—	80	—
(2) Shady Plot																												
1907	14	2	—	—	2	14	0.82	28	3	—	1	4	14	0.58	14	2	2	—	4	29	0.85	28	4	—	2	6	21	0.67
1908	14	6	—	5	11	79	1.73	28	7	7	2	16	57	1.27	14	5	3	5	13	93	1.85	28	7	7	8	22	79	1.48
1909	14	3	—	10	13	93	2.36	28	10	—	17	27	96	1.73	14	1	2	11	14	100	2.48	28	—	2	26	28	100	1.82
1910	11	6	1	3	10	91	2.79	28	20	—	5	25	89	2.18	14	8	2	2	12	86	2.91	28	16	2	9	27	96	2.55
1611	11	2	—	8	10	91	3.61	28	8	1	19	28	100	2.85	14	1	2	11	14	100	3.58	28	3	3	22	28	100	3.15
1912	11	7	—	5	10	91	4.27	28	20	—	8	28	100	3.48	14	5	2	6	13	93	4.24	28	13	0	14	27	96	3.76
Average	—	—	—	—	—	77	—	—	—	—	—	—	76	—	—	—	—	—	—	84	—	—	—	—	—	—	82	—
(3) Wet Plot																												
1907	18	—	3	2	5	28	0.76	52	2	2	2	6	12	0.70	18	—	—	1	1	6	0.94	49	4	3	1	8	16	0.79
1908	18	2	1	11	14	78	1.79	52	9	3	15	37	71	1.64	18	2	2	11	15	83	2.12	49	11	4	25	40	87	1.94
1909	18	1	1	16	18	100	2.61	52	7	1	43	51	98	2.32	18	1	3	13	17	64	3.03	49	1	11	34	46	94	2.51
1910	18	5	1	10	16	89	3.21	52	28	6	13	47	90	3.00	18	6	1	9	11	89	3.88	49	15	8	24	47	96	3.09
1911	18	—	—	18	18	100	3.67	52	8	—	42	50	96	3.45	18	0	1	18	18	100	4.36	49	—	3	45	48	98	3.70
1912	18	10	—	17	17	96	4.38	52	26	11	9	46	89	4.18	18	8	—	9	17	94	4.94	49	17	2	24	43	90	4.36
Average	—	—	—	—	—	82	—	—	—	—	—	—	76	—	—	—	—	—	—	78	—	—	—	—	—	—	80	—

(4) DRY PLOT

Years on which researches were done	No. 1 PLOT. (Field soil) No. of trees tested	Number of flowered seedlings: Female flower	Male flower	Both male and female flower	Total	Per cent	Average h't., m	No. 3 PLOT (Yellow clayish soil) No. of trees tested	Number of flowered seedlings: Female flower	Male flower	Both male and female flower	Total	Per cent	Average h't., m	No. 2 PLOT (Rich soil) No. of trees tested	Number of flowered seedlings: Female flower	Male flower	Both male and female flower	Total	Per cent	Average h't., m
Old Mother Trees																					
1907	24	5	—	3	8	33	0.55	12	—	1	3	4	33	0.55	12	—	—	2	2	17	0.76
1908	24	8	1	4	13	45	1.00	12	2	1	4	7	58	1.24	12	2	2	5	9	75	1.76
1909	24	7	—	16	23	96	1.21	12	3	—	8	11	92	1.67	12	—	1	10	11	92	2.24
1910	24	10	1	5	16	67	1.48	12	4	—	5	9	75	1.97	12	6	1	4	11	92	2.91
1911	24	5	2	16	23	96	1.79	12	1	—	10	11	92	2.42	12	—	—	12	11	100	3.42
1912	24	15	—	4	19	78	2.30	12	4	2	6	12	100	3.09	12	7	—	4	11	92	4.09
Average	24	—	—	—	—	17	—	—	—	—	—	—	75	—	—	—	—	—	—	78	—
Young Mother Trees																					
1907	24	5	3	—	8	33	0.55	12	3	—	—	3	25	0.55	12	1	3	—	4	33	0.82
1908	24	6	4	6	16	67	1.18	12	2	1	4	7	58	1.12	12	2	1	8	11	92	1.82
1909	24	6	2	15	23	96	1.58	12	1	2	9	12	100	1.42	12	—	—	12	12	100	2.30
1910	24	12	1	3	16	67	1.91	12	6	1	2	9	75	1.61	12	5	2	3	10	83	2.97
1911	24	2	4	17	23	96	2.21	12	1	1	9	11	92	1.85	12	—	—	12	12	100	3.45
1912	24	13	4	5	22	92	2.67	12	4	1	6	11	92	2.15	12	3	1	7	11	92	4.36
Average	—	—	—	—	—	75	—	—	—	—	—	—	74	—	—	—	—	—	—	83	—

Considering the average of the 6 years we came to the following conclusions.

(1) The number of flowered saplings are almost the same for different plots, regardless of position, surroundings and the nature of soil.

(2) The number of the flowered saplings, as in the previous experiment made with regard to locality, are influenced by the age of the mother trees and is always greater for younger mother trees.

(3) The saplings, although dependent upon the soil on which they planted, showed always far better growth when they originated in young mother trees.

In general, better grown saplings give more flowers. In other words, number of flowered saplings perfectly show likewise vigorous life.

V. Conclusion

The following conclusions may be drawn from the statements on the previous pages:—

(1) Seeds obtained from a young mother tree are large and seedlings grown from such seeds show a better growth.

(2) Seedlings from the seeds produced in localities warmer than that of the nursery, will give a better growth over than those obtained from colder districts, so that it is always advisable to bring seeds from warmer places. If there is fear on frost, care should be taken to protect well against it, since the seeds from warmer localities continue their vegetation later in the fall, so that new buds coming late may suffer from an early frost and perish in winter.

(3) Forest trees grown from seedlings originating in warmer districts than the nursery bear many flowers and fruits already in their early years; trees grown from the seeds of a climate colder than that of the nursery bear few flowers and fruits and are very slow in growth.

As to the influence of the age of the mother tree, old trees give rise to a smaller number of flowering and fruits bearing saplings and those of slower growth. This is particularly true in the case of Sugi; but in case of Akamatsu and Kuromatsu, the difference is hardly recognisable.

For the reasons above stated, the best tree seeds should be taken from a young mother tree grown in a locality resembling in climate of the place where the seeds are to be sown.

In the preceding pages the term "Young tree" is taken to signify the tree from 20 to 30 years old.

EXPERIMENTS ON THE PRESERVATION OF PRINCIPAL FOREST TREE SEEDS

By Dr. HOMI SHIRASAWA, Forest Expert and MITSUO KOYAMA, Assistant Forest Expert

Few forest trees produce seeds every year, most of them producing every other year. The harvest of seeds and the interval between seed bearing years vary with the tree species while the climatic condition of the year and particularly the temperature, moisture and wind at the time of inflorescene and fructification greatly affect the harvest of tree seeds.

Of the six principal trees in this country that are used in replantation, Akamatsu *(Pinus densiflora)* and Kuromatsu *(Pinus Thunbergii)* only produce seeds every year; Sugi *(Cryptomeria japonica)*, Hinoki *(Chamæcyparis obtusa)* and Kusu *(Cinnamomum Camphora)*, generally every other year while Karamatsu *(Larix leptolepis)* produces only once in every 4 to 7 years, and the other year they bear no seed at all or only those of a less vigorous nature. The germinating power of seeds varies with the tree species. Thus, the seeds of Akamatsu and Kuromatsu keep their germinating power for 2 or 3 years while those of Sugi, Hinoki, Karamatsu and Kusu can not retain this power even for one year losing it in the summer of the next year.

In view of this fact, it is only natural to suppose that the price of seeds rises enormously in the year of a poor crop. Consequently seeds of poor quality are frequently offered in the market to meet the demand of the seeds.

The regular supply of sound seeds and strong seedlings at reasonable prices is an important factor in successfully carrying out the replantation of forest land. If these supplies can be obtained, sylvicultural works extending over a term of years can be safely undertaken. Seeds of Sugi and Hinoki are procurable everywhere as the trees are common throughout the country. Any shortage in these seeds in one locality can well be covered by drawing upon the surplus stock in others. The use of seeds may likewise be avoided by using plants obtained from cuttings or layers. It is quite otherwise with a tree such as the Karamatsu which bears seeds only once for every 4 to 7 years and the growth of which is limited to a certain locality. In bad years, hardly a single seed is obtainable. Neither can the gap be filled up by the use of cuttings nor leyers as this conifer cannot be propagated by these ways. Thus, often the intending planters of Karamatsu forests are obliged to wait for the coming of a good crop of seeds and must put of the execution of their plan for several years. This causes loss of money and often induces dishonest seedsmen to dispose of their stale stock of the seed at a high price. It is necessary therefore to investigate how to so preserve seeds that a good supply of vigorous seeds can be had at any time. This was the object of the researches described herein.

I. First Experiment

The experiments were conducted in a space of four consecutive years from March, 1906, to September, 1909. Seeds used for the purpose were harvested in 1905 being those of Sugi, Kuromatsu, Karamatsu and Kusu. They were subjected to different treatment as follows:—

A. PRESERVATION IN AN ORDINARY ROOM.

1. Air-dried seeds in cotton sacked were hung up in an ordinary airy room.

B. PRESERVATION IN A CELLAR.

2. Air-dried seeds.
3. Fire-dried seeds.
4. Fire-dried seeds kept in small bottles hermetically sealed from the air.

As may be supposed, the first mentioned method is a form of preservation of forest seeds most common in this country.

In the so-called "cellar conservation," B, seeds were kept in a cellar that was digged on the side of a slope found in the compound of the Station. It is 8 m deep sidewise and is located 5 m beneath the surface of the ground. The height of the cavity is 2 m and is deprived of light inside. It has an almost constant temperature averaging 15.5°C. the year round. According to the data observed for 1906 and 1907, the difference of the maximum and minimum temperature does not exceed 1°C. a year. The moisture inside the cellar is always at the saturating point as is shown by the frequent condensation on the glass bottle containing the seeds. On October, 1908, the cellar was enlarged to a length of 9.5 metres and was put 5.3 metres below the ground with a height of 3 metres. It was made in brick masonry of four sides and is provided with air passage. The moisture in the cellar after the alteration showed no change while the temperature rose considerably according to the season.

Fire-dried seeds were obtained by drying the ordinary air-dried seeds in the air bath at 40°C. in March, 1906.

The last mentioned seeds was obtained by the following process; a small quantity of seeds was put into a small glass bottle having a well fitting cork stopper and sealed hermetically by means of a paraffine coating. A small glass tube was inserted through the hole in the cork stopper in order to remove the air by means of an air pump. After removal of the air, the bottle was immediately sealed.

Air-dried seeds were put into bottles 13.2 cm high with a diameter of 8.3 cm; fire-dried seeds into those 7.3 cm high with a diameter of 4.4 cm. Every bottle so filled was well sealed with a paraffine coating on the stopper to prevent the passage both of air and humidity and were put in the cellar above referred to.

In the case of air-dried seeds, seeds from the same bottles were used for each trial. In the case of fire-dried seeds, out of 15 bottles originally put into the cellar, one bottle is taken out every month to supply seeds for each trial, the content of the same bottle never being used for two trials.

After three experiments tried during March, 1906, we obtained the following results expressed in percentage of seeds which germinated.

Species	Percentage of germination
Sugi *(Cryptomeria japonica)*	83
Kuromatsu *(Pinus Thunbergii)*	97
Karamatsu *(Larix leptolepis)*	68
Kusu *(Cinnamomum Camphora)*	98

The figures may be reckoned as the ordinary germination percentage of seeds and are served in comparing with those of subsequent experiment. In June, trial was made for the second time and similar trials were repeated in March, June, September and December every year for four successive years making 15 trials in all. Every species showed peculiarity in germination for every trial as is shown by the following figures.

Percentage of Germination according to Tree Species and Mode of Preservation

Species	Mode of preservation	DATE OF TRIAL														
		1906				1907				1908				1909		
		Mar.	June	Sept.	Dec.	Mar.	June	Sept.	Dec.	Mar.	June	Sept.	Dec.	Mar.	June	Sept.
SUGI (*Cryptomeria japonica*)	In an ordinary room	83	80	4	1											
	In a cellar:															
	Air-dried	83	82	77	74	66	30	5	1	3						
	Fire-dried	83	82	76	44	20										
	Kept in bottles free from air ..	83	82	70	57	13										
KARAMATSU (*Larix leptolepis*)	In an ordinary room	89	89	3												
	In a cellar:															
	Air-dried	89	86	76	77	70	68	64	61	59	41	29	13	2	3	1
	Fire-dried. ..	89	88	73	71	51	20	3	0	2						
	Kept in bottles free from air ..	89	89	74	69	51	2	5								
KUROMATSU (*Pinus Thunbergii*)	In an ordinary room.	98	98	85	83	81	81	54	46	54	48	34	32	40	29	12
	In a cellar:															
	Air-dried	98	97	98	95	96	96	98	98	93	96	97	94	95	95	94
	Fire-dried	98	98	97	96	96	91	95	70	96	78	95	41	33	94	93
	Kept in bottles free from air. ..	98	97	98	97	94	94	62	65	92	93	56	82	75	68	45
KUSU (*Cinnamomum Camphora*)	In an ordinary room.	97	12													
	In a cellar:															
	Air-dried.	97	86	76	71	42	36									
	Fire-dried	97	82	48	21											
	Kept in bottles free from air...	97	89	71	51	41	20									

The results of the trials recorded above may be recapitulated as follows:—

(1) Sugi-seeds: Sugi-seeds kept in an ordinary room already showed great fall in the germination percentage in September (the end of summer) of the next year of the collected. In December these seeds had totally lost their germinating power. Those kept in a cellar, however, retained their germinating power till March, 1907, so that they could well be used in sowing. The air-dried ones in the cellar especially showed the high germination percentage of 66 and so the mode of preservation was fully justified.

(2) Karamatsu-seeds: The changes in germinating power of Karamatsu-seeds kept in a room were quite similar to those in the case of Sugi. After the summer of 1906, more than half of the seeds had lost their germinating power.

The same seeds kept in a cellar, however, retained well their germinating power and when sown in 1907 proved most satisfactory. Later, in March, 1908, the seeds so kept were sown and germinated up to 60%. It is indeed only after a lapse of 3 full years that the germinating power began to fail.

Karamatsu-seeds fire dried and those which were kept in bottles free from air showed a considerable fall of germinating power just after June, 1907, and in March, 1908, the germination percentage was reduced to 1–2%.

(3) Kuromatsu-seeds: These seeds, unlike those of Sugi and Karamatsu, kept in an ordinary room keep germinating power until after the summer of the year subsequent to gathering. The germinating power of Kuromatsu-seeds used in our investigations retained their germinating power for the first 3 years. In September of the 4th year 12% of the seeds still germinated and probably germinating power continued for half of the ensuing year.

The persistent nature of the germinating power in Kuromatsu-seeds is still more conspicuous when they are kept in a cellar and indeed late in September of the 4th year, 93–94% of the seeds sown germinated which is not much different from the results for the fresh crop.

(4) Kusu-seeds: The fall in germinating power in Kusu-seeds is still more remarkable than in the case of Sugi. Thus, Kusu-seeds kept in

an ordinary room lose their germinating power toward the June of the following year and in September not a single seed germinated. In a cellar, excepting the fire-dried seeds, all the other seeds could be used for sowing in April of 1907, the power, however, has totally gone on September.

II. The Second Experiment

With the view of ascertaining the conditions which influence the germinating power of seeds the second experiment extended from 1909–1912.

The seeds used in the trials were those of Sugi, Hinoki and Akamatsu which were brought in the market as seeds of the year 1909 and they were immediately preserved as follows without undergoing any drying or without any special selection.

Mode of preservation		Stopper of the vessel	Remarks
In a cellar		1. Cotton. 2. Glass stoppers with paraffine coating.	Place of preservation same as explained in Experiment I.
In an ordinary room	In a dark wooden chest	3. Same as 1. 4. Same as 2.	
	Laid on a table	5. Same as 1. 6. Same as 2.	

Glass bottles 13.2 cm high, with a diameter of 8 cm at the mouth were used.

The temperature and moisture of the room where the seeds were kept are shown in the table. The moisture of the air is taken from the record furnished by the Central Meteorological Observatory, Tokyo. The temperature in the cellar which undergoes a regular variation during the course of a year showed its minimum of 11°–12°C. in January and February, with its maximum of 16°–17°C. in September-October, thence gradually falling. No variation is observable within 24 hours (only a slight fluctuation of less than 0.5°C. being sometimes noticeable) and the moisture in the cellar was always at the point of saturation.

Experiments in germination were made in general in March, July, September and December, but sometimes a month earlier or later. Trials made in three consecutive years numbering 12. In every experiment only the seeds taken from the same bottle were used and the average of three sets of 100 seeds were obtained.

Fall of germinating power of seeds, and temperature and moisture of the room are shown by the following tables:

PERCENTAGE OF GERMINATING SEED WITH REGARD TO MODE OF PRESERVATION AND TREE SPECIES

Species	Mode of preservation		1910				1911				1912			
			Mar.	June	Sept.	June	Mar.	June	Sept.	Dec.	Apr.	June	Sept.	Dec.
AKAMATSU (*Pinus densiflora*)	In an ordinary room ..	(1)	88.0	86.0	67.6	0.3	—	—	—	—	—	—	—	—
		(2)	88.0	94.7	88.7	89.3	89.7	90.3	88.4	80.0	81.7	76.0	86.7	85.7
	In a cellar:													
	In a dark wooden chest	(1)	88.0	89.7	73.0	74.0	70.0	66.0	43.0	30.0	26.7	24.7	19.3	*
		(2)	88.0	89.7	88.0	86.7	93.0	81.3	70.3	77.0	66.7	60.0	75.0	66.3
	Laid on the table ..	(1)	88.0	87.3	67.0	70.7	63.7	84.3	45.0	40.3	39.0	33.7	11.0	*
		(2)	88.0	86.6	88.7	87.0	87.7	89.6	82.0	82.0	74.3	73.7	67.5	65.7
SUGI (*Cryptomeria japonica*)	In an ordinary room ..	(1)	59.0	54.4	29.0	10.6	—	—	—	—	—	—	—	—
		(2)	59.0	59.7	57.7	49.0	44.3	41.0	26.0	12.0	2.3	4.0	2.3	1.7
	In a cellar:													
	In a dark wooden chest	(1)	59.0	50.0	1.7	—	—	—	—	—	—	—	—	—
		(2)	59.0	54.7	48.4	38.7	17.0	11.7	0.7	—	—	—	—	—
	Laid on the table ..	(1)	59.0	49.3	1.3	0.3	—	—	—	—	—	—	—	—
		(2)	59.0	56.0	54.0	30.3	26.7	15.3	2.0	1.3	—	—	—	—
HINOKI (*Chamaecyparis obtusa*)	In an ordinary room ..	(1)	35.0	28.0	21.0	4.6	—	—	—	—	—	—	—	—
		(2)	35.0	31.0	28.0	23.3	6.7	0.3	—	—	—	—	—	—
	In a cellar:													
	In a dark wooden chest	(1)	35.0	30.0	1.7	0.7	0.7	—	—	—	—	—	—	—
		(2)	35.0	32.7	10.7	1.3	—	—	—	—	—	—	—	—
	Laid on the table ..	(1)	35.0	29.0	4.3	1.0	—	—	—	—	—	—	—	—
		(2)	35.0	35.0	11.7	1.7	0.3	—	—	—	—	—	—	—

Remarks: (1) The vessel had cotton as stopper.

(2) The vessel was kept air-tight by means of a glass stoppers with paraffin coating.

* Unable to continue the trial owing to damage by rate.

TEMPERATE AND MOISTURE IN THE ROOM WHERE SEEDS WERE PRESERVED (MEAN OF THE MONTH)

Year	Temperature and Humidity	Jan.	Feb.	Mar.	Apr.	Mar.	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Remarks
1910	Air temperature, C°. Maximum	—	—	—	—	19.0	23.0	24.8	26.6	21.5	21.3	18.5	18.8	The considerable rise of the maximum temperature witnessed between Dec., 1910 and Feb., 1911, is explained by the use of a stove during the day time.
	Minimum	—	—	—	—	15.8	20.1	22.2	23.2	17.7	15.7	8.3	3.5	
	Relative humidity, %..	—	—	—	—	74.6	85.9	87.8	84.8	83.6	83.2	71.7	65.7	
1911	Air temperature, C°. Maximum	19.6	21.4	20.8	19.9	21.3	25.1	28.1	28.9	26.7	21·3	19.4	11.2	
	Minimum	2.5	4.1	6.7	11.4	13.7	18.6	23.1	23.6	2.11	14.6	10.6	3.5	
	Relative humidity, %..	65.4	62.1	70.0	68.6	73.6	84.7	83.4	82.5	82.5	76.6	71.7	66.0	
1912	Air temperature, C°. Maximum	6.6	10.3	18.6	21.9	22.5	24.3	27.5	29.9	23.9	21.5	14.3	8.8	
	Minimum	0.8	3.7	6.2	11.1	15.1	18.6	22.3	23.4	18.7	14.2	8.5	3.8	
	Relative humidity, %..	57.8	65.6	66.6	68.8	75.0	83.0	83.0	81.0	83.0	78.0	74.0	72.0	

A glance on the above table shows that the persistence of germinating power of seeds as well as the gradual fall in the percentage of germinating seeds varies considerably with the tree species and the method of preservation adopted. Thus the seeds of Akamatsu kept in a cellar in hermetically closed bottles have the same germinating power as fresh ones as late as December of the 4th year while Hinoki-seeds, whatever method of preservation be adopted, lose their germinating power almost entirely by March of the 3rd year. As to Sugi-seeds they stand midway between those of the two conifers mentioned above, the best seeds retaining geminating power to a certain extent till December of the 4th year. This conifer seeds to be used in propagation will not, however, be kept later than June of the 3rd year.

Turning next to the methods of perservation we find that seeds without regard to tree species kept in bottles with cotton stoppers in an ordinary room showed the most rapid fall of germinating power while those kept in air-tight bottles in an ordinary room came next to them. Seeds kept in air-tight bottles in a cellar kept their germinating power best. Seeds kept in bottles provided with cotton stopper in the cellar showed the highest geminating power in the case of Sugi and Hinoki but the same method proved a negative result in the case of Akamatsu-seeds. As to Sugi-and Hinoki-seeds, kept on a table exposed to the light, showed equally or better results compared with those preserved in the dark. As to Akamatsu, nothing can be said with certainty on the subject.

The two experiments show that persistency of germinating power differs considerably with the mode of preservation adopted and the surrounding conditions.

1. PERSISTENCE OF GERMINATING POWER WITH REGARD TO TEMPERATURE.

That low temperature is indispensable for the preservation of tree seeds was clearly shown by the results of the two experiments. Particularly, in the second experiment, Akamatsu-seeds kept air-tight in a cellar, where the temperature was rather low, in front of the same seeds which were kept air-tight in a room, where the temperature was relatively higher and the fluctuation likewise considerable, showed not the marked distinction in the fall of germination percentage untill March or even June of the third year after the crop. The fall of the power for the first year or year and a half after gathering is regardless of temperature but for longer periods the germinating power depends upon the mode of preservation. The great resistance of Akamatsu-seeds to changes of temperature is thus explained.

Sugi-and Hinoki-seeds, on the other hand, show a great difference even in early days. Those kept in a colder temperature showed a great advantage over those kept in a warmer temperature. One must also note that the resistance of Hinoki-seeds to changes of temperature is small as compared with other seeds. Indeed, Sugi-seeds which in an ordinary room can only keep their germinating power for one year when kept in a cellar in an air-tight condition preserve a high germination percentage even as late as the sowing season of the 3rd year.

Hinoki-seeds lose their germinating power by March of the third year after gathering, no matter what means of preservation are adopted. This shows that Hinoki-seeds are more affected by the surrounding temperature than Sugi-seeds so that perfect preservation can only be attained by providing still a temperature lower than that in cellar of a minimum of 11°C.

In proof of this, we have the following fact:—

The staff of Kochi Major Forest Reserve kept Hinoki-seeds in a subterranean cavity at Shiragayama, Kochi, where the people store silk worm eggs and where the temperature ranges between 0° to 8°C. The seeds so stored gave a high germinating percentage.

2. PERSISTENCE OF GERMINATING POWER WITH REGARD TO MOISTURE.

(1) Persistence of the germinating power with relation to the moisture contained in seeds (refer experiment I).

That the moisture contained in seeds bear a relation to the germinating power is well shown in practice. Everybody knows that wet seeds are liable to fermentation and rottening if kept for sometime. To prevent this, farmers generally expose their freshly gathered seeds in sun light from time to time or dry them by fire. The artificial drying so much advocated by scholars for agricultural seeds was not successful in our investigations on tree seeds. Excessive desiccation of seeds is of course unfavourable to germination; still the drying at 40°C. for 1 hour as practised in our experiment, can not be regarded as an excessive heat nor as an excessive length of time.

Haberland who artificially dried seeds at 50°–60°C. for 10 hours to reduce their moisture to half of that air-dried seeds, advocates strongly such a method of desiccation. Our trial in which both temperature and time were far less than those adopted by the German authority showed, however, results telling against artificial drying and led us to the conclusion that tree seeds need no drying other than ordinary air-drying and that further treatment is not only useless but harmful.

The form of drying commonly followed by farmers of putting tree seeds in the shade so avoiding direct sunshine is indeed the most suitable form of drying.

(2) Moisture of surroundings of seeds in relation to germinating Power.

(a) A preservation in a cellar.

The presence of moisture almost at the saturating point in a cellar exerted an undesirable influence on the germination of seeds as was shown in the second experiment.

The resistance to excessive humidity is greatest in the case of Hinoki-seeds. Sugi-seeds come next and Akamatsu offers the least resistance of moisture, probably on account of the construction of the seed shell which is easily attacked by micro-organisms.

(b) Preservation in an ordinary room.

The influence of the atmospheric moisture in the room, in which seeds are kept, upon the germinating power was shown in both experiments. In the first experiment, we could not, however, separate the effects of moisture from those of temperature of the room; we shall speak only of Akamatsu-seeds which were shown in the second experiment to retain their germinating power well.

Comparison of Akamatsu-seeds kept in bottles with cotton stoppers with those kept in air-tight bottles in an ordinary room shows a distinct difference in the germination percentage and in the time of change. The former were characterised by a low germination percentage and the fall in germinating power percentage was most conspicuous between June and September every year. From September up the June of the following year the fall, however, is less remarkable and is almost irregular. Seeds kept in an air-tight bottle showed no marked distinction in germination percentage throughout the year having only an occasional irregular fall. Thus, the principal cause of the fall in the germinating power in the two experiments must be the moisture contained in the air. The temperature of the interval, June to September, must be certainly the highest in the year, still such a rise does not affect the seeds so badly as does the moisture. This is made the more evident by the fact that the condition of seeds remains almost the same so long as they are kept hermetically sealed whether the bottles are kept in a cellar or in an ordinary room.

The necessity of keeping tree seeds in air-tight vessels for the preservation of germinating power was studied by Cieslar (Versuche über Aufbewahrung von Nadelholzsamen unter luft-dichtem Verschlusse, Mittheil, d. K. K. Forstl. Versuchsanstalt in Mariabrunn) and Haack (Die Kiefernsamen, Zeitschrift F. u. J-wesen, 1909). In both of these investigations, the germination percentages were taken only for one year and no mention is made of what season of year was taken for the experiment or to what extent the moisture influenced on the seeds. Fortunately, the results of our two experiments enable us to speak on these points and we give below the conclusions arrived at.

(1) The benefit arising from the use of air-tight vessels in preserving the germinating power of seeds lies in the fact that the seeds are preserved from the influence of moisture.

(2) It may further be asserted that in this country the greatest influence is exerted by moisture on seeds between June and September.

3. PERSISTENCE OF THE GERMINATING POWER IN RELATION TO THE ATMOSPHERE (REFER EXPERIMENT I).

How does the air contained in the receptacle of the seeds influence up the germinating power of the latter? Seeds so long as they are alive must, of course, continue to perform respiration, and seeds placed in a perfect vacuum must perish. The air pumps in common use, however, do not produce an absolute vacuum, but only rarefy the air. Excepting camphor-seeds, the presence of ordinary air is always desireable for the preservation of seeds, and there is no need of keeping them in rarefied air.

4. PERSISTENCE OF GERMINATING POWER IN RELATION TO INTENSITY OF LIGHT.

What influence light has upon the germinating power of tree seeds, is not yet determined by the two experiments made. Still, excepting Akamatsu, all seeds placed in the light showed better results than those placed in the dark. The same result was arrived at by Moroku Nohara who tried experiments on the preservation of seeds of hybrid of Salix purpurea L. var. mulinervis Matsum. and Salix gracilistyla Miq. (cf. Tokyo Botanical Magazine, XXVII, 1913). The same report shows that seeds should never be placed in the dark as had hitherto been believed best as this is quite unfavorable for the preservation of germinating power. Whether the effect is due solely to light and how light influences the physiological functions of the seeds are questions that remain unsolved and further study of the subject is desirable.

III. Conclusions

From the statements above given we conclude as follows:—

The persistence of the germinating power of forest tree seeds varies according to species, and is influenced by the suroundings where seeds are kept. Of the seeds tried, Kuromatsu and Akamatsu keep their germinating power best being followed by Karamatsu, Sugi and Kusu in order while Hinoki loses its germinating power the soonest.

The seeds of every species tried and of similar trees are best stored in air-tight vessels in as low a temperature as possible. Hinoki-seeds should be stored in a temperature lower than 10°C. at the highest. No artificial drying of seeds is necessary previous to storing.

The best place for storing seeds is a cellar so made that the temperature is uniform, for which purpose in Tokyo it is necessary to dig 8–10 metres below the surface. The so-called " wind holes " where the people store silk worm eggs found in mountains would serve well for storing of tree seeds.

COMPOSITION OF FALLEN LEAVES OF FOREST TREES AND THEIR QUANTITIES

By SHIGEMASA MORIYA, Chemist of Forest Experiment Station

In many localities fallen leaves are collected and used either as fuel or for other purposes. The country people generally consider only how to use these waste products for their own profit. Such a time-honored usage should, however, be discredited, since, from the stand point of forest economy, the fallen leaves form the principal source of nutrients for the growing trees and also exert a beneficial effect by retaining water and protecting the excessive evaporation of moisture from soil.

I. Composition of Fallen Leaves of Forest Trees

To ascertain the manurial value of fallen leaves of forest trees, the fallen leaves of Sugi *(Criptomeria Japonica)*, Akamatsu *(Pinus densiflora)*, Kuromatsu *(Pinus Thunbergii)*, Kunugi *(Quercus serrata)*, Konara *(Quercus glandulifera)*, and Shirakashi *(Quercus Vibrayeana)* grown at the Experiment Station were duly collected and analysed in the usual way:—

Of 100 parts of air-dried substance	Leaves					
	Sugi	Akamatsu	Kuromatsu	Kunugi	Konara	Shirakashi
Water	11.264	10.005	11.340	10.030	12.316	9.900
Organic matter	82.636	87.915	86.394	86.420	80.814	80.974
Nitrogen	0.972	0.886	0.855	1.116	0.945	1.001
Ash	6.100	2.080	2.276	3.550	6.870	9.126
P_2O_5	0.257	0.163	0.174	0.165	0.134	0.210
K_2O	0.340	0.132	0.124	0.280	0.297	0.489
Na_2O	0.125	0.053	0.040	0.093	0.149	0.163
CaO	2.999	0.836	0.867	1.261	1.814	1.908
MgO	0.509	0.189	0.172	0.417	0.418	0.456
SO_3	0.082	0.053	0.055	0.088	0.095	0.126
Fe_2O_3	0.149	0.029	0.032	0.059	0.102	0.227
Al_2O_3	0.448	0.182	0.194	0.237	0.315	0.811
SiO_2	0.747	0.356	0.591	0.764	3.293	4.709

(a) Nitrogen.

The most important ingredient of fallen leaves is no doubt nitrogen. Among conifers, the Sugi leaves are richest in nitrogen containing 0.972% or about 1% of the air-dried substance. Sugi is followed by Akamatsu showing a percentage of 0.885% and Kuromatsu of 0.855%. Broad-leaves are generally richer in nitrogen than needle-leaves, those of Kunugi containing 1.116%, Shirakashi 1.0%, and Konara 0.945%.

(b) Ash.

Broad-leaved trees have a larger proportion of ash in their leaves than conifers. Among conifers, Sugi, however, is relatively rich in ash containing 6.1% of the air-dried substance which is 3 times of the ash content of Akamatsu or Kuromatsu. Among broad-leaved trees, Kunugi has an ash content of 3.55% while Konara contains nearly twice as much of the preceding and Shirakashi has a still larger quantity, the content being 9.12%.

Taking the three important ash ingredients known as phosphoric acid, potash and lime among the fallen leaves of the six aforesaid trees, Sugi leaves are richest in phosphoric acid and lime. Its richness in lime is particularly noteworthy as it contains 2.999% of the air-dried substance or 49.164% of the total ash. Phosphoric acid too is found in considerable amount in Sugi leaves. Akamatsu and Kuromatsu leaves despite the small quantity of ash they contain, are rich in phosphoric acid being not inferior to those of broad-leaved trees, although they are poor in potash content. The content of silica in Kuromatsu is richer than that in Akamatsu, and to this, is due the difference in the total ash contents of the two pines, though there is no particular difference in other ingredients of the ash. Further, among broad-leaved trees, Shirakashi and Konara are rich in ash content owing to the large amount of silica while phosphoric acid and lime are found almost in the same quantity as in other oaks such as Kunugi.

Shirakashi is further characterised by the rich content of potash.

II. Quantities of Fallen Leaves

What quantity of leaves fall every year in the forests? Researches on this subject were made on Kunugi in 1911 at the Forest of the Experiment Station. A similar study was made simultaneously on Kuromatsu and is still carried on every year in the State Forest of Nakayama, Higashi Ibaraki County, Ibaraki Prefecture, by the Major Forest Reserve of Tokyo.

The results of the researches in the years 1911 and 1912 are as follows:—

QUANTITY OF FALLEN LEAVES

Species	Time of Collection	Area on which fallen leaves were collected	Weight of fallen leaves	Air-dried weight of leaves	Weight of air-dried leaves per hectar
		ar.	Kg.	Kg.	Kg.
Kuromatsu	Winter, 1911	50	2,235.788	1,913.025	3873.7
	Winter, 1912	,,	2,698.688	1,960.643	
Kunugi	Winter, 1911	,,	2,035.8	1,804.8	3609.6

The forest feature where the fallen leaves were collected may be summarised as follows:—

	Species	Kuromatsu	Kunugi
	Localities	Nakayama State Forest, Ibaraki Prefecture	Forest Experiment Station, Tokyo
Land feature	Direction and declivity	Flat.	Declivity 5°, fronting to north.
	Depth of surface soil	Medium.	Medium.
	Consistency	Soft.	Soft.
	Moisture	Wet.	Fairly wet.
Forest feature	Age of the trees ..	37 years about.	16 years about.
	Average height ..	15.15 metres.	7.6 metres.
	Diam. of the stem at B.H.	0.15 metre.	0.09 metre.
	No. of trees per ha.	1,100.	3,000.
	Density	Dense.	Sparse.
	Formation	Artificially planted.	Artificially planted.
	Remarks	Since no thinning has ever been practiced, trees are thick and closely overheaded.	In the spring of 1910, thinning was effected and Momi (silver fir) was planted as underwood.

The quantities of the principal ingredients found in fallen leaves per hectar a year round based on the analysis above refered to is as follows:—

Ingredients	Kuromatsu Forests	Kunugi Forests
	per hectar.	per hectar.
Nitrogen (N)	33.2 kg.	40.3 kg.
Phosphoric acid (P_2O_5)	6.8	6.0
Potash (K_2O)	4.8	10.1
Lime (CaO)	33.7	45.5

III. Composition of Rotten Leaves

With the object of determining the difference in the composition of fresh fallen leaves and well rotten ones, samples were taken from beds of well rotten leaves in the spots where fallen leaves were collected.

COMPOSITION OF ROTTEN LEAVES

Of 100 parts of air-dried substance	Akamatsu	Kunugi
Water	15.775	13.839
dry matter:	84.225	86.161
N.	1.401	1.548
Ash	27.968	17.604
P_2O_5	1.048	0.166
K_2O	0.277	0.178
Na_2O	0.214	0.157
CaO	3.120	1.225
MgO	1.182	0.922
SO_3	0.430	0.156
Fe_2O_3	0.716	0.922
Al_2O_3	6.980	3.859
Sand and SiO_2	13.816	9.979

According to the above table, well rotten leaves are richer in nitrogenous content than fresh fallen leaves. Since well rotten leaves of Akamatsu and Kunugi contain 1.5% of nitrogen in round numbers, they both have a certain manurial value owing to their nitrogenous content. Rotten leaves contain a larger quantities of ash which is due to the fact that organic matter suffers decomposition and decreases in quantity while the loss of mineral matter through rain is relatively small and the composition of leaves thus approaches the surface soil. Compared with freshly collected leaves, the silica, magnesia and oxide of iron contained in the ash of well rotten leaves are remarkebly large in quantity. Phosphoric acid, potash and lime are, however, gradually washed away and decrease with the lapse of years. Still, rotten leaves, of course, always show a far richer content of these last mentioned ingredients than ordinary surface soil.

The fallen leaves of broad-leaved trees decompose readily while those of conifers are hard to rot owing to the rich content of resin and their strong fibres. Large heaps of coniferous leaves often give rise to humic acid and other objectionable organic compounds doing thereby great harm to growing plants.

IV. Composition of the Soils of Wooded Area

The upper soils of Sugi, Akamatsu and Kunugi woods of the Forest Experiment Station, from whence fallen leaves for our study were collected, as well as the soil of nurseries of the Station, where seedlings are raised, were fully analysed to serve in making a comparison between the composition of fully rotten leaves and that of the soils of wooded land as well as that of the soil of the nursery bed.

COMPOSITION OF THE SOILS OF WOODED AREA AND THE NURSERY AT THE STATION

Air-dried fine soil (100 parts)	Sugi wood lot	Akamatsu wood lot	Kunugi wood lot	Nursery lot
Water	10.670	10.770	10.990	10.457
Loss on ignition	25.684	24.713	28.206	20.850
Total nitrogen	0.922	0.878	0.918	0.327
Insoluble residue in HCl	49.184	54.898	51.830	49.332
Silica soluble in HCl	0.705	0.232	0.675	0.722
Allumina (Al_2O_3)	7.984	7.108	14.400	12.827
Oxide of iron (Fe_2O_3)	7.984	4.580	5.800	10.569
Lime (CaO)	0.820	2.340	0.490	0.746
Magnesia (MgO)	2.931	1.327	1.943	1.729
Potash (K_2O)	0.155	0.217	0.213	0.026
Soda (Na_2O)	0.246	0.324	0.252	0.365
Phosphoric acid (P_2O_5)	0.423	0.305	0.214	0.069
Sulphuric acid (SO_3)	0.284	0.209	0.332	0.183

The land features of places where above soils were taken may be given as follow:—

Land and forest features		Species		
		Sugi	Akamatsu	Kunugi
Land feature	Direction and declivity	Level.	Level.	Fronting the north with a declivity of 5°.
	Nature of soil ..	Alluvial, loamy soil.	Alluvial, loamy soil.	Alluvial, loamy soil.
	Depth of surface	Deep.	Medium.	Medium.
	Consistency of the soil	Soft.	Soft.	Soft.
Forest feature	Age of trees ..	About 40 years.	About 13 years.	About 16 years.
	Average height ..	50 ft.	12 ft.	25 ft.
	Average diam. at breast-height ..	0.56 ft.	0.24 ft.	0.3 ft.
	No. of tree per ar.	150.	300.	About 300.
	Density and closur	Somewhat thin.	Suitable closure but owing to shortness of trees, the land is exposed to direct sunshine in several places.	Thin.

Land and forest features		Species		
		Sugi	Akamatsu	Kunugi
Forest feature	Under-wood covering	Usually fallen leaves are not collected. Under-grass grows to some extent.	Generally fallen leaves are not collected. Rushes and other grasses appear in several places.	Fallen leaves are not collected. Rushes and bamboo grass abound.
Remarks		Artificially planted.	Artificially planted. Since the wood has never been lopped, ground is thickly covered with fallen twigs, etc.	Artificially planted. Looped in the spring of 1912, and under-wood of Momi (*Abies firma*) planted.

A close study of the above table shows that the soils of these three wooded lands are quite different in composition. This is chiefly due to the difference of tree species, the age and closure of the standing trees as well as the other forest conditions. One point common to the three lots is the richness in nitrogen, phosphoric acid, potash and lime, the lots being thus fertile as compared with the soil of the nursery bed at the Station.

The above statements will evince that the richness of the soil of a woods is depend upon the fallen leaves which greatly enrich originally poor soil or the land left waste for the lack of fertility. Such land will of course be considerably improved by the planting of trees thereon.

THE PROPER SEASON FOR APPLICATION OF FERTILIZERS TO SUGI *(Criptomeria japonica)* AND HINOKI *(Chamaecyparis obtusa)* SEEDLINGS AND THE EFFICACY OF FERTILIZERS

By SHIGEMASA MORIYA, Chemist of Forest Experiment Station

Sugi and Hinoki are known as the principal forest trees of the country, and the supply of sound seedlings of these trees is indeed an important part of the work of forestry. Accurate investigations of fertilizers and of the proper time for their applications so as to bring about the best results are of the greatest importance.

Although the efficacy of nitrogenous manures on farm crops has already been established by a series of trials by different authorities; little is known on the manurial value of these fertilizers for forest tree seedlings. To fill the gap, thus left, the author has occupied since 1911 in determining the efficacy and the proper time for applying nitrogenous manures to forest tree seedlings and the results obtained therefrom are as follows.

I. Method of Experiment

(1) Soil used for the Trial:—Loamy soil in the Forest Experiment Station, Tokyo. It was rich in humus where Keyaki *(Zelkowa acuminata)* seedlings had been raised and where no manure had been used for the preceding 7—8 years.

The composition of the air-dried soil was a follows:—

	%
Water (H_2O)	10.457
Loss by ignition	20.850
Humus	5.935
Total nitrogen	0.327
Residue insoluble in HCl	49.332
Silica soluble in HCl	0.722
Silica soluble in Sodium Carbonate	21.905
Sum of Silica	22.627
Alumina (Al_2O_3)	12.827
Ferric oxide (Fe_2O_3)	10.570

	%
Lime ($Ca0$)	0.746
Magnesia ($Mg0$)	1.729
Potash (K_20)	0.026
Soda (Na_20)	0.365
Phosphoric acid (P_20_5)	0.069
Sulphuric acid ($S0_3$)	0.183

(2) Apparatus used for the Trial:—70 bottomless zinc cylinders having a diam. of 92.4 cm, corresponding to a surface of about 1/15000 hectare were buried in the field. The top of the cylinders were raised 3 cm above the surface of the ground; in the bottom, yellow subsoil was spread uniformly, and upon it the soil to be tried was put to the depth of 70 cm.

(3) Seedlings used for the Trial:—Fully one year old Sugi seedlings weighing 1.4–1.5 gram apiece, and Hinoki seedlings weighing 0.5 apiece of uniform size and growth were taken from the beds at the Station and were planted 12. cm apart from each other at the rate of 32 plants in each cylinder.

(4) Fertilizers used:—The Fertilizers used for the trial consisted of ammonium sulphate, Chili saltpetre, rape-seed cake and night soil as nitrogenous manures, to which the necessary quantities of sodium phosphate and potassium sulphate were mixed to make up the deficiency of phosphoric acid and potash respectively. Thus, the total quantity of nitrogen, phosporic acid and potash comes up to 112.5 Kg. per hectar or 7.5 grams per cylinder.

The ammonium sulphate used was that common in the market, having 20.2%. of N.

Chili Saltpetre:—The ordinary commercial article containing 15.5% of N.

Rape-seed Cake:—Nitrogen 5%, phosphoric acid 2%, potash 0.4%.

Night Soil:—Night soil collected from the official residences of the Station was used after being well rotted. Its nitrogen content was 0.5–0.55%.

Sodium phosphate and Potassium sulphate:—Pure chemicals were used.

(5) Mode of Manuring:—The aforesaid four nitrogenous manures were applied to 8 distinct lots, by various modes as follows:—

Lot No. 1. The total quantity to be given for 2 years was applied in its entirety at the outset as base manure on May 6th, 3 days previous to planting of seedling.

Lot No. 2. The entire quantity was divided into two equal portions; 1/2 of the total quantity being given as base manure on May 6th, and the remaining half on September 16th, the same year.

Lot No. 3. The entire quantity was divided into three equal portions; 1/3 of the total quantity being given as base manure on May 6th, another 1/3 on September 16th, and the remaining 1/3 on May 6th, the next year.

Lot No. 4. The entire quantity was divided into four equal portions; 1/4 of the total quantity being given as base manure on May 6th, and the same quantity on June 7th, September 16th, the same year and on May 6th, the next.

Lot No. 5. No base manure was given at the outset. On June 7th, one month after planting the seedlings, the entire quantity was given once for all.

Lot No. 6. No base manure was given at the outset and the entire quantity was divided to two portions; 1/2 being given on June 7th, and the remaining half on June 24th, the next year.

Lot No. 7. No base manure was given at first. The entire quantity, divided into three equal portions, was given on June 7th, September 16th, the same year and on May 7th, the next.

Lot No. 8. No base manure was given. The entire quantity, divided into four equal portions, was given on June 7th, September 16th, the same year and on May 7th, as well as on September 5th, the next.

The fertilizers applied were well mixed with the soil. In the case of top-dressings, the manures applied could not be fully mixed with the soil as it was in the case of the base manure for fear of injuring the seedlings planted. The soil was carefully loosened and was well mixed with the top-dressing. Lots where no base manure had been applied, were hoed in the same way to keep the condition of soil as nearly alike as possible.

II. Growth of Seedlings Compared

On November 5th, 1913, two years after the planting, during that time the different fertilizers had been applied on the mode above stated, the length of seedlings were measured and weighed after uprooting them. As the figures are too numerous to be given in full, we reproduce below only the average length and weight of the seedlings about the every lot.

Mode of Manuring		Mode and number	1	2	3	4	5	6	7	8	Average
		Quantity of base manure used	Entire quantity.	½ of the entire quantity.	⅓ of the entire quantity.	¼ of the entire quantity.	—	—	—	—	
		Quantity of top-dressing and No. of dressings applied	—	½ of the entire quantity was given at one time.	⅔ of the entire quantity was given in 2 different times.	¾ of the entire quantity was given in 3 different times.	Entire quantity at one time.	entire quantity was given in 2 different times.	entire quantity was given in 3 different times.	entire quantity was given in 4 different times.	
		Time of manuring	—	on Sept. 16th, First year.	on Sept. 16th, First year; on 6th May, Second year.	on 7th June & Sept. 16th, First year; on 6th May, Second year.	on 7th June, First year.	on 7th June, First year; on June 24th, Second year.	on 7th June & 16th Sept, First year; on 5th May, Second year.	on 7th June & 16th Sept, First year; on 6th May & 5th Sept, Second year.	
SUGI	Amm. sulphate	Weight of seedling in gr.	127.0	132.8	156.4	71.3	125.0	101.8	55.8	100.0	108.7
		Length of seedling in cm.	50.6	59.7	64.2	39.7	57.5	46.7	29.7	47.5	49.5
	Chili saltpetre	Weight of seedling in gr.	81.3	79.0	134.0	94.8	65.0	60.9	83.4	56.2	81.8
		Length of seedling in cm.	45.7	40.6	48.4	47.0	41.0	43.0	37.2	26.0	41.1
	Rape-seed cake	Weight of seedling in gr.	55.3	93.7	128.7	88.7	86.1	62.5	48.4	76.6	80.0
		Length of seedling in cm.	27.0	47.3	52.7	40.9	43.3	32.1	30.6	41.8	39.5
	Night soil	Weight of seedling in gr.	117.5	108.0	92.2	72.2	109.7	65.7	56.6	73.3	86.9
		Length of seedling in cm.	49.0	55.1	43.9	35.1	52.4	28.1	29.4	38.4	41.4
	No manure	Weight of seedling in gr.	—	—	—	—	—	—	—	—	40.6
		Length of seedling in cm.	—	—	—	—	—	—	—	—	22.4
HI-NOKI	Amm. sulphate	Weight of seedling in gr.	49.5	59.1	61.0	63.0	35.5	46.8	41.1	46.0	50.2
		Length of seedling in cm.	32.7	33.9	36.6	34.5	24.8	30.0	29.4	32.7	31.7
	Chili saltpetre	Weight of seedling in gr.	50.0	40.8	63.0	59.0	54.5	35.2	42.6	40.1	48.1
		Length of seedling in cm.	29.0	29.0	31.5	35.1	29.0	27.0	30.3	27.8	29.9
	Rape-seed cake	Weight of seedling in gr.	28.0	37.0	48.0	47.1	43.3	42.1	40.2	43.7	41.2
		Length of seedling in cm.	25.1	27.0	33.9	31.2	30.9	30.3	29.5	28.7	29.2
	Night soil	Weight of seedling in gr.	57.0	40.5	52.1	43.0	37.6	31.0	37.0	36.8	42.0
		Length of seedling in cm.	29.4	27.5	27.6	27.2	31.2	29.4	26.6	26.3	28.1
	No manure	Weight of seedling in gr.	—	—	—	—	—	—	—	—	20.0
		Length of seedling in cm.	—	—	—	—	—	—	—	—	18.6

On comparing the efficacy of the manures with regard to the number of times of application and the seasons of manuring as tried on Sugi and Hinoki seedlings, we note that the lots which showed the best results are much alike in the mode of manuring, regardless of manures and tree species. Thus, for ammonium sulphate, Chili saltpetre and rape-seed cake Lot No. 3 showed the best result both for Sugi and Hinoki; with night soil, the best results was obtained both for Hinoki and Sugi in Lot No. 1, while with rape-seed cake, the result of Lot No. 1 was far inferior both for Sugi and Hinoki. Evidently, organic fertilizers like rape-seed cake, decompose slowly and when the considerable quantity of them are given at one time it necessarily give rises to a great quantity of objectionable organic acids, whereby the growth of seedlings seems to be greatly injured.

The average growth of seedlings produced by the different modes of manuring is arranged according to the lots as follows:—

Species	No. of Lots	Average weight of seedlings	Average height of seedlings	Average weight of seedlings taken that of the best lot (No. 3) as 100	Order by weight
		gr.	cm.		
SUGI	Lot No. 1	95.2	43.0	82	4
	2	103.4	50.5	96	2
	3	127.6	52.4	100	1
	4	81.7	40.6	77	5
	5	96.4	48.5	92	3
	6	72.9	37.6	72	7
	7	61.0	30.9	59	8
	8	76.5	38.5	73	6
	No manure	40.6	22.4	43	9
HINOKI	Lot No. 1	46.1	29.0	82	3
	2	44.3	29.3	79	4
	3	56.0	32.4	100	1
	4	53.0	32.0	95	2
	5	42.7	28.9	76	5
	6	38.8	29.1	69	8
	7	40.2	28.9	71	7
	8	41.6	28.9	74	6
	No manure	2.00	18.6	36	9

III. Efficacy of the Base Manure

Mode of manuring are classified two divisions, viz. those which have base manure (previous planting seedlings) and those which have no base manure.

The former are marked A and the later are marked B.

The figures in parenthesis after A or B, indicate the number of applications.

Species	Number of application	Average weight of seedlings in gr.			
		Ammonium sulphate	Chili saltpetre	Rape-seed cake	Night soil
SUGI	A (1)	127.0	81.2	55.3	117.5
	B (1)	125.0	65.0	86.1	109.7
	A (2)	132.8	79.1	93.7	108.0
	B (2)	101.8	60.9	62.5	65.7
	A (3)	156.4	134.0	128.7	92.2
	B (3)	55.8	83.4	48.4	56.6
	A (4)	71.3	94.8	88.7	72.2
	B (4)	100.0	56.2	76.6	73.3
HINOKI	A (1)	49.5	50.0	28.0	57.0
	B (1)	35.5	54.5	43.3	37.6
	A (2)	59.1	40.8	37.0	40.5
	B (2)	46.8	35.2	42.1	31.0
	A (3)	61.0	63.0	48.0	52.1
	B (3)	41.1	42.6	40.2	37.0
	A (4)	43.0	59.0	47.1	43.0
	B (4)	46.0	40.1	43.7	36.8

From the above table, we see that the growth of seedlings which have the base manure, are remarkable good except those have Ammonium and night soil given in four times; rape-seed cake given in one time to Sugi; Chili saltpetre given in one time; and the rape-seed cake given in one and two times to Hinoki.

IV. Comparative Efficacy of Different Fertilizers

The scope of the experiments was to establish the appropriate time of manuring of principal nitrogenous manures used in this country of Sugi and Hinoki seedlings. Comparison was also made of the efficacy of the ordinary nitrogenous manures upon these species. The average weight and length of seedlings and the quantity of nitrogen absorbed in each lot after 2 years planting are given in the following table.

Species	Fertilizer applied	Weight of a seedling in gr.	Length of a seedling in cm.	Weight of seedlings taking that of Amm. section as 100	Average weight (gr.) of N. absorbed by seedlings planted in a cylinder	Percentage of nitrogen absorbed	Absorption ratio taking that of Amm. as 100
SUGI	Ammonium sulphate	108.7	49.5	100	11.06	86.98	100.0
	Chili saltpetre	81.8	41.1	75	9.12	61.31	70.5
	Rape-seed cake	80.0	39.5	74	8.92	58.63	67.4
	Night soil ..	86.9	41.4	80	9.69	68.89	79.2
	No manure ..	40.6	22.4	37	4.53		
HINOKI	Ammonium sulphate	50.2	31.7	100	8.96	71.87	100.0
	Chili saltpetre	48.1	29.9	96	8.58	66.87	93.0
	Rape-seed cake	41.2	29.2	82	7.35	50.46	70.2
	Night soil ..	42.0	28.1	84	7.49	52.36	72.8
	No manure ..	2,00	18.6	40	3.57		
Remarks:		Nitrogen content of a Sugi seedling ranged between 0.89–0.93% of the dry matter and that of Hinoki 0.96–1.2%.					

V. Conclusions from the Results of the Trials

The results of trials to fix the appropriate time of manuring for the 4 principal nitrogenous manures (ammonium sulphate, Chili saltpetre, rape-seed cake, night soil) with a sufficient amount of potash and phosphoric acids to Sugi and Hinoki seedlings grown on the loamy soil, rich in humus, of the nursery in the Forest Experiment Station lead to the following conclusions:—

(1) The manures above-mentioned show less efficacy even though they are applied for many times, unless applied at the proper times.

(2) The efficacy of base manures was especially noted both for Sugi and Hinoki. This is partly due to the fact that the manure so applied is accessible for the seedlings from the beginning, and partly to the perfect mixing of the manure with the soil so that the tender rootlets of the young plants can take the nutrient in the soil. The best example of the base manure both for Sugi and Hinoki is observable with No. 3 for Ammonium sulphate, Chili saltpetre, Rape-seed cake where 1/3 of the entire quantity was given as base manure in a few days previous to the planting of seedlings while the rest was given as the top-dressings in two times, viz., in the middle of September and early in May, next year.

(3) As to the night soil, the best effect was obtained when the entire quantity was given previous to the planting.

(4) With Sugi, the second good result was obtained in Lot No. 2, both for the Ammonium sulphate, Rape-seed cake, and Night soil, where one-half of the entire quantity was given at first as base manure while the rest was given in September, the next, and also in Lot No. 4 for the Chili saltpetre, where the entire quantity was given at four times, viz., at first as base manure, beginning of June, middle of September and early in June, next year.

(5) As to the Hinoki, the second good result was obtained in Lot No. 4 for all manures though this lot showed a medium result with Sugi. In the Rape-seed cake, the lot where the entire quantity was given previous to planting showed the most disappointing result for both tree species.

(6) Methods other than those above described, proved more or less inferior in general. Further, the efficacy of fertilizers was more remarkable for Sugi than Hinoki, as its growth is far quicker and the similar results were obtained for the each of these tree species. Among the manures applied, Ammonium sulphate showed the best result for both trees and Rape-seed cake the worst. With Sugi, Night soil showed better results than Chili saltpetre but it was just the opposite in the case of Hinoki.

INVESTIGATION OF THE TRANSVERSE STRENGTH IN WOOD

By KITARO MOROTO, Assistant Professor

Unlike minerals, wood is not homogeneous. Its strength, thus, differs much according to species, moisture content, age, breadth of year rings, as well as number of knots. The strength of wood also is in general influenced by the size of the piece.

It is important to determine the strength of wood in relation to its moisture content, age, breadth of year rings and number of knots so as to enable the forester to grow such products as are most marketable timber on the one hand, and to furnish the builder with the needed factors in calculating the strength of wood on the other. A full investigation of the subject was therefore undertaken by the writer in March 1904, and since then the woods commonly offered on the market have been thoroughly tested. It is now a great pleasure to publish a portion of the results thus obtained: namely those connected with the transverse strength, the investigation of which was terminated in 1906. Further, all the data are given in English measure, since they are commonly used by builders.

I. Object of the Investigation

1. DETERMINATION OF TRANSVERSE STRENGTH OF WOOD AND ITS MODULUS OF ELASTICITY.

The strength of wood is distinguished as transverse, tensile, compressive, shearing etc.

As the transverse strength of wood is by far the most important in building and as the determination of the modulus of elasticity is most conveniently obtained by the same test, we undertook, first of all, to test this property.

2. LOCATION OF THE HEART OF THE WOOD IN RELATION TO ITS STRENGTH.

To determine the relation of strength of wood with the location of the heart the test was made with the beams, of which the heart was so placed as to be near the top or else near the bottom.

3. STRENGTH OF WOOD WITH RELATION TO ITS MOISTURE CONTENTS.

To determine the relation of moisture content of wood to its strength for every wood species one or two beams of every size and species were tested after drying in a kiln.

4. STRENGTH OF WOOD IN RELATION TO STEAM TREATMENT.

To determine the relation of steam treatment to the strength of wood, one or two beams of every size and species to be tested were steamed and tested after drying.

II. Machine used for the Testing

Buckton's 50 ton testing machine belong to the laboratory of the Engineering College of the Tokyo Imperial University was used. Since the machine is intended for use chiefly in testing the strength of iron, the span is limited to 5 ft. but for our purpose special fitting were made so as to make possible a span of 98 inches.

III. Wood Tested

The principal species used for building purpose such as Sugi *(Cryptomeria japonica)*, Hinoki *(Chamaecyparis obtusa)*, Akamatsu *(Pinus densiflora)* and Asunaro *(Thujopsis dolabrata)* were duly tested. Sugi was obtained from Yoshino, Owashi and Kiyosumi; Hinoki from Kiso, Yoshino and Owashi; Akamatsu from Mito, and Asunaro from Aomori.

The beams tested were 9 ft. long, their cross-sections were either square or rectangular, being 7 in. breadth with thicknesses of 2, 3, 4, 5, 6, and 7 inches respectively. These beams classified according to the locality of production and forest features are as follows:—

IV. Method Adopted

1. TEST OF TRANSVERSE STRENGTH.

The span of beam was taken as 98 inches and it was supported at two ends; load was charged at the middle; deflection of the beam was duly read by the gradual increase of loading in weight till the beam finally breaks.

The cross-head and the supports in the two ends of the beam are obtuse wedge shaped so that they will not cut into the beam, but with a few species, the beams were damaged to some extent. Further, to rectify the defect arising in the determination of deflection, the distance from the base of the machine to the mark made on the neutral plane of the beam at one end just above the support as well as the distance from the same base to the mark at the middle of the beam on the same plane where the load falls were duly read, and the difference of the two distances so obtained was taken as the true deflection. The increase of load differs according to the size of the beam subject to the test. With small beams every increase of 0.2 tons, with large beams 0.5 tons was read to determine the deflection. The work was effected both for small and large beams without pause until complete rupture set in.

The results of the tests with maximum, minimum and mean will be learnt from the subjoined Table I–IV.

2. STRENGTH OF WOOD AND ITS MODULUS OF ELASTICITY TESTED.

RESULTS OF THE BENDING TESTS OF A FEW TYPICAL BEAMS.

DRIED BEAMS					UNDRIED BEAMS				
Locality of the beam tested	Load in tons	Deflection at the loading point	Yields of the beam at the support	Rectified deflection	Locality of the beam tested	Load in tons	Deflection at the loading point	Yields of the beam at the support	Rectified deflection
	Inch	Inch	Inch	Inch			Inch	Inch	Inch
Sugi of Yoshino, 1 of No. 9. (7″.1x7″.0)	0.00	0.00	0.00	0.00	Sugi of Yoshino, 2 of No. 10. (7″.0 x 7″.1)	0.00	0.00	0.00	0.00
	0.50	0.14	0.02	0.12		0.58	0.17	0.04	0.13
	1.00	0.20	0.03	0.17		1.35	0.34	0.07	0.27
	1.50	0.30	0.04	0.26		1.50	0.38	0.08	0.30
	2.00	0.40	0.05	0.35		2.00	0.50	0.10	0.40
	2.50	0.51	0.08	0.43		2.50	0.66	0.11	0.55
	3.00	0.63	0.10	0.53		3.00	0.89	0.15	0.74
	3.50	0.76	0.12	0.64		3.50	1.30	0.16	1.14
	4.00	0.96	0.15	0.81		4.05	3.00	—	—
	4.50	1.20	0.18	1.02		—	—	—	—
	5.00	1.73	0.22	1.51		—	—	—	—
	5.50	3.05	0.25	2.80		—	—	—	—

Species		Locality of production.	Land feature			Forest feature	Original trees of tested beams					Tested beams						
												Breadth × Thickness						Total
Japanese name	Botanical name		Forest zone	Altitude above sea level in ft.	Geology, soil, etc.		Time of felling	No. of trees tested	Age of the tree	Circ. at breast height	Height in ft.	7"×7"	7"×6"	7"×5"	7"×4"	7"×3"	7"×2"	
										ft.	ft.							
Hinoki	Chamaecyparis obtusa.	Kiso Crown Forest, Nagano Prefecture.	Temperate Zone.	800–830	Granite with thin overlying soil; fronting N. E. with declivity of 15°.	Mixed natural forests of conifers and broad-leaved trees. Age 170–200 years. Medium closure of crowns.	April, 1906.	15	172–217	4.0–5.0	67–81	5	10	10	10	10	10	55
,,	,,	Yoshino, Nara Prefecture.	Lower part of Temperate Zone.	1,150	Clay-slate or lime of Palaeozoic Formation; fronting N.W.; declivity of 30°–40°. Quality, III.	Pure artificial forests. Age 115 years.	March, 1904.	12	115	3.2–3.9	50.5–72.5	5	10	11	10	10	10	56
,,	,,	Owashi, Miye Prefecture.	Sub-tropical Zone.	200	Tertiary Formation with thick layer of overlying soil; declivity 20–40°. Quality, III.	Mixed forests of Sugi and Hinoki.	March, 1904.	15	80	3.0–3.5	65–81	5	10	10	10	10	10	55
Total							—	42	—	—	—	15	30	31	30	30	30	166
Akamatsu	Pinus densiflora.	Mito, Ibaraki Prefecture.	Temperate Zone.	83	Loam or humus soil of old Quarternary Formation; land level; porous light soil. Quality, III.	Pure artificial forests. Density 0.6; age 98.	Nov., 1914.	14	98	3.0–4.5	72–84	5	10	10	10	10	10	55
Sugi	Cryptomeria japonica.	Yoshino, Nara Prefecture.	Lower part of Temperate Zone.	1,000	Palaeozoic Formation, with predominance of lime, fronts to N.E.; declivity 10–46°. Quality, III.	Artificial forests; age 75.	March, 1904.	15	75	2.9–3.8	72–100	7	9	15	9	9	7	56
,,	,,	,,	,,	—	Climate and soil, same as above, slop more slant. Surface soil deeper. Quality, I.	Pure artificial forests; age 55.	,,	7	55	3.1–3.9	76–98	3	7	8	6	6	7	37
,,	,,	Owashi, Miye Prefecture.	Sub-tropical Zone.	200	Tertiary with overlying heavy soil; Slant. Quality, III.	Mixed forests of Sugi and Hinoki; age 60.	,,	6	60	3.1–3.8	74–81	4	5	3	4	4	3	23
,,	,,	,,	,,	660	Soil same as the preceding; declivity 16–30°. Quality, I.	Mixed forests of Sugi and Hinoki. Age: Sugi 70, Hinoki 80.	,,	6	70	2.9–3.7	78–89	—	5	4	6	6	4	25
,,	,,	,,	,,	400	Soil and rock same as the preceding; declivity 12.° Quality, II.	Mixed forests of Sugi and Hinoki. Age: Sugi 60, Hinoki 80.	,,	2	60	3.1–3.4	81	2	—	3	—	—	3	8
,,	,,	Kiyosumi, Chiba Prefecture.	Upper part of Temperate Zone.	825	Tertiary Formation: sandy tuff with deep layer of soil; declivity 20–30°. Quality, I.	Pure forests; age 60. Sparse growth.	,,	4	60	3.4–3.6	78–84	3	3	3	3	3	3	18
,,	,,	,,	,,	1,230	Same as the preceding; rocky; exposed to harsh wind.	Do.	,,	4	60	3.0–3.8	70–78	—	3	2	3	3	2	13
,,	,,	,,	,,	1,155	Soil same as the preceding but deeper.	Artificial forests. Age 150. Medium closure of the crowns.	April, 1904.	2	150	3.4–3.6	77–80	—	—	3	4	4	3	14
,,	,,	,,	,,	1,100	Do.	Pure artificial forests. Age 42. Somewhat sparse.	,,	2	42	3.1–3.6	70–73	2	2	—	—	—	—	4
,,	,,	,,	,,	985	Do.	Patches of Sugi grow in coppice wood.	,,	1	—	3.3	64	—	—	2	—	—	2	4
,,	,,	,,	,,	890	Do.	Artificial forests, Age 70; found in mixture with Momi; naturally generated.	,,	1	70	3.2	64	—	2	—	—	—	—	2
Total							—	49	—	—	—	21	36	43	35	35	34	204
Asunaro	Thujopsis dolabrata.	Masukawa State Forest, Aomori Prefecture.	Temperate Zone.	250	Three miles distant from the shore, fronting S. and S.E. to the sea. Soil formed by the decomposition of Andesite of Tertiary Formation, rhyolite, tuff and clayslate. Sandy loam. Sloping. Quality medium.	Natural forests with full closure of crowns. Age 150; average height 60 ft.; circumference at breast-height 3.8 ft.	Sept. and Dec., 1902.	—	—	—	—	17	10	12	15	10	10	74
Grand total							—	—	—	—	—	58	86	96	93	85	84	499

DRIED BEAMS					UNDRIED BEAMS				
Locality of the beam tested	Load in tons	Deflection at the loading point	Yields of the beam at the support	Rectified deflection	Locality of the beam tested	Load in tons	Deflection at the loading point	Yields of the beam at the support	Rectified deflection
		Inch	Inch	Inch		Inch	Inch	Inch	Inch
Sugi of Owashi, 1 of No.6. (7″.2 x 7″.2)	0.00	0.00	0.00	0.00	Sugi of Owashi, 4 of No. 6 (7″.35x7″.2)	0.00	0.00	0.00	0.00
	0.58	0.15	0.02	0.13		0.50	0.10	0.02	0.08
	1.31	0.24	0.03	0.21		1.00	0.21	0.06	0.15
	1.50	0.30	0.05	0.25		1.50	0.35	0.12	0.23
	2.00	0.40	0.06	0.34		2.00	0.53	0.18	0.35
	2.50	0.50	0.07	0.43		2.50	0.70	0.22	0.48
	3.00	0.60	0.09	0.51		3.00	0.90	0.27	0.63
	3.50	0.71	0.12	0.59		3.50	1.13	1.31	0.82
	4.00	0.85	0.12	0.73		4.00	1.49	0.35	1.14
	4.50	0.98	0.14	0.84		4.42	2.95	—	—
	5.00	1.11	0.15	0.96		—	—	—	—
	5.50	1.26	0.17	1.09		—	—	—	—
	6.00	1.45	0.20	1.25		—	—	—	—
	6.50	1.68	0.20	1.48		—	—	—	—
	7.00	2.65	0.23	2.42		—	—	—	—
	7.01	3.14	—	—		—	—	—	—
Hinoki of Kiso, 3 of No. 11 (5″.25 x 7″.15)	0.00	0.00	0.00	0.00	Hinoki of Kiso, 1 of No. 10 (4″.9 x 7.″4)	0.00	0.00	0.00	0.00
	0.50	0.13	0.08	0.05		0.50	0.10	0.03	0.07
	1.00	0.23	0.11	0.12		1.00	0.27	0.05	0.22
	1.50	0.33	0.13	0.20		1.53	0.41	0.07	0.34
	2.00	0.45	0.16	0.29		2.00	0.55	0.11	0.44
	2.60	0.55	0.18	0.37		2.50	0.73	0.15	0.58
	3.00	0.67	0.20	0.47		3.00	0.90	0.18	0.72
	3.50	0.80	0.21	0.59		3.50	1.15	0.20	0.95
	4.08	0.93	0.22	0.71		4.00	1.47	0.22	1.25
	4.50	1.03	0.22	0.81		4.50	2.12	0.28	1.84
	5.00	1.20	0.24	0.96		4.60	2.72	—	—
	5.50	1.41	0.25	1.16		—	—	—	—
	6.00	1.67	0.27	1.40		—	—	—	—
	6.00	1.85	—	—		—	—	—	—
Hinoki of Yoshino, 3 of No. 6. (5″.05 x 6″.95)	0.00	0.00	0.00	0.00	Hinoki of Yoshino, 2 of No. 7 (4″.9 x 7″.05)	0.00	0.00	0.00	0.00
	0.64	0.17	0.08	0.09		0.56	0.20	0.03	0.17
	1.17	0.32	0.11	0.21		1.00	0.34	0.04	0.30
	1.64	0.42	0.12	0.30		1.56	0.51	0.05	0.46
	2.00	0.54	0.15	0.39		2.00	0.65	0.09	0.56
	2.50	0.67	0.17	0.50		2.50	0.80	0.10	0.70
	3.00	0.81	0.18	0.63		3.00	1.00	0.13	0.87
	3.50	0.96	0.18	0.78		3.50	1.19	0.14	1.05
	4.00	1.14	0.21	0.93		4.00	1.60	0.18	1.42
	4.50	1.32	0.22	1.10		4.46	2.50	—	—
	5.00	1.60	0.25	1.35		—	—	—	—
	5.56	2.40	—	—		—	—	—	—

The diagrams in Plate I show in curves the results of the preceding tests, from which the elastic limit and amount of work done can be read. The deflection at the moment of rupture being unobtainable, was graphically prepared on the diagram. The formulas used in computing the results of tests on rectangular beams were as follows:—

$$f=\frac{3wl}{2bh^2} \dots\dots\dots\dots\dots\dots \quad (1)$$

$$E=\frac{pl^3}{4bh^3d}\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \quad (2)$$

where w=maximum load at the center of the beam in lbs.

b, h, l=breadth, height, and span of the beam, in inches.

d=deflection produced by the load given in inches within the elastic limit.

p=load at a point in the beam within the elastic limit, corresponding to d given in lbs.

f=Modulus of rupture, pounds per square inch.

E=modulus of elasticity, pounds per square inch.

In fact, within the limit of elasticity, diagram showing the resulting stress and strain is a straight line according to Hooke's law. Beyond that limit, the deflection increases suddenly out of proportion to the load, forming a curve. The modulus of elasticity (E) is obtainable from formula (2) by applying load (p) and corresponding deflection (d). By computing from formula (1) f at the moment of rupture is obtainable. The amount of work done denoted by (A) upon the beam is read graphically by means of a planimetre on the diagram.

3. Determination of Weight.

With the purpose of determining the relation of the strength of wood to its weight, the weight was taken immediately after testing. The weight so obtained will furnish the weight of the wood per cubic ft.

4. Drying and Steaming.

For the drying the wood was put into a drying chamber; for the steaming wood it was put into a steaming room closed with a well-fitted lid. After steaming the wood for 9 hours it was taken out and was introduced into drying chamber where warm air was passed over it at a temperature from 35° to 43°C. by artificial means and after two weeks the wood was fully dried.

5. Determination of Moisture Content.

With the object of studying the relation between the moisture content of wood and the strength of wood, one-inch section was cut off from one end of the tested beam used for cross-breaking after the termination of the test. The piece was weighed and the weight so obtained was taken as that at the moment of testing; subsequently the same piece was put into drying oven and was heated at 100°–120°C. for 6 hours till no decrease of weight was observable and this was taken as the net weight of the piece at the moment of perfect desiccation. Deducting the latter from the former, the difference obtained is the moment content of wood.

6. DETERMINATION OF THE QUALITY OF TIMBER FOR BUILDING.

Durability of strength are of course desired in wood to be used for building purposes.

The toughness of wood as advocated by Tetmajer should never be overlooked. Thus, the area included between the stress-strain curve and initial line (which is zero) will readily denote the amount of work done upon the beam and will serve as a good measure of the quality of wood. Brittle wood shows the least work done while tough wood shows the most. Since, however, a large deflection is so undesirable in building timber the amount of work alone does not serve as a good criterion in determining the quality of timber. The author was consequently led to accept instead of the amount of the work done, the quotient obtained by dividing the same by the deflection at the moment of rupture. Such a quotient is used in comparing the quality of woods.

V. Results of the Experiment

Results of the above experiments has been entered in Table I–IV, the main points in which are as follows:—

(1) The rupture of wood generally begins with the strained tissues of the wood tested, in other words, the tissues in the under part of the beam.

(2) The nature of the rupture differs according to the amount of moisture contained in the wood. In general, wet wood shows instead of perfect rupture a shearing of the strained surface under side of the beam. Wet wood shows a greater deflection than dried wood.

(3) Dried wood is stronger than wet.

(4) The strength of wood decreases when steamed while the modulus of elasticity increases.

(5) Wood with many year rings is stronger than that with few.

(6) As to the location of the heart of the wood in relation to strength, the best results were obtained when the heart of the wood was placed above, and the poorest when it was placed below.

(7) Woods of different species having different deflection can be arranged as follows (see Table) according to deflection.

(8) Different wood species are arranged in the Table to their strength.

(9) The woods of different species tested differ in their moduli of elasticity as can be learnt from the Table.

(10) The amount of work done by different woods divided by the respective deflections at the moment of rupture are arranged as in Table.

Species	Deflection of the beam (ins.)		
	Average of the maximum	Total average	Average of the minimum
Sugi of Kiyosumi	0.86	0.73	0.58
Sugi of Owashi	0.86	0.67	0.54
Asunaro of Aomori	0.88	0.63	0.37
Sugi of Yoshino	0.68	0.58	0.49
Hinoki of Yoshino	0.69	0.57	0.45
Akamatsu of Mito	0.64	0.52	0.38
Hinoki of Owashi	0.63	0.51	0.40
Hinoki of Kiso	0.52	0.43	0.35

Species	Strength (lbs. per sq. in.)		
	Average of the maximum	Total average	Average of the minimum
Hinoki of Yoshino	8,265	7,351	5,541
Hinoki of Kiso	8,794	7,063	5,585
Akamatsu of Mito	8,385	6,660	5,214
Hinoki of Owashi	6,872	6,544	4,826
Sugi of Yoshino	7,640	5,992	4,456
Asunaro of Aomori	7,347	5,168	4,035
Sugi of Kiyosumi	5,892	4,987	4,118
Sugi of Owashi	6,155	4,487	3,340

Species	Modulus of elasticity (lbs. per sq. in.)		
	Average of the maximum	Total average	Average of the minimum
Hinoki of Kiso	1,781,000	1,501,000	1,270,000
Akamatsu of Mito	1,980,000	1,500,000	1,141,000
Hinoki of Owashi	1,886,000	1,445,000	1,134,000
Sugi of Yoshino	1,792,000	1,410,000	1,039,000
Hinoki of Yoshino	1,668,000	1,370,000	1,096,000
Sugi of Owashi	1,533,000	1,175,000	807,000
Asunaro of Aomori	1,592,000	1,133,000	755,000
Sugi of Kiyosumi	1,366,000	1,108,000	850,000

Species	The amount of work done divided by the deflection at the moment of rupture (inch-pounds)		
	Average of the maximum	Total average	Average of the minimum
Hinoki of Kiso	7,162	5,718	4,149
Hinoki of Owashi	7,561	4,906	3,440
Hinoki of Yoshino	5,848	4,885	4,021
Akamatsu of Mito	6,249	4,724	3,728
Sugi of Yoshino	5,813	4,515	3,378
Sugi of Kiyosumi	5,052	4,132	3,124
Sugi of Owashi	4,643	3,480	2,598
Asunaro of Aomori	4,810	3,379	2,334

As the above Tables will show, the species tested are arranged according to the suitability as timber in the following order:—

1. Hinoki.
2. Akamatsu.
3. Sugi.
4. Asunaro.

(11) Modulus of rupture differs according to the size of the beam tested. Assuredly, beams of smaller breadth and thickness are stronger than those of larger breadth and thickness.

VI. Conclusion

The above investigation led to the results mentioned above. Since, however, factors exercise a considerable influence upon the strength of the wood are numerous, no precise determination of the real cause of rupture can be arrived at. Moreover, the presence of knots considerably impairs the strength of wood and foresters desirous to get the best growth of timber trees should take great care in pruning so as not to produce large knots. Also the felled trunks must be properly seasoned.

TABLE I. STRENGTH (lbs. per sq. in.)

	Width X thickness (ins.)											
	7 x 7	6 x 7	5 x 7	4 x 7	3 x 7	2 x 7	7 x 6	7 x 5	7 x 4	7 x 3	7 x 2	Total average
Hinoki of Kiso.												
Maximum	6,425	8,360	7,370	8,370	8,310	8,270	8,270	7,350	10,480	12,425	11,100	8,794
Average	5,747	5,468	6,086	6,569	6,603	6,523	6,384	6,531	9,382	9,327	9,011	7,063
Minimum	4,940	3,460	5,610	4,940	5,180	4,460	4,910	5,425	8,085	7,670	6,770	5,586
Hinoki of Yoshino.												
Maximum	6,570	8,760	7,500	6,040	8,835	7,400	6,990	8,535	7.930	11,200	11,150	8,265
Average	6,090	6,848	5,946	5,730	6,654	5,913	6,141	7,462	6,934	8,571	8,375	7,351
Minimum	4,970	5,070	4,490	5,320	4,825	4,615	5,690	6,880	5,390	6,565	7,135	5,541
Hinoki of Owashi.												
Maximum	7,440	8,510	10,500	7,550	8,450	9,420	8,095	7,150	11,440	9,555	9,480	8,872
Average	5,231	5,644	6,523	5,730	6,242	5,792	6,691	6,549	8,365	7,816	7,400	6,544
Minimum	3,250	3,490	4,540	4,240	4,155	3,940	5,610	5,890	5,975	6,430	5,565	4,826
Akamatsu of Mito.												
Maximum	6,400	7,380	8,030	7,790	7,640	9,050	7,760	7,865	6,400	9,220	14,705	8,385
Average	5,148	6,403	6,596	6,715	6,436	7,517	5,311	6,489	5,578	7,158	9,907	6,660
Minimum	4,510	5,580	5,010	5,640	5,090	6,330	4,160	5,100	4,210	5,330	6,390	5,214
Sugi of Yoshino.												
Maximum	5,840	6,410	7,500	5,940	7,280	6,080	7,510	7,790	8,260	8,230	13,200	7,640
Average	4,987	5,481	5,446	5,118	5,591	5,275	5,732	6,205	6,831	6,827	8,415	5,992
Minimum	3,780	4,280	3,680	4,080	3,730	4,250	4,390	5,010	4,950	4,390	6,480	4,456
Sugi of Owashi.												
Maximum	6,190	4,860	5,610	5,145	5,060	4,830	6,775	5,340	7,140	5,640	11,120	6,155
Average	4,068	3,598	4,348	3,688	4,111	4,021	4,405	4,049	5,350	6,048	5,783	4,497
Minimum	3,270	2,960	2,535	2,310	2,245	2,765	2,540	3,090	4,200	4,285	3,090	3,340
Sugi of Kiyosumi.												
Maximum	4,905	5,580	4,930	6,100	6,030	5,790	6,650	7,285	5,910	5,520	6,115	5,892
Average	4,322	4,961	4,556	5,237	5,043	4,674	5,041	5,655	5,107	4,796	5,461	4,987
Minium	3,455	4,410	4,340	3,870	3,335	3,450	4,240	4,800	4,390	4,335	4,670	4,118
Asunaro of Aomori.												
Maximum	6,495	5,510	6,230	6,580	6,390	6,660	6,680	7,830	8,285	9,660	10,500	7,347
Average	3,903	4,488	4,284	4,126	4,346	4,915	4,814	6,090	4,909	7,120	7,848	5,168
Minimum	2,420	3,910	2,470	2,965	3,475	3,290	3,480	4,040	3,680	4,410	5,935	4,035

TABLE II. MODULUS OF ELASTICITY (lbs. per sq. in.)

	Width X thickness (ins)											
	7 x 7	6 x 7	5 x 7	4 x 7	3 x 7	2 x 7	7 x 6	7 x 5	7 x 4	7 x 3	7 x 2	Total average
Hinoki of Kiso.												
Maximum	1,425,000	1,718,000	1,945,000	1,660,000	1,917,000	1,848,000	1,595,000	1,713,000	1,926,000	2,038,000	1,805,000	1,781,000
Average	1,208,000	1,448,000	1,508,000	1,405,000	1,564,000	1,521,000	1,422,000	1,325,000	1,789,000	1,787,000	1,536,000	1,501,000
Minimum	1,079,000	1,281,000	1,300,000	1,176,000	1,175,000	1,230,000	1,178,000	1,034,000	1,438,000	1,610,000	1,470,000	1,270,000
Hinoki of Yoshino.												
Maximum	1,541,000	1,584,000	1,628,000	1,737,000	1,564,000	1,881,000	1,529,000	1,619,000	1,547,000	1,831,000	1,883,000	1,668,000
Average	1,324,000	1,419,000	1,275,000	1,366,000	1,347,000	1,310,000	1,358,000	1,471,000	1,374,000	1,488,000	1,310,000	1,370,000
Minimum	1,103,000	1,205,000	973,000	1,061,000	1,000,000	1,058,000	1,092,000	1,296,000	1,138,000	1,065,000	1,066,000	1,096,000
Hinoki of Owashi.												
Maximum	1,501,000	2,345,000	1,655,000	2,197,000	1,993,000	1,636,000	1,742,000	1,440,000	1,890,000	2,044,000	2,300,080	1,886,000
Average	1,320,000	1,488,000	1,396,000	1,476,000	1,650,000	1,409,000	1,505,000	1,322,000	1,351,000	1,633,000	1,346,000	1,445,000
Minimum	1,116,000	1,155,000	1,128,000	1,062,000	934,000	1,160,000	1,212,000	1,255,000	1,145,000	1,220,000	1,084,000	1,134,000
Akamatsu of Mito.												
Maximum	1,483,000	2,258,000	2,409,000	1,658,000	1,887,000	2,159,000	1,909,000	1,832,000	1,700,000	1,980,000	2,525,000	1,980,000
Average	1,274,000	1,627,000	1,822,000	1,314,000	1,455,000	1,660,000	1,488,000	1,443,000	1,411,000	1,503,000	1,504,000	1,500,000
Minimum	1,029,000	1,142,000	1,226,000	1,068,000	1,274,000	1,329,000	1,129,000	1,137,000	1,130,000	1,110,000	983,000	1,141,000
Sugi of Yoshino.												
Maximum	1,757,000	1,562,000	2,254.000	1,466,000	1,988,000	1,686,000	1,643,000	1,909,000	1,613,000	1,725,000	2,112,000	1,792,000
Average	1,299,000	1,545,000	1,454,000	1,213,000	1,492,000	1,408,000	1,396,000	1,378,000	1,392,000	1,509,000	1,422,000	1,410,000
Minimum	1,065,000	943,000	1,176,000	923,000	1,168,000	1,206,000	1,086,000	962,000	1,160,000	683,000	1,053,000	1,039,000
Sugi of Owashi.												
Maximum	1,421,000	1,148,000	1,770,000	1,193,000	1,201,000	1,025,000	1,418,000	1,202,000	1,500,000	2,651,000	2,338,000	1,533,000
Average	1,188,000	970,000	1,514,000	997,000	1,112,000	915,000	1,093,000	878,000	1,220,000	1,509,000	1,526,000	1,175,000
Minimum	770,000	866,000	582,000	669,000	765,000	821,000	869,000	629,000	1,030,000	885,000	989,000	807,000
Sugi of Kiyosumi.												
Maximum	1,147,000	1,482,000	1,211,000	1,437,000	1,374,000	1,356,000	1,758,000	1,352,000	1,103,000	1,218,000	1,590,000	1,366,000
Average	874,000	1,253,000	1,004,000	1,251,000	1,172,000	1,180,000	1,258,000	1,087,000	984,000	1,010,000	1,115,000	1,108,000
Minimum	758,000	912,300	848,000	930,000	886,000	909,000	832,000	927,000	805,000	802,000	736,000	850,000
Asunaro of Aomori.												
Maximum	1,700,000	1,344,000	1,556,000	16,64,000	1,333,000	1,712,000	1,388,000	1,958,000	1,210,000	1,756,000	1,888,000	1,592,000
Average	1,066,000	1,002,000	1,065,000	1,192,000	982,000	1,065,000	1,086.000	1,321,000	1,113,000	1,067,000	1,506,000	1,133,000
Minimum	731,000	581,000	781,000	732,000	706,000	701,000	776.000	918,000	794,000	576,000	1,009,000	755,000

TABLE III.

THE AMOUNT OF WORK DONE, DIVIDED BY THE DEFLECTION AT THE MOMENT OF RUPTURE (inch-pounds.)

	Width X thickness (ins.)											Total average
	7 x 7	6 x 7	5 x 7	4 x 7	3 x 7	2 x 7	7 x 6	7 x 5	7 x 4	7 x 3	7 x 2	
Hinoki of Kiso.												
Maximum	12,125	11,730	8,880	7,890	6,510	4,590	9,870	6,790	5,340	2,925	2,130	7,162
Average	10,980	8,063	7,744	5,859	5,115	3,226	7,888	5,717	4,515	2,500	1,294	5,718
Minimum	10,010	5,825	6,245	3,795	3,770	1,740	6,435	4,640	3,630	2,100	755	4,149
Hinoki of Yoshino.												
Maximum	10,000	11,700	7,780	4,680	4,915	2,660	8,560	6,360	3,545	2,870	1,235	5,846
Average	8,794	9,045	5,970	4,567	4,160	2,350	6,726	5,657	3,327	2,206	937	4,885
Minimum	7,440	6,080	4,830	4,440	3,310	1,910	5,615	5,140	3,230	1,580	660	4,021
Hinoki of Owashi.												
Maximum	12,010	10,400	11,500	5,790	6,850	3,460	10,200	5,310	5,260	2,540	9,850	7,561
Average	8,726	7,023	7,445	4,693	4,418	2,378	7,600	4,605	4,002	2,188	888	4,906
Minimum	4,820	4,130	5,270	3,940	2,610	1,720	6,270	3,560	3,100	1,840	575	3,440
Akamatsu of Mito.												
Maximum	12,420	10,700	10,800	6,380	3,880	3,500	8,190	5,880	3,270	2,430	1,290	6,249
Average	8,606	8,402	7,112	5,580	3,700	2,900	5,508	4,690	2,540	1,934	992	4,724
Minimum	7,190	6,480	4,860	4,430	3,360	2,240	4,350	3,640	2,000	1,570	710	3,728
Sugi of Yoshino.												
Maximum	9,680	9,640	9,850	4,900	4,820	2,530	8,700	6,350	3,880	2,520	1,070	5,813
Average	8,252	7,554	6,286	4,389	3,530	2,289	6,814	4,773	3,226	1,762	793	4,515
Minimum	6,530	5,900	4,720	3,020	2,460	1,760	4,800	3,480	2,720	1,270	495	3,378
Sugi of Owashi.												
Maximum	10,370	6,440	6,870	4,420	4,005	2,270	6,655	3,515	3,210	2,135	1,180	4,643
Average	7,338	4,744	4,930	3,257	2,975	1,903	4,794	3,034	2,768	1,816	716	3,480
Minimum	6,000	3,755	2,990	2,490	1,470	1,345	3,335	2,720	2,505	1,435	535	2,598
Sugi of Kiyosumi.												
Maximum	9,020	7,775	7,050	5,660	4,380	2,580	8,155	5,555	2,695	1,955	745	5,052
Average	7,034	7,086	5,447	4,794	3,915	2,088	6,042	4,444	2,346	1,582	671	4,132
Minimum	5,520	5,095	4,340	3,500	2,805	1,655	4,365	3,310	2,035	1,180	560	3,124
Asunaro of Aomori.												
Maximum	10,600	6,450	5,670	5,190	3,480	1,930	6,650	5,960	3,660	2,260	1,060	4,810
Average	5,741	5,594	4,201	3,414	2,330	1,584	5,358	4,214	2,275	1,743	718	3,379
Minimum	2,660	4,880	2,710	2,600	1,800	1,390	3,720	2,780	1,540	1,180	410	2,334

TABLE IV. DEFLECTION IN INCHES OF THE BEAM PER UNIT LOAD (ton)

	Width X thickness (ins.)											
	7 x 7	6 x 7	5 x 7	4 x 7	3 x 7	2 x 7	7 x 6	7 x 5	7 x 4	7 x 3	7 x 2	Total Average
Hinoki of Kiso.												
Maximum	0.15	0.16	0.22	0.25	0.38	0.68	0.27	0.50	0.78	1.80	—	0.52
Average	0.14	0.15	0.18	0.22	0.24	0.49	0.23	0.39	0.66	1.56	—	0.43
Minimum	0.13	0.14	0.14	0.20	0.22	0.35	0.20	0.32	0.56	1.25	—	0.35
Hinoki of Yoshino.												
Maximum	0.20	0.20	0.28	0.36	0.48	0.80	0.30	0.44	1.18	2.70	—	0.69
Average	0.17	0.18	0.25	0.30	0.40	0.67	0.27	0.41	0.91	2.10	—	0.57
Minimum	0.15	0.16	0.19	0.24	0.35	0.50	0.23	0.36	0.72	1.64	—	0.45
Hinoki of Owashi.												
Maximum	0.17	0.20	0.27	0.35	0.48	0.76	0.28	0.48	1.04	2.22	—	0.63
Average	0.15	0.15	0.21	0.25	0.34	0.60	0.24	0.46	0.80	1.86	—	0.51
Minimum	0.13	0.11	0.18	0.16	0.26	0.45	0.21	0.42	0.62	1.50	—	0.40
Akamatsu of Mito.												
Maximum	0.18	0.22	0.24	0.32	0.41	0.62	0.30	0.52	1.01	2.57	—	0.64
Average	0.16	0.16	0.17	0.24	0.35	0.49	0.25	0.44	0.90	2.06	—	0.52
Minimum	0.14	0.13	0.13	0.12	0.29	0.38	0.18	0.30	0.68	1.48	—	0.38
Sugi of Yoshino.												
Maximum	0.20	0.26	0.25	0.38	0.44	0.81	0.30	0.57	1.08	2.50	—	0.68
Average	0.17	0.18	0.22	0.31	0.37	0.66	0.25	0.44	0.94	2.23	—	0.58
Minimum	0.13	0.17	0.15	0.26	0.32	0.52	0.21	0.31	0.75	2.10	—	0.49
Sugi of Owashi.												
Maximum	0.28	0.27	0.28	0.37	0.48	0.80	0.50	1.20	1.60	2.84	—	0.86
Average	0.20	0.22	0.24	0.33	0.40	0.75	0.34	0.82	1.09	2.29	—	0.67
Minimum	0.15	0.19	0.16	0.29	0.36	0.68	0.24	0.58	0.87	1.86	—	0.54
Sugi of Kiyosumi.												
Maximum	0.26	0.25	0.30	0.34	0.50	0.98	0.36	0.52	1.42	3.70	—	0.86
Average	0.23	0.20	0.28	0.29	0.39	0.76	0.27	0.48	1.48	2.96	—	0.73
Minimum	0.16	0.16	0.23	0.24	0.32	0.60	0.20	0.42	1.08	2.34	—	0.58
Asunaro of Aomori.												
Maximum	0.27	0.44	0.40	0.57	0.74	1.10	0.48	0.65	1.36	2.80	—	0.88
Average	0.20	0.28	0.31	0.37	0.57	0.89	0.36	0.51	1.20	1.57	—	0.63
Minimum	0.12	0.22	0.22	0.30	0.38	0.68	0.24	0.34	0.68	0.50	—	0.37

DETERMINATION OF THE CALORIFIC POWER OF WOOD

By KITARO MOROTO, Assistant Professor

In the present trial, Berthier's litharge method was adopted to determine the amount of heat evolved by woods of different species. For simplicity's sake, the wood was considered as a mass of carbon alone, so that the one rich in hydrogen, produced far smaller figures than the real heat possessed by it. Wood which contained a large quantity of water on the other hand gave an excessively high figure owing to failure to calculate the amount of heat needed for the evaporation of this moisture.

Two grams of saw-dust of every kind of wood and 50 grams of lead oxide were put into a clay crucible and well mixed. To prevent free access of air, 30 grams more of lead oxide was introduced, to fully cover the mixture. The crucible was then closed with the lid and heated in a charcoal fire; when the perfect fusion of the contents had taken place, the crucible was taken from the fire and the weight of the reduced lead was taken, to which the multiplying factor of 117 was applied. The product thus obtained gives the quantity of heat evolved by the different wood species tried. Below we give the amount of heat produced by 1 gram of the various species.

THE AMOUNT OF HEAT PRODUCED BY 1 GRAM OF THE VARIOUS SPECIES

SPECIES	Carolie
Icho (*Ginkgo biloba, L.*)	3,802.5
Nagi (*Podocarpus Nageia, Zoll. et Moritz.*)	3,451.5
Inumaki (*Podocarpus macrophylla, D. Don.*)	3,568.5
Araragi (*Taxus cuspidata, S. et Z.*)	4,001.4
Kaya (*Torreya nucifera, S. et Z.*)	2,106.0
Inugaya (*Cephalataxus drupacea, S. et Z.*)	3,685.5

THE AMOUNT OF HEAT PRODUCED BY 1 GRAM OF THE VARIOUS SPECIES, CONTINUED

SPECIES	Calorie
Akamatsu (*Pinus densiflora, S. et Z.*)	2,223.0
Kuromatsu (*Pinus Thunbergii, Parl.*)	3,393.0
Himekomatsu (*Pinus parviflora, S. et Z.*)	3,627.0
Goyomatsu (*Pinus pentaphylla, Mayr.*)	3,650.4
Chosenmatsu (*Pinus koraiensis, S. et Z.*)	2,281.5
Tōhi (*Picea hondoensis, Mayr.*)	3,159.0
Iramomi (*Picea bicolor, Mayr.*)	3,416.4
Akayezomatsu (*Picea Glehni, Mayr.*)	3,568.5
Togasawara (*Tsuga japonica, Shiras.*)	2,492.1
Kometsuga (*Tsuga diversifolia, Maxim.*)	2,281.5
Momi (*Abies firma, S. et Z.*)	3,638.7
Hesomomi (*Abies umbellata, Mayr.*)	3,123.9
Shirabe (*Abies Veitchii, Lindl.*)	3,685.5
Todomatsu (*Abies sachalinensis, Mast.*)	3,240.9
Koyamaki (*Sciadopytis verticillata, S. et Z.*)	3,135.6
Sugi (*Cryptomeria japonica, Don.*)	3,100.5
Asunaro (*Thujopsis dolabrata, S. et Z.*)	3,276.0
Nezuko (*Thuja japonia, Maxim.*)	1,813.5
Hinoki (*Chamaecyparis obtusa, S. et Z.*)	3,861.0
Nezumisashi (*Juniperus rigida, S. et Z.*)	3,498.3
Byakushin (*Juniperus chinensis, L.*)	3,685.5
Sawagurumi (*Pterocarya rhoifolia, S. et Z.*)	3,393.0
Onigurumi (*Juglans Sieboldiana, Maxim.*)	3,240.9
Himegurumi (*Juglans Sieboldian, Max. var. cordiformis, Mak.*)	3,568.5
Yamamomo (*Myrica rubra, S. et Z.*)	3,428.1
Dero (*Populus balsamifera, L. var. suaveolens, Loud.*)	3,159.0
Yamanarashi (*Populus tremula, L. var villosa, Wesm.*)	2,948.4
Kawayanagi (*Salix purpurea, L. var. sericea, Wimm.*)	3,486.6
Sawashiba (*Carpinus cordata, Bl.*)	3,334.5
Kumashide (*Carpinus japonica, Bl.*)	3,147.3
Inushide (*Carpinus yedoensis, Max.*)	3,334.5
Akashide (*Carpinus laxiflora, Bl.*)	2,726.1
Shirakamba (*Betula alba, L. var. vulgaris, DC.*)	3,334.5
Makamba (*Betula Bhojpattra, Wall. var. japonica, Shir,*)	3,568.5
Ono-ore (*Betula dahurica, Pall.*)	2,024.1
Yogusominebari (*Betula ulmifolia, S. et Z.*)	3,508.5
Hannoki (*Alnus japonica, S. et Z.*)	3,451.5
Yamahannoki (*Alnus incana, Willd. var. sibirica, Spach.*)	3,451.5
Miyamahannoki (*Alnus alnobetula, Hartig. var. fruticosa, Reg.*)	3,393.0
Buna (*Fagus sylvatica, L. var. Sieboldi, Max.*)	3,276.0
Inubuna (*Fagus japonica, Max.*)	2,808.0
Kuri (*Castanea sativa, Mill.*)	3,217.5

THE AMOUNT OF HEAT PRODUCED BY 1 GRAM OF THE VARIOUS SPECIES, CONTINUED

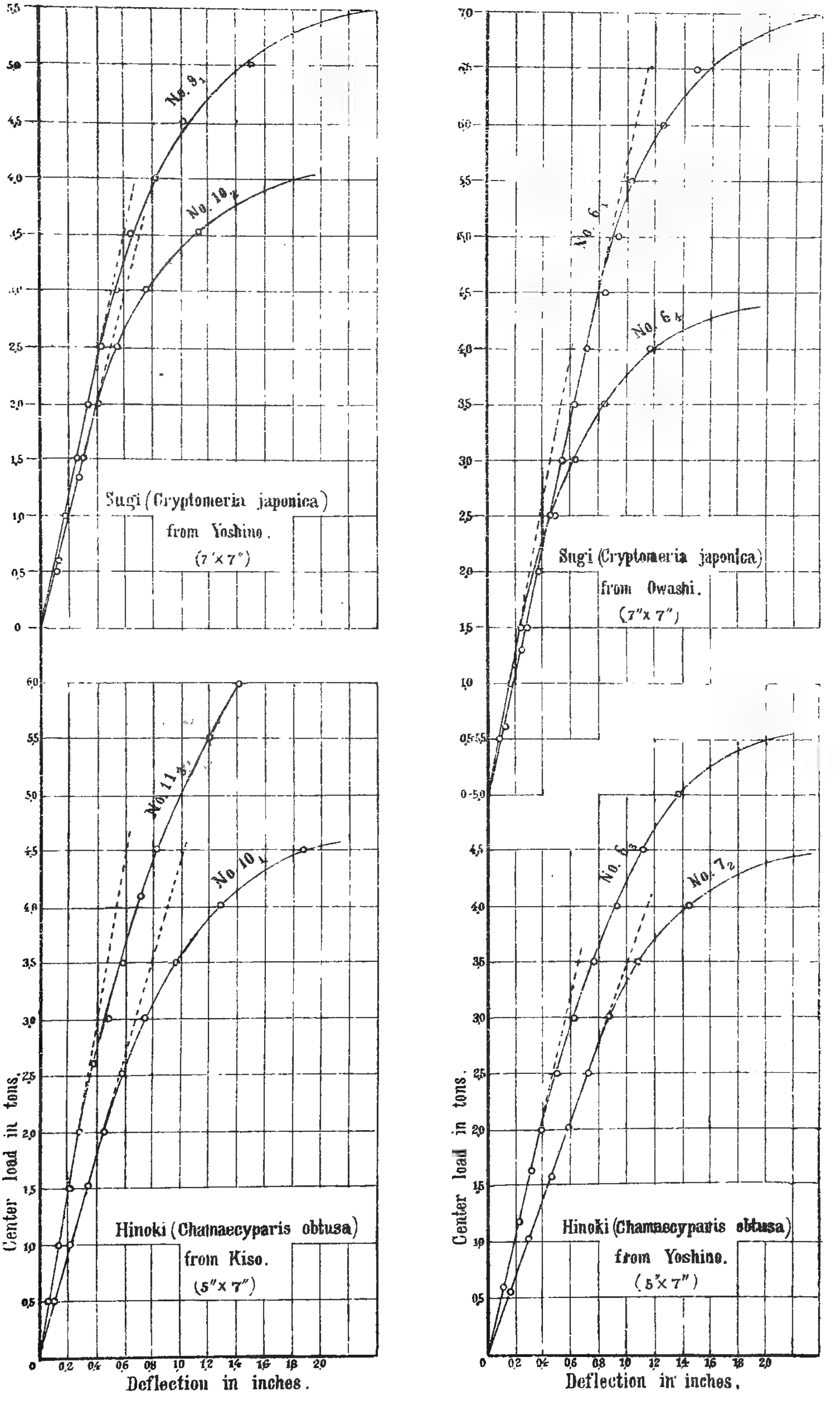
SPECIES	Calorie
Shii (*Pasania cuspidata, Oerst.*)	3,042.0
Shiribukagashi (*Pasania glabra, Oerst.*)	3,451.5
Kashiwa (*Quercus dentata, Th.*)	3,357.9
Kunugi (*Quercus serrata, Th.*)	2,515.5
Abemaki (*Quercus serrata, Th. var, chinensis, Miq.*)	3,428.1
Onara (*Quercus crispula, Bl.*)	2,457.0
Konara (*Quercus glandulifera, Bl.*)	3,334.5
Akagashi (*Quercus acuta, Th.*)	3,276.0
Ichiigashi (*Quercus gilva, Bl.*)	2,925.0
Shirakashi (*Quercus myrsinaefolia, Bl.*)	2,106.0
Urajirogashi (*Quercus glauca, Th. var. stenophylla, Bl.*)	2,457.0
Ubamegashi (*Quercus Ilex, L. var. phylliraeoides, Franch.*)	2,925.2
Harunire (*Ulmus campestris, Sm. var. laevis, Planch.*)	3,182.4
Kobunire (*Ulmus campestris, Sm. var. vulgaris, Planch.*)	3,393.0
Niganire (*Ulmus campestris, Sm. var. major, Planch.*)	2,831.4
Ohyonire (*Ulmus montana, Sm. var. laciniata, Trautv.*)	3,182.4
Akinire (*Ulmus parvifolia, Jacq*)	3,276.0
Yenoki (*Celtis sinensis, Pers.*)	3,240.9
Keyaki (*Zelkowa acuminata, Pl.*)	3,334.5
Yamaguwa (*Morus alba, L. var stylosa, Bureau.*)	3,240.9
Shimaguwa (*Morus alba, L. var indica, Bureau.*)	3,627.0
Gajimaru (*Ficus retusa, L. var. nitida, Miq.*)	2,574.0
Ho-no-ki (*Magnolia hypoleuca, S. et Z. var. concolor, Miq.*)	1,175.5
Kobushi (*Magnolia Kobus, DC.*)	3,568.5
Ogatama (*Michelia compressa, Max.*)	3,416.4
Shikimi (*Illicium anisatum, L.*)	2,889.9
Katsura (*Cercidiphyllum japonicum, S. et Z.*)	1,345.5
Fusazakura (*Euptelaea polyandra, S. et Z.*)	3,334.5
Yamaguruma (*Trochodendron aralioides, S. et Z.*)	3,030.3
Kusu (*Cinnamomum Camphora, Nees. et Eberm.*)	4,352.4
Yabunikkei (*Cinnamomum pedunculatum, Nees.*)	3,568.5
Tamagusu (*Machilus Thunbergii, S. et Z.*)	1,427.4
Awokagonoki (*Actinodaphne acuminata, Meisn.*)	3,334.5
Aburachan (*Lindera praecox, Bl.*)	3,205.8
Kanakuginoki (*Lindera Thunbergii, Mak.*)	3,501.0
Utsugi (*Deutzia scabra, Th. var. crenata, Mak.*)	3,100.5
Isu (*Distylium racemosum, S. et Z.*)	3,100.5
Nashi (*Pirus sinensis, Lindl.*)	3,006.9
Ozumi (*Malus baccata, Desf. var. mandshurica, Max. f. Zumi, Matsum.*)	2,808.0
Azukinashi (*Micromeles alnifolia, Hedl.*)	3,240.9
Ushikoroshi (*Photnia villosa, DC.*)	3,240.9
Yamazakura (*Prunus Jamasakura, Sieb. var spontanea, Max.*)	1,889.0

THE AMOUNT OF HEAT PRODUCED BY 1 GRAM OF THE VARIOUS SPECIES, CONTINUED

SPECIES.	Calorie
Inuzakura (*Prunus Buergeriana, Mig.*)	3,685.5
Rimboku (*Prunus spinulosa, S. et Z.*)	3,568.5
Ume (*Prunus Mume, S. et Z.*)	3,451.5
Saikachi (*Gleditschia horrida, Mak.*)	4,469.2
Fujiki (*Cladrastis platycarpa, Mak.*)	3,276.0
Sansho (*Xanthoxylum piperitum, DC.*)	3,474.9
Karasuzansho (*Fagara ailanthoides, Engl.*	3,217.5
Kiwada (*Phellodendron amurensis, Rupr.*)	1,579.5
Nigaki (*Picrasma quassioides, Benn.*)	3,159.0
Chanchin (*Toona sinensis, Roem.*)	3,159.0
Tsuge (*Buxus sempervirens, L.*)	3,568.5
Urushi (*Rhus vernicifera, DC.*)	3,533.4
Haze (*Rhus succedanea, L.*)	3,217.5
Inutsuge *Inutsuge* (*Ilex crenata, Th.*)	3,334.5
Aohada (*Ilex dubia, Trel.*)	3,510.0
Tarayo (*Ilex latifolia, Th.*)	3,100.5
Kayede (*Acer palmatum, Thunb,*).	3,393.0
Itayakayede (*Acer pictum, Thunb. var. typicum. Graf. subvar. eupictum, Pax.*)	3,334.5
Urihadakayede (*Acer rufinerve, S. et Z.*)	3,451.5
Marubakayede (*Acer distylum, S. et Z.*)	3,147.3
Tochinoki (*Aesculus turbinata, Blume.*)	3,510.0
Awabuki (*Meliosma myriantha, S. et Z.*)	3,042.0
Obashinanoki (*Tilia Maximowicziana, Shiras.*)	3,006.9
Aogiri (*Sterculia platanifolia, L.*)	3,334.5
Tsubaki (*Thea japonica, Nois.*)	3,334.5
Saruta (*Stewartia monadelpha, S. et Z.*	3,685.5
Sakaki (*Eurya ochnacea, Szyse.*)	2,316.6
Hisakaki (*Eurya japonica, Thunb. var. Thunbergii, Thw,*)	3,451.5
Koshiabura (*Kalopanax sciadophylloides, Harms.*)	2,655.9
Harigiri (*Kalopanax ricinifolium, Miq.*)	3,217.5
Aoki (*Aucuba japonica, Thunb*)	3,474.9
Ryobu (*Clethra barbinervis, S. et Z.*)	3,451.5
Mamegaki (*Diospyros Lotus, L.*)	3,240.9
Egonoki (*Styrax japonica, S. et Z.*)	3,276.0
Hakuumboku (*Styrax Obassia, S. et Z.*)	3,159.0
Toneriko (*Fraxinus Bungeana, DC. var. pubinervis, Wg.*)	3,627.0
Yachidamo (*Faxinus mandshurica, Rupr.*)	2,866.5
Ibotakoki (*Ligustrum Ibota, Sieb.*)	3,416.4
Chishakoki (*Ehretia buxifolia, Roxb.*)	3,416.4
Kiri (*Paulownia tomentosa, Bail.*)	3,486.6

PLATE I.

Stress-Strain Diagrams.



EXPERIMENT OF THE ELECTRIC RESISTANCE IN WOOD

By JUJIRO HIRUMA, Forest Expert

It is generally known that wood offers great resistance to the electric current but the resistance in no small degrees, is influenced by the quantity of moisture contained in the wood. Wood is since long time looked upon as an imperfect insulator but no experiment has been tried to determine its resistance.

The experiments undertaken by me to determine the resistance of wood to the electric current were tried on different species of wood in regard to the disposition of wood tissues, amount of moisture content and specific gravity.

I. Apparatus used for the Determination

Meg-ohm Normal Resistance Box; D'Arsonval's Galvanometer and Shunt.

II. Connection of Electric Poles with the Wood to be Tested

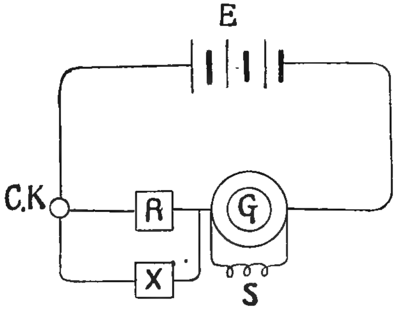
To ensure the close contact of electric poles with the wood to be tested, copper plates, copper gauze and tin-foil were first used. The experiments showed, however, that the resistance varied according to the amount of the different pressure used in bringing these materials in contact, thereby giving rise to apparent irregularities in the resistance of the wood. We, therefore, used mercury instead of the materials above named, and perfect contact was secured so that no irregularity arose. One end of the wood to be tested was dipped into a vessel filled with mercury while the other end was wrapped with insulating tape or fitted with a projecting wooden frame into which mercury was poured in. The two electric poles were then inserted in the upper and lower vessels of mercury.

III. Electro-motive Force

In the case of high resistance, the voltage should generally be equal to or twice or thrice as great as that which used for the material to be tested in practical use.

Since the present trial aims to determine the resistance of wood to electricity in general, no particular choice of voltage was considered necessary, so an ordinary direct current of 110 volts was applied.

IV. Measurement of Resistance



In the present measurements, the arrangement was as shown in the figure. The instruments used, were a D'Arsonval's Galvanometer, a Shunt, a Resistance box, a Change-over-key and Battery. Thus, d°, to be read by the inclination of the galvanometer.

Let resistance of galvanometer be G, resistance of the shunt S, resistance of resistance-box R, motive force of the battery E, its inner resistance b, and constant of the galvanometer K (by constant K we mean the circuit resistance necessary to produce the inclination of one grade on galvanometer by the voltage applied). We obtain:—

$$d^\circ : \frac{E}{R+\frac{GS}{G+S}+b} \times \frac{S}{G+S} = 1^\circ : \frac{E}{K}$$

$$K = d\ \left(R+\frac{GS}{G+S}+b\right)\ \frac{G+S}{S}$$

Let *n* indicate multiplying factor of the shunt. So long as the resistances of the galvanometer and of the inner part of the battery are small compared with the other resistance, the two last values in the bracket can practically be neglected, so we obtain $K=dRn$, $n=\frac{G+S}{S}$

In place of resistance-box, the test specimen X will be connected by change-over-key, to read the inclination of the galvanometer. Then the factor of the shunt will be known as n_1, and angle of inclination d_1, resistance needed x. We obtain:—

$$x=\frac{K}{d_1 n_1}=\frac{d}{d_1}\ R\ \frac{n}{n_1}$$

V. Wood to be Tested

Woods to be tested were cut into cubes having cross, radial and tangential sections taken from the nearly same part for every species chosen.

(A) A Cube measuring 4 cm was tested for its resistance in three different directions.

(B) A cube of 3 cm was varnished on 4 sides to prevent the change subsequent to moisture content during the determination. Two opposite sides, either cross, radial or tangential sections were left unvarnished.

VI. Relation between Electric Resistance and Quantity of Moisture Content in the Wood

The quantity of moisture contained in the wood and its distribution bear a direct relation to the resistance. Thus, wood almost absolutely deprived of its moisture offers high resistance to the current; and for such specimen a current of 100 volts is quite inadequate to determine the resistance. The resistance to electricity decreases, however, as the moisture in the wood increases. That the resistance of wood to electricity is directly governed by the moisture therein contained is best shown by reference to Table III. Especially, careful notice shows change in resistance due to variation in moisture found on the surface of wood which is so easily affected by exterior physical condition. The disproportion of resistance to the moisture content as shown in Tables I and II, is due to the change in amount of moisture on the surface of wood during the experiment. Since the moisture of the surface of wood is constantly influenced by the surrounding conditions, the resistance of wood to electricity can hardly be determined and the figures given below are only the approximate one.

VII. Relation Existing between Direction of Wood Tissues and Electric Resistance

(1) The cross section of the wood has the least resistance (cf. Tables I and II).

(2) The radial section of the wood has the great resistance (do).

(3) The differences in resistance between the cross and radial section of wood are generally more remarkable in the case of broad-leaved species such as Shirakashi *(Quercus myrsinæfolia, Bl.)*, Buna *(Fagus sylvatica. L. var. Sieboldi. Maxim.)*, Sakura *(Prunus Yamasakura, Sieb. var. Spontanea, Max.)* and Nara *(Quercus crispula, Bl.)* than in the case of Sugi *(Cryptomeria japonica, Don.)*, Hinoki *(Chamaecyparis obtusa, S. et Z.)*, Akamatsu *(Pinus densiflora, S. et Z.)* and other coniferous trees.

VIII. Electric Resistance of Woods and Specific Gravity

Woods having high specific gravity offer far less resistance than those having low specific gravity, so long as the amount of moisture content is same.

TABLE I.

Species	Number of observations	Spacific gravity over-dry	Moisture content %	Resistance in meg-ohms			Remarks
				Direction of tissues			
				Cross section	Radial section	Tangential section	
Shirakashi (*Quercus myrsinaefolia, Bl.*)	I	0.780	15.3	1.20	7.40	4.50	The wood tested was in cubes of 4 cm; 5 cubes were tested for each species.
	II	—	14.8	1.48	8.50	5.40	
	III	—	14.7	1.94	12.17	7.35	
	IV	—	15.3	1.30	7.66	4.11	
	Average	—	15.0	1.48	8.93	5.34	
	Against the resistance of cross section taken as 1...	—	—	1.00	6.00	3.60	
Buna (*Fagus sylvatica, L. var. Sieboldi, Max.*)	I	0.587	16.1	1.90	9.81	4.22	
	II	—	15.9	1.74	8.62	4.02	
	III	—	15.7	2.71	13.58	6.02	
	IV	—	16.6	1.89	8.96	4.54	
	Average	—	16.1	2.06	10.24	4.70	
	Against the resistance of cross section taken as 1...	—	—	1.00	4.46	2.27	
Sugi (*Cryptomeria japonica, Don.*)	I	0.320	16.8	0.85	2.29	1.83	
	II	—	16.6	0.89	2.21	1.81	
	III	—	16.6	1.43	4.06	3.27	
	IV	—	17.3	0.97	2.55	2.23	
	Average	—	16.8	1.04	2.78	2.29	
	Against the resistance of cross section taken as 1...	—	—	1.00	2.67	2.20	
Akamatsu (*Pinus densiflora S. et Z.*)	I	0.503	17.5	4.60	11.01	10.93	
	Against the resistance of cross section taken as 1...	—	—	1.00	2.39	2.35	
Nara (*Quercus crispula, Bl.*)	I	0.557	17.1	1.49	5.81	3.45	
	Against the resistance of cross section taken as 1...	—	—	1.00	3.90	2.32	
Hinoki (*Chamaecyparis obtusa, S. et Z.*)	I	0.362	15.4	10.73	38.52	35.36	
	Against the resistance of cross section taken as 1...	—	—	1.00	3.58	3.29	
Mizume (*Betula carpinifolia, S. et Z.*)	I	0.597	19.3	1.66	7.58	5.78	
	Against the resistance of cross section taken as 1...	—	—	1.00	4.56	3.48	
Isu (*Distylium racemosum, S. et Z.*)	I	0.710	25.6	1.58	0.626	0.441	
	Against the resistance of cross section taken as 1...	—	—	1.00	3.96	2.79	

TABLE II.

Species	No. of observations	RESISTANCE Cross section Specific gravity over-dry	 Cross section Moisture content, %	 Cross section Resistance in meg-ohms	 Radial section Specific gravity over-dry	 Radial section Moisture content, %	 Radial section Resistance in meg-ohms	 Tangential section Specific gravity over-dry	 Tangential section Moisture content, %	 Tangential section Resistance in meg-ohms	Remarks
Kiri (*Paulownia tomentosa, Bail.*)	I	0.230	10.5	267.17	0.236	11.6	723.67	0.238	11.0	473.83	The wood tested was in a cube of 3 cm; varnished9 cubes were tested for each species; three for each of cross, radial and tangential sections.
	II	—	10.8	259.67	—	11.4	767.30	—	11.0	573.33	
	Average	—	10.7	264.42	—	11.5	745.49	—	11.0	523.58	
	Against the resistance of cross section taken as 1.	—	—	1.00	—	—	2.82	—	—	1.98	
Sakura (*Prunus Yamasakura, Sieb. var. Spontanea, Max.*)	I	0.590	13.3	75.47	0.582	13.6	288.67	0.597	14.1	227.17	
	II	—	13.0	80.30	—	13.3	240.00	—	13.7	168.63	
	Average	—	13.2	77.89	—	13.5	264.34	—	13.9	197.90	
	Against the resistance of cross section taken as 1.	—	—	1.00	—	—	3.39	—	—	2.54	
Nara (*Quercus crispula, Bl.*)	I	0.627	14.5	18.88	0.633	14.1	64.37	0.628	14.6	28.85	
	II	—	14.2	15.12	—	14.2	53.67	—	14.4	23.90	
	Average	—	14.4	17.00	—	14.2	59.02	—	14.5	26.37	
	Against the resistance of cross section taken as 1.	—	—	1.00	—	—	3.47	—	—	1.55	
Shirakashi (*Quercus myrsinaefolia, Bl.*)	I	0.775	13.0	8.41	0.785	13.6	54.16	0.766	13.8	45.50	
	II	—	13.4	8.54	—	13.3	40.70	—	13.4	28.23	
	Average	—	13.2	8.48	—	13.5	47.43	—	13.6	36.87	
	Against the resistance of cross section taken as 1.	—	—	1.00	—	—	5.59	—	—	4.34	
Hinoki (*Chamaecyparis obtusa S. et Z.*)	I	0.444	13.0	59.70	0.444	14.2	127.50	0.440	14.7	129.03	
	II	—	12.8	28.23	—	14.0	88.73	—	14.1	104.93	
	Average	—	12.9	43.97	—	14.1	108.17	—	14.4	116.98	
	Against the resistance of cross section taken as 1.	—	—	1.00	—	—	2.48	—	—	2.66	
Sugi (*Cryptomeria japonica, Don.*)	I	0.307	14.3	6.43	0.307	16.0	15.40	0.307	16.5	14.33	
	II	—	13.9	4.19	—	15.6	12.47	—	16.3	10.76	
	Average	—	14.1	5.31	—	15.8	13.94	—	16.4	12.55	
	Against the resistance of cross section taken as 1.	—	—	1.00	—	—	2.62	—	—	2.36	
Asunaro (*Thujopsis dolabrata, S. et Z.*)	I	0.374	15.7	68.37	0.379	14.7	242.17	0.385	14.5	156.63	
	II	—	14.4	51.70	—	13.9	163.67	—	14.4	94.53	
	Average	—	15.1	60.04	—	14.3	202.90	—	14.5	125.58	
	Against the resistance of cross section taken as 1.	—	—	1.00	—	—	2.98	—	—	2.09	

TABLE III

Species	Tested wood	Specific gravity	RESISTANCE						Remarks
			Cross section		Radial section		Tangential section		
			Moisture content %.	Resistance in meg-ohms	Moisture content %.	Resistance in meg-ohms	Moisture content %.	Resistance in meg-ohms	
Shirakashi	A	0.780	15.1	5.92	15.1	35.72	15.1	21.36	The present table shows the resistance of various wood of 1cc calculated from the average data given on Table I and II.
	B	0.775	13.2	25.44	13.5	142.29	13.6	110.61	
Nara	A	0.557	17.1	5.96	17.1	23.24	17.1	13.80	
	B	0.629	14.4	51.00	14.2	177.06	14.5	79.11	
Hinoki	A	0.362	15.4	42.92	15.4	154.08	15.4	141.44	
	B	0.443	12.9	131.91	14.1	324.51	14.4	350.94	
Sugi	A	0.320	16.8	4.16	16.8	11.12	16.8	9.16	
	B	0.307	14.1	15.93	15.8	41.82	16.4	37.67	

CHARCOAL BURNING IN JAPAN

By Dr. SHOZABURO MIMURA, Forest Expert

Charcoal is an article of particular importance in Japanese household owing to the construction of the houses without chimneys. The consumption of this wooden products amounts to some 1,000,000,000 kilos a year. To supply this, the coppice wood from an area of 5,000,000 *a.* is needed; that is, an enormous area of about 200,000,000 *a.* should be provided as reserve with a 40 years' rotation. This clearly shows that the charcoal industry and the means of improving it are matters of great importance in the study of forest economy.

Japanese charcoal is classified roughly as follows:—

(1) Kurosumi or "Black Charcoal."
(2) Shirosumi or "White Charcoal."

"Black charcoal" is a product which is perfectly carbonized in the kiln and which is taken out from it after the perfect extinction of the fire inside, by closing both the chimney and air passage. The product obtained is characterised by its peculiar black color, hence the name derived.

"White charcoal" is produced by unclosing the mouth as soon as the perfect carbonization of billets sets in to accelerate the oxidation process inside. By this process the temperature evolves to the red heat and the temperature of charring rises considerably, so producing harder charcoal. After the standing of red heated charcoal for some time, it is taken out from the kiln and a mixture of moist charcoal dust and ashes is spread over extinguishing the fire. In this process not only the bark of billets but also the outer parts are turned into ash forming a white coating, hence the name derived.

"Black charcoal" is generally soft and kindles easily but has weak burning power while "White charcoal" is characterised by its difficulty in kindling and its strong burning power.

In order to produce "White charcoal," naturally a stronger heat is needed for the carbonization and the kiln must therefore be strongly built. "Black charcoal" is generally burnt in an earthen kiln while the kiln for "White charcoal" should always be made of stone.

"Dogama-zumi" or "Earthen kiln charcoal" is the designation given to soft charcoal in contrast with hard charcoal which named "Ishigama-zumi" or "Stone kiln charcoal."

It would be more appropriate to classify the two methods as "Inside Kiln Extinction Method," in the case of "Black charcoal" and "Outside Kiln Extinction Method" for the production of "White charcoal" and this nomenclature is adopted in this treatise.

I. Construction of Japanese Charcoal Kilns

The charcoal burning in its primitive form in Japan dates back to somewhere between the 9th and 10th centuries. After gradual advance in the construction, the so-called "Ikeda Method" came into first existence on 1563; later the so-called "Bincho Method" and "Sakura Method" came also into use in 1687 and 1797 respectively. Of these, the "Ikeda Method" is somewhat dissimilar from the other two types of later device, and it is now but little used. Bincho and Sakura kilns are much alike in shape, and are only distinguished by the fact that more stone masonery is used in the former than in the latter and particularly by the double height of borders (*koshi*) of the former.

For sake of brevity we shall only mention the general constructions of the kiln which are common to both kinds.

The base of the kiln used in charcoal burning in the country is either oval or eliptical, dug out of the needed depth. In the case of a stone kiln, the bordering wall is made of massive stones, but in an earthen kiln only the mouth and flue passage are made of stones while the rest is of earth. Inside the kiln wall, billets are piled up endwise and upon these billets, small sized split wood is so disposed as to form a paraboidal dome. Over this, an earthen covering is put and is tramped down to make a perfect roof.

Through the mouth, the contents are gradually kindled so as to dry up the wood at the top first. After burning sometime a stronger fire is set up to ignite the billets forming the back of the roof. At the lower part of the mouth an air passage of 1–2 inches wide is left and the rest of it is closed gradually admitting necessary air to cause imperfect oxidation of the billets. The progress of the burning can best be distinguished by the color of smoke evolved.

In the "Inside Kiln Extinction Method" both air and flue passages are closed as soon as the carbonization is completed, and the product is taken out from the kiln after the perfect extinction of the fire.

In the "Outside Kiln Extinction Method," the lower part of the mouth is gradually opened in proportion to the progress of carbonization introducing the air into the kiln so as to elevate the temperature inside. Then the red heated charcoal is taken out, and over which, mixture of moist ash and charcoal dust is spread to extinguish the fire.

In the "Inside Kiln Extinction Method," one naturally aims to complete the cooling of the kiln as well as the production of perfectly formed charcoal so that the billets should be piled up with great care in the beginning while in the "Outside Kiln Extinction Method" billets are put at random into the still warm kiln.

II. Carbonization of Billets in the Kiln

It is of prime importance to know the direction of carbonization within the kiln in connection with the improvement of the construction of it. Limited knowledge on the subject was only known and indeed only on a few European kilns. "If the billets are kindled at the mouth of the kiln, fire will subsequently set into the hinder part thence, proceeding downward, and then it will gradually tend to burn the front." To establish this, we have taken out billets piled in the kiln at a regular interval of 24 hours till after the kindling to the complete carbonization. We came to the conclusion that the carbonization process of billets within a Japanese kiln, contrary to the hitherto accepted saying, "forces its way to the roof horizontally from the mouth and thence proceed downward in all directions."

III. On the Kindling Method

The methods of kindling so far known are two:—

1. To kindle at the mouth by the Burner. By this, kindling is easy but billets on the front part in the Kiln are firstly set into fire then perfect conbustion in that part follows, due to the access of air, to the subsequent increase of ash composition in the yield.

(2) Close the lower part of the mouth and then kindle from the above. Since the kindle hole is made at the top of the mouth kindling is troublesome and besides there is an undesirable large production of ashes not much different from the above case in percentage.

Owing to these disadvantages, we have arranged to shut up the lower portion of the mouth, and have succeeded in kindling from the upper portion by setting out the necessary eaves. As soon, however, as the fire attacks the billets under the roof of the kiln, the upper half of the mouth is likewise closed, allowing to pass the necessary draft through a small passage opened in the centre of the base. By this device, we could avoid the direct contact of the air with burning billets. Still, the air passage at the centre of the base often causes the excessive oxidation of the neighboring billets and conversion into ash, owing to the constant fall of scintillating charcoal dust from the roof. For this defect, two kilns were so combined into a set as to form an air passage at the centre of the two, and this happily well removed the disadvantage.

IV. Temperature of Carbonization

Owing to the various uses of charcoal in this country on one side and to the many tree species used for its material on the other, we are in possession of many grades of charcoal varying in hardness, ease of kindling, species of wood, and mode of fabrication. According to the researches of Violett, the igniting point of charcoal is proportional to the temperature of carbonization. Thus, charcoal produced at a low heat kindles readily at low temperature while that which was burnt at a high temperature requires a high heat to kindle it. Still, carbonization, unlike dry distillation of wood, is never brought about by heat from the outside. On the contrary, in carbonization the wood is oxidized by heat from itself, so that any regulation of that heat is hardly practicable. Such regulation is only effected in some extent by admitting air to the red heated charcoal in the kiln after carbonization.

In our researches, to establish the relation of the hardness and igniting point of charcoal, we have examined the carbonization temperature inside the kiln for the "Inside Kiln Extinction Method;" as well as for the "Outside Kiln Extinction Method" and the temperature observed at the moment of the introduction of air after the carbonization are as follows:—

(a) CARBONIZATION TEMPERATURE INSIDE THE KILN

(Inside Kiln Extinction Method)

Type of kiln	No. of molten Segelkegels			Heat from chimney, C°	Hours required for carbonization	Remarks
	Position I	Position II	Position III			
Fujisaki	—	—	—	87	49	
„	—	022	022	160	80	Billets at III slightly charred.
„	022	022	022	135	65	Billets at III turned into ash.
„	—	—	—	175	67	2 billets at III, turned into ash.
Tanaka	022 (half molten)	—	—	190	83	
„	—	022	—	230	84	Turned into ash up to 2.5 ft. from the mouth.
„	022	—	—	150	124	Heat of T earthen pipe.
„	022	022	022 (half molten)	170	104	Do.
„	022 021	022 019	022 021	250	73	Billets lying 1.5 ft. from the mouth turned into ash.

From this, we learn that in "Inside Kiln Extinction Method" the heat within the kiln does not exceed 600°C.

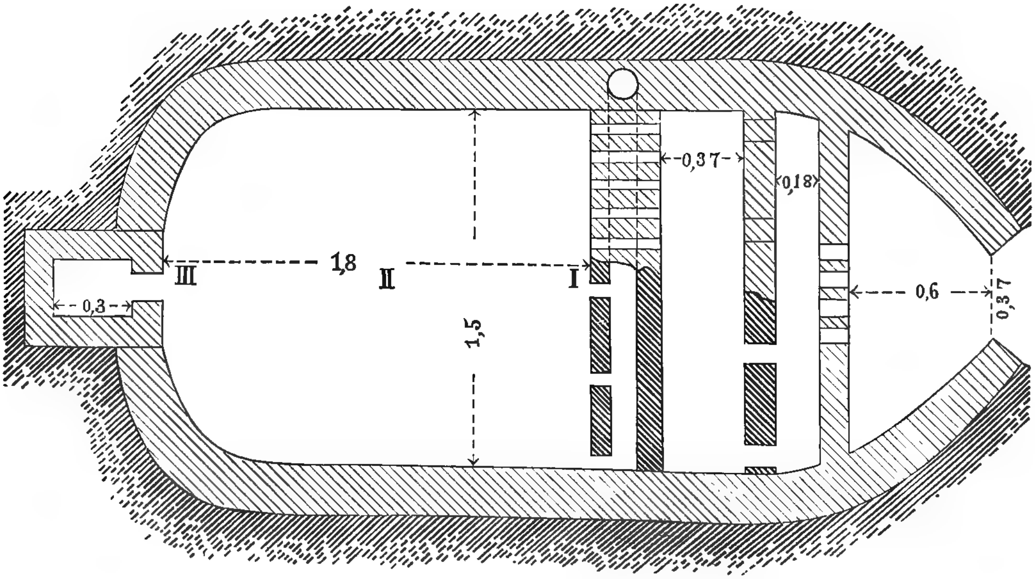


Fig. 1. Position of Segel-kegel introduced in Fujisaki Kiln.

(b) TEMPERATURE OBSERVED AT THE MOMENT OF THE INTRODUCTION OF AIR AFTER THE CARBONIZATION

(Outside Kiln Extinction Method)

Position	Number of unmolten Segelkegels (fusing point)			
Front	08a (940°)	08a (940°)	08a (940°)	08a (940°)
Centre	08a („)	08a (940°)	09a (920°)	8a (940°)
Back	08a („)	05a (1000°)	09a (920°)	8a (940°)

This will readily show that the "Nerashi" (Finishing ignition) in the "Outside Kiln Extinction Method" does not exceed 900°C.; this is doubtless due to the partial formation of carbon mono-oxide in place of carbon dioxide caused by the limited supply of air on the red heated charcoal in the kiln.

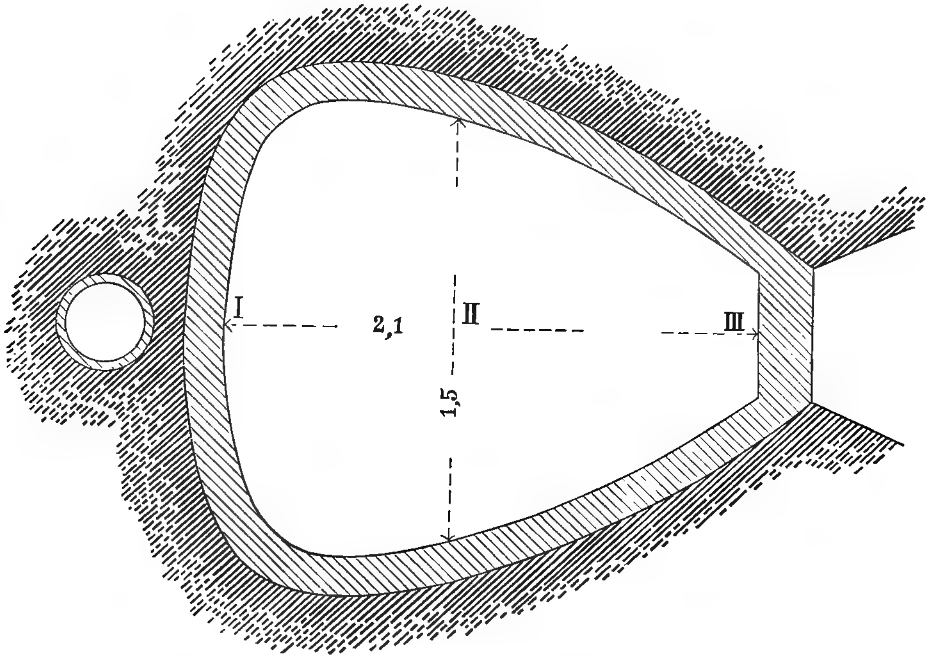


Fig. 2. Position of segel-kegel introduced in stone Kiln.

We can readily see from these tables that the temperature needed for the carbonization of charcoal in a Japanese kiln seldom exceeds 600°C.; and that the heat rises up to 900°C. where "Finishing ignition" is carried out. Further the billets of the same tree species burnt in the same kiln give rise either to Black or White charcoal. The latter product is distinguished from the former by the subsequent oxidation process.

V. Specific Gravity and Igniting Points of Charcoal

So long as charcoal is used for household purposes, the easily ignited product is much sought for, as two or three pieces of charcoal are always kept in a brazier (hibachi) for the smoking etc., to which indeed fetch fire at the presence of small splinters introduced. In urban districts where such easily kindled products naturally find a ready market, the charcoal burners try to produce the soft article while in remote upland districts, where means of transport are lacking, the harder product for smelting and industrial purposes is generally produced. Below, we give the results of our researches as to the specific gravity and igniting points of grades of charcoal produced from various tree species.

“White Charcoal”

(Produced by Outside Kiln Extinction Method)

Species	Specific gravity	Kindling point, C°
Quercus myrsinaefolia Bl.	1,597	619
Quercus acuta Thunb.	1,544	606
Quercus glandulifera Bl.	1,535	604
Quercus stenophylla Mak.	1,520	604
Quercus glauca Thunb.	1,492	603
Osmanthus Aquifolium B. et H.	1,478	581
Ligustrum Ibota Sieb.	1,471	580
Zelkowa acuminata Pl.	1,470	580
Prunus pseudo-cerasus Lindl. var. spontanea Max.	1,469	578
Illicium anisatum L.	1,458	588
Eurya ochnacea Szysz.	1,455	567
Torreya nucifera S. et Z.	1,452	556
Morus alba L. var. stylosa Bur.	1,451	554
Abies firma S. et Z.	1,450	553
Vaccinum bracteatum Thunb.	1,410	553
Cinnamomum pedunculatum Nees	1,340	544
Magnolia hypoleuca S. et Z.	1,338	540
Pasania Sieboldi Mak.	1,319	540
Mallotus japonicus Muell. Arg.	1,301	535
Actinodaphne acuminata Meisn.	1,296	504

“Black Charcoal”
(Produced by the “Inside Kiln Extinction Method”)

Species	Specific gravity	Kindling point C°
Stewartia pseudo-camellia Max.	1,494	603
Quercus glauca Thunb.	1,444	554
Quercus serrata Thunb.	1,354	544
Illicium Anisatum L.	1,353	538
Aphananthe aspera Planch.	1,309	531
Clethra barbinervis S. et Z.	1,289	519
Prunus pseudo-cerasus Lindl. var. spontanea Max.	1,286	515
Osmanthus Aquifolium B. et H.	1,273	510
Carpinus laxiflora Bl.	1,257	508
Stewartia monadelpha S. et Z.	1,249	498
Fraxinus Bungeana DC. var. pubinervis Wg.	1,244	495
Quercus glandulifera Bl.	1,242	493
Styrax japonica S. et Z.	1,216	488
Cornus macrophylla Wall.	1,216	487
Ilex integra Thunb.	1,202	480
Viburnum dilatatum Thunb.	1,195	479
Ilex pedunculosa Miq.	1,171	469
Quercus acuta Thunb.	1,169	465
Diervilla coraeensis DC.	1,166	464
Magnolia hypoleuca S. et Z.	1,115	461

VI. Amount of Heat evolved by Charcoal

The amount of heat produced by a given fuel greatly differs by the methods of its use. The figures obtained by use of the accurate calorimeter though impracticable in a sence serve, nevertheless, to show the relation existing between the charcoal and the method of production. To this end, both the reduction of led oxide and Thompson's calorimeter were used in determining the temperature of charcoals from different woods.

(a) Amount of Heat produced by “White Charcoal”

Species	Grams of lead oxide reduced by 1 gram of charcoal	Calorics
Illicium anisatum L.	32.6	7635
Quercus myrsinaefolia Bl.	32.1	7507
Vaccinum bracteatum Thunb.	31.9	7460
Osmanthus Aquifolium B. et H.	31.9	7460
Magnolia hypoleuca S. et Z.	31.6	7400
Torreya nucifera S. et Z.	31.3	7330

Species	Grams of lead oxide reduced by 1 gram of charcoal	Calorics
Actinodaphne acuminata Meisn.	31.1	7283
Quercus glauca Thunb.	30.7	7190
Quercus glandulifera Bl.	30.4	7119
Quercus stenophylla Mak.	30.4	7119
Prunus pseudo-cerasus var. spontanea Max.	30.2	7072
Cinnamomum pedunculatum Nees.	30.2	7072
Eurya japonica Thunb.	30.1	7049
Zelkowa acuminata Planch.	29.6	6932
Ligustrum Ibota Sieb.	29.6	6932
Pasania Sieboldi Mak.	29.1	6814
Quercus acuta Thunb.	28.8	6745
Eurya ochnacea Szysz.	28.1	6581
Mallotus japonicus Muell. Arg.	26.7	6253
Morus alba L. var. stylosa Bur.	25.1	5878
(b) AMOUNT OF HEAT PRODUCED BY "BLACK CHARCOAL"		
Stewartia pseudo-camellia Max.	31.1	7280
Carpinus laxiflora Bl.	30.7	7190
Illisium anisatum L.	30.5	7125
Quercus glauca Thunb.	29.6	6930
Aphananthe aspera Planch.	29.4	6925
Ilex integra Thunb.	29.1	6813
Osmanthus Aquifolium B. et H.	29.0	6811
Styrax japonica S. et Z.	28.9	6752
Clethra barbinervis S. et Z.	28.9	6751
Quercus serrata Thunb.	28.8	6748
Magnolia hypoleuca S. et Z.	28.4	6732
Betula grossa S. et Z.	28.3	6718
Quercus acuta Thunb.	27.9	6700
Quercus glandulifera Bl.	27.8	6351
Fraxinus Bungeana DC. var. pubinervis Wg.	27.7	6348
Ilex macropoda Miq.	27.6	6340
Viburnum dilatatum Thunb.	27.5	6340
Prunus pseudo-cerasus Lindl. var. spontanea Max.	26.9	6225
Diervilla coraeensis DC.	25.7	6048

VII. Yield of Charcoal

The yield of charcoal is depend upon the form of the kiln, the kind of wood, the amount of moisture in the wood, and the season. It is further influenced by the method adopted; in case of the "Inside Kiln Extinction Method," it depends upon the choice of the moment for extinction; and in case of the "Outside Kiln Extinction Method," upon the "Finishing ignition." It is hard, therefore, to obtain any fixed standard with regard to the yield.

(a) Inside Kiln Extinction Method

1. Sakuragama (a)

Species	Quantity of billets, Kilo.	Percentage of charcoal produced	Hours of carbonization
Quercus glandulifera Bl.	751	16.3	33
”	843	19.4	20
”	864	15.6	32
”	706	19.5	31
Quercus glandulifera Bl. Carpinus laxiflora Bl.	736	15.9	34
”	748	15.6	32

2. Sakuragama (b)

Quercus glandulifera Bl.	845	19.1	34
”	827	20.1	34
”	848	19.8	57
Quercus glandulifera Bl. Carpinus laxiflora Bl.	845	18.8	67
”	977	18.8	53
”	1,056	15.0	54

3. Fujisakigama

Quercus glandulifera Bl.	1,290	15.9	95
Quercus glandulifera Bl. Carpinus laxiflora Bl.	1,323	14.4	90
”	1,274	17.2	55
”	1,315	17.4	66

(b) Outside Kiln Extinction Method

Species	Quantity of billets, Kilo	Percentage of charcoal produced	Hours of carbonization
Carpinus laxiflora Bl.	887	17.7	50
”	943	16.3	53
Quercus glandulifera Bl. Quercus glauca Thunb.	997	15.7	48
Quercus glandulifera Bl.	928	21.3	33
”	1,240	16.9	31
”	1,241	16.2	53

VIII. Conclusions

As a result of the researches summarized above we came to the following conclusions:—

(1) The temperature of carbonization in a Japanese kiln does not as a rule exceed 600°C.

(2) In the "Outside Kiln Extinction Method" the heat can readily be raised to 900°C. by admitting air through the mouth.

(3) In the "Outside Kiln Extinction Method," hard charcoal is produced subsequent to the so-called "Finishing combustion."

(4) In the "Inside Kiln Extinction Method," only 20% of the wood used is obtained in the form of charcoal; if a higher percentage be obtained it is naturally a poorer product which produced disagreeable smoke.

In the "Outside Kiln Extinction Method," the percentage of the products ranging from 15 to 18% differs according to the "Finishing combustion" process underwent.

Results of investigations on charcoal produced in Japanese kilns agree well with those stated by Violett so far as specific gravity, igniting point and amount of heat are concerned; in other words, specific gravity of charcoal, etc. are directly proportional to the carbonization temperature.

CONDENSATION OF WOOD VINEGAR IN CHARCOAL BURNING IN JAPAN

By Dr. SHOZABURO MIMURA, Forest Expert

The annual output of charcoal in Japan may be put at 1,000,000,000 kilos in round numbers. So enormous a production makes it possible to undertake dry distillation of wood without any fear of the shortage of material.

As the charcoal kiln in Japan differs somewhat from the one adopted in Europe termed "Meiler," and being provided with a fixed chimney, it enables the burner to collect the smoke into a condenser. Crude wood vineger thus obtained is in nature very much like to that produced by the dry distillation of wood and can be made into calcium acetate. In this way, the production of calcium acetate can be easily effected in this country as a secondary product of the charcoal industry. The collection of wood vinegar in Japanese charcoal kilns, was first conceived by the late Dr. Moriya in 1895; The author of this paper who followed Dr. Moriya in his work in 1898, went on to make successive trials and it is a great pleasure to state that the extraction of wood vinegar is now carried out extensively in different parts of the country.

I. Installation used for the Extraction of wood vinegar

Charcoal kilns in Japan are mostly erected on remote upland district where the water supply so much needed for the condensation of the vapour is not available. Air cooling, though defective in principle, must not be altogether rejected. Japanese kilns are simple in their construction, and naturally any change therein will influence the quality of the products obtained, the percentage of the charcoal, the time of carbonization, etc., but these have not be affected by the condensation of wood vinegar as well. Iron pipes, so commonly used in condensation should be substituted by earthen ones to prevent the objectionable coloring of calcium acetate due to formation of acetate of iron.

II. Quantity of Wood Vinegar

In charcoal burning, unlike dry distillation of wood, the constant influx of a limited supply of air is allowed within the kiln to cause imperfect oxidation and the subsequent formation of charcoal. Certainly a stronger oxidation goes on in charcoal burning than in dry distillation and for this reason, weaker vinegar is obtained through charcoal burning than through dry distillation. Moreover the green wood, which is used to produce the good charcoal, supplies a greater amount of moisture thus affecting the quality of the vinegar. The following are the results of different experiments tried on different tree species with different types of kiln.

1. OUTSIDE KILN EXTINCTION METHOD

Species	Billets taken (Kilo.)	Percentage of charcoal produced	Hours of burning	Quantity of wood vinegar (litr.)	Percentage of the wood vinegar	Percentage of calcium acetate to the wood used
Quercus glandulifera Quercus glauca	9970	15.7	48	231	3.6	1.15
Quercus glandulifera	9280	21.3	33	282	3.6	1.68
,,	12406	16.9	51	314	3.2	0.93
,,	12406	16.2	53	294	2.4	1.10
,,	12330	13.7	51	246	6.8	1.13

2. INSIDE KILN EXTINCTION METHOD

a. Sakura Kiln (a)

Species	Billets taken (Kilo.)	Percentage of charcoal produced	Hours of burning	Quantity of wood vinegar (litr.)	Percentage of the wood vinegar	Percentage of calicium acetate to the wood used
Quercus glandulifera	7510	16.3	33	174	3.2	1.03
Quercus glandulifera Carpinus laxiflora.	7360	15.9	34	182	4.0	1.42
,,	7480	15.6	32	181	5.0	1.68

b. Sakura Kiln (b)

Species	Billets taken (Kilo.)	Percentage of charcoal produced	Hours of burning	Quantity of wood vinegar (litr.)	Percentage of the wood vinegar	Percentage of calcium acetate to the wood used
Quercus glandulifera	9450	18.8	57	245	2.8	0.79
Quercus glandulifera Carpinus laxiflora	8450	18.8	67	344	5.0	1.06
,,	9770	18.8	53	333	2.0	0.93
,,	10560	15.0	54	182	4.0	0.71

c. Fujisaki Kiln

Species	Billets taken (Kilo.)	Percentage of charcoal produced	Hours of burning	Quantity of wood vinegar (litr.)	Percentage of the wood vinegar	Percentage of calcium acetate to the wood used
Quercus glandulifera	12900	15.9	95	442	3.4	1.42
Quercus glandulifera Carpinus Laxiflora	13230	14.4	90	349	4.8	1.64
,,	12740	17.2	55	684	5.0	3.02
,,	13150	17.4	66	518	3.2	1.99

III. Extraction of Methyl Alcohol

The amounts of wood spirit found in the wood vinegar produced through the "Outside Kiln Extinction Method" are as follows:—

Species	Billets used (Kilo.)	Wood vinegar (litr.)	Wood spirit			Percentage to wood spirit	
			Litres	Specific gravity	%	Methyl alcohol	Acetone
Quercus glauca	29880	321	2.06	0.877	0.63	65.51	7.28
,,	29960	270	2.43	0.866	0.88	58.42	8.99
Quercus acuta	32320	434	2.56	0.891	0.58	64.16	4.58
Illicium Anisatum Eurya japonica	28120	254	1.70	0.881	0.66	60.66	6.58

IV. Conclusions

(1) With regard to the condensation of wood vinegar in Japanese kilns, so long as a proper method is adopted no disadvantage will follow in the quality of the charcoal, the percentage of the yield and the time of carbonization.

(2) The quantity of calcium acetate produced in the Japanese kiln does not exceed one-quarter of the quantity produced through dry distillation. Still owing to the simple fittings used in the condensation of wood vinegar, the charcoal burner of small means will find some profit from using his spare labor to obtain this secondary products.

(3) As to wood spirit, the quantity produced is too small to be taken into account.

Fig. 1. Fig-shped Sakura Kiln.

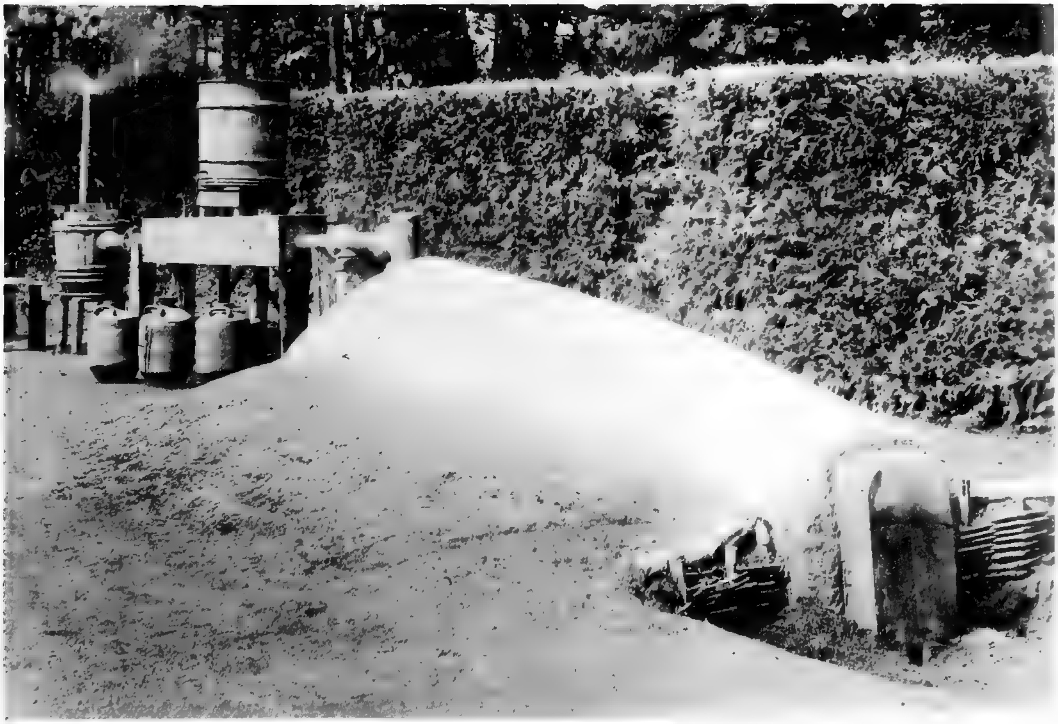


Fig. 2 Sakura Kiln with concave bottom fitted with wood vineger producing installation.

NOTES ON SOME FATTY AND ESSENTIAL OILS

By SHUHEI HIGUCHI, Chemist of Forest Fxperiment Station

I. Yabunikkei Seed Oil

The oil is obtained by pressing the seeds of the *Cinnamomum pedunculatum Nees.* which is a large tree growing along the southern coast of the Main Island. The seed which is the size of pea contains in its kernel a considerable quantity of oil. The exact figures are 61.86% of the oil and 4.69% of water. On a manufacturing scale, the seeds yield oil in the ratio of 37.7% of their weight.

The oil obtained by pressing the seeds is brown in color and has a peculiar smell. Both color and smell can, however, be removed by washing with hot water. The oil which is liquid only during summer months solidifies in other seasons forming a crystalline mass much like Japanese wax in appearance. It is a non-drying oil and is well suited for the manufacture of hard soap.

The physical and chemical constants of the oil of Yabunikkei seeds are as follows:—

Specific gravity at 100°C.	0.8743
Melting point	11–15°C
Acid value	0.78
Saponification value	276.9
Iodine value	8.46
Hehner value	90.97
Reichert-Meissl	1.30

Physical and chemical constants of mixed fatty acids:—

Specific gravity	0.8671
Melting point	31°C.
Solidifying point	29°C.
Neutralization value	285.2
Mean molecular weight	196.6
Iodine value	8.05

II. Oil of Shiraki Seeds

This oil is obtained by pressing the seeds of the *Excoecaria japonica Muell Arg.*, a tree growing in the North-eastern part of Japan. The kernal which constitutes about 58% of the weight of the seed, contains 53.9% of oil and 4.76% of water. On a manufacturing scale, 23.2% of the weight of the seeds can be obtained as oil.

The oil is faint yellow in color; on exposure to the sunlight in a thin layer it turns into a sort of hard varnish after a few days. Under the Eleiden test, the oil takes a reddish brown color and gives rise to a small quantity of reddish precipitate.

The oil is a good drying oil and furnishes a good substitute for linseed oil.

The physical and chemical constants of Shiraki seed oil are as follows:—

Specific gravity at 15°C.	0.9365
Solidifying point	On cooling to –18°C. the oil becomes turbid.
Acid value	0.51
Saponification value	197.1
Iodine value	164.0
Reichert-Meissl value	0.17
Hehner value	92.0

III. Beech-Nut Oil

The oil is obtained from the seeds of the *Fagus sylvatica L. var. Sieboldi, Maxim.* The kernel which constitutes about 49% of the nut, contains 39.6% of oil and 7.3% of water. Entire nuts when pressed give 10.6% of their weight in oil on a manufacturing scale.

The cold drawn oil is pale yellow in color and possesses a slight agreeable smell; it is transparent at indoors temperature, and becomes somewhat turbid on cooling. Under the Eleiden test, the oil precipitates after 2 hours' standing a little of a flocculent substance of orange color and the oil turns into a gelatinous mass after 2 days. The oil is semi-drying and is used as a table oil as well as lubricant.

The physical and chemical constants of Beech-nut oil are as follows:—

Specific gravity	0.9205
Acid value	0.78
Saponification value	201.5
Iodine value	112.2

Physical and chemical constants of mixed fatty acids:—

Specific gravity	0.9040
Melting point	17–17.5°C.
Solidifying point	18.5–19°C.
Neutralization value	210.4
Iodine value	118.8

IV. Oill of Inugaya Seeds

The oil is obtained by pressing the seeds of the *Cephalotaxus drupacea S. et Z.* The nut which is found in a hard brown shell has a somewhat resinous odour and contains 62.02% of the oil with 4.52% of water. The oil can be produced of a manufacturing scale up to 28% of the weight of the entire seeds.

The cold drawn oil is of pale yellow color, being freely soluble in ordinary solvents. Under the Eleiden test, the oil remains perfectly liquid even after 24 hours' standing, at the end of which a small quantity of yellowish brown visicous precipitate is formed on the bottom of the test tube. It is a semi-drying oil and furnishes material for soap and blown oil; when rectified by alkali, it is likewise well suited for edible purposes.

Physical and chemical constants of the oil are as follows:—

Specific gravity	0.9222
Solidifying point	On cooling to –12°C., a small amount of solid matter precipitates.
Acid value	0.51
Saponification value	195.6
Iodine value	129.2
Reichert-Meissl value	0.85
Hehner value	97.06
Viscosity (Engler's viscosimetre at 15°C.)	123 seconds.

Physical and chemical constants of mixed fatty acids:—

Specific gravity	0.9085
Melting point	23°C.
Solidifying point	22°C.
Neutralization value	201.0
Iodine value	130.8

V. Oil of Onigurumi

The oil is obtained from the nut of the *Juglans Sieboldiana, Maxim.* The kernel constituting about 28% of the entire nut contains 62.02% of oil and 28.19% of water. The cold drawn oil is colorless and has a pleasant smell and an agreeable taste.

Under the Eleiden test, the oil remains perfectly liquid.

It is a drying oil and is used in making white paint for artists.

The physical and chemical constants of Onigurumi oil are as follows:—

Specific gravity at 15°C.	0.9272
Solidifying point	On cooling to –18°C., the oil remains liquid.
Acid value	0.51
Saponification value	187.5
Iodine value	153.7
Reichert-Meissl value	4.9
Hehner value	96.74

Physical and chemical constants of mixed fatty acids:—

Specific gravity	0.9037
Melting point	28°C.
Solidifying point	29°C.
Neutralization value	193.8
Iodine value	150.6

VI. Oil of Tsunohashibami Nuts

The oil is obtained by pressing the seeds of the *Corylus rostrata Ait. var. Sieboldiana Maxim.* The kernel, found in a hard grey brown shell, contains 46.06% of oil and 11.65% of water. The yield of the oil from the entire seed is only 6.7% on the weight on a manufacturing scale.

The oil is colorless and has a slight agreeable smell. Under the Eleiden test, it solidifies after 40 hours. It is used in a hair dressing and is likewise a fine table oil.

Physical and chemical constants of Tsunohashibami nut oil are as follows:—

Specific gravity	0.9195
Solidifying point	On cooling to –15°C., a small amount of crystals separates.
Acid value	0.46
Saponification value	190.9
Iodine value	104.6
Reichert-Meissl value	3.2
Hehner value	95.68

Physical and chemical constants of mixed fatty acids:—

Specific gravity	0.8964
Melting point	16°C.
Solidifying point	8°C.
Neutralization value	211.4
Iodine value	103.5

VII. Styrax Oil

The oil is prepared from the seeds of the *Styrax japonica, S. et Z.* The kernel which constitutes about 40% of the weight of the seed contains 41.12% of oil and 4.58% of water. On a manufacturing scale, the oil is produced up to 8.15% of the weight of the entire seed. It is a tasteless and odourless oil of violet color and is hard to decolorize. Under the Eleiden test, the oil remains liquid forming only a small amount of coagulated substance. It is non-drying and is used as a lubricant of inferior quality.

The physical and chemical constants of Styrax oil are so follows:—

Specific gravity	0.9341
Solidifying point	Below–23°C.
Acid value	0.75
Saponification value	185.1

Iodine value	108.1
Reichert-Meissl value	6.94
Hehner value	93.19

The physical and chemical constants of mixed fatty acids:—

Specific gravity	0.9164
Melting point	41°C.
Solidifying point	15°C.
Neutralization value	195.2
Iodine value	118.4

VIII. Oil of Tsubaki

The oil is prepared by pressing the seeds of the *Thea japonica Nois.* The kernel which constitutes about 50% of the seed, contains 56.78% of oil and 17% of water. On a manufacturing scale, the yield of the oil from the seed is 28.3%. Under the Eleiden test, the oil solidifies after 3 hours. It is non-drying and is used in a hair-dressing for women, also as machine oil and table oil. It is also used in the preparation Turkey red oil.

The physical and chemical constants of Tsubaki seed oil are as follows:—

Specific gravity	0.9159
Solidifying point	When cooled to –12°C. the oil becomes turbid.
Acid value	4.6
Saponification value	196.13
Iodine value	80.9
Reichert-Meissl value	0.41
Hehner value	95.57
Viscosity (Engler's viscosimeter at 15°C.)	156 seconds.

Chemical properties of mixed fatty acids:—

Iodine value	81.23

IX. Sazanqua Oil

The oil is obtained by pressing the seeds of the *Thea sazanqua Nois.* The seed consists 23% of husk and 67% of kernel; the latter contains

61.76% of oil and 4.8% of water. On a manufacturing scale, the yield of the oil from the entire seed is 27.8%. The cold drawn oil of Sazanqua is very much like to Camellia oil in appearance being, however, somewhat lighter in color and is particularly distinguished by its peculiar smell. Under the Eleiden test, the oil solidifies after 4 hours.

The oil is used for hair-dressing and it furnishes a good material for machine oil.

The physical and chemical constants of Sazanqua seed oil are as follows:—

Specific gravity	0.91447
Acid value	7.68
Saponification value	193.3
Iodine value	81.41
Reichert-Meissl value	0.35
Hehner value	95.03

Physical and chemical constants of mixed fatty acids:—

Specific gravity	0.8947
Melting point	22°C.
Solidifying point	15°C.
Neutralization value	186.3
Iodine value	80.68

X. Kaya Oil

The oil is obtained by pressing the seed of the *Torreya nucifera, S. et Z.* The yellowish white kernel, constitutes about 66% of the weight of the seed, contains 48% of oil, and 6.09% of water. The yield of the oil from the seed amounts to 24% on a manufacturing scale.

The oil is edible and is used as a raw material for paints and varnishes.

Under the Eleiden test, the oil precipitates a small quantity of reddish brown solid matter on the bottom of the test tube.

The Physical and chemical constants of Kaya seed oil are as follows:—

Specific gravity	0.9236
Solidifying point	Below −17°C.

Acid value	0.48
Saponification value	190.1
Iodine value	135.8
Reichert-Meissl value	0.66
Hehner value	95.89
Viscosity (Engler's viscosimeter at 15°C.)	114.5 seconds.

Physical and chemical constants of mixed fatty acids:—

Specific gravity	0.9075
Melting point	18°C.
Solidifying point	11°C.
Neutralization value	195.2
Iodine value	137.84

XI. Essential Oil of Yabunikkei Leaves

The Yabunikkei (*Cinnamomum pedunculatum Nees*), from which the oil is distilled, is a large tree growing along the Pacific coast of the southern parts of Japan. The bark, roots, and leaves all contain volatile oil. Dried leaves weighing 37.5 kilos produced 520 gr. of this volatile oil on distillation with steam, being equivalent to 1.4% of the material used.

The oil is mobile and has a fresh and pungent smell. It is almost colorless just after distillation, but it takes a yellow color after standing or on exposure to the sunlight. By cooling to -8°C. the oil becomes milky. When distilled under atmospheric pressure, it begins to boil at about 190°C. and continues to distill till the thermometer reaches 245° being mostly distilled between 230°–240°C. By the addition of dilute ferric chloride solution, the oil assumes a dark green color; it does not decolorize a fuchsin solution. The oil has the following constants:—

Acid value	1.1
Ester value	0
Ester value after acetylation	821

The phenol extracted from the oil by dilute caustic potash solution, boils at 264°–267°C. and has a density $d_{15}=1.0665$, the melting point of the benzoil compound is 65°C.

NOTES ON SOME ESSENTIAL OILS

By SO UCHIDA, chemist of Forest Experiment Station

I. Hinoki Oil

The Hinoki (*Chamaecyparis obtusa, S. et Z.*) which is extensively grown in Japan furnishes a valuable timber wood of superior quality and is likewise prized for the manifold uses to which the wood is well adopted. Both leaves and wood contain an essential oil; the sample obtained by the dry distillation of wood was sent to us through the courtesy of the Forest office of Arisan Range, Formosa, where Hinoki trees thrive most wonderfully forming a splendid virgin forest. The Formosan species is richer in this oil than that of the Main Island.

The oil obtained by the dry distillation of Hinoki wood is brown in color and is mobile, possessing a woody and empyreumatic smell. The yield of the oil sent from the producing locality, was mentioned to be 2.4% of wood. The oil thus obtained was rectified by distillation with steam and the subsequent treatment with dilute solution of sodium carbonate. The rectified oil gives a density of $d_{15.5}=0.8821$ and $[\alpha]_d^{15}=-50^\circ\ 37'$ in a 10% chloroform solution. 448 grams of the oil thus rectified underwent fractional distillation under atmospheric pressure and the following fractions were obtained:—

157°—200°C.	68.5%
200°—240°C.	8.0%
240°—270°C.	21.5%

The residue remaining in the distillation flask amounted to 1.5% of the oil; it was a resinous substance of a reddish brown color.

The first fraction (157°–200°C.) was almost colorless; after repeated rectification by distilling it over sodium, it boiled mostly between 156°–157°. Thus, the chief fraction has the density of $d_{15.5}=0.8616$, $\alpha_D=+44^\circ\ 42'$, $n_D^{20}=1.4662$.

The identification of *α*-pinen with the fraction above obtained was established by the hydrochloride of the latter ($CH_{10}H_{16}H\,Cl$). It is noteworthy that the melting point of pinene hydrochloride was 132°.5

–133°.5C. in my experiment (Corr), This is different from the observation made by Wallach who puts the melting point of the same substance at 125°C. (Ann. Chemie, 239, 4) and J. H. Long's report of 131°C. as the melting point (Jour of Amer. Chem. Soc. 21, 637).

The third fraction (240°–270°) gave a slight yellowish liquid of a somewhat visicous nature possessing the wood smell of Hinoki. After the liquid was rectified by distillation over sodium under atmospheric pressure the chief fraction was collected between 260°–270°C. The oil thus separated boils mostly between 267°–268°C. When the fraction is dissolved in a little glacial acetic acid and is shaken with a few drops of concentrated sulphuric acid, the liquid assumes a faint reddish color which turns to red with a violet tint after a little while. After standing over night, it finally turns to brownish red.

The identification of cadinen with this fraction was confirmed by its hydrochloride ($C_{15}H_{24}$. 2 HCl, m. p. 117–118°C.) and hydrobromide ($C_{15}H_{24}$. 2 HBr, m. p. 124–125°).

Again, the rectified oil of the original product was distilled under atmospheric pressure in a flask provided with Le-Bel Henninger's still-head; the fraction distilling under 170°C. was collected to the amount of 60% of the original oil; the substance thus collected is colorless and free from empyreumatic odour. The physical properties and the practical application to paint and varnish of this fraction and of common-turpentine oil was compared and it proved that the fraction thus collected from the Hinoki oil can well be used in place of the turpentine oil of the best quality. The Arisan forests, which are fully stocked with Hinoki trees rich in this oil, promise to furnish an abundant supply of the material to produce this useful oil.

II. Essential Oil of Sansho

The essential oil of Sansho is obtained from the berries of a shrub (*Xanthoxylum piperitum of Rutacae*) growing wild in Japan. The skin of the berry has a strong aromatic smell and biting taste. The berry is green but turns brown on ripening; it is used as a drug by Chinese chemists, and is likewise used as condiment.

The essential oil is contained in considerable quantity in the large oil cells of the fruit cortex but not in the seeds. 40 kg. of dried berries produced 800 gr. of the essential oil on steam distillation, equivalent to 5.7% of the material used.

The oil is pale yellow in color and mobile in nature with an aromatic smell resembling that of citronella oil. When the oil is cooled to 5°C. in a mixture of ice and salt, it turns turbid.

On distillation in a flask under atmospheric pressure, the oil begins to boil at about 110°C. and continues to distill till 239°C.; the chief fraction, however, boiled between 176°–186°, amounting to 80% of the original oil. The viscous residue left in the frask after the distillation amounted to 0.7%; it is yellowish brown in color and possesses a peculiar empyreumatic odour.

The oil reduces ammoniacal silver oxide. It combines with bromine strongly, evolving a considerable quantity of heat. When the oil is shaken with a saturated bisulphite solution minute white crystals are formed. A drops of oil dissolved in a small quantity of acetic acid anhydride and shaken with a drop of concentrated sulphuric acid, the liquid assumes at once a brownish violet color which turns brown and finally becomes brownish violet again. A drop of the oil is dissolved in 1 cc of acetic acid anhydride and shaken with a small quantity of anhydrous zinc chloride, the liquid gives a pale yellow color which turns pale orange at once and becomes perfectly brown after a while. It has a density $d_{15.5}=0.8504$, $\alpha_D^{20}=+46° 30'$, $N_D^{20}=1.46$, acid value = 3.3, ester value = 19.28, ester value after acetylation of the non-aldehyde constituent of the oil =23.23, and aldehyde content=15%.

The oil amounting to 350 grams. was shaken with a dilute caustic potash solution and the alkaline liquid was acidified and extracted with ether. By evaporating off ether, a reddish brown solid substance (18%) is obtained which after recrystallizing from methyl alchool, was identified to be palmatic acid by its melting point and the analysis of its silver salt.

The aldehydic or the ketonic constituent of the oil, which was subsequently separated from the oil by treating with a saturated bisulphite solution, is a mobile liquid of pale yellow color with an agreeable smell. It distills between 140°–240° under atmospheric pressure and seems to consist at least of two substances, of which the one is colorless and the other is yellow.

The oil thus treated with a bisulphite solution was then distilled under 40 mm pressure and the fraction below 80° C. was collected (240 gr.). The fraction so obtained after rectification by repeated distillation over metallic sodium under 38 mm pressure, was finally distilled under atmospheric pressure and the chief fraction was collected at 177°–178°C. amounting to 95% of the fraction introduced.

It has a density $d_{15}=0.8440$, $\alpha_D^{20}=+61° 42'$. The fraction obtained is tetrabromic. The identification, of dipentene in this fraction, was confirmed by it nitrosobromide ($C_{10}H_{16}NOCl$, m. p. 103°) and tetrabromide ($C_{10}H_{16}Br_4$ m. p. 124°–125°).

After the removal of the greater part of the terpene, the residual oil was hydrolised with alcoholic potash and by the subsequent examination of the alkaline liquid, the pressence of acetic acid and a small quantity of a lactone was proved.

The relative proportion of the constituents is approximately as follows:—

Free acid (chiefly palmitic acid)	2.0%
Aldehyde	15.0%
Ester (as acetic ester of $C_{10}H_{18}O$)	5.7%
Free alcohol ($C_{10}H_{18}O$)	1.1%
Terpene (chiefly dipenten)	77.0

Sansho oil has a very agreeable odour and can be used in the preparation of perfumes and perfumed oil; it is especially suited for confectionery, the preparation of liquers, lemonade, etc.

III. Essential oil of Sugi Leaves

The Sugi is a coniferous tree, indigenous to Japan, and is extensively cultivated through the Empire as a valuable timber tree. The wood is most widely used and prized as a timber for building and in general wood-work. The stems, leaves and roots contain essential oil. No study hitherto has been made of the oil contained in the leaves.

The green leaves of the Sugi (*cryptomeria japonica, Don.*) growing in our institute at Meguro, Tokyo, weighing 87.4 kilogrammes in amount was distilled with steam. This gave 612 grams of the volatile oil, equivalent to 0.70%. The oil is mobile, brownish yellow in color and has a fresh aromatic odour. When cooled to –5°C. for an hour in a mixture of ice and salt, the oil does not seperate any solid substance.

A small quantity of the oil was distilled in a flask under atmospheric pressure; it began to boil at about 155°C. and which continued to distill till the thermometer reaches 350°C. and the following fractions were obtained: 155–190° 33%, 190–230°C. 4%, 230–270°C. 4%, 270–310°C. 28%, 310–350°C. 23%.

When bromine was introduced drop by drop, the oil combined with it violently, evolving a large amount of heat and turning into greenish viscous oil. When 2 drops of the oil is dissolved in 1 cc of acetic acid anhydride and shaken with a drop of concentrated sulphuric acid, the liquid assumes an intense green color and becomes very viscous. When a few drops of the oil are introduced in 20 cc of concentrated sulphuric acid, they dissolve for the greater part, and assume a yellowish brown color while a small quantity of deep reddish brown oil floats on it. The oil does not give any characteristic color reaction in presence of dilute ferric chloride. The oil does not reduce ammoniacal silver oxide. The oil neither contains nitrogen nor sulphur, and has the following constants:—

$d_{15.5}=0.9217$

$[\alpha]_D^{15}=+19.29$ in 10% chloroform solution.

$N_D^{20}=1.4895$.

Acid value $=1.0$

Ester value$=6.56$

Ester value after acetylation$=14.35$

The oil is completely soluble in the ordinary organic solvents. The total quantity of oil used was 454 grams. The oil, after treated with dilute Na_2CO_3 solution, was subjected to fractional distillation under 15 mm pressure, a current of CO_2 being passed into the liquid to ensure regular ebullition and was separated into the following three fractions:—

(1)	50°—100°C. (especially boiled at 56°–62°C) ..	31%
(2)	100°—180°C.	42%
(3)	110°—200°C. (especially boiled at 197°–171°C.)	17%

Fraction No. 1 (b. p. 50°–100°C. under 15 mm pressure). The fraction is mobile, colorless and has a somewhat lemon-like smell. When purified by repeated distillation over sodium under diminished pressure and finally under atmospheric pressure, it boils mostly at 161°–165°C. and is proved to be identical with α-pinen by the nitrosochloride (m. p. 102°–103°), the nitrolpiperidine (m. p. 118°–190°) and nitrolbenzylamine (m. p. 122°–123°).

Fraction No. 2 (b. p. 100°–180°C. under 15 mm pressure). This fraction, after hydrolysing with 5% alcoholic potash, was distilled under atmospheric pressure and was separated into 4 fractions having the range of boiling point 195°–235°, 235°–280°, 280°–310°, 310°–330°. From these fractions, there were detected an alcohol ($C_{10}H_{18}O$,b.p. 212–214, $N_D^{18}=1.4832$), a dihydrochloric sesquiterpene ($C_{15}H_{24}$; b. p. 266°–268°, $[\alpha] = +15.19$ in a 6% chloroform solution, $d_{15}=0.9335$, $N_D^{22.8}=1.5041$), Cadinene ($C_{15}H_{24}$; b.p. 272) and a sesquiterpene alcohol ($C_{15}H_{26}O$; b. p. 284°–286°; $d_{15.5}=0.9623$, $[\alpha]_D^{15}= +16.76$ in 5% chloroform solution, $N_D^{22.8}=1.5048$).

Fraction No. 3 (b. p. 180°–200°C. under 15 mm pressure). This fraction was a very viscous oil of a yellowish color which solidified on cooling to a hard mass. When recrystallised from acetic ether, white lustrous needle crystals were obtained. By combustion and the determination of molecular weight, the substance was proved to be a new diterpene $C_{20}H_{23}$ (m. p. 61°C; b. p.$_{760}$ 345°C; b. p.$_{15}$ 198°; $[\alpha]_D^{20}=-34.22°$ in a 4.7% chloroform solution), for which the author ventures to propose the name *α-cryptomerene* to show its derivation from the *Cryptomeria japonica.*

Also, from the alkaline liquid gained by hydrolysis of the fraction (100°–180°C. 15 mm), a lactone ($C_{20}H_{32}O_2$) and caprylic acid (C_7H_5COOH) were detected but they were exceedingly small in amount. The relative proportion of the constituents is approximately as follows:—

Free acid (as acetic acid)	0.1%
Free alcohol (as $C_{10}H_{18}O$)	3.14%
Ester (as caprylic ester of $C_{10}H_{18}O$)	3.28%
Terpen (chiely a-pinnen)	about 34%
Sesquiterpen (cadinen and a sesquiterpen)	about 30%
A sesquiterpen alcohol ($C_{15}H_{26}O$)	12%
Crystalline diterpene (α-cryptomerene)	about 18%

TAPPING OF LAC

By Dr. MONOSHIRO MORIYA, Professor and Dr. HOMI SHIRASAWA, Forest Expert

Lacquer ware is an industrial products peculiar to this country which is highly prized in the West. The material for making this beautiful ware so suitable for the making of household article is obtained from the lac of *Rhus vernicifera.* There are many methods for the tapping, and we shall give a comparison of these methods with regard to yield of lac, quality, age of tree and locality of production. This comparison is based on personal researches made by the authors during the years 1906 to 1908 in Kanagawa, Ibaraki and Iwate Prefectures, well-known districts for the production of lac.

I. Methods of Tapping

1. ORDINARY EXHAUSTION TAPPING *(Koroshigaki)*.

In this method, incisions 6 cm long and 0.6 cm deep are cut horisontally on both sides of the stem with a distance of 33 cm between the gashes. The lowest gash is cut at the height of 24 cm from the ground and number of gashes differs according to the size and height of the tree. In a tree 21–24 cm in circumference, the initial gashes are commonly cut at 9–11 places and on every 4th day fresh gashes are cut at a distance of 0.6 cm above the gash and from these gashes the lac is collected.

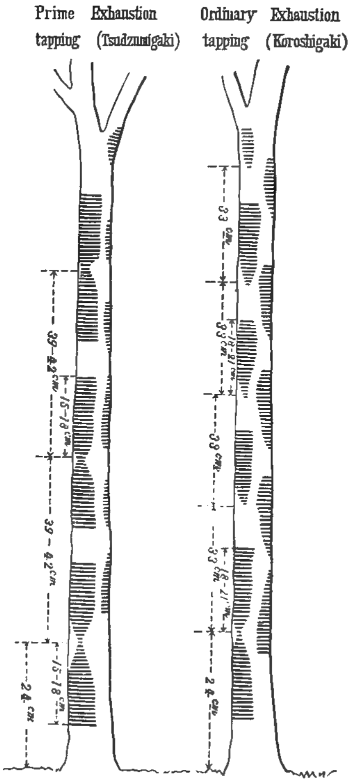
The length of gashes is short at the beginning of the tapping but it is made gradually longer till it attains to the regular length of 7 cm.

The lac collected from the middle of June up to the middle of July is called "Early lac" (Hatsu-urushi); the lac collected thence up to the beginning of September is called "Prime lac" (Sakari-urushi) and subsequently that which collected up to the beginning of October is called "Final lac" (Suye-urushi). These three sorts of Early, Prime and Final lac are generally named as "Original lac" (Hen-urushi) and form the principal product of the tapping.

When the tapping of "Original lac" has terminated, the greater part of the stem is covered with gashes and the juice can only pass through the narrow portions of bark left unwounded. Then long heavy gashes are cut on the bark left uncut and the so-called "Short lac" (Urame-urushi) and "Tail lac" (Tome-urushi) are collected to the destruction of the tree. Finally the tree is cut down and the unwounded branches and twigs are plunged into water for 3 or 4 days when incisions are cut at a distance of 15.2 cm on the branches to collect the so-called "branch lac" (Seshime-urushi).

2. PRIME EXHAUSTION TAPPING *(Tsudzumigaki).*

In this method, the initial gashes are cut with a distance of 39 cm on both sides of the trunk, the lowest being 24 cm high above the ground and fresh gashes are cut in above and below of the each of gashes at a distance of 13 cm apart for every four days. The number of gashes are 6 or 7 on a tree of 7 or 8 years. The length of the gashes and the distance between them are much the same as in the first method. "Early lac" is obtained from the middle of June, and the tapping of "Original lac" terminates towards the middle of August. No "Final lac" is collected but the tapping of "Urame-urushi" and "Tome-urushi" are proceeded as in the case of first method.



The peculiarity of this method is the tapping of the largest possible quantity of lac while the tree is in its prime of life within the shortest season from the middle of June up to the end of August, numerous gashes being cut both above and below the original incision. When the secretion of sap is over, the principal production has already been secured in this method.

3. SPARE TAPPING *(Yojōgaki)*.

Gashes are made almost like those in the Ordinary Exhaustion Tapping. The main feature of this tapping is that it does not injure the growth of the tree greatly in the first year, and successive tapping is kept up for the ensuing two years. To this end, far fewer gashes are cut and the tapping of "Original lac" starting at the beginning of July terminates at the end of August or at the beginning of September. No further collection of "Short lac" (Urame-urushi) is underkaten, and the trunk is left to grow for the next year. The tapping is carried on successively every ensuing year till the tree finally dies. Only well-grown large tree over 15 years old are suited to the purpose.

4. THREE YEARS' SPARE TAPPING.

The tapping differs but little from the preceding in principle. Its peculiarity is the duration of tapping which lasts only for three years, at the end of which exhaustion is effected. Thus, the number of gashes is more greater than in the 3rd method and the tapping goes on from the end of June up to the middle of August. At the end of the 3rd year, the tree is subjected to the same treatment as in the Ordinary Exhaustion Tapping.

In comparing the four methods of tapping above described, in the first two methods, total exhaustion is aimed at in one season since the trunk is killed after a single year's tapping while the other two aim to have successive production for ensuing years. We shall only compare the first two methods, since the other two are quite different in the principle.

II. Quantities of Lac produced by "Ordinary Exhaustion" and "Prime Exhaustion" Methods

According to the result of experiments carried out in Hatano, Kanagawa Prefecture, in 1906, the quantity of the lac obtained by both methods was inconsiderable till the end of June; from the beginning of July to the end of August, the production was the largest, and it fell from September when the vegetation was greatly checked partly by the fall of temperature and partly by the continued tapping, and the vigor of the tree fails just when the production does. The prime exhaustion method showed better results at the beginning of work and up to the middle of August giving a far greater production than the ordinary exhaustion method but the product suddenly fell at the close of August while in the latter method the excretion in September is still quite considerable. In the ordinary exhaustion method, the gashes being fewer than in the prime exhaustion method, the excretion is slow and regular but it continues longer.

In this experiment in Kanagawa Prefecture, the trees were too young being only 18–22 cm in circumference to make a perfect comparison between the two systems and these trials can only be considered as preliminary to further experiments.

A similar experiment made in 1908 in Iwate Prefecture on larger trees being 63 cm in circumference produced good results in making a comparison of two methods. The ordinary exhaustion method was tried on 25 trees having an average circumference of 64.2 cm and they produced 62,387 grams of lac. The prime exhaustion method was also tried on 25 trees of an average circumference of 62 cm and they produced 59,513 grams of juice.

According to the results obtained in preliminary experiments in Kanagawa and Ibaraki Prefectures in the previous year, the production of lac from the rhus tree was directly proportional to the square of the radius of the trunk from which it was collected so long as no abnormality exists in height and circumference. This empirical formula agrees well with the results shown in Iwate and the total productions of lac obtained is about the same in both methods.

Taking the best time for tapping, when a large yield of superior quality is obtainable, the tapping of "Original lac" lasts 95 days in the ordinary exhaustion method and only 75 days in the prime exhaustion method. The lac extracted from one tree daily on these periods averaged 7.5 grams and 11.3 grams respectively for the ordinary and the prime exhaustion methods. The daily extraction of lac by the prime exhaustion method was larger in quantity than by the other, although somewhat smaller sized trees were used. It is in favor of this method that we can fully extract lac in a shorter period and that the yields of "Short lac"

(Urame-urushi) and "Tail lac" (Tome-urushi) are about the same as in the other method.

Comparing the two methods one notes that in the prime exhaustion method a large quantity of better juice is obtainable in a shorter interval than in the other method, although the total yield of lac is about the same in both methods. Such advantages are, however, greatly offset by the drawback unavoidable in the use of the prime exhaustion method that more workmen are needed for tapping.

III. Comparison of Lac produced from Large and Small Trees

The average production of lac in the ordinary exhaustion method is 1,273 grams from a large tree having a circumference of 63.6 cm and 133 grams from a smaller one having a circumference of 20.3 cm.

In order to ascertain whether the formula that the production varies with the square of radius is applicable to large trees, we may apply it to the above case. The square of the radius of the large tree is 102.4 and that of the smaller tree is 10.4 while the ratio of these two numbers is 9.84. Trees having the average circumference of 20.3 cm may well be taken to represent "smaller trees" of this locality and will serve as a basis for calculation. Such trees will produce 133 grams of lac, and by multiplying this figure by 9.84, we obtain 1,309 grams as the calculated quantity for a large tree, and this figure nearly agrees with the actual quantity produced by a large tree, viz., 1,273 grams. This shows that the rule of yield of lac is directly proportional to the square of the radius of the trunk of the tree holds true in case of big trees. Whether, the number of experiments too limited to enable us to accept this empirical formula is universally true or not, but it is no doubt applicable to lac trees within a certain limit of size.

IV. Yield of Lac in Relation to Locality of Trees

Three consecutive experiments differing in locality and surroundings as above stated will serve well for comparing the yields of the trees in different sections of the country.

To this end, the yield of 30 trees, 21.4 cm in circumference each, was fully examined and they produced an average for a single tree as follows:—

Locality	Method of Tapping	Original lac in grams	"Urame" (Short lac)	"Tome" (Tail lac)	Lac from branches	Total
Naka County, Kanagawa Prefecture ..	Ordinary Exhaustion Tapping	157.1	11.3	9.4	3.4	181.1
Kuji County, Ibaraki Prefecture ..	„	108.4	15.8	9.0	2.3	135.4
NinoheCounty, Iwate Prefecture ..	„	106.1	13.1	7.1	4.9	131.2

According to this table, Naka county in Kanagawa gave the largest yield, followed by Kuji county in Ibaraki, and Ninohe county in Iwate in order. On comparing the climates of these districts we find the following facts. In Kanagawa, the climate is generally mild, especially the place in which the trees were planted fronts the south, and is well secured from harsh winds by oak and camphor trees. In Ibaraki, the place was located in a mountainous districts and was destitute of the ever-green trees common in the milder parts of that Prefecture. In Iwate, place was rather cold and not well suited to the growth of the tree. Thus, we can say with all probability that the production of the lac is greatly influenced by the climate, the yields being less in a colder region.

V. Quality of Lac

(A) CHEMICAL PROPERTIES OF LAC.

The freshly collected lac is termed crude lac which cannot be used for lacquering. In the making of lacquer, perilla oil must first be mixed with the crude lac and the operation of "Nayashi" (ripening) and "Kurome" (blackening) must be carried out so that the water contained is removed. The refind lacquer (Seishi-urushi) is used for coating wood, metal, etc.

Crude lac consists of water, urushiol, a gummy substance and nitrogenous matter.

Water:—Ordinary crude lac contains of 10-30% of water. Such a large content of water is unnecessary in crude lac, but 3–4% is indispensable in order to keep the nitrogenous and gummy substances dissolved and to insure uniform drying when used.

Urushiol:—Crude lac contains 60–80% of urushiol, the most important ingredient of lac. Freshly collected crude lac is translucent, but it turns to a dark brown viscous liquid when exposed to the air. Urushiol is soluble in common organic solvents and it readily hardens with lac juice when exposed to the air owing to the nitrogenous matter contained in it. Pure urushiol, however, does not readily harden; yet it does so when heated at a temperature of 100°–150°C. Once dried, it is no more liable to be attacked by ordinary solvents such as ether, alcohol, benzine or even by acids and alkalies.

Nitrogenous Substance:—The nitrogenous substance contained in crude lac is only 2–3% but it gives an important drying property to urushiol; the substance is insoluble in ether or alcohol, but it is soluble in water to a certain extent. When heated above 60°C. the nitrogenous substance renders urushiol hard to dry.

Gummy Substance:—The gummy substance contained in crude lac ranges between 7–20% or sometimes over 30%, rendering the lac viscous and often hindering the work of lacquering. The gummy substance which left on the coated surface after hardening of lac absorbs the moisture and thereby renders the surface weak, so a large content of this substance in the liquid is undesirable.

Since the knife or spatula used in tapping are daubed with the oil for easy working crude lac commonly contains a small quantity of perilla oil but it is not an ingredient of lac itself.

The lacquer used in varnishing is further mixed with a certain quantity of the same oil, because pure lac is expensive and it produces a rather rough and less lustrous effect; moreover, it is not easy to put on pure lac. For containing the crude lac, wooden tubs or bent wood cases are commonly used. When kept for a long time, the water and gummy substance generally settled to the bottom while the urushiol always floats as a thin liquid of brownish black color. Thus, the upper part of the crude lac in a tub is therefore generally far superior than the lower part. For this reason, in taking the sample for analysis, the tub must be carefully stirred from the bottom, otherwise a considerable error will occur in estimating the value.

Analysis of Lacquer:—The crude lac is filtered through a kind of paper called "Yoshinogami" to remove the foreign substances and the filtrate is treated as follows:—

Water: 1–2 grams of the sample is put in an evaporating dish or a watch glass and is well agitated on a water bath; it is then kept in a steam oven from two to three hours and weighed. The loss thus ascertained is taken as the water content.

Urushiol: A small weighed quantity of absolute alcohol is heated and added to the sample treated as above and the mixture is filtered through filter paper of known weight. In this process, the smallest possible quantity of alcohol should be used. After evaporating the spirit, the filtrate is weighed and the weight is taken as the urushiol content.

Nitrogenous Substance: The residue found on the filter paper is washed with 300 cc of boiling water and the insoluble portion left on the filter paper is then dried in a weighing bottle and weighed together with the paper. The nitrogenous content of the crude lac is thus obtained.

Gummy Substance: The filtrate after evaporating the water, is weighed and taken as the gummy substance content.

Different samples taken from crude lac collected from 18 years old tree with a circumference of 63.6 cm and a 6–7 years old tree with a circumference of 21.2 cm in Iwate Prefecture gave the following composition.

Analysis of crude lac						Percentage of anhydrous substance		
Sort of lac	Mode of tapping	Water	Urushiol	Gummy substance	Nitrogenous substance	Urushiol	Gummy substance	Nitrogenous substance
Early lac	Ordinary Exhaution	24.30	68.10	6.02	1.60	89.94	7.95	2.11
	Prime Exhaustion	22.67	69.16	6.22	1.95	89.44	8.04	2.52
Prime lac	Ordinary Exhaution	20.62	72.30	5.70	1.55	90.89	7.17	1.94
	Prime Exhaustion	19.78	73.60	4.67	1.95	91.75	5.82	2.43
Final lac	Ordinary Exhaution	20.20	70.11	6.82	2.87	87.86	8.55	3.59

	Analysis of crude lac					Percentage of anhydrous substance		
Sort of lac	Mode of tapping	Water	Urushiol	Gummy substance	Nitrogenous substance	Urushiol	Gummy substance	Nitrogenous substance
Short lac	Ordinary Exhaustion	18.70	71.52	7.38	2.50	87.86	9.07	3.07
	Prime Exhaution	18.25	71.77	6.82	3.16	87.79	8.34	3.87
Tail lac	Ordinary Exhaution	18.20	70.55	8.13	3.12	86.24	9.95	3.81
	Prime Exhaution	18.90	70.76	8.02	2.32	87.25	9.89	2.86
Lac collected from branches	Ordinary Exhaution	26.65	64.35	6.20	2.80	87.79	8.45	3.82
	Prime Exhaution	27.50	62.43	6.35	3.72	86.10	8.80	5.10
small trees (Early)	Ordinary Exhaution	27.60	65.40	5.05	2.00	90.27	6.97	2.76
(Prime)	Prime Exhaution	25.42	66.20	6.15	2.23	88.76	8.25	2.99

As shown in the above table, "Early lac" contains much water especially that produced from small trees; "Prime lac" has less water content; "Final lac" has the same water content while "Short lac" and "Tail lac" have much less water. The quantity of urushiol is an important factor in determining the quality of lac, and "Prime lac" is naturally richest in it. In the crude form, "Early lac" shows a somewhat smaller content of urushiol than "Short lac" (Urame) and "Tail lac" (Tome) owing to its large content of water. In the anhydrous form, however, the quantity of urushiol is the largest in the "Prime lac" followed by "Early lac," "Short lac" (Urame) and "Tail lac" (Tome) in the order given.

Gummy and nitrogenous substances increase the viscosity of lac and also greatly impair the lustre and transparency of the lacquer coating and they are least in "Prime lac." "Prime lac" is therefore the best considered from every point of view. "Early lac," though rich in water content, has less of gummy and nitrogenous substances and surpasses "Short lac" and "Tail lac" so far as this is concerned.

The quality of lac can never be judged by the results of analysis alone, since the physical properties such a drying power, transparency and lustre must of course be taken into consideration.

Lac obtained from branches being rich in water content and poor in urushiol with a heavy admixture of gummy and nitrogenous substances, is naturally regarded as an inferior product. (Since the nitrogenous substance is somewhat soluble in hot water, it inevitably admixed with the gummy substance in smaller quantity. The transparency and the lustre of lac should be given great weight in grading lac).

(B) PHYSICAL PROPERTIES OF LAC.

Every sample was filtered through the paper so called "Yoshino-gami" and the liquid so obtained, was put with a brush on panes of glass in uniform thin layers. The coated panes were carefully placed in shelves of box called "Furo" to be dried. The inside of the box is moistened and a wet cloth is placed on the bottom as well as to keep the inside moist; the panes so coated were examined occasionally to ascertain the time needed for drying. Indeed, some of them began to harden after 2 hours and entirely hardened in 3 to 4 hours; others remained still undried even after 30–40 hours, and others varied in time required between these limits.

Sort of lac	Early (Hatsu)		Prime (Sakari)		Final (Sue)	Short (Urame)		Tail (Tome)		Branches (Seshime)		Small trees	
												Early	Prime
Mode of tapping	Ordinary	Prime	Ordinary	Prime	Ordinary	Ordinary	Prime	Ordinary	Prime	Ordinary	Prime	Ordinary	Prime
Drying	A	B	B	B	C	D	D	E	E	D	C	B	A

Though the nitrogenous substance accelerates the drying of urushiol, it seems to be very objectionable when it exists in a large quantity. In general, lac containing a large quantity of nitrogenous substance is likewise rich in gummy substance and poor in drying power.

Transparency and Lustre:—The quality of lac can never be fully judged by the results of analysis alone; for it depends greatly on the two physical properties. A coating on glass readily reveals the degree of transparency of the lac used when dried. The degree of lustre can well be examined at the same time as that of transparency. Freshly coated glass hardly shows any distinction between different kinds of lac applied. Later, when the coatings are almost dry and assume a dark color, the distinction is clearly shown. For example, lac rich in urushiol becomes transparent and brown in color while one with a large admixture of gummy and nitrogenous substances becomes opaque.

Sort of lac	Early		Prime		Final	Short		Tail		Branches		Small trees	
												Early	Prime
Mode of tapping	Ordinary	Prime	Ordinary	Prime	Ordinary	Ordinary	Prime	Ordinary	Prime	Ordinary	Prime	Ordinary	Prime
Degree of transparency	A_2	A_2	A_1	A_1	B	C	D	D	D	D	C	B	A_2

The more urushiol lac contains, the more transparent and lustrous it is, and the better is the quality, on the other hand, the more rich in gummy and nitrogenous substances the lac is, the worse is the quality.

VI. Qualities of Lac Compared

1. COMPARISON OF DIFFERENT SORTS OF LAC.

By comparing the results of analysis, the drying power, transparency and lustre of the different sorts of lac produced in the Iwate Prefecture, from trees having an average circumference of 63.6 cm we see that "Prime lac" stands first in quality, "early lac" next, followed by "final lac," "short lac" (urame), "tail lac" (tome) and "branch lac" in order of quality. As to the lac collected from trees, 21.2 cm in circumference, in Kanagawa Prefecture "prime lac" took the lead while "early lac" was surpassed by "final lac" and "short lac" in quality. In general, lac obtained by the prime exhaustion method was slightly richer in urushiol than the corresponding product obtained by the ordinary exhaustion method but not much difference was observed so far as the content of nitrogenous and gummy substances was concerned. As to quality, the lac obtained by the prime exhaustion method is somewhat better.

2. COMPARISON IN QUALITY OF LAC OBTAINED FROM LARGE AND FROM SMALL TREES.

As shown in the foregoing pages, the nature of the lac is greatly influenced by the mode and time of tapping, etc. The age of the trees also exerts a considerable influence upon the quality of the lac, as is shown by the results given below.

PRODUCT OF LARGE TREES (16 years old) AND SMALL TREES (6–7 years old) COMPARED

Sort of lac	Method of tapping	Tree	Water	Urushiol	Gummy substance	Nitrogenous substance
Early	Ordinary Exhaustion	Large	24.30	68.10	6.02	1.60
"	"	Small	26.70	65.40	5.05	2.00
Prime	"	Large	20.62	72.30	5.70	1.55
"	"	Small	25.42	66.20	6.15	2.23

Compared with the product from small trees, "early lac" from large trees is less in water content by 3.3%, in nitrogenous substance by 0.4% while it is richer in urushiol by 2.7%, and in gummy substance by 0.97%. "prime lac" from large trees is less in water content by 5.2%, in gummy substance by 0.45%, in nitrogenous substance by 0.68% while it is richer in urushiol content by 6.1% as compared with that from small trees. Thus, both in "prime" and "early" lac, large trees surpass small trees in their products. "early lac" of large trees compared with "prime" of small trees is still richer in content of urushiol by 2% and somewhat poorer in content of gummy and nitrogenous substances; thus again to the credit of "early lac" from old trees is better than "prime lac" from young trees.

3. COMPARISON OF THE PRODUCTS WITH REGARD TO LOCALITY.

To show the influence of the producing locality upon the quality of lac, the composition of "prime lac" obtained from similar trees in different localities is given below:—

Locality of the production	Mode of tapping	Sort of lac	Water	Urushiol	Gummy substance	Nitrogenous substance
Kanagawa.	Ordinary Exhaustion	Prime	22.21	69.35	6.54	1.49
Ibaraki....	„	„	23.21	67.25	7.40	1.75
Iwate	„	„	25.42	66.20	6.15	2.23

"Prime lac" alone was considered in the above comparison, as it forms the principal product of the lac tree and is of the best quality.

From the above table, it will be seen that the product of Kanagawa is the least in water content and that of Iwate, the largest. As to the content of urushiol, the Kanagawa product is richer by 2.1% than the Ibaraki product while the latter in turn surpasses that of Iwate by 1.05%. Further, the nitrogenous substance is the least in the Kanagawa product followed in order by the Ibaraki and Iwate products; the gummy substance is comparatively small in the Iwate product. Obviously, the Kanagawa product is the best, followed by that of Ibaraki and Iwate. Thus, the product of warmer regions are better than those of the colder regions lying in the north-eastern part of the country.

VII. Comparison of Yield with regard to Size of Tree

Trees that are used in the tapping of lac are in general 21 cm in circumference and range in age from 6 to 10 years but among the lac trees of Iwate Prefecture tried by us it must be remembered that there were some large trees 60 to 85 cm in circumference. Comparing the yield of lac we find that it is always advisable to collect lac when trees have attained the greatest possible size, it having been established by our experiments that the quantity of lac always increases in proportion to the size of the trees. In comparing trees of 8 years old with those of 16 years old, the former gave a production of 150 grams apiece while the latter produced 1,273 grams; in other words, when the age of the tree was doubled the production was increased eight-fold.

VIII. Conclusion

Our experiments were limited to 3 seasons so that there still remains much to be examined in relation to the botanical physiology of the tree and the cost of tapping but we give here a summary of the results of our experiments.

1. The method of tapping commonly practised in this country is in accord with the principles of the growth of trees. It enables one to collect the largest amount of lac from the tree, yet, when considered from the economical point of view, it cannot be accepted as the best mode of tapping.
2. The prime exhaustion method incurs less expense in tapping than the ordinary exhaustion method.
3. Lac should be collected from trees that have attained a larger size than those commonly used which seldom exceeds 21 to 24 cm in circumference.
4. The yield of lac from a lac tree is directly proportional to the square of the radius of the stem within certain limits of age.
5. The lac trees in warmer regions give a large yield of better quality than those in colder regions.
6. Large trees produce better lac than small ones.

NOTES ON "SHIITAKE" *(Cortinellus Shiitake Schröt)* CULTURE

By Dr. SHOZABURO MIMURA, Forest Expert

The Shiitake mushroom which is an important forest by-product to this country, is produced to the extent of 2,000,000 kilograms a year, of which annually over 700,000 kilos. valued at $500,000 are exported. The study of this important product in the forest industry should not be disregarded.

I. Shiitake Culture as Hitherto Known

The Shiitake is known to have been used as a nutritious article of food for over 1,000 years. The people in ancient times seem to have learned how to grow Shiitake having noticed its occasional appearance on fallen trunks and rotten wood after fall of rain. They, then, began to fell trees in autumn, on which the mushroom grows better than the trees felled in other seasons and lately they learned to grow the mushrooms by the method so called "soak and strike." The Shiitake is a saprophyte and the wood on which it is to be grown should become thoroughly seasoned. The Shiitake can grow on almost any broad-leaved tree trunk, but it is mostly grown on the wood of oak or birch. In the case of deciduous trees, they should be felled early in the fall, ever-green oaks should be felled in mid-winter, and both cut into sticks 2 metres long. The bark should be cut to accelerate incisions as the "arrangement of leaf." The well seasoned wood so prepared is then piled up in shady places and covered them with leaves and branches of the tree so as to ensure successful development of spores. In the old method the people attached much importance to the time of felling trees and the place in which the billets are piled. The cause of the parasitic fungus, however, remained little known among the country people and consequently no artificial inoculation was ever tried prior to 1903, when the author undertook for the first time close study of the nature of the mushroom as well as of its spores and mycelium. The result that is the inoculation of spores and mycelium on seasoned wood was successful. The particulars of the work so effected have appeared in the "Journal of the Forestry Society of Japan" of April, 1904.

II. Properties of the Shiitake Spore

1. Spores germinate after a lapse of 24 hours in 16°C. or after 16 hours in 24°C.
2. Between 95 and 96% of the spores generally germinate.
3. Only 50–55% of spores kept for one month germinate.
4. Only 2–3% of spores kept for 3 months germinate.
5. Only 5–6% of spores kept after collection for 5 hours in sunlight germinate.
6. Only 1–5% of spores kept for 1 hour in 45°C. germinate.
7. 30–35% of spores kept for 2 hours in 42°C. germinate.
8. 80–90% of spores kept for 2 hours in ice germinate.
9. 50–60% of spores kept in ice for 24 hours germinate.
10. 10–15% of spores kept at 0°F. for 2 hours in a dried state germinate.
11. When spores in a nutrition liquid cooled at 0°F. for 1 hour they lose their germinating power totally.
12. The strong spores that retain germinating power in great heat or cold thrive wonderfully.
13. Spores germinate most readily in a decoction of Konara *(Quercus glandulifera Bl.)* wood.

III. Property of the Shiitake Mycelium

1. Mycelium perishes when dried.
2. Mycelium in the nutrition liquid, perishes when they are heated at 40°C.
3. Mycelium perishes when frozen.
4. The growth of mycelium in a decoction of Konara is most remarkable.
5. In a decoction of mother logs thin mycelium is only slowly produced.
6. In starch or sugar solutions or in the mixture of both, mycelium does not grow well.
7. The same solutions acidified or alkalized show no difference.

8. In distilled water, spore germinates but does not send out mycelium.

9. In the natural water mycelium only grows to a limited extent.

IV. Economical Method of Shiitake Culture

We have so far described the nature of spore and mycelium of the Shiitake mushroom and can immediately proceed to set forth a rational mode of culture. Such the method would not pay if tried as a secondary industry in the country and we shall herebelow give the details of the method found practicable in our own experiment.

(a) INOCULATION WITH BILLETS ON WHICH MUSHROOMS HAD GROWN.

The starch within the leaves of a tree generally moves toward the root at the end of autumn, hence, trees felled in the autumn are naturally richer in starch. Further, the billets obtained from trees felled between the fall and the time of budding in spring firmly kept their bark. Billets rich in starch and with a good bark covering are the most favorable for culture of mushroom. Therefore deciduous trees to be used in the culture should be felled before the fall of the leaves in localities, where there is no deep snow while in regions where snow falls heavily, trees should be felled early before spring buds sets in. The felled trees should be cut into appropriate lengths and well dried. The dried billets are then taken to a wet shady place, and among them the billets that already bore mushrooms are inserted. The spores from the mushrooms grown on the mother billets disseminate on the fresh billets and so ensure successful inoculation. The matured billets give ordinarily a harvest of mushrooms both in spring and autumn. Previous to the season, however, the billets should be kept in water for 24 hours and then struck heavy blows on both ends, the practice being termed "soak and strike." After this operation, mushrooms will appear only 1 week.

(b) DISSEMINATION OF THE SPORE.

Mushrooms grown in spring are generally collected when the fruit-body has fully developed. They are much used for home consumption and are termed "Spring mushrooms" ("Haruko"). The "Winter mushrooms" ("Tōko") are collected in the late of autumn or early in winter before the cap (thallus) is fully developed. They are much sought for in the Chinese market. Both kinds of mushrooms should immediately after collection be dried either in the sunlight or by fire, any delay in this work spoiling the flavor of the product. During the drying, spores fall in quantities from the matured caps and they should of course be collected for use in dissemination. For this purpose, rotten wood is ground into a meal and strewn over the mats on which mushrooms are placed for drying. The same meal loaded with spores may be used many times for this end. The mixture thus obtained is kept and can be used in inoculation by mixing with water and sprinkling it upon fresh billets.

(c) PROPAGATION BY MEANS OF MYCELIUM.

It is impossible in practice to obtain mycelium as is done in culture. The most convenient method to obtain them is to remove the outer coating of old billets that have been used in mushroom growth. The rotten part of the wood in which mycelium is abundantly found is ground into a meal. This meal is mixed with water and be spread on fresh Konara billets. The work is best done in winter when strong mycelium able to resist the cold can be produced.

The mushroom can be propagated by inoculation, but the method is of so scientific that it could hardly be comprehended by country people who remained ignorant of the possibility.

After the results of study of spores and mycelium of the mushroom made by us became fully known, they gave a great impetus everywhere to the culture of Shiitake. An increase of over 20% in amount was obtained by the adoption of the methods. Not only this but in districts where Shiitake culture had hitherto failed, the success was obtained as elsewhere by the adoption of our new method. There is no doubt that the artificial inoculation of the mushroom as now carried on throughout country redounds to the credit of this discovery and adds to success of the forest industry.

V. Conclusion

The spore of mushrooms loses its germinative power after a short interval, so it should be used immediately after collection and this is best done by inserting "mother billets" among the new billets to be used in culture.

The spore of the winter mushroom resists the cold well and therefore spores grown late in winter by the "Soak and strike" method may be used in propagation to advantage.

Mycelium grown on mother billets is also available for propagation. To this end, old mother billets declining the growth of mushrooms should be made into meal, and this meal, mixed with water, should be spread on fresh billets. This is best done late in winter or early in spring.

As the mushroom can be propagated either by the spore or by mycelium, there is no place where the culture cannot be carried on, contrary to the belief generally held prior to our investigations.

EXPLANATION OF THE PLATE III.

Cortinellus Shiitake Shröt. (Leitz V × 7)

(1) Germination of Spores in Konara bark decoction (at 26°C.).

1. Spore.
2. after 18 hours.
3. after 24 hours.
4. after 48 hours.
5. after 72 hours.

(2) Germination of Spores in decoction of rotten tree stumps.

6. after 18 hours.
7. after 24 hours.
8. after 48 hours.
9. after 72 hours.
10. after 118 hours.

(3) Germination of Spores in distilled water.

11. after 24 hours.
12. after 72 hours.

(4) Germination of Spores in natural water (at 26°C.).

13. after 24 hours.
14. after 72 hours.

(5) Germination of Spores in starch solution (at 26°C.).

15. after 24 hours.
16. after 72 hours.

(6) Germination of Spores in sugar solution. (at 26°C.).

17. after 24 hours.
18. after 72 hours.

(7) Germination of Spores in solution of starch and sugar (at 26°C.).

19. after 24 hours.
20. after 72 hours.

(8) Germination of Spores after exposure to sunlight for five hours.

21. after 24 hours.
22. after 72 hours.

(9) Germination of Spores kept at 42°C. for two hours.

23. after 16 hours.
24. after 72 hours.

(10) Germination of Spores kept at 45° C for one hours (at 25°C.).

25. after 18 hours.
26. after 72 hours.

(11) Germination of Spores kept two hours in ice.

27. after 18 hours.
28. after 72 hours.

(12) Germination of Spores kept in ice for four hours.

29. after 18 hours.
30. after 72 hours.

(13) Germination of Spores kept at 0°F. for one hour.

31. after 18 hours.
32. after 72 hours.

PLATE III.

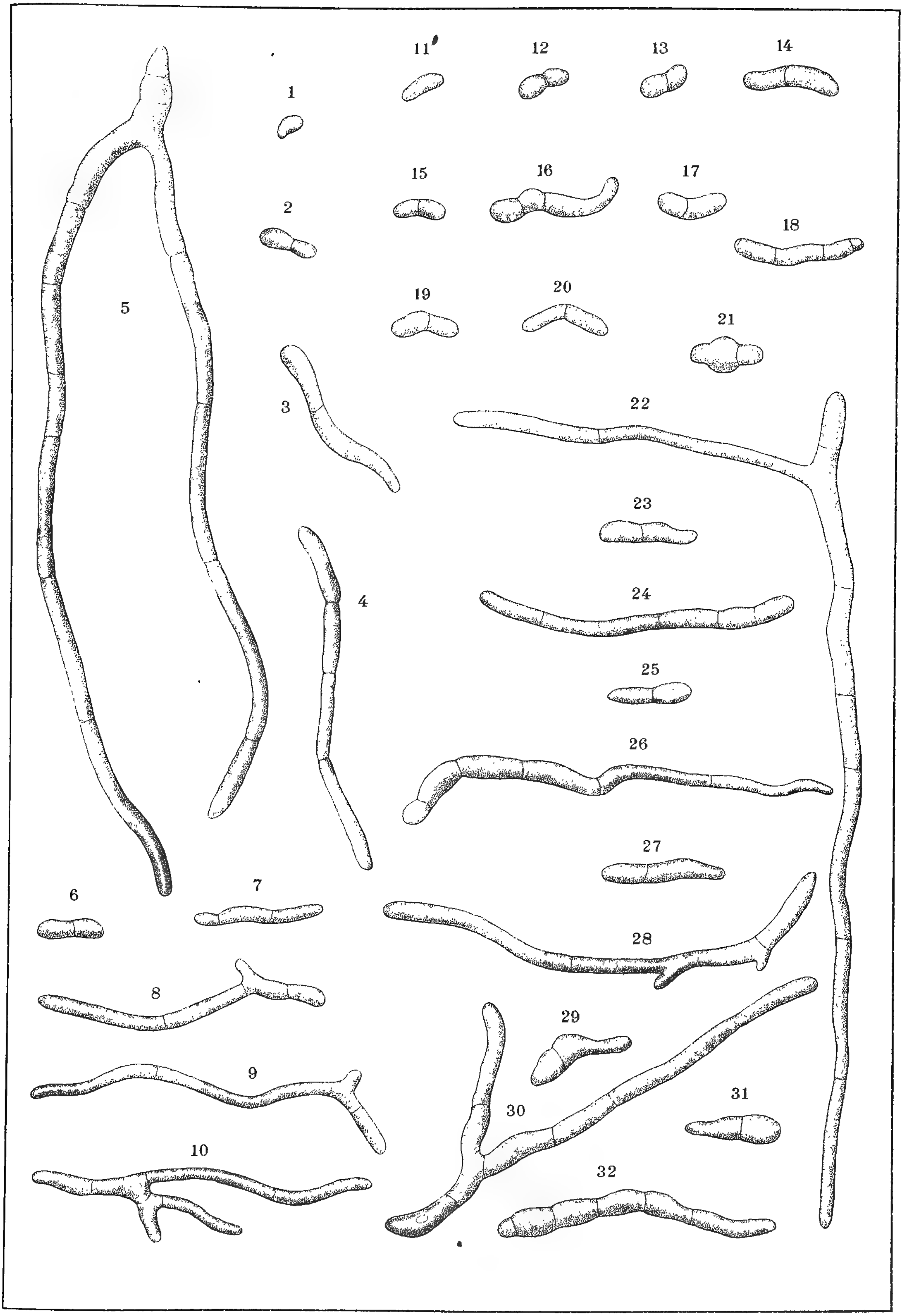

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PLATE IV.

Fig. 1. Shiitake culture in a mountainous district.

Fig. 2. "Soak and strike" methode of Shiitake culture.

RESEARCHES ON THE CULTURE OF "MATSUDAKE"

(Cortinellus Edodes P. Henn.)

By Dr. SHOZABURO MIMURA, Forest Expert

The Matsudake which ranks only next to the Shiitake in importance, is produced to the amount of 2,500,000 kilos. a year. Unlike the Shiitake which grows on felled trunks, the mushroom grows naturally in forests of Akamatsu *(Pinus densiflora, S. et Z.)* whose distribution throughout the country is quite extensive and it should not be overlooked in the exploitation of pine forests from the economical point of view.

The Matsudake is found then everywhere in the Country, from the southern extremity of Kyushu up to the northern part of the Main Island. Until the experiments herein recorded were made, the Matsudake was only left to the natural product, so that it has remained less valuable than it would otherwise have been.

There were some, indeed, who attempted to carry out the culture of the mushroom, but within our knowledge nobody so far succeeded. Thus, the artificial means of propagation remained unknown.

To artificially inoculate the mushroom one must be fully conversant with the parasitic habits and the nature, so in this Station particular study has been made of the spores, the results of studies we shall proceed and summarize:—

I. On the Spores of the Matsudake

The mushroom which is classified among Basidiomycetes grows late in autumn and produces colorless oval spores.

1. The spore so obtained germinate well after a period of 5 months so long as kept under ordinary conditions.

2. The spores germinate in a distilled water, decoction of young pine roots as well as in acid and alkaline.

3. In a temperature of 16°C., the spores germinate after 20 hours while in temperatures of 20° and 28°, 18 hours and 12 hours respectively are required.

4. At a temperature of 0°F., in a nutrition liquid, the spores do not

perish after standing 4 hours, nor do they perish in 24 hours at a temperature below 0°C.

Since the spores of this mushroom are not easily affected by the cold, they can safely pass the winter in the woods.

II. On the Mycelium of Matsudake

1. The mycelium which germinated in distilled water, acid or alkaline liquid grows rapidly at the ordinary temperature but they are not thick in size.

2. Mycelium grown in a decoction of pine roots makes rapid growth and attains a length of 1 cm after 24 hours.

3. The mycelium perishes immediately if dried.

4. The mycelium does not freeze after 7 hours' standing, at 0°C.

The rapid growth of the mycelium from a spore will well explain how mycelium finds their hosts readily as soon as they fall on ground.

III. How the Mushroom remains Parasite ?

1. The pine mushroom is invariably found in Akamatsu woods either alone or in association with other trees. Indeed, when the Akamatsu is felled, the land will not produce a single mushroom after the year immediately following. It should be noted that when the mushrooms are removed from the original woods together with some of the surrounding soil and kept carefully in pots, they will gradually fail to grow and the next year no new mushroom will appear. This lead us to conclude that the mushroom cannot live save as a parasite.

2. Take the soil where the mushroom have just appeared for the first time, say a pine forest of 15 years old and carefully study it around the sprouts. Under the naked eyes, one notes that the upper layer of the soil so taken is covered with raw humus and the rootlets which have well developed coral rhizomes while the lower part of the soil contains pine roots loaded with coral rhizomes and humus with clustered white hyphae side by side with the ordinary mycelium from which the mushroom grow. After careful study of one of these pine roots which had mushrooms in the previous year, one notes that coatings of grey

dark mycelium are clustering just below the epidermis and also the occasional presence of white mycelium and hyphae which will form into fruit bodies in later days. Also, in the rootlets of the pine stretching on the uppersoil grey mycelium are always found. The mycelium of fresh roots are always white, viz. at the end of November; they will, however, turn dark early next spring.

3. When a soil, poor in raw humus in which mushroom made their appearance, is carefully studied, somewhat large pine-roots are found therein, well provided with clustered coral rhizomes and rootlets just where the same are in contact with raw humus; and further research will show that the epidermis is covered with dark greyish mycelium with white ones well distributed in the soil as well, so that it gives an appearance of "Shiro" (white mycelium).

4. In over-matured pine forests where the mushrooms gradually fail to grow, one notes that under a heavy layer of humus the soil apparently seems to be full of white mycelium. Under the microscope, he sees, however, that what appears to be "Shiro" is no other than the cell-walls of decayed rootlets and that the layer above it consists of humus poor in rootles. The so-called "Shiro" of the mushroom is nothing else than this white fibrous sub-soil just below the ordinary soil from which the mushroom make their appearance in great abundance.

Both Agaricus mellus Vahl after Hartig and Agaricus campestris L. after Sachs are distinctly composed of rhizome-strands and fruit bodies; this, however, is not so in the case of the Matsudake where no full distinct line can be drawn between the nutritive mycelium and the reproductive ones or fruit bodies. In other words, although one can easily establish the relation between the mycelium found in the soil and the mushroom itself, but he will be difficult to know the direct relation existing between regular mycelium of the mushroom and the one found in the pine root.

From these facts, if Matsudake will be taken to have grown of mycelium found in the soil or humus it must logically be classified as a saprophyte. We know, however, well as stated above that the removal of the host tree, or the death of the latter, immediately results in the disappearance of the parasite Matsudake even though the surroundings remain unchanged. This lead us to the final conclusion that the mushroom must be taken as a true parasite thriving only on living trees.

IV. Mycorhiza that takes the Pine Root as Host

To successfully propagate Matsudake, one must commence with the study of the host. To this end we have carefully examined the roots of 1–2 years old seedlings of Akamatsu *(Pinus densiflora S. et Z.)* and Kuromatsu (*Pinus Tunbergii Parls.*) grown in the nurseries of the Station and have noticed two distinct mycorhizas both leading a parasitic life on the root.

With the view of ascertaining whether the same mycorhiza are invariably found in the root of pines of Japan or not, careful microscopical studies have been made on Akamatsu and Kuromatsu seedlings grown in the nursery of the Agricultural College of Komaba as well as on those taken from the Domain Forest of Shirasu, Yamanashi Prefecture, and from the Kyoto Local Nursery. The conclusion was that the mycorhizas just referred to are the parasites common to seedling grown everywhere; they invariably take these two pine species as hosts.

1. ECTOTROPHIC MYCORHIZA OF AKAMATSU AND KUROMATSU.

It has long been known that European pines have ectotrophic mycorhiza; we must, however, give thanks to Von Tubeuf for his discovery that the Akamatsu is likewise affected with ectotrophic mycorhiza. Whether this authority made the discovery on Akamatsu seedlings grown in European soil or those imported from Japan is not stated; we can not identify the mycorhiza with that discovered by ourselves. At any rate, we do not hesitate to say that the ectotrophic mycorhiza of the Akamatsu grown in this country are composed of colorless mycelium of 2–3 micron in diameter; they cover the outer parts of rootlets giving an appearance of net work which sometime grow so heavy that the root may appear as a white hairy substance to the naked eye. The reason why the parasite may be classified as a mycorhiza lies in the fact that it possesses every property of mycorhiza The same ectotrophic mycorhiza is, however, hardly met with on the rootlets found in the raw humus which is particularly suited to the growth of the mushroom.

2. ENDOTROPHIC MYCORHIZA OF AKAMATSU AND KUROMATSU.

The endotrophic mycorhiza found in *Pinus sylvestris L.* described by Möller do not seem to have been studied by the same author on Japanese pines. After our close studies on the subject with regard to *Pinus densiflora S. et Z.* and *Pinus Thunbergii Parl.* grown in Komaba and Meguro nurseries, we succeeded in finding the said parasite. These parasites are also found on the roots of the pine grown in localities where the mushroom is known to grow well.

V. The Mushroom Culture

In the autumn of 1907, some 50 Akamatsu seedlings of 2 years old were carefully up-rooted and washed so as not to injure the tender rootlets. Every possible precaution was taken. The seedlings were put in water and kept in a room where the temperature remained constantly at 16°C. during the trial. The rootlets that had stopped their growth for a time began to show activity with successive development of fresh shoots.

Later, the seedlings grown so promisingly in water were duly inoculated with spores of mushrooms collected from the Crown Forest; their daily progress was watched microscopically and it was learnt how the mycelium coming out from spores succeed in finding their host in the Akamatsu root. To our great regret, however, we could not continue the researches on the plan above stated, since, as everyone is aware, the seedlings of conifers in water culture are not fitted for long and delicate experiments. The seedlings gradually began to fail; so, at last, we were obliged to give up the original plan and substitute sand for water for half of the surviving seedlings. The other half we planted in ordinary pots with the necessary care and our pains were not entirely useless for a small mushroom appeared in one of these pots during the autumn of the next year, 1908.

VI. Personal Researches in Mushroom Growing Districts

Personal researches were made in places well known for mushroom production, the result of investigations are briefly recorded herein.

1. Kokura State Forest, Minamiazumi County, Nagano Prefecture.

The pine groves of this place are situated in a plain where the soil is formed of the decomposed granite. The age of the pine trees was about 60 years and they were well grown giving shade enough to protect the soil thus favouring the production of mushrooms. Moreover, Azalea, Enkianthes and other shrubby bushes provide a rich soft humus, and the rootlets of the pine branch out to this raw humus, with its rich layer of "Shiro," which is so favourable to the rich growth of mushrooms.

2. Crown Forest of Shirasu, Kitatama County, Yamanashi Prefecture.

Red pine about 100 years old grow on a shallow layer of granite pebbles and the decomposition product, the results of a great inundation in that locality about 100 years ago. Raw humus and bushy grasses are scattered here and there. The pine seedlings that come out either perished or are pulled up by people of the locality in their gathering of grass for forage. The growth of the mushrooms is very irregular and the rootlets of the trees are frequently exposed.

3. State Forest of Oyama, Atago County, Kyoto Prefecture.

The underlying rock is granite, having decomposition product of loam with raw humus on it. The pine trees range in age from 30 to 60 years and are sufficient close together to retain the moisture of the ground underneath while bushes and coppice also grow well. Where the mushrooms are abundant, the land covering is thin or the ground is very steep.

4. State Forest of Kamikamo, Atago County, Kyoto Prefecture.

The underlying rock which is of Palaeozoic Formation has on it a close growth of Akamatsu, 25 years old, while both coppice and bushes grow abundantly. Where Hinoki (*Chamaecyparis obtusa S. et Z.*) intermixed the soil is particularly deep and the mushroom grows well. On other places, where the mushroom grow equally well the soil is mostly shallow or the ground precipitous.

5. Kinugasa Crown Forest, Kadono County, Kyoto Prefecture.

The underlying rock of the place, which is of Palaeozoic Formation, has but shallow layer of soil with a tree covering of Akamatsu 30—50 years old and a good covering of bushes and coppice. On ridges, there is but a shallow coating of soil and occasinal cropping out of rocks and there the under-growth is sparse with but poor covering of trees; it is indeed on such places that mushrooms of rich flavor and good quality abound.

6. Shinomura-dainichizan, Minami Kuwata County, Kyoto Prefecture.

The underlying rocks of the place belongs to the Palaeozoic Formation forming in most places denuded barren ridges. Where only a thin coating of soil and humus are found with a persistent growth of low pines 40 to 50 years old, the best mushrooms are obtained.

7. Suchi Pine Grove, Funai County, Kyoto Prefecture.

The trees are mostly 20 years old and grow on a plain of alluvial origin. The soil is heavy and is hardly permeable so that under one foot the hole fills with water. Here bushes grow wonderfully and in a thick coating of raw humus the rootlets of pines stretch out in all directions.

In addition to the above-mentioned places researches were made at the following places:—

Mikatagahara, Hamana County, Shidzuoka Prefecture; Sekidzu, Kurita County, Shiga Prefecture; Kanayama, Nishiibaraki County, Ibaraki Prefecture; Nagano, Minami-kawachi County, Osaka Prefecture; Matsushima, Miyagi County, Miyagi Prefecture; Yamanaka, Enuma County, Ishikawa Prefecture; Higashiyama, Kita-aizu County, Fukushima Prefecture.

Everywhere the rule obtains that invariably follows where mushrooms are found there rootlets of Akamatsu exisit and where there are no rootlets, there are no mushrooms. Even in crevices of granite rock, not perfectly decomposed, mushrooms are found so long as there is a fair intrusion of pine roots. Indeed, these roots and rootlets always give rise to "Shiro" (white hyphae) which again on their turn give rise to mushrooms. Closer examination of these rootlets will at once show that these apparently sterile roots are living and that they all have broom-like endings.

Thus, we are led to conclude from our personal researches and experiments in inoculation carried out in the Institute that Matsudake is nothing else than the Ectotrophic Mycorhiza of the Akamatsu. The following facts are established:—

1. That the mushroom is the Ectotrophic Mycorhiza found on Akamatsu (*Pinus densiflora S. et Z.*) as a parasite.

2. The Akamatsu has both Ectotrophic and Endotrophic Mycorhiza.

3. The Ectotrophic Mycorhiza that generally takes the Akamatsu as its host is never found on the pine root where the mushroom is found as the parasite.

4. No foundation exists for the old belief that granite rocks are specially favourable to the growth of mushrooms. The growth of the mushroom has no particular relation to the existence of granite rocks.

5. The mushroom can easily be grown on wood land, where the pine can only send out their rootlets to the surface soil, owing to the rocky nature of the underlying layer, etc. Where the land is naturally rich, such rootlets must be forced by human agency to stretch out near the surface soil in order to produce mushrooms.

6. The spores of the mushroom should be sown immediately after the harvest.

RESEARCHES ON THE "WHITE JUDAS'-EAR"

(Tremella fuciformis Berk)

By Dr. SHOZABURO MIMURA, Forest Expert

The Chinese, who are particularly fond of mushrooms, use various sorts for culinary purposes and among these the "white Judas'-ear" is undoubtedly the one most highly prized by oriental epicurists. The article generally commands a price in the market of 15 to 20 Dollars per kilo. Since it is a saprophyte found on broad-leaved trees, it may well be cultivated side to side with Shiitake mushrooms in districts rich in oaks; and a study of this peculiar saprophyte fungus will prove of general interest to those connected with foresty.

I. Classification of the "White Judas'-Ear"

The "white Judas'-ear" offered in the market is a white hard irregularly folded fungus. The light yellow variety is known as the "Golden Ear" while the colorless one is known as the "Silver Ear."

When the dry "white Judas'-ear" is put in water, it swells considerably after a while and turns into a semi-transparent gelationous substance. Freshly collected ears show under the microscope the basidios, peculiar to the Tremellinea family. The fruit body is formed of a gelatinous substance divided into irregular folds, much resembling to the cocks-comb in shape. The round pear-shaped, longitudinally divided basidios bear four elongated sterigmata, situated apically, and 4 basidio spores are united into the hymenium on the surface of the fruit body. This shows that it is of the Genus Tremella in the Tremellineae. Through successive culture of the spore we came to the conclusion that the "White Judas'-ear" is nothing else than Tremella fuciformis Berk.

II. On the Spore of the "White Judas'-Ear"

To know the nature of the spore of "White Judas'-Ear" is of considerable importance for its culture and we give some of the results of our researches in this line.

1. The bacidio-spores kept in distilled water or in a decoction of oak bark give rise to yeast-like buddings after 48 and 52 hours at temperatures under 28°C. and 16°C. respectively.
2. In a decoction of oak bark, the formation of yeast-like buddings is very active.
3. Basidio-spores do not perish in a temperature of 0°C. in a period of 24 hours.
4. Basidio-spores standing 2 hours at 0°F. do not lose their germinating power.
5. Basidio-spores often give rise to mycelium directly in distilled water.

III. On the Mycelium of the "White Judas'-Ear"

The mycelium of this basidiomycetes may likewise be used in the propagation and the following are the results of investigations:—

1. The mycelium of the "White Judas'-Ear" perishes when dried.
2. The Mycelium does not perish at a temperature of 0°C.
3. The mycelium perishes when kept at a temperature of 0°C. for 5 hours.

IV. Notes on the Culture of the "White Judas'-Ear"

The fruit-body of the "White Judas'-Ear" is a substance which appears after a rain or on wet season so that the collection of spores is particularly difficult. Owing to the difficulty, propagation by means of mycelium was first tried in April, 1907. The rotten billets of Konara (*Quercus glandulifera Bl.*) grown with this mushroom was turned into a soft mealy substance adding sufficient water. This was inoculated on Konara billets which had been cut in the previous September, and were carefully kept. About July, the first fruit-body appeared and after that time both in spring and autumn fruit bodies appeared. The fruit-body produced on the same billets in June was made into meal with water and was inoculated on Konara and Shide (Hornbeam) wood previously stelirised. The billets so treated were piled on heaps with other billets grown with the "White Judas'-Ear" produced in the Institute. Again on Konara wood, felled on November, 1912, meal of the "White Judas'-Ear" was inoculated in June of the following year. They both gave rise to a new crop of fruit-bodies.

As a result of these researches, we are convinced that the artificial inoculation of the "White Judas'-Ear" is easily carried out and that it is an enterprise of great promise.

V. Conclusion

1. The "White Judus'-Ear" is Tremella fuciformis Berk botanically.
2. The "White Judas'-Ear" can easily be grown on the broad-leaved species of the oak family.
3. The "White Judas'-Ear" is best inoculated by the chopped fruit-body mixing with water.
4. Generally three months after inoculation gives the "White Judas'-Ear" rise to a fruit-body, after which the same appears regularly both in June and late in the autumn.

EXPLANATION OF PLATE V.

(1) Germination of Matsudake (*Cortinellus Edodes P. Henn*) spores in decoction of pine roots (Leitz V×7).

1. Spore.
2. After 18 hours.
3. After 24 hours.
4. After 48 hours.
5. After 72 hours.

(2) Micorhiza on Akamatsu (*Pinus densiflora, S. et Z.*).

6. Endotrophic micorhiza (Leitz IV×4)
7. Ectotrophic micorhiza (Leitz III×7)
8. Longitudinal section of pine cortex through which Matsudake mycelium appeared (Leitz III×7)
9. Do. transverse section (Leitz III×7)

(3) "White Judas'-Ear" Spores germinating in distilled water at 25°C. (Leitz IV×7).

10. Vertical section of a part of the fruit-body.
11. Spore.
12. Basidio-spore with yeast-like buddings (48 hours).
13. Mycelium (52 hours).
14. & 15. Basidio-spore with yeast-like buddings (52 hours).
16. Do. 72 hours.
17. Do. 96 hours.

EXPLANATION OF PLATE VI. Fig. 1.

1. Clusters of coral rhizomes growing on rootlets of pine.
2. Matsudake mycelium in the tissues of rootlets and rhizomes of the pine.
3. Matsudake mushroom, its mycelium and rootlets of the pine.
4. Overlying layer of soft humus with rootlets of the pine and mycelium of the mushroom intermixed.

PLATE V.

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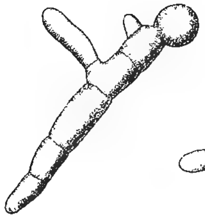

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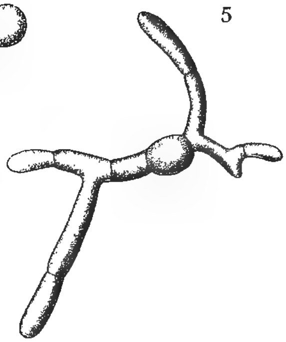

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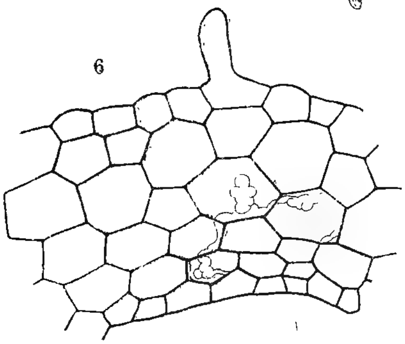

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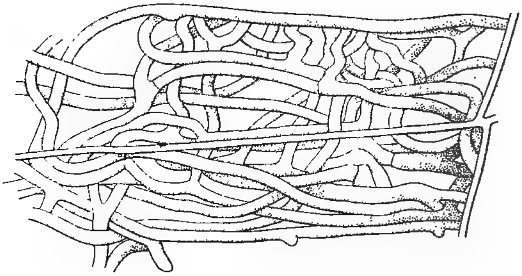

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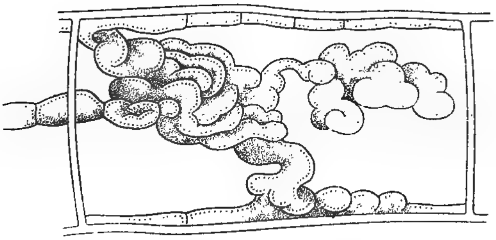

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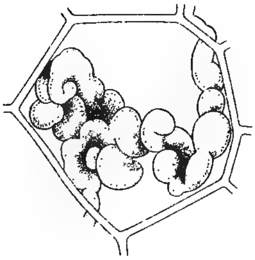

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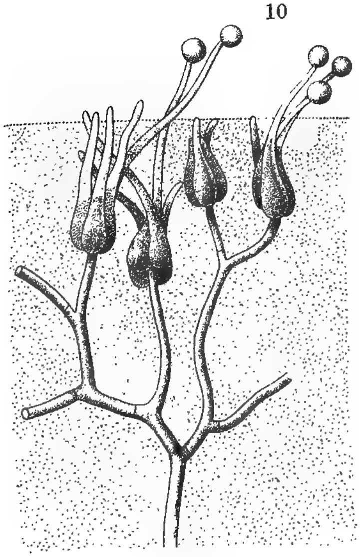

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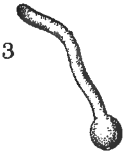

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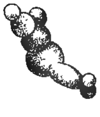

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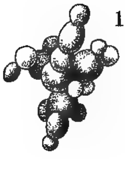


Fig. 1. Mycelium of Matsudake and pine roots.

Fig. 2. Matsudake mushrooms raiced in Akamatsu trees.

Fig. 1. Shiitake mushrooms grown from spores.

Fig. 2. "White Judas Ear" grown on Konara wood.

THE HYDROPSY OF "MADAKE"

(Phyllostachys Bambusoides)

By SEIICHI KAWAMURA, Botanist of Forest Experiment Station

"Madake" (*Phyllostachys Bambusoides*) is a species of bamboo which has been most extensively cultivated from old times. It is widely used in house construction as well as in the industries.

Kyoto and the surrounding districts being particularly suited in its climate and soil for the growth of this valuable plant are well known for the culture of this species of bamboo. In recent years, "Madake" has been planted extensively in neighboring provinces. Unfortunately, of late hydropsy (Midzugarebyo) has made its appearance and the malady is spreading.

The malady is characterised by the accumulation of water in the hollow part of the stem which causes the gradual fall of leaves. Though there are many diseases that affect "Madake," none is comparable to hydropsy in the damage done, since the affected stem loses all its toughness and is rendered unfit for any use.

I. Symptoms and Characteristics of the Malady

No particular symptom of the malady is observable in the early stages of bamboo, e.g. such as at the time of sprouting. It is only in bamboos two or three years old that the stem becomes affected and the terminal leaves began to fall in February or March. The affected bamboos are hardly discernable in the grove, but they are clearly seen when the grove is viewed from a distance. Later, in April and May, the stems so attacked begin to lose their bright fresh colour and the leaves fall. On splitting the affected stem lengthwise, however, one does not yet find any of the liquid peculiar to the malady in the stem. With the progress of the malady, the top of the stem is totally discolored, and the lower part of it also turns to lighter colour being less lustrous than the sound stem. Still later, the upper end of the stem turns to reddish yellow in colour and a clear liquid accumulates in the stem, particularly in May and June. The amount of the liquid varies according to the individual plant, but in general, the one-third of the hollow is filled, although sometimes about two-thirds of it is filled. As a rule, the liquid accumulates mostly in the fifth or sixth joint above the ground. The higher and lower nodes have little of the liquid, and those at the top have none.

At this time, the affected stem turns to greenish purple in colour and finally a dark purple, the colour being so striking that the affected stems can easily be distinguished from a distance. Finally the stems so affected become rotten through the attack of other parasitic fungi, the interior liquid dry up and the stem presents a withered gray appearance.

II. Stem, Root Stem, and Root Tissue of the Affected Bamboo

With regard to size of stem, thickness of woody tissue, distance between nodes, and age, the affected stems were compared with those of sound ones, and the abnormality of the tissue was fully studied. In Plate VIII, Fig. 1, shows a micro-photograph of the cross section of a healthy "Madake" stem cut in 1909 after sound growth from May, 1907. Apparently, parenchyma in this stem has considerably thickened with well developed vascular bundles. Cell layers around them show every trace of vigorous growth giving strength and toughness to the woody stem.

In Plate VIII. Fig. 2, is the micro-photographical representation of two years old "Madake" stem which sprouted in July, 1907, and perished from the malady. The stem serves well as a comparison with the healthy grown stem above referred to, and specimens of the two stems agreeing in height, distance between nodes, circumference of stem, and thickness of woody tissues were fully compared.

On comparing affected pieces (Fig. 2.) with those of the sound stem (Fig. 1.) one sees immediately that the parenchyma of Fig. 2. shows at a first glance no marked distinction, excep ting that the fibrous cells in Fig. 2. are surrounded only by a series of weak tissues composed of shin-walled cells not observable in Fig. 1. In Plate VIII. Fig. 3. is the micro-photograph of a stem one year old that sprouted in May, 1909, and died in the course of the next year. Compared with Fig. 2. it shows still poorer parenchyma havi ng a far thinner wall of cells than Fig. 2. It is evident that the stem of Fig. 3. during one year of its life did not developed as shown in sound stems in thickening the walls of cells. Only a small portion of fibre tissues that thickened their walls was found near the vessels, and the outer tissues showed but a poor development compared with the strong tissues found around the vascular bundles of sound stems of the same age. Comparison was likewise made of the inner tissues of healthy and affected stems, with regard to size, age, progress of malady, etc. The conclusion reached was that the affected stems have in most cases thin parenchyma and their fibrous tissues around the vascular bundles have only an imperfect development.

Under the microscope we find that in the affected stems the thick fibrous layers around the vessels are reduced to thin ones by the attack of the mycelium. Apparently, vessels can no more sustain the pressure of liquid on their walls and admit the perculation of the liquid, which otherwise would have remained in the vessels themselves, to be ultimately accumulated in the hollow surrounded by tissues poor in vascular bundles. On the other hand, the external tissues of the stem hardly admits the percolation of the liquid which thus most naturally find its way into the hollow.

The tissues forming the lower part of the affected stem are interlaced with mycelium and naturally give easier access to the liquid than the upper part. Since, however, the tissues of lower part of the stem are strong and thick walled, they do not allow the percolation of the liquid in large amounts, and large accumulations are moreover impossible in that part of the stem. This shows that the percolation of the liquid depends upon the thickness of surrounding tissues more than on the irregularities of cell layers caused by the attack of mycelium.

In Plate VIII. Fig. 4. is a micro-photographic representation of the cross section of the affected root stem. The tissues are little distinguished from those of the stem; when compared with healthy ones, they show likewise traces of imperfect development. Roots are most easily attacked by the mycelium both in the exterior and interior tissues and when they are attacked by mycelium then they often have been prevented from discharging their proper functions by interlacing mycelium.

III. Effects of Malady and its Diffusion

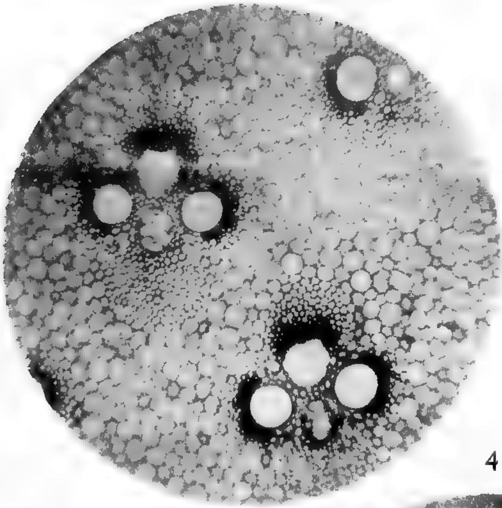
We have already described how the stems and roots of bamboo are affected by the malady that they cannot perform their natural development. The malady attacks the subterranean stems or roots of bamboos at the time of sprouting. Once subterranean stem or roots are infested by the mycelium of hydropsis they are invariably hindered in growth and owing to the poor nutrition, they end in the producing stems that are weak in a way characteristic of the malady.

It is commonly known that among ordinary trees, when attacked by a malady on their roots, show immediate signs of the trouble in their crowns. With bamboos, on the contrary, the affected stems differ in appearance but little from the healthy ones in the early stages of the malady. Since, no cambium layer exists in bamboo, growth in the size of the stem is limited to the first two weeks. In later days, the stem gradually grows inwardly, so that the five years old stem is not notably larger than the one year old stem so far as the circumference is concerned although it is far heavier and more compact.

As to fruit-body no conclusion is yet arrived at and we must wait for full researches on this subject.

PLATE VIII.

3



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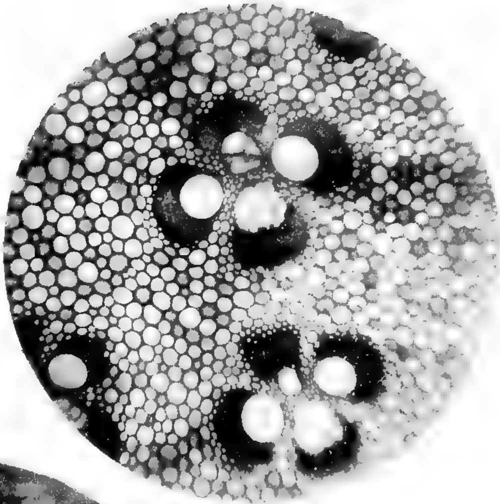

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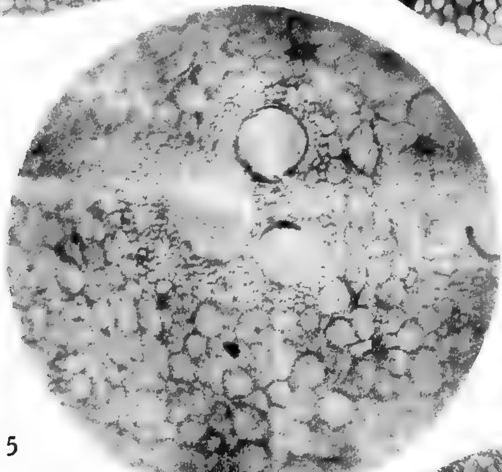

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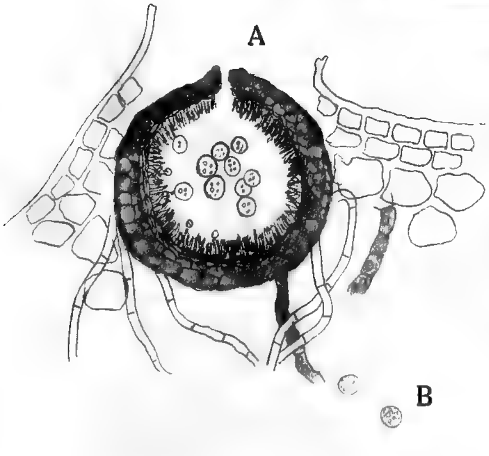
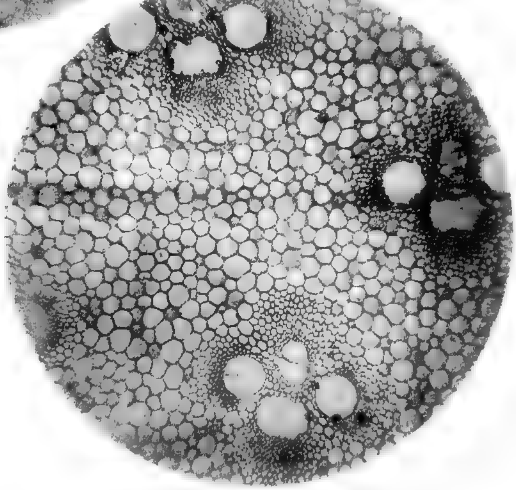




THE RED PLAGUE OF "SUGI" *(Cryptomeria Japonica)* SEEDLINGS

By SEIICHI KAWAMURA, Botanist of Forest Experiment Station

Since the " Akagarebyo " or red plague, which attacks " Sugi " *(Cryptomeria japonica)* seedlings, became known a few years ago, the plague is reported to have spread to various parts of Japan. The one or two years old seedlings suffer most while larger saplings are less liable to attack, and even when strong sound saplings are infected by the plague, they can resist the attack.

The writer has made personal investigations since December, 1911, in various places where the plague has spread. The conclusion reached is that the plague attacks only seedlings of " Sugi " *(Cryptomeria japonica)* under five years of age, and that the plague is met with neither in other coniferous trees nor in broad-leaved trees. The plague cannot be assumed to have been caused by physiological derangement in seedlings, owing to the influence of climate, unfavorable condition of soil or else by human agency. The " Yoshino Sugi " has ever been seriously infested by *Pestalozzia Shiraina,* and even though he often came across with this fungus on the dead leaves of " Sugi " seedlings infected by this plague he assigns the plague caused to other origin than this fungus, Thus, he has every reason to name the plague with a specific designation.

The plague is now reported throughout the country from Kagoshima in the South up to Aomori in the North and fear of further diffusion alarms the foresters of the country. The authorities and the people are now striving to fight with this formidable pestilence.

Three different fungi are found on " Sugi " seedlings infected with the plague, viz., *Phyllosticta, Cercospora* and *Pestalozzia.* Of these, *Pestalozzia* is far rarer than the other two fungi and is generally found in association with other parasitic fungi mostly on old decayed leaves, so that it (*Pestalozzia*) could not be taken as the specific cause of the plague. We must assign the origin of this trouble therefore either to *Phyllosticta* or else to *Cercospora.*

In the present treatise, we shall discuss only the nature of *Phyllosticta,* since investigations are still unfinished so far as *Cercospora* is concerned.

I. Morphology of Parasite

The fungus which infects "Sugi" leaves is wanting in stroma; its presence is always characterised by dark minute spots noticeable to the naked eye, which are nothing but the opening of the picnidium. The picnidium is immersed in epidermis, 120–140μ in diameter, the wall 15–19μ thick; spore one celled, round, sometimes, ovoid or elliptical, colourless, 8–10.5μ in diameter. The mycelium is, as a rule, hyaline. But on examing the tissue of the dark brown part in the infected leaves, the mycelium was found to be dark brown or yellowish brown and with numerous septa having often an appearance of beads.

II. Classification of the Fungus

The fungus of the red plague belongs to *Sphaeropsidales* of *Fungi Imperfecti.* As to further subdivision, according to the classification hitherto known, one must assign it either to *Phyllosticta* or *Phoma* or *Macrophoma.* This classification is based on the size of spores and the part of plants affected by fungi. Thus, fungi that bear the spores above 15μ in diam. are classified as *Macrophoma;* below 15μ as *Phyllosticta,* so long as they attack leaves; while those that infest other parts of the plant are classified as *Phoma.* In other respects, especially in morphology, the three are altogether alike. As we have just said, *Macrophoma* is nothing but the designation given to fungi bearing spores above 15μ in diam; but the distinction is illogical, since that spores contained in one and the same picnidium are always dissimilar in size. How can a species bearing spores of 14–16μ in the same picnidium classified? It may be classified as *Macrophoma* considering that spores above 15μ are contained, or it may again reasonably be classified as *Phoma* when spores below 15μ are contained. In view of this fact, we do not see any particular need of classifying as *Macrpohoma* expressly. Again, we do not see any need to make particular distinction between *Phyllosticta* and *Phoma,* simply because the former attacks leaves while the latter does not. It has been customary among mycologists to group parasites which attack needle leaves as *Phoma,* in consideration of the fact that leaves of conifers resemble twigs of other trees but such a distinction can never be called a scientific one.

In fact, so long as the leaf is taken as the determining point, anything that performs the function of a leaf should be classified as leaf, without regard to outward appearance; and the same rule must equally be followed in the classification of parasites occur on them. It follows therefore that *Macrophoma*, *Phoma* and *Phyllosticta* should be comprehended in a single division. Such a classification would certainly be natural and it should have a comprehensive name relating also to the name of the host. Discarding *Macrophoma* on account of its ethymological significance, we may take one of the two remaining names and it is appropriate to adopt that of *Phyllosticta* since the fungi referred to, invariably bear their picnidium on leaves or else on twigs.

The malady, although so injurious in nature, has never been studied, and naturally there is not the literature on the subject. After careful consideration, the author has decided to designate the fungus as *Phyllosticta, (Phoma) Cryptomae*, the name being derived in part from that of the host tree. Besides *Phyllosticta*, above-mentioned, *Cercospora* may be accountable as the cause of the red plague.

III. Symptoms of the Plague

The red plague attacks severely " Sugi " *(Cryptomeria japonica)* seedlings of 1 to 2 years old mostly; those 3 to 4 years old suffer far less, while saplings are least affected. The plague first make its appearance on leaves near the ground, since there are defficient of sunshine, less ventilation and excessive moisture from the ground.

The fungus injuries leaves at its early stage; it passes into branches and twigs later on, causing brownish dark spots on the surface. Evidently, the fungus which thus attacks the leaves and gradually makes its way into other parts of the young plant, hinders the growth.

In proportion to the progress of the red plague, the chlorophyll grains contained in leaves and twigs turn brown, giving them a dark brown appearance. The next step is the utter failure of the growth of the tissue and then the leaves become dry and brittle.

PLATES VIII.

Fig. 5. A. Cross section of picnidium magnified III × V, Seibert.

Fig. 5. B. Spores do.

WHITE ANTS IN JAPAN

By MUNEMOTO YANO, Entomologist of Forest Experiment Station

There are about 14 species of white ants known in Japan; they are mostly found in the warmer parts, viz. in Ogasawara, Riukiu and Formosa. Only three of these are found in the Main Island, Shikoku and Kiushu. In the present treatise, we purpose to describe these insects to give their life history and to consider the damage done by them.

I. *Leucotermes (Reticulitermes) speratus* Kolbe

1. DESCRIPTION.

Winged form: Length 4.5–6.5 mm. Body blackish brown; head darker; legs and dorsal surface of the body lighter; pronotum, tibia and tarsus light yellow; wings grayish. Head somewhat smooth and shining. Body covered with short brownish hairs, sparsely on the head. Head quadrate oval, longer than broad. Vertex transversely depressed anteriorly. Front in the middle with a shallow longitudinal impression. Compound eyes small; ocelli small, situated near the eyes. Basal portion of clypeus short, distinctly limited. Antennæ 17–jointed; third joint very short. Pronotum narrower than the head, flat; its anterior and posterior margins have distinct incisions. Meso- and metanotum distinctly, but somewhat broader posteriorly, with rectangular border. Wing membrane very strongly reticulated; media simple in the middle portion between the radius sector and cubitus; cubitus 7–10–branched. Cerci short.

King: Length 5 mm similar to the winged form in color but with no wing.

Queen: Length 9.5 mm. Length of the abdomen 6.5 mm, width 2 mm. Head and thorax similar to the winged form. Abdomen light brownish white; lateral surface with fine pubescence.

Substitute queen: Length 5.5–7.3 mm. Width of the abdomen 1.5–2 mm. Whole body brownish or milky white. Compound eyes flat, colorless, occasionally with trace of brownish pigment. Antennæ 17–jointed. Meso- and metanotum have short rudimentary wing sheath.

Pubescence sparsely; lateral surface of the abdomen covered with silky pubescence.

Substitute king: Length 4.5–5.5 mm. Head and thorax similar to the substitute queen.

Nymph of the winged form: Length 5–6 mm. Milky white with white hairs. Compound eyes somewhat prominent and light brown in color. Antennæ 16–17–jointed. Wing sheath projecting long.

Nymph of the substitute royal form: Similar to that of the winged form, compound eyes flat and colorless; Wing sheath less conspicuous.

Soldier: Length 4.5–6 mm. Head yellow, brownish anteriorly; mandibles brown; thorax and abdomen yellowish white; pronotum somewhat darker. Pubescence on the head sparse. Head cylindrical with nearly parallel lateral margins and round posterior margin. Front with a long and broad groove in the anterior part. Basal portion of the clypeus short. Labrum tongue-shaped with an acute white apex. Mandibles stout, somewhat curved. Antennæ 16–17–jointed, sometimes 18; third or fourth joint shorter than others. Pronotum narrower than the head, anterior and posterior margins with distinct incision. Abdomen elongate; cerci long.

Worker: Length 4–5 mm. Yellowish white. Body covered with brownish pubescence, in the thorax and abdomen densely. Head broad oval, fontanel and sutures invisible, basal portion of clypeus is very short. Antennæ 16–18–jointed. Pronotum distinctly narrower than the head, saddle-shaped, anterior and posterior margins are provided with incisions. Abdomen spindle-shaped.

Newly hatched larva: Length 1 mm. Similar to the worker. Whitish in colour covered with white hairs. Antennæ 10–jointed; 2nd joint shortest.

Egg: Length 1 mm. Width 0.3 mm. Whitish in colour.

2. LIFE HISTORY.

The winged termite after leaving its nest flies about between the end of April and the end of May. During this period, they fly 3 or 4 times in swarms. The same activity is shown in every nest lying in the same localty and it take place between 10 o'clock a. m. and 3, p. m., especially between 10–11 a. m. They first fly for some 10 to 300 feet from their nest. Later, they come down to the ground and press their wings on the ground bending their bodies so that the wings are broken off at their basal joint. The wingless termite goes about with great activity. The male follows the female and finding a small crevice in rotten wood or soil, large enough to conceal the two, the couple takes it for their habitation. Their actions can well be watched by feeding a couple of the termites in a glass tube, in which wood or soil is placed; after feeding on wood and remaining quiet for two weeks, they copulate and an egg is laid every day for 4 or 5 consecutive days. After this, the laying of eggs is stopped till August when it is again begun. The eggs thus laid hatch after 3 weeks; the larvæ so obtained are fed by imago at first but they soon begin to get their food for themselves. They mostly turn into workers, occasionally into soldiers, but never into generators. During the winter months, the Queen does not lay eggs waiting till May for laying. White ants kept in a glass tube for three years never gave rise to nymphs, the larvæ produced during the interval turning into workers and soldiers. This failure of nymphs is most probably to be ascribed to the shortage of the workers owing to the scarce supply of food in the tube. Should they be left alone, nymphs would probably produced from 3rd year.

In case of the lack of generators from the death of the king and queen or other reasons a so-called neoteinic kings and queens are produced as substitutes, but they never give birth to a true king and queen. Such substitute kings and queens generally appear very soon. In case of the true royal form there is invariably a regular couple of two while neoteinic queens vary from about 50 to 100 in number. Different combinations of larvæ, soldiers and workers were made to ascertain if a detached colony taken from a family produces same differentiation. Where workers and larvæ are combined together they always follows a number of neoteinic kings and queens. These substitute royal generators can be obtained from larvæ alone so long as workers exist to feed them. As larvæ and workers can live in isolation as they are found in many nests, we can easily imagine that such a formation of new families is quite common in nature.

In winter, the white ants make a deep hole in wood and pass time; they do not remain entirely dormant and especially the workers show considerable activity on warm days in their subterranean life. The activity becomes greatest from April to the end of November. Towards May, they lay eggs which apparently develop into the workers and soldiers to be seen late on July. The eggs which are laid after June give rise invariably to workers, soldiers and nymphs. Towards June to July, young numphs make their appearance. They attain considerable size by the end of November; get their wings in April, the next, and about two weeks later leave their nest and swarm.

3. NATURAL ENEMIES.

So long as the white ants are living in their nest, they are seldom attacked by enemies other than parasitic mites, etc. Often where the nest is not well guarded, true ants intrude, and *Euponera soliteria* are known to be their powerful enemies. The winged forms in their flights are often caught by swallows, robber flies such as *Asilus scutellaris* and dragon flies such as *Orthetrum japonicus,* etc. Wingless imagoes often fell victim to the true ants such as *Formica fusca japonica, Tetramorium cuespitum,* etc.

4. DISTRIBUTION.

The species is widely distributed all over the country and it is found in Hokkaido, the Main Island, Shikoku, Kiushu, Formosa and Korea, being most abundantly met with in the central and southern parts of the Main Island and north of Kiushu.

5. DAMAGES.

The species that lives in wet wood is fond of fences, bridge work, railway sleepers, the foundations of houses, etc., covered with earth or in contact with it so as to be kept damp. Particularly, wood foundations and the lower ends of posts are their favorite abodes; they creep up and make their way into higher parts of pillars and walls and are sometimes known to spoil household utensils and furnitures. The white ants also often take their abode on the under-side of roofing when they are expelled from the leakage of rain water, etc. This species owing to their smaller reproductive power is relatively harmless.

This species is also known to do harm to cherry, pine, willow, mulberry, tea, pear and other living trees; they make their way into the wood through cracks or other openings in the wood. Sound camphor seedlings with no wound whatever often suffer from attacks of this white ant.

II. *Coptotermes formosanus* Shiraki

1. DESCRIPTION.

Winged Form: Length 6.5–7.5 mm. Brownish yellow, head darker, ventral surface and legs yellowish brown, meso- and metanotum whitish anteriorly. Wing yellowish, at the basal portion with brownish tint. Body covered with brownish long hairs; in the abdomen densely. Pubescence of the wing dense and comparatively long. Head oval. Fontanel indistinct. Compound eyes normal in size, prominent. Ocelli small, placed near to the compound eyes. Basal portion of the clypeus short. Labrum subtriangular. Antennæ 19–20–jointed. Pronotum as broad as head, with somewhat concave anterior margin and nearly straight posterior margin. Meso- and metanotum narrower posteriorly, on posterior margins with a deep incision. Scale of the anterior wing large. Length of wing 11–12 mm. Media very near to the cubitus. Cubitus about 8–branched.

King: Length 7 mm similar to the winged form.

Queen (old): Length 24–27 mm. Width of the abdomen 7–8 mm. Abdomen long elliptical, milky white in color, with yellowish tints in the intermediate portions between the dorsal plates.

Nymph of the winged form: Length 7 mm. Whitish in color, with short light brownish hairs. Compound eyes and ocelli present but colourless. Wing sheath broad. Antennæ 15–20–jointed.

Nymph of the substitute royal form: Length 6 mm. Yellowish in color, with short whitish hairs. Compound eyes colorless. Antennæ 15–18–jointed. Pronotum small, narrower than head.

Soldier: Length 5–5.5 mm. Head brownish yellow, darker anteriorly; mandibles brownish black; pronotum pale yellow; thorax and abdomen yellowish white. Pubescence brownish; in the head sparsely. Head rounded and narrower anteriorly, fontanel large and directed forward. Antennæ 15 jointed. Pronotum much narrower than head.

Worker: Length 4–4.5 mm. Head yellowish white; body whitish. Antennæ 15–16–jointed.

Egg: Length 1.3 mm. Width 0.3 mm. Whitish in color.

2. LIFE HISTORY.

The swarming of the winged form of this species generally take place 3 or 4 times between the end of May and first part of July in the Main Island and Kiushu; in Formosa between the early part of May and that of June. The swarmings are simultaneous for all the nests lying within a certain locality as in the case of the above-mentioned species, although the time is between 6 p.m. and 10 p.m. The swarm is attracted by bright lights. As with the above mentioned species, the winged insects form new homes after the swarming; they mostly copulated and lay their eggs in wood covered with earth where they form their nest. Often they make their nest in a damp portion of a house. Being strongly reproductive, a single matured queen lays hundred eggs. Thus, the family grows enormously in a short time.

As the queen advances in her stages of growth, the workers plaster wooden particles with saliva around the queen's room; the nest thus made often attains a size of 3 ft. in diameter which is either oval or spherical in shape; it is mostly formed several feet below the surface of the ground, but sometimes in a building.

The workers make ravages on every possible part of a building and other wooden articles around their nest and they often make their resting places there. Like the preceding species, the white ants pass the winter in the nest and lead a dormant life. Toward April, they wake and show considerable activity. Soldiers secrete an acid juice in their heads to protect themselves against enemies such as true ants.

Unlike the preceding, this species does not give rise to a substitute royal form, even if a detached colony of a family is formed. This was proved by the successive experiments and the colonies so treated soon perished. The formation of nymph of the substitute royal form seems only to be possible after the total extinction of the true royal forms. The latter are always characterised by the small number of members being limited to one pair or few.

3. DISTRIBUTION.

The species is widely distributed on the southern coast of the Main Island, Shikoku, Kiushu, Hachijo, Riukiu Islands, Formosa and the southern part of China. Considering their habitat, it may be concluded that the species can live in any region where the mean temperature is above 15°C. but not in regions where it is lower than that.

4. DAMAGES.

This species does damage to railway sleepers, bridges, fences, etc. The insects are particularly apt to make their nests at the bottom of buildings, whence they creep into cracks in the house, or climb up to the top. They damage dry part of the house as well as the damp. Being highly reproductive, this white ant is far more formidable than any other species. Most of our principal construction woods are attacked by this species, particularly the pine wood.

This species often attacks living trees. Pine trees of 1–2 ft. diam. often fall victim to this noxious insect which eats up the centre of the tree. Cherry, willow, ginkgo and camphor trees also often attacked.

III. *Calotermes (Glyptotermes) satsumensis* Matsumura

1. DESCRIPTION.

Winged Form: Length 7 mm. Head reddish brown; pronotum brownish yellow; abdomen yellowish. Wing hyalin; anterior rib brown. Pubescence very sparse. Head broad oval. Compound eyes middle-sized. Ocelli small, situated immediate near to the compound eyes. Basal portion of the clypeus indistinctly limited, very short. Antennæ 15–jointed, short, every segments thickened towards apicarly; 2nd joint as long as 3rd and 4th taken together; 3rd shorter than 4th. Pronotum narrower than the head, anterior margin strongly concave, posterior arched. Wing membrane strongly tuberous; radius sector not branches; media with many continuate nervures directing radius sector; cubitus invisible, with about 15 branches.

King and Queen: Similar to the winged form in size and coloulation.

Soldier major: Length 6–11 mm. Head yellowish red, brownish anteriorly. Body yellowish. Pubescence very sparse. Head elongate, cylindrical, much longer than broad. Length 2.1–2.9 mm. width 1.3–1.9 mm. Front in the middle with an incision, two-lobed; side knob rounded. Compound eyes distinct, with no pigment. Ocelli rudiment. Basal portion of the clypeus very short, labrum reached to one-third of the mandible, relatively long, very robust. Antennæ very short, 12–13–jointed, 2nd joint hardly longer than broad, somewhat longer than 3rd, and as long as 4th. Pronotum as broad as in the head, or somewhat narrower. The anterior margin concave with strongly rounded borders, and posterior margin arched. Meso- and metanotum with short rudimentary wing sheath. Legs short.

Soldier minor: Length 5–5.5 mm. Head brownish yellow, darker anteriorly; pronotum pale yellow; other parts of the body yellowish white. Head ovate; length 1.5–1.8 mm. Width 1.1 mm. Antennæ 11–jointed. Pronotum narrower than head.

Nymph: Length 6–7.5 mm. Antennæ 13–15–jointed, milky white. Compound eye brownish. Wing sheath with yellow tint longitudinally.

2. LIFE HISTORY.

The species living on rotten twigs and branches of trees in the woods, makes but a small family of about 100 individuals. The queen has only peculiarly swollen abdomen, the winged ants take their flight on July.

3. DISTRIBUTION.

Locality of distribution of the species is limited where mean temperature is above 16° C. a year, and is found in the southern part of Kiushu (Kagoshima and Miyazaki Prefectures) as well as whole of Formosa.

EXPLANATION OF PLATES

Plate IX. *Leucotermes (Reticulitermes) speratus* KOLBE.

Fig. 1. Winged form. ×10.
Fig. 2. King. ×10.
Fig. 3. Queen. ×10.
Fig. 4. Substitute queen. ×10.
Fig. 5. Nymph of the winged form. ×10.
Fig. 6. Nymph of the substitute royal form. ×10.
Fig. 7. Worker. ×10.
Fig. 8. Soldier. ×10.

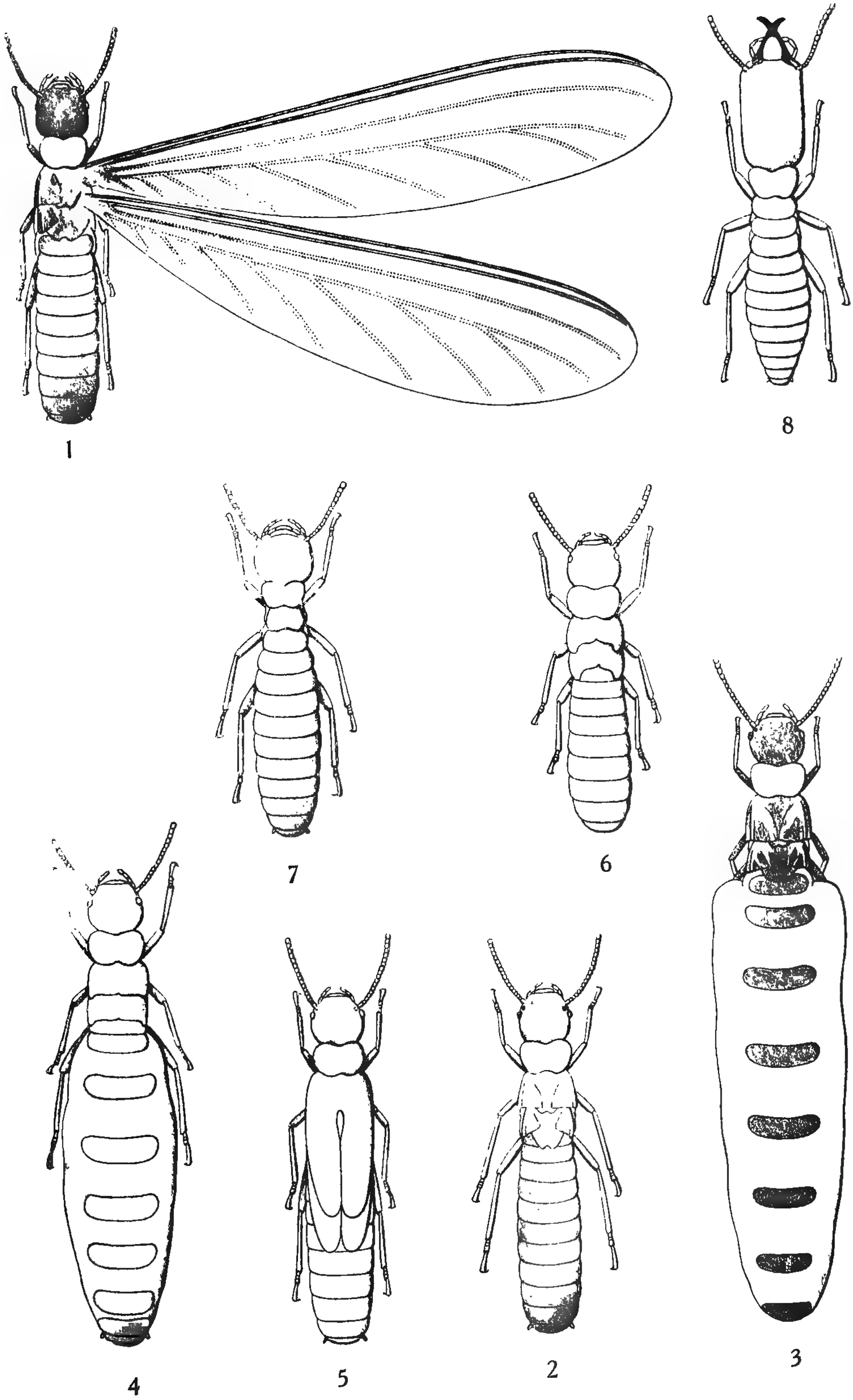
Plate X. *Coptotermes formosanus* SHIRAKI.

Fig. 1. King. ×2.
Fig. 2. Queen. ×2.
Fig. 3. Queen. ×2.
Fig. 4. Ditto. Ventral view. ×2.
Fig. 5. Winged form. ×10.
Fig. 6. Nymph of the winged form. ×10.
Fig. 7. Nymph of the substitute royal form. ×10.
Fig. 8. Worker. ×10.
Fig. 9. Soldier. ×10.

Plate XI. *Calotermes (Glyptotermes) satsumensis* MATSUMURA.

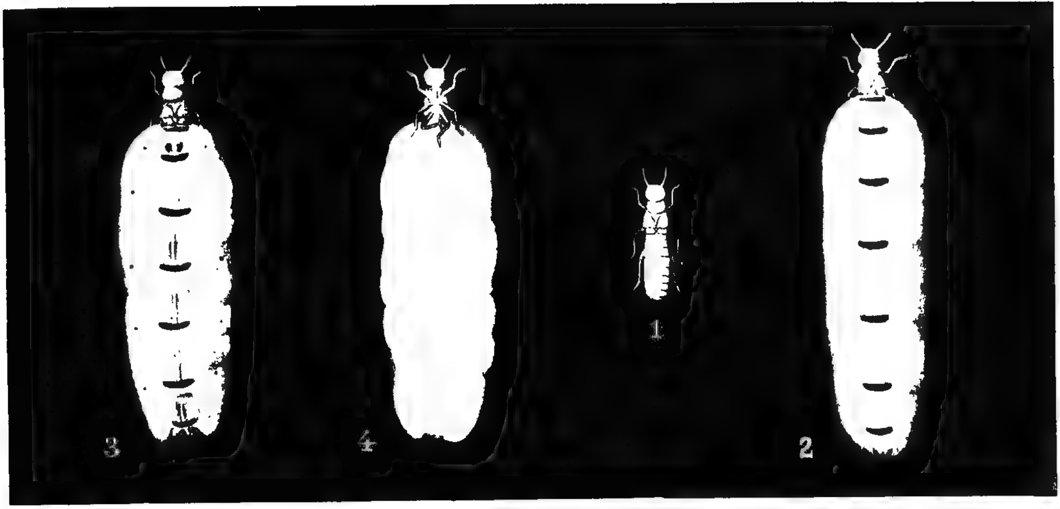
Fig. 1. Winged form. ×10.
Fig. 2. Larva. ×10.
Fig. 3. Young nymph. ×10.
Fig. 4. Nymph. ×10.
Fig. 5. Minor soldier. ×10.
Fig. 6. Major soldier. ×10.

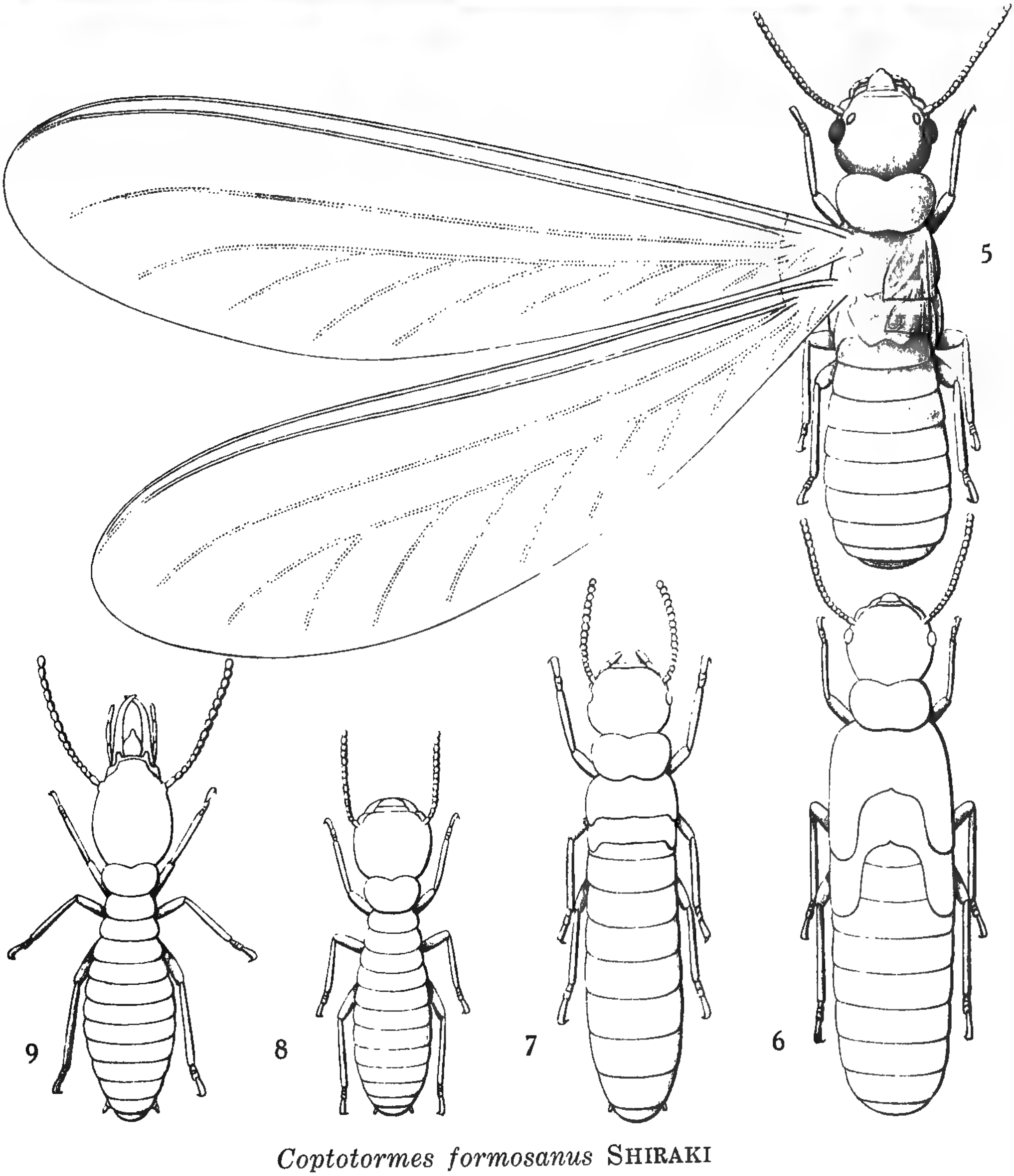
PLATE IX.



Leucotermes (Reticulitermes) speratus KOLBE.

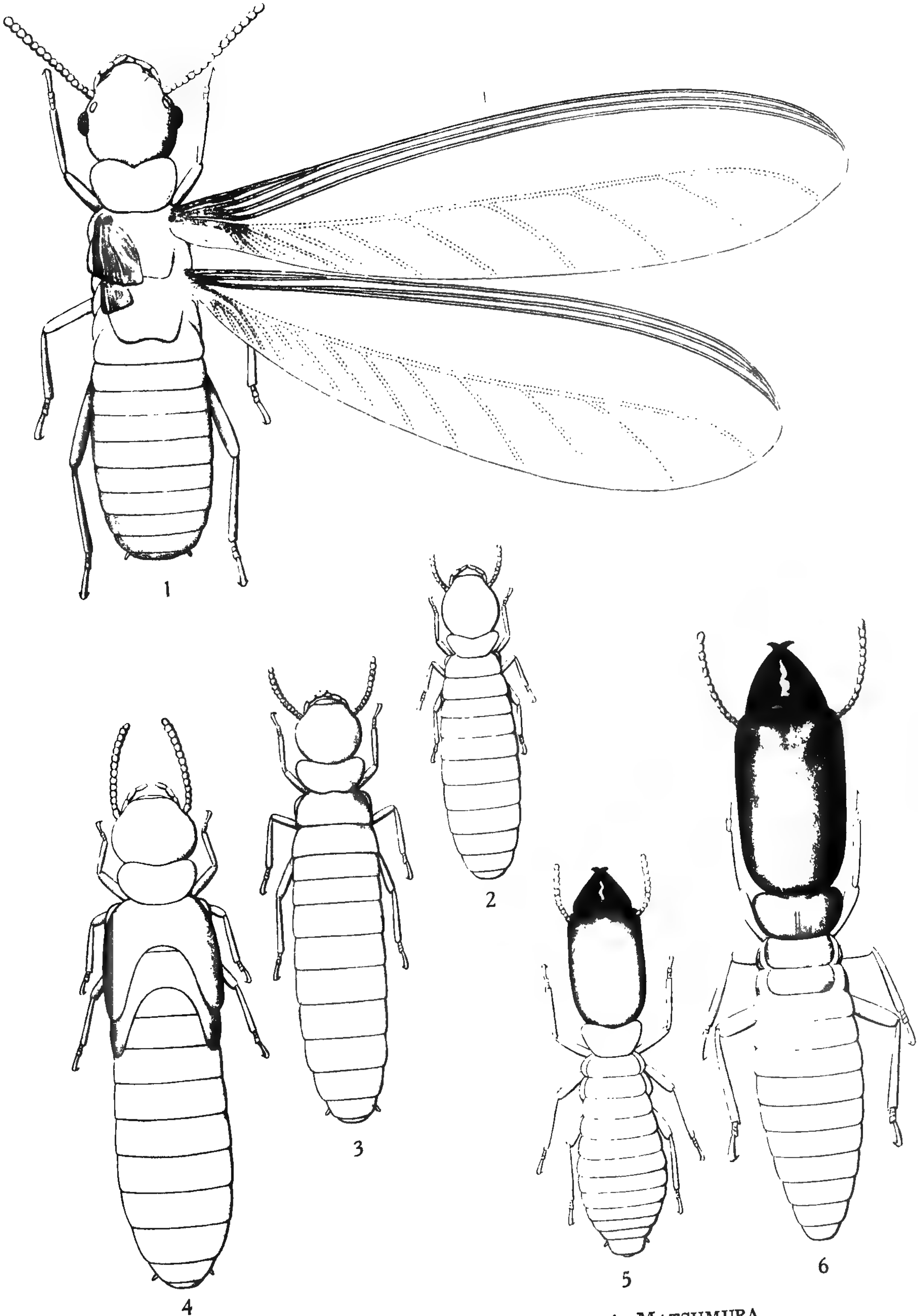
PLATE X.





Coptotormes formosanus SHIRAKI

PLATE XI.



Calotermes (Glyptotermes) satsumensis MATSUMURA.

WHITE WAX COCCID (*Ericerus pela* CHAV.)

By MUNEMOTO YANO, Entomologist of Forest Experiment Station

I. General Notes

The white wax coccid, a species of scale insect or Coccidae, is found in China and Japan. The male larvae secrete white wax from the surface of the body known in commerce as insect wax or Chinese wax. It is composed principally of ceryl cerotate ($C_{25}H_{53} \cdot C_{26}H_{51}O_2$) melting at 80.5°–83°C. having thus a distinctly higher melting point than any other wax or fats. This article which has a peculiar use in industries is produced in large quantities in Shishang, China, and also in small quantities in other places. It costs about Tael 50–55 per picul and the annual production is over 1,000,000 Tael in value. The principal use among the Chinese for this wax is in the preparation of candles, mixed with lard; the wax is likewise used in coating pills by chemists. The most extensive use, however, is for giving lustre to raw silk and silk fabrics. The insect is hardly known to be grown in Japan. The natural product obtained by collecting from wild insects is used to give polish hard-wood works and for sundry other uses.

II. Description

Adult female: Spherical. Length 8–11 mm, width 8–10 mm, height 7–8 mm. Color chestnut or reddish brown with dark irregular markings; smooth and shining, covered with waxy, grayish white secretion.

Adult male: Length, 2–2.5 mm, length of wings 2.3–2.5 mm, width of the mesothorax 0.5 mm. Pale yellow, with brownish markings on the head and thorax; abdomen greyish. Eyes 12, globular and prominent; dark reddish in color. Antennae composed of 10 segments; grayish in color and with long fine hairs; the first segment short and dark yellowish; the second small; the third longest; remaining segements are nearly equal, but gradually increase in length towards the apex. The thorax is large and stout, nearly equal in length to the abdomen, mesothorax is the broadest. Wings subhyaline, the costal space fuliginous, veins brownish yellow; thickly covered with fine cilia. Haltere large, club-shaped, bearing stout hooks at the apex. Abdomen conical in shape; style comparatively short but stout. On the dorsal surface of the eighth abdominal segment there are found secretions of two long waxy filaments; they are about 1½ of length of body.

Egg: Length 0.4 mm. width 0.2 mm. Oval, light orange; male egg is lighter than the female in color,

Newly hatched larva: Length 0.5–0.55 mm. width 0.25–0.28 mm. elliptical in shape and depressed. Mouth-part large, well developed. Antennae 6-jointed; sixth segment the largest; second, fourth and fifth segments are provided with one hair; third with two hairs; and sixth with seven hairs. Legs short and stout. Ventral surface of the body bears many short capitate hairs, which are formed into 4 rows at the abdomen. Caudal lobes terminate with a long hair. Body light orange; male larva is lighter in color than the female.

Second stage of larva: Length 0.7 mm. width 0.35–0.4 mm. Elliptical in form, and depressed, slightly narrow posteriorly. Antennae: third and sixth segments sub-equal, second, fourth and fifth segments short and sub-equal. Legs slender and long. Margin of the body is provided with long hairs.

Third stage of the male larva: Body oval, and increasing in height over the second stage. Legs rudimentary.

Male pupa: Length 2.5 mm. width 1 mm. Oval in shape; head slender, abdomen round; style comparatively short.

Young female: Oval in shape; dorsally conical, and ventrally flattened. Length 1.5–1.7 mm.

III. Life History

The eggs which are laid under the body of the mother insect toward the end of May and hatch out in the middle of June, when the larvae slip off from the body of the mother. The mode of separation varies with the sex.

Generally, the female larvae leave the mother's body earlier than the male by one week. As soon as the female larvae leave the mother body, they find a new abode on the upper surface of leaves and by carefully inserting their mouths along the veins of the leaves suck juice for food.

Toward the middle of July, they leave this abode and settle on twigs in groups of more or less and live on the juice of the tree. At this time the body which was flattened in the early stage becomes somewhat thicker on the back.

As soon as the male larvae hatch out, they begin to remove to the under surface of leaves, where they live in clusters and feed on the juice inserting their mouths into the laminae, and two or three days afterwards, they begun to secrete a white waxy substance in small quantities. After living ten days on the back of leaves they begin to moult and remove to twigs in clusters. They continue to secrete a white thread-like wax which will totally cover the whole body after about 10 days. The secretion goes steadily and increase the white coating to a thickness of 6 to 7 mm. The larvae under the white wax coating, continue to grow during the interval and become gradually thick; they hang down on the twigs with their heads attached to them while the antennae and legs generally deteriorate. Toward the middle of September, the male larvae undergo metamorphosis and became pupae which in turn change into imago after 4 or 5 days. The winged insects fly away to a distance of about 50 ft. in search of female coccids for copulation.

The female larvae which undergo gradual development turn into perfect balls towards the end of March, attaining a length of 6–8 mm. They are greenish brown in color with black spots. About this time, the insect secretes honey from the body, to which ants (*Pristomyrmex japonicus* Forel and *Cremastogaster sordidula* var. *osakensis* Forel) crowd. The matured female imago is reddish brown in color and carries eggs under the body to the number of 5,000.

IV. Host Plants

In China, the wax insect is raised principally on *Ligustrum lucidum* and *Fraxinus chinensis*, but *Ligustrum glabrum* and *Fraxinus bungeana* can be used to some extent of host plants for the insect. In this country, *Ligustrum Ibota, Ligustrum Japonicum, Ligustrum medium, Fraxinus bungeana* var. *pubinervis, Fraxinus longicuspis,* and *Chionanthus retusus* are known as host plants. In order to study the life history of the insect, the mother coccid was raised on *Fraxinus exelsior* of european origin and

Fraxinus americana of american origin, as well as on *Ligustrum* and *Fraxinus* of demestic origin. Those which were raised on *Fraxinus bungeana* var. *pubinervis, F. longicuspis, F. americana, F. exelsior, Ligustrum Ibota* and *L. medium* showed successful growth, and secreted large quantities of wax and gave birth to mother insects, those which were raised on *Fraxinus sieboldiana, Ligustrum japonicum* and *Chionanthus retusus* made but imperfect development.

V. Natural Enemies

The young larvae of the insects during their movements in search of their abode are often blown away by wind or washed away by rain. Beside these natural disaster which are quite destructive to them they often suffer from parasitic insects or fall victim to insectivorous animals.

I. *Brachytarsus niveovariegatus* ROELOFS

(COLEOPTERA: ANTHRIBIDAE).

Imago: Length 4–5 mm. Long ovoidal in shape. Head small, concealed under comparatively large pronotum, which is round anteriorly with two protuberances on both sides of its posterior margin. Elitra has nine deep vertical grooves with incisions at the bottom. The antennae of 11 segments are brown in color, with short grey hairs; the three apical segments are broad and flattened. The body is black; the protholax, elitra and legs have invariably grey and black scaly pubescence with occasional spots. Tarsus brown with yellowish grey hairs underneath.

Larva: Body elongated cylindrical, length 5–6 mm, somewhat curved towards ventral surface. Legs rudimentary and terminating in knob-like protuberance. Body milky white, mandibles brown; with brownish pubescence over the body.

Pupa: Length 4–5 mm. Milky white in color.

Beetles belonging to Anthribidae with the exception of *Brachytarsus* generally feed on rotten wood and mushrooms of the *Boletus* group. It is indeed an exception that this beetle leads a parasitic life on the coccid.

The imago appears in May, and deposits its eggs on the mother coccids. The larvae when hatched eat the eggs carried on the mother coccids. About June they undergo metamorphosis into pupae, one week later, they turn into imagoes when they emerge from the body of the mother coccid. Thus, either one or two of the young live on the eggs of a mother coccid. Since the parasite take up 50% of eggs of the mother, the damage done is quite considerable.

2. *Dasyneura sp*

(DIPTERA: CECIDOMYIDAE).

Imago: 1 mm. length. Head and thorax brown; abdomen yellowish brown; antennae and legs light yellowish brown. Compound eyes large and dark brown. Antennae rather long, composed of 14 segments; first two segments globular in shape, the following segments, in the female, somewhat compressed in the middle and provided each with 8 hairs. The middle depression of the antennal segments is still more remarkable in the male than in the female, giving an appearance of two distinct segments laid side by side; a raw of 8 hairs and a long curved filament encircle the basal part of the segment; the terminal part of the segment has two rows of 8 hairs and two curved filaments growing around it. Mouth parts generally degenerated. Forewings broad and having slight veins. Pubescence over the whole body. Abdomen broad and thick.

Insects belonging to Cecidomyidae generally live on buds, leaves, twigs and roots of ordinary plants causing them to form galls on the affected parts. It is only in exceptional cases that they lead a parasitic life on aphyd, mites and other cecidormyid insects. The present species is one of these exceptions but the percentage of those that are parasites is comparatively small.

3. CHARCIS-FLY

(HYMENOPTERA: CHARCIDIDAE).

Prof. Sasaki has given a description of an unnamed species of charcis-fly that is parasitic on young female coccids. I have not been fortunate enough to collect the imago of the fly, so that nothing further can be said.

4. *Chilocorus similis* Rossi

(COLEOPTERA: Coccinellidae).

Imago: 3.5–4 mm. in length. Hemispherical, somewhat elongated. Body smooth and shining, black. On the middle of the elitra with reddish spots. Antennae yellowish brown. Abdomen yellowish brown; ventral side of the basal segment has a black spot. Legs black, articulations and tarsus dark brownish. Whole surface of body covered with minute dots. Abdomen and legs covered with pubescence.

Egg: 1 mm in length. Spindle shaped, turning in color from light yellow to orange in course of development.

Larva: 6 mm in length. Light greyish brown; dead black. Thorax and abdomen clothed with black spines bearing dark hairs; five pairs on prothorax, 4 pairs each on the mesothorax and metathorax, 3 pairs each on first to eight abdominal segments. Head and legs black.

Pupa: Remains within the larval skin exposing its upper surface from inside. Body 3.5 mm in length, reddish brown.

The species which is known to feed on scale insects of *Diaspis*, *Aspidiotus*, etc. were shipped to the United States to serve as an enemy of noxious coccid. But since this lady-bird eats large numbers of young larvae of the white wax insect, it is a formidable enemy of the latter. The imago of this lady-bird passes through the winter and lays eggs under the scale of the scale insect in April. The larvae which feed on noxious scale insects pupate towards the beginning of June are converted into imago, and destroy the larvae of the white wax insects.

5. *Chilocorus tristis* Fold

(COLEOPTERA: Coccinellidae).

Imago: Length 5–6 mm, hemispherical, somewhat elongated and tapering on the end. Black, smooth and shining, on the middle of each elitra are red marking, the margin is merged into black with no particular distinction recognizable. Antennae brown. Ventral surface of tarsus with soft light brown hairs. Marginal part of dorsal surface of thorax and abdomen with a few short hairs.

Larva: Length 7–8 mm. Pupa: Length 5 mm. Both larvae and pupae resemble those of the preceding species.

The beetles pass through the winter and lay eggs in April. Larvae feed on scale insects of genus *Lecanium* or their eggs; they pupate toward the end of May and two weeks afterwards turn into imagoes. One imago often devours more than 200 larvae of the white wax insects in a day. The imago of Novius limbatus Motsch. and larvae of Scymnus sp. also feed on the larvae of the white wax insect. They are, however, not numerous. The insect known among Chinese as the "wax-dog" seems to be no other than a lady-bird of this group.

6. BIRDS.

From autumn to winter, 1913, singing birds too prey on Female coccids to no small degree.

EXPLANATION OF PLATES

Plate XII.

Ericerus pela. (Figs. 1.—17.).

Fig. 1. Egg. ×35.
Fig. 2. Newly hatched larva. ×35.
Fig. 3. Ditto. Ventral surface. ×35.
Fig. 4. Ditto. Antennae. ×100.
Fig. 5. Second larval stage. ×35.
Fig. 6. Ditto. Ventral surface. ×35.
Fig. 7. Ditto. Antenna. ×100.
Fig. 8. Young female. ×20.
Fig. 9. Ditto. Lateral surface. ×20.
Fig. 10. Third stage of the male larva. ×20.
Fig. 11. Male pupa. ×20.
Fig. 12. Adult male. ×20.
Fig. 13. Male larvae on the under surface of a leaf.
Fig. 14. Female larvae on the upper surface of a leaf.
Fig. 15. Male larvae on a twig.

Fig. 16. Young females on a twig.
Fig. 17. White wax secreted by male larvae.

Bracytarsus niveovariegatus ROELOFS. (Figs. 18.—20.)
Fig. 18. Larva. × 6.
Fig. 19. Pupa. × 6.
Fig. 20. Imago. × 6.

Dasyneura sp. (Fig. 21.)
Fig. 21. Imago. × 20.

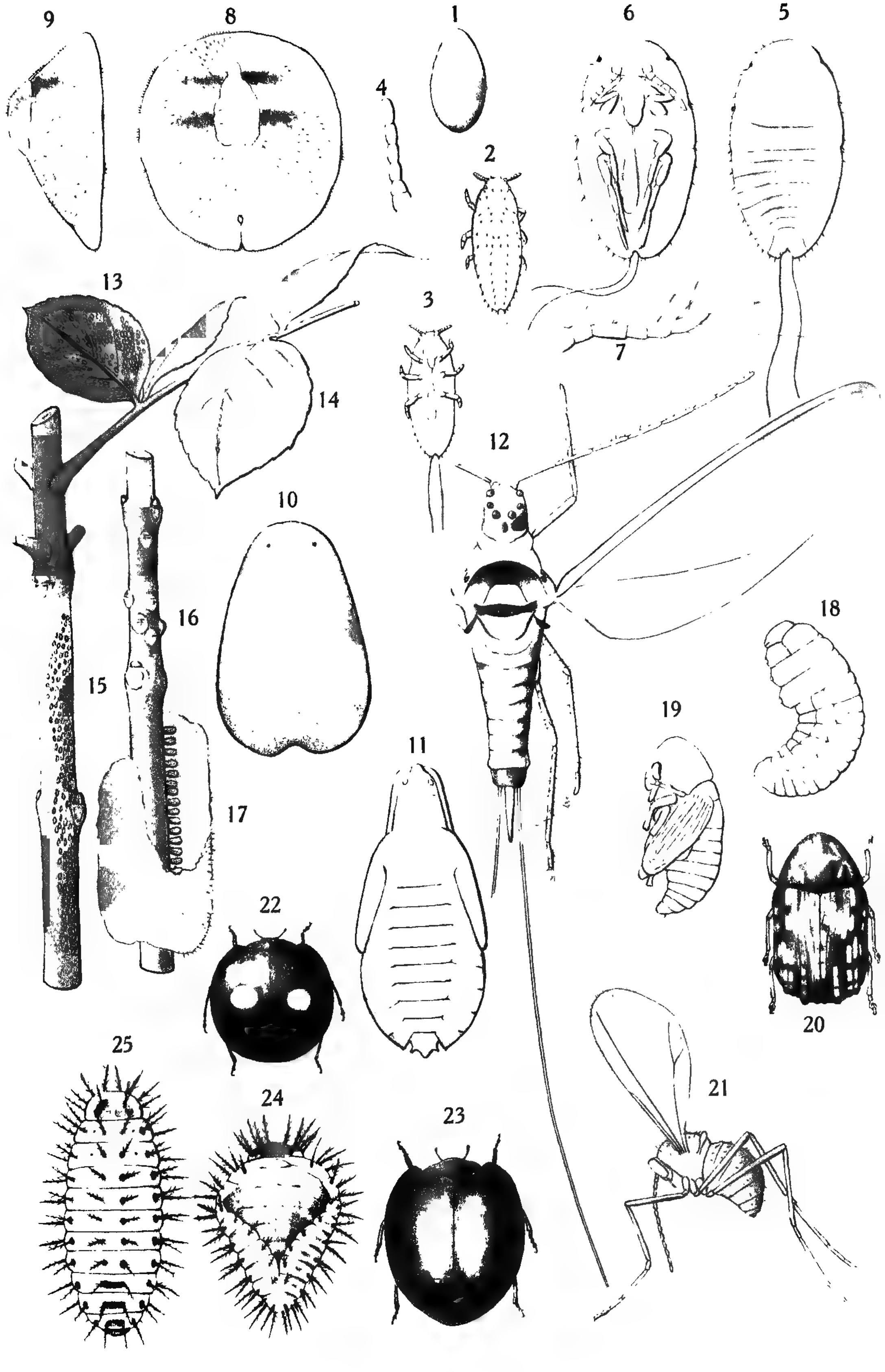
Chilocorus similis RCSSI. (Fig. 22.)
Fig. 22. Imago. × 5.

Chilocorus tristis FALD. (Figs. 23.—25.)
Fig. 23. Imago. × 5.
Fig. 24. Pupa. × 5.
Fig. 25. Larva. × 5.

Plate XIII.

Fig. 1. White wax secreted by male coccids on the twig of *Ligustrum Ibota*. $\frac{1}{10}$
Fig. 2. White wax secreted by male coccids on the twig of *Ligustrum medium*. Natural Size.
Fig. 3. Adult females on a twig of *Fraxinus bungeana* var. *pubinervis*.

PLATE XII.

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NOTES ON THE ANALYTICAL INTERPRETATION OF GROWTH CURVES FOR SINGLE TREE AND STANDS AND ON APPLICATION FOR THE CONSTRUCTION OF YIELD TABLE FOR SUGI *(Cryptomeria Japonica)*

By WATARU TERAZAKI, Forest Expert

Introductory Remarks

The following is a supplementary notes on three memoirs published in Bulletin No. 4 of the Forest Experiment Station in 1907 and No. 11 in 1915. In 1907 I gave in Bulletin No. 4 of the Forest Experiment Station an account of certain applications of analytical methods to data collected from pure, normally stocked, even-aged stands of Karamatsu *(Larix leptorepis)* planted near Mt. Asama in Nagano Prefecture, and of Sugi *(Cryptomeria)* in the Yoshino district in Nara Prefecture. The object of that report was to throw light upon investigations on equations of curves, showing the mean trends of factors which represent the growth of stand; and also to show the applications of the method of smoothing curves for the construction of yield table from data collected simultaneously. In the paper cited, the data are too few and the results obtained from such an investigations could not be generalized without inquiry as to whether they are applicable to species in general.

Since then, I have investigated data given in the works on yield tables, published in Germany, Switzerland and Sweden, and have shown that the analytical interpretations cited in the report issued in 1907, could be generalized as applicable to pure, normally stocked, even-aged stands of any species. Furthermore, I have given a solution in first approximations for the relationships on the growth and yield of stand on each quality of site in different forms of density.

There is not less doubt that a proper statistical and analytical study on the growth of stand for the purpose of constructing a yield table would be of very great value. Such a study is of the first importance when we turn to the accurate discussions on the grouping and grading simultaneously surveyed stands as members of the same chain of growth, and on smoothing the curves for the mean trends of the factors, representing the growth of stands.

As to grouping and grading, there are two methods in use, the first being the horn method, after Baur; and the second, the stem analysis method. I do not propose to give here any account of the methods, for we have no data for criticism. But for the sake of convenience and simplicity, I used a method something like the horn method, i. e. a method depending upon the laws governing the mutual relations on the factors, V, H, G, N and D of sample plots, to one another and on their elements, viz., the dimensions, v, h, d of test tree in each sample plot. This last method has been described by such authorities as Schuberg, Wimmenauer, Eichhorn and Gehrhardt. However it seems to me that in some points the method can be improved; also the laws, generalised while the laws can be adopted to the grouping and grading as members of the same chain of growth. Furthermore from the laws, I have readily deducted empirical equations on the mutual relations on the factors representing the growth of stand and on the elements representing the developments of individual tree with respect to age and I have attempted a method of smoothing curves for the mean trends of the factors. One illustration of the applications of the method, I have reported in Japanese Bulletin No. 11, in 1915, under the title "The growth and yield for *Cryptomeria* Stands."

The yield tables, constructed by many authorities, excepting Schuberg and Schiffel, are limited to one of the forms of density. In practice it is evident that the overheaded leaf canopy of pure, even-aged, normally stocked stands will be of different forms of density. This has received considerable attention and is of theoretical interest at least, as well as perhaps of much practical importance in ascertaining the degree of influence on the growth and yield of stand by the sort and grade of thinnings. Recently Dr. Schwappach, in his work "Die Kiefer," published a yield table from the data obtained from the permanent sample plots for the discussion on the grades of thinnings, but unfortunately he has not published analytical investigations of the laws subsisting between the growth and yield of stand and the development of its elements with regard to the form of density. While I have distinguished the growth and yield of *Cryptomeria* for each quality of site under different forms of density and have attempted to solve the question relating to the forms of density in the first approximation, still there are some ambiguities caused by using data without having any permanent sample plot. However these ambiguities were decreased by using the laws deduced from data, collected in sample plots established in Saxony, for the purpose of the comparative study of the grade on thinnings.

It is not proposed, however, to give here any account of the work which has been done in the attempt to elicit informations on the more difficult subject of the nature of the growth of tree and the aggregate, stand but only to publish the empirical formula for the purpose of showing clearly the general trend of the growth.

Such an investigation has indeed been attempted by European authorities and has remained as a problem for fifty years and over. Among authorities who have dealt with this subject, the names of Baur, Breymann, Eichhorn, Endres, Gehrhardt, Gram, Grundner, Guttenberg, Koller, Lorey, Schiffel, Schuberg, Weber, Weise, Wimmenauer are well known. So far as I can determine, while the value of their works is great, the effect is chiefly negative. No formula can be accepted as theoretically perfect. It is a very necessary and important work to discuss the investigations attempted by European authorities, but such reviews of this field is too far from our present purpose in this paper. We shall confine ourselves to attention to certain general deficiencies in the previous works.

(1) In many cases, in data grouped as member of the same chain of growth the correlations subsisting between each factor of the stand and the age and mutual relation of each factor have been disregarded.

(2) The method of grading of stand is limited only to the volume per unit area and average height. Still, as stated by Schuberg, Wimmenauer and Haug, the number of trees per unit area and the frequency distribution of number of trees in diameter classes in stand are of very noteworthy elements in the classification. Usually these do not allow of comparison as stated by Baur, for the sake of complexity. The advantage of carrying out such investigations lead us the normal characteristics of the stands in the same chain of growth. The difficulty which had to be faced in that investigations was, I think, the task of ascertaining the normal characteristics of the growth of stand. To this end, we define the conditions to be grouped in the same chain of growth. To make this latter inquiry complete, it is essential to make some com-

parison of the growth of trees by means of stem analysis and of stands by means of repeated surveys of permanent sample plots with regards to the data from a large number of sample plots simultaneously surveyed.

Thus we may divide this paper into four parts:

(I) On the normal rate of growth of a single tree, recorded by the method of stem analysis.

(II) The normal rate of growth of stand which is periodically thinned under a given grade.

(III) On the normal trend of growth and yield of stands which was given in yield tables.

(IV) On the application of the laws deduced from the first three parts to the construction of a yield table.

I. On the normal rate of growth of a single tree, recorded by the method of stem analysis

In 1902, it was pointed out by J. Leob[1] that all-growth or the synthesis of cytoplasma is in all probability an autocatalytic reaction. If this is the theory, then the velocity of the all-growth should be represented by the formula, by Gulberg-Waag's law. From this point of view, the normal rate of growth of a single tree should be represented by the formula

$$\frac{dy}{dt}=\beta' y\varphi(y,\ t). \qquad \ldots\ldots\ldots\ldots 1,$$

where $\frac{dy}{dt}$ is the normal rate of the growth, i. e. of the height, the diameter at breast-height or the stem volume at the instant dt, y is the amount of growth which has been attained at the time t and β' is a constant which differs with the factor to be represented.

From the equation (1), we have

$$\frac{dy}{ydt}=\beta'\varphi(y,\ t). \qquad \ldots\ldots\ldots\ldots \text{1a.}$$

Now calculating $\frac{\Delta y}{y\Delta t}$ from the various records of stem-analysis of test trees from our forests, it will be readily seen that the general trend of $\frac{\Delta y}{y\Delta t}$ of a single tree with regard to t will be represented as an inverse function of t, i. e.,

PLATE XIV.

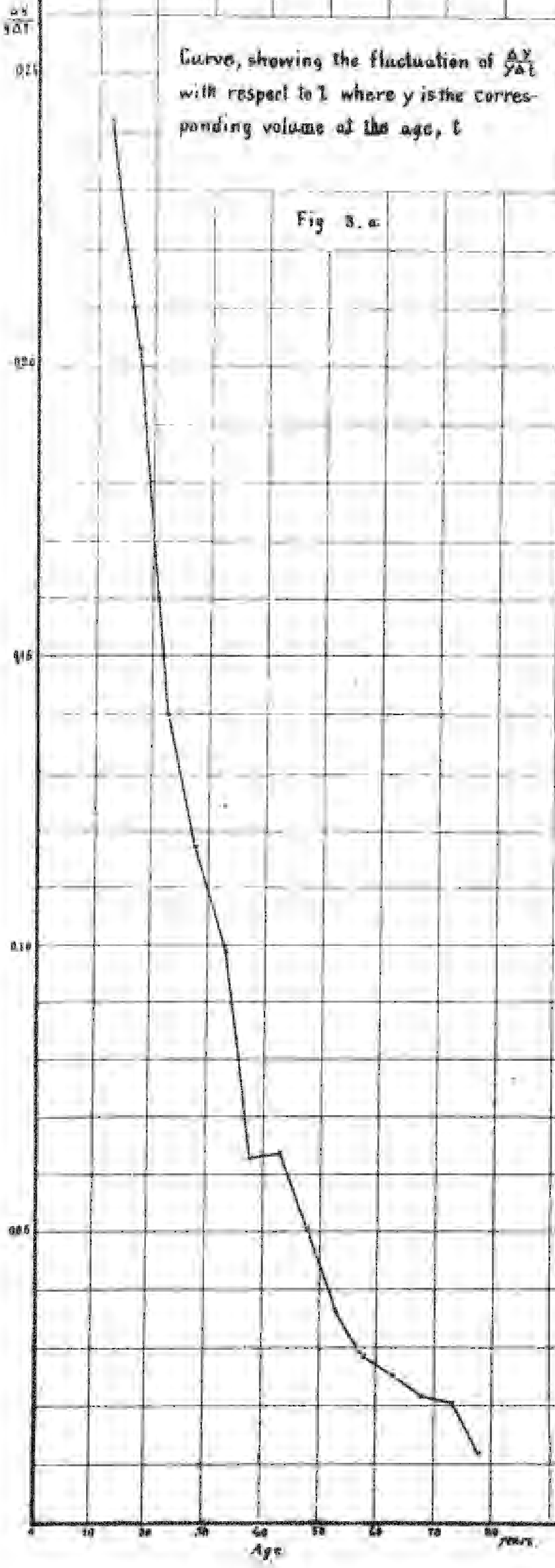

Curve, showing the fluctuation of $\frac{\Delta y}{y\Delta t}$ with respect to t where y is the corresponding volume at the age, t

Fig 3. a.

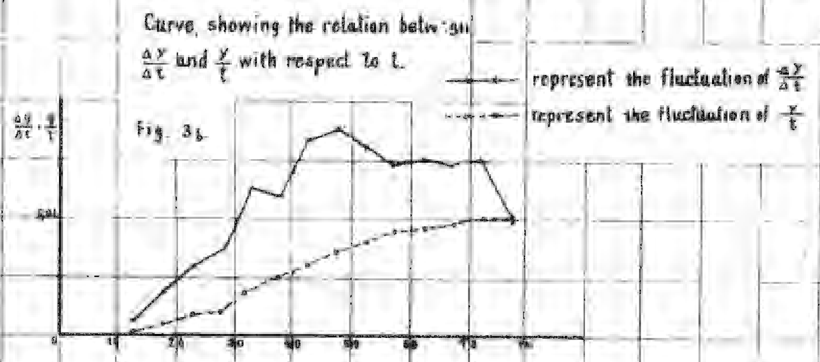

Curve, showing the relation between $\frac{\Delta y}{\Delta t}$ and $\frac{y}{t}$ with respect to t.

Fig. 3 b.

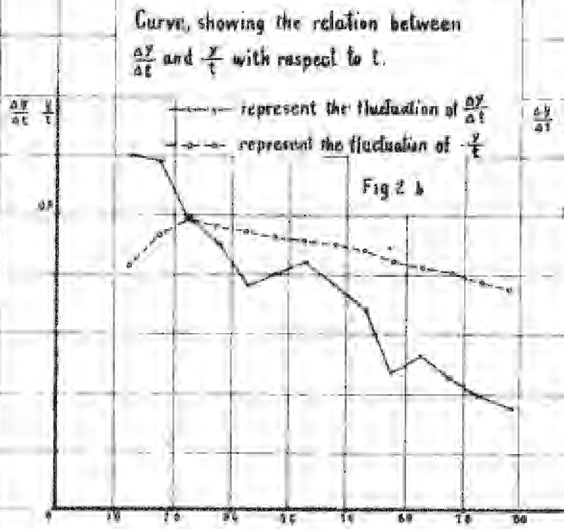

Curve, showing the relation between $\frac{\Delta y}{\Delta t}$ and $\frac{y}{t}$ with respect to t.

Fig 2 b

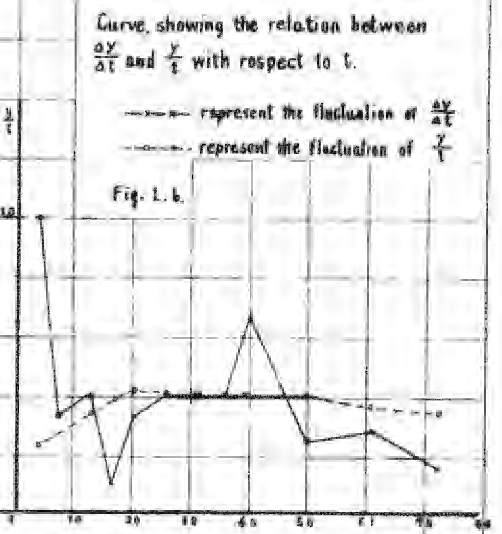

Curve, showing the relation between $\frac{\Delta y}{\Delta t}$ and $\frac{y}{t}$ with respect to t.

Fig. 1. b.

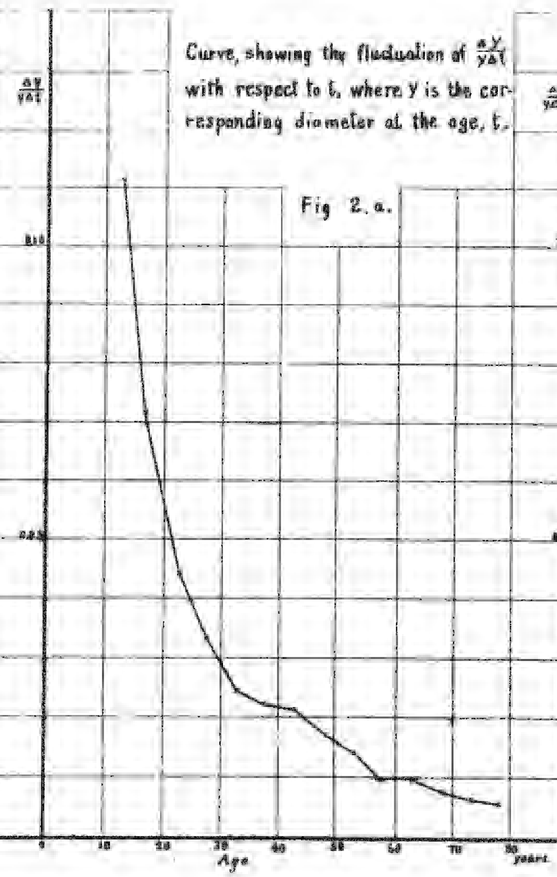

Curve, showing the fluctuation of $\frac{\Delta y}{y\Delta t}$ with respect to t, where y is the corresponding diameter at the age, t.

Fig 2. a.

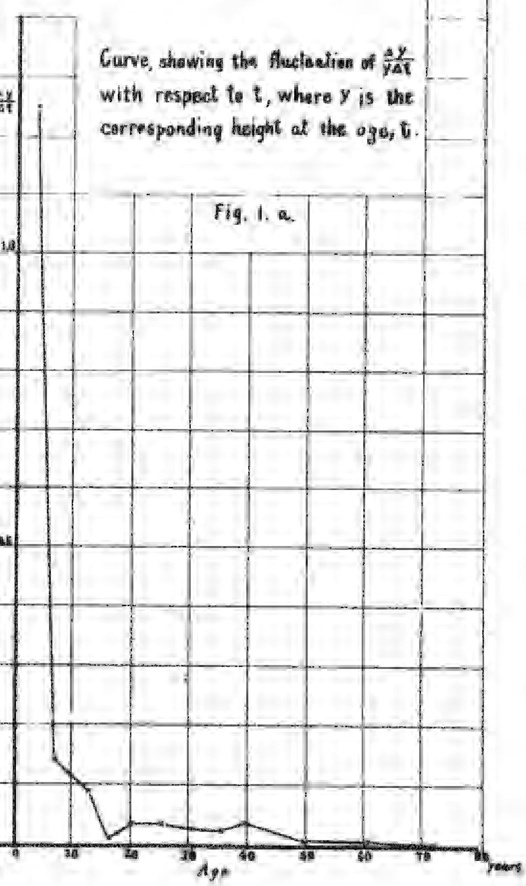
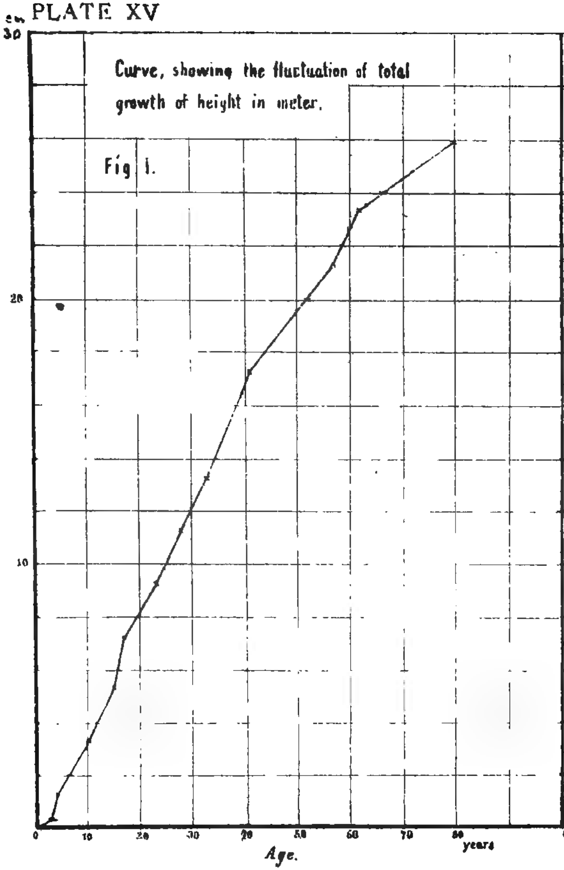

Curve, showing the fluctuation of $\frac{\Delta y}{y\Delta t}$ with respect to t, where y is the corresponding height at the age, t.

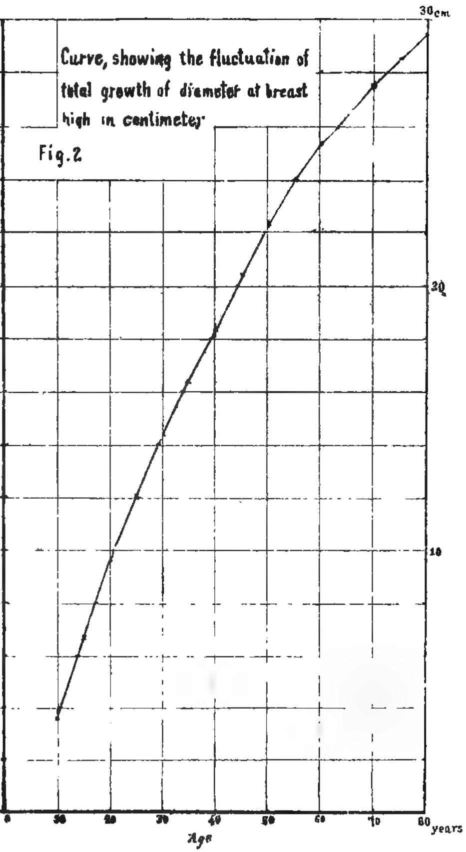
Fig. 1. a.

PLATE XV



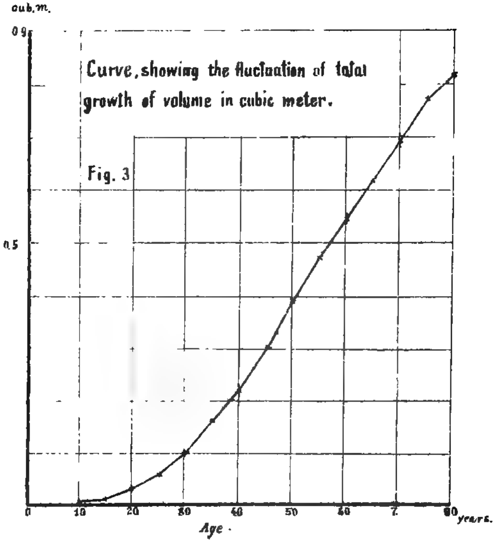
Curve, showing the fluctuation of total growth of height in meter.

Fig. 1.



Curve, showing the fluctuation of total growth of diameter at breast high in centimeter

Fig. 2



Curve, showing the fluctuation of total growth of volume in cubic meter.

Fig. 3

$$\frac{dy}{ydt}=\beta\frac{1}{\varphi_1(t)}. \qquad \ldots\ldots\ldots\ldots\text{lb},$$

or if we use Maclaurin's theorem for $\varphi_1(t)$,

$$\frac{dy}{ydt}=\beta'\frac{1}{1+a_1t+a_2t^2+a_3t^3+\ldots.}.$$

Practically, it may evidently be determind as follows:

$$\frac{dy}{ydt}=\beta'\frac{1}{a_2t^2}.$$

i.e. putting $\frac{\beta'}{a_2}=\beta$,

$$\frac{dy}{ydt}=\beta\frac{1}{t^2}. \qquad \ldots\ldots\ldots 2.$$

However strictly speaking, it will be pointed out in our investigation of the normal growth of a single tree in our forest that we may part the fluctuation of the rate of growth into two cycles or phases and that for each phase, above given formula interprets the rate of growth in the nearest degree. Unfortunately, so far as I have collected materials from our forests, I cannot arrive at any conclusion as to the causes. Some examples seem to suggest that the phase is caused by the conditions of the underground soils or the degree of density and others make us consider the difference of the root systems of the species. We are now investigating this matter.

The following illustration makes clearer the fluctuation of $\frac{dy}{ydt}$ with respect to t, which is one of examples of deep rooted species where the fluctuation of $\frac{dy}{dt}$ with respect to t has disturbed once, or has two phases through the range of the life of the tree. (Plate XIV.)

Test tree for *Cryptomeria* from Ushirozawa in the Kiyosumi Working Circle of the Tokyo Imperial University forest in Awa Province in Chiba Prefecture.

Age: 80 years. Total height: 25.9 m.
Diameter at breast-height: 30.0 cm.
Stem-volume: 0.8664 m³. (Plate XV)

1°. Applying the equation $h=ce^{-\frac{c'}{t}}$ to the given data, we find;

$$h_{\text{I}}=11.98e^{-\frac{10.6933}{t}} \quad \text{for the first phase in m,}$$

$$h_{\text{II}}=39.82e^{-\frac{34.9813}{t}} \quad \text{for the second phase in m.}$$

Comparing the calculated and observed results, we have:

For the first phase

t	Obs.	Cal.	% Diff.
3	0.3	0.3	0.0
4	1.3	0.8	+3.8
10	3.3	4.1	−2.4
15	5.3	5.9	−1.1
17	7.3	6.4	+1.2

Probable % Diff. ±2.3%.

For the second phase

t	Obs.	Cal.	% Diff.
23	9.3	8.7	+6.4
28	11.3	11.4	−0.9
33	13.3	13.8	−3.8
38	15.3	15.9	−6.0
41	17.3	17.0	+1.7
57	21.3	21.6	−1.4
64	23.3	23.1	+0.9
80	25.9	25.9	0.0

Probable % Diff. ±2.7%.

2°. Applying the equation $d = c_1 e^{-\frac{c_1'}{t}}$ for each phase, we find:

$$d_{I} = 26.87\, e^{-\frac{20.21732}{t}} \quad \text{for the first phase in cm,}$$

$$d_{II} = 46.22\, e^{-\frac{36.3507}{t}} \quad \text{for the second phase in cm.}$$

Comparing the calculated and observed results, we have:

For the first phase

t	Obs.	Cal.	% Diff.
10	3.70	3.54	+4.3
15	6.70	6.95	−2.9
20	9.66	9.75	−0.9
25	12.10	11.95	+1.2

Probable % Diff. ±2.5%.

For the second phase

t	Obs.	Cal.	% Diff.
30	14.36	13.76	+4.18
35	16.26	16.36	−0.62
40	18.26	18.62	−1.97
45	20.36	20.61	−1.23
50	22.26	22.35	−0.44
55	23.96	23.86	+0.42
60	25.14	25.22	−0.52
65	26.44	26.42	+0.08
70	27.56	27.50	+0.22
75	28.54	28.46	+0.28
80	29.40	29.34	+0.20

Probable % Diff. ±1.1%.

3°. Applying the equation $v_S = c_2 e^{-\frac{c'_2}{t}}$ for each phase, we find:

$$v_S = 1.442 e^{-\frac{61.303}{t}} \quad \text{for the first phase in cub. m,}$$

$$v_{S_{II}} = 3.014 e^{-\frac{103.0746}{t}} \quad \text{for the second phase in cub. m.}$$

Comparing the calculated and observed results, we have:

PLATE XVI

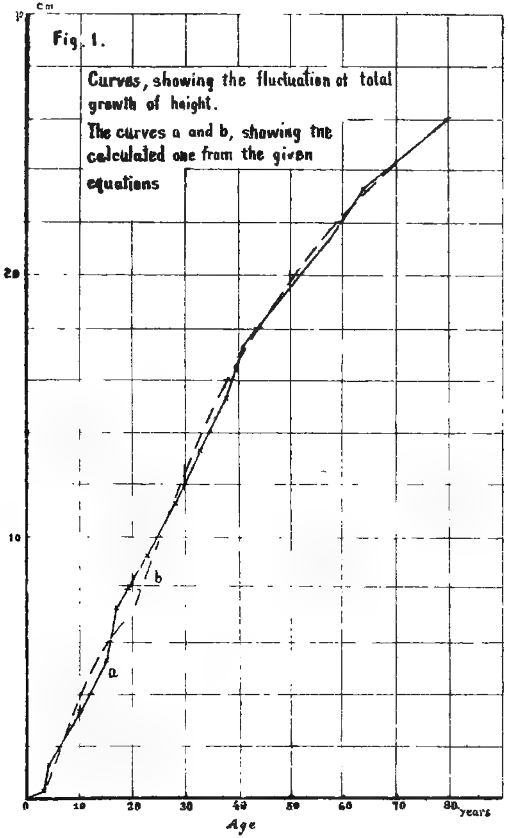


Fig. 1.

Curves, showing the fluctuation of total growth of height.
The curves a and b, showing the calculated one from the given equations

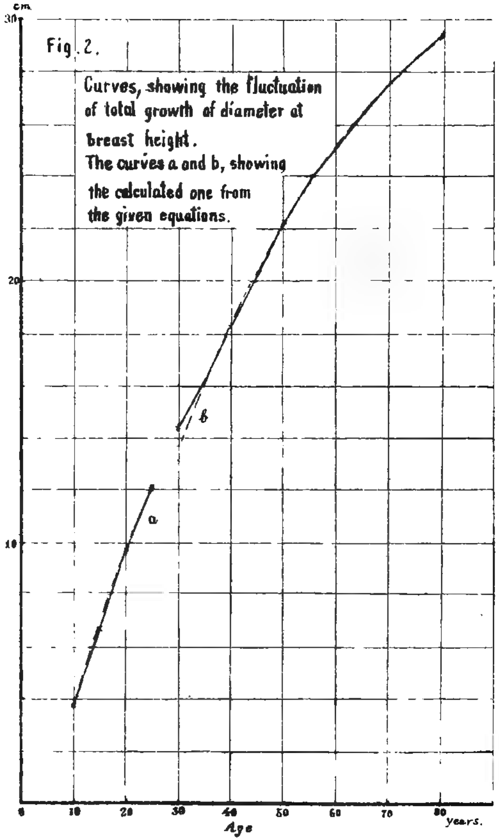


Fig. 2.

Curves, showing the fluctuation of total growth of diameter at breast height.
The curves a and b, showing the calculated one from the given equations.

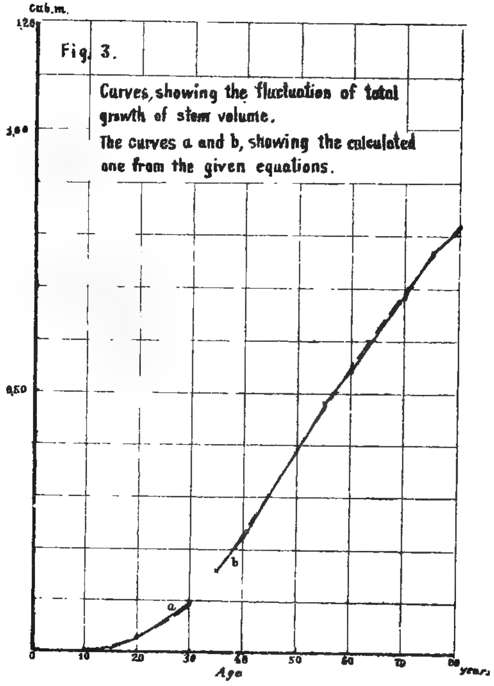


Fig. 3.

Curves, showing the fluctuation of total growth of stem volume.
The curves a and b, showing the calculated one from the given equations.

For the first phase

t	Obs.	Cal.	%Diff.
10	0.0022	0.0015	+31.8
15	0.0094	0.0117	−24.4
20	0.0284	0.0323	−13.7
25	0.0597	0.0598	+ 0.2
30	0.0966	0.0899	+ 6.9

Probable % Diff. ±16.5%.

For the second phase

t	Obs.	Cal.	% Diff.
35	0.1594	0.1586	+0.5
40	0.2196	0.2295	−4.5
45	0.3029	0.3051	−0.7
50	0.3912	0.3831	+2.2
55	0.4718	0.4631	+1.8
60	0.5445	0.5406	+0.7
65	0.6169	0.9251	−0.3
70	0.6925	0.6913	−1.7
75	0.7675	0.7625	+0.6
80	0.8161	0.8271	−1.3

Probable % Diff. ±1.4%.

From these results, it is evident that the agreement between calculated and observed results is excellent. (Plate XVI.)

SUMMARY.

Thus, in the case of the growth of tree, it may be said that we cannot consider the growth as illustrated by the autcatalytic reaction only. In 1908, Robertson[2] published in his work "On the normal rate of growth of an individual and its biochemical significance" the proposition that through any particular cycle the rate of growth is correlated in accordance with the formula:

$$\frac{dy}{dt} = \beta y(A - y).$$

I cannot, however, support this proposition. In 1909, Enriques[3] proposed in his work "Wachstum und seine analytische Darstellung" from the biological point of view that the rate of growth is correlated in accordance with the formula:

$$\frac{dy}{dt} = a + by + cy^2.$$

From my investigations, however, I arrived at the conclusion that through any particular cycle the rate of growth accords with the formula:

$$\frac{dy}{dt} = \beta \frac{1}{t^2}.$$

II. On the normal rate of growth of permanent sample plots periodically thinned under a given grade

In the preceding part, we have been dealing with a single tree and pointed out that any particular cycle of normal growth of a single tree accords with the formula: $y=ke^{-\frac{k_1}{t}}$. The given formula is *a priori* applicable on the assumption that through the observed duration the stand is managed in the same manner and with the same grade of thinning, and so long as it is not seriously damaged by any accidental disturbance of the growth.

It seems to me that this view is supported in the report[4] published, under the name of Dr. M. Kunze, by the Royal Saxon Experiment Station at Tharandt dealing with the influence of various grades of thinnings on the increment of Scotch pine stands. The investigation was made in the State Forest of Kunersdorf near Schanden. It was begun in 1862 when the stand was 20 years old and was ended in 1912 when the stand was 70 years old. During these 50 years, three comparative areas was thinned ten times to wit: in the years 1862, 1869, 1874, 1879, 1883, 1889, 1894, 1900, 1905, and 1912, one area always with a light (A-grade) thinning, another with a moderate (B-grade) thinning, and a third with a heavy (C-grade) thinning. According to the description and the fluctuation of index number we considered that the data observed in 1874 up to that in 1894 may be adopted in the discussion on the equations for the fluctuation of the growth-factors for stand and for its elements, because the data observed throughout these years may be approximately considerd as those of the one phase. Strictly saying, however, the data observed in 1874 up to 1889 will best answer the purpose. (Plate XVII.)

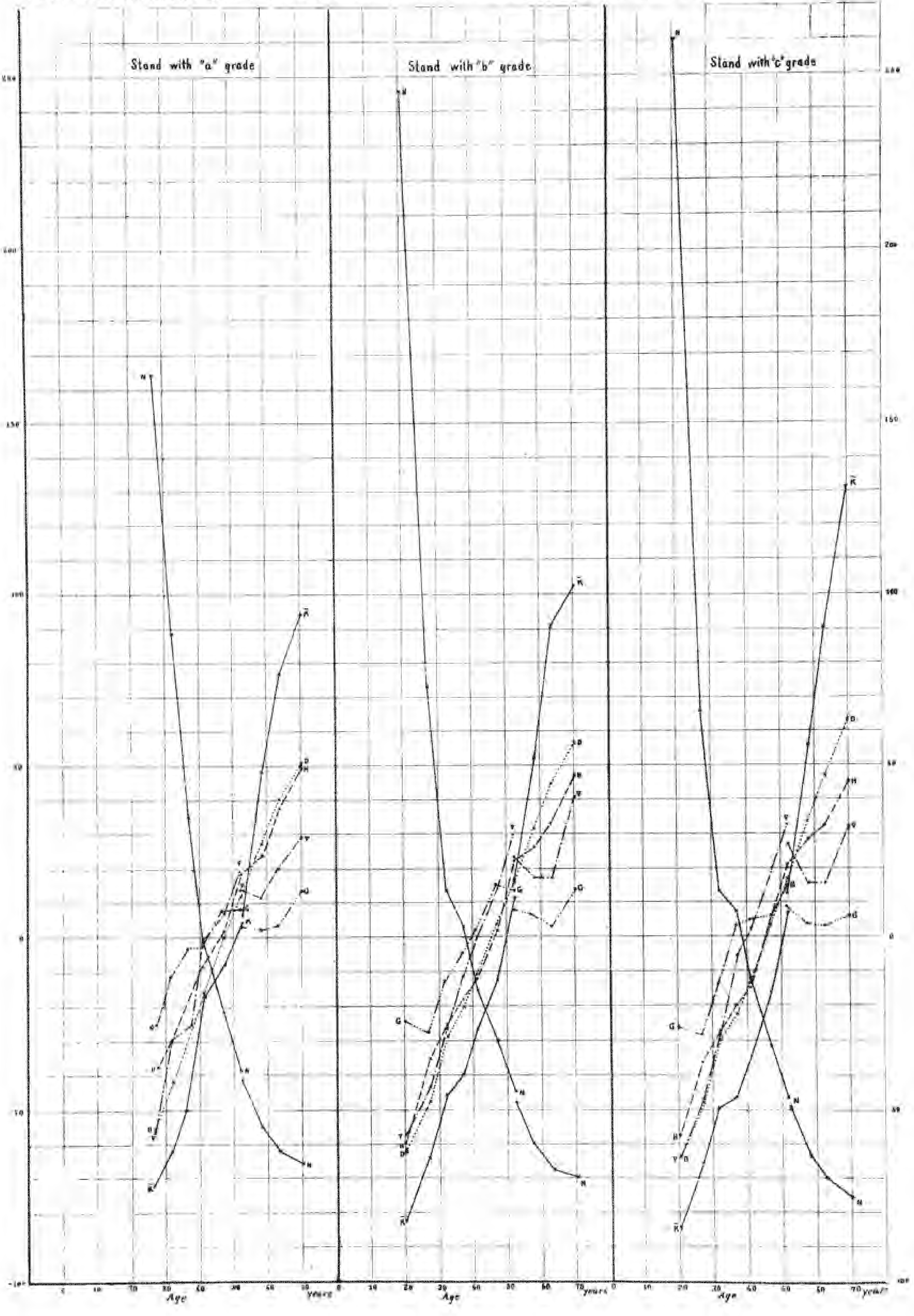
The given diagrams show the following facts:—

(i) The fluctuation of each factor with respect to age shows discontinuity at the age of 52.

(ii) But the fluctuation of each factor shows the similarity in its direction and in its form.

(iii) The fluctuation from the age of 20 up to 52 shows a comparatively regular change, but the fluctuation of G and $\frac{10000}{N}=\kappa$ show much irregulaity, especially at ages up to 32 and the age of 52.

PLATE XVII. Curves, showing the fluctuations of index numbers for N, $\bar{K}$, H, D, $\bar{V}$, and G with respect to t, respectively.



(iv) The fluctuation from the age of 52 up to 70 shows very great irregularity.

From these trends, we may arrive at the following conclusions:—

(a) Change of the grade of thinning or of the form of density for a single stand makes a phase in the fluctuation of growth and shows discontinuity. Thus, in the grouping of a large number of sample plots simultaneously surveyed, as members of the same chain of growth, it is a very necessary and sufficient condition that the management of stands must be the same and that the growth of the stand is not severely retarded by any accident.

(b) The period of repeated thinning must be determined at the time when the condition of the overhead leaf canopy of individuals in the stand is approximately the same as at the previous thinning. The reason for this is that, I think, irregularities in the fluctuation of G and $\frac{10000}{N}=\kappa$ are due to lack of time caused by the period of thinning and furthermore the irregularities caused by the selection of trees to be cut out in the thinning. This last estimate may be illustrated from the frequency distribution of number of trees in diameter classes of each stand, i. e. from the variabilities of individuals of each stand. Therefore before entering upon the investigations of the growth curves for factors of stand, it is necessary to study relations subsisting in the developments of the dimension of individuals in stand, e.g. element of growth.

(a) ON THE DEVELOPMENT OF DIAMETER.

The development of diameters of trees in a given stand with respect to age will be readily determined by the comparison of the frequency distribution of the number of trees in diameter class. As to the frequency distribution, Schuberg[5] discussed it comparatively in detail in his work, "Rotbuche", and Guttenberg[6] gave a brief sketch in his work "Die Aufstellung von Holzmassen-und Geldertragstafeln auf Grundlage von Stammanalysen."

Applying now the modern statistical methods, we have the following results. At first it seemed of importance to determind whether the trees in a stand might fairly be treated as homogeneous throughout the changes in age.

VARIABILITY OF DIAMETERS.

Age in years.	Stand with "a" grade.		Stand with "b" grade.		Stand with "c" grade.	
	S. D.	C. of V.	S. D.	C. of V.	S. D.	C. of V.
32	3.344	0.442	3.204	0.386	2.896	0.294
37	3.522	0.378	3.126	0.260	2.685	0.249
41	3.583	0.314	3.338	0.266	3.438	0.248
47	4.014	0.294	3.794	0.259	3.945	0.245
52	4.083	0.264	3.933	0.232	3.996	0.220

In this table, S.D. and C. of V. represent the standard deviation and coefficient of variation, respectively. Considering the given figures, we arrive at these conclusions:—

(i) The more older, the more disperse as long as the stand remain with the same grade of thinning; the more heavier, the more less disperse so long as the age is same.

(ii) The more older, the distribution is the less variable when the stand thinned with the same grade, and the heavier, the distribution is the less variable when the age is the same.

We think therefore that we are justified in treating the trees in a stand a homogeneous when the age is greater or when the grade is heavier.

On comparing the mean diameter which was calculated by the first moment and the corresponding probable errors we get the following results.

COMPARISON OF MEAN.

Age in years	Stand with "a" grade	Stand with "b" grade	Stand with "c" grade
	Mean	Mean	Mean
32	7.568±0.226	11.196±0.216	9.842±0.195
37	9.577±0.238	12.061±0.211	10.767±0.181
41	11.397±0.242	12.589±0.225	13.441±0.232
47	13·621±0.271	14.660±0.256	16.119±0.266
52	15.470±0.275	16.517±0.265	18.107±0.270

Judging the given figures, we see that the greater the age, the greater is the mean when the stand is thinned with the same grade; and that the heavier the thinnings, the greater is the mean when the age of the stand is the same.

I will now discuss the nature of frequency using the notation of Pearson's memoir[7] on Skew Variation.

The following tables give the chief analytical constants of the skew curves. The second column gives the sum of the percentage number of trees in a stand on which the calculation is based; the third shows the unit in terms of which the 2nd, 3rd, 4th moments (μ_2, μ_3 and μ_4) are calculated; after the moments follow columns giving β_1, $\sqrt{\beta_1}$, the difference between β_2 and the number 3, i. e. $3-\beta_2$ and the "criterion" ($\kappa_1=2\beta_2-3\beta_1+6$) ; the next three columns given the mean, the amount of skew and the distance from mean to mode.

The amount of skew was calculated from the moments directly by the formula $\mathrm{SK}=\frac{1}{2}\,\frac{\sqrt{\beta_1}(\beta_2+3)}{5\beta_2-6\beta_1-9}$, and from this the distance from mean to mode was obtained by multiplying by .

Age in years	No	Unite	μ_2	μ_3	μ_4	β_1	$\sqrt{\beta_1}$	$3-\beta_2$	κ_1	Mean	Skewness	The distance from mean to mode
					Stand with " a " grade.							
32	100.1	1cm.	11.1791	19.3217	347.1585	0.2672	0.5170	+0.2221	−1.2458	7.568	0.4545	1.5198
37	99.9	1cm.	12.4068	21.7493	422.5860	0.2477	0.4971	+0.2547	−1.2525	9.577	0.4422	1.5574
41	100.2	1cm.	12.8511	19.5214	441.2438	0.1796	0.4238	+0.3282	−1.1952	11.397	0.3663	1.3128
47	100.0	1cm.	16.1081	35.4888	771.2744	0.3013	0.5491	+0.0275	−0.9589	13.621	0.4044	1.6233
52	99.8	1cm·	16.6702	34.8887	784.5014	0.2714	0.5210	+0.1770	−1.1682	15.470	0.4351	1.7765
					Stand with " b " grade.							
32	99.9	1cm.	10.2683	22.2901	367.8495	0.4589	0.6774	−0.4888	−0.3991	11.196	0.3862	1.2374
37	100.2	1cm.	9.7688	17.5817	320.4697	0.3316	0.5758	−0.3582	−0.2784	12.061	0.3155	0.9862
41	100.2	1cm.	11.1452	19.6651	402.7196	0.2793	0.5285	−0.2421	−0.3537	12.589	0.2980	0.9947
47	99.0	1cm.	14.3912	24.1016	572.1703	0.1949	0.4414	+0.2373	−1.0593	14.660	0.3490	1.3243
52	100.0	1cm.	15.4624	14.2331	686.2946	0.0548	0.2341	+0.1295	−0.4234	16.517	0.1368	0.5380
					Stand with " c " grade.							
32	99.9	1cm.	8.3875	11.9755	298.3489	0.2430	0.4930	−1.2409	+1.7528	9.842	0.1661	0.4810
37	100.0	1cm.	7.2074	9.4436	170.3731	0.2380	0.4881	−0.2798	−0.1550	10.770	0.2567	0.6886
41	100.2	1cm.	11.8022	17.7095	377.5890	0.1908	0.4359	−0.2892	−1.1508	13.441	0.3651	1.2559
47	99.8	1cm.	15.5663	29.9975	723.1916	0.2385	0.4884	+0.0154	−0.7463	16.119	0.3253	1.2833
52	99.9	1cm.	15.9693	27.8511	776.9473	0.1905	0.4365	−0.9534	0.4783	18.107	0.2493	0.9962

Dealing first with the skewness, we observe that in all the cases it is positive, or the mean is greater than the mode. We will next examine the constants β_1 and β_2. If $\beta_1=0$ and $\beta_2=3$, the curve representing the distribution is the normal curve, and, therefore, in order to see how far the skew curves diverge from the normal we must first observe how much β_1 and β_2 differ from zero and 3 respectively. Taking the $\sqrt{\beta_1}$ column first, we note that in all the cases $\sqrt{\beta_1}$ is greater, but not more than 4 times, greater than the probable error. Taking next the deviation of β_2 from 3 in comparison with the probable error of β_2 we see that except one case β_2 differs from 3 by an insignificant amount. In one case the difference is less than thrice the probable error and hence may be considered possibly or even perhaps, probably insignificant.

Thus we get the general fact that the percentage distribution of number of trees in diameter class of stand comes very close to the condition demanding a curve of Pearson's Type I and sometimes a curve of Type IV.

The deviation of these frequency curves from the normal type I believe to be due to an undue accumulation of individuals in the small diameter classes. It seems, from our permanent sample plots for thinning for *Larix leptorepis* and from data from *Cryptomeria japonica* and from *Chamaecyparis obtusa*, possible that some of the individuals should to be cut out by thinning. What the source of abnormality it is, of course, impossible now to determine. Thus Schuberg and Guttenberg, the authorities in German school, pointed out that the percentage frequency distribution obeys the skew curve, while Prytz,[8] the authority in Denmark, stated that it obeys the normal curve. These consideration seems to be of considerable importance as indicating the worth of diameter statistics relating with the sort of thinnings.

(b) ON THE DEVELOPMENT OF HEIGHT AND VOLUME OF TEST TREES IN STAND.

The corresponding development of height and volume of individual tree in a given stand with that of the diameter at breast-height varies with the age and the grade of thinning. On this point, Guttenberg wrote briefly. The relation with respect to the corresponding development of height and volume of test trees with that of diameter at breast-height was at first investigated by Kopezky[9] and discussed by Hadek and Carolyi.[10] Furthermore Gehrhardt[11] published in his work "Die theoretische und praktische Bedeutung des arithmetische Mittelstammes," the application of Kopezky's law on the construction of a yield table.

From the previous part, we have seen that through the given phase, the relation subsisting between the height and the age of a single tree and between the diameter at breast-height and the age will be expressed by the formulae:

$$\frac{dy}{dt}=c_1\frac{y}{t^2} \text{ and } \frac{dx}{dt}=c'\frac{x}{t^2}$$

$$\therefore \qquad \frac{dy}{dx}=\frac{c_1}{c'}\frac{y}{x}.$$

In which y is the height corresponding to the diameter x, t is the age and c and c' are constants.

Thus by integrating and transforming the last equation, we get the following relation:

$$y=\alpha' x^{\beta'}$$

where $\beta'=\frac{c_1}{c'}$ and α' are the constants, respectively.

Assuming that the growth of trees in a stand is approximately the same, then the relation subsisting between the height and diameter of test trees in a stand may be represented approximately by the formula.

$$y=\alpha x^{\beta}.$$

Again changing the origin to the diameter corresponding to the average diameter, says D, which was the weighted one by means of basal area, of a given stand, we get, from the given equation $y=\alpha x^{\beta}$,

$$y=\alpha x^{\beta}=\alpha D^{\beta}\left(1+\frac{x'}{D}\right)^{\beta}\doteqdot\alpha D^{\beta}\left(1+\beta\frac{x'}{D}\right),$$

where $\qquad x=D+x'$

$$\therefore \qquad y=\alpha D^{\beta}+\alpha\beta D^{\beta}\left(\frac{x}{D}-1\right).$$

Hence we have

$$h=\tau_1\left(\frac{x}{D}-1\right)+\tau_2$$

where we put $\alpha D^{\beta}=\tau_2$ and $\alpha\beta D^{\beta}=\tau_1$.

In this last equation, the coefficient τ_1 and the term τ_2 are the constants in a given stand at a given age; they form indeed the function of the age.

Again from the relations existing between the volume without the bark and the age and between the diameter at breast-height and the age, we get, through the given phase,

$$\frac{dz}{dt}=c_1\frac{z}{t^2} \text{ and } \frac{dx}{dt}=c'\frac{x}{t^2}.$$

so we get

$$\frac{dz}{dx}=\frac{c_1}{c'}\frac{z}{x}.$$

In which z is the volume corresponding to the diameter x and c_1 is the constant.

Thus by integrating and transforming the last equation, we get the following relation:

$$z=\alpha'' x^{\beta''}$$

where $\beta''=\frac{c_1}{c'}$ and α'' are the constants, respectively.

Assuming as in the case of the height, it will be deduced that the relation existing between the volume and diameter of test trees in a stand, may be approximately represented by the formula.

$$z=\alpha_1 x^{\beta_1}$$

Now changing the origin to the diameter corresponding to the average diameter D, of a given stand, we get from the equation $z=\alpha_1 x^{\beta_1}$

$$z=\alpha_1 x^{\beta_1}=\alpha_1 \mathrm{D}^{\beta_1}\left(1+\frac{x'}{\mathrm{D}}\right)^{\beta_1}=\alpha_1 \mathrm{D}^{\beta_1}\left(1+\beta_1\frac{x'}{\mathrm{D}}\right)$$

where $x=\mathrm{D}+x'$

$$\therefore \quad z=\alpha_1 \mathrm{D}^{\beta_1}+\alpha_1\beta_1 \mathrm{D}^{\beta_1}\left(\frac{x}{\mathrm{D}}-1\right)$$

Thus we get

$$v=\tau'_1\left(\frac{x}{\mathrm{D}}-1\right)+\tau'_2$$

where we put $\alpha_1 \mathrm{D}^{\beta_1}=\tau'_2$ and $\alpha_1\beta_1 \mathrm{D}^{\beta_1}=\tau'_1$.

In which the coefficient τ'_1 and the term τ'_2 are the constants in a given stand at a given age, but these are the variable constants depending upon the age.

The results are given in the following tables:

PLATE XVIII.

Curves, showing the fluctuation of height of test trees for each stand.

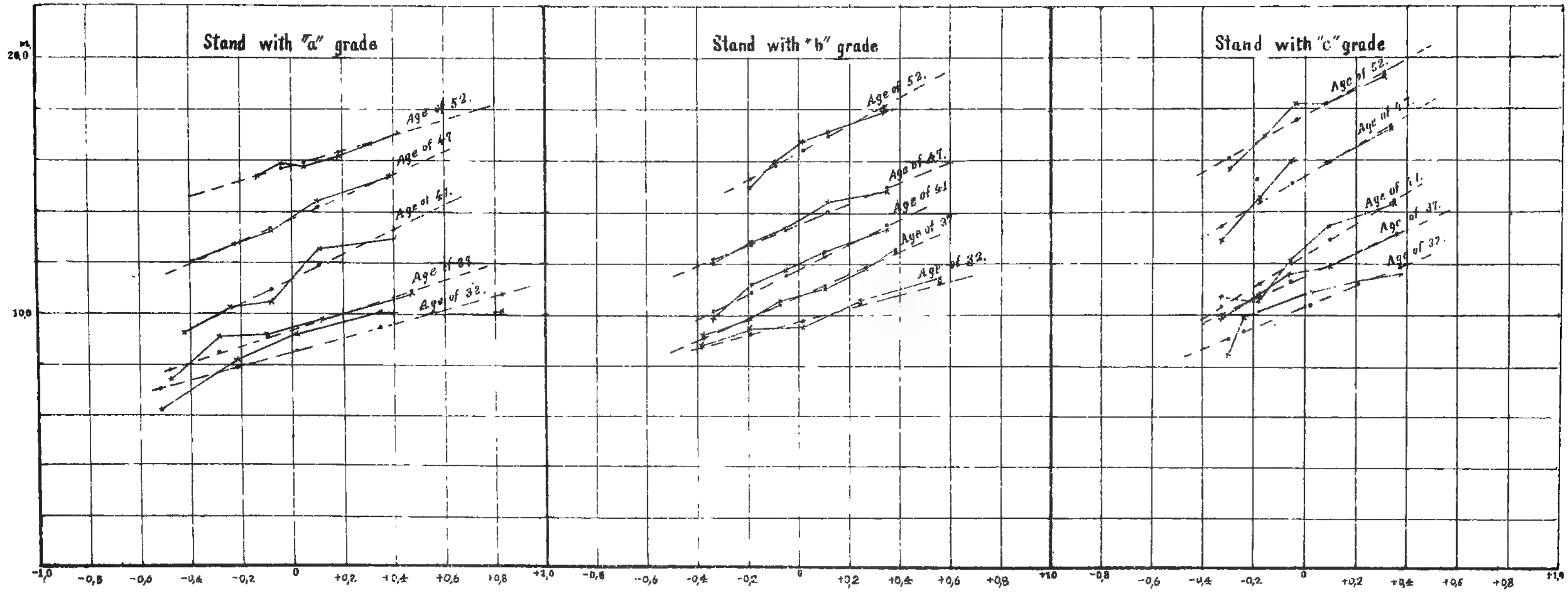


TABLE I.

ON THE HEIGHT CURVES.

1°. For a stand with “a” grade:

	Equation	Probable % Diff.	Equation in first approximation	Probable % Diff.	Kopezky's Equation	Probable % Diff.
		%		%		%
Age of 32	$h=3.936\,l^{0.3712}$	±5.0	$h=2.7850\left(\frac{x}{D}-1\right)+8.4998$	±7.2	$h=10.4681-\frac{78.8439}{a^2}$	±3.3
Age of 37	$h=4.381d^{0.3344}$	±2.9	$h=3.2262\left(\frac{x}{D}-1\right)+3.3982$	±3.3	$h=11.2897-\frac{144.325}{a^2}$	±7.4
Age of 41	$h=4.304d^{0.3761}$	±3.2	$h=4.6758\left(\frac{x}{D}-1\right)+11.3577$	±3.1	$h=13.9494-\frac{292.2896}{d^2}$	±6.9
Age of 47	$h=8.504d^{0.1860}$	±3.1	$h=4.3290\left(\frac{x}{D}-1\right)+13.7418$	±0.8	$h=16.3612-\frac{434.8855}{d^2}$	±6.0
Age of 52	$h=9.026\,i^{0.2026}$	±0.8	$h=2.9793\left(\frac{x}{D}-1\right)+15.8180$	±0.7	$h=19.0681-\frac{823.1033}{d^2}$	±2.3
2°. For a stand with “b” grade:						
Age of 32	$h=5.364d^{0.2624}$	±2.2	$h=2.6528\left(\frac{x}{D}-1\right)+9.7927$	±1.7	$h=11.8348-\frac{174.2832}{d^2}$	±7.1
Age of 39	$h=4.304d^{0.3716}$	±1.8	$h=4.3163\left(\frac{x}{D}-1\right)+10.7448$	±1.1	$h=13.4356-\frac{303.1313}{d^2}$	±7.4
Age of 41	$h=6.162d^{0.2626}$	±1.4	$h=4.9115\left(\frac{x}{D}-1\right)+11.8157$	±2.1	$h=14.4164-\frac{367.8556}{d^2}$	±2.1
Age of 47	$h=6.034d^{0.3016}$	±1.0	$h=4.1477\left(\frac{x}{D}-1\right)+13.5855$	±1.2	$h=15.7986-\frac{423.2740}{d^2}$	±2.2
Age of 52	$h=6.120d^{0.3481}$	±1.0	$h=5.2971\left(\frac{x}{D}-1\right)+16.3701$	±1.1	$h=19.5906-\frac{861.8794}{d^2}$	±0.2
3°. For a stand with “c” grade:						
Age of 32	$h=4.297d^{0.3715}$	±2.2	$h=4.0586\left(\frac{x}{D}-1\right)+10.3519$	±4.8	$h=12.3844-\frac{180.5480}{d^2}$	±1.4
Age of 37	$h=4.200d^{0.4059}$	±1.4	$h=4.7620\left(\frac{x}{D}-1\right)+11.5863$	±1.5	$h=14.1498-\frac{331.6468}{a^2}$	±2.9
Age of 41	$h=3.572d^{0.4752}$	±3.8	$h=6.0383\left(\frac{x}{D}-1\right)+12.3891$	±3.6	$h=15.8575-\frac{571.4958}{d^2}$	±6.8
Age of 47	$h=5.146d^{0.3944}$	±2.2	$h=5.9933\left(\frac{x}{D}-1\right)+15.4818$	±2.7	$h=18.4979-\frac{708.4157}{d^2}$	±3.1
Age of 52	$h=6.998d^{0.3210}$	±1.3	$h=5.6425\left(\frac{x}{D}-1\right)+17.8054$	±1.6	$h=20.6551-\frac{867.2826}{d^2}$	±0.9

The following diagrams (Plate XVIII) show a comparison of theoretical and observed results. Futhermore the probable percentage differences of the approximate equation do not exceed twice those from the original equations or, in other words, the results of the two equations are nearly equivalent. So we may arrive at the conclusion that the relation exist between the height and diameter of test tree will be represented by the equation:

$$h=\tau_1\left(\frac{x}{D}-1\right)+\tau_2.$$

This last equation is a very convenient one to apply, but in the application, care must be taken in selecting the test tree.

TABLE II.

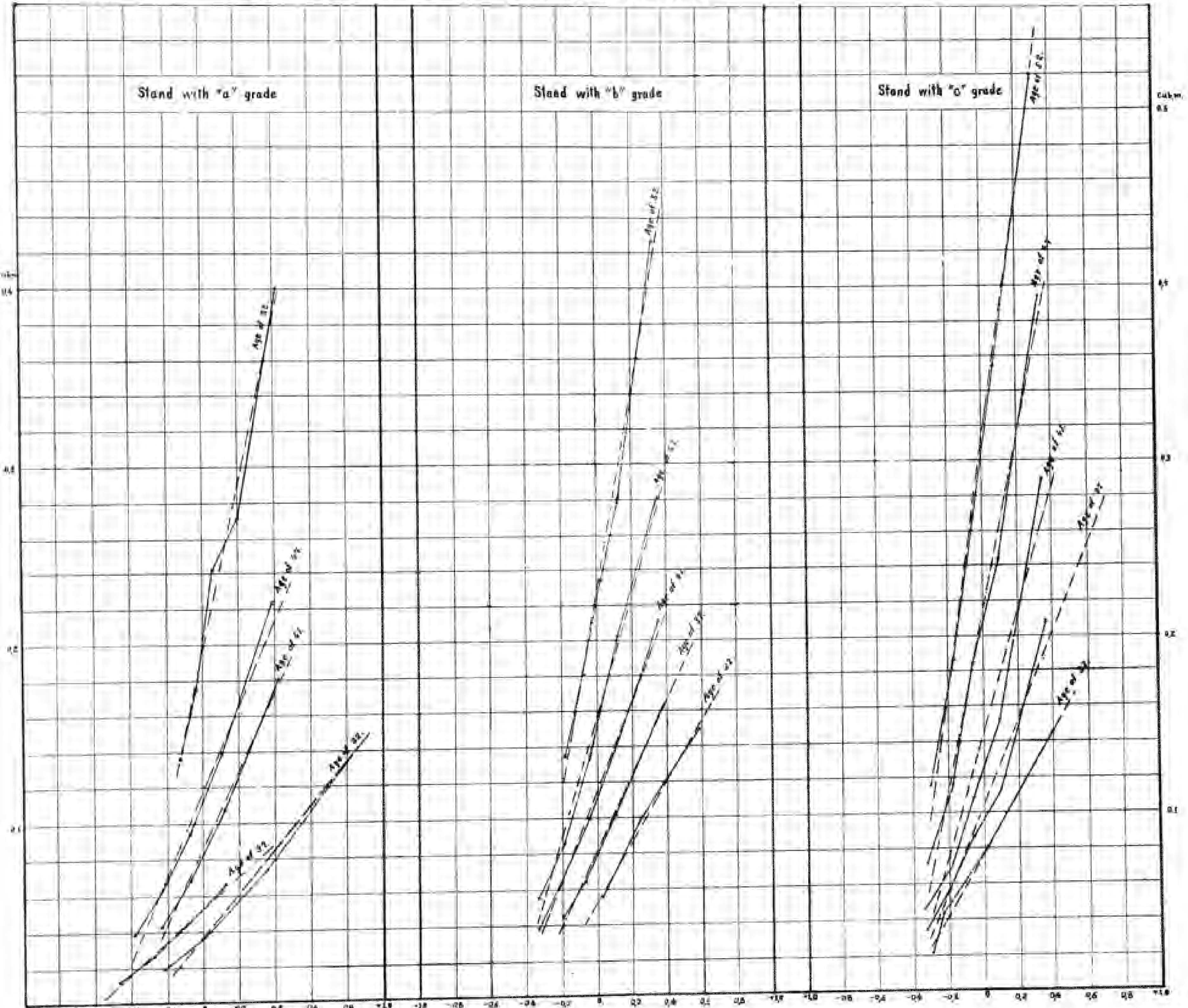
On the Volume Curve.

	Equation	Probable % Diff. %	Equation in first approximation	Probable % Diff. %	Kopezky's Equation	Probable % Diff. %
1°. For a stand with "a" grade:						
Age of 32	$v=0.0003860d^{2.3181}$	±3.2	$v=0.1234\left(\frac{x}{D}-1\right)+0.0384$	±20.6	$v=0.0006d^2-0.0082$	±4.4
Age of 37	$v=0.0003567d^{2.1195}$	±1.6	$v=0.0900\left(\frac{x}{D}-1\right)+0.0542$	± 9.2	$v=0.0005d^2-0.0010$	±2.0
Age of 41	$v=0.0004060d^{2.3433}$	±2.3	$v=0.2154\left(\frac{x}{D}-1\right)+0.0895$	± 7.0	$v=0.0007d^2-0.0141$	±2.2
Age of 47	$v=0.0003593d^{1.4121}$	±6.6	$v=0.2411\left(\frac{x}{D}-1\right)+0.1222$	±10.5	$v=0.0006d^2-0.0079$	±1.0
Age of 52	$v=0.0001882d^{2.1260}$	±3.3	$v=0.4682\left(\frac{x}{D}-1\right)+0.1989$	± 4.3	$v=0.0008d^2-0.0047$	±5.4
2°. For a stand with "b" grade:						
Age of 32	$v=0.0003925d^{2.3095}$	±7.0	$v=0.1729\left(\frac{x}{D}-1\right)+0.0546$	± 4.6	$v=0.0006d^2-0.0082$	±7.3
Age of 37	$v=0.0004372d^{2.3865}$	±2.0	$v=0.2070\left(\frac{x}{D}-1\right)+0.0831$	± 5.3	$v=0.0007d^2-0.0144$	±2.3
Age of 41	$v=0.003567\ d^{1.4555}$	±3.1	$v=0.2506\left(\frac{x}{D}-1\right)+0.1177$	± 3.2	$v=0.0007d^2-0.0128$	±2.8
Age of 47	$v=0.0003716d^{2.3256}$	±4.0	$v=0.3384\left(\frac{x}{D}-1\right)+0.1603$	± 1.6	$v=0.0007d^2-0.0168$	±4.0
Age of 52	$v=0.0002828d^{2.2708}$	±1.6	$v=0.5473\left(\frac{x}{D}-1\right)+0.2292$	± 4.0	$v=0.0009d^2-0.0345$	±1.8
3°. For a stand with "c" grade:						
Age of 32	$v=0.0003440d^{2.2962}$	±4.6	$v=0.1766\left(\frac{x}{D}-1\right)+0.0787$	±11.4	$v=0.0006d^2-0.0052$	±4.8
Age of 37	$v=0.0005518d^{2.4980}$	±2.5	$v=0.2532\left(\frac{x}{D}-1\right)+0.1080$	±12.3	$v=0.0008d^2-0.0212$	±2.6
Age of 41	$v=0.0007418d^{2.6053}$	±3.4	$v=0.3489\left(\frac{x}{D}-1\right)+0.1444$	±10.9	$v=0.0009d^2-0.0455$	±1.5
Age of 47	$v=0.005368\ d^{2.4792}$	±2.7	$v=0.4909\left(\frac{x}{D}-1\right)+0.2161$	±10.9	$v=0.0009d^2-0.0411$	±5.0
Age of 52	$v=0.004618\ d^{2.4585}$	±2.3	$v=0.6955\left(\frac{x}{D}-1\right)+0.3080$	± 6.2	$v=0.0010d^2-0.0522$	±1.3

The following diagrams (Plate XIX) show a comparison of the theoretical and observed results. Again comparing the probable percentage difference of both forms of the equation of volume with respect to age, we see that generally the probable percentage difference of the equation in first approximation is greater than that of the original one. So we may arrive at the conclusion that the relation existing between the volume and diameter of test tree will be expressed in crude approximation by the equation:

$$v=\tau'_1\left(\frac{x}{D}-1\right)+\tau'_2.$$

PLATE XIX. Curves, showing the fluctuation of volume of test trees for each stand.



Now, turning to the tables given above, we see that the probable percentage differences of the stand with "a" grade at the age of 32 is greater than any other one, and that the probable percentage differences of each stand diminishes with the age and the grade. The first fact is due to the variability of the dimension of trees and the second to the increase of the grade of homogenity (as to the grade of homogenity we have already explained it in previous parts). Thus, we do not hesitate to state that the equations above given for the height curve and the volume curve of test trees are almost probable ones to be accepted.

Kopezky proposed that the height curve accords with the formula:

$$h=\alpha_1-\frac{\beta_1}{d^2},$$

where α_1 and β_1 are the constants, respectively and that the volume curve accords with the formula:

$$v=\alpha d^2-\beta,$$

where α and β are constants. According to our investigations, it will be readily seen that Kopezky's formula is only roughly approximate and that in practical application it is inadequate.

Now if we turn to discuss the variations of the coefficients and constants in the equation $h=\tau_1\left(\frac{x}{D}-1\right)+\tau_2$ with regard to age, we may readily see that the general trend of both τ_1 and τ_2 may be represented by the formula:

$$\tau_1=ae^{-\frac{a_1}{t}} \quad \text{and} \quad \tau_2=be^{-\frac{b_1}{t}}$$

The results are as follows:

1°. for a stand with "a" grade.

Equation.	Probable % Diff.
$\tau_1=4.158e^{-\frac{6.5596}{t}}$	±16.9%
$\tau_2=45.29e^{-\frac{55.8323}{t}}$	± 3.6%

2°. for a stand with "b" grade.

$\tau_1=11.57e^{-\frac{41.5207}{t}}$	±13.6%
$\tau_2=36.48e^{-\frac{44.2921}{t}}$	± 4.2%

3°. for a stand with " *c* " grgde.

Equation:	Probable % Diff.
$\tau_1 = 10.12e^{-\frac{26.6524}{t}}$	± 6.8%
$\tau_2 = 43.47e^{-\frac{48.2452}{t}}$	± 4.8%

The following diagrams (Plate XX) show a comparison of the theoretical and the given results.

Again, discussing the variations of the coefficients and constants in the equation $v=\tau'_1\left(\frac{x}{D}-1\right)+\tau'_2$ with regard to age, we may readily see from the graphical study that the general trend of both τ'_1 and τ'_2 may be expressed by the formula:

$$\tau'_1=a'e^{-\frac{a'_1}{t}} \quad \text{and} \quad \tau' = b'e^{-\frac{b'_1}{t}}$$

The results are as follows:

1°. for a stand with " a " grade.

Equation:	Probable % Diff.
$\tau'_1=4.672e^{-\frac{129.5551}{t}}$	±39.9%
$\tau'_2=3.191e^{-\frac{148.9388}{t}}$	± 9.9%

2°. for a stand with " b " grade.

$\tau'_1=3.995e^{-\frac{99.2377}{t}}$	±11.1%
$\tau'_2=2.176e^{-\frac{119.5731}{t}}$	± 3.9%

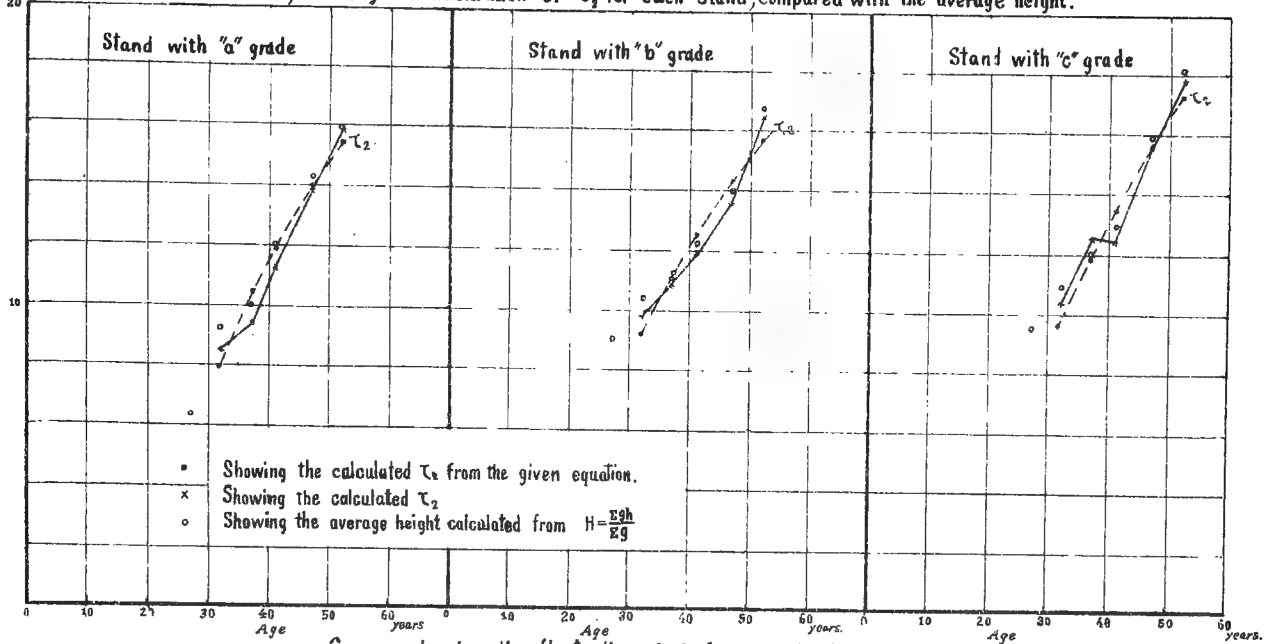
3°. for a stand with " c " grade.

$\tau'_1=6.091e^{-\frac{115.1846}{t}}$	± 5.2%
$\tau'_2 2.=786e^{-\frac{118.0828}{t}}$	± 6.7%

The following diagrams (Plate XXI) show the comparison of the theoretical and the given results:

We have thus investigated the elementary factors of the growth of

PLATE XX. Curves, showing the fluctuation of τ_2 for each stand, compared with the average height.



Curves, showing the fluctuation of τ_1 for each stand.

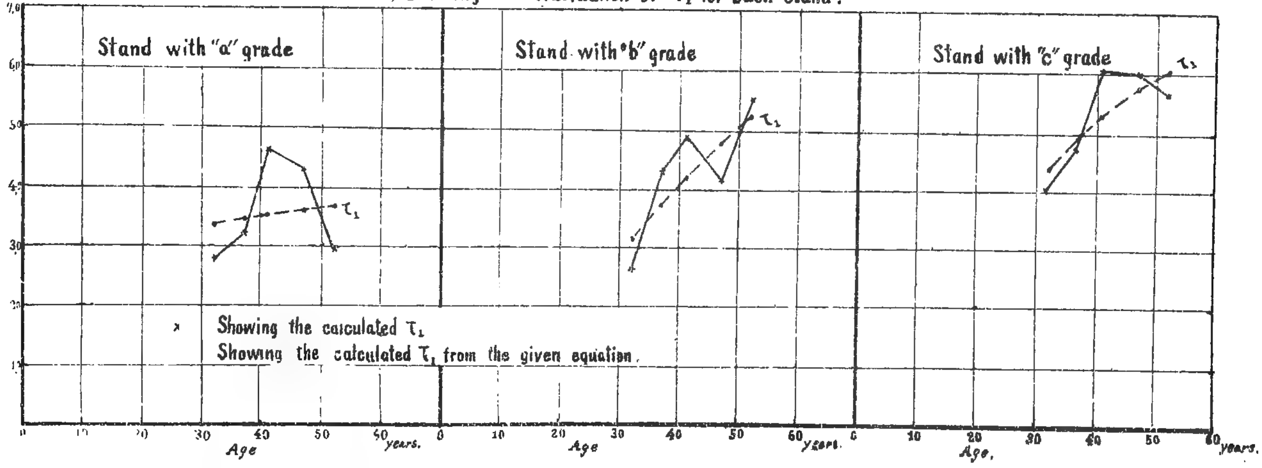
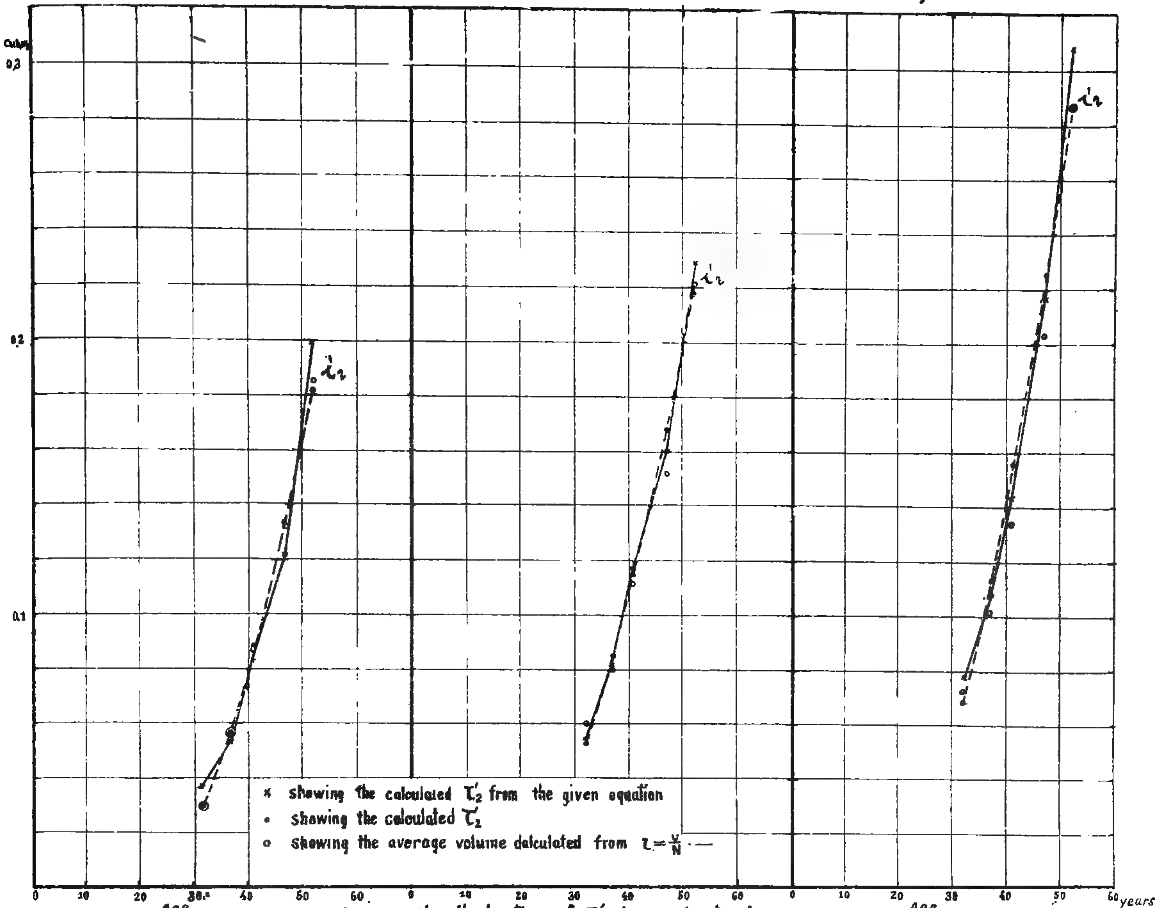
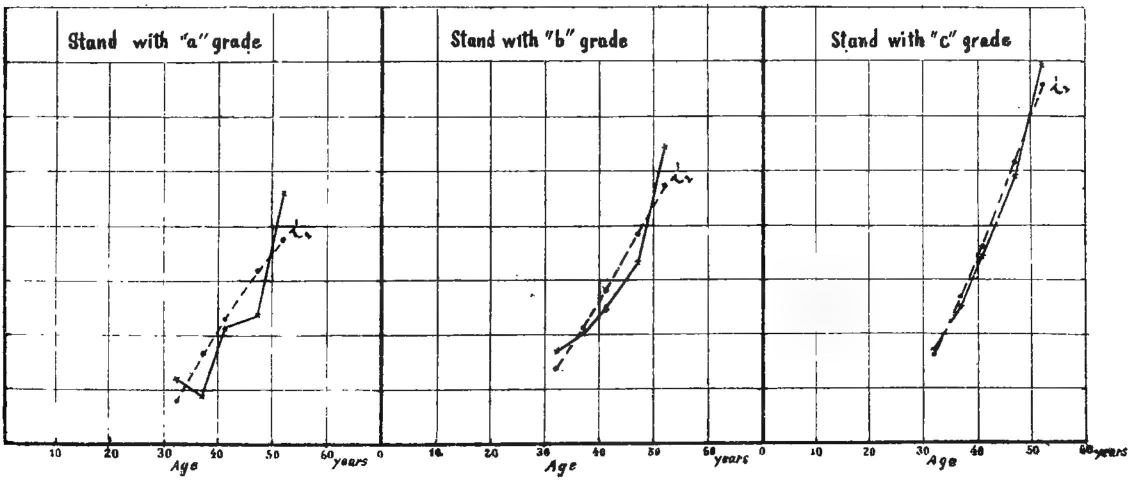


PLATE XXI. **Curves, showing the fluctuation of τ'_2 each stand, compared with the average volume.**



Curves, showing the fluctuation of τ'_1 for each stand.



the stand. From these results, we may easily deduce the relations existing between the factors which represent the growth of the stand and the age. Especially the results of the preceding investigations lead us readily to determine the equations of the average height, diameter and volume of a stand with respect to the age. Before entering upon the discussion of the equations for each factor with respect to the age, it is a necessary and important preliminary work to compare the form of the curves, showing the fluctuation of each factor. To this end, it is much better to calculate the index numbers corresponding to the average diameter, average height, average volume, average crown area, total basal area per unit area and volume per unit area. (Plate XVII)

(c) ON THE AVERAGE DIAMETER.

In the preceding part, we have investigated the height curve of test trees in a given stand and have made the preposition that the height curve may be represented by the formula.

$$h=\tau_1\left(\frac{x}{D}-1\right)+\tau_2$$

and $$\tau_1=ae^{-\frac{a_1}{t}} \qquad \tau_2=be^{-\frac{b_1}{t}}$$

In which we have given:

$$\alpha D^{\beta}=\tau_2=be^{-\frac{b_1}{t}}$$

From this, we get

$$D=\left(\frac{b}{\alpha}\right)^{\frac{1}{\beta}\quad-\frac{b_1}{\beta}\frac{1}{t}}$$

Thus it will be assumed that the equation for D may be represented by the following formula:

$$D=\triangle e^{-\frac{\triangle_1}{t}}$$

Applying the equation to the given data, we find:

for a stand with "a" grade:

$$D_a=43.69e^{-\frac{52.8138}{t}} \qquad \text{Probable \% Diff.} \quad \pm 1.8\%$$

for a stand with "b" grade:

$$D_b = 38.56 e^{-\frac{43.6145}{t}} \qquad \text{Probable \% Diff.} \quad \pm 3.2\%$$

for a stand with "c" grade:

$$D_c = 44.63 e^{-\frac{46.1913}{t}} \qquad \text{Probable \% Diff.} \quad \pm 3.3\%$$

The following diagrams (Plate XXII) show the comparison between the theroetical and the observed results.

(*d*) ON THE AVERAGE HEIGHT.

In the preceding part, we have investigated the height curve of test trees in a given stand and asserted that the height curve may be represented by the formula:

$$h = \tau_1 \left(\frac{x}{D} - 1 \right) + \tau_2$$

and $\tau_1 = a e^{-\frac{a_1}{t}}$ $\qquad$ $\tau_2 = b e^{-\frac{b_1}{t}}$

Hence if we put $x = D$, then we get

$$h = \tau_2 = b e^{-\frac{b_1}{t}}$$

This last equation shows that the trend of the height of test tree corresponding to the average diameter with respect to the age, will be expressed by the formula:

$$h = b e^{-\frac{b_1}{t}}.$$

Hence if the height of the test tree corresponding to the average diameter of a stand corresponds to the average height of the given stand calculated from the formula: $H = \frac{\Sigma gh}{\Sigma h}$, the fluctuation of the average height of a stand will be expressed by the equation

$$H = b e^{-\frac{b_1}{t}}$$

However it is generally recognised that the average height of a stand is greater than that of a test tree corresponding to the average diameter, but from the diagrams which we have shown in the previous part, we

PLATE XXII

Curves, showing the comparison of the Average diameter for each stand.

– – – – – – showing the curves from the equation.

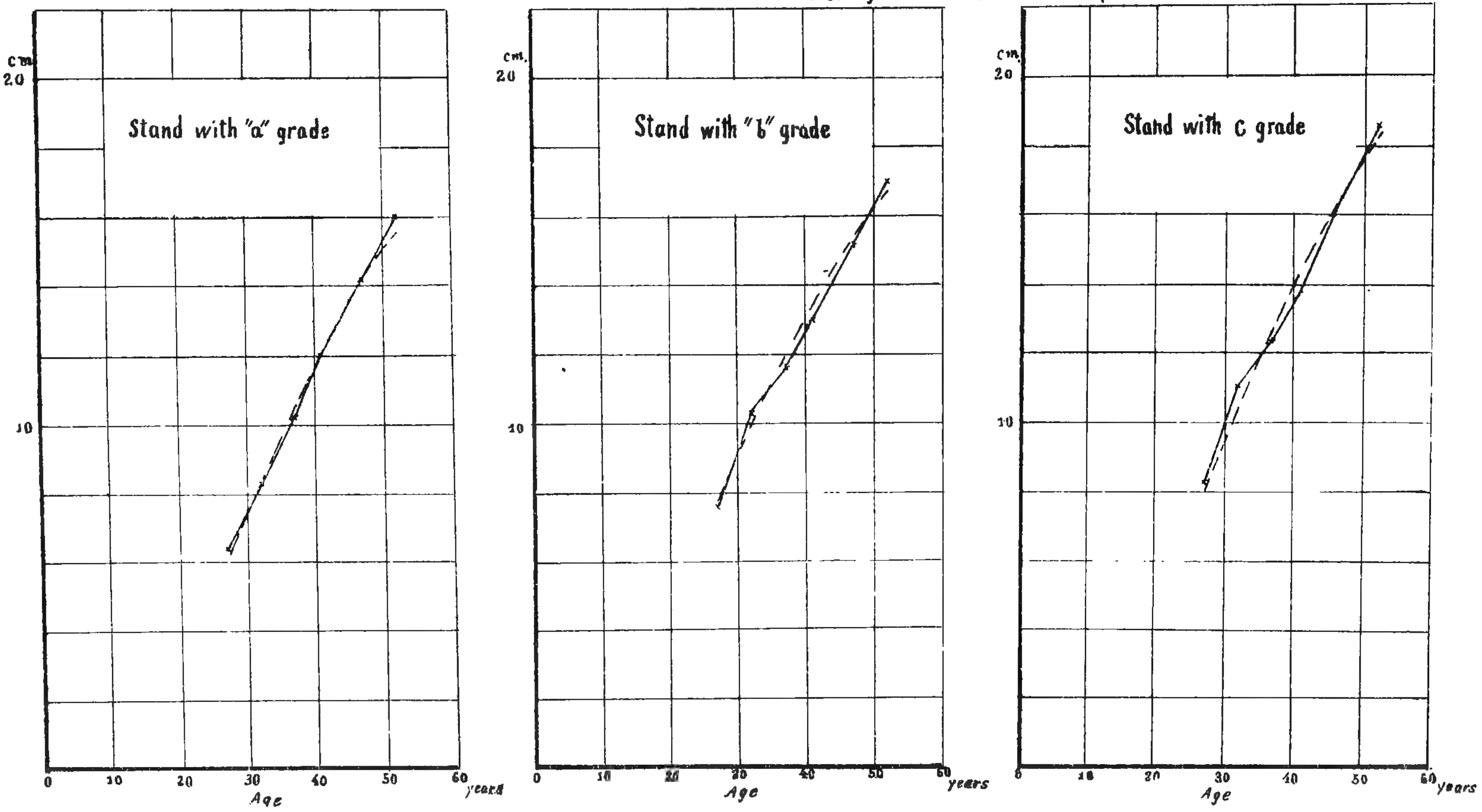
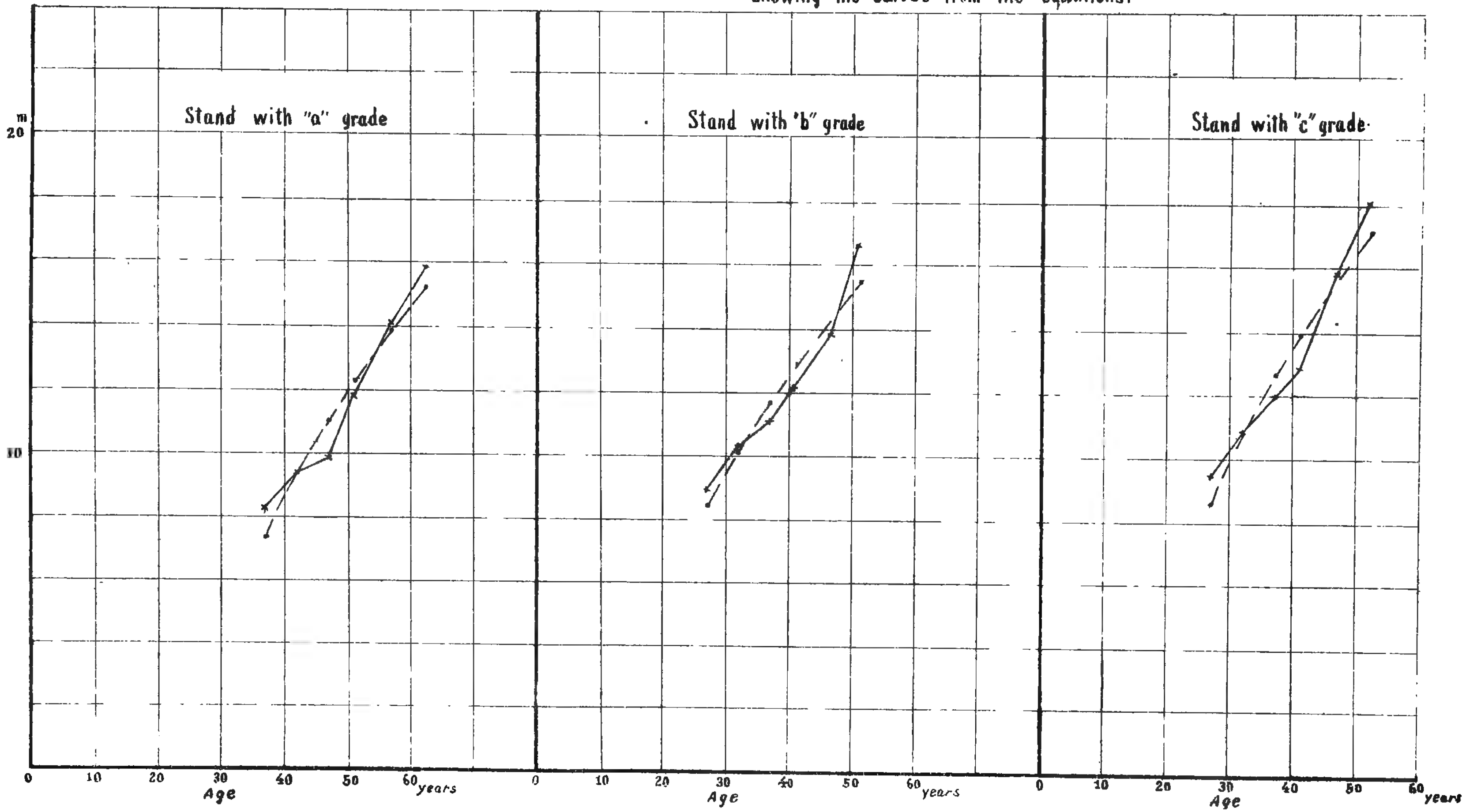


PLATE XXII

Curves, showing the comparison of Average height.

– – – – showing the curves from the equations.



may say that such a conclusion is very questionable, and that the both heights are nearly equal to one another.

For convenience of comparison of fluctuation of the two sorts of heights, if we calculate the index number and draw the diagrams, then we may conclude that the fluctuation of the two sorts of heights are precisely the same.

Thus the fluctuation of the average height may be represented by the equation:

$$H = \lambda e^{-\frac{\lambda_1}{t}}$$

Applying the equation to the given data, we find:

for a stand with "a" grade;

$$H_a = 33.34 e^{-\frac{40.6837}{t}} \qquad \text{Probable \% Diff.} \quad \pm 5.9\%$$

for a stand with "b" grade;

$$H_b = 30.80 e^{-\frac{35.3762}{t}} \qquad \text{Probable \% Diff.} \quad \pm 4.3\%$$

for a stand with "c" grade;

$$H_c = 36.29 e^{-\frac{38.8214}{t}} \qquad \text{Probable \% Diff.} \quad \pm 4.7\%$$

The following diagrams (Plate XXIII) show the comparison between observed and calculated results for each stand.

(*e*) ON THE AVERAGE VOLUME.

In the preceding part, we have investigated the volume curve of test trees in a stand and stated that the volume curve may be represented by the formula:

$$v = \tau'_1\left(\frac{x}{D} - 1\right) + \tau'_2$$

Hence if we put $x = D$, then we get

$$\iota = \tau'_2 = b' e^{-\frac{b'_1}{t}}$$

This last equation shows that the trend of the volume of a test tree corresponding to the average diameter with respect to the age, will be expressed by the formula:

$$\iota_D = b' e^{-\frac{b'_1}{t}}$$

Hence if the volume of a test tree corresponding to the average diameter of a stand correspond to the average volume, calculated by the formula: $\iota = \frac{V}{N}$, then the fluctuation of the average volume of a stand will be expressed by the equation:

$$\iota = b' e^{-\frac{b'_1}{t}}$$

From the comparison of ι_D with ι which was given in the previous section, we arrive at the conclusion that the average volume may be expressed by the formula:

$$\iota = \varkappa e^{-\frac{\varkappa_1}{t}}$$

Applying the equation to the given data, we find:
for a stand with "a" grade;

$$\iota_a = 2.657 e^{-\frac{139.6264}{t}} \qquad \text{Probable \% Diff.} \quad \pm 3.7\%$$

for a stand with "b" grade;

$$\iota_b = 2.613 e^{-\frac{118.1089}{t}} \qquad \text{Probable \% Diff.} \quad \pm 6{,}4\%$$

for a stand with "c" grade;

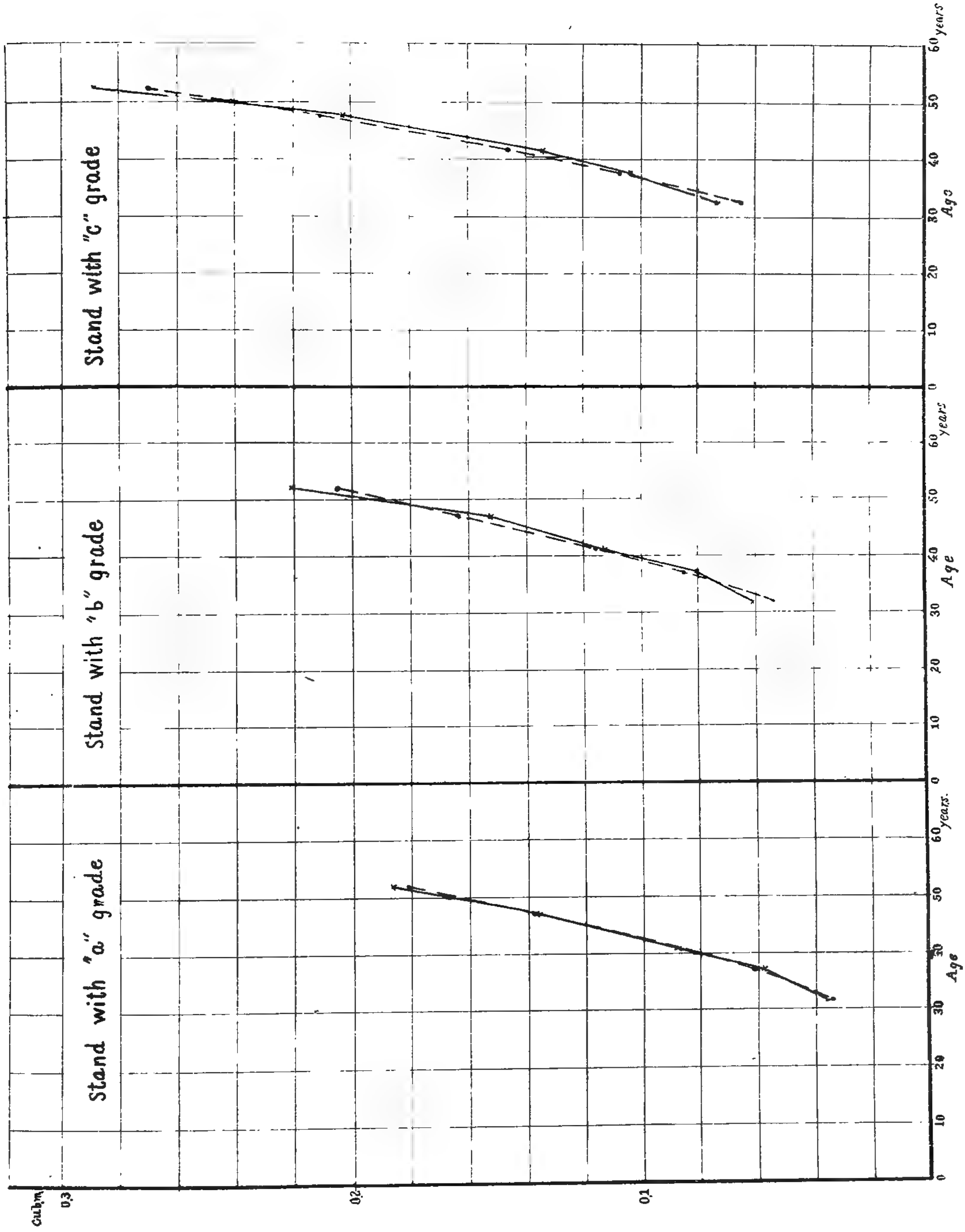
$$\iota_c = 1.740 e^{-\frac{111.1139}{t}} \qquad \text{Probable \% Diff.} \quad \pm 6.6\%$$

The following diagram (Plate XXIV) show the comparison between observed and calculated results for each stand:

(*f*) ON THE VOLUME PER UNIT AREA.

From the similarity of the fluctuation of the index number of volume with that of the average diameter, average height or average volume, we may suggest that the equation of the volume per unit area with respect to the age may be represented by the formula:

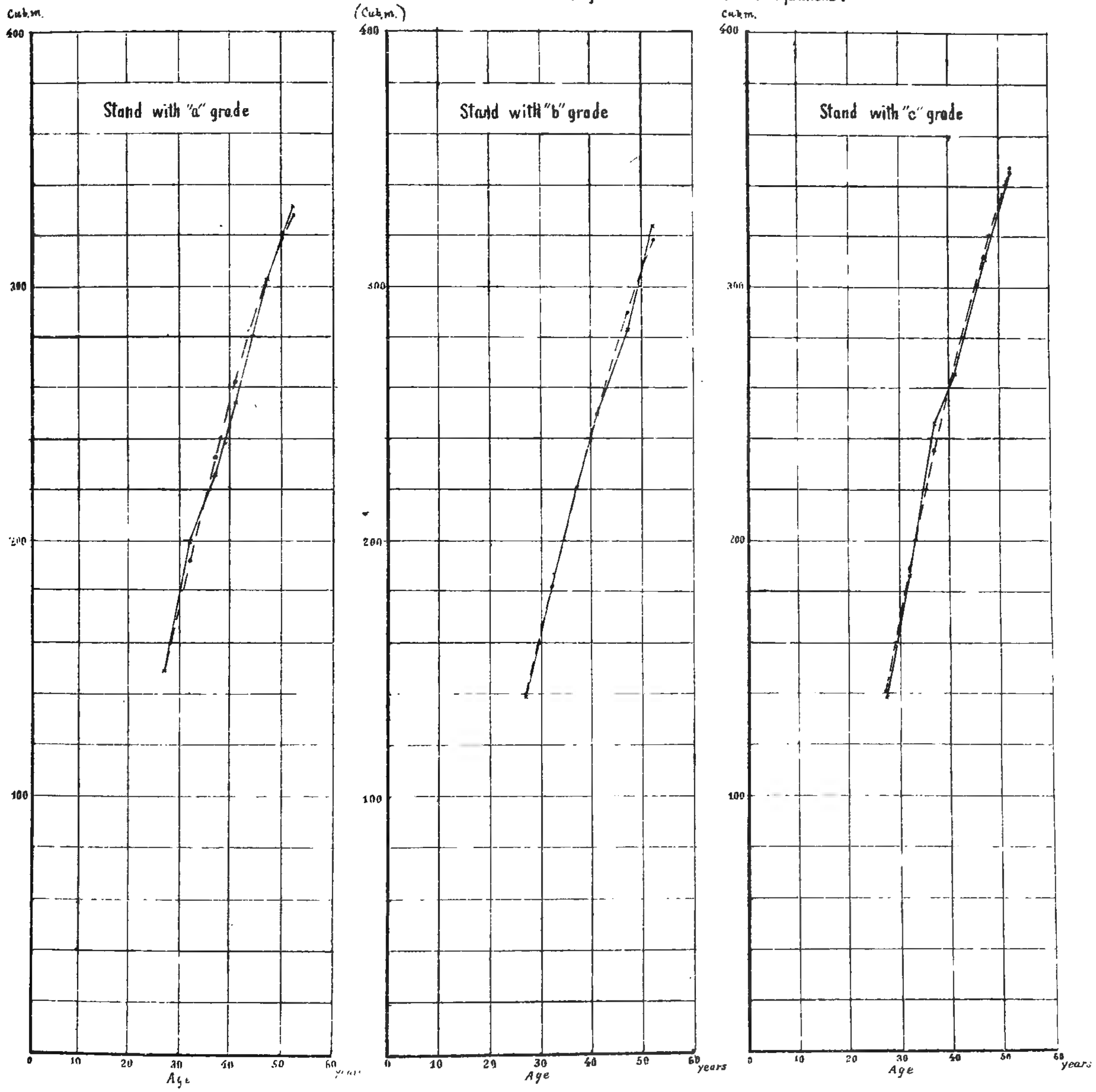
$$V = \xi e^{-\frac{\xi_1}{t}}$$



Stand with "a" grade
Stand with "b" grade
Stand with "c" grade
Cubm
0,3
0,2
0,1
0
10
20
30
40
50
60 years
Age

PLATE XXV. **Curves, showing the comparison of stem volume per ha.**

— - — — showing the curves from the equations.



Now applying this equation to the given data, we find:
for a stand with "a" grade;

$$V_a = 773.6e^{-\frac{44.5608}{t}} \qquad \text{Probable \% Diff.} \ \pm 1.7\%$$

for a stand with "b" grade;

$$V_b = 777.5e^{-\frac{46.4669}{t}} \qquad \text{Probable \% Diff.} \ \pm 1.1\%$$

for a stand with "c" grade:

$$V_c = 915.4e^{-\frac{50.4774}{t}} \qquad \text{Probable \% Diff.} \ \pm 1.9\%$$

The following diagrams (Plate XXV) show the comparison between the observed and calculated results for each stand:

(*g*) ON THE NUMBER OF TREES PER UNIT AREA.

It was stated from the investigations given by König, Kraft and Martin that the average sectional area of the crown-area of stand, says κ, is approximately correlated with the average basal sectional area, says $\bar{g}$, at breast height and it will be readily assumed that such a relation will be represented by the equation:

$$\frac{d\kappa}{\kappa} = k_1 \frac{d\bar{g}}{\bar{g}} \, .$$

where k_1 is the constant.

From this last equation, we have, by integrating and transforming,

$$\kappa = k\bar{g}^{k_1}$$

where k is the integral constant.

$$\text{Hence} \qquad \kappa = \frac{10000}{N} = k\bar{g}^{k_1}$$

$$\text{i. e.} \qquad N = \frac{10000}{k\left(\frac{\pi}{4}\right)^{k_1}} D^{-2k_1}$$

Substituting the equations: $D = \Delta e^{-\frac{\Delta_1}{t}}$ into the last equation, we have

$$N = \frac{10000}{k\left(\frac{\pi}{4}\right)^{k_1}} \cdot \Delta^{-2k_1} e^{+\frac{2k_1\Delta_1}{t}}$$

i. e. $$N=\eta e^{+\frac{\eta_1}{t}}$$

where we put $\eta=\frac{10000}{k\left(\frac{\pi}{4}\right)^{k_1}}\Delta^{-2k}$ and $\eta_1=2k_1\Delta_1$

Now applying the last obtained equation $N=\eta e^{+\frac{\eta_1}{t}}$ to the given data, we get:

for a stand with "a" grade

$$N_a=354.5e^{+\frac{86.2641}{t}} \qquad \text{Probable \% Diff.} \quad \pm 5.2\%$$

for a stand with "b" grade

$$N_b=497.3e^{+\frac{60.1057}{t}} \qquad \text{Probable \% Diff.} \quad \pm 4.9\%$$

for a stand with "c" grade

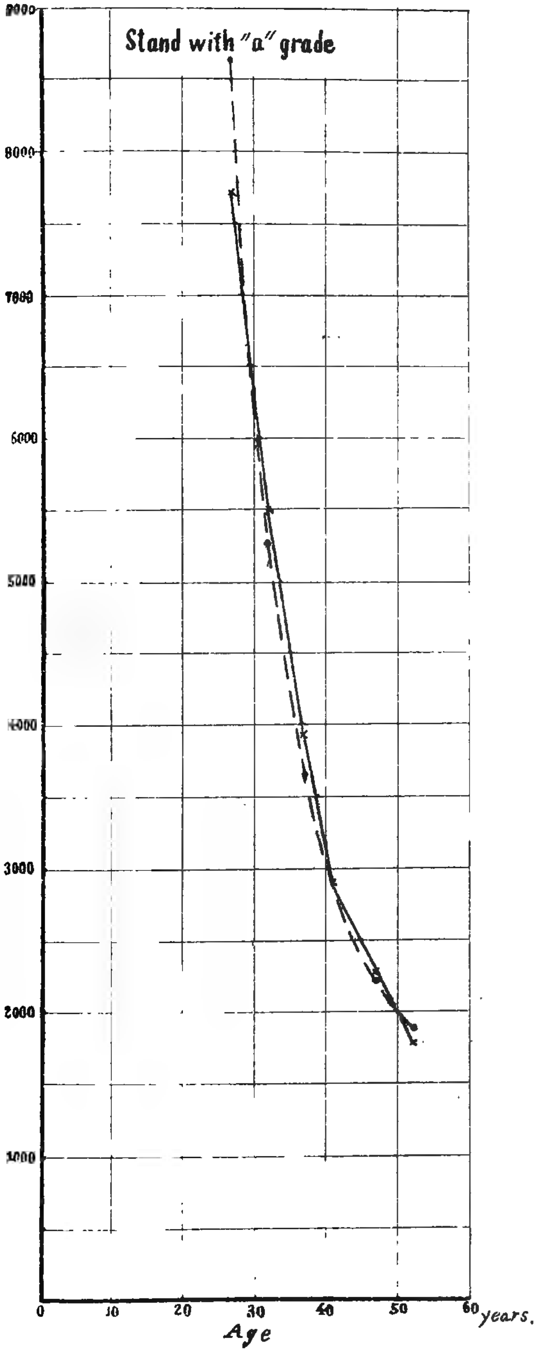
$$N_c=386.1e^{+\frac{63.2377}{t}} \qquad \text{Probable \% Diff.} \quad \pm 7.0\%$$

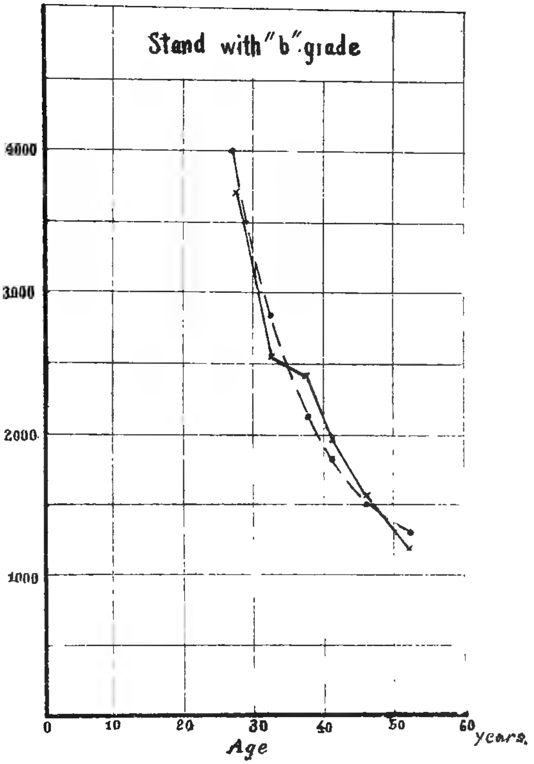
The following diagrams (Plate XXVI) show the comparison between the observed and calculated results, still one must bear in mind that the fluctuation index of the number for $\kappa=\frac{10000}{N}$ for each stand is similar for the remaining three factors excepting the total basal area per unit area, while only the irregularities is observable at the age of 52. Consequently the probable percentage difference is somewhat greater. Such an irregularity seems to be the outcome of the time-lack, or in other words, such abnormality was caused since the overheaded leaf canopy of stand at the age of 52 years did not fully attain the same degree of density gained at the previous period. Hence, sometimes, we may offer some other good formula as $N=\eta t.^{-\eta_1}$ But, this formula does not exist from the theoretical point of view. Because from the equation $N=\eta t^{-\eta_1}$, we get $\kappa=\frac{10000}{\eta}t.^{+\eta_1}$ This last equation shows us that in the fluctuation of $\frac{d\kappa}{dt}$, there is no maximum to be reached. Here at the limit, κ increases into the practical infinity at the age when the latter proceeds into the practical infinity. And if the formula, $N=\eta t^{-\eta_1}$ consists in generally, then the fluctuation of D must be expressed by the formula; $D=\Delta t.^{\Delta_1}$ But we cannot suggest

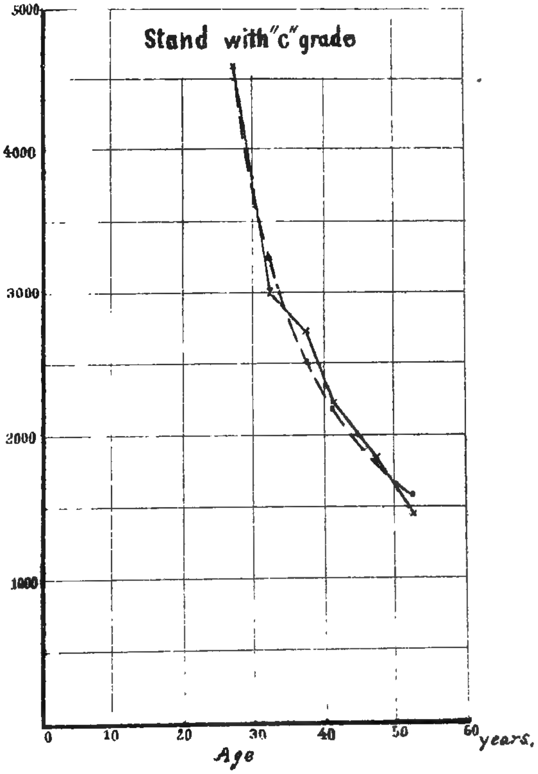
Curves, showing the comparison of number of trees per ha.

— — — showing the curves from the equations.

PLATE XXV







such a trend from the general trend of vital phenomenon, nor from the relationship existing between G, D, H. ι and V and the age, and from the mutual relations in κ, N, G, D, H, ι and V.

(*h*) ON THE TOTAL BASAL AREA PER UNIT AREA.

The fluctuation of the index number for the total basal area per unit area does not take the similar direction with any other factor, though the characteristics of the fluctuation is similar, i. e., this differs only in the smallness of the angle of the direction. So the equation to the curve of the total basal area per unit area may be expressed by the formula:

$$G=\varsigma e^{-\frac{\varsigma_1}{t}}$$

Again this equation may be readily deduced from the relation $N\bar{g}=G$, i. e., from the previous study on the equations of N and D with respect to the age, we have

$$N=\eta e^{+\frac{\eta_1}{t}} \quad \text{and} \quad \bar{g}=\frac{\pi}{4}\Delta^2 e^{-\frac{2\Delta_1}{t}}$$

So that

$$G=N\bar{g}=\frac{\pi}{4}\eta\Delta^2 e^{\frac{\eta_1-2\Delta_1}{t}}$$

where $\eta_1-2\Delta_1<o.$

Hence we get

$$G=\frac{\pi}{4}\eta\Delta^2 e^{-\frac{2\Delta_1-\eta_1}{t}}=\varsigma e^{-\frac{\varsigma_1}{t}}$$

where $\frac{\pi}{4}\eta\Delta^2=\varsigma$ and $2\Delta_1-\eta_1=\varsigma_1.$

Now applying the equation to the given data, we find:

for a stand with " a " grade,

$$G_a=52.89e^{-\frac{19.3105}{t}}$$ Probable % Diff. ±2.2%

for a stand with " b " grade,

$$G_b=54.31e^{-\frac{24.0223}{t}}$$ Probable % Diff. ±2,7%

for a stand with " c " grade,

$$G_c=55.42e^{-\frac{25.7700}{t}}$$ Probable % Diff. ±3.2%

The following diagrams (Plate XXVII) show the comparison between the observed and calculated results.

SUMMARY.

On surveying the results of the foregoing inquiry the following relations appear to be fairly well confirmed.

1) The relations showing the developments of the dimensions of trees in stand will be expressed by the following formulae:

a) On the development of diameter,

$$n'_r=\frac{n_r}{N}100=y_o\left(1+\frac{x}{a_1}\right)^{m_1}\left(1-\frac{x}{a_2}\right)^{m_2}$$

or

$$=y_o\left(1+\frac{x^2}{a^2}\right)^{-m}e^{-\nu\tan^{-1}\frac{x}{a}}$$

where n_r is the number of trees in diameter-class, N is the total number of trees of stand, y_o is the mode and y_o and other constants depend on the age, the quality of site and the form of density. And in crude approximation, the development of diameter may be expressed by the formula:

$$n'_r=y_oe^{-\frac{x^2}{2\sigma^2}}.$$

In which it will be estimated that y_o and $\frac{1}{2\sigma^2}$ are the functions of D.

b) On the development of height,

$$h=\alpha d^{\beta}$$

and in crude approximation, $h=\tau_1\left(\frac{x}{D}-1\right)+\tau_2$,

where $\tau_1=ae^{-\frac{a_1}{t}}$ and $\tau_2=be^{-\frac{b_1}{t}}$

c) On the development of volume,

$$v=\alpha_1d^{\beta_1}$$

and in crude approximation, $v=\tau'_1\left(\frac{x}{D}-1\right)+\tau'_2$

where $\tau'_1=a'e^{-\frac{a'_1}{t}}$ and $\tau'_2=b'e^{-\frac{b'_1}{t}}$

In which D is the average diameter and a and a_1, b and b_1, a' and a'_1, and b'_1 are the constants which depend on the quality of site and the form of density.

Curves, showing the comparison of basal area at breast height per *ha*.

– – – – showing the curves from the equation

PLATE XXVII

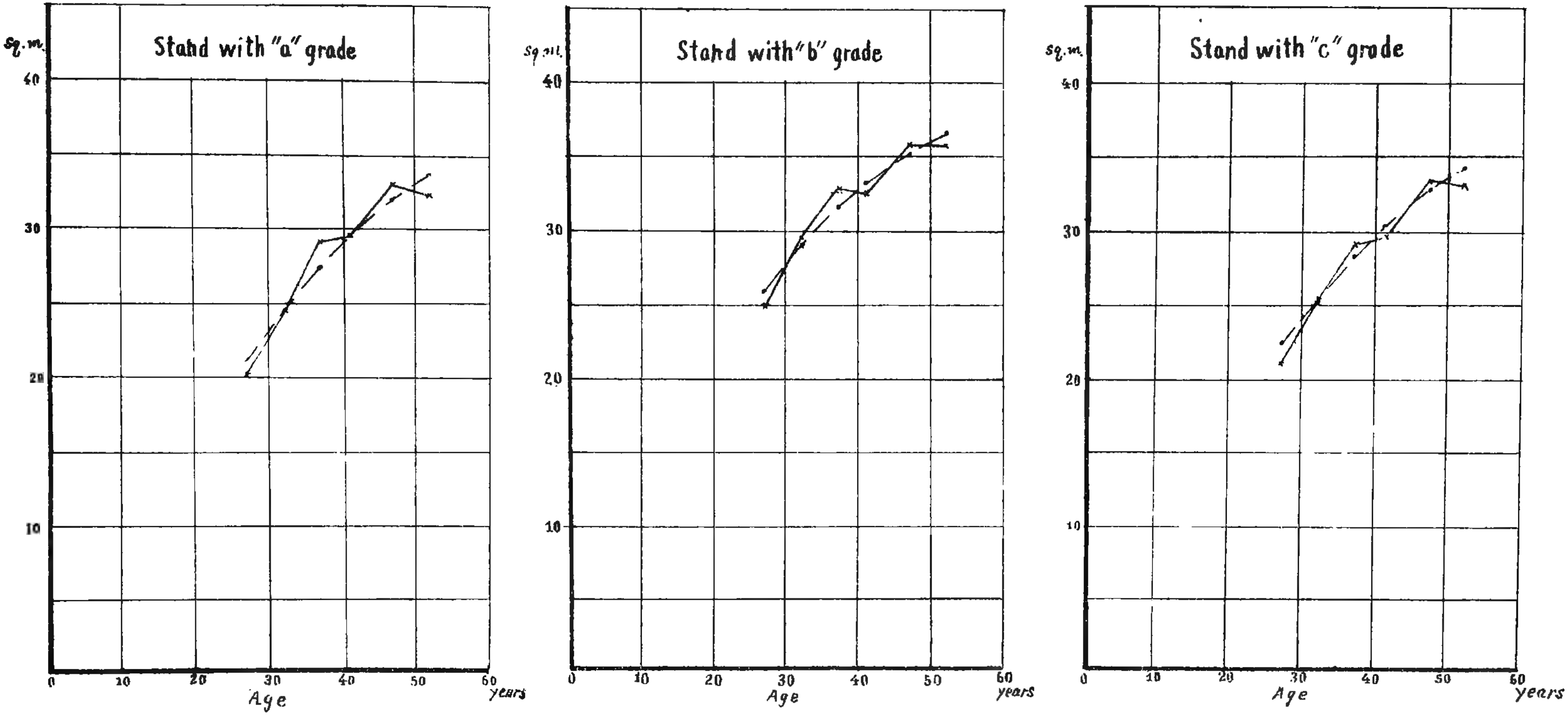
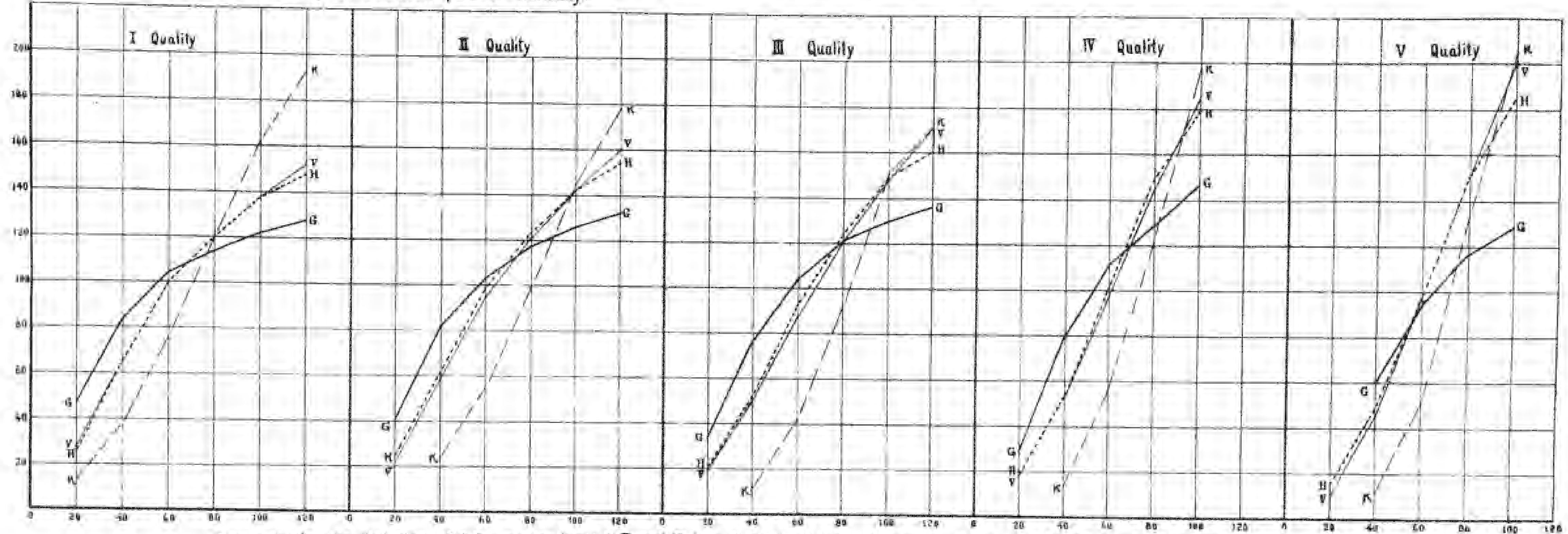
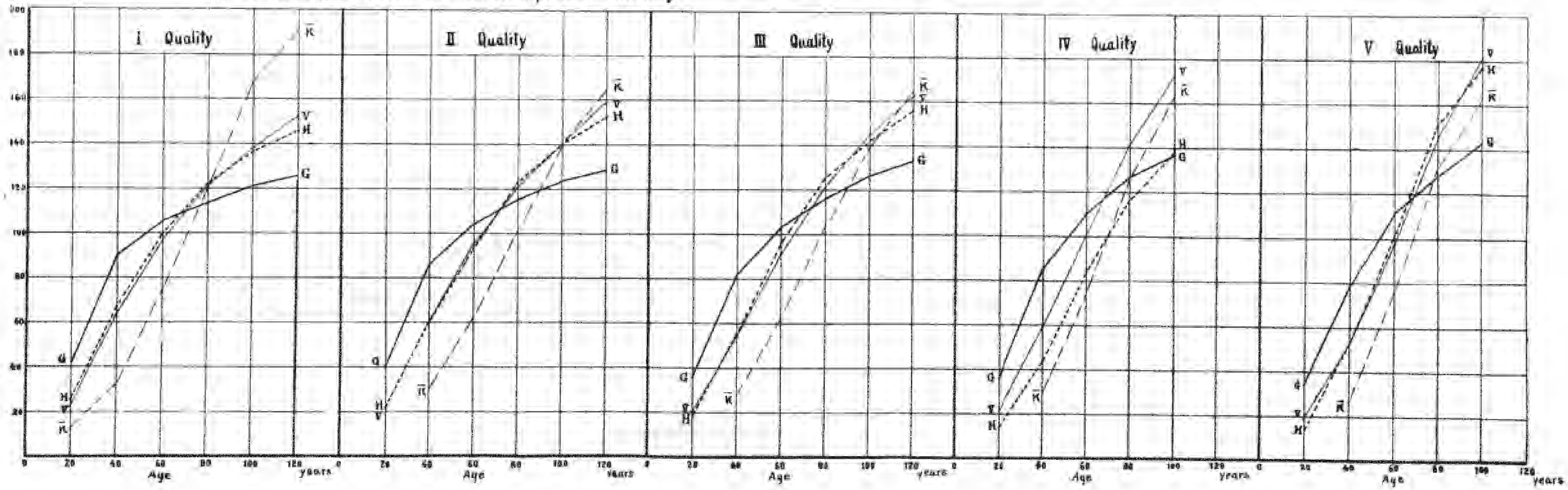


PLATE XXVIII

Curves, showing the fluctuations of index number for V, G, $\bar{K}$ and H from the Yield table for Spruce Stand, constructed by Dr. A. Schwappach, in the locality of southern part of Germany.



Curves, showing the fluctuations of index number for V, G, $\bar{K}$ and H from the Yield table for Spruce Stand, constructed by Dr. A Schwappach. in the localities of middle and northern parts of Germany.



2) Any particular cycle of growth of stand V, G, $\frac{10000}{N}$, H and D accords with the formula $y=ke^{-\frac{k_1}{t}}$ where y is the amount of factors which has been attained at time t, k is the ideal maximum total amount of growth attained during the cycle and the constants k and k_1 vary with the quality of site and the form of density.

(III) ON THE NORMAL TREND OF THE GROWTH OF STAND GIVEN IN THE YIELD TABLE

This part will be divided into two parts, one on the normal trend of the growth of stands simultaneously surveyed and managed with same manner of thinning and the other on the trend of the growth and yield given in yield table. For simplicity and convenience, we will confine our remarks to the last part and for illustration will discuss only the yield table for spruce in Germany which was constructed by Dr. A. Schwappach in 1890.

The following diagrams (Plate XXVIII) show the fluctuations of index numbers for the factors—V, G, $\frac{10000}{N}$, H and D. From these diagrams, we see that these fluctuations are similar to one another with respect to the age, and differ only in their absolute values, so that the equation for each factor may be the same in form.

Applying the equation $y=ke^{-\frac{k_I}{t}}$ we find:

Spruce in the middle and northern parts of Germany.			Spruce in the southern part of Germany.		
	Equation	Probable % Diff.		Equation	Probable % Diff.
1.	$\log H_I = 1.6893 - \frac{18.9333}{t}$	± 3.5%	1.	$\log H_I = 1.7257 - \frac{19.0540}{t}$	± 4.3%
	$\log H_{II} = 1.6607 - \frac{21.6373}{t}$	± 5.3%		$\log H_{II} = 1.6911 - \frac{21.5790}{t}$	± 7.5%
	$\log H_{III} = 1.6127 - \frac{24.0597}{t}$	± 7.3%		$\log H_{III} = 1.6562 - \frac{25.3760}{t}$	± 9.8%
	$\log H_{IV} = 1.5654 - \frac{27.6948}{t}$	±11.5%		$\log H_{IV} = 1.6046 - \frac{28.9624}{t}$	±16.6%
	$\log H_V = 1.4832 - \frac{30.0480}{t}$	±12.5%		$\log H_V = 1.5083 - \frac{31.7020}{t}$	±17.6%
2.	$\log V_I = 3.2551 - \frac{21.2597}{t}$	± 3.9%	2.	$\log V_I = 3.2471 - \frac{20.4740}{t}$	± 6.0%
	$\log V_{II} = 3.1847 - \frac{23.0283}{t}$	± 6.7%		$\log V_{II} = 3.1870 - \frac{23.3100}{t}$	± 9.5%

Spruce in the middle and northern parts of Germany.

Equation	Probable % Diff.
$\log V_{III} = 3.1044 - \frac{24.9673}{t}$	±10.4%
$\log V_{IV} = 2.9782 - \frac{25.7480}{t}$	±13.6%
$\log V_{V} = 2.8642 - \frac{28.5364}{t}$	±17.4%
3. $\log G_{I} = 1.9117 - \frac{10.3127}{t}$	± 4.3%
$\log G_{II} = 1.8739 - \frac{11.5000}{t}$	± 3.0%
$\log G_{III} = 1.8362 - \frac{13.3443}{t}$	± 1.7%
$\log G_{IV} = 1.7744 - \frac{14.1528}{t}$	± 0.6%
$\log G_{V} = 1.7134 - \frac{16.0576}{t}$	± 3.1%
4. $\log N_{I} = 2.2721 + \frac{48.1620}{t}$	± 3.2%
$\log N_{II} = 2.3956 + \frac{46.8752}{t}$	± 4.8%
$\log N_{III} = 2.5031 + \frac{47.8540}{t}$	± 2.5%
$\log N_{IV} = 2.6008 + \frac{49.3745}{t}$	± 1.6%
$\log N_{V} = 2.6728 + \frac{51.8915}{t}$	± 3.4%

Spruce in the southern part of Germany.

Equation	Probable % Diff.
$\log V_{III} = 3.1232 - \frac{26.9403}{t}$	±13.5%
$\log V_{IV} = 3.0075 - \frac{29.5324}{t}$	±16.9%
$\log V_{V} = 2.9668 - \frac{38.3192}{t}$	±19.1%
3. $\log G_{I} = 1.9302 - \frac{10.6637}{t}$	± 0.9%
$\log G_{II} = 1.8865 - \frac{12.4883}{t}$	± 0.4%
$\log G_{III} = 1.8466 - \frac{14.8157}{t}$	± 0.9%
$\log G_{IV} = 1.7994 - \frac{17.5308}{t}$	± 0.2%
$\log G_{V} = 1.7728 - \frac{21.5910}{t}$	± 1.1%
4. $\log N_{I} = 2.3021 + \frac{44.6172}{t}$	± 4.6%
$\log N_{II} = 2.2704 + \frac{55.8316}{t}$	± 6.8%
$\log N_{III} = 2.1729 + \frac{74.7700}{t}$	± 2.0%
$\log N_{IV} = 2.1726 + \frac{80.2740}{t}$	± 2.0%
$\log N_{V} = 2.2189 + \frac{86.6089}{t}$	± 2.8%

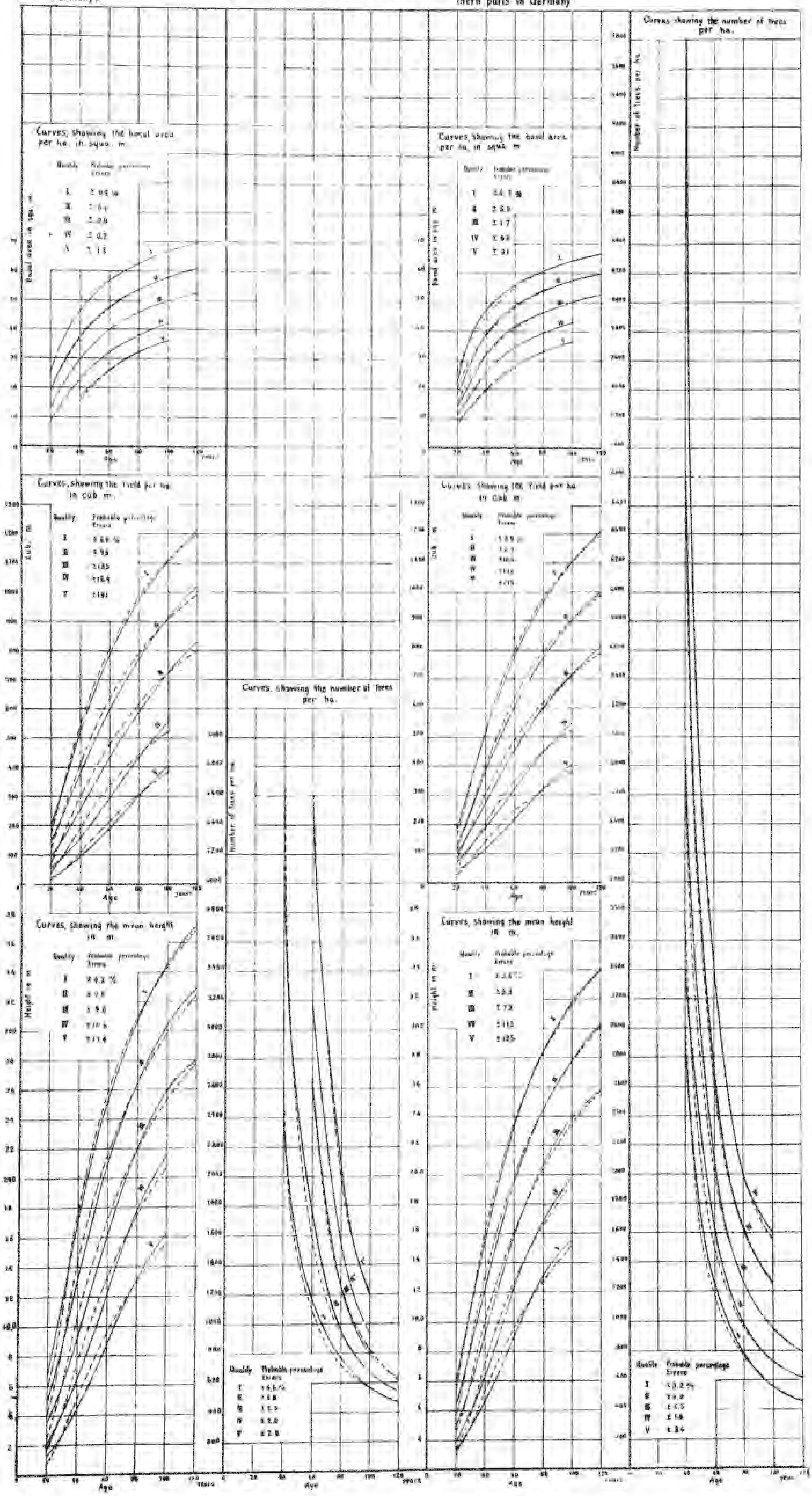
The following diagram (Plate XXIX) show the comparison between the theoretical and the given results.

From the above table and the plates it will be obviously seen that there are some regular discordances between the curves from the tables and those from the equations. This comes to happen, I think, from the disagreement of the curves from the tables with the given data, of which the tables must be constructed. I have examined the agreement of equation: $y = ke^{-\frac{k_1}{t}}$ directly with the given data. From these results, I continue to assert the truth of the above equation. To ascertain this formula it is needed to give numerous illustrations, but this is not the object of the paper.

PLATE XXIX

Graphic representation for the agreement between the curves from the equations and those from the Yield table for Spruce stand, constructed by Dr A. Schwappach, in the locality of southern part in Germany.

Graphic representation for the agreement between the curves from the equations and those from the Yield table for Spruce stand, constructed by Dr. A. Schwappach in the localities of middle and northern parts in Germany



IV. Application to the Construction of the Yield Table

In 1907, I showed in Bulletin No. 4 of the Forest Experimental Station that similar considerations apply to the construction of a yield table of the normally stocked, pure, even-aged stands for *Larix leptorepis* and to the discussion of the relative growth of stands for *Cryptomeria* with respect to sort and degree of thinning, commonly in use in the district of Yoshino, Nara Prefecture. Furthermore, in 1915, the formulae and relations with respect to the factors of the growth of stand described in the previous parts, were tested by application to the construction of a yield table on the normally stocked, pure, even-aged stands of different forms of density of *Cryptomeria* in the Main Island and Kiushu, and reported in Bulletin No. 11 of the Forest Experiment Station. In this short communication I have thought it would be advisable to report briefly the results of a fairly accurate application of the formulae and relations stated fully in the Japanese article.

I have collected the data from 153 stands of *Cryptomeria* in the Main Island and Kiushu. These may be summarised as follows:

Form of density.	Quality of site.	Number of sample plots in the localities.				Total number.
		Tōhoku.	Central part.	Chūgoku.	Kiushu.	
Thin.	I	1	—	1	1	3
	II	1	3	2	—	6
	III	—	1	2	1	4
	Total	2	4	5	2	13
Middle.	I	8	18	6	7	39
	II	8	9	7	6	30
	III	4	1	—	—	5
	Total	20	28	13	13	74
Dense.	I	11	19	12	7	49
	II	1	3	3	6	13
	III	2	1	—	1	4
	Total	14	23	15	14	66

Quality of site.	Form of density.	Number of sample plots in the localities.				Total number of sample plots.
		Tōhoku.	Central part.	Chūgoku.	Kiushu.	
I.	Thin	1	—	1	1	3
	Middle	8	18	6	7	39
	Dense	11	19	12	7	49
	Total	20	37	19	15	91
II.	Thin	1	3	2	—	6
	Middle	8	9	7	6	30
	Dense	1	3	3	6	13
	Total	10	15	12	12	49
III.	Thin	—	1	2	1	4
	Middle	4	1	—	—	5
	Dense	2	1	—	1	4
	Total	6	3	2	2	13

	Forms of density.			Total number.	Quality of site.			Total number.
	Thin.	Middle.	Dense.		I.	II.	III.	
Number of stands.	13	74	66	153	91	49	13	153

I. Equation for Average Height

I. QUALITY.

$$\log H = 1.4412 - \frac{10.6003}{t}$$

$$\text{i.e. } H = 27.62e^{-\frac{23.2570}{t}}$$

Age.	Obs.	Cl.	Diff. %
12	4.1	3.6	+12.2
13	4.5	4.2	+6.7
14	4.8	4.8	0.0
15	5.4	5.4	0.0
16	6.2	6.0	+3.3
17	6.6	6.6	0.0
18	7.0	7.1	−1.4
19	8.0	7.6	+5.0
20	8.6	8.7	+1.2
22	9.2	9.1	+1.1
24	10.0	10.0	0.0
25	10.4	10.4	0.0
26	10.6	10.8	−1.9
27	11.1	11.2	−0.9
28	11.4	11.5	−0.9
30	12.0	12.2	−1.7
32	12.7	12.9	−1.6
33	13.2	13.2	0.0
35	13.5	13.8	−2.2
37	14.0	14.3	−2.1
40	14.8	15.0	−1.4
46	16.0	16.1	−0.6
48	16.5	16.6	−0.6
50	16.6	16.9	−1.8
56	17.8	17.9	−0.6
60	18.5	18.4	+0.5
70	19.5	19.5	0.0
75	19.7	19.7	−1.0
100	22.1	22.1	+2.3

$m = \pm 3.1\%$

$r = \pm 2.1\%$

Diff.$>r$ 7 in number
Diff.$<r$ 22 in number

II. QUALITY.

$$\log H = 1.4310 - \frac{12.7226}{t}$$

$$\text{i.e. } H = 26.98e^{-\frac{29.2951}{t}}$$

Age.	Obs.	Cal.	Diff %.
16	4.7	4.3	+8.5
17	5.1	4.8	+5.9
20	6.4	6.2	+3.1
22	7.4	7.1	+4.1
23	7.4	7.6	−2.7
24	8.0	8.0	0.0
25	8.4	8.4	0.0
26	8.6	8.7	−1.2
27	9.2	9.1	+1.1
28	9.2	9.5	−3.3
29	9.6	9.8	−2.1
30	10.2	10.0	+2.0
32	10.6	10.8	−1.9
33	10.3	11.4	+7.1
34	11.7	11.4	+2.6
35	11.8	11.7	+0.8
54	15.5	15.7	−1.3
55	15.9	15.8	+0.6
60	16.4	16.6	−1.2
65	17.3	17.2	+0.6
100	20.3	20.1	+1.0

$m = \pm 3.6\%$

$r = \pm 2.4\%$

Diff.$>r$ 8 in number
Diff.$<r$ 13 in number

III. QUALITY.

$$\log H = 1.3657 - \frac{12.9639}{t}$$

$$\text{i.e. } H = 23.21e^{-\frac{29.8507}{t}}$$

Age.	Obs.	Cal.	Diff %.
23	5.9	6.3	−6.2
25	6.8	7.0	−2.9
28	8.1	8.0	+1.2
30	8.5	8.6	−1.2
33	9.8	9.4	+4.1
34	10.2	9.6	+5.9
35	9.9	9.9	0.0
90	16.0	16.7	−4.4
100	17.7	17.2	+2.8

$m = \pm 4.4\%$

$r = \pm 2.9\%$

Diff.$>r$ 4 in number
Diff.$<r$ 5 in number

Thus for the accuracy of the equation $H=\lambda e^{-\frac{\lambda_1}{t}}$ is shown as follows:

Quality of site.	m	r	General mean for r.
I	± 3.1%	± 2.1%	± 2.5%
II	± 3.6%	± 2.4%	
III	± 4.4%	± 3.9%	

II. Equation for Number of Trees per *Cho.*

Form of density: Thin.

I. QUALITY.

$$\log N=2.6486+\frac{8.1058}{t}$$

$$\text{i.e. } N=445.2e^{+\frac{18.6644}{t}}$$

Age.	Obs.	Cal.	Diff %
12	2100	2109	− 0.5
30	972	826	+14.7
56	600	622	− 3.7

$m=\pm 15.2\%$

$r=\pm 10.1\%$

Diff.>r 2 in number

Diff.<r 1 in number

II. QUALITY.

$$\log N=2.7462+\frac{11.4655}{t}$$

$$\text{i.e. } N=557.5e^{+\frac{26.4005}{t}}$$

Age.	Obs.	Cal.	Diff %
22	1900	1851	+ 2.6
25	1326	1603	−20.9
33	1347	1243	+ 9.5
54	1001	609	+ 9.2
60	811	866	− 6.8
100	722	731	− 1.2

$m=\pm 12.9\%$

$r=\pm 8.6\%$

Diff.>r 3 in number

Diff.<r 3 in number

III. QUALITY.

$$\log N=2.8246+\frac{13.7042}{t}$$

$$\text{i.e. } N=667.7e^{+\frac{31.5553}{t}}$$

Age.	Obs.	Cal.	Diff %
23	2500	2633	− 5.3
28	2144	2061	+ 3.9
90	968	948	+ 2.1
100	899	915	− 1.8

$m=\pm 5.1\%$

$r=\pm 3.4\%$

Diff.>r 2 in number

Diff.<r 2 in number

Form of density: Middle.

I. QUALITY.

$$\log N = 2.7639 + \frac{9.3150}{t} + \frac{21.4487}{t}$$

i.e. $N = 580.6e$

Age.	Obs.	Cal.	Diff. %
12	3750	3468	+ 9.5
13	2955	3023	+ 2.3
14	2918	2687	+ 7.6
15	2458	2426	+ 1.3
16	1943	2219	−14.2
17	1898	2050	− 8.0
18	1887	1912	− 1.3
19	1590	1796	−13.0
20	1676	1697	− 1.3
22	1568	1539	+ 1.8
24	1336	1419	− 6.2
25	1300	1370	− 5.4
28	1291	1249	+ 3.3
30	1158	1187	− 2.5
32	1184	1128	+ 4.7
33	1124	1113	+ 1.0
40	1013	992	+ 2.1
46	1075	926	+13.8
48	886	907	− 2.4
50	911	892	− 2.1
56	851	852	− 0.1
70	776	776	0.0
100	706	720	− 2.0

$m = \pm 6.4\%$

$r = \pm 4.3\%$

Diff.$>r$ 9 in number
Diff.$<r$ 14 in number

II. QUALITY.

$$\log N = 2.8531 + \frac{11.1366}{t} + \frac{25.6831}{t}$$

i.e. $N = 713.1e$

Age.	Obs.	Cal.	Diff. %
16	3174	2541	−11.6
17	3220	3222	− 0.6
20	2620	2569	+ 2.0
22	2248	2289	− 1.8
24	2075	2075	0.0
25	2113	1989	+ 5.9
26	1930	1912	+ 0.9
27	1836	1844	− 0.4
28	1799	1781	+ 1.0
29	1693	1738	− 2.7
30	1739	1676	+ 3.6
32	1683	1589	+ 5.6
34	1428	1516	− 6.2
35	1457	1484	− 1.9
55	1090	1137	− 4.3
60	1065	1093	− 2.6
65	1100	1058	+ 3.8

$m = \pm 4.3\%$

$r = \pm 2.8\%$

Diff.$>r$ 7 in number
Diff.$<r$ 10 in number

III. QUALITY.

$$\log N = 2.7961 + \frac{15.9179}{t} + \frac{36.6526}{t}$$

i.e. $N = 625.3e$

Age.	Obs.	Cal.	Diff. %
23	3005	3077	− 2.4
25	2781	2709	+ 2.6
35	1776	1782	− 0.3

$m = \pm 3.66\%$

$r = \pm 2.40\%$

Diff.$>r$ 2 in number
Diff.$<r$ 1 in number

Form of density: Dense.

I. QUALITY.

$$\log N = 2.7931 + \frac{9.3150}{t}$$

$$i.e.\ N = 621.0e^{+\frac{21.4487}{t}}$$

Age	Obs.	Cal.	Diff. %
15	3100	3189	− .9
16	2770	2879	− 3.9
17	2517	2631	− 4.5
18	2587	2428	+ 6.1
19	2061	2260	− 9.7
20	1974	2118	− 7.3
22	1767	1895	− 4.2
24	1657	1727	− 4.2
25	1684	1658	+ 1.5
26	1560	1596	− 2.3
27	1512	1506	+ 0.4
28	1552	1504	+ 3.1
30	1477	1407	+ 4.7
32	1300	1338	− 2.9
33	1312	1306	+ 0.5
35	1340	1252	+ 6.6
37	1286	1206	+ 6.2
40	1222	1148	+ 6.1
50	1131	1015	+10.3
60	946	935	+ 1.2
75	819	861	− 5.1
100	760	794	− 4.5

$m = \pm 5.6\%$

$r = \pm 3.7\%$

Diff.$>r$ 12 in number
Diff.$<r$ 8 in number

II. QUALITY.

$$\log N = 3.0010 + \frac{9.6898}{t}$$

$$i.e.\ N = 1002.0e^{+\frac{22.3313}{t}}$$

Age.	Obs.	Cal.	Diff. %
17	3682	3715	− 0.9
23	2758	2644	+ 4.1
26	2380	2363	− 0.7
27	2217	2291	− 3.2
28	2205	2224	− 0.9
30	2128	2109	+ 0.9
32	2032	2017	+ 0.7

$m = \pm 2.5\%$

$r = \pm 1.6\%$

Diff.$>r$ 2 in number
Diff.$<r$ 5 in number

III. QUALITY.

$$\log N = 2.966 + \frac{14.0139}{t}$$

$$i.e.\ N = 924.9e^{+\frac{32.2687}{t}}$$

Age.	Obs.	Cal.	Diff %
28	2760	2929	− 6.1
30	2940	2712	+ 7.8
33	2485	2460	+ 1.0
34	2315	2390	− 3.2

$m = \pm 7.4\%$

$r = \pm 4.9\%$

Diff.$>r$ 2 in number
Diff.$<r$ 3 in number

The accuracy of the equation $N=\eta e^{+\frac{\eta_1}{t}}$ is shown in the table:—

Form of density.	Quality of site.	Number of observed stands.	m.	r.	Mean for r.	General mean for r.
Thin	I	3	± 15.2%	± 10.1%	± 7.9%	± 5.4%
	II	6	± 12.9%	± 8.6%		
	III	4	± 5.1%	± 3.4%		
Middle	I	23	± 6.4%	± 4.3%	± 3.2%	
	II	17	± 4.3%	± 2.8%		
	III	3	± 3.6%	± 3.4%		
Dense	I	22	± 5.6%	± 3.7%	± 3.7%	
	II	7	± 2.5%	± 1.6%		
	III	4	± 7.4%	± 4.9%		

III. Euation for Basel Sectsional Area per *Cho.*

Form of density: Thin.

I. QUALITY.

$$\log G=3.3911-\frac{9.1801}{t}$$

$$i.e.\ G=2461e^{-\frac{21.1381}{t}}$$

Age.	Obs.	Cal.	Diff. %
12	451	423	+12.1
30	1115	1216	− 9.1
56	1720	1688	+ 1.9

$m=\pm 15.3\%$

$r=\pm 10.2\%$

Diff.>r 1 in number

Diff.<r 2 in number

II. QUALITY.

$$\log G=3.3234-\frac{12.2213}{t}$$

$$i.e.\ G=2106e^{-\frac{28.1408}{t}}$$

Age.	Obs.	Cal.	Diff. %
22	591	586	+ 0.8
25	696	683	+ 1.9
33	866	898	− 3.7
54	1310	1250	+ 4.6
60	1258	1317	− 4.7
100	1596	1590	+ 0.4

$m=\pm 3.9\%$

$r=\pm 2.6\%$

Diff.>r 3 in number

Diff.<r 3 in number

III. QUALITY.

$$\log G=3.2950-\frac{15.1832}{t}$$

$$i.e.\ G=1972e^{-\frac{34.9608}{t}}$$

Age.	Obs.	Cal.	Diff. %
23	463	451	+ 2.6
28	552	566	− 2.5
90	1230	1338	− 8.8
100	1485	1399	+ 6.4

$m=\pm 8.1\%$

$r=\pm 5.4\%$

Diff.>r 2 in number

Diff.<r 2 in number

Form of density: Middle.

I. QUALITY.

$$\log G = 3.3032 - \frac{9.7514}{t}$$

i. e. $= G2010e^{-\frac{22.4536}{t}}$

Age.	Obs.	Cal.	Diff. %
12	360	309	+14.3
13	424	357	+15.8
14	418	404	+ 3.3
15	426	450	− 5.6
16	548	494	+ 9.9
17	526	536	− 1.9
18	557	578	− 3.8
19	617	617	0.0
20	778	654	+15.9
22	614	724	−17.9
24	748	789	− 5.5
25	840	918	+ 2.5
28	915	922	− 0.8
30	890	951	− 6.9
32	1015	996	+ 1.9
33	944	1017	− 7.7
40	1155	1146	+ 0.8
46	1418	1234	+1.30
48	1165	1259	− 8.1
50	1233	1283	− 4.0
56	1294	1346	− 4.0
70	1440	1458	− 1.3
100	1653	1606	+ 2.8

$m = \pm 8.3\%$

$r = \pm 5.5\%$

Diff. $> r$ 11 in number
Diff. $< r$ 12 in number

II. QUALITY.

$$\log G = 3.2337 - \frac{12.5002}{t}$$

i. e. $G = 1710e^{-\frac{28.7830}{t}}$

Age.	Obs.	Cal.	Diff. %
16	261	283	− 8.4
17	372	315	+15.3
20	408	406	+ 0.5
22	503	462	+ 8.2
24	504	516	− 2.4
25	526	541	− 2.9
26	560	565	− 0.9
27	582	589	− 1.2
28	566	612	− 8.1
29	613	634	− 3.4
30	732	655	+10.5
32	698	696	+ 0.3
34	690	733	− 6.2
35	732	752	− 2.7
55	1064	1013	+ 4.8
60	975	1059	− 8.6
65	1155	1099	+ 4.8

$m = \pm 7.0\%$

$r = \pm 4.7\%$

Diff. $> r$ 9 in number
Diff. $< r$ 8 in number

III. QUALITY.

$$\log G = 3.1933 - \frac{15.7346}{t}$$

i. e. $G = 1561e^{-\frac{36.2305}{t}}$

Age.	Obs.	Cal.	Diff, %
23	317	323	− 1.8
25	374	367	+ 1.9
35	553	554	− 0.2

$m = \pm 2.6\%$

$r = \pm 1.8\%$

Diff. $> r$ 2 in number
Diff. $< r$ 1 in number

Form of density: Dense.

I. Quality.

$$\log G = 3.2399 - \frac{11.7212}{t}$$

i. e. $G = 1738e^{-\frac{26.9892}{t}}$

Age.	Obs.	Cal.	Diff. %
15	362	287	+20.7
16	380	322	+15.3
17	391	355	+ 9.2
18	448	388	+13.4
19	458	420	+ 8.3
20	488	450	+ 7.8
22	538	509	+ 5.4
24	581	564	+ 2.9
25	565	590	− 4.4
26	591	616	− 4.2
27	610	640	− 4.9
28	650	663	+ 2.0
30	687	707	− 2.9
32	653	747	−14.4
33	726	767	− 5.6
35	752	804	− 6.9
37	813	838	− 3.1
40	844	855	− 1.3
50	1005	1013	− 0.8
60	1094	1108	− 1.3
75	1197	1213	− 1.3
100	1382	1327	+ 4.0

$m = \pm 8.6\%$

$r = \pm 5.7\%$

Diff. $> r$ 8 in number

Diff. $< r$ 14 in number

II. Quality.

$$\log G = 3.1430 - \frac{11.7262}{t}$$

i. e. $G = 1390e^{-\frac{27.0007}{t}}$

Age.	Obs.	Cal.	Diff. %
17	301	284	+ 5.6
23	401	430	− 7.2
26	498	482	+ 1.2
27	494	511	− 3.4
28	533	530	+ 0.6
30	580	565	+ 2.6
32	603	598	+ 0.8

$m = \pm 4.6\%$

$r = \pm 3.0\%$

Diff. $> r$ 3 in number

Diff. $< r$ 4 in number

III. Quality.

$$\log G = 3.2264 - \frac{17.8813}{t}$$

i. e. $G = 1685e^{-\frac{41.1735}{t}}$

Age.	Obs.	Cal.	Diff. %
28	357	387	− 8.4
30	466	427	+ 8.4
33	517	484	+ 6.4
34	461	502	− 8.9

$m = \pm 11.4\%$

$r = \pm 7.6\%$

Diff. $> r$ 3 in number

Diff. $< r$ 1 in number

The accuracy of the equation $G=\varsigma e^{-\frac{\varsigma_1}{t}}$ is shown in the table:—

Form of density	Quality of site	Number of observed stand	m	r	Mean for r	General mean for r
Thin	I	3	± 15.3%	± 10.2%	± 6.8%	± 5.7%
	II	6	± 3.9%	± 2.6%		
	III	4	± 8.1%	± 5.4%		
Middle	I	23	± 8.3%	± 5.5%	± 4.3%	
	II	17	± 7.0%	± 4.7%		
	III	3	± 2.6%	± 1.8%		
Dense	I	22	± 8.6%	± 5.7%	± 5.8%	
	II	7	± 4.6%	± 3.0%		
	III	4	± 11.4%	± 7.6%		

IV. Equation for Stem Volume per *Cho*.

Form of density: Thin.

I. QUALITY

$$\log V_s = 3.9251 - \frac{16.2906}{t}$$

i. e. $V_s = 8416 e^{-\frac{37.5114}{t}}$

Age.	Obs.	Cal.	Diff. %
12	459	369	+19.6
30	2081	2410	−15.8
56	4448	4307	+ 3.2

$m = \pm 25.4\%$

$r = \pm 16.9\%$

Diff.$>r$ 1 in number

Diff.$<r$ 2 in number

II. QUALITY

$$\log V_s = 3.8847 - \frac{20.1074}{t}$$

i. e. $V_s = 7668 e^{-\frac{46.2993}{t}}$

Age.	Obs.	Cal.	Diff. %
22	832	935	−12.4
25	1380	1203	+12.8
33	1593	1886	+18.0
54	3764	3253	+13.6
10	3478	3545	− 1.6
100	4730	4826	− 2.0

$m = \pm 14.4\%$

$r = \pm 9.6\%$

Diff.$>r$ 4 in number

Diff.$<r$ 2 in number

III. QUALITY

$$\log V_s = 3.8118 - \frac{24.3867}{t}$$

i. e. $V_s = 6483 e^{-\frac{56.1528}{t}}$

Age.	Obs.	Cal.	Diff. %
23	610	564	+ 7.5
28	845	873	− 3.3
90	3205	3474	− 8.4
100	3942	3698	+ 6.2

$m = \pm 9.4\%$

$r = \pm 6.1\%$

Diff.$>r$ 2 in number

Diff.$<r$ 2 in number

Form of density: Middle.

I. QUALITY

$$\log V_s = 3.9071 - \frac{18.1304}{t}$$

$$i.e\ V_s = 8074e^{-\frac{41.7471}{t}}$$

Age	Obs.	Cal.	Diff. %
12	318	249	+21.7
13	574	325	+43.4
14	394	409	− 3.8
15	456	499	− 9.4
16	704	594	+15.7
17	717	693	+ 3.3
18	794	794	0.0
19	842	897	− 6.5
20	1254	1001	+20.2
22	1373	1211	+11.8
24	1337	1418	− 6.1
25	1882	1520	+19.2
28	1806	1818	− 0.7
30	1841	2008	− 9.1
32	2179	2190	− 0.5
33	1852	2279	−23.1
40	2556	2843	−11.2
46	2820	3258	−15.5
48	3143	3384	− 7.7
50	3658	3503	+ 4.2
56	3624	3831	− 5.7
70	3864	4447	+15.1
100	6075	5319	+12.4

$m = \pm 15.7\%$

$r = \pm 10.5\%$

Diff.$>r$ 11 in number

Diff.$<r$ 12 in number

II. QUALITY

$$\log V_s = 3.7832 - \frac{21.2326}{t}$$

$$i.e.V_s = 6270e^{-\frac{48.8902}{t}}$$

Age	Obs.	Cal.	Diff. %
16	255	286	−12.2
17	402	342	+14.9
20	517	527	− 1.9
22	738	658	+10.8
24	711	792	−11.3
25	872	859	+ 1.5
26	909	926	− 9.6
27	944	993	− 5.2
28	868	1059	−22.0
29	1060	1125	− 6.1
30	1692	1190	+29.7
32	1334	1317	+ 1.3
34	1244	1441	−15.8
35	1530	1502	+ 1.8
55	2777	2496	+10.1
60	2561	2688	− 5.0
65	2796	1860	− 2.2

$m = \pm 13.0\%$

$r = \pm 8.7\%$

Diff.$>r$ 9 in number

Diff.$<r$ 8 in number

III. QUALITY

$$\log V_s = 3.6254 - \frac{23.4341}{t}$$

$$i.e.V_s = 4221e^{-\frac{53.6594}{t}}$$

Age	Obs.	Cal.	Diff. %
23	390	404	− 3.6
25	507	488	+ 3.7
35	899	904	− 0.6

$m = \pm 5.2\%$

$r = \pm 3.5\%$

Diff.$>r$ 2 in number

Diff.$<r$ 1 in number

Form of density: Dense.

I. QUALILY

$$log V_s = 3.7384 - \frac{16.8786}{t} - \frac{38.8647}{t}$$

i.e. $V_s = 5475e$

Age	Obs.	Cal.	Diff. %
15	405	410	− 1.2
16	464	482	− 3.9
17	548	556	− 1.5
18	642	632	+ 1.6
19	663	708	+ 6.8
20	850	784	+ 7.8
22	929	936	+ 0.8
24	961	1084	+12.8
25	1086	1164	+ 7.2
26	1010	1228	−21.6
27	1268	1298	− 2.4
28	1316	1367	− 3.9
30	1409	1499	− 6.4
32	1478	1625	− 9.9
33	1598	1686	− 5.5
35	1992	1804	+ 9.4
37	1903	1915	− 0.6
40	2121	2072	+ 2.6
50	2664	2516	+ 5.6
60	3487	2865	+17.8
75	2849	3261	+14.5
100	3737	3712	+ 0.7

$m = \pm 9.1\%$

$r = \pm 6.1\%$

Diff. $>r$ 9 in number
Diff. $<r$ 13 in number

II. QUALITY

$$log V_s = 3.6982 - \frac{21.5269}{t} - \frac{49.5678}{t}$$

i. e. $V_s = 4.991e$

Age	Obs.	Cal.	Diff. %
17	240	270	+12.5
23	576	579	− 0.5
26	843	742	+12.0
27	820	796	+ 2.0
28	809	850	− 5.1
30	874	956	− 9.4
32	1027	1060	− 3.2

$m = \pm 9.3\%$

$r = \pm 6.2\%$

Diff. $>r$ 3 in number
Diff. $<r$ 3 in number

III. QUALITY

$$log V_s = 3.6584 - \frac{25.0942}{t} - \frac{57.7819}{t}$$

i. e. $V_s = 4554e$

Age	Obs.	Cal.	Diff. %
28	535	578	− 8.0
30	745	667	+10.5
33	771	791	− 2.6
34	821	832	− 1.3

$m = \pm 9.6\%$

$r = \pm 6.4\%$

Diff. $>r$ 2 in number
Diff. $<r$ 2 in number

The accuracy of the equation $V=\xi e^{-\frac{\xi_1}{t}}$ is shown in the table:—

Form of density	Quality of site	Number of observed stands	m	r	Mean for r	General mean for r
Thin	I	3	± 25.4%	± 16.9%	± 11.7%	± 9.0%
	II	6	± 14.4%	± 9.6%		
	III	4	± 9.4%	± 6.3%		
Middle	I	23	± 15.7%	± 10.5%	± 8.2%	
	II	17	± 13.0%	± 8.7%		
	III	3	± 5.2%	± 3.5%		
Dense	I	22	± 9.1%	± 6.1%	± 6.2%	
	II	7	± 9.3%	± 6.2%		
	III	4	± 9.6%	± 6.4%		

The above given comparison between the calculated and the observed values for the factors of growth of stands adds confirmation to the views expressed in my investigation.

Now comparing the constants of the equations for the factors of growth of stands with respect to equality of site for the same form of density and with respect to the different form of density for the same quality of site, we may evidently conclude that the curve for each factors satisfies the conditions of similarity.

Hence we get following corrected equations.

I. Equation for Average Height in *Ken.*

Quality of site: Equation:

I $\log H_{I} = 1.4493 - \frac{10.9152}{t}$, or $H_{I} = 28.14 e^{-\frac{25.1333}{t}}$

II $\log H_{II} = 1.4115 - \frac{12.0986}{t}$, or $H_{II} = 25.79 e^{-\frac{27.8512}{t}}$

III $\log H_{III} = 1.3737 - \frac{13.2819}{t}$, or $H_{III} = 23.64 e^{-\frac{30.5839}{t}}$

II. Equation for Number of Trees per *Cho.*

Quality of site	FORM OF DENSITY		
	Thin	Middle	Dense
I	$\log N_{I} = 2.6670 + \frac{8.2215}{t}$	$\log N_{I} = 2.7579 + \frac{8.9637}{t}$	$\log N_{I} = 2.8488 + \frac{9.7059}{t}$
II	$\log N_{II} = 2.7313 + \frac{11.3750}{t}$	$\log N_{II} = 2.8215 + \frac{11.5562}{t}$	$\log N_{II} = 2.9117 + \frac{11.7374}{t}$
III	$\log N_{III} = 2.7956 + \frac{14.5285}{t}$	$\log N_{III} = 2.8851 + \frac{14.1487}{t}$	$\log N_{III} = 2.9746 + \frac{13.7689}{t}$

Or, these may be rewritten as follows:—

Quality of site	FORM OF DENSITY		
	Thin	Middle	Dense
I	$N_{I} = 464.5e^{+\frac{18.9308}{t}}$	$N_{I} = 572.7e^{+\frac{20.6398}{t}}$	$N_{I} = 706.0e^{+\frac{22.3488}{t}}$
II	$N_{II} = 538.7e^{+\frac{26.1922}{t}}$	$N_{II} = 663.0e^{+\frac{26.6093}{t}}$	$N_{II} = 816.0e^{+\frac{27.0265}{t}}$
III	$N_{III} = 624.6e^{+\frac{33.4533}{t}}$	$N_{III} = 767.6e^{+\frac{32.5788}{t}}$	$N_{III} = 943.1e^{+\frac{31.7043}{t}}$

III. Equation for Basel Sectional Area per *Cho*, in Square *Shaku.*

Quality of site	FORM OF DENSITY		
	Thin	Middle	Dense
I	$\log G_{I} = 3.3848 - \frac{9.1020}{t}$	$\log G_{I} = 3.2974 - \frac{9.8535}{t}$	$\log G_{I} = 3.2100 - \frac{10.6050}{t}$
II	$\log G_{II} = 3.3296 - \frac{12.0873}{t}$	$\log G_{II} = 3.2607 - \frac{12.8782}{t}$	$\log G_{II} = 3.1939 - \frac{13.6691}{t}$
III	$\log G_{III} = 3.2702 - \frac{15.0726}{t}$	$\log G_{III} = 3.2240 - \frac{15.9029}{t}$	$\log G_{III} = 3.1778 - \frac{16.7332}{t}$

Or, these may be rewritten as follows:—

Quality of site	FORM OF DENSITY		
	Thin	Middle	Dense
I	$G_{I} = 2426e^{-\frac{20.9583}{t}}$	$G_{I} = 1983e^{-\frac{22.6887}{t}}$	$G_{I} = 1622e^{-\frac{24.4191}{t}}$
II	$G_{II} = 2126e^{-\frac{27.8322}{t}}$	$G_{II} = 1823e^{-\frac{29.6533}{t}}$	$G_{II} = 1563e^{-\frac{31.4745}{t}}$
III	$G_{III} = 1863e^{-\frac{34.7062}{t}}$	$G_{III} = 1675e^{-\frac{36.6180}{t}}$	$G_{III} = 1506e^{-\frac{38.5299}{t}}$

IV. Epuation for Average Diameter in *Shaku.*

Quality of site	FORM OF DENSITY		
	Thin	Middle	Dense
I	$\log D_{I} = 0.4113 - \frac{8.6618}{t}$	$\log D_{I} = 0.3222 - \frac{9.4036}{t}$	$\log D_{I} = 0.2330 - \frac{10.1554}{t}$
II	$\log D_{II} = 0.3505 - \frac{11.7312}{t}$	$\log D_{II} = 0.2720 - \frac{12.2172}{t}$	$\log D_{II} = 0.1935 - \frac{12.7032}{t}$
III	$\log D_{III} = 0.2897 - \frac{14.8006}{t}$	$\log D_{III} = 0.2218 - \frac{15.0258}{t}$	$\log D_{III} = 0.1540 - \frac{15.2511}{t}$

Or, these may be rewritten as follows:—

Quality of site	FORM OF DENSITY		
	Thin	Middle	Dense
I	$D_{I} = 2.578e^{-\frac{19.9446}{t}}$	$D_{I} = 2.100e^{-\frac{21.6642}{t}}$	$D_{I} = 1.710e^{-\frac{23.3836}{t}}$
II	$D_{II} = 2.242e^{-\frac{27.0123}{t}}$	$D_{II} = 1.871e^{-\frac{28.0303}{t}}$	$D_{II} = 1.562e^{-\frac{29.2504}{t}}$
III	$D_{III} = 1.948e^{-\frac{34.0800}{t}}$	$D_{III} = 1.666e^{-\frac{34.5984}{t}}$	$D_{III} = 1.426e^{-\frac{35.1172}{t}}$

V. Equation for Stem Volume per *Cho* in *Shakujime.*
(1 Shakujime. . . .12 cub. ft.)

Quality of site	FORM OF DENSITY		
	Thin	Middle	Dense
I	$\log V_{s_{I}} = 3.9567 - \frac{16.7620}{t}$	$\log V_{s_{I}} = 3.8603 - \frac{17.1846}{t}$	$\log V_{s_{I}} = 3.7639 - \frac{17.6072}{t}$
II	$\log V_{s_{II}} = 3.8692 - \frac{20.3346}{t}$	$\log V_{s_{II}} = 3.7812 - \frac{20.7872}{t}$	$\log V_{u_{II}} = 3.6932 - \frac{21.2398}{t}$
III	$\log V_{s_{III}} = 3.7817 - \frac{23.9032}{t}$	$\log V_{s_{III}} = 3.7021 - \frac{24.3898}{t}$	$\log V_{s_{III}} = 3.6225 - \frac{24.8724}{t}$

Or, these may be rewritten as follows:—

Quality of site	FORM OF DENSITY		
	Thin	Middle	Dense
I	$V_{s_{I}} = 9051e^{-\frac{38.5962}{t}}$	$V_{s_{I}} = 7249e^{-\frac{39.5693}{t}}$	$V_{s_{I}} = 5806e^{-\frac{40.5423}{t}}$
II	$V_{s_{II}} = 7399e^{-\frac{46.8224}{t}}$	$V_{s_{II}} = 6042e^{-\frac{47.8646}{t}}$	$V_{s_{II}} = 4939e^{-\frac{48.3068}{t}}$
III	$V_{s_{III}} = 6049e^{-\frac{55.0487}{t}}$	$V_{s_{III}} = 5036e^{-\frac{56.1600}{t}}$	$V_{s_{III}} = 4193e^{-\frac{57.2712}{t}}$

VI. Equations for Current Annual and Mean Annual Growth of Average Height as follows:

Quality of site	Current annual growth	Mean annual growth
I	$\lambda H_{I} = H_{I}\frac{25.1333}{t^2}$	$\partial H_{I} = 28.14t^{-1}e^{-25.1333/t}$
II	$\lambda H_{II} = H_{II}\frac{27.8512}{t^2}$	$\partial H_{II} = 25.79t^{-1}e^{-27.8512/t}$
III	$\lambda H_{III} = H_{III}\frac{30.5839}{t^2}$	$\partial H_{III} = 23.64t^{-1}e^{-30.5839/t}$

VII. (1) Equations for Current Annual Growth of Average Diameters as follows:

Quality of site	FORM OF DENSITY		
	Thin	Middle	Dense
I	$\lambda D_{I} = D_{I}\frac{19.9446}{t^2}$	$\lambda D_{I} = D_{I}\frac{21.6642}{t^2}$	$\lambda D_{I} = D_{I}\frac{23.3836}{t^2}$
II	$\lambda D_{II} = D_{II}\frac{27.0123}{t^2}$	$\lambda D_{II} = D_{II}\frac{28.1313}{t^2}$	$\lambda D_{II} = D_{II}\frac{29.2504}{t^2}$
III	$\lambda D_{III} = D_{III}\frac{34.0800}{t^2}$	$\lambda D_{III} = D_{III}\frac{34.5984}{t^2}$	$\lambda D_{III} = D_{III}\frac{35.1172}{t^2}$

VII. (2) Equations for Current Mean Aunual Growth of Average Diameters as follows:

Quality of site	FORM OF DENSITY		
	Thin	Middle	Dense
I	$\partial D_{I} = 2.590t^{-1}e^{-91.9446/t}$	$\partial D_{I} = 2.100t^{-1}e^{-21.6642/t}$	$\partial D_{I} = 1.710t^{-1}e^{-23.3836/t}$
II	$\partial D_{II} = 2.241t^{-1}e^{-27.1113/t}$	$\partial D_{II} = 1.871t^{-1}e^{-28.1313/t}$	$\partial D_{II} = 1.562t^{-1}e^{-29.2504/t}$
III	$\partial D_{III} = 1.948t^{-1}e^{-34.0800/t}$	$\partial D_{III} = 1.666t^{-1}e^{-34.5984/t}$	$\partial D_{III} = 1.426t^{-1}e^{-35.1172/t}$

VIII. (1) Equations for Current Annual Growth of Stem Volume per *Cho* as follows:

Quality of site	FORM OF DENSITY		
	Thin	Middle	Dense
I	$\lambda V_{S_{I}} = V_{S_{I}}\frac{38.5962}{t^2}$	$\lambda V_{S_{I}} = V_{S_{I}}\frac{39.5693}{t^2}$	$\lambda V_{S_{I}} = V_{S_{I}}\frac{40.5423}{t^2}$
II	$\lambda V_{S_{II}} = V_{S_{II}}\frac{46.8224}{t}$	$\lambda V_{S_{II}} = V_{S_{II}}\frac{47.8646}{t^2}$	$\lambda V_{S_{II}} = V_{S_{II}}\frac{48.9068}{t^2}$
III	$\lambda V_{S_{III}} = V_{S_{III}}\frac{55.0487}{t^2}$	$\lambda V_{III} = V_{III}\frac{55.1600}{t^2}$	$\lambda V_{S_{III}} = V_{S_{III}}\frac{57.2712}{t^2}$

VIII. (2) Equations for Current Mean Annual Growth of Stem Volume per *Cho* as follows:

Quality of site	FORMS OF DENSITY		
	Thin	Middle	Dense
I	$\partial V_{S_{I}} = 9051t^{-1}e^{-38.5962/t}$	$\partial V_{S_{I}} = 7249t^{-1}e^{-39.5693/t}$	$\partial V_{S_{I}} = 5806t^{-1}e^{-40.5423/t}$
II	$\partial V_{S_{II}} = 7399t^{-1}e^{-46.8224/t}$	$\partial V_{S_{II}} = 6042t^{-1}e^{-47.8646/t}$	$\partial V_{S_{II}} = 4934t^{-1}e^{-48.9068/t}$
III	$\partial V_{S_{III}} = 6049t^{-1}e^{-55.0487/t}$	$\partial V_{S_{III}} = 5036t^{-1}e^{-56.1600/t}$	$\partial V_{S_{III}} = 4193t^{-1}e^{-57.2712/t}$

YIELD TABLE FOR DOMINANT TREES OF SUGI STAND

Quality of site	Age in years	Average height in Ken	Average diameter in Shaku			Number of trees per Cho			Basal sectional area per Cho in sq. Shaku			Stem volume per Cho in Koku		
			Thin	Middle	Dense	Thin	Middle	Dense	Thin	Middle	Dense	Thin	Middle	Dense
I.	10	2.3	0.35	—	—	(3000)	—	—	298	—	—	229	—	—
	13	4.1	—	0.40	—	—	(3000)	—	—	346	—	—	414	—
	15	5.3	0.68	0.50	0.36	1641	2268	(3000)	600	437	318	829	622	407
	20	8.0	0.96	0.71	0.53	1196	1607	2158	851	638	478	1577	1202	917
	30	12.2	1.32	1.02	0.78	873	1140	1487	1206	931	719	3000	2326	1804
	40	15.0	1.56	1.22	0.95	746	959	1234	1436	1125	881	4138	3235	2530
	50	17.0	1.73	1.36	1.07	678	865	1102	1595	1260	994	5020	3943	3097
	60	18.5	1.85	1.46	1.16	637	807	1024	1710	1359	1079	5707	4496	3541
	70	19.6	1.94	1.54	1.22	609	769	972	1798	1434	1144	6257	4943	3905
	80	20.6	2.01	1.60	1.28	589	741	934	1865	1494	1195	6706	5305	4196
	90	21.3	2.06	1.65	1.32	575	721	905	1922	1542	1237	7074	5604	4441
	100	21.9	2.12	1.69	1.35	560	704	884	1967	1581	1271	7384	5857	4645
I.	12	2.5	0.24	—	—	(4320)	—	—	209	—	—	180	—	—
	14	3.5	—	0.25	—	—	(4320)	—	—	219	—	—	238	—
	15	4.0	0.37	—	—	3087	—	—	322	—	—	374	—	—
	16	4.5	—	—	0.25	—	—	(4320)	—	—	219	—	—	278
	20	6.4	0.58	0.46	0.36	1995	2506	3152	529	413	324	854	662	514
	30	10.2	0.91	0.73	0.59	1290	1610	2008	848	678	547	1864	1471	1159
	40	12.8	1.14	0.93	0.75	1037	1289	1603	1060	868	712	2754	2191	1744
	50	14.8	1.31	1.06	0.89	908	1129	1402	1218	1007	833	3480	2784	2216
	60	16.2	1.43	1.17	0.96	832	1033	1280	1337	1112	925	4068	3265	2621
	70	17.3	1.52	1.25	1.03	782	969	1200	1429	1193	993	4548	3659	2044
	80	18.2	1.60	1.32	1.08	748	924	1144	1502	1258	1054	4945	3986	3212
	90	18.9	1.66	1.37	1.13	721	891	1102	1561	1311	1102	5279	4260	3438
	100	19.5	1.71	1.41	1.16	700	865	1069	1610	1355	1141	5561	4493	3578
III.	16	3.5	0.23	—	—	(5400)	—	—	213	—	—	233	—	—
	17	3.9	—	0.22	—	—	(5400)	—	—	194	—	—	222	—
	18	4.3	—	—	0.20	—	—	(5400)	—	—	177	—	—	209
	20	5.1	0.36	0.30	0.25	3327	3913	4603	329	268	219	463	365	286
	30	8.5	0.63	0.53	0.44	1905	2274	2713	586	494	417	1159	930	745
	40	11.0	0.83	0.70	0.59	1442	1733	2034	746	671	575	1834	1434	1202
	50	12.8	0.99	0.83	0.71	1220	1472	1787	931	804	697	2414	1966	1601
	60	14.2	1.10	0.94	0.79	1091	1321	1600	1045	909	792	2900	2370	1937
	70	15.3	1.20	1.02	0.87	1007	1223	1485	1134	992	868	3306	2708	2220
	80	16.1	1.27	1.08	0.92	949	1153	1402	1207	1059	930	3648	2995	2460
	90	16.8	1.34	1.13	0.96	906	1103	1342	1267	1115	981	3838	3239	2666
	100	17.4	1.39	1.18	1.00	873	1063	1795	1317	1161	1010	4186	3446	2837

GROWTH TABLE FOR AVERAGE HEIGHT OF DOMINANT TREES

Quality of site	Age in years	Current annual increment in Ken	Mean annual increment in Ken	Quality of site	Age in years	Current annual increment in Ken	Mean annual increment in Ken	Quality of site	Age in years	Current annual increment in Ken	Mean annual increment in Ken
I.	10	0.58	0.23	II.	12	0.48	0.21	III.	16	0.42	0.22
	13	0.61	0.32		14	0.50	0.25		17	0.41	0.23
	15	0.59	0.35		15	0.50	0.27		18	0.40	0.24
	20	0.50	0.40		16	0.49	0.29		20	0.39	0.26
	30	0.34	0.41		20	0.45	0.32		30	0.29	0.28
	40	0.24	0.38		30	0.32	0.34		40	0.21	0.28
	50	0.17	0.34		40	0.22	0.32		50	0.16	0.26
	60	0.13	0.31		50	0.16	0.30		60	0.12	0.24
	70	0.10	0.28		60	0.12	0.27		70	0.10	0.22
	80	0.08	0.26		70	0.09	0.25		80	0.08	0.20
	90	0.07	0.24		80	0.08	0.23		90	0.06	0.19
	100	0.06	0.22		90	0.06	0.21		100	0.05	0.17
					100	0.05	0.20				

GROWTH TABLE FOR VOLUME OF DOMINANT TREES PER CHO

Quality of site	Age in years	Thin		Middle		Dense	
		Current annual increment in Koku	Mean annual increment in Koku	Current annual increment in Koku	Mean annual increment in Koku	Current annual increment in Koku	Mean annual increment in Koku
I.	10	87.95	22.80	—	—	—	—
	13	—	—	97.21	31.92	—	—
	15	242.24	55.28	109.32	41.44	84.11	27.12
	20	152.15	78.84	118.94	60.12	92.93	45.84
	30	128.65	100.00	102.25	77.52	81.25	60.12
	40	99.82	103.44	80.00	80.88	64.10	63.24
	50	77.50	100.39	62.41	78.86	50.23	61.94
	60	61.19	95.11	49.42	74.94	39.88	59.02
	70	49.28	89.39	39.92	70.61	32.30	55.79
	80	40.44	83.82	32.78	66.31	25.38	52.45
	90	33.71	78.84	27.37	62.26	22.22	49.34
	100	30.50	73.84	23.17	58.57	18.83	46.45
II.	12	58.52	15.00	—	—	—	—
	14	—	—	58.02	16.79	—	—
	15	81.41	26.08	—	—	—	—
	16	—	—	—	—	53.18	17.40
	20	100.01	42.72	79.26	33.12	62.80	25.68
	30	96.96	62.12	78.24	49.04	62.99	38.64
	40	80.59	68.86	65.56	54.78	53.29	43.58
	50	67.57	69.60	53.30	55.68	43.36	44.33
	60	52.91	67.80	43.42	54.42	35.60	43.68
	70	43.46	64.97	35.74	52.27	29.38	42.05
	80	36.18	61.81	29.93	49.82	24.55	40.15
	90	30.50	58.66	25.18	47.33	20.75	38.20
	100	26.04	55.61	21.59	44.93	17.50	35.78
III.	16	50.06	14.52	—	—	—	—
	17	—	—	43.14	13.06	—	—
	18	—	—	—	—	32.91	11.60
	20	63.72	23.16	51.22	18.24	40.90	14.28
	30	70.90	38.64	58.03	31.00	47.42	24.84
	40	63.08	45.84	52.09	37.10	43.04	30.06
	50	53.16	48.29	44.16	39.31	36.67	32.02
	60	44.35	48.34	36.96	39.49	30.82	32.28
	70	37.14	47.28	30.94	38.66	25.94	31.72
	80	30.47	45.60	26.28	37.44	22.02	30.74
	90	26.77	43.76	22.46	35.88	18.85	29.63
	100	23.04	41.86	19.36	34.46	16.25	28.37

GROWTH TABLE FOR AVERAGE DIAMETER OF DOMINANT TREES

Quality of site	Age in years	Thin		Middle		Dense	
		Current annual increment in Shaku	Mean annual increment in Shaku	Current annual increment in Shaku	Mean annual increment in Shaku	Current annual increment in Shaku	Mean annual increment in Shaku
I.	10	0.070	0.035	—	—	—	—
	13	—	—	0.051	0.031	—	—
	15	0.060	0.045	0.048	0.033	0.037	0.024
	20	0.042	0.048	0.038	0.036	0.031	0.026
	30	0.029	0.044	0.025	0.034	0.020	0.026
	40	0.020	0.039	0.016	0.031	0.014	0.022
	50	0.014	0.035	0.012	0.027	0.010	0.021
	60	0.010	0.031	0.009	0.024	0.008	0.019
	70	0.008	0.028	0.006	0.022	0.006	0.017
	80	0.006	0.025	0.005	0.020	0.005	0·016
	90	0.005	0.023	0.004	0.018	0.004	0.015
	100	0.004	0.021	0.004	0.017	0.003	0.014
II.	12	0.045	0.020	—	—	—	—
	14	—	—	0.036	0.018	—	—
	15	0.044	0.025	—	—	—	—
	16	—	—	—	—	0.028	0.016
	20	0.039	0.029	0.032	0.023	0.026	0.018
	30	0.027	0.030	0.023	0.024	0.019	0.020
	40	0.019	0.028	0.016	0.023	0.014	0.019
	50	0.014	0.026	0.012	0.021	0.010	0.018
	60	0.011	0.024	0.009	0.020	0.008	0.016
	70	0.008	0.022	0.007	0.018	0.006	0.015
	80	0.007	0.020	0.006	0.016	0.005	0.014
	90	0.006	0.018	0.005	0.015	0.004	0.013
	100	0.005	0.017	0.004	0.014	0.003	0.012
III.	16	0.031	0.014	—	—	—	—
	17	—	—	0.026	0.013	—	—
	18	—	—	—	—	0.022	0.011
	20	0.031	0.018	0.026	0.015	0.022	0.012
	30	0.024	0.021	0.020	0.018	0.017	0.015
	40	0.018	0.021	0.015	0.018	0.013	0.015
	50	0.014	0.020	0.012	0.017	0.010	0.014
	60	0.010	0.018	0.009	0.016	0.008	0.013
	70	0.008	0.017	0.007	00.15	0.006	0.012
	80	0.007	0.016	0.006	0.014	0.005	0.012
	90	0.006	0.015	0.004	0.013	0.004	0.011
	100	0.005	0.014	0.004	0.012	0.004	0.010

YIELDS OF SUGI STAND IN THIN FORM OF DENSITY

Quality of site	Age in years	Principal trees					Secondary trees							
		Average height in Ken	Average diameter in Shaku	Per Cho			Per Cho						Average diameter in Shaku	Average height in Ken
				Number of trees	Basal section in sq. Shaku	Volume of stems in Koku	Number of trees	Percentage of number of trees	Basal section in sq. Shaku	Percentage of basal section	Volume of stems in Koku	Percentage of volume of stems		
I.	10	2.3	0.35	3000	298	229								
	15	5.3	0.68	1641	600	829	1359	45.3	53	17.7	24	10.6	0.22	2.4
	20	8.0	0.96	1196	851	1577	445	27.1	88	14.6	114	13.8	0.55	2.3
	30	12.2	1.32	873	1206	3000	323	27.1	124	14.6	217	13.8	0.70	6.8
	40	15.0	1.56	746	1436	4138	127	14.5	94	7.8	222	7.4	0.97	10.6
	50	17.0	1.73	678	1595	5020	68	9.1	70	4.9	191	4.6	1.14	13.1
	60	18.5	1.85	637	1710	5707	41	6.1	53	3.3	156	3.1	1.25	14.8
	70	19.6	1.94	609	1798	6257	28	4.5	41	2.4	131	2.3	1.37	16.2
	80	20.6	2.01	587	1865	6706	20	3.3	32	1.8	107	1.7	1.43	17.2
	90	21.3	2.06	575	1922	7074	14	2.4	24	1.3	80	1.2	1.48	18.0
	100	21.9	2.12	560	1967	7384	15	2.6	27	1.4	92	1.3	1.51	18.6
II.	10	2.5	0.24	4320	209	180								
	15	4.0	0.37	3087	322	374	1233	28.6	23	11.2	12	6.7	0.15	2.6
	20	6.4	0.58	1995	529	854	1092	35.4	63	19.1	67	18.1	0.27	2.9
	30	10.2	0.91	1290	848	1864	705	35.2	101	19.0	154	18.0	0.43	5.1
	40	12.8	1.14	1037	1060	2754	253	19.5	89	10.5	185	9.9	0.67	9.0
	50	14.8	1.31	908	1218	3480	129	12.4	71	6.7	176	6.4	0.84	11.6
	60	16.2	1.43	832	1337	4068	76	8.4	55	4.5	150	4.3	0.96	13.5
	70	17.3	1.52	782	1429	4548	50	8.0	48	4.3	139	4.1	1.11	15.0
	80	18.2	1.60	748	1502	4945	34	4.3	33	2.3	100	2.2	1.12	16.1
	90	18.9	1.66	721	1561	5279	27	3.6	28	1.9	89	1.8	1.16	16.8
	100	19.5	1.71	700	1610	5561	21	2.9	25	1.6	79	1.5	1.19	17.4
III.	16	3.5	0.23	5400	213	233								
	20	5.1	0.36	3327	329	463	2072	38.3	49	14.9	22	9.0	0.17	2.0
	30	8.5	0.63	1905	586	1159	1422	42.7	76	23.1	101	21.8	0.26	3.3
	40	11.0	0.83	1442	746	1834	460	24.1	76	13.0	142	12.3	0.46	7.5
	50	12.8	0.99	1220	931	2414	225	15.6	61	8.2	146	8.0	0.59	10.6
	60	14.2	1.10	1091	1045	2900	129	10.5	53	5.7	207	5.4	0.72	12.5
	70	15.3	1.20	1007	1134	3306	84	7.7	44	4.2	113	3.9	0.82	14.0
	80	16.1	1.27	949	1207	3648	58	5.8	35	3.1	100	3.0	0.88	15.2
	90	16.8	1.34	906	1267	3838	43	4.5	29	2.4	84	2.3	0.92	16.0
	100	17.4	1.39	873	1317	4186	33	3.6	24	1.9	71	1.8	0.97	16.5

YIELDS OF SUGI STAND IN MIDDLE FORM OF DENSITY

Quality of site	Age in years	Principal trees					Secondary trees							
				Per Cho			Per Cho							
		Average height in Ken	Average diameter in Shaku	Number of trees	Basal section in sq. Shaku	Volume of stems in Koku	Number of trees	Percent-age fo number of trees	Basal section in sq. Shaku	Percent-age of basal section	Volume of stems in Koku	Percent-age volume of stems	Average diameter in Shaku	Average height in Ken
I.	13	4.1	0.40	3000	346	414								
	15	5.3	0.50	2268	437	622	732	24.4	33	9.5	24	5.7	0.24	3.3
	20	8.0	0.71	1607	638	1202	661	29.0	69	15.7	92	14.8	0.36	4.3
	30	12.2	1.02	1140	931	2326	467	29.1	100	15.7	178	14.8	0.52	6.8
	40	15.0	1.22	959	1125	3235	181	15.8	79	8.5	188	8.1	0.75	10.6
	50	17.0	1.36	865	1260	3943	94	9.8	60	5.3	162	5.0	0.90	13.1
	60	18.5	1.46	807	1359	4496	58	6.7	45	3.6	134	3.4	0.99	14.8
	70	19.6	1.54	769	1434	4943	38	4.7	34	2.5	108	2.4	1.07	16.2
	80	20.6	1.60	741	1494	5305	28	3.6	27	1.9	89	1.8	1.11	17.2
	90	21.3	1.65	720	1542	5604	21	2.8	22	1.5	74	1.4	1.18	18.0
	100	21.9	1.69	704	1581	5857	16	2.2	18	1.2	56	1.1	1.20	18.6
II.	14	3.5	0.25	4320	219	238								
	20	6.4	0.46	2508	413	662	1814	42.0	36	16.4	24	9.9	0.16	2.6
	30	10.2	0.73	1610	678	1471	896	35.7	80	19.3	121	18.2	0.34	5.1
	40	12.8	0.93	1289	868	2191	321	19.9	74	10.8	150	10.2	0.55	9.0
	50	14.8	1.06	1129	1007	2784	160	12.4	58	6.7	138	6.3	0.68	11.6
	60	16.2	1.17	1033	1112	3265	96	8.5	46	4.6	120	4.3	0.78	13.5
	70	17.3	1.25	964	1193	3659	64	6.2	38	3.4	104	3.2	0.87	15.0
	80	18.2	1.32	924	1258	3986	45	4.6	30	2.5	88	2.4	0.92	16.1
	90	18.9	1.37	891	1311	4260	33	3.6	24	1.9	72	1.8	0.98	16.8
	100	19.5	1.41	865	1355	4493	26	2.9	19	1.4	55	1.3	0.98	17.4
III.	17	3.9	0.22	5400	194	222								
	20	5.1	0.30	3913	268	365	1487	27.5	21	10.8	14	6.5	0.13	2.2
	30	8.5	0.53	2274	494	930	1639	42.0	61	22.7	78	21.4	0.22	3.3
	40	11.0	0.70	1733	671	1484	541	23.8	63	12.8	113	12.1	0.38	7.5
	50	12.8	0.83	1472	804	1966	261	15.0	54	8.1	113	7.6	0.52	10.5
	60	14.2	0.94	1321	909	2370	151	10.2	44	5.5	102	5.2	0.61	12.5
	70	15.3	1.02	1223	992	2708	98	7.4	36	4.0	90	3.8	0.68	14.0
	80	16.1	1.08	1153	1059	2995	70	5.7	28	2.8	78	2.9	0.71	15.2
	90	16.8	1.13	1103	1115	3239	50	4.3	24	2.3	66	2.2	0.78	16.0
	100	17.4	1.18	1063	1161	3446	40	3.6	21	1.9	59	1.8	0.82	16.5

YIELDS OF SUGI STAND IN DENSE FORM OF DENSITY

Quality of site	Age in years	Principal trees					Secondary trees							
				Per Cho			Per Cho							
		Average height in Ken	Average diameter in Shaku	Number of trees	Basal section in sq. Shaku	Volume of stems in Koku	Number of trees	Percent-age of number of trees	Basal section in sq. Shaku	Percent-age of basal section	Volume of stem in Koku	Percent-age of volume of stems	Average diameter in Shaku	Average height in Ken
I.	15	5.3	0.36	3000	318	467	842	28.1	35	11.0	31	6.6	0.23	4.3
	20	8.0	0.53	2158	478	917	677	31.3	81	16.9	91	16.0	0.39	6.3
	30	12.2	0.78	1487	719	1804	247	16.7	65	9.0	73	8.5	0.58	10.6
	40	15.0	0.95	1234	881	2530	132	10.7	51	5.8	58	5.5	0.70	13.1
	50	17.0	1.07	1102	994	3097	78	7.1	38	3.8	43	3.6	0.79	14.8
	60	18.5	1.16	1024	1079	3541	52	5.1	30	2.8	34	2.6	0.86	16.2
	70	19.6	1.22	974	1144	3905	36	3.7	23	2.0	26	1.9	0.90	17.2
	80	20.6	1.28	934	1195	4196	31	3.3	22	1.3	24	1.7	0.95	18.0
	90	21.3	1.32	905	1237	4441	21	2.3	15	1.2	18	1.2	0.95	18.6
	100	21.9	1.35	884	1271	4645								
II.	16	4.5	0.25	4320	219	278	1168	27.0	23	10.5	17	5.9	0.16	3.3
	20	6.4	0.36	3152	324	514	1144	36.3	64	19.6	95	18.5	0.27	5.1
	30	10.2	0.59	2008	547	1159	400	19.9	59	10.8	118	10.2	0.42	9.0
	40	12.8	0.75	1603	712	1744	206	12.3	47	6.9	113	6.5	0.54	11.0
	50	14.8	0.89	1402	833	2216	122	8.7	39	4.7	97	4.4	0.64	13.6
	60	16.2	0.96	1280	925	2621	80	6.2	31	3.4	84	3.2	0.70	15.0
	70	17.3	1.03	1200	993	2944	56	4.7	25	2.5	71	2.4	0.77	16.1
	80	18.2	1.08	1144	1054	3212	42	3.7	21	2.0	61	1.9	0.80	16.8
	90	18.9	1.13	1102	1102	3438	33	3.0	18	1.6	52	1.5	0.83	17.4
	100	19.5	1.16	1069	1141	3578								
III.	18	4.3	0.20	5400	177	209	797	14.8	10	5.8	7	3.5	0.12	2.3
	20	5.1	0.25	4603	219	286	1890	41.0	48	22.1	60	20.9	0.18	3.3
	30	8.5	0.44	2713	417	745	629	23.2	52	12.5	88	11.8	0.32	7.5
	40	11.0	0.59	2084	575	1202	297	14.2	44	7.7	86	7.2	0.43	10.5
	50	12.8	0.71	1787	697	1601	187	10.5	40	5.7	86	5.4	0.52	12.5
	60	14.2	0.79	1600	792	1937	115	7.2	31	3.9	72	3.7	0.59	14.0
	70	15.3	0.87	1485	868	2220	83	5.6	26	3.0	86	3·9	0.63	15.2
	80	16.1	0.92	1402	930	2460	60	4.3	21	2.3	54	2.2	0.67	16.0
	90	16.8	0.96	1342	981	2666	47	3.5	19	1.9	48	1.8	0.71	16.5
	100	17.4	1.00	1295	1010	2837								

Conclusion

1. As I have stated in the preceding parts, the general trend of fluctuation for each factors of growth of a single tree and the aggregate, or stand may be interpreted by the equation $y=ke^{-\frac{k_1}{t}}$ in the particular cycle of the growth. However I cannot yet interpret the general trend of the fluctuation as a continuous function with respect to throughout the long life of the tree and the stand. This may be interpreted by the formula $y=k\varphi(t)e^{-\frac{k_1}{t}}$ and so there remains the study of $\varphi(t)$. Furthermore there is left for study the biological interpretation of the equation $y=ke^{-\frac{k_1}{t}}$

2. The development of diameter in stand interpreted by the formula corresponding to the type I or IV in Pearson's skew curves. But in nearest degree the frequency curve corresponds to the type V.

The development of the corresponding height and volume of trees in the stand with respect to the diameter interpretend by the formula:

$$h=\tau_1\left(\frac{x}{D}-1\right)+\tau_2$$

and

$$v=\tau'_1\left(\frac{x}{D}-1\right)+\tau'_2.$$

In which the constants τ_1 and τ_2 τ'_1 and τ_2' are functions of the age, and each of them is expressed by the formula:

$$y=Ae^{-\frac{A_1}{t}}.$$

in the given cycle of the growth.

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INVESTIGATION ON FORM-HEIGHT TABLES FOR THE PRINCIPAL CONIFERS AND SOME BROAD-LEAVED TREES IN JAPAN AND BASES ON WHICH THEY MAY BE CONSTRUCTED

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INTRODUCTORY REMARKS

The following paper is an abstract of two memories published in Bulletins of the Forest Experiment Station (No. 8 in 1910 and No. 9 in 1913). The work itself is an attempt to ascertain the relationship between the variation of the breast-height form-factor and the characteristics of the form of the tree bole.

A. Form of Tree Boles

A tree does not grow, like crystals, according to purely mathematical laws. The form of a tree depends on its relative growth in diameter at different sections. From this point of view and the assumption, i.e. that the mantel surface of the body of tree bole will be considered as a rotation-surface of a curve outlined by the longitudinal section, to the geometical axis as the rotation-axis, we have the empirical equation for the outline curve.

According to my investigation of the growth curve for a single tree, the differential equation for the growth of height and for that of radius will be expressed as follows:

$$\frac{dx}{dt}=k_1\frac{x}{t^2}\quad\ldots.(1)\quad\text{and}\quad\frac{dy}{dt}=k_2\frac{y}{t^2}\quad\ldots.(2)$$

where x and y denote the height and the radius at a given section, measured from the tip respectively and t the age.

In these expressions, the constant k_1 is the constant coefficient for a given single tree, while the constant k_2 varies with the situation of the section.

Hence k_2 must be considered as a function of a distance x measured from the tip, so we put

$$k_2=\varphi\ (x)$$

and by substituting into the expression 2),

$$\frac{dy}{dt}=\varphi(x)\frac{y}{t^2}$$

so we get

$$\frac{dy}{dx}=\frac{\varphi(x)}{k_1}\frac{y}{t^2}$$

or

$$\frac{dy}{y}=\frac{\varphi(x)}{k_1}\frac{dx}{x}.$$

Hence by intergrating and transforming we get

$$y=ce^{\frac{1}{k_1}\int_o^x\frac{\varphi(x)}{x}dx}$$

where c is the integral constant.

Thus if we know the form of expression for $\int_o^x\frac{\varphi(x)}{x}dx$, then we may easily determine the equation of the outline curve of the tree bole.

According to my investigation, $\frac{\varphi(x)}{k_1}$ may be expressed empirically as follows:

$$\frac{\frac{dy}{dx}}{\frac{y}{x}}=\frac{\varphi(x)}{k_1}=\varphi_1(x)=ax+\frac{b}{x}$$

where a and b are the constants depending on the individual tree bole.

The characteristics of the expression $ax+\frac{b}{x}$ are as follows:

(i) $\mathrm{Lt}_{x=}\varphi_1(x)=\infty$. $\mathrm{Lt}_{x=o}\frac{d\varphi_1(x)}{dx}=\infty$ and $\mathrm{Lt}_{x=o}\frac{d^2\varphi_1(x)}{dx^2}=\infty$,

(ii) $\mathrm{Lt}_{x=h}\varphi_1(x)=ah+\frac{b}{h}=\text{const.}$, ${}_{x=h}\mathrm{Lt}\frac{d\varphi_1(x)}{dx}=a-\frac{b}{h^2}=\text{const.}$

and $\mathrm{Lt}_{x=h}\frac{d^2\varphi_1(x)}{dx^2}=+\frac{2b}{h^3}=\text{const.}$

(iii) when $x=+\sqrt{\frac{b}{a}}$, $\frac{d\varphi_1(x)}{dx}=o$, $\varphi_1(x)=\text{const.}$ and

$\frac{d^2\varphi_1(x)}{dx^2}=+\text{const.}$

So it is evident that $\varphi_1(x)$ reaches a minimum at the corresponding ordinate to the abscissa $x=+\sqrt{\frac{b}{a}}$.

Illustration:* Showing the variation of radius in the longitudinal section of tree bole of *Tsuga sieboldii* in a natural mixed stand at Yanase Working Circle in Shikoku State Forest.

Distance from the tip in *Ke* (x)	Mean radius in *Sun* (y)	$\frac{\Delta y}{\Delta x}$	$\frac{y}{x}$	x	$\frac{\Delta y}{\Delta x} \Big/ \frac{y}{x}$	Remarks
0.8	0.55	0.286	0.565	1.15	0.504	Diameter at breast-height =1.86 Shaku. Total height =16.0 Ken. The figures and graphs show clearly that the variations of radius with respect to the distance from the tip do not represent the relative growth under the uniform condition, especially at the sections of the top part from 1.10 Ken to 5.0 Ken.
1.5	0.75	0.800	0.575	2.00	1.391	
2.5	1.55	0.850	0.658	3.00	1.292	
3.5	2.40	0.250	0.631	4.00	0.391	
4.5	2.65	1.400	0.670	5.00	2.090	
5.5	4.05	0.450	0.712	6.00	0.632	
6.5	4.50	1.000	0.714	7.00	1.401	
7.5	5.50	0.600	0.850	8.00	0.706	
8.5	6.10	0.200	0.689	9.00	0.302	
9.5	6.30	0.400	0.650	10.00	0.615	
10.5	6.70	0.700	0.641	11.00	1.092	
11.5	7.40	0.050	0.623	12.00	0.080	
12.5	7.55	0.700	0.608	13.00	1.151	
13.5	8.25	0.450	0.605	14.00	0.744	
14.5	8.70	0.600	0.600	15.00	1.000	
15.5	9.30	1.833	0.612	15.65	2.995	
15.8	9.85					

From these figures, we get the best possible freehand curves for $\frac{\Delta y}{\Delta x}$ and $\frac{y}{x}$ with respect to x, of which curve a in Fig. 2 of Plate XXX. shows the variation of $\frac{\Delta y}{\Delta x}$ and curve b in Fig. 2 of the Plate XXX. shows that of $\frac{y}{x}$. Now tracing the curves for $\frac{\Delta y}{\Delta x}$ and $\frac{y}{x}$ with respect to x, we obivously find the following characteristics:

(i) for $x=o$, $y=o$, $\frac{\Delta y}{\Delta x}=o$ and $\frac{y}{x}=o$,

(ii) for $x=h$, $y=$constant, $\frac{\Delta y}{\Delta x}=$constant and $\frac{y}{x}=$constant,

(iii) for $x=1$ Ken and $x=12$ Ken, there are two tangents which cross the curve y,

(iv) for $x=2$ Ken and $x=15$ Ken, there are two tangents from the origin, of which one at the corresponding ordinate for the abscissa $x=2$ contacts at the concave side of the curve y, the other at the corresponding ordinate for the abscissa $x=15$ Ken contacts at the convex side of the curve y.

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* I have given illustrations of the principal trees in Bulletin of the Forest Experiment Station, No. 8, pp. 126, 128, 130, 131, 132 and 133.

Thus the curve $\frac{y}{x}$ intersects the curve $\frac{\triangle y}{\triangle x}$ at two points only; and at the point whose abscissa is $x=2$ Ken, the curve $\frac{y}{x}$ reaches the maximum and at another point whose abscissa is $x=15$ Ken, the curve $\frac{y}{x}$ reaches the minimum.

(v) Furthermore tracing the curve of $\left(\frac{\triangle y}{\triangle x}\right)\Big/\left(\frac{y}{x}\right)$ with respect to x, we get the curve which starts from the infinitely great, and gradually falls and reaches a minimum. After passing through the minimum point, the curve rises rapidly as it will be seen Fig. 3 in the Plate XXX.

These are the common characteristics of the outline curve of tree boles. Unfortunately this has not been pointed by any European authority. The importance of these characteristics is so great that it seems absolutely necessary to ascertain the equation of the outline curve of the tree bole before we conclude, since parabolic equation shows a discordance with the observed data.

Now, we assume

$$\frac{\frac{dy}{dx}}{\frac{y}{x}}=ax+\frac{b}{x},$$

then we get

$$\frac{dy}{y}=\left(a+\frac{b}{x^2}\right)dx.$$

By intergrating and transforming, we have

$$y=ce^{ax-\frac{b}{x}}$$

where c is the integral constant.*

Applying the equation to the above given data we find:

$$\log y=0.5667+0.0296x-\frac{0.6759}{x}$$

In the following table the theoretical and experimental results are compared:

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* I have discussed this formula in Bulletin of the Forest Experiment Station, No. 8, p. 129.

PLATE XXX.

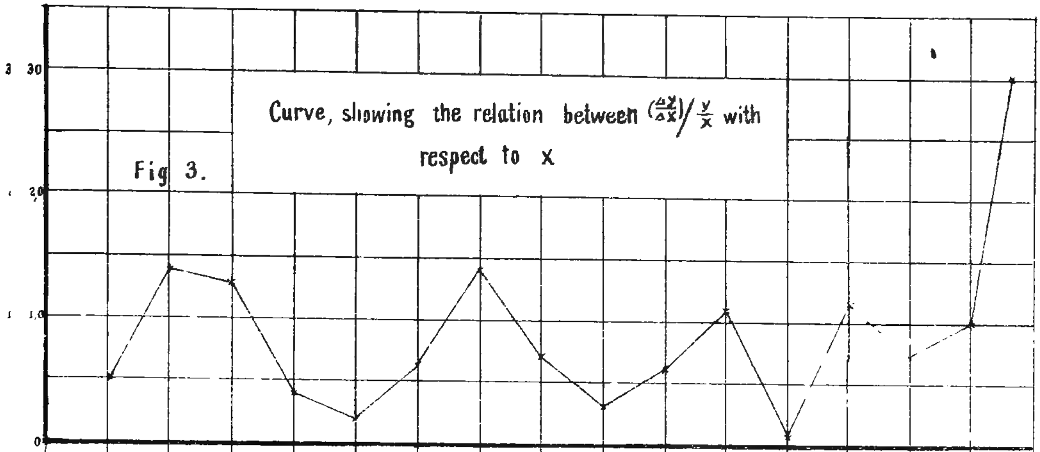


Fig 3.

Curve, showing the relation between $\left(\frac{\Delta y}{\Delta x}\right) / \frac{y}{x}$ with respect to x

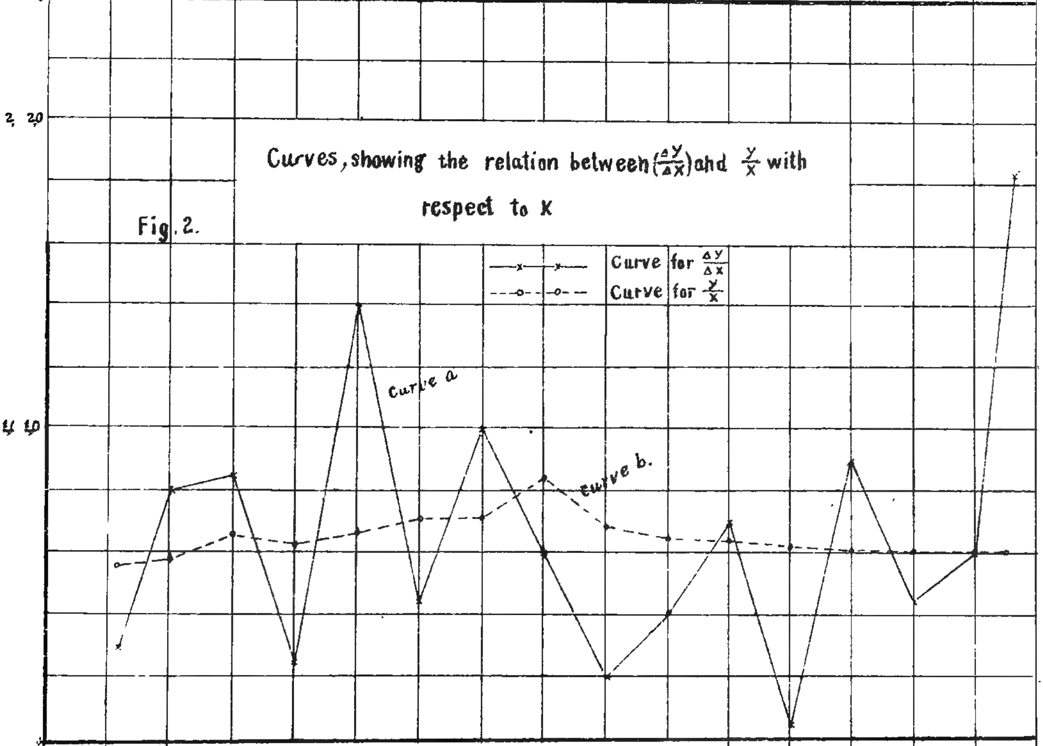


Fig. 2.

Curves, showing the relation between $\left(\frac{\Delta y}{\Delta x}\right)$ and $\frac{y}{x}$ with respect to x

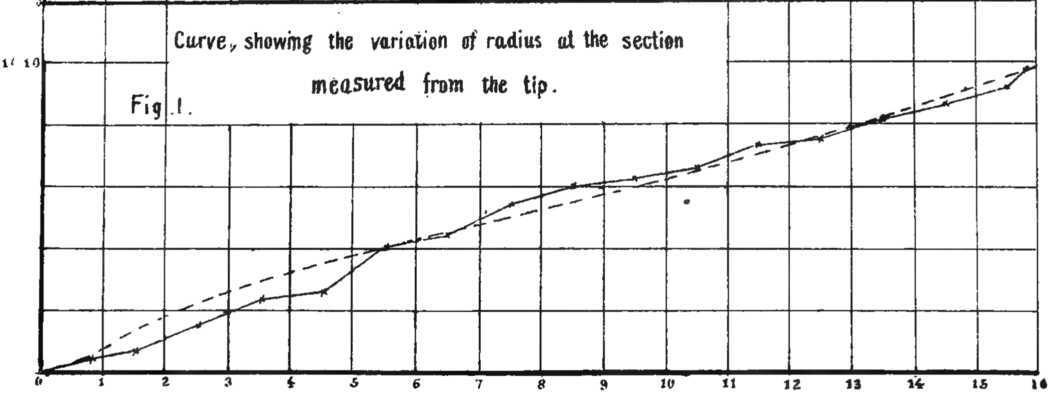


Fig. 1.

Curve, showing the variation of radius at the section measured from the tip.

Distance from the tip in *Ken*	Mean radius in *Sun* Obs.	Mean radius in *Sun* Cal.	Difference	Remarks
0.8	0.55	0.56	−0.01	The equation of the outline curve is represented as
1.5	0.75	1.45	−0.70	
2.5	1.55	2.34	−0.79	
3.5	2.40	3.00	−0.60	
4.5	2.65	3.55	−0.90	
5.5	4.05	4.04	+0.01	
6.5	4.50	4.52	−0.02	
7.5	5.50	4.99	+0.51	
8.5	6.10	5.48	+0.62	
9.5	6.30	5.98	+0.32	
10.5	6.70	6.50	+0.20	
11.5	7.40	7.05	+0.35	
12.5	7.55	7.63	−0.08	
13.5	8.25	8.25	0.00	
14.5	8.70	8.90	−0.20	
15.5	9.30	9.59	−0.29	
15.8	9.85	9.81	+0.04	
			−3.59	
			+2.05	
		Probable Difference	±0.314	

$$y=3.687\,e^{0.0682x-\frac{1.5563}{x}}$$

Difference.	Given.	Calculated.	Diff.
0.00−0.20	8	6	+2
0.21−0.40	3	5	−2
0.41−0.60	2	3	−1
0.61−0.80	3	2	+1
0.81−1.00	1	1	0
	17	17	0

It is evident that the agreement between calculated and observed results is excellent; such divergences as found at the sections 1.0 and 5.0 Ken from the tip is evidently due to an irregularity in the sectional form. Nevertheless, the agreement between theory and observation is highly satisfactory throughout and of such a nature as to justify the conclusion that in all probability the hypotheses from which the theoretical relations were deduced are essentially correct.

Again calculating the "form-quotient" with respect to the breast-height radius, we obtain the following tables:

Distance from the tip in Ken (r)	"Form-quotient" $\frac{y}{y_m}=Y$	$\frac{\Delta Y}{\Delta x}$	$\frac{Y}{x}$	x
0.8	0.0591			
		0.0307	0.0607	1.15
1.5	0.0806			
		0.0861	0.0618	2.00
2.5	0.1667			
		0.0914	0.0708	3.00
3.5	0.2581			
		0.0268	0.0679	4.00
4.5	0.2849			
		0.1506	0.0720	5.00
5.5	0.4355			
		0.0484	0.0766	6.00
6.5	0.4839			
		0.1075	0.0768	7.00
7.5	0.5914			
		0.0644	0.0790	8.00
8.5	0.6558			
		0.0216	0.0741	9.00
9.5	0.6774			
		0.0430	0.0699	10.00
10.5	0.7204			
		0.0753	0.0689	11.00
11.5	0.7957			
		0.0161	0.0670	12.00
12.5	0.8118			
		0.0753	0.0653	13 00
13.5	0.8871			
		0.0484	0.0651	14.00
14.5	0.9355			
		0.0645	0.0645	15.00
15.5	1.0000			
		0.0692	0.0661	15.65
15.8	1.0692			

From these figures, the characteristics of the curves Y, $\frac{\Delta Y}{\Delta x}$ and $\frac{Y}{x}$ are precisely the same as in the previous case (Plate XXXI.) Thus we may determine the equation for Y as follows:—

$$Y = c'e^{a'x - \frac{b'}{x}}$$

or

$$y = c'y_m e^{a'x - \frac{b'}{x}}$$

By applying the equation to the above given data we find:

$$\log Y = 0.2761 + 0.0234x - \frac{1.1995}{x}$$

In the following table the theoretical and experimental results are compared:

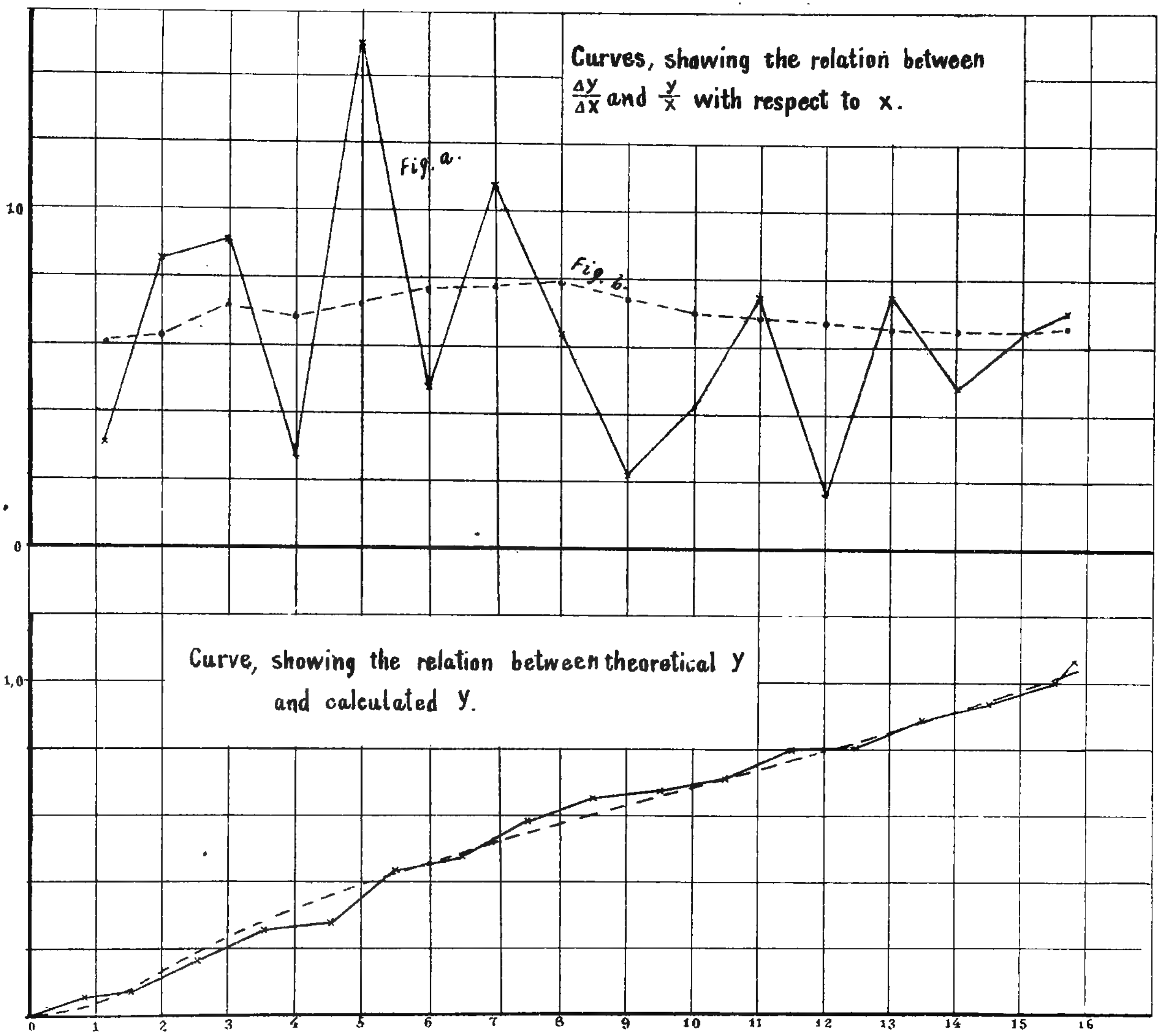
Distance from the tip in Ken	Y		Difference	Remarks
	Obs.	Cal.		
0.8	0.0561	0.0175	+0.0416	Equation to the Y is $Y = 0.5295e^{0.0539x - \frac{2.7620}{x}}$
1.5	0.0809	0.0911	−0.0105	
2.5	0.1667	0.2007	−0.0340	
3.5	0.2581	0.2905	−0.0324	
4.5	0.2849	0.3653	−0·0804	
5.5	0.4355	0.4310	+0.0045	
6.5	0.4839	0.4915	−0.0076	
7.5	0.5914	0.5489	+0.0425	
8.5	0.6658	0.6049	+0.0509	
9.5	0.6774	0.6606	+0.0168	
10.5	0.7204	0.7168	+0.0036	
11.5	0.7957	0.7739	+0.0218	
12.5	0.8118	0.8326	−0.0208	
13.5	0.8871	0.8932	−0.0061	
14.5	0.9355	0.9561	−0.0206	
15.5	1.0000	1.0210	−0.0210	
15.8	1.0092	1.0420	+0.0272	
			+0.2089	
			−0.2334	
		Probable Difference	± 0.023	

Difference.	Given.	Calculated.	Diff.
0.000−0.020	7	7	0
0.021−0.040	4	6	−2
0.041−0.060	5	3	+2
0.061−0.080	—	1	−1
0.081−0.100	1	—	+1
	17	17	0

It will be seen that the agreement is precisely the same as in the above illustration.

B. Volume of Tree Bole

In the previous part, we have explained the outline curve of a tree bole expressed by the equation:



Curves, showing the relation between $\frac{\Delta y}{\Delta x}$ and $\frac{y}{x}$ with respect to x.

Curve, showing the relation between theoretical y and calculated y.

$$y = ce^{ax - \frac{b}{x}}$$

or

$$y = c' y_m e^{a'x - \frac{b'}{x}}$$

So we have the rotation-volume as follows:

$$v_s = \pi \int_{x=0}^{x=h} y^2 dx = \pi c^2 \int_{x=0}^{x=h} e^{2ax - \frac{2b}{x}} dx$$

$$= \frac{\pi}{4a} \cdot c^2 e^{2ah - \frac{2b'}{h}} \left[1 + 4ah + \frac{4b}{h} - \sum_0^\infty \frac{1}{\beta^{n+1}} \mathrm{P}^n(k)\,(n+1-\alpha)\left|\underline{n}\right. \right]$$

where $\alpha = 2ah - \frac{2b}{h}$, $\beta = 2ah + \frac{2b}{h}$ and $k = \frac{\alpha}{\beta}$

or

$$v_s = \pi \int_{x=0}^{x=h} y^2 dx = \pi c' y_m^2 \int_{x=0}^{x=h} e^{2a'x - \frac{2b'}{x}} dx$$

$$= g_m \frac{c'^2}{4a'} e^{2a'h - \frac{2b'}{h}} \left[1 + 4a'h + \frac{4b'}{h} - \sum_0^\infty \frac{1}{\beta^{n+1}} \mathrm{P}^n(k')\,(n+1-\alpha')\left|\underline{n}\right. \right]$$

where $\alpha' = 2a'h - \frac{2b'}{h}$, $\beta' = 2a'h + \frac{2b'}{h}$ and $k' = \frac{\alpha'}{\beta'}$

Empirically it will be determined that

$$\alpha < 1,\quad \beta > 1 \text{ and } \frac{\alpha}{\beta} < 1 \text{ or } \alpha' < 1,\ \beta' > 1 \text{ and } \frac{\alpha'}{\beta'} < 1$$

and $$1 - \sum_0^\infty \frac{1}{\beta^{n+1}} \mathrm{P}^n(k)\,(n+1-\alpha)\left|\underline{n}\right. \doteqdot 0$$

or $$1 - \sum_0^\infty \frac{1}{\beta'^{n+1}} \mathrm{P}^n(k')\,(n+1-\alpha')\left|\underline{n}\right. \doteqdot 0$$

So we have $$v_s = \frac{\pi}{4a} c^2 e^{2ah - \frac{2b}{h}} \left[4ah + \frac{4b}{h} \right]$$

or $$v_s = g_m \frac{c'^2}{4a'} e^{2a'h - \frac{2b'}{h}} \left[4a'h + \frac{4b'}{h} \right].$$

From the second equation we have

$$\frac{v_s}{g^{u}} = hf_s = \frac{c'^2}{4a'} \left[4a'h + \frac{4b'}{h} \right] e^{2a'h - \frac{2b'}{h}}$$

so we may evidently determine that the form-height, hf_s depends upon the form of a tree bole, i.e. that the breast-height form factor may be considered as a true expression of the form of the tree bole. Still, it is questionable to apply the conclusion to the mean hf_s for a given height of a given species because there are various forms of tree for a given height. In this case the breast-height form factor, means merely the coefficient for estimating contents of tree boles by means of $g_m h$.

C. Form Factor

From the previous part it will be evidently seen that the volume of the tree bole may be calculated by the formula:

$$v_s = g_m \frac{c'}{4a'} e^{2a'h - \frac{2b'}{h}} \left[4a'h + \frac{4b'}{h} \right].$$

when we know the equation of the outline curve on the longitudinal section of the tree bole as

$$y = c' y_m e^{a'x - \frac{b'}{x}}$$

From the formula of v_s, it will be suggested that the variation of v_s for different heights, and diameters at breast-height, may be expressed thus:—

$$v_s = L\, g_m e^{L_1 h - \frac{L_2}{h}}$$

where L, L_1, and L_2 are the constants depending upon the species and "form-quotients."

So we get

$$\frac{v_s}{g_m} = hf_s = Le^{L_1 h - \frac{L_2}{h}}$$

or

$$f_s = L \frac{1}{h} e^{L_1 h - \frac{L_2}{h}}$$

Now if we assume that for given species the breast-height form factor varies as the height of tree only and is independed of the "form-quotient," then f_s is the mono-valued function of h. But such an assumption is a very crude approximation. Yet the practical estimation of the contents of a standing tree in a stand sometimes demands such a crude approximation, and to this end, I constructed form factor table.

The data are as follows:—

Total height in Ken	*Pinus densiflora*																		Total	Remark
	Breast-height diameter classes in Shaku																			
	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9		
	NUMBER OF TREES																			
2	2 **0,025**																		2	In this table and the following one, the figures in the black type represent the average volume of the tree bole.
3	16 **0,033**	2 **0,049**																	18	
4	19 **0,046**	17 **0,087**	16 **0,153**	8 **0,224**	3 **0,310**		3 **0,537**												66	
5	11 **0,070**	34 **0,115**	23 **0,200**	13 **0,285**	11 **0,379**	4 **0,513**													96	
6	4 **0,102**	19 **0,147**	23 **0,242**	21 **0,349**	15 **0,442**	12 **0,577**	5 **0,823**	5 **0,999**		2 **1,518**									106	
7		23 **0,198**	22 **0,291**	15 **0,403**	13 **0,501**	27 **0,670**	17 **0,836**	14 **1,114**	8 **1,361**	4 **1,661**		4 **2,350**		1 **3,206**					148	
8		5 **0,249**	10 **0,352**	12 **0,420**	21 **0,567**	17 **0,752**	15 **0,973**	11 **1,280**	14 **1,524**	15 **1,835**	8 **2,186**	3 **2,637**							131	
9				22 **0,525**	41 **0,682**	32 **0,903**	30 **1,071**	8 **1,309**	16 **1,645**	14 **2,030**	9 **2,485**	5 **2,865**		2 **3,820**	3 **4,035**				182	
10				4 **0,675**	12 **0,788**	19 **1,027**	19 **1,207**	16 **1,512**	11 **1,852**	18 **2,184**	5 **2,764**	4 **3,151**		1 **3,995**	5 **4,731**	1 **5,420**		1 **6,754**	116	
11					10 **0,939**	6 **1,152**	20 **1,374**	20 **1,657**	15 **2,024**	8 **2,488**	8 **2,973**	5 **3,467**	1 **3,755**	5 **4,312**	2 **4,992**	3 **5,711**		1 **6,976**	104	
12					3 **1,081**	5 **1,296**	5 **1,527**	9 **1,899**	12 **2,193**	12 **2,712**	5 **3,262**	5 **3,729**	5 **4,040**	7 **4,800**	4 **5,479**		1 **6,654**	2 **7,515**	75	
13						1 **1,554**	3 **1,681**	11 **2,249**	3 **2,601**	4 **3,076**	7 **3,430**	5 **4,171**	6 **4,591**		3 **5,956**		1 **7,314**	2 **8,433**	46	
14							2 **1,911**		2 **2,883**	2 **3,304**	2 **3,778**	3 **4,718**	5 **5,360**	3 **5,893**	2 **6,250**	1 **7,056**	1 **7,720**	1 **9,074**	24	
15										2 **3,732**	3 **4,022**		2 **5,624**	6 **6,152**	3 **6,592**	1 **7,530**		2 **9,554**	19	
16														3 **6,656**	1 **7,014**				4	
17											1 **4,670**		1 **6,647**				1 **9,847**		3	
18																			—	
19											1 **5,162**						1 **10,782**		2	
20																			—	
Total	52	100	49	95	129	123	119	94	81	81	49	34	20	28	23	6	5	9	1142	

Total height in Ken	*Cryptomeria japonica*																					Total
	Breast-height diameter classes in Shaku																					
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	
	NUMBER OF TREES																					
1																						
2	5 0,007	1 0,018																				6
3		6 0,026																				6
4		2 0,041	6 0,067																			8
5			2 0,087			1 0,262																3
6			5 0,117	2 0,188		2 0,335	1 0,454															10
7			2 0,184	9 0,224			1 0,472	2 0,754		1 1,354	2 1,635			1 2,949								18
8				5 0,275	1 0,337		1 0,558	2 0,850	3 1,167	1 1,500												13
9				5 0,324	5 0,399	5 0,547	7 0,750	6 0,930	7 1,246	3 1,611		1 2,400	2 2,828									41
10				2 0,395	7 0,484	3 0,669	1 0,876	9 1,090	4 1,391	1 1,788		5 2,583	5 3,041	1 3,406	1 3,811	1 4,348	3 4,897			1 6,259	1 6,879	45
11					7 0,592	6 0,783	9 1,016	3 1,259		3 1,901	3 2,365	3 2,803	5 3,327	2 3,774	1 4,127		2 5,295			1 6,872		45
12						2 0,878	2 1,144	6 1,397	7 1,764	6 2,084	4 2,592	5 3,004	3 3,472		2 4,382	4 4,942	2 5,642			2 7,296		45
13								1 1,551	6 1,951	5 2,305	4 2,677	7 3,286	1 3,674	10 4,065	2 4,692	4 5,446	3 5,948	2 6,292	1 6,932	2 8,088		48
14								2 1,832	1 2,106	5 2,473	5 3,017	4 3,462	3 3,876	6 4,513	2 4,858	2 5,870	1 6,235	2 7,082			1 9,646	34
15									1 2,357	6 2,749		4 3,656	6 4,248	3 4,770	4 5,590	4 6,104			2 7,851	1 8,726	3 10,241	34
16								1 2,143		2 2,817	6 3,377	3 4,071	4 4,562	2 5,252	2 5,859	1 6,553	5 7,361	2 7,828	4 9,014	2 9,502	1 11,272	35
17									1 2,703	1 3,302	1 3,705	1 4,297	1 4,827	1 5,844	2 6,205	2 7,165	4 7,925	4 8,856	1 9,720	1 10,976	4 12,177	24
18												2 4,742			2 6,632		2 8,518			3 11,855	1 12,717	10
19																2 8,148	1 9,132	2 10,366		1 12,234	1 13,121	7
20																					1 14,034	1
21																	1 10,314			1 13,442		2
Total	5	9	15	23	20	19	22	32	30	34	25	35	30	26	18	20	24	12	8	15	13	435

Total height in Ken	*Thujopsis dolabrata*																				Total
	Breast height diameter classes in Shaku																				
	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	
	NUMBER OF TREES																				
5		1 0,288																			1
6	4 0,238	1 0,360																			5
7		1 0,411		2 0,714	1 0,822																4
8			1 0,656	2 0,706	1 0,968	2 1,262	1 1,589														7
9		1 0,459		2 0,840	4 1,217	6 1,329	2 1.702	5 2,157	4 2,331												24
10						4 1,551	5 1,964	5 2,329		2 2,994	1 2,914		1 4,810								18
11						3 2,019	1 2,268	3 2,669	2 2,926	1 3,453	2 3,713	2 4,662	1 5,537								15
12						4 2,286		3 2,944	2 3,424	3 4,026	2 4,452	1 5,208		1 6,295				1 8,537			17
13									1 3,923		1 5,170		2 6,118	1 7,178	2 7,329			1 10,270			8
14										1 5,412	1 5,617				2 7,832						4
15															2 8,312					1 13,020	3
Total	4	4	1	6	6	19	9	16	9	7	7	3	4	2	6			2		1	106

Total height in Ken	*Chamaecyparis obtusa*																Total
	Breast-height diameter classes in Shaku																
	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	
	NUMBER OF TREES																
3	2 **0,090**																2
4		1 **0,179**	1 **0,248**														2
5	3 **0,160**			1 **0,434**													4
6	14 **0,194**	4 **0,310**	2 **0,376**	1 **0,630**													21
7	12 **0,220**	11 **0,333**	6 **0,480**	2 **0,654**	3 **0,800**	1 **1,153**	1 **1,420**										36
8	6 **0,257**	12 **0,400**	5 **0,565**	2 **0,740**	2 **0,974**	3 **1,312**		1 **1,969**									31
9	4 **0,355**	8 **0,478**		6 **0,941**				4 **2,119**	1 **2,524**	1 **2,675**							24
10		1 **0,602**			3 **1,252**	2 **1,826**	1 **2,190**		2 **2,563**		1 **3,720**					1 **5,518**	11
11			2 **0,803**	5 **1,114**			1 **2,319**		2 **3,137**	2 **3,300**							12
12						1 **2,342**											1
13							1 **3,087**		1 **3,557**			1 **5,571**					3
14																	
15																	
16																	
17																	
18														1 **8,117**			1
Total	41	37	16	17	8	7	4	5	6	3	1	1		1		1	148

Total height in Ken	*Tsuga sieboldii*																						Total
	Breast-height diameter classes in Shaku																						
	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	
	NUMBER OF TREES																						
4	1 0,038																						1
5																							
6																							
7				1 0,434	1 0,707	2 0,915					3 2,062	1 2,499											8
8									3 1,683	1 2,044		1 2,784											5
9					1 0,830			5 1,622	1 1,951		4 2,682	2 3,042	3 3,504	1 3,668						1 7,904			18
10					1 0,935	1 1,176	3 1,518		2 2,214	2 2,464	3 3,148	3 3,266	1 3,710			3 5,391	2 7,043	1 6,047					22
11									1 2,439		3 3,290	2 3,770	9 4,123	1 5,050	4 5,473	1 6,080		2 6,849	1 6,872	1 8,897		1 10,392	26
12										3 2,986	1 3,663	3 4,062	3 4,819	3 5,340	1 6,116	3 6,434		2 8,249				2 11,096	21
13										1 3,307	2 3,771	3 4,589	1 5,304	5 5,950	6 6,764	2 7,314	3 8,219	1 8,834					24
14											2 4,184	1 5,300			1 7,503	2 7,708		2 9,470	1 10,790	1 11,872			10
15										1 4,201	1 4,946		1 6,596	2 7,566	1 7,824	2 8,542					1 14,681	1 14,681	10
16															1 8,195								1
Total	1			1	3	3	3	5	7	8	19	16	18	12	14	13	5	8	2	3	1	4	146

Total height in Ken	*Abies firma*																											Total
	Breast-height diameter classes in Shaku																											
	0.1	0 2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.7	2.8	
	NUMBER OF TREES																											
1	3 0,006																											3
2		2 0,026																										2
3		1 0,031																										1
4			2 0,092			1 0,271																						3
5			1 0,152	4 0,186		1 0,413			1 0,753																			7
6					3 0,292	1 0,469	4 0,592	3 0,722						1 2,484	1 2,876													13
7						1 0,602	5 0,771		7 1,173																			13
8								1 0,970	3 1,278	2 1,406	5 1,796	1 2,025	1 2,503	1 3,001	1 3,340	1 3,737												16
9						1 0,822			2 1,451	2 1,612	3 2,129																	8
10								1 1,251	3 1,539	3 1,850	3 2,227	5 2,528	3 3,411	6 3,715	1 3,926	3 4,806												28
11									1 1,928	1 2,200	3 2,816	6 2,950			3 4,222	3 5,337		4 6,749				1 9,665						22
12								1 1,528		1 2,538		1 3,238		1 4,066	4 4,842		2 6,284			1 8,160		1 9,868	1 10,485					13
13														3 4,449		2 5,916	3 6,584	1 7,077		1 8,725	1 9,067	1 10,430		1 12,335				13
14													1 4,651			1 6,632	1 7,288	4 7,924	1 8,683	2 9,494		1 11,412		2 12,688	2 13,998	1 16,358		16
15													1 5,146	1 5,723		1 7,276	1 8,176	2 8,704		1 9,976			1 12,933			1 17,126	1 18,389	10
16																							1 13,380					1
17																			1 10,543				1 15,027	1 15,645		1 18,750		4
Total	3	3	3	4	3	5	9	6	17	9	14	13	6	13	10	11	7	11	2	5	1	4	4	4	2	3	1	173

Total height in Ken	*Quercus vibrayeana*																										Total
	Breast-height diameter classes in Shaku																										
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	33	
	NUMBER OF TREES																											
1																												
2		1 0,023																										1
3	1 0,016	2 0,029																										3
4		7 0,041																										7
5		5 0,065	13 0,102	3 0,172	1 0,224																							22
6		3 0,092	5 0,122	6 0,199	2 0,304					1 1,190																		17
7			1 0,164	1 0,198	2 0,396		1 0,783					1 1,444																6
8				1 0,318							2 1,516	1 1,795	1 1,808		1 3,232													6
9											5 1,864	2 1,836	5 2,092	5 2,399			1 3,269											18
10										1 1,363		2 1,995	3 2,632	2 3,133	3 2,924	1 3,167				1 4,706						1 10,026		14
11											1 1,888	1 1,763	2 1,886	1 3,464	3 3,402		3 4,478	1 5,850				1 6,573	1 7,042					14
12																	2 4,166					1 9,123	1 6,698					4
13																												
14																										1 10,412	1	2
Total	1	18	19	11	5		1			2	8	7	11	8	7	1	6	1		1		2	2			2	1	114

Total height in Ken	*Fagus sylvatica var. sieboldii*																	Total
	Breast-height diameter classes in Shaku																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
	NUMBER OF TREES																	
1																		
2	1 0,006																	1
3																		
4		1 0,028																1
5			3 0,090	4 0,122														7
6			7 0,117	17 0,164														24
7			5 0,137	6 0,215														11
8				7 0,258	8 0,350	9 0,558	3 0,611				2 1,422							29
9					1 0,516	3 0,681	5 0,800	3 0,898	4 1,324	3 1,547	3 1,836			1 2,801				23
10						1 0,732	1 1,000	2 1,156	2 1,468	2 1,670	7 2,004	4 2,290	2 2,684		2 3,820			23
11						1 0,766				2 1,815	4 2,336	3 2,511	2 3,020	2 3,574				14
12								1 1,304		1 2,088	3 2,549	2 2,918	1 3,184		2 4,574	1 4,738	1 5,504	12
13										2 2,390			1 3,619					3
14																		
Total	1	1	15	34	9	14	9	6	6	10	19	9	6	3	4	1	1	148

Total height in Ken	*Castanea vulgaris var. japonica*															Total
	Breast-height diameter classes in Shaku															
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
	NUMBER OF TREES															
5		1 0,133	2 0,214	4 0,277												7
6	1 0,100	3 0,186	2 0,298		1 0,634	1 0,594										8
7				2 0,409	1 0,625	1 0,745	1 0,974		1 1,334							6
8			3 0,329				1 1,337	2 1,581		3 1,990		1 1,965		1 3,180		11
9		1 0,306	2 0,466	4 0,597		2 1,013	1 1,568				1 2,866	1 2,820		1 3,935		13
10					1 0,915						1 3,193		1 3,249			3
11			1 0,606	1 0,776	1 0,983	1 1,244	3 1,666						1 4,339			8
12															1 6,395	1
Total	1	5	10	11	4	5	6	2	1	3	2	2	2	2	1	57

PLATE XXXII

Curves, representing ½hfs with respect to h.

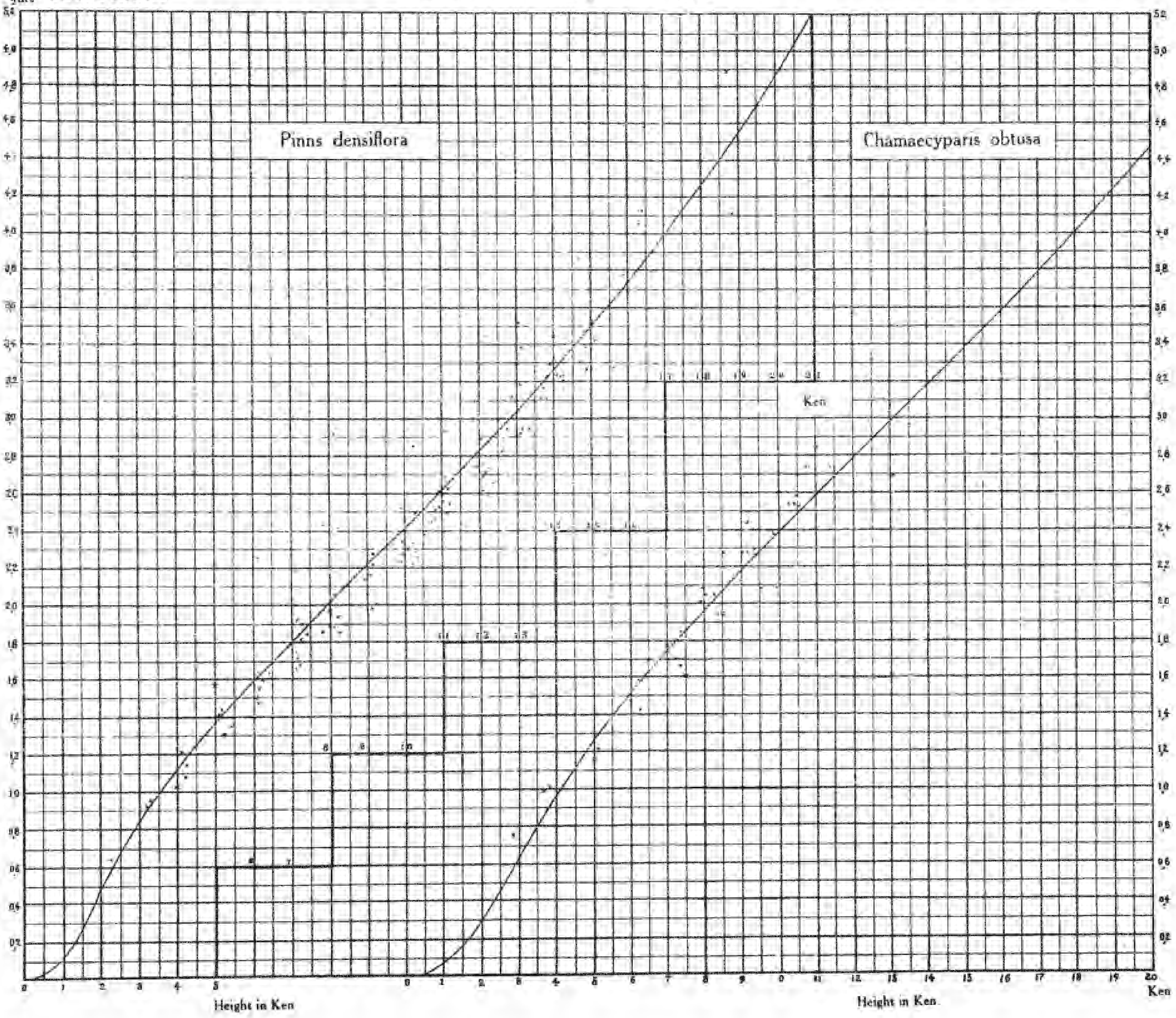
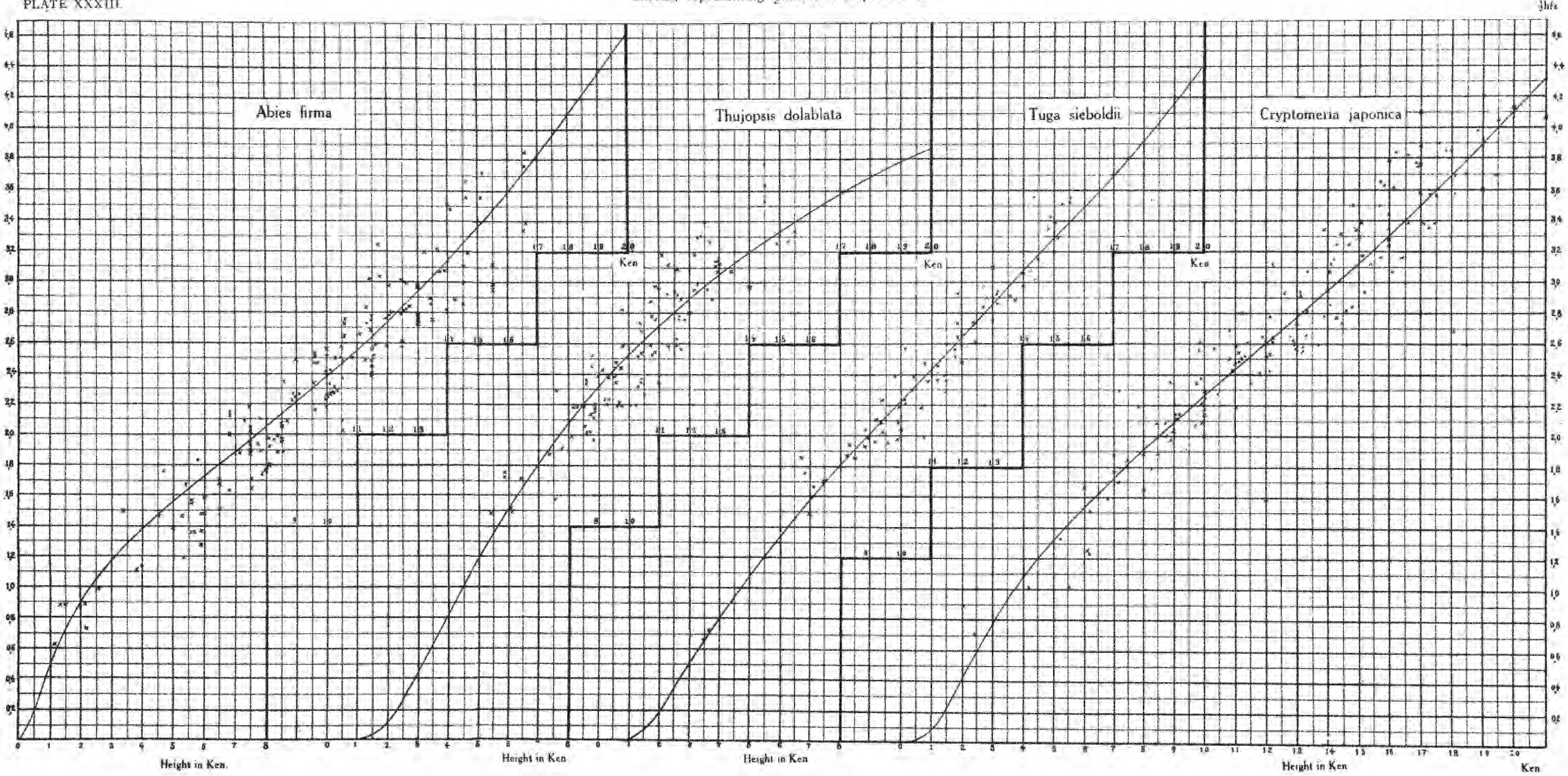


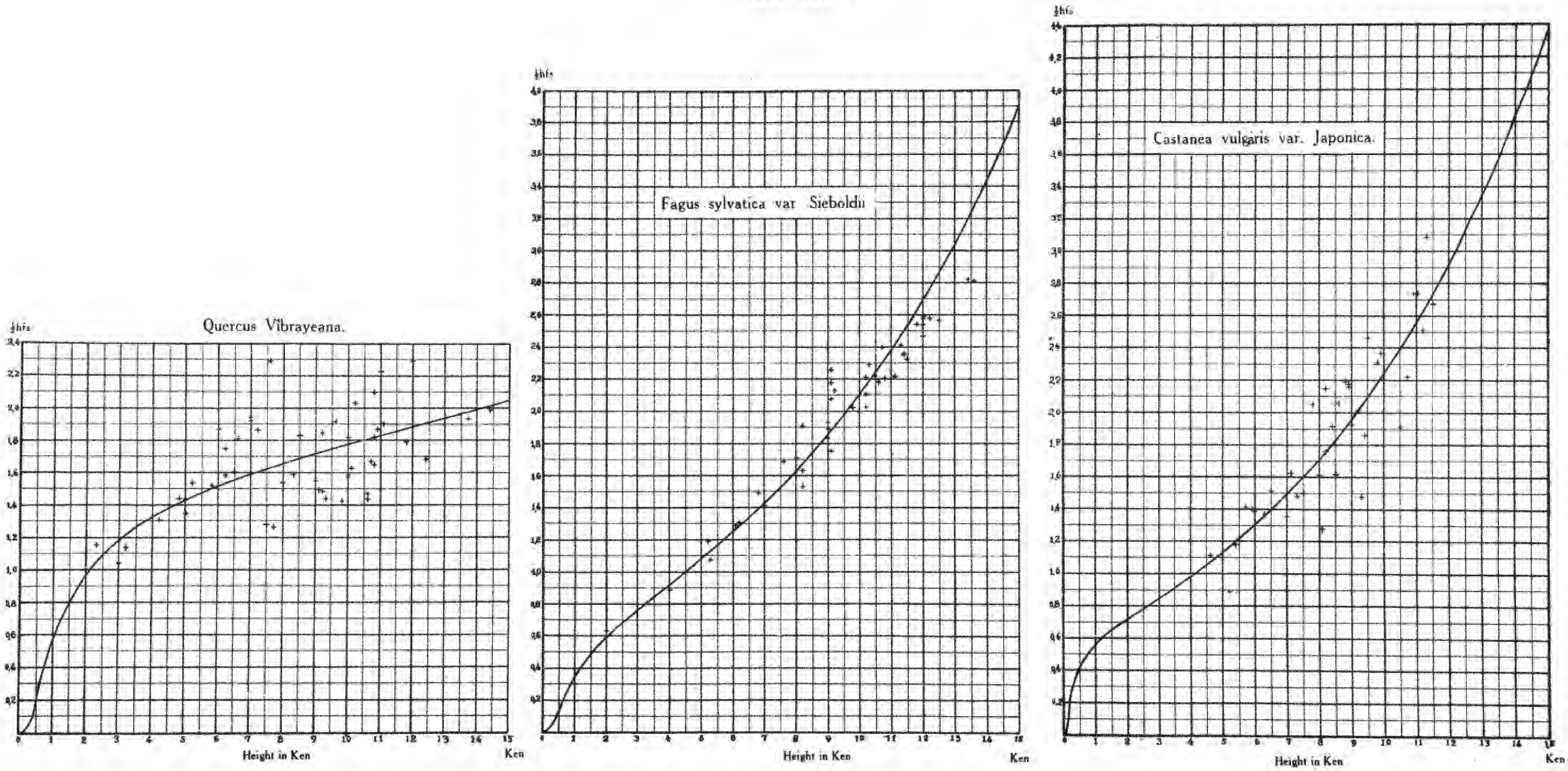
PLATE XXXIII.

Curves, representing $\frac{1}{2}hfs$ with respect to h.



Curve, representing $\frac{1}{2}$hfs with respect h.

PLATE XXXIV



Quercus Vibrayeana.

Fagus sylvatica var Sieboldii

Castanea vulgaris var. Japonica.

The results are as follows:

For *Pinus densiflora:*

$\frac{1}{2}hf_s^{*}=1.845e^{0.0557h-\frac{2.9105}{h}}$ Probable error=±0.150

For *Cryptomeria japonica:*

$\frac{1}{2}hf_s=1.995e^{0.0437h-\frac{3.1753}{h}}$ Probable error=±0.236

For *Abies firma:*

$\frac{1}{2}hf_s=1.455e^{0.0608h-\frac{1.1953}{h}}$ Probable error=±0.385

For *Chamaecyparis obtusa:*

$\frac{1}{2}hf_s=2.460e^{0.0408h-\frac{4.4095}{h}}$ Probable error=±0.230

For *Tsuga sieboldii:*

$\frac{1}{2}hf_s=2.427e^{0.0428h-\frac{5.1735}{h}}$ Probable error=±0.167

For *Thujopsis dolabrata:*

$\frac{1}{2}hf_s=4.753e^{0.0728h-\frac{7.1176}{h}}$ Probable error=±0.182

For *Fagus sylvatica var. Sieboldii:*

$\frac{1}{2}hf_s=1.391e^{0.1165h-\frac{0.8531}{h}}$ Probable error=±0.119

For *Quercus Vibrayeana:*

$\frac{1}{2}hf_s=1.594e^{0.0214h-\frac{1.0758}{h}}$ Probable error=±0.161

For *Castanea vulgaris var. japonica:*

$\frac{1}{2}hf_s=1.632e^{0.1322h-\frac{2.2473}{h}}$ Probable error=±0.166

The fluctuations of $\frac{1}{2}hf_s$ for given species are given in the plates, XXXII, XXXIII and XXXIV.

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[*] $v_s=\frac{1}{2}hf_s g_m$, where the unit of volume of tree bole is the "*shakujime*" (1 *shakujime* =12 cubic *Shaku*), the unit of the length or height is the "*Ken*" (1 *Ken*=6 *Shaku*), and the unit of the length of diameter is the "*Shaku.*"

The calculated $\frac{1}{2}hf_s$ from the above given equations are given in the following table:

For Conifers:

Height in Ken	*Thuga sieboldii*	*Abies firma*	*Thujopsis dolabrata*	*Chamaecyparis obtusa*	*Cryptomeria japonica*	*Pinus densiflora*
1.0	0.01	0.47	0.00	0.07	0.09	0.11
1.5	0.07	0.72	0.04	0.16	0.24	0.29
2.0	0.20	0.90	0.12	0.29	0.44	0.48
2.5	0.34	1.06	0.28	0.46	0.60	0.66
3.0	0.50	1.18	0.46	0.63	0.79	0.83
3.5	0.64	1.28	0.62	0.80	0.93	0.98
4.0	0.79	1.38	0.82	0.96	1.07	1.11
4.5	0.94	1.46	1.00	1.10	1.20	1.22
5.0	1.07	1.56	1.19	1.25	1.32	1.35
5.5	1.21	1.65	1.37	1.39	1.42	1.46
6.0	1.33	1.72	1.52	1.51	1.53	1.59
6.5	1.46	1.81	1.67	1.63	1.62	1.69
7.0	1.56	1.88	1.81	1.74	1.72	1.80
7.5	1.68	1.96	1.94	1.85	1.82	1.91
8.0	1.79	2.04	2.07	1.96	1.91	2.00
8.5	1.89	2.12	2.19	2.07	1.99	2.11
9.0	2.01	2.20	2.30	2.17	2.08	2.22
9.5	2.11	2.28	2.41	2.28	2.16	2.31
10.0	2.22	2.37	2.51	2.38	2.26	2.41
10.5	2.32	2.46	2.60	2.48	2.34	2.51
11.0	2.43	2.55	2.70	2.58	2.42	2.62
11.5	2.54	2.64	2.78	2.68	2.50	2.72
12.0	2.64	2.73	2.87	2.78	2.60	2.83
12.5	2.75	2.82	2.95	2.88	2.68	2.94
13.0	2.84	2.92	3.02	2.98	2.77	3.04
13.5	2.95	3.02	3.10	3.08	2.86	3.15
14.0	3.06	3.13	3.18	3.18	2.94	3.27
14.5	3.18	3.23	3.23	3.27	3.03	3.39
15.0	3.28	3.35	3.30	3.38	3.12	3.51
15.5	3.38	3.46	3.36	3.48	3.21	3.62
16.0	3.49	3.58	3.43	3.58	3.31	3.75
16.5	3.59	3.69	3.49	3.69	3.41	3.87
17.0	3.70	3.82	3.54	3.79	3.50	4.01
17.5	3.80	3.95	3.60	3.91	3.60	4.13
18.0	3.92	4.07	3.66	4.01	3.69	4.28
18.5	4.04	4.21	3.71	4.12	3.79	4.42
19.0	4.16	4.34	3.77	4.23	3.89	4.56
19.5	4.28	4.47	3.81	3.34	4.00	4.70
20.0	4.41	4.62	3.85	4.46	4.10	4.86
20.5	—	—	—	—	4.21	5.02
21.0	—	—	—	—	4.32	5.18

For broad trees:

Height in Ken	*Quercus Vibrayeana*	*Fagus Sylvatica var. Sieboldii*	*Castanea vulgaris var. japonica*	Height in Ken	*Quercus Vibrayeana*	*Fagus Sylvatica var. Sieboldii*	*Castanea vulgaris var. japonica*
0.5	0.187	0.138	0.418	8.0	1.654	1.642	1.714
1.0	0.555	0.344	0.558	8.5	1.685	1.751	1.835
1.5	0.804	0.485	0.643	9.0	1.715	1.867	1.963
2.0	0.972	0.592	0.713	9.5	1.745	1.988	2.099
2.5	1.093	0.684	0.779	10.0	1.773	2.117	2.247
3.0	1.188	0.767	0.845	10.5	1.802	2.253	2.402
3.5	1.264	0.847	0.912	11.0	1.829	2.397	2.568
4.0	1.327	0.926	0.982	11.5	1.585	2.549	2.746
4.5	1.382	1.005	1.056	12.0	1.884	2.710	2.936
5.0	1.431	1.086	1.134	12.5	1.912	2.881	3.139
5.5	1.475	1.169	1.216	13.0	1.939	3.062	3.356
6.0	1.515	1.255	1.305	13.5	1.965	3.254	3.588
6.5	1.552	1.345	1.397	14.0	1.992	3.456	3.834
7.0	1.588	1.438	1.496	14.5	2.019	3.671	4.100
7.5	1.622	1.538	1.602	15.0	2.046	3.899	4.381

D. Summary

On surveying the results of the foregoing inquiry, the following relations appear to be throughly confirmed.

(1) The form of any tree bole obeys the formula

$$y = c e^{ax - \frac{b}{x}} \qquad \text{or} \quad y = c' y_m e^{a'x - \frac{b'}{x}}$$

where y is the radius at the section which is situated at the distance x from the tip, and a, b, c and a', b', c' are the constants which vary with the individual tree.

(2) As a crude approximation, the contents of an entire tree bole may be estimated by the formula

$$v_s = \mathrm{L} g_m e^{\mathrm{L}_1 h - \frac{\mathrm{L}_2}{h}}$$

where, v_s, g_m and h are the content of an entire tree bole, breast-height basal area and total height, respectively and L, L_1 and L_2 are the constants which vary only with the species.

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