On the Chemistry of Japanese Plants, III. Chemical Development in the Growth of Bamboo Shoots.

By

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Bamboo is found everywhere in Japan, and is regarded as an important item for various economical purposes, and for the ornamentation of gardens. Bamboo shoots are esteemed for food material. There are more than 50 species, according to the specialist, in Japan.

Of the bamboo grown in Japan, the Madake (*Phyllostachys quilioli* F. M.) is the most useful, being valued principally for its varied usefulness as an aid, e. g. as a pole, and for food. Its stem is green and the internodes comparatively long. The sprout comes up in June, and the sheath is marked with purple blotches, its flavour is bitter, and it is eaten after boiling with water to remove the irritating matter.

The growth of the bamboo shoot is very rapid, and interesting. Here cite a few lines from " The Cultivation of the Bamboo in Japan " by Sir E. Satow[1]. " Dr. Dupin, a Frenchman, once observed to me that while many plants grow with rapidity, none is comparable to the bamboo in this respect. It will grow as much as six feet or more in a single night. When the sprout is still tender, it draws its nourishment from the rhizome, but in a few days reaches a height of from eight to ten feet. As soon as it becomes able to absorb moisture from

[1] Trans. Asia. Soc., [3], **27**, 14 (1899).

the ground through its fibre-like roots, its rate of growth becomes more energetic, and each internode rapidly lengthens, so that in a single night it will grow as much as six feet."

The study of the chemical composition of the bamboo and its sprout is very important from the point of view of industrial chemistry, and also of bio-chemistry. The bases and carbohydrates of the plant have been investigated by many chemists[1].

The chemical changes of the substances, during the growth, of this vigorously growing plant, however, has remained to us as mysterious as in ancient times except for the study by S. Kaeriyama of the gases consituents of the internoides[2].

The present contribution dealing with the shoot in its growing period, therefore, treats of the Madake, from the biochemical standpoint.

Our specimens were grown in Saga near Kyoto, and were secured through the courtesy of Mr. G. Oyagi.

5 shoots— one from the east, west, north, south and middle parts of the same bamboo jungle — were obtained on June 19th., 1923, and we started the experiment the next-day. Each sample has the following weight, length and knots :

Table I.

	Length in cm.	Weight in grm.	No. of Knot
East	127·3 cm.	635·2 grm.	26
West	134·9	579·0	26
North	124·4	823·0	23
South	116·6	542·0	28
Middle	121·1	813·0	25

1 Y. Kozai : Bull. Imp. Coll. Agri., **1**, 37 (1890) ; G. Todani : Z. Physiol. Chem., **62**, 113 (1909) ; **70**, 388 (1911) ; K. Miyake & T. Tadokoro : J. Tokyo Chem. Soc., **33**, 557 (1912) ; W. Schmeil : Z. Papier., **1**, 153 (1921).

2 S. Kaeriyama : J. Tokyo Chem. Soc., **26**, 333 (1905).

The content of moisture, pentose, hexose, pentosan, hexosan, cellulose, lignin, total nitrogen, soluble nitrogeneous matter, and ash of each sample was determind in the following way :—

Shoot cut into five parts, each part has the following length, weight and knots.

Table II.

	East.			West.			North.			South.			Middle.		
	Length in cm.	Weight in grm.	No. of Knot.	L.	W.	No.	L.	W.	No.	L.	W.	No.	L.	W.	No.
I.	31·4	211	2	34·3	201	1	29·8	266	1	26·7	166	1	28·8	259	1
II.	26·4	155	1	24·8	125	1	24·1	197	1	22·6	126	1	20·3	177	1
III.	17·8	98	2	20·1	101	2	16·5	128	2	17·8	92	2	17·8	132	2
IV.	18·0	84	2	20·1	79	2	19·7	118	2	24·1	100	3	24·1	151	3
V.	33·7	88	19	35·6	74	ca. 20	34·3	113	ca. 17	25·4	58	ca. 21	30·1	95	ca. 18

1. MOISTURE.

A quater part of each portion was dried at 105° to constant weight, loss of weight was designated as the moisture-content, and the results are shown in Table III.

Table III.

Moisture-content.

	East.	West.	South.	North.	Middle.	Mean.
I.	92·15%	92·48%	91·43%	92·87%	90·78%	91·94%
II.	92·59	92·96	92·33	92·95	92·60	92·68
III.	92·27	92·01	92·03	92·68	92·39	92·27
IV.	91·57	91·88	91·78	92·05	91·48	91·75
V.	89·92	91·20	90·78	90·94	90·86	90·74

2. WATER EXTRACT.

A. Total reducing sugars.

Three-fourths of each portion were cut into small pieces, boiled with 150 c.c. water for two hours, filtered through silk-cloth, and the solution pressed out. The pressed cake was treated again with some boiling water for 30 minutes. The combined extract make up to 250 c. c., reacts with litmus paper to neutral, contains no free ammonium ion and the total reducing sugars in the extract were estimated by determining the reducing power of Fehling's solution, and were calculated as d-glucose.

Table IV.

Total Reducing Sugars.

	North.	Middle.	East.	South.	West.	Mean.
I.	16·02%	16·08%	16·98%	18·34%	15·89%	16.66%
II.	20·02	20·19	19·50	21·44	18·52	19·39
III.	16·90	17·42	18·86	17·34	—	17·63
IV.	14·01	14·06	14·74	15·20	14·94	14·71
V.	10·28	10·13	8·27	11·15	9·89	9·94

B. Pentoses.

The presence of pentose in the water extract was confirmed by transforming it into furfurol.

50 c. c. of the extract were taken in a distilling flask, evaporated to dryness and the residue was subjected to distillation with 12% hydrochloric acid, furfurol distilled out was determined by means of phloroglucinol as usual. The results are shown in Table V.

Table V.

Pentoses.

	North.	East.	West.	South.	Middle.	Mean.
I.	0·91%	0·88%	0·97%	0·82%	0·69%	0·85%
II.	1·10	1·08	1·19	0·96	0·98	1·06
III.	1·10	1·49	1·25	1·18	1·04	1·21
IV.	1·09	1·20	—	1·16	0·99	1·11
V.	1·02	1·07	1·10	0·97	—	1·06

C. Hexoses.

The hexose-content in the extract was determined by subtracting the pentose-content from the total sugar-content, and the results are shown in Table VI.

Table VI.

	Pentoses as Xylose.	Pentoses as d-Glucose.	Total Reducing Sugars as d-Glucose.	Hexoses as d-Glucose.
I.	0·85%	0·84%	16·66%	15·82%
II.	1·06	1·04	19·39	18·35
III.	1·21	1·19	17·63	16·44
IV.	1·11	1·09	14·71	13·62
V.	1·06	1·04	9·94	8·90

D. Total Soluble Nitrogen.

25 c. c. of the water extract were digested with conc. sulphuric acid, and the quantity of ammonia generated was determined as usual, form which the total nitrogen was calculated and the results are shown in Table VII.

Table VII.

Total Soluble Nitrogen.

	North.	East.	West.	South.	Middle.	Mean.
I.	1·68%	1·80%	1·27%	1·14%	0·80%	1·34%
II.	2·08	1·82	1·54	1·55	1·36	1·67
III.	2·87	2·41	1·91	1·80	1·66	2·13
IV.	3·39	2·86	3·17	1·89	2·12	2·69
V.	3·30	3·10	3·40	2·78	2·58	3·03

E. Total Soluble Matter.

The water extract was evaporated to dryness on a water bath and dried at 105° to the constant weight.

Table VIII.

Total Soluble Matter.

	South.	West.	East.	North.	Mean.
I.	36·61%	38·76%	41·15%	43·09%	39·90%
II	45·18	41·65	47·59	50·56	46·25
III.	48·65	47·85	49·37	55·85	50·43
IV.	50·98	55·38	55·53	59·05	55·21
V.	47·71	51·19	56·26	53·69	51·96

F. Total Insoluble Matter.

The insoluble residue in boiling water, was dried at 105°, to constant weight.

Table IX.

Total Insoluble Matter.

	South.	West.	East.	North.	Mean.
I.	63·39%	61·24%	58·85%	56·91%	60·10%
II.	54·82	58·35	52·41	49·44	53.75
III.	51·35	52·15	50·63	44·15	49·57
IV.	49·02	44·62	44·47	40·05	44·79
V.	52·29	48·81	43·74	46·31	48·04

3. 95% ALCOHOL EXTRACT.

A. Soluble Nitrogenous Matter.

The insoluble residue in hot water, was treated with boiling 95% alcohol for 2 hours, and the extract was coloured green. Of the extract, the content of nitrogen and fatty compounds with other soluble matters was determined. The total quantity of the extracted matter was determined, the solvent distilling off and the residue dried to constant weight at 98° in a steam bath.

Table X.

Fatty Compounds.

	South.	North.	West.	East.	Mean.
I.	4·14%	3·32%	2·63%	4·20%	3·58%
II.	3·93	4·07	3·50	4·40	3·98
III.	4·86	4·60	4·53	4·92	4·73
IV.	5·05	4·80	4·82	5·45	5·03
V.	5·72	5·67	5·87	5·80	5·76

95% Alcohol Soluble Nitrogen.

	West.	South.	North.	Mean.
I.	0·06%	0·09%	0·10%	0·08%
II.	0·09	0·09	0·11	0·10
III.	0·10	0·14	0·15	0·13
IV.	0·14	0·17	0·16	0·16
V.	0·13	0·12	0·19	0·15

4. CELLULOSE.

The amount of cellulose was determined of the insoluble residue in water and alcohol by the directions of Cross and Bevan.

Table XI.

Cellulose.

	%
I.	29·58
II.	20·10
III.	15·32
IV.	10·32
V.	8·50

5. LIGNIN–CONTENT.

This was calculated from the methoxyl value in 0·6—0·9 grm. of the insoluble dry substance.

Table XII.

Lignin.

	%
I.	5·31
II.	5·59
III.	5·40
IV.	5·16
V.	5·03

6. PENTOSAN.

Its content in the insoluble substance was estimated by the method of Tollens and Kruger, and also by determining the reducing power of the Fehling's solution of the hydrolytic product of the residue by heating with 1% hydrochloric acid at 123—128° in a sealed-tube for 2 hours.

Table XIII.

Pentosan.

	As Xylose. (by 1%-HCl Hydrolyse)	As Xylose. (by Tollens' method)	Difference. as Xylose.
I.	19·24%	18·77%	0·47%
II.	15·62	13·90	1·72
III.	14·02	11·67	2·53
IV.	11·06	9·36	1·70
V.	10·41	8·35	2·06

7. PROTEIN.

The nitrogen-content of 0·2—0·5 grm. of the insoluble dry substance was estimated, from which the protein-content in the sample was calculated.

Table XIV.

Protein Nitrogen.

	% N.	% Protein.
I.	0·97	6·06
II.	1·16	7·25
III.	1·54	9·63
IV.	1·85	11·56
V.	2·49	15·56

8. TOTAL NITROGEN.

Of 0·2—0·4 grm. of the sample dried at 105°, the total nitrogen was estimated as usual.

Table XV.

Total Nitrogen.

	%
I.	2·72
II.	3·69
III.	4·00
IV.	4·78
V.	5·78

9. ASH.

The dry sample was ignited carefully at low temperature and the crude ash, thus obtained was heated in an electric furnace to a constant weight. The amount of calcium, manganese, aluminium, iron, alkali metals (sodium and potassium), phosphoric acid and silica in the ash were determined and the results were shown in Table XVI.

Table XVI.

	Total Ash % in Dry Weight.	% in Total Ash.					
		P_2O_5.	SiO_2.	$Fe_2O_3+Al_2O_3$.	Mn_3O_4.	CaO.	Na_2O+K_2O.
I.	7·32%	8·57%	5·26%	0·53%	—	1·32%	58·85%
II.	8·91	13·52	4·07	0·33	—	1·64	55·32
III.	9·64	16·79	3·73	0·32	1·61	2·05	—
IV.	10·99	19·52	2·56	0·57	1·91	2·18	53·82
V.	12·88	22·17	1·59	0·36	2·22	2·85	52·43

The figures in Table XVII are the results of the recalculation on water free bases and plotted in Fig. 1, 2, 3, 4, 5, and 6.

In the growth of bamboo shoots, these separate processes—assimilation, transference, metabolism and respiration—were noticed.

The upper part of the shoots—the first section or the youngest part, soft and white in skin, was supposed to be the most vigorous

growing part, and where the transference of the food materials from the mother plant to maintain life and respiration for a supply of energy took place on a large scale. Consequently, as we actually observed, there is a loss of weight, and it contains the least mono and polysaccharides, on the other hand, the largest quantity of simple nitrogeneous matter and fatty acids. The chemical changes of the substances in this part are quite the same as those that occur in the germination of seeds in darkness.

Going to the lower part — the old part, the destructive process takes place on a smaller scale than the synthetic process — metabolism ; transformation of the food materials into plant tissues or reserves and synthesis of complex substances will be noticed as seen in the ripening of seeds.

In other words there occurred a diminution of protein, soluble nitrogenous matter and fatty compounds, on the contrary, the polymerization of sugars into polysaccharides gradually increased.

In the lower part of the shoot, the stem was coloured green with chlorophyll, and assimilation of carbon should take place. The process will become vigorous after the sheath has fallen off.

It was very interesting to notice that the pentose-content was constant throughout the bamboo-shoot life while pentosan-hemicellulose, which is considered to make up the constituents of the cell wall, was resorved in proportion to age. Such a phenomenon is also noticed in the case of seedlings, germinated and grown in the dark.

As to the origin of pentose sugars in the shoot, the authors have ascribed it to the metabolism of hexose but not to the photosynthesis of carbon dioxide. This hypothesis will be discussed in detail in an other article.

The ash-content changes not only in different organs of the same plant but in the various stages of development of the same organ, as the organic constituents occur[1].

The distribution of ash in the shoot at various stages of the growth is, therefore, a very interesting problem in connection with that of the organic constituents.

The experimental result indicates that the total ash-content decreases with age, and this harmonises with the hypothesis accepted

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[1] A. Mayer : Agricultur Chemie, I. 92 (1920) ; Livingston and Palladin : Plant Physiol., p. 175 (1917) ; W. Detmer : Vergleichende Physiologie des Keimungs Processes, 189 (1880).

universally by chemists that the tissues richest in ash are those in which living cells are most numerous, and our subject bears this out in the variation of ash-content with that of seeds in germination[2].

Silicium and alminium were regarded as important elements in plants growing under natural conditions to protect the increasing reserve materials from unfavorable external conditions. Consequently the amount of these elements would be increased with age, and the analytical results were consistent with this interpretation.

The calcium and phosphorus amount decreased with age while the amount of alkali metals remains almost constant as shown in the experimental result, since these elements were regarded as necessary to promote the formation of carbohydrates and proteins.

Iron and manganese[3] were believed to stimulate the plant growth acting like a catalyst, and accordingly the amount of them will be increased in the younger part of the plant, as was actually proved in the experimental results.

Nov. 1923. Laboratory of Organic- and Bio-Chemistry.

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1 M. Berthelot : Chimie Végétable et Agricole IV (1899) : A. Mayer : Agricultur Chemie, I. 247 (1920).

2 W. Detmer : p. 115.

3 G. Berthland : Sur le rôle des infiniment petits Chimiques en agriculture, 15 (1912) ; G. Bertrand and Rosenblatt : Bull. Soc. Chim., (4) 31, 125 (1922).

Fig. 1.

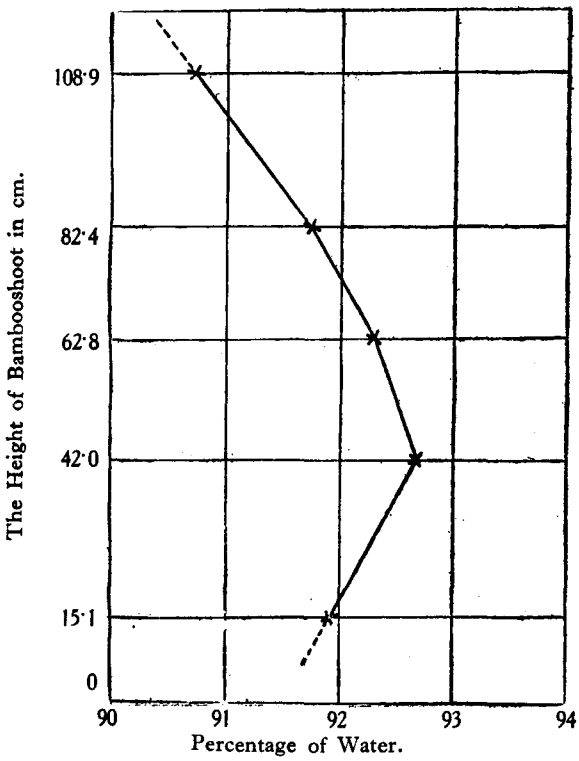

108·9
82·4
62·8
42·0
15·1
0
90
91
92
93
94
The Height of Bambooshoot in cm.
Percentage of Water.

Fig. 2.

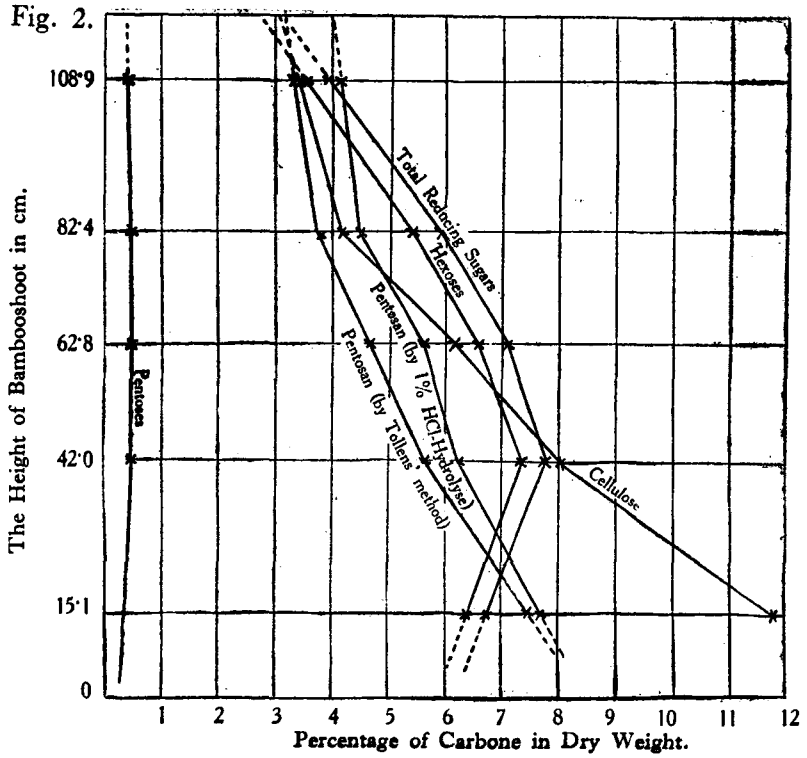

108·9
82·4
62·8
42·0
15·1
0
1
2
3
4
5
6
7
8
9
10
11
12
The Height of Bambooshoot in cm.
Percentage of Carbone in Dry Weight.
Total Reducing Sugars
Hexoses
Pentosan (by 1% HCl-Hydrolyse)
Pentosan (by Tollens' method)
Pentoses
Cellulose

Fig. 3.

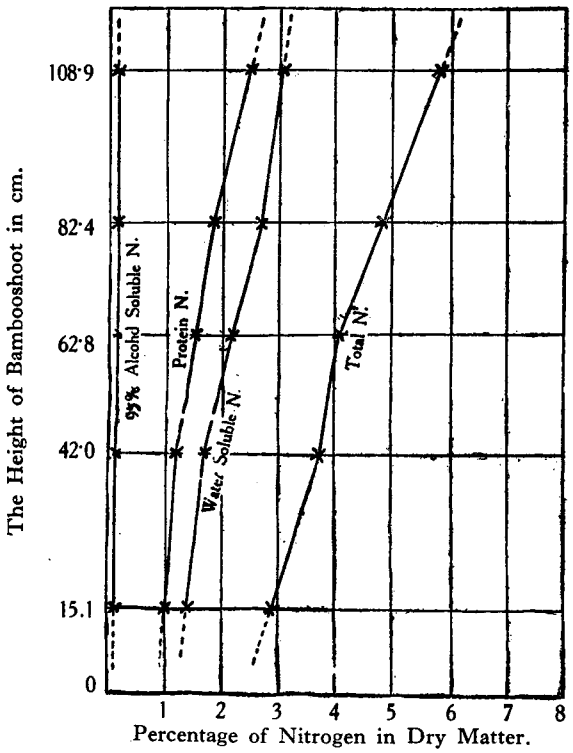

108·9
82·4
62·8
42·0
15.1
0
95% Alcohol Soluble N.
Protein N.
Water Soluble N.
Total N.
1
2
3
4
5
6
7
8
The Height of Bambooshoot in cm.
Percentage of Nitrogen in Dry Matter.

Fig. 4.

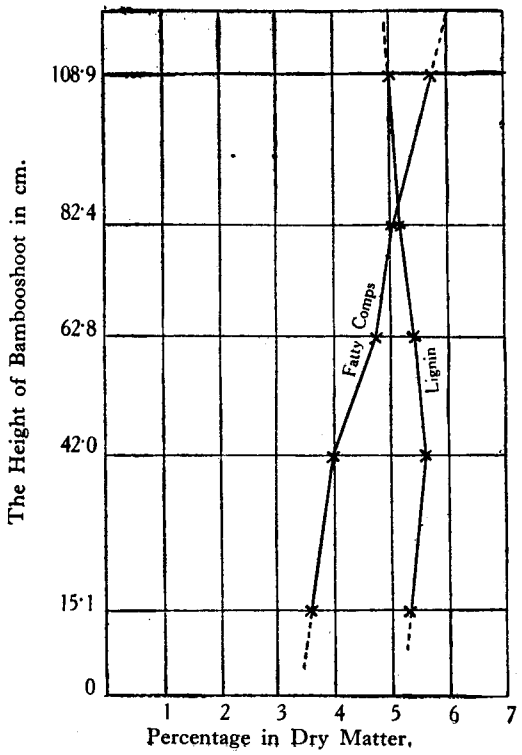

108·9
82·4
62·8
42·0
15·1
0
Fatty Comps
Lignin
1
2
3
4
5
6
7
The Height of Bambooshoot in cm.
Percentage in Dry Matter.

Fig. 5.

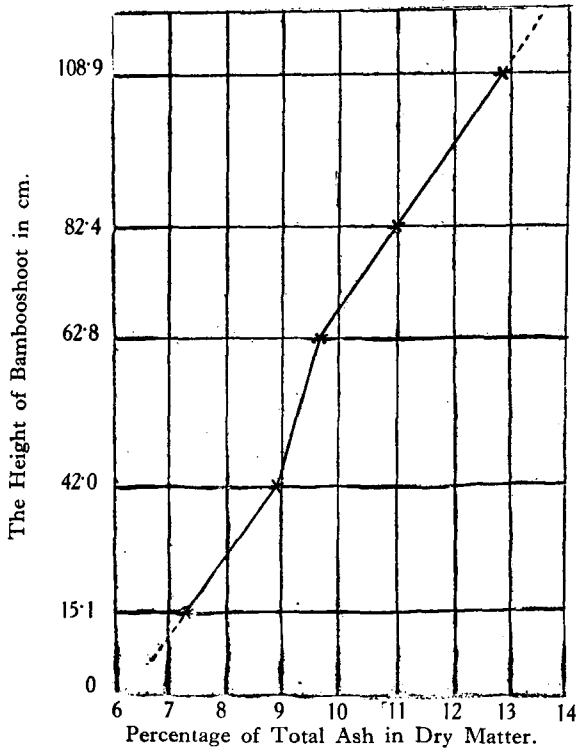
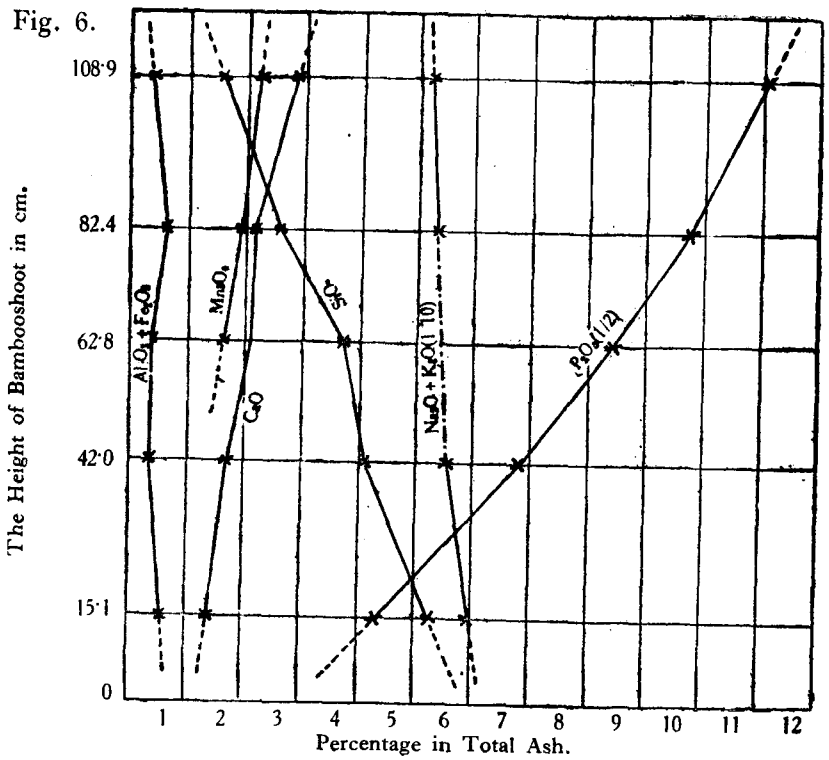

108·9
82·4
62·8
42·0
15·1
0
The Height of Bambooshoot in cm.
6 7 8 9 10 11 12 13 14
Percentage of Total Ash in Dry Matter.

Fig. 6.


108·9
82.4
62·8
42·0
15·1
0
The Height of Bambooshoot in cm.
Al2O3+Fe2O3
MnO2
CaO
SiO2
Na2O+K2O(1/10)
P2O5(1/2)
1 2 3 4 5 6 7 8 9 10 11 12
Percentage in Total Ash.