Biochemical Studies on the "Maturity" of Sugar Cane

By

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I. Introduction to the Study of Sugar Cane

By

Shigeru Komatsu

One spring day in 1928, Mr. H. Amano of the Niitaka Sugar Manufacturing Co. Tyuryo, Formosa, called the writer to the laboratory in order to clear up the question why the yield of sucrose in his factory was as low as 11 % as compared with that of other factories in the island and if possible to find out a way by which to increase the sugar production.

Formosa is one of the great sugar producing centers in Japan; the sugar-cane is cultivated in an area of 120,000 'chōbu,' according to the statistical returns, and the annual production amounts to some 15,000,000 piculs. Soon after Formosa was ceded to Japan, sugar factories and sugar cane plantations were established there although the climatic conditions are not so favorable as in the Hawaiian and Java Islands for agricultural production, and moreover there was constant danger of assault from the savages of the interior. After 30 years of struggle and difficulty in the management of the industry and technical improvement to increase the rate of sugar cane production, the sugar industry has reached the present stage in its development

1. Togyo-Benran (Pocket-book for Sugar Industry), Formosa, 1924. The Industry of Japan (1928) p. 64; Japan in Industry (1929) p. 128.

where it is on a self-supporting and paying bases. The yield of sugar cane is now 13 per cent on an average, which figure is only a little over half that of Hawaiin production.

Mr. Amano's question interested the writer, since it was concerned mostly with the photosynthesis and metabolism of carbohydrates in the sugar cane, and a method for the plantation of the sugar cane was proposed by the writer based on the investigations of photosynthesis and metabolism of carbohydrates with rice[1] and bamboo[2] (both plants belonging to the same species as the sugar cane), to which he has devoted himself for many years.

According to the writer's experience, hitherto the sugar cane plantations in Formosa, especially in the middle part of the island, seem to have endeavoured only to increase sugar production by importing new strains from Java but not by an improvement in the methods of planting. However, the writer's proposal for the increase of sugar production emphasized the point of planting, which should be performed according to the correct view for the formation of sucrose in the plant, taking the climatic conditions of Formosa into consideration.

The present state of our knowledge concerning the first sugar produced by photosynthesis in the plant world is confused[3]; starch is the most easily detached product in a plant, but a new theory has recently been proposed by chemists in which glucose is favoured as the first sugar formed by photosynthesis, but the demonstration of glucose actually being the first sugar formed is still wanting.

In the glucose theory, dessication of the tissues is required, to bring about the accumulation of sucrose in the cane stalk,

$$2C_6H_{12}O_6 = C_{12}H_{22}O_{11} + H_2O - x \text{ cal.}$$

while, the chemical process of converting starch into sucrose, shown in the following equation,

$$(C_6H_{10}O_5)_n + \frac{n}{2}H_2O = \frac{n}{2}C_{12}H_{22}O_{11} + y \text{ cal.}$$

proceeds in the presence of water in the system from left to right with evolution of heat.

The idea that water is an essential compound in the chemical reactions comprising the photosynthetic process, as is indicated in the well known chemical equation,

1. Unpublished.
2. The Anniversary Vol. dedicated to Prof. M. Chikashige (1930) 119—181.
3. H. A. Spoehr: Photosynthesis (1926) 215.

$$6CO_2 + 6H_2O = C_6H_{12}O_6 + 6CO_2 - z \text{ cal.}$$

and also in many metabolic processes, has been supported by many chemists, but the sugar cane planters seem to pay no attention to the fact that the water in the plant tissues plays an important rôle in the vital processes of living organs. The vital processes which are intracellar, involve changes in both matter and energy ; energy is released for the growth by the oxidation of the tissue materials produced by photosynthesis, and the substance produced by metabolism, which occurs mostly in the presence of water, will be stored in the body. The writer is thus inclined to believe that the first sugar formed in sugar cane by photosynthesis is a polysaccharide of starch nature, which is converted by metabolism in the cane tissues into sucrose, cellulose and pentosan ; the conditions under which the polysaccharide will be converted into sucrose, cellulose or pentosan will be influenced greatly by the external and internal factors such as salt, water in the tissue, and temperature of the atmosphere. The writer's proposal on the cultivation of the cane crop was based on the above principle, and when it was found that his proposal for attaining greater sugar production was in agreement with the opinion of the chief members of the Niitaka Sugar Manufacturing Co. at the request of the company, Mr. Ozawa of this laboratory was despatched to Formosa to investigate practically the process of sugar cane cultivation.

The chemical analysis of the canes grown under various conditions, which was performed by him with his assistants in the laboratory of the factory, was reported with observations on the field performed in conjunction with Mr. H. Amano from time to time to the writer, and discussions on the reports were exchanged between Kyoto & Formosa. The present research entitled "Biochemical Studies on the 'Maturity' of Sugar Cane" is the result of three years of researches on the cane plant.

Soon after Mr. S. Ozawa returned to our laboratory on the 17th of December 1931, he was obliged to enter the hospital of the Kyoto Imperial University suffering from typhoid fever. Though his parents and beloved wife nursed him with great care, it had no effect, and after one week's struggle with the pains of sickness he passed away on the 29th. The writer mourns his pupil's death, is disappointed of this great loss of a young chemist of great promise and is extremely mortified at having had no opportunity of communicating this life work to the public in a paper or in a lecture before his death.

It was most unexpected that this research work should be offered to our young friend's tomb as a token of our reverence and love.

His interest in the investigation of plant biochemistry was directed gradually to the theoretical side by his taste and culture after his first scientific investigation in the line of biochemical study on the autumn fall of the leaf. Owing to his knowledge of languages and mathematics he stood head and shoulders above his fellows of our laboratory.

The reader of this research work will notice that the article on the utilisation of solar energy in the cane, which constitutes the most important part of this biochemical study of sugar cane, is one expression of his talent. It is considered that the chapter containing the mathematical treatment of the formation of sucrose in the plant, which is started on a hypothesis different from the writer's, should be published in his own way without any revision, as a commemoration of his efforts, his hard work under the unfavorable external conditions of Formosa. According to his private communications to the writer from time to time, he had spent his three years there very delightfully with his beloved wife and children, corresponding with friends at home and societies, enjoying the natural beauty of Formosa and his researches on the sugar plant in the laboratory. All of these pleasant days in Formosa were due to the kindness of Mr. S. Akiyama, the Director of the sugar factors and Mr. Amano and here the writer wishes to express his hearty thanks to these gentlemen.

II. Investigations on the Chemical Life-History of the "Hayaue-" Plant Canes

By

Shinsaku Ozawa and **Shigeru Komatsu**

The carbohydrates which occur in plants are originated by the vital process under the influence of solar energy; of them sucrose, distributed widely in plants[1] and especially in the sugar cane[2], is one

1. Maquenne: Les Sucres et leurs principaux derives, (1900) p. 652.
2. K. Krishnamurthi Rao: Planter and Sug. Manufacturer (1929) **83**, No. 1, p. 4.

of the most important substances from the point of view of plant physiology and human nutrition.

In the life-history of the sugar cane, the accumulation of sucrose in the cane stalk is the most remarkable phenomenon connected with its maturity. The maturity of the plant is usually regarded as that stage when the stalk has reached the stage of maximum sucrose content. The flowering of the plant grown in some parts of Japan, does not happen even when it has reached a state of high sucrose content.

In Formosa the flowering of the cane is observed to occur when the plant has reached a certain age under certain environmental conditions among which the temperature and moisture may be accounted as important factors in the production of this phenomenon.

Reference to the literature on the maturity of the sugar cane shows that dry weather in winter is the most favorable factor for the accumulation of sugar in the cane and this theory that a dry winter induces early maturity seems to agree with the rainfall statistics, though the theoretical basis of the explanation of it is quite uncertain; but exceptions to the above theory are often met in the literature[1].

Although a dry winter favours the accumulation of sugar in the cane, the fact that sucrose cannot be formed without the presence of water is acknowledged by many investigators and also complete absence of water has a bad effect on the plant, as was noticed by Noel Deerr[2], and frequent showers during the period of maturity have a favourable effect. Lack of water in the cane tissues tends to cause the cane strive to oxidise the carbohydrate previously stored in its body in order to keep its moisture content at a certain level, as we easily can judge from the starvation experiments upon cacti by Spoehr[3], and in consequence, diminution of the sucrose content results.

Cool and dry weather is considered to exert some negative effect upon the use of energy for growth, and such conditions as diminish the vegetative activity on the cane, may favour the maturity.

Turning our attention to the growth of cane, bad drainage of the plantation may be regarded as a condition unfavourable to growth and consequently accumulation of sugar in the body results. In fact the canes grown in a badly drained plantation show a high sucrose content,

1. Noel Deerr: Cane Sugar, p. 29.
2. Noel Deerr: Cane Sugar, p. 29.
3. Spoehr: Carbohydrate Economy of Cacti, p. 70.

and a statement to the same effect has been met with in an article entitled, "De Rijping van 2878 POJ[1]," in which it is emphasized that acceleration of maturity is the result of water-shortage in the body of the cane, but that growth is sometimes stopped by the insufficient activity of the root system injured by excess of water.

It seems to the writer that the reasonable way is to take into consideration the effect of temperature on the physiological activity of sugar cane in connection with the shortage of water or bad drainage of the soil, and he has taken in hand to investigate this subject fundamentally from the view point of the metabolism of carbohydrates in the sugar cane.

The accumulation of sucrose in sugar cane may be considered to occur in the following way :—

Some carbohydrate such as starch, produced by assimilation in the presence of the solar energy, is used for the growth on the one hand and on the other is accumulated in the form of sucrose in the body when the growth of the cane becomes very slow.

There are innumerable observations concerning the changes in the chemical composition, especially in the sucrose content, of the cane-stalk, of which the studies of sugar-formation in the cane carried out by Went[2], and the determination of the maturity-coefficient by Dr. Ishida[3] are, so far as the writer is aware, the most noteworthy from the view point of scientific investigation. The former being experiments carried out with canes in Java, and the latter with the "Osoue-" plant cane in Formosa, the results of neither of these investigations can be applied to the study of the "Hayaue-" plant cane which is now generally to be cultivated in Formosa, for the reason that the Formosa cane mets with two cool seasons in its life and so is grown under different climatic coditions from the former, and is planted at a different time from the latter. The writer therefore first studied the changes in the chemical composition of the leaves and stalks of the cane during the vegetative period in order to understand briefly the mode of assimilation of the carbon compounds and the metabolism of the carbohydrates in the plant.

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1. Aich'ef, Deel II, Afl. No. 52 (1928)
2. Archief (1856) p. 525.
3. Kansyoto Seizo Kagaku (1920) Zyo, p. 125.

1. Descriptions of the Samples.

The garden at Katokyaku which is used for the planting of the canes is situated near an irrigation canal and composed of sandy soil of the following composition, so that drainage and water-supply are easily controlled.

	above	0.1 mm.	83.9 %
Sands	0.1	0.05	6.7
	0.05	0.01	5.5
Clay	below	0.01	3.9
Water capacity			20.6
Humus-content			1.2
pH			5.9

2725 and 2878 POJ canes were planted on the 10th of August, 1929, in a double-row system, and high earthing-up was carried out completely.

Two canes were taken for analysis as samples from each of five different parts of the garden in order to get the average value for the garden, four at the corners and one at the centre.

The first analysis was made on the 10th of March, 1930, and after this, samples were taken to be analysed at about three weeks' intervals.

The Leaf.

The leaf of the cane may be considered to function in utilising the solar energy in two ways, the one is transpiration and the other photosynthesis, and the analytical examination of the constituents—such as water, ash, carbohydrates, nitrogenous matter and chlorophyll—of the leaf-system, will afford some knowledge concerning its functions since some of these compounds that occur in leaves play an important rôle in the processes of photosynthesis and metabolism, and also are regarded as reaction products of these processes.

A. The Moisture-Content.

The leaf sample was taken from the cane, and weighed and dried at 105° to a constant weight; the loss of weight is designated as moisture.

B. Method of Estimation of Chlorophyll.

The leaves, cut with a cork-borer, were treated at once with a suitable quantity of absolute alcohol in a water-bath for about 3 hrs.

To 30 c.c. of the alcohol-extract of the leaf-pigments, 1 c.c. of alcoholic potash (prepared with 100 parts of alcohol, 20 parts of caustic potash and a little water) was added, and the mixture was shaken occasionally and allowed to stand at the room temperature for about one hour to complete the saponification of the chlorophyll and the resulting precipitate was filtered. The filtrate was diluted with three times its volume of water, and the yellow colouring matter accompanied by chlorophyllin extracted with ether. The alcoholic solution of chlorophyllin potassium, thus obtained, was compared in a Duboscq colorimeter with a standard solution prepared for each experiment from the crystallised methylchlorophyllid obtained from fresh wild rose leaves by Willstätter's method[1].

The results of the experiments are expressed in terms of methylchlorophyllid (mgms. of methylchorophyllid per square centimeter)

C. Method of Estimation of Sugar-Content in Juice.

The sugar-content in the juice obtained from the leaves by grinding with a test-mill was determined by means of Fehling's solution before and after hydrolysis of the juice with dilute hydrochloric acid and the quantity of reducing and non-reducing sugars in 100 c.c. of the juice was calculated in the usual way. The rotatory power of the juice was also estimated.

D. Changes of Chlorophyll-Content during the Development of Leaf.

On July 27th, 1931, 10 leaves taken from top to bottom from each

Table I

Analysis of Juices

No. of leaf from top	Weight of one leaf (gms.)	Red. sug. gms/100 c.c.	Non-red. s. gms/100 c.c.	$[\alpha]_D$ of T. S.
1	22.4	0.89	0.79	−8.2°
2	26.9	1.15	0.63	13.6
3	26.5	1.15	0.78	16.6
4	25.8	0.99	0.79	17.5
5	25.9	1.05	0.94	29.6
6	25.5	1.23	1.32	20.4
7	25.0	1.28	1.17	18.4
8	24.5	1.44	1.01	14.1
9	23.4	1.39	1.06	10
10	22.0	1.49	1.06	15.4

1. R. Willstätter & A. Stoll: Untersuchungen über Chlorophyll (1913) 78.

of one hundred stalks of 2725 POJ Kialieng plant cane, grown in a garden near the laboratory, were gathered, and their mean weights and the composition of their juices were determined with the foregoing results.

The weight of unit area, and the content of moisture, chlorophyll, and of yellow pigments were estimated with the following results:

Table II

No. of leaf from top	Weight of unit area mgms/cm^2	Moisture %	Chlorophyll mgms/cm^2	Amounts relative of yel. pig'ts
1	22.5	74.0	0.095	1.6
2	23.6	70.9	0.241	4.5
3	24.8	71.6	0.228	5.4
4	23.1	71.5	0.287	5.4
5	23.7	72.2	0.287	5.0
6	22.8	69.7	0.261	6.5
7	23.4	67.2	0.295	4.5
8	22.7	71.9	0.280	2.8
9	21.1	73.1	0.267	5.0
10	23.2	73.1	0.187	1.0

Judging from the content of moisture, chlorophyll and other pigments above mentioned, leaves No. 1 and No. 2 are considered to be in a premature state; No. 3 to No. 8 are in a normal state of vital activity, and the activity of No. 9 and No. 10 has declined.

In some cases, the third leaf is exceptional in that it shows less vital activity in its appearance than No. 10; in such a leaf, the sheath is easy to detach from the stalk and the blade is definitely yellow in colour.

However, the estimation of the chlorophyll-content was always carried out with leaf No. 3 as the representative of any stalk.

All the leaves attached to the sample stalks were collected and their total weight was determined. The weight of unit area of leaves and the moisture and chlorophyll-content per unit area were determined with the third leaf from the top of each stalk; a portion of the leaf, cut by means of a cork-borer, was weighed and dried at 105°C to constant weight for the estimation of moisture and the other portion of the leaf was used for extraction of the chlorophyll determination of the chlorophyll-content.

The total area of leaf-surface for a single stalk was calculated from the total weight of the leaves by dividing by the weight of the unit area, the weight of the mid-rib being taken into consideration, and the results are as follows:

Variety	Total weight gms.	Mid-rib gms.	Ratio %
2725 POJ	120	35	29
	123	28	23
		Mean:	26
2878 POJ	129	48	37
	169	60	35
		Mean:	36

Fig. 1

Area of Leaf-Crown, Moisture & Chlorophyll-Contents

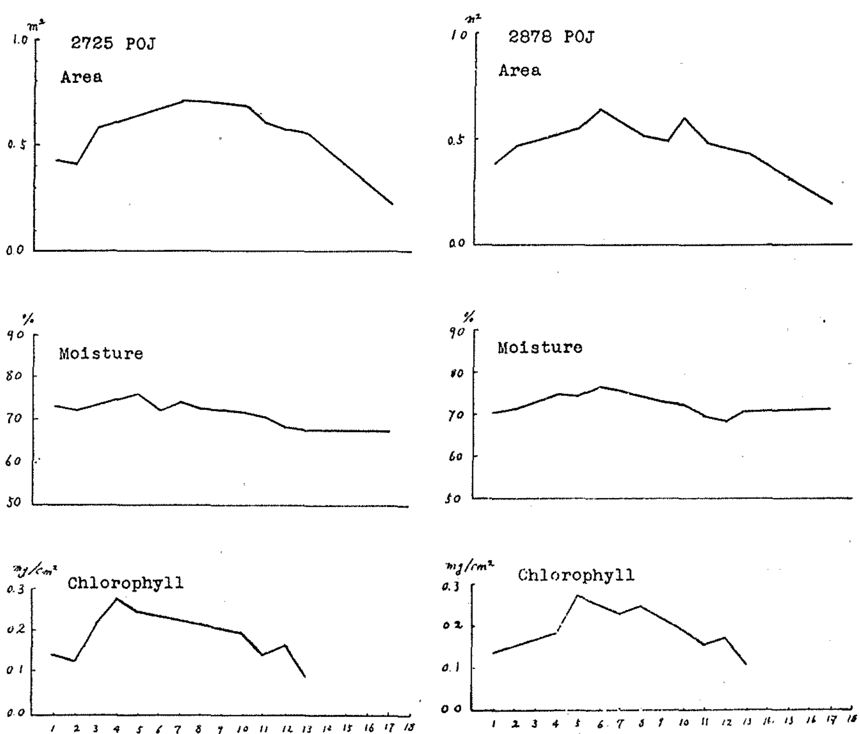


Table III

Results of Examinations of Leaves.

2725 POJ

No.	Date	Moisture %	Weight of unit area mgms/cm²	Chlorophyll in unit area mgms/cm.²	Total area m.²	In juice R.S. %	In juice N.R.S. %	$[\alpha]_D$ T.S.
1	III–10	73.5	25.9	0.142	0.428			
2	IV–1	72.7	26.8	0.125	0.413			
3	21	—	24.2	0.217	0.582			
4	V–8	75.1	30.8	0.275	—			
5	VI–2	76.1	27.2	0.250	—			
6	VI–23	72.6	25.3	—	0.673	1.2	0.8	—
7	VII–15	74.4	24.1	—	0.707	1.4	0.5	10.5°
8	VIII–4	73.0	24.8	0.218	—	1.4	1.0	33.6
9	25	72.7	24.4	—	0.700	1.5	0.7	−4.9
10	IX–15	72.1	21.6	0.197	0.685	1.7	1.4	—
11	X–6	71.0	24.2	0.144	0.611			
12	24	68.7	23.5	0.165	0.519			
13	XI–17	67.7	24.3	0.092	0.550			
14	5	—	—	—	—			
15	XII–28	—	—	—	—			
16	I–18	—	—	—	—			
17	II–10	67.9	25.2	—	0.221			
2878 POJ								
1		70.6	24.7	0.134	0.388			
2		71.1	25.6	—	0.472			
3		—	29.1	0.163	—			
4		74.9	29.6	0.184	—			
5		74.4	24.0	0.266	0.557			
6		76.5	25.8	—	0.643	1.3	—	—
7		75.4	27.2	0.228	—	1.8	0.7	0.7°
8		74.2	23.6	0.248	0.512	1.3	0.9	19.7
9		73.2	22.2	—	0.491	1.5	0.6	1.6
10		72.2	23.7	0.182	0.595	1.4	0.6	—
11		70.0	22.6	0.152	0.482			
12		68.3	22.4	0.169	0.455			
13		70.6	23.9	0.101	0.427			
14		—	—	—	—			
15		—	—	—	—			
16		—	—	—	—			
17		71.5	24.2	—	0.187			

The moisture-content of the leaf is expressed as a result of dynamic equilibrium of the water-supply from the root-system and the loss of water by transpiration and by photosynthesis of carbohydrates. As may be seen in table III & Fig. 1, this content actually increases as the summer approaches and reaches the maximum (76%) in June, and drops gradually thereafter.

The chlorophyll-content changes in a much the same way as the moisture-content; it attains its maximum (0.27) at the end of May or the beginning of June, and then falls.

E. Seasonal Variations in Chlorophyll-Content of Leaf.

The seasonal changes in the chlorophyll-content of leaves in the 2725 POJ and 2878 POJ "Hayaue-" plant canes were found to be as follows. (Table IV)

Table IV

No. of sample	Date	2725 POJ Chlorophyll	Date	2878 POJ Chlorophyll
1	III–10	0.142	III–10	0.134
2	IV– 1	0.125	IV– 1	0.083
3	21	0.217	21	0.163
4	V– 8	0.275	V– 8	0.184
5	VI– 2	0.250	VI– 2	0.266
6	23	0.123	25	0.153
7	VII–15	0.184	VII–17	0.228
8	VIII– 4	0.218	VIII– 6	0.248
9	25	0.134	26	0.132
10	IX–15	0.197	IX–17	0.182
11	X– 6	0.144	X– 8	0.152
12	24	0.165	27	0.169
13	XI–17	0.092	XI–19	0.101

In order to learn the influence of the environmental conditions upon the chlorophyll-content of the leaves, the meteorological conditions during the course of the investigation were obtained from the records kept at the Tyuryo Observatory.

From the comparison of these data, we noticed that an abnormally low value of chlorophyll-content was generally found after rainy or cloudy days (see next chapter).

F. Changes in Chlorophyll-Content and Environment.

To obtain more definite knowledge concerning the relation between the environmental conditions and the colorophyll-content of cane-leaf, sample leaves of 2725 POJ cane growing in the two gardens were taken twice a day for a fortnight and examined, and the environmental conditions during the experiment were studied.

The cane investigated was 2725 POJ "Hayaue- " plant in garden I, a garden with sandy soil and pretty good drainage, and Kialieng in garden II, which has rather a clay soil and somewhat inefficient drainage.

The results obtained were as follows:

Table V

Date	Chlorophyll-Content in Leaf (mgsm./cm.^{2})			
	Garden I		Garden II	
	a. m.	p. m.	a. m.	p. m.
V–27	0.154	0.164	0.123	0.127
28	0.126	0.171	0.126	0.119
29	0.127	0.105	0.111	0.167
30	0.144	0.106	0.147	0.093
31	0.124	0.105	0.103	0.085
VI– 1	0.118	0.115	0.094	0.085
2	0.106	0.107	0.074	0.094
3	0.095	0.159	0.095	0.133
4	0.130	0.155	0.114	0.136
5	0.121	0.148	0.135	0.107
6	0.127	0.099	0.114	0.099
7	0.087	0.141	0.090	0.113
8	0.138	0.155	0.116	0.155
9	0.159	0.151	0.155	0.130
10	0.136	0.133	0.133	0.121

(a.m.: 5.30–6.30. p.m.: 3.30–4.30.)

Table VI

Temperatures in Garden I.

Date	Underground (at 0.5 m.)			Atmospheric		
	a. m.	Noon	p. m.	a. m.	Noon	p. m.
V–11	24.5	24.7	25.7	24.0	32.5	24.8
12	24.8	25.8	—	21.2	22.6	—
13	—	23.3	—	—	23.5	—
14	—	23.8	—	—	31.7	—
15	—	24.6	—	—	25.0	—
16	—	24.7	—	—	30.0	—
17	—	—	—	—	—	—
18	—	25.0	—	—	34.0	—
19	—	25.2	—	—	30.9	—
20	—	25.6	—	—	32.0	—
21	—	26.4	—	—	34.7	—
22	—	26.5	—	—	34.5	—
23	—	26.8	—	—	35.0	—
24	—	26.8	—	—	32.5	—
25	—	26.6	—	—	27.9	—
26	—	25.7	—	—	30.0	—
27	25.5	25.9	26.4	23.5	30.2	28.7
28	26.0	25.8	26.2	24.5	30.0	31.0
29	26.5	26.2	26.5	25.5	35.2	30.0
30	26.5	26.3	26.5	24.0	30.0	27.2
31	26.0	26.0	25.8	25.5	25.0	25.0
VI– 1	25.5	25.5	25.0	23.0	24.0	23.0
2	24.8	25.0	25.3	21.5	30.6	28.0
3	24.7	24.8	25.4	21.5	31.6	29.5
4	25.0	25.0	25.5	22.5	29.9	27.8
5	25.0	25.2	25.5	23.0	32.8	29.0
6	25.5	25.6	26.0	25.0	34.0	31.5
7	25.5	25.8	25.8	23.5	27.9	27.9
8	25.0	25.2	25.8	23.5	30.7	28.2
9	25.5	25.6	26.2	23.5	33.0	30.0
10	25.5	26.0	25.8	23.5	30.5	29.1

Table VI

(*Continued*)

Date	Underground			Atmospheric		
	a. m.	Noon	p. m.	a. m.	Noon	p. m.
V—11	25.5	25.5	26.0	24.4	31.0	25.0
12	26.5	25.4	—	—	22.5	—
13	—	24.4	—	—	25.7	—
14	—	24.5	—	—	33.3	—
15	—	25.4	—	—	24.3	—
16	—	24.3	—	—	32.0	—
17	—	—	—	—	—	—
18	—	25.8	—	—	32.8	—
19	—	26.0	—	—	30.1	—
20	—	26.4	—	—	34.2	—
21	—	27.0	—	—	35.0	—
22	—	27.2	—	—	34.5	—
23	—	27.5	—	—	35.0	—
24	—	27.5	—	—	33.0	—
25	—	27.5	—	—	29.4	—
26	—	26.5	—	—	29.8	—
27	27.0	26.5	26.5	23.0	31.0	30.0
28	27.0	24.8	26.8	24.0	30.0	32.0
29	—	27.0	27.0	25.0	36.5	30.0
30	27.0	26.9	27.0	24.0	30.8	29.0
31	26.7	26.5	26.5	25.0	25.4	25.0
VI— 1	26.0	26.0	25.5	23.0	25.0	24.5
2	25.5	25.5	25.5	22.0	31.0	28.0
3	25.5	25.5	25.5	21.5	30.8	29.2
4	26.0	25.3	26.0	22.5	29.0	27.8
5	25.5	25.6	26.5	23.0	32.0	32.5
6	26.0	26.0	—	25.0	34.0	—
7	26.5	27.0	27.0	23.5	28.0	28.0
8	26.0	25.0	26.0	22.5	31.0	29.0
9	26.2	26.0	26.3	23.5	32.8	30.0
10	26.5	26.5	26.5	24.5	31.8	28.9

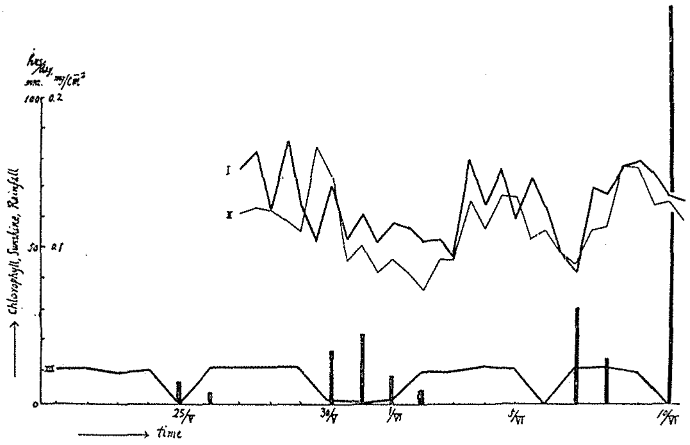
Table VII

Tyuryo Observatory.

Date	Max. temp.	Min. temp.	Insolation	Rainfall
V—11	29	24	8.6	
12	23	19	9.5	11.5
13	25	18	11.5	0.9
14	30	20	6.9	0.1
15	25	23	0.0	11.5
16	27	22	10.9	71.5
17	29	24	11.2	
18	29	22	10.9	
19	29	22	10.5	
20	30	24	11.3	
21	31	26	11.6	
22	31	25	12.0	
23	32	25	10.6	
24	30	25	11.9	
25	28	24	0.0	7.5
26	29	23	11.8	3.8
27	29	23	12.1	
28	30	23	11.9	
29	31	24	12.0	
30	29	24	1.2	18.0
31	26	23	0.0	23.0
VI— 1	26	23	0.8	9.0
2	27	22	10.9	5.0
3	29	20	11.2	
4	27	22	12.3	
5	30	22	12.2	
6	32	23	0.0	
7	29	23	11.9	32.5
8	28	22	12.3	15.7
9	29	23	11.2	
10	29	23	0.0	131.0

Fig. 2.

Chlorophyll-Contents (I, II), Sunshine (III) and Rainfall (Columns)



In the course of the investigations, the effect of stagnant water in the soil upon the chlorophyll-content (cf. I) was studied, because it was noticed on Sept. 2, 1930 that the chlorophyll-content in the leaves of "Hayaue-" 2725 POJ at the Koken Experimental Station, languishing from the water-logged condition of the soil, was lower than in the normally growing ones, as is shown in the following table:

Table VIII

	Suffering from water logged conditions	Normal
Length of stalk (cms.)	174	225
Weight of stalk (gms.)	1109	1324
Number of internodes	18	20
Chlorophyll (mgms/cm.^{2})	0.069	0.115

As may be seen in the accompanying figure (Fig. 2) the chlorophyll-content was also observed to be affected by insolution, but further investigation is required to elucidate the influence of environment upon the chlorophyll-content.

The Stalk.

In preparing samples of the cane stalk for analysis, the usual way is to cut it into three or ten portions of equal length[1], but this method, as remarked by Booberg[2], can hardly be applied in the study of "doorgroei". The method proposed by Went, of dividing the stalk by nodes, is not only too tedious in manipulation but also inapplicable to stalks with different numbers of internodes. In the present case, therefore, the method adopted throughout this experiment, was to cut the stalks in the manner shown schematically in Fig. 3, this method being based on the fact that a certain correlation exists between the size of the stalk and its chemical composition.

In the experiment, both 2725 POJ and 2878 POJ canes were sampled from time to time, at intervals of 20 days. The whole length and weight were measured and then each sample was divided into certain portions and the length and weight of every portion was measured, with the results shown in Tables IX, and X Fig. 4.

Fig. 3
Method of Division of Stalk.

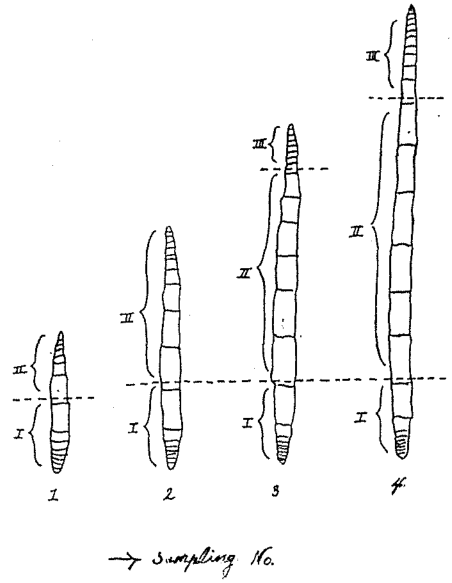


Table XI shows the number of internodes of a single stalk and that of every portion of the stalk.

1. Kuyper: Archief (1922) II, p. 251.
2. Verslagen (1929) p. 289.

In Table XII and Fig. 5, the mean length and weight of a single internode in the stalk and the stalk-portions are shown.

Table IX

Length & Weight of Stalk.

No.	2725 POJ Date	2725 POJ Length cms.	2725 POJ Weight gms.	2878 POJ Date	2878 POJ Length cms.	2878 POJ Weight gms.
1	III—10	31	189	III—10	44	258
2	IV— 1	32	185	IV— 1	54	331
3	21	51	358	21	63	388
4	V— 8	53	359	V— 8	73	467
5	VI— 2	118	919	VI— 2	123	850
6	23	182	1498	25	190	1346
7	VII—15	217	1656	VII—17	231	1433
8	VIII— 4	228	1573	VIII— 6	305	2082
9	25	289	2203	27	315	2120
10	IX—15	333	2325	IX—17	337	2323
11	X— 6	351	2609	X— 8	346	2196
12	24	365	2511	27	349	2123
13	XI—17	390	3064	XI—19	369	2475
14	XII— 5	404	3024	XII— 8	377	2341
15	28	375	2597	30	368	2286
16	I—18	363	2684	I—20	384	2463
17	II—10	393	3200	II—12	388	2559

(cf. Fig. 1)

Fig. 4

Weight & Length of Stalk.

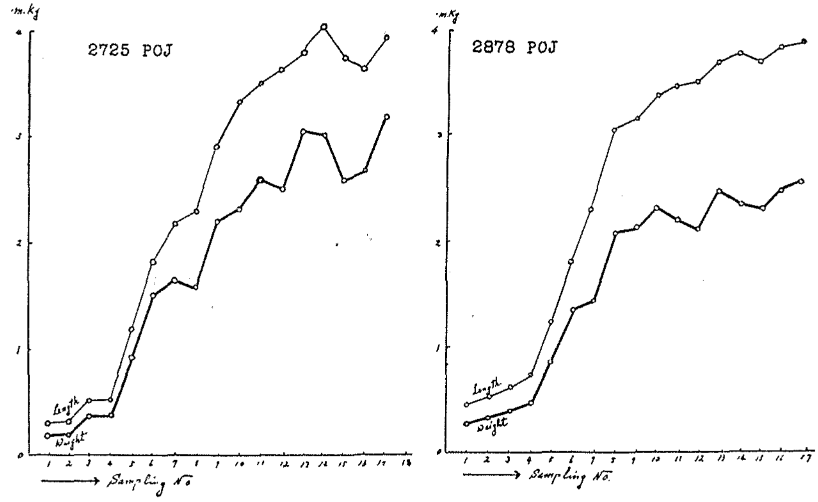


Table X

Length & Weight of Each Portion of Stalk.

No.	2725 POJ									
	Length (cms.)					Weight (gms.)				
	Stalk portion					Stalk portion				
	I	II	III	IV	V	I	II	III	IV	V
1	21	10				145	44			
2	24	8				138	47			
3	20	31				179	179			
4	27	26				222	137			
5	51	68				459	460			
6	55	64	63			498	588	414		
7	55	81	81			488	634	534		
8	40	78	86	34		329	605	512	128	
9	42	85	101	61		424	757	669	354	
10	45	83	101	104		387	701	682	555	
11	42	91	109	109		367	815	796	631	
12	39	94	115	117		329	794	769	619	
13	38	116	117	92	27	371	1134	912	567	80
14	38	111	123	107	25	356	988	960	656	64
15	30	109	107	90	32	313	857	765	571	91
16	38	97	102	104	22	389	877	745	619	56
17	33	103	114	109	34	327	1042	910	796	126

	2878 POJ									
1	34	10				216	43			
2	33	21				236	96			
3	28	35				205	183			
4	36	37				292	175			
5	46	77				350	500			
6	54	92	44			435	707	205		
7	41	88	102			229	604	491		
8	51	84	107	63		417	665	711	289	
9	45	89	116	65		387	712	745	276	
10	44	97	109	87		387	804	689	433	
11	45	102	113	86		388	760	667	381	
12	41	99	110	99		351	719	635	418	
13	39	101	110	95	23	334	840	735	487	80
14	38	106	111	96	26	307	814	686	465	69
15	38	94	104	95	39	313	739	658	462	114
16	37	104	120	108	25	304	797	796	510	64
17	29	100	121	116	22	264	852	843	550	51

Table XI

Number of Internodes.

No.	2725 POJ					
	Whole stalk	Stalk portion				
		I	II	III	IV	V
1	15.1	9.0	6.1			
2	14.5	8.8	5.7			
3	17.0	9.0	8.0			
4	16.2	9.6	6.6			
5	19.6	11.5	8.1			
6	24.5	11.9	6.0	6.6		
7	27.7	13.1	6.2	8.4		
8	25.9	10.1	6.5	6.0	3.3	
9	29.1	9.5	6.0	6.0	7.6	
10	34.0	10.4	7.1	6.1	10.4	
11	35.6	8.5	8.2	7.4	11.4	
12	37.0	9.6	7.8	7.6	12.0	
13	42.5	8.0	8.8	9.2	9.7	6.8
14	43.6	9.0	9.2	8.6	10.3	5.5
15	40.8	9.6	7.6	7.0	9.4	7.2
16	40.0	8.0	7.7	7.0	10.2	7.1
17	41.5	8.7	8.6	7.5	10.7	6.0

	2878 POJ					
1	13.7	8.7	5.0			
2	15.0	10.1	4.9			
3	15.4	8.7	6.7			
4	15.8	9.6	6.2			
5	18.1	10.7	7.4			
6	24.2	13.4	6.0	4.8		
7	22.4	9.1	6.0	7.3		
8	28.5	10.5	6.4	6.0	5.6	
9	29.2	11.9	6.1	6.0	5.2	
10	32.1	9.0	6.4	6.1	10.6	
11	34.7	9.6	7.1	6.4	11.6	
12	34.6	8.7	6.5	6.2	13.2	
13	33.8	7.0	6.4	6.1	8.7	5.6
14	38.6	8.8	8.0	6.2	9.4	6.2
15	37.3	8.7	6.6	6.1	8.7	7.2
16	38.4	7.8	8.0	6.9	10.5	5.2
17	39.4	7.2	7.9	7.5	11.1	5.7

Table XII

Length & Weight of Single Internode.

No.	2725 POJ					
	Length (cms.)					
	Whole stalk	Stalk portion				
		I	II	III	IV	V
1	2.1	2.4	1.7			
2	2.2	2.7	1.5			
3	3.0	2.3	3.8			
4	3.3	2.8	3.9			
5	6.0	4.5	8.2			
6	7.4	4.5	10.6	9.5		
7	7.8	4.2	13.1	9.6		
8	8.8	3.9	11.9	14.3	10.1	
9	9.9	4.5	14.2	16.8	8.7	
10	9.8	4.5	11.7	16.5	9.7	
11	9.8	4.9	11.1	14.6	9.5	
12	9.9	4.1	12.0	15.1	9.7	
13	9.2	4.7	13.1	12.7	9.5	4.4
14	9.3	4.2	12.3	14.3	10.4	3.9
15	9.2	3.1	14.4	15.3	9.6	4.5
16	9.1	4.8	12.6	14.6	10.2	3.1
17	9.5	3.8	12.0	15.2	10.2	5.7

	2725 POJ					
1	13	16	7			
2	13	16	8			
3	21	20	22			
4	22	23	21			
5	47	40	57			
6	61	42	98	63		
7	56	37	102	64		
8	61	33	93	85	39	
9	76	45	126	111	47	
10	86	39	99	112	53	
11	73	43	99	107	55	
12	68	33	102	101	52	
13	72	46	128	99	58	12
14	69	40	108	112	64	10
15	64	33	113	110	61	13
16	67	49	114	116	61	8
17	77	38	101	121	74	21

Table XII

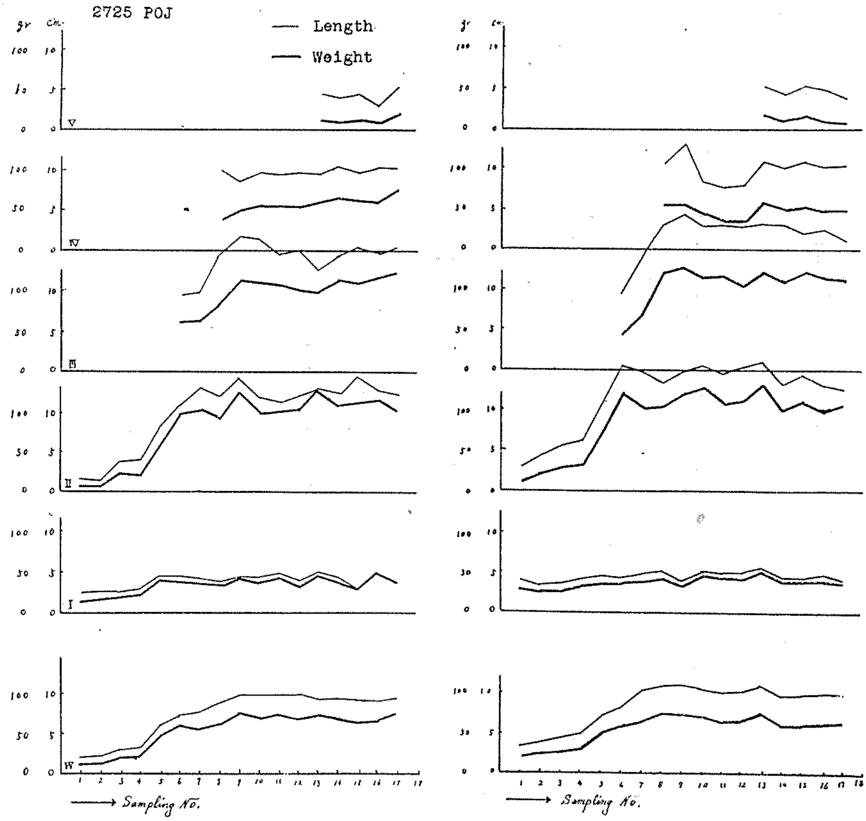
(*continued*)

No.	2878 POJ					
	Length (cms.)					
	Whole stalk	Stalk portion				
		I	II	III	IV	V
1	3.2	3.9	2.6			
2	3.6	3.2	4.3			
3	4.1	3.3	5.2			
4	4.6	3.8	5.9			
5	6.8	4.3	10.4			
6	7.9	4.1	15.3	9.2		
7	10.3	4.5	14.6	14.1		
8	10.7	4.9	13.2	17.9	10.3	
9	10.8	3.8	14.7	19.2	12.8	
10	10.5	4.9	15.2	17.8	8.2	
11	10.0	4.7	14.4	17.7	7.4	
12	10.1	4.7	15.2	17.6	7.6	
13	10.9	5.5	15.8	17.9	10.9	5.0
14	9.8	4.3	13.2	18.0	10.2	4.2
15	9.9	4.1	14.2	17.0	10.9	5.4
16	10.0	4.7	13.0	17.4	10.2	4.8
17	9.9	4.0	12.7	16.1	10.4	3.8

2878 POJ						
1	19	25	9			
2	22	23	20			
3	25	24	27			
4	30	30	28			
5	47	38	68			
6	56	33	118	43		
7	64	37	101	67		
8	73	40	104	119	52	
9	73	53	118	124	53	
10	72	43	126	112	41	
11	63	41	107	114	33	
12	62	40	111	102	32	
13	73	48	131	120	56	14
14	61	35	102	111	50	11
15	61	36	112	120	53	16
16	64	39	100	115	49	12
17	65	37	108	113	49	9

Fig. 5

Length & Weight of Single Internode



From these following results, the change of weight with thickness at each portion of stalk, and the weight per unit length of stalk were calculated, and the results given in Table XIII and Fig. 6 show that when the cane stalk is divided in the manner shown therein, each corresponding portion has an equal value of weight per unit length of stalk.

1. Juice.

The chemical nature of the cell-sap of every portion of the stalk was examined in order to see the effect of the state of vegetation of the plant on it; the stalk was cut into halves longitudinally, and one

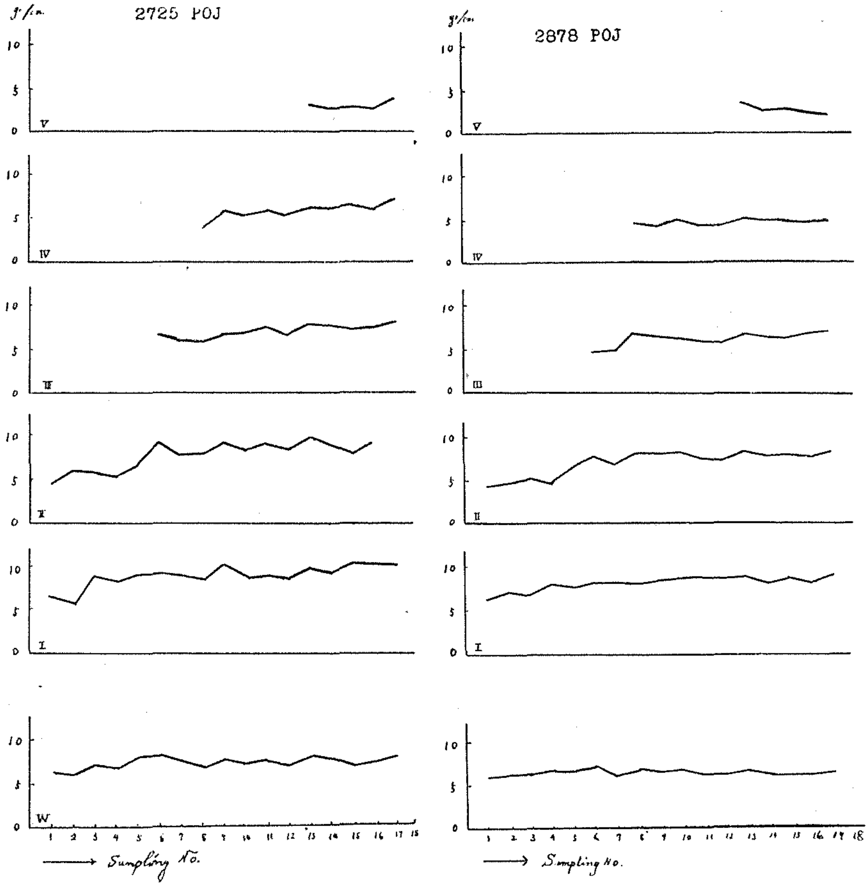
Table XIII

Weight of Unit Length of Stalk (gms./cms.)

No.	Whole stalk	Stalk portion I	II	III	IV	V
	2725 POJ					
1	6.1	6.7	4.4			
2	5.8	5.8	5.9			
3	7.0	8.8	5.8			
4	6.8	8.1	5.3			
5	7.8	8.9	6.8			
6	8.2	9.1	9.2	6.6		
7	7.6	8.8	7.8	6.0		
8	6.9	8.3	7.8	5.9	3.8	
9	7.6	10.0	9.0	6.6	5.8	
10	7.0	8.6	8.4	6.8	5.3	
11	7.4	8.7	8.9	7.3	5.8	
12	6.9	8.4	8.4	6.7	5.3	
13	7.9	9.7	9.8	7.8	5.3	3.0
14	7.5	9.4	8.9	7.8	6.1	2.6
15	6.9	10.2	7.9	7.2	6.4	2.8
16	7.4	10.0	9.0	7.3	6.0	2.5
17	8.1	9.9	10.1	8.0	7.3	3.7
	2878 POJ					
1	5.9	6.4	4.3			
2	6.1	7.2	4.6			
3	6.3	7.0	5.2			
4	6.4	8.1	4.7			
5	6.9	7.6	6.5			
6	7.1	8.0	7.7	4.7		
7	6 2	8.2	6.9	4.8		
8	6.8	8.1	7.9	6.6	4.6	
9	6.7	8.5	8.0	6.5	4.3	
10	6.9	8.7	8.2	6.3	5.0	
11	6.3	8.6	7.4	5.9	4.4	
12	6.1	8.6	7.3	5.8	4.2	
13	6.7	8.7	8.3	6.7	5.1	3.5
14	6.2	8.1	7.7	6.2	4.9	2.7
15	6.2	8.7	7.9	6.3	4.9	2.9
16	6.4	8.3	7.6	6.6	4.7	2.5
17	6.6	9.1	8.5	7.0	4.8	2.3

Fig. 6

Weight of Unit Length of Stalk



part was crushed with the test-mill and the juice was thrown away; then the other part was milled twice, the juice was collected for examination, and the volume of juice and the weight of bagasse for the whole stalk were calculated.

A. Acidity of the juice: This was determined by titration with a standard alkali solution, phenolphthalein being used as the indicator, and expressed in milliequivalent per 100 c.c. and also the pH-value was determined at room-temperature with Dr. Itano's quinhydrone-electrode apparatus. The results are shown in Table XIX.

B. Total solid in juice: This was estimated by the aerometric method, but when there was not sufflicient juice, the refractometric

Table XIX

Acidity and pH of Juice.

No.	2725 POJ									
	Acidity					pH				
	I	II	III	IV	V	I	II	III	IV	V
1	1.3	2.9				5.3	4.7			
2	1.4	2.7				5.0	4.8			
3	1.8	2.1				5.3	4.8			
4	2.0	2.1				5.4	4.1			
5	1.8	2.0				4.9	4.7			
6	1.1	0.6	0.9			5.3	5.2	4.7		
7	—	—	—			5.5	5.3	4.8		
8	2.1	1.1	0.7	2.1		5.1	5.1	5.0	5.0	
9	2.7	2.5	2.1	2.5		5.2	4.9	5.0	4.7	
10	1.4	0.7	0.7	1.6		5.0	5.1	4.9	5.0	
11	1.4	0.9	1.1	1.3		5.4	5.2	5.1	4.9	
12	1.4	0.7	0.7	1.4		4.8	4.8	4.7	4.7	
13	0.9	0.7	0.7	1.1	2.7	—	—	—	—	—
	2878 POJ									
1	1.2	3.4				5.6	4.8			
2	1.3	3.9				5.2	4.7			
3	1.3	2.0				5.3	4.8			
4	1.8	2.0				5.2	5.1			
5	2.1	2.5				4.8	4.7			
6	1.7	0.8	1.9			5.2	5.0	4.8		
7	—	—	—			5.1	5.2	4.8		
8	2.5	1.4	1.4	1.8		4.9	4.8	4.7	4.7	
9	2.5	2.5	1.8	2.5		5.1	5.0	5.2	4.8	
10	1.8	1.1	0.7	1.1		5.1	5.0	4.9	4.9	
11	1.6	1.4	1.6	1.1		5.5	5.3	5.1	4.9	
12	1.4	1.1	1.1	1.3		5.1	4.8	4.8	4.7	
13	1.1	0.8	0.6	0.9	2.5	5.4	5.0	5.1	4.9	4.8

Table XX

Total Solid (Brix) in Juice.

No.	2725 POJ					
	W	I	II	III	VI	V
1	11.2	12.1	5.4			
2	10.8	12.1	5.3			
3	10.7	13.0	8.0			
4	11.8	13.5	8.6			
5	8.1	10.8	6.1			
6	9.3	13.0	8.6	6.1		
7	8.1	11.2	8.3	5.6		
8	9.4	12.3	9.9	7.9	6.4	
9	10.1	12.5	10.9	9.5	6.6	
10	11.0	13.6	11.7	11.1	8.3	
11	13.4	16.0	14.3	14.0	9.9	
12	14.4	17.1	14.8	14.4	12.2	
13	17.5	19.2	18.0	17.6	15.3	13.1
14	17.2	18.1	17.7	17.1	16.5	8.3
15	19.1	18.5	19.3	19.3	19.1	14.6
16	19.6	19.5	19.9	19.4	19.5	14.9
17	20.3	20.0	20.4	20.4	20.4	18.6

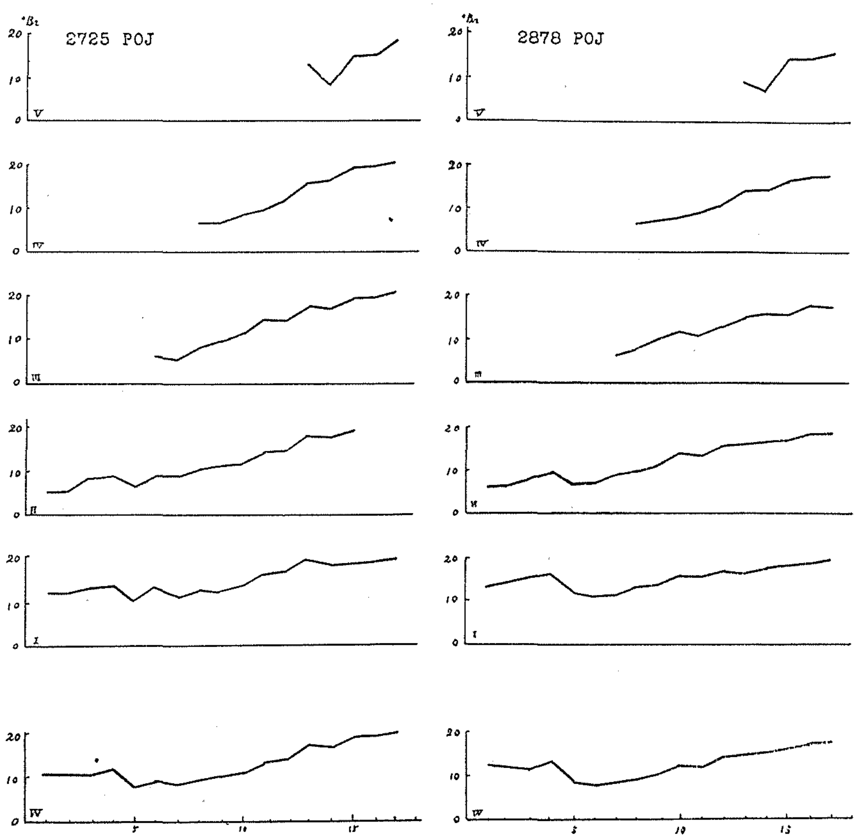
2878 POJ

No.	W	I	II	III	VI	V
1	12.7	13.0	6.1			
2	12.0	14.1	6.3			
3	11.7	15.3	7.5			
4	13.5	16.2	9.3			
5	8.8	11.9	6.6			
6	7.8	11.1	6.8	—		
7	8.7	11.5	8.5	6.3		
8	9.1	13.2	9.5	7.8	6.3	
9	10.5	13.8	11.0	9.6	6.8	
10	12.4	15.6	13.8	11.4	7.9	
11	12.2	15.6	13.2	11.0	8.8	
12	14.1	16.7	15.4	12.9	10.8	
13	15.1	16.4	15.6	14.9	13.7	8.5
14	15.5	17.3	16.5	15.3	14.1	7.1
15	16.2	17.9	16.9	15.6	16.1	14.1
16	17.5	18.3	18.0	17.2	16.9	14.4
17	17.7	18.9	18.2	17.1	17.4	15.1

method was used, and the results, after correcting for temperature, were expressed in degrees Brix at 20°C (Table XX & Fig. 7.)

Fig. 7

Total Solid in Juice.



C. Total and reducing sugars: The sugar content of the juice was estimated by the Bertrand method and also by measuring its rotatory power before and after being heated with 3% sulphuric acid in a water-bath at about 70°C for three hours. The results expressed as d-glucose are shown in Tables XXI & XXII and Figs. 8 and 9.

The acidity of the juice, as shown in Table XIX, presents a high value with a low pH-value. This is especially so in the case of the juice of the upper portion of the stalk owing to the formation of

Table XXI

Reducing & Non-Reducing Sugars in Juice.

No.	2725 POJ					
	Red. sug. (gms./100 c.c.)					
	W	I	II	III	IV	V
1	1.6	1.6	2.0			
2	2.1	2.1	2.2			
3	3.1	1.6	4.9			
4	3.7	3.1	4.8			
5	3.9	3.5	4.3			
6	3.8	2.3	4.4	4.5		
7	4.1	3.4	4.8	3.8		
8	4.0	2.7	4.5	4.4	3.7	
9	4.1	3.1	4.2	4.6	3.9	
10	4.3	2.9	4.3	4.7	4.8	
11	3.8	1.8	3.7	4.0	4.8	
12	3.8	2.1	3.7	4.1	4.5	
13	2.5	1.0	2.4	2.8	3.3	3.8
14	2.2	1.0	2.0	2.5	2.6	2.4
15	1.5	0.7	1.5	1.5	1.7	2.1
16	1.2	0.7	1.1	1.3	1.5	1.2
17	2.2	1.5	2.6	2.2	1.8	1.8

2878 POJ

1	2.0	2.0	2.9			
2	2.3	1.9	3.4			
3	3.3	2.0	5.0			
4	3.4	2.2	5.5			
5	3.8	3.0	4.4			
6	3.7	2.9	4.3	2.7		
7	4.6	3.4	5.4	4.3		
8	4.7	2.6	5.3	5.2	4.4	
9	5.2	3.5	5.7	5.7	4.4	
10	3.9	2.2	4.7	5.3	5.0	
11	5.3	2.5	5.5	6.4	5.4	
12	4.4	1.9	4.4	5.5	4.9	
13	3.9	1.7	3.7	4.9	4.4	4.1
14	3.4	1.0	3.1	4.3	3.9	3.3
15	3.0	0.9	2.9	3.8	3.0	3.2
16	2.4	0.9	2.2	3.0	2.6	2.3
17	2.4	0.6	2.0	3.2	2.4	2.4

Table XXI

(*continued*)

No.	2725 POJ					
	Non-red. sug. (gms./100 c.c.)					
	W	I	II	III	IV	V
1	8.1	9.1	1.3			
2	7.1	8.3	0.9			
3	5.5	9.6	0.9			
4	7.0	4.6	2.0			
5	2.7	5.3	0.1			
6	2.8	8.4	1.9	0.2		
7	3.0	6.2	2.0	0.7		
8	4.2	8.3	4.6	2.2	0.7	
9	5.0	8.4	6.0	3.7	1.2	
10	5.7	9.9	6.3	5.7	2.2	
11	9.5	14.6	10.6	9.7	4.8	
12	10.4	14.9	11.4	8.1	6.7	
13	14.8	17.8	16.0	14.6	11.9	4.8
14	14.7	16.7	15.5	14.5	13.3	4.2
15	17.4	17.7	17.9	17.6	16.7	11.1
16	18.4	19.2	18.8	18.0	18.0	10.8
17	17.4	17.8	17.1	17.4	17.9	15.5

2878 POJ

1	9.1	9.8	1.2			
2	8.2	11.0	0.9			
3	5.2	12.3	0.8			
4	9.2	13.3	2.3			
5	3.4	6.4	1.3			
6	2.0	5.8	0.5	—		
7	2.1	5.9	1.5	0.5		
8	3.2	8.7	3.0	1.5	0.7	
9	3.8	8.1	4.3	2.1	0.9	
10	7.3	12.3	8.3	4.7	1.3	
11	6.3	12.0	7.1	4.0	1.8	
12	10.1	13.6	10.3	7.4	5.1	
13	10.3	14.0	11.5	9.0	8.0	1.8
14	12.0	16.4	13.3	11.0	9.7	2.6
15	13.1	16.4	14.0	11.2	12.9	8.1
16	14.9	17.3	15.8	13.9	13.9	9.1
17	14.6	17.3	15.3	13.3	14.5	12.5

Table XXII

Specific Rotation of Total Sugar in Juice.

No.	2725 POJ					2878 POJ				
	I	II	III	IV	V	I	II	III	IV	V
1	55.2	10.4				56.8	8.3			
2	51.2	5.5				54.3	−10.2			
3	57.8	1.9				60.0	− 1.6			
4	42.2	7.6				52.3	10.0			
5	39.6	−6.8				46.8	−17.9			
6	55.3	25.4	−6.7			51.1	6.9	−17.9		
7	48.9	23.4	−3.3			47.7	16.2	− 1.8		
8	47.9	31.6	15.3	3.5		56.2	25.5	9.3	1.4	
9	49.5	37.6	25.8	2.0		52.7	25.2	18.7	−0.5	
10	47.8	42.5	31.5	12.3		55.0	41.7	11.6	5.6	
11	54.8	50.6	48.3	25.7		59.9	42.3	27.0	14.2	
12	60.0	50.4	48.1	38.6		60.5	49.6	36.7	31.6	
13	58.2	52.2	50.8	43.4	7.5	54.2	46.0	37.8	37.3	8.4
14	64.7	62.8	57.0	57.2	37.5	65.0	57.2	47.6	47.8	21.5
15	66.7	64.8	65.1	65.1	51.6	64.8	54.8	51.6	51.0	45.5
16	66.0	66.0	64.7	63.6	58.2	65.1	60.8	56.6	56.2	53.2
17	68.0	67.8	67.4	67.2	65.2	68.2	63.0	56.8	57.8	40.7

Table XXIII

Molar Concentration of Sugars in Juice.

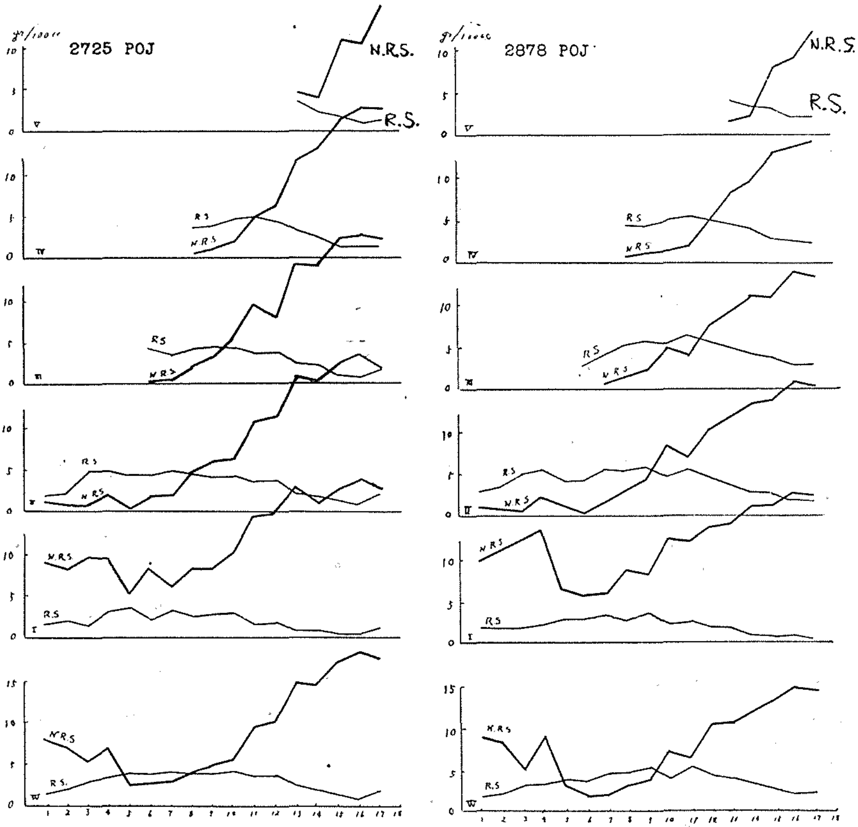
No.	2725 POJ					2878 POJ				
	I	II	III	IV	V	I	II	III	IV	V
1	0.34	0.15				0.38	0.20			
2	0.35	0.15				0.41	0.20			
3	0.36	0.30				0.45	0.30			
4	0.44	0.32				0.49	0.37			
5	0.34	0.24				0.35	0.28			
6	0.36	0.30	0.26			0.32	0.25	0.15		
7	0.36	0.32	0.23			0.35	0.31	0.25		
8	0.38	0.38	0.31	0.23		0.39	0.38	0.33	0.27	
9	0.41	0.40	0.39	0.25		0.42	0.44	0.38	0.27	
10	0.44	0.41	0.42	0.33		0.47	0.49	0.43	0.31	
11	0.51	0.50	0.49	0.40		0.47	0.50	0.46	0.35	
12	0.53	0.52	0.45	0.44		0.49	0.53	0.51	0.41	
13	0.55	0.57	0.56	0.52	0.35	0.49	0.53	0.52	0.47	0.28
14	0.54	0.56	0.56	0.53	0.26	0.53	0.56	0.56	0.50	0.26
15	0.55	0.60	0.60	0.57	0.44	0.53	0.57	0.54	0.54	0.41
16	0.60	0.61	0.60	0.61	0.38	0.55	0.58	0.57	0.55	0.39
17	0.60	0.64	0.63	0.62	0.55	0.54	0.56	0.57	0.56	0.50

organic acids in considerable quantities by oxidation of sugar, which will occur intensively in the younger parts of the stalk.

The changes in the total solid-content (Table XX, Fig. 7) are quite analogous with those in the content of non-reducing sugar (Table XXI, Fig. 8). The sugar content of the whole or of the lowest portion of the stalk shows the minimum in June and thereafter increase steadily, but that of the upper portions increases with time.

Fig. 8

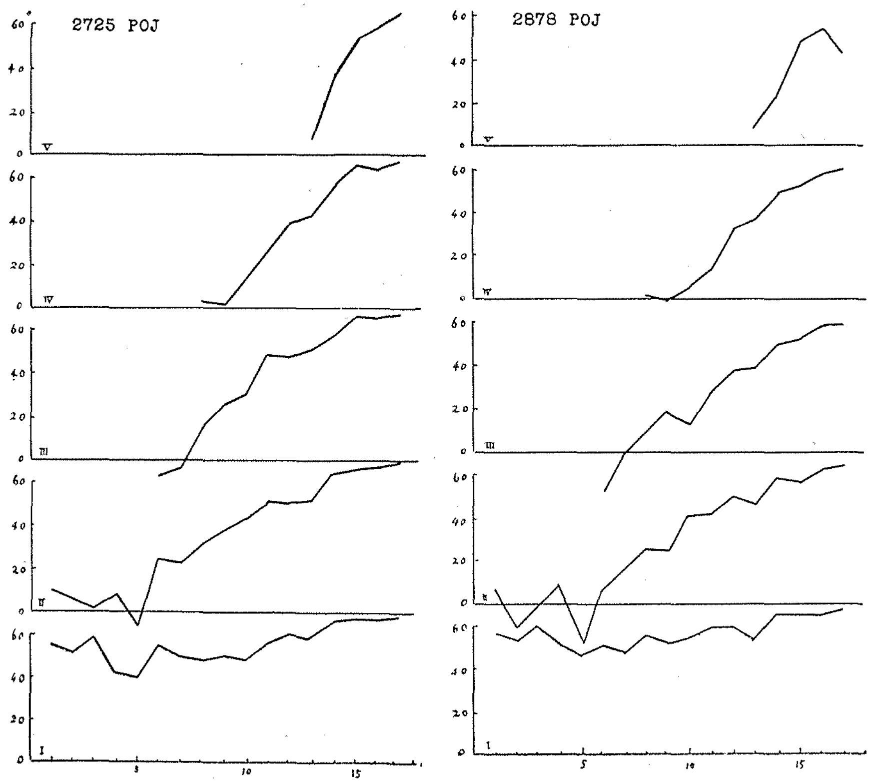
Reducing & Non-Reducing Sugars in Juice.



The changes in the reducing-sugar content (Tables XXI & XXII, Fig. 8 and 9) are quite different from those in the non-reducing sugar, the former showing the maximum when the latter is at the minimum.

Fig. 9

Specific Rotation of Total Sugar in Juice.



The sugar-content, being concerned mostly with the juice-solid and also the osmotic pressure of the cell-sap, is expressed in terms of molar concentration and the results are shown in Table XXIII and Fig. 10.

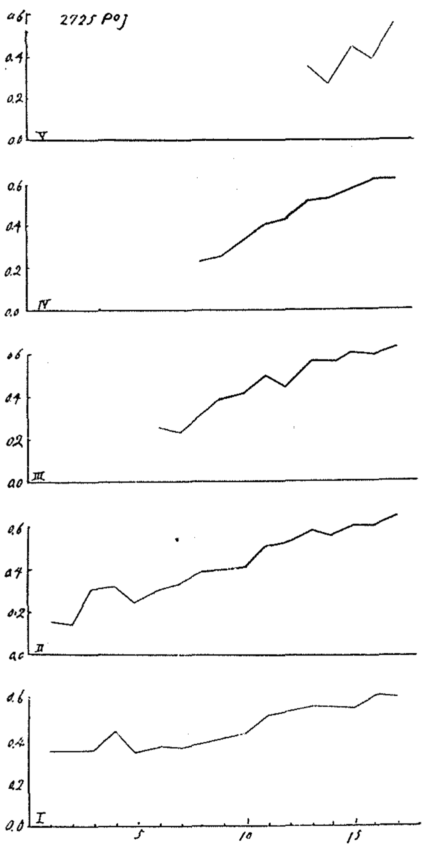
The full-grown portions in every single stalk are quite similar to each other in sugar concentration (such values are shown in the graph by thick lines) while the top portion shows only lower values owing to the vigorous metabolic changes.

2. The Chemical Constituents of the Stalk.

The moisture, reducing and non-reducing sugar and crude fibre content of the stalks was estimated. The moisture content in the stalk was estimated by drying to constant weight in an air-oven heated

Fig. 10

Molar Concentration of Sugars in Juice.



electrically to 105°C, and the results are shown in Table XXIV and Fig. 11.

The sugar-content: The residue left after the juice had been expressed by the test-mill, usually called "bagasse", was chipped as finely as possible, and treated twice with boiling water for one hour or half an hour. The sugars extracted with boiled water were estimated in the usual way, and the results, combined with the sugar content of the juice, are expressed as the whole content of sugars in the stalk-portion are shown in Table XXV and Fig. 12.

The fibre: The residue left after the sugar had been extracted from the bagasse was recorded as crude "fibre" and is shown in Table XXVI and Fig. 13.

Table XXIV

Moisture in Stalk (%)

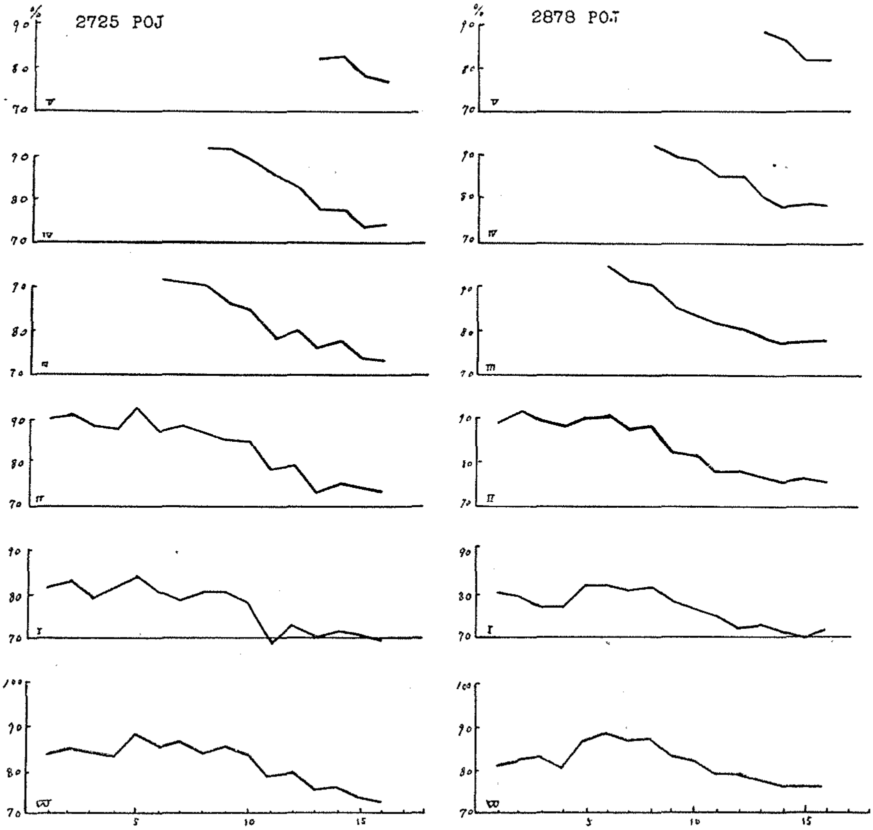
No.	2725 POJ					
	W	I	II	III	IV	V
1	83.8	81.9	90.0			
2	85.2	83.3	90.9			
3	84.1	79.5	88.7			
4	83.9	81.5	87.7			
5	88.2	84.2	92.2			
6	85.9	80.2	87.3	91.6		
7	86.4	78.8	88.2	91.2		
8	84.3	80.8	86.9	90.0	91.7	
9	85.6	80.7	85.1	86.2	91.3	
10	83.9	78.2	84.9	84.9	88.7	
11	78.9	69.8	78.4	78.4	85.3	
12	79.4	73.0	79.1	80.1	82.6	
13	75.3	70.8	73.5	76.7	77.8	82.1
14	76.4	71.8	75.2	77.1	77.6	82.5
15	73.8	70.8	74.4	73.8	73.8	78.1
16	72.9	69.2	72.9	73.1	74.2	76.9
17	—	—	—	—	—	—

2878 POJ

1	81.8	80.4	89.2			
2	82.9	79.4	91.7			
3	83.2	77.6	89.5			
4	81.6	77.7	88.3			
5	87 0	81.9	90.5			
6	88.7	82.1	91.0	94.7		
7	87.5	81.3	87.7	91.3		
8	87.4	81.6	88.5	90.0	92.7	
9	83.7	78.3	82.2	85.6	89.9	
10	82.8	76.8	82.0	83.4	88.8	
11	79.8	75.1	78.0	81.3	85.4	
12	79.3	72.7	77.8	80.7	85.4	
13	77.9	73.5	76.1	78.9	80.7	88.4
14	76.2	71.3	75.2	77.2	78.3	86.6
15	76.4	70.2	76.4	77.8	78.9	82.1
16	76.6	72.7	75.4	77.6	78.7	82.1
17	—	—	—	—	—	—

Fig. 11

Moisture in Stalk.



The mean value of the water-content in the stalks of 2725 POJ cane increased from 84% in March to 88% in May and then decreased gradually with time; the monthly variation in the water-content of of the stalk is proportionately the same as that of the leaves. The younger portion of the stalk usually contains a higher percentage of water than the older portion, owing to the accumulation of water formed by the intracellular oxidation in the plant tissues, but the water-content in the younger stage obviously varies with the season; the young part of the stalk shows the highest water content in June and July (91%). There is no marked difference between the two strains 2725 POJ and 2878 POJ in their water content and its variation.

The reducing-sugar content in the stalks both of 2725 POJ and 2878 POJ changes in the same way as the water-content in every

Table. XXV

Sugars in Stalk (%)

2725 POJ

No.	Red. sug. W	I	II	III	IV	V
1	1.3	1.2	1.7			
2	1.8	1.8	2.0			
3	2.4	1.3	3.5			
4	3.0	2.5	3.7			
5	3.1	2.5	3.6			
6	2.9	1.7	3.4	3.7		
7	3.1	2.3	3.7	3.2		
8	3.2	2.1	3.5	3.5	2.9	
9	3.3	2.4	3.4	3.8	3.3	
10	3.3	2.1	3.2	3.6	4.0	
11	2.9	1.7	2.9	2.9	3.6	
12	2.7	1.6	2.7	2.9	3.0	
13	1.8	0.8	1.7	2.0	2.4	2.5
14	2.1	1.1	1.8	2.4	2.6	3.1
15	1.1	0.7	1.0	1.2	1.3	1.3
16	0.9	0.6	0.9	0.9	1.2	0.7
17	1.6	1.0	1.8	1.7	1.4	1.1

2878 POJ

No.	W	I	II	III	IV	V
1	1.7	1.6	2.3			
2	2.0	1.6	2.9			
3	2.8	1.6	4.2			
4	2.5	1.9	3.6			
5	3.0	2.3	3.5			
6	2.8	2.2	3.3	2.2		
7	3.7	2.5	4.4	3.6		
8	3.6	1.9	4.1	4.3	3.5	
9	3.9	2.4	4.5	4.3	3.5	
10	3.6	1.6	3.6	4.2	4.4	
11	3.9	1.8	3.9	4.7	4.0	
12	3.2	1.4	3.2	3.9	3.7	
13	2.9	1.4	2.6	3.6	3.3	2.4
14	2.4	0.9	2.1	3.1	3.0	2.5
15	2.2	0.8	2.1	2.8	2.7	2.2
16	1.7	0.8	1.5	2.2	1.9	1.2
17	1.8	0.4	1.5	2.5	1.7	1.2

Table XXV

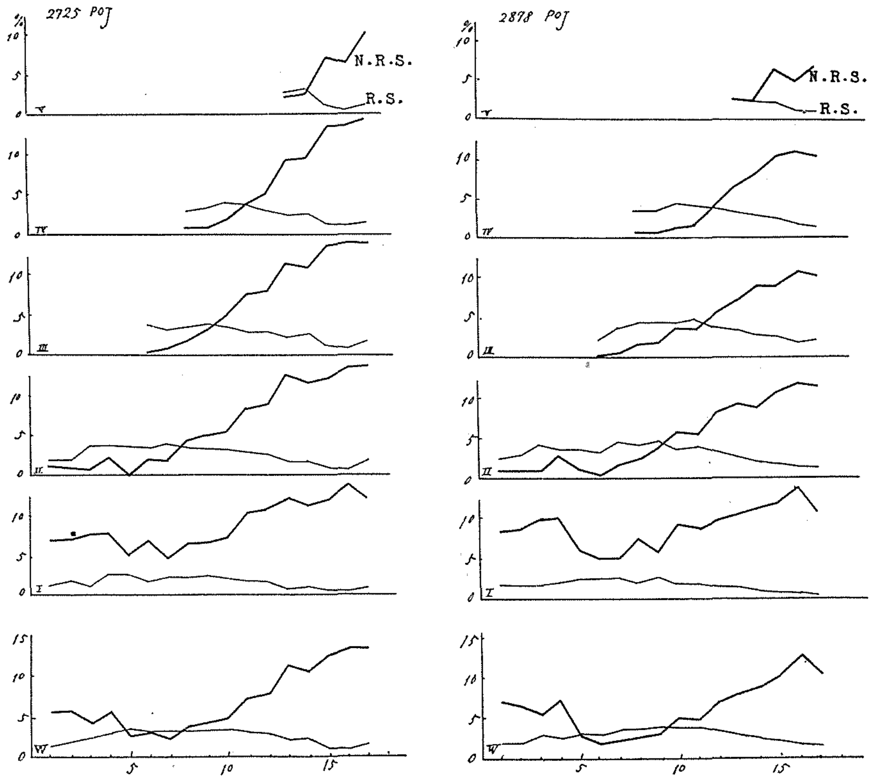
(continued)

No.	2725 POJ					
	Non-red. sug.					
	W	I	II	III	IV	V
1	5.6	6.9	1.2			
2	5.5	7.1	1.0			
3	4.2	7.6	0.9			
4	5.6	7.8	2.1			
5	2.6	5.0	0.1			
6	3.0	6.7	1.9	0.1		
7	2.4	4.8	2.0	0.8		
8	3.6	6.4	4.2	1.8	0.7	
9	4.2	6.6	4.9	3.3	0.9	
10	4.8	7.4	5.4	4.8	2.0	
11	7.2	10.3	8.3	7.4	3.7	
12	7.9	10.8	8.8	8.0	5.0	
13	11.2	12.1	12.4	11.4	9.0	2.3
14	10.6	11.3	11.6	10.8	9.4	2.5
15	12.6	11.9	12.2	13.5	13.5	7.0
16	13.5	13.8	13.4	13.9	13.7	6.4
17	13.6	12.3	13.6	13.9	14.6	10.1

2878 POJ

No.	W	I	II	III	IV	V
1	6.9	8.1	0.8			
2	6.3	8.5	0.8			
3	5.5	9.6	0.8			
4	7.3	10.0	2.8			
5	2.9	5.8	1.0			
6	1.8	4.8	0.4	0.1		
7	2.1	5.0	1.6	0.6		
8	2.8	7.2	2.4	1.5	0.7	
9	3.0	5.8	3.7	1.8	0.7	
10	4.9	9.0	5.7	3.8	1.2	
11	4.8	8.8	5.5	3.8	1.8	
12	6.8	9.7	8.1	5.5	3.9	
13	8.0	10.3	9.3	7.2	6.3	2.4
14	8.9	11.3	8.9	9.0	8.0	2.3
15	10.2	12.2	10.9	9.4	10.1	6.3
16	12.5	13.9	11.9	11.0	10.9	4.7
17	10.9	10.8	11.7	10.5	10.5	6.7

Fig. 12
Reducing & Non-Reducing Sugars in Stalk.



respect, but the non-reducing sugar content changes inversely with the reducing-sugar content. The fibre content of the stalk changes in paralell manner with the non-reducing sugar.

At the end of may and the beginning of June the chlorophyll-content of the leaves, the weight of unit length of stalk and the reducing-sugar content of the stalk attain a maximum while the total solid in the stalk, the juice, fibre and non-reducing sugar content of the stalk are minimum. This is due to the metabolism of the carbohydrates formed by the photosynthesis, and accordingly the cane stalk in a vigorously growing stage is characterized by the presence of organic acids formed by the intracellular oxidation of sugars. Such a relation among the chemical constituents stalks under different environmental conditions was also observed in the chemical composition of stalks of different growing stages and the young and old portions of single stalks. The young portions, corresponding to the stalks in the summer

Table XXVI

Fibre in Stalk (%)

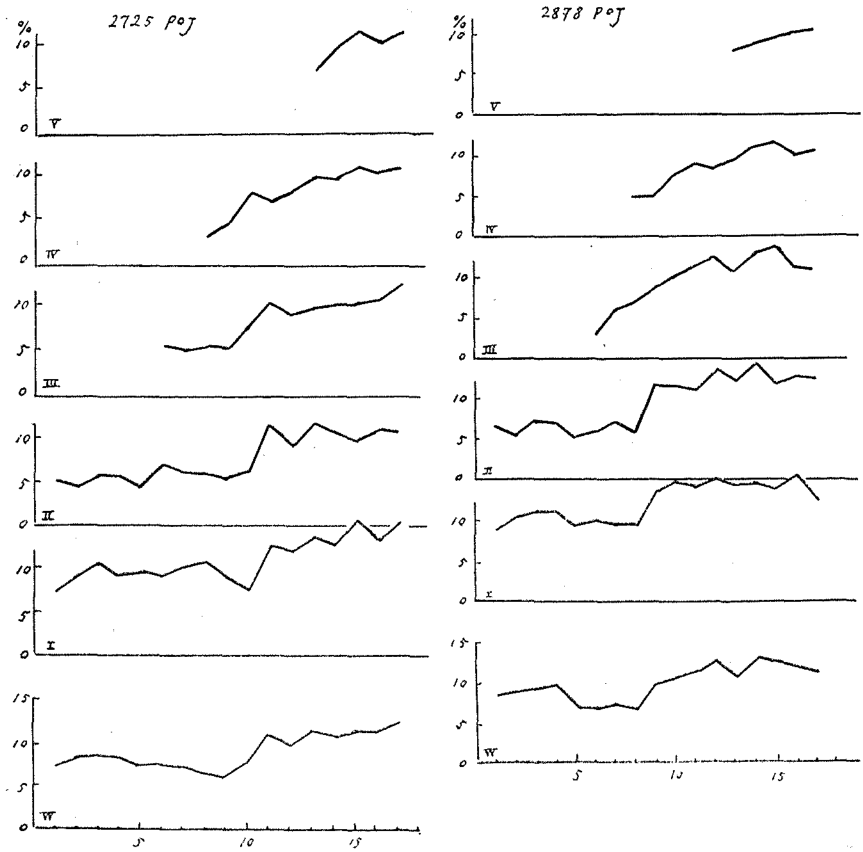
No.	2725 POJ					
	W	I	II	III	IV	V
1	7.2	7.7	5.4			
2	8.2	9.4	4.8			
3	8.4	10.8	6.1			
4	8.4	9.5	6.0			
5	7.3	9.8	4.7			
6	7.5	9.5	7.2	5.9		
7	7.2	10.3	6.3	5.4		
8	6.7	10.7	6.1	5.8	3.4	
9	6.1	8.2	5.8	5.7	4.8	
10	7.6	7.7	6.5	8.0	8.6	
11	10.7	12.7	11.8	11.0	7.7	
12	9.8	12.3	9.5	9.8	8.7	
13	11.3	13.7	12.1	10.3	10.3	7.3
14	11.0	12.9	11.1	10.7	10.2	10.1
15	11.4	15.5	10.3	10.9	11.4	11.7
16	11.5	13.4	11.3	11.4	11.0	10.7
17	12.3	15.3	11.4	13.0	11.3	11.8

2878 POJ

1	8.4	8.8	6.5			
2	8.8	10.2	5.6			
3	9.3	11.0	7.4			
4	9.6	11.1	7.1			
5	7.0	9.4	5.3			
6	6.7	9.9	5.8	2.8		
7	7.2	9.5	7.1	5.7		
8	6.8	9.4	6.1	6.7	5.1	
9	9.8	13.4	11.4	8.3	5.1	
10	10.6	14.7	11.5	9.9	7.6	
11	11 3	14.2	11.2	11.2	8.9	
12	12.5	14.8	13.6	12.3	8.4	
13	10.8	14.3	12.1	10.7	9.4	7.8
14	13.0	14.6	14.3	12.8	10.8	8.4
15	12.4	13.8	11.6	13.6	11.6	9.2
16	11.7	15.2	12.6	10.8	9.8	10.1
17	11.4	12.4	12.5	10.7	10.8	10.5

Fig. 13

Fibre in Stalk.



season, contain much reducing sugar but less non-reducing sugar and fibre.

However, the variation in the chemical composition of the stalk, which is obvious in the young plant, diminishes as the season advances from summer to winter because the vital activity of the process in the plant tissues of the various portions is decreased by the fall in the atomspheric temperature.

Of the environmental conditions, the change in temperature seems to favour the formation of sucrose in the cane body and under these external conditions, the sugar formed by photosynthesis, being consumed in a less degree for the growth of plant is stored in the form of sucrose produced by partial hydrolysis of the parent sugar.

III. The Meaning of Sucrose Accumulation in the Sugar Cane.

By

Shinsaku Ozawa and **Shigeru Komatsu**

The sucrose[1], which is accumulated abundantly in the cane stalk or culm, in some cases as high as 18%, is generally considered as a reserve food stuff[2] by the release of which young branches are caused to spring forth when the cane stalk is under certain environmental conditions. However, the writers are inclined to believe, from their examination of the chemical life-history of the cane, that this high content of sucrose is the result of cultivation and is not produced entirely for the nournishment of the young plant. The following investigation of 5 cases was engaged in from September 1929 to October 1930 to substantiate their theory of the sucrose-accumulation in the cane.

A. Cane cutting or ordinary seed cane.
B. "Rajoengan," another form of seed cane.
C. "Tsunsun," the spring sprout.
D. Arrowing.
E. Vigorous vegetation of young cane.

A. Cane Cutting.

The most common type of seed cane, which is prepared by cutting the young cane culm to contain two nodes, is called the two-eyed cutting. When the cutting is planted, the set-roots and young shoots are sprouted, as shown in plate I, by the release of some substance stored in the cutting, and the chemical changes which take place in the substances in the cutting during the process were studied.

Thirty cuttings of similar size and appearence were prepared on the 26th of September, 1929, from 2725 POJ ratoon cane grown at

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1. Maquenne states that sugar cane contains an average of 20% of sugar. (Les sucres et leurs principaux dérives, (1900) p. 652). But this value seems rather too high for the mean value. 15% may be the reasonable average estimate.
2. Czapek: Biochemie der Pflanzen. (1913) 2te Aufl. I. 284.

Kari, and ten of them were analysed at once. The remainder were planted in river sand to allow them to put out shoots and when the young plants had developed to a certain stage, the reducing and non-reducing sugars in the sets were examined.

The development of the young plants and the changes in the chemical composition of the sets during the course of the investigation are shown in Table XXVII. In the data there given, the weights of the sets, shoots and roots were corrected by reference to the mean initial weight of the single cutting.

Table XXVII

Germination of Seed Cane.

Date	Sept. 26	Oct. 18	Nov. 1
Weight of a cutting (gms.)	171	160	157
Weight of shoots (gms.)	—	12.6	19.8
Weight of roots (gms.)	—	5.7	11.2
Analytical Results of Sets.			
Moisture	82%	86%	87%
Reducing sugars	3.2	2.9	2.2
Non-red. sugars	5.4	2.6	1.7
Insoluble matter (Fibre)	9.0	8.9	8.6

As may be seen in the above table, the content of non-reducing sugar, probably sucrose, in the set, decreases rapidly with the development of the shoots, showing that the young plants are formed by the release of the stored sugar.

B. "Rajoengan"

A number of stalks of 2878 POJ cane growing in the Koken Experimental Station were topped on the 30th of August, 1930, and the composition of these stalks was determined by analysis on the same day. On the 26th of September, the sprouts had grown enough to be used as "rajoengan," as is illustrated in plates II and III showing stages, and the composition of the stalks was examined.

The results shown in Table XXVIII were compared with those from the stalks left untouched as control and analysed on the same day.

The experimental results show clearly that the sucrose stored in the stalk was consumed in the production of sprouts; more especially, the relation between the decrease in the content of the non-reducing sugars in the middle and lower portions and the state of germination, only a few small shoots being sent out there, tells us to what extent the reserve sucrose is utilized.

Table XXVIII

"Rajoengan-" Production.

	Upper portion	Middle portion.	Lower portion	Whole stalk
Aug.				
Red. sug.	3.2%	3.8%	2.9%	3.2%
Non-red. sug.	2.2	4.3	7.3	5.0
Sept. 26 (Control: Untopped)				
Red. sug.	3.1%	3.4%	2.2%	8.9%
Non-red. sug.	3.4	5.3	8.3	6.0
Sept. 26 (Sprouted)				
Weight of sprouts (gms.)	43.5	4.5	0.5	48.5
Red. sug.	2.8%	3.7%	1.8%	2.7%
Non-red. sug.	2.1	2.9	5.6	3.8

C. "Tsunsun"

When canes in the fully ripened stage are left to stand in the garden until the warmer weather comes, a number of large shoots are sprouted from the ground. These shoots grow more rapidly than ordinary canes because their food material is adequately supplied from the mother plant.

The writer examined the composition of cane stalks from the beginning of the crop season of 1929 to June 1930 and noticed that a great number of large shoots had sprouted in the garden while some old stalks were dead or decayed. The fact that the changes in the chemical composition of the healthy stalks, as may be seen in Tables XXIX and XXX, were slight, leads the writers to the conclusion that the young shoots are produced by the release of only a small quantity of the material preserved in the mother plant.

Table XXIX

Sample Garden A. 2725 POJ "Koa-" Plant Cane, at Hokyoron.

Date	Moisture %	Red. sug. %	Non-red. s. %	Fibre %
Dec. 13	80	1.1	11.5	10.8
Jan. 2	73	0 9	9.0	10.8
Jan. 22	78	1.2	11.5	10.8
Feb. 11	75	0.7	11.7	10.6
Mar. 5	77	0.8	12.9	10.1
Mar. 23	71	0.7	13.9	11.9
Apr. 11	71	0.9	15.0	13.3
May 2	76	1.4	11.1	12.3
May 28	70	0.9	14.3	12.7
June 16	75	1.1	13.5	11.4

Table XXX

Sample Garden B. 2725 POJ Ratoon Cane, at Geron.

Date	Moisture %	Red. sug. %	Non-red. S. %	Fibre %
Jan. 20	73	0.9	11.7	11.3
Feb. 8	74	0.8	13.0	11.9
Feb. 28	73	0.7	13.8	12.4
Mar. 20	73	0.6	13.6	12.8
Apr. 9	71	0.9	14.7	11.9
Apr. 30	71	1.1	13.7	12.3
May. 20	72	0.7	11.8	12.1
June 16	76	1.3	11.7	13 6

D. Arrowing.

It is said that in the case of maize the sucrose is accumulated in the culms to form the seeds, but according to Ishida's observation on the flowering of sugar cane, a small decrease in sucrose-content occurs in the course of flowering.

The writer examined the content of solid matter in juices obtained from cane stalks in different stages of tasseling and the experimental results are compared with those from cane stalks without flowers studied for the control. The results are shown in the following table (Table XXXI).

Table XXXI

Effect of Arrowing on the Concentration of Juice.

Locality	Date	Refractive solids in juices obtained from cane stalks preparing to tassel	Control
Ai	Dec. 3	18.4	17.8
Hokyoron	Dec. 13	14.4	14.9
		Several weeks after tasseling	
Seimonko	Dec. 28	19.7	20.2
Seimonko	Dec. 30	19.5	21.2
		Gravity solids in juices obtained from cane stalks ca. 3 months after tasseling	
Koken	Feb. 22	17.5	19.4
Koken	Feb. 22	16.8	19.3

These results show that some quantity of solid matter in cane juice, probably sucrose, is consumed partly owing to the formation of flowers and partly to deterioration[1] of the plant, and the latter phenomenon is especially met with in the tasseled stalks.

E. Vigorous Vegetation of Young Cane Stalks.

The sucrose content of young cane stalks planted in the summer is in fact, remarkably high in the following winter, but falls rapidly in spring. The growth of the cane and the change in the chemical composition were studied from the end of winter to the close of summer, the period of vigorous vegetation. In this experiment, ten young 2725 and 2878 POJ canes, planted on 10th of August, 1929 in a garden at Katokyaku, were used.

(The Plates IV—XII show the different stages of growth.)

Both the 2725 and the 2878 POJ canes show an increase in the content of reducing sugars throughout the period of investigation, but the non-reducing sugar-content decreased in the early period of vegetation, reached a minimum in June and then increased gradually during summer. The erroneous view on the metabolism of sugars in sugar-

1. Noël Deerr: Cane Sugar, 2nd ed'n, (1921). p. 135.

Table XXXII

2725 POJ

Date	Weight of single stalk gms.	Moisture %	Reducing sugars %	Non-red. sugars %	Fibre %
Mar. 10	189	84	1.3	5.6	7.2
Apr. 1	185	85	1.8	5.5	8.2
Apr. 21	358	84	2.4	4.2	8.4
May 8	359	84	3.0	5.6	8.4
June 2	919	88	3.1	2.6	7.3
June 23	1498	86	2.9	3.0	7.5
July 15	1656	86	3.1	2.4	7.2
Aug. 4	1573	84	3.2	3.6	6.7
Aug. 25	2203	86	3.3	4.2	6.1
Sept. 15	2325	84	3.3	4.8	7.6

Table XXXIII

2878 POJ

Date	Weight of single stalk gms.	Moisture %	Reducing sugars %	Non-red. sugars %	Fibre %
Mar. 10	258	82	1.7	6.9	8.4
Apr. 1	331	83	2.0	6.3	8.8
Apr. 21	388	83	2.8	5.5	9.3
May 8	467	82	2.5	7.3	9.6
June 2	850	87	3.0	2.9	7.0
June 25	1346	89	2.8	1.8	6.7
July 17	1433	88	3.7	2.1	7.2
Aug. 6	2082	87	3.6	2.8	6.8
Aug. 27	2120	84	3.9	3.0	9.8
Sept. 17	2323	83	3.6	4.9	10.6

cane, that sucrose stored during winter is consumed for the vigorous growth of the plant in spring, arose from the study of the change in the percentage composition of sugars. But, the fate of the sugar in the course of the growth of the plant can only be learned from the change in the absolute amount of the sugar in a single stalk, and the actual amount of sugars, expressed in grams per one stalk, has been calculated from the data shown in Tables XXXII and XXXIII, and is given in Tables XXXIV and XXXV.

The reducing sugars and the non-reducing sugar in a single stalk increased in weight gradually during the period of vigorous vegetation, and this fact indicates that the sucrose is not entirely accumulated in the cane stalk during the cool season as reserve food material for the young plant.

Table XXXIV

2725 POJ. Values obtained by Interpolation.

Date	Weight of single stalk gms.	reducing sugars %	Non-red. sugars %	In single Stalk	
				Reducing sugars gms.	Non-red. sugars gms.
Mar. 10	170	1.3	5.4	2	9
Apr. 1	200	1.9	5.3	4	11
Apr. 21	300	2.4	5.0	7	15
May 8	490	2.7	4.3	13	21
June 2	800	3.0	3.3	24	26
June 23	1190	3.1	2.7	37	32
July 15	1560	3.2	2.7	50	42
Aug. 4	1900	3.2	3.2	61	61
Aug. 25	2180	3.2	4.1	70	89
Sept. 15	2400	3.2	5.2	77	125

Table XXXV

2878 POJ. Values obtained by Interpolation.

Date	Weight of single stalk gms.	Reducing sugars %	Non-red. sugars %	In single stalk	
				Reducing sugars gms.	Non-red. sugars gms.
Mar. 10	280	1.6	6.5	5	18
Apr. 1	320	2.1	6.6	7	21
Apr. 21	390	2.5	6.5	10	25
May 8	550	2.8	5.6	15	31
June 2	860	3.1	3.1	27	27
June 25	1240	3.3	2.0	41	25
July 17	1600	3.5	2.0	56	32
Aug. 6	1900	3.6	2.5	69	46
Aug. 27	2110	3.7	3.4	78	72
Sept. 17	2200	3.6	4.4	79	97

The General Conclusion.

The cases given above show that the utilisation of sucrose to provide the energy required for production of young plants is most prominent in the case of planted cuttings, and not so marked in the case of "rajoengans," "tsunsun," and tasseling.

Thus, the sucrose in the cane is considered to be formed in the natural course of the life of the cane by a vital process occurring in the plant tissues, but the solar energy fixed in the stalk in the form of sucrose is used as nourishment in case of emergency[1], and the accumulation of sucrose in the cane in cool weather is only the result of a change in the mode of energy transformation, though it is called the ripening of the cane, and seems somewhat different in its physiological nature from the ripening of fruits[2].

On the Tasseling of Cane.

The practical significance of the tasseling of cane, which is concerned with the ripening of the plant, has also been studied. Canes differ in this tasseling property, 2725 POJ cane, for instance, is a tasseling variety, and also 2878 POJ, though it has not so great a tendency to produce flowers, but 2725 POJ or Badila never produces tassels.

Noël Deerr[3], referring to the works of Harrison and of Prinsen Geerlings, states, that accumulation of sugar does not take place in the cane stalk after it has arrowed, but an entirly different opinion as to the formation of the sugar was reported by Prinsen Geerligs[4] in connection with his observation of the Black Cheribon cane, which shows a somewhat higher sucrose-content in the flowered stalks than in those not flowered. According to the observation carried out upon strains J. 26, J. 181, J. 247 and D 1135 by Ishida[5], however, the flowered cane shows slightly lower values in the sugar content than the other.

1. J. L. Beeson (Am. Chem. Journ., (1894) **16**, 457) regards some solids, not sugars, which abundantly present in the nodes of cane, as the chief reserve food stuff consumed in germination.

2. When an apple ripens, sucrose appears in it at the expense of a starch-like substance. (Lindet: Bull. (**3**) **11**, 18; Kamiya: Sci. Papers Inst. Chem. Res. (1930) **9**, 629). A rapid disappearance of starch accompanied by an increase of sucrose-content is also observed in the case of the banana. (Bridel et Bourdouil: C. r. (1929), **18**, 543.)

3. Cane Sugar, p. 135 (1921).

4. Archief (1895) I, p. 69; Handboek V.

5. Kansyoto Seizo Kagaku, zyo, p. 53 (1920).

The writers have previously reported (cf. II) the experimental results obtained from refractometric observations of cane juice, in which it was shown that more sucrose is consumed in flowered cane than in the other.

v. Deventer[1] has stated that poorly grown cane produces flowers more vigorously and earlier than others, but the writers' observations on 2725 POJ cane cultivated in many gardens do not support v. Deventer's view; canes which have grown either very well or very poorly show less flowering than those of moderate growth, and the cane produces flowers and shows a high sucrose-content when its vegetative activity is hindered to some extent at the beginning of winter, but cane which is in a state of vigorous growth or too weak in its activity does not arrow. Accordingly, the vegetative activity of canes which are in a state of preparation for arrowing, may be represented to some extent by their sucrose-content.

It has been reported[2] that a cane planted early in the season shows a higher sucrose-content in an early stage than one planted later and cultivated under similar conditions. The 2725 POJ cane already mentioned was planted in different months of the year 1929 at the Koken Experimental Station and the chemical composition of the canes was examined on Feb. 27th, 1931.

The results are shown in the following table:

Table XXXVI

Planted in	June	July	Aug.	Sept.	Oct.
Stalk-length (m.)	4.5	4.2	4.3	3.7	3.8
Stalk-weight (kg.)	3.47	2.93	3.04	2.71	2.47
% of Tasseled stalk	12	45	63	33	37
Analysis on Jan. 14th.					
Brix	—	18.2	18.4	17.4	14.6
Pol'n in juice	—	16.35	16.95	15.75	12.45
Glucose in juice	—	0.21	0.25	0.42	0.98
Pol'n in cane	—	13.01	13.71	12.18	9.87
Glucose in cane	—	0.17	0.20	0.32	0.78
Fibre in cane	—	11.62	10.10	14.06	11.88

1. Handboek, V. p. 100.
2. Government Research Institute, (Togyoka Zigyoseiseki Gaiyo), (1928). p. 133),

Table XXXVI
(*continued*)
Analysis on Feb. 20th.

Planted in	June	July	Aug.	Sept.	Oct.
Brix	—	19.0	19.2	18.4	16.9
Pol'n in juice	—	17.25	18.00	16.85	15.01
Glucose in juice	—	0.16	0.20	0.21	0.51
Pol'n in cane	—	12.58	14.50	13.60	11.83
Glucose in cane	—	0.10	0.16	0.17	0.40
Fibre in cane	—	9.02	10.42	10.31	12.38

As may be seen from the above data, the canes planted in June and July are too weak in their vegetative activities, but the ones planted in September and October were too vigorous to produce abundant flowers.

In his investigation of the Black Cheribon cane, Prinsen Geerligs[1] gives the following comparison of the chemical composition of arrowed and not arrowed stalks.

Table XXXVII

	Arrowed	Not arrowed
Weight of stalk with top	1.55	1.66
The same without top	—	1.51
Glucose	0.50	0.47
Purity	89.8	88.9
Available sugar	17.10	16.69

On Feb. 23rd, 1931, the writers examined 2725 POJ cane planted in the last ten days of June, 1929, with the results shown in Table XXXVIII.

Table XXXVIII

	Arrowed	Not arrowed
Length of stalk (m.)	4.53	4.29
Weight of stalk (mg.)	3.90	2.68
Brix of juice	18.9	19.5
Polarisation in juice	17.0	17.9

1. Loc. cit.

The difference between the analytical results reported by P. Geerlings and those of the writers may be attributed to the difference in the vegetative activities of cane stalks at the beginning of arrowing.

In general, the larger stalks, having a higher sucrose-content, seems to have a stronger tendency to arrow than those of normal size and less sugar content, grown in the same garden.

So far as our investigations go, it seems that the very point on which opinion as to the flowering of canes is divided, can be cleared up by thorough examination of the internal and external conditions under which the cane will be in flower, and the chemical study both of tasseling stalks and non-tasseling ones has been carried out with four stalks of similar size of a "Hayaue-" 2725 POJ cane planted in a garden in the neighbourhood of the laboratory, with the following results (Table XXXIX).

As may be seen in the accompanying plate (Plate XIII), which shows the various arrowing stages of the cane in this garden, the cane stalk was not very well developed, nor the flowers, and the side-shoots are pretty slow in appearing probably because there was not always enough moisture in the garden soil. The difference between tasseling and non-tasseling canes in the rate of ripening was quite remarkable, and therefore if the sucrose-content usually found in the tasseling stalks is higher at the beginning of the development of the flowers than that of non-tasseling ones at the corresponding state, they will show a marked difference in the sugar-content as time goes on.

Table XXXIX

Tasseling State of flower	Nov. 6 Preparing	Dec. 18 Complete	Feb. 15 Dead
Length of flower (cms.)	26	120	—
Weight of flower (gms.)	10	52	—
Length of stalk (cms.)	211	218	237
Weight of stalk (gms.)	1446	1564	1530
Number of internodes	32	24	28
Not tasseling			
Length of stalk (cms.)	194	193	207
Weight of stalk (gms.)	1456	1585	1453
Number of internodes	28	27	30

Table XXXIX

(*continued*)

Analytical Results

Tasseling	Nov. 6	Dec. 18	Feb. 15
State of flower	Preparing	Complete	Dead
Brix of juice	16.1	17.1	16.6
Red. sug. in juice	1.48	0.94	0.50
Pol'n in juice	13.63	14.69	14.88
Fibre in cane	12.64	11.32	—
Pol'n in cane	10.71	11.72	—
Not tasseling			
Brix of juice	17.9	20.0	20.5
Red. sug. in juice	1.38	0.16	0.25
Pol'n in juice	15.78	19.38	19.20
Fibre in cane	11.08	11.62	—
Pol'n in cane	12.63	15.39	—

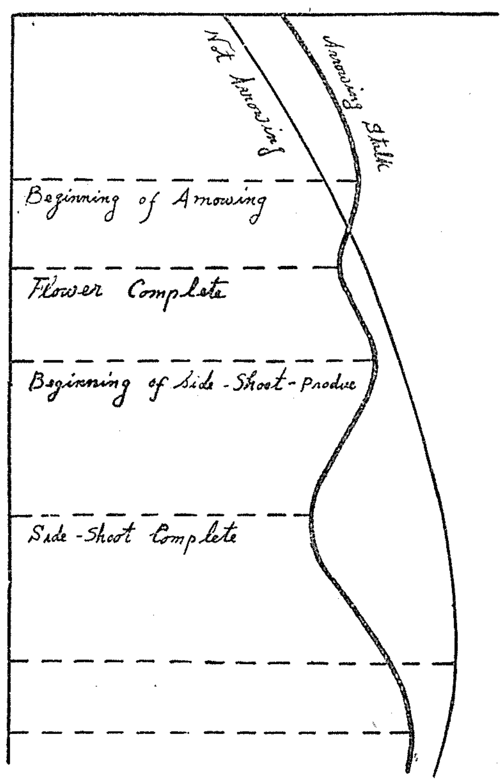
When the problem is considered theoretically, it is seen that the mode of ripening in the tasseled cane must be different from that in the normal one. The energy used for the production of flowers or side shoots may be supplied either by comsuption of substances formed by photosynthesis in the leaves or of substances such as sucrose stored in the stalk. If the growth of the stalk is small while the photosynthetic activity of the leaf-system is comparatively vigorous, the sucrose-content of the stalk will increase, but if the production of flowers or side-shoots is vigorous, as is often observed, and if also the leaves on the stalk die off soon after tasseling, decrease of the stored sucrose must result from the consumption of sugar for continuation of the plant activity.

Thus, the chemical composition of cane stalks in the tasseling or side-shoot-production stage depends wholly upon the physical state of plant.

When side-shoots attain a certain stage they can live on the substances formed by the photosynthesis of their own leaves but their growth is usually slow and thus an accumulation of sucrose in the stalk will result from such an alteration of the living conditions in the plant, and actually we observed a case in which a tasseled cane with many side-shoots showed only 16° as the refractive brix of the juice in January, while this reached 22° in the last ten days of March.

Generally speaking, the effect of tasseling and production of side-shoots on the plant activity is to diminish the rate of ripening, and this diminution may make, in some cases, the rate of ripening assume a negative value, according to circumstances.

Fig 14.



An extreme case of the disturbance of the ripening by the influence of vigorous development of flowers and side-shoots, may be represented schematically by the accompanying figure. (Fig. 14)

IV. The Significance of Water in "Maturity" and the Possibility of Making Cane Mature Earlier by Inundation

By

Shinsaku Ozawa and Shigeru Komatsu

A. The Effects of Inefficient Drainage.

It is a well known fact that bad drainage causes suppression of growth, and also raises the refractive solid in the cane juice before the proper ripening season of the crop has set in.

It is reported that F 19 cane, grown in a too moist garden in Inrin-Gun, Taityu-Shu, showed as high as 18% of mean refractive solids in September 1929, and that the canes of the same strain grown in a badly drained garden belonging to the Kobi factory of the Dai-nihon Seito, contained 26% of a refractive solid.

Moreover, a few interesting cases of the effect of inefficient drainage on the crop production are reported from our Tyuzaisyo farm.

a) The canes grown in low ground at Gebusi were reported to contain 20.5% of mean refractive solid on Nov. 6th, while canes in a dry field gave 16.7%.

b) The 2725 POJ canes grown in a badly drained garden at Hokyoron, which were ratooned in Feb. 1929, showed a high refractivity (18%) on Oct. 21st., but well grown canes showed 14—15% as the mean refractive value (cf. the analytical results, Table XL).

c) The 27 5 POJ "Koa" canes grown in a badly drained garden at Kyosito gave an extraordinarily high refractive solid on Oct. 24th. (cf. the results of examinations, Table XLI).

d) It was reported on the 23rd of Nov., that the 2725 "Osoue-" POJ canes grown in a low garden with a small spring of water in it at Oiwake gave a refractive solid of 20.4%, while those in a well-drained garden gave 17.4%. (Table XLII).

The cane grown in a badly drained garden so far mentioned shows a high refractive solid in juice in the early stage of ripening, and

Table XL (Preliminary test)

Locality: Eelung (Pokyunglung)
Variety: 2725 POJ, Ratooned near the end of Feb. this year.
Sample taken: Oct. 21st., 1929. a.m. 11.15.
(The white top and the under-ground part were discarded, and the remainder only was examined.)

Sample	Length m.	Weight kgms.	Diameter			Internodes
			Upper cms.	Middle cms.	Lower cms.	
A	1.485	1.093	2.58	3.18	3.24	14
B	1.360	0.794	2.33	3.03	3.03	19

Yield of juice c.c./100gms.	53.32
Brix	18.2

Analysis	Juice	Cane
		Moisture 74.7% fibre 9.47%
Total sugar gms./100c.c.	16.67	12.39
Reducing sugar "	2.04	1.65
Non-reducing sugar "	14.63	10.74
Red. sug./non-red. sug.	0.1395	0.1535

Table XLI Expt. 2 (i)

Locality: Kyoatau, (Kadan)
Variety: 2725 POJ. "Koa," Planted: 1st decade of Oct. 1928.
Taken: Oct. 24th, 1929. p.m.1.15. Analysed: p.m. 3.00.

	Sample	Length m.	Internodes	Weight kgms.
	A	2.18	19	1.520
	B	2.12	16	1.842
	C	2.18	17	1.652

	Sample	Upper	Middle	Lower
Diameter (cms.)	A	2.97	3.18	3.03
	B	3.24	3.18	3.49
	C	3.03	3.03	3.24
Weight (gms.)	A	520	535	465
	B	497	610	735
	C	427	540	685

Table XLI (*continued*)

Analysis of Juice.

	Upper	Middle	Lower	Total
Yield of J. c.c./100gms.	55.0	57.6	53.2	
Brix	15.34	18.49	19.39	17.8
Refractive solid	15.92	19.40	20.04	18.5
Total sug.	15.55	(18.95)	19.09	18.02
Red. sug.	2.61	1.73	1.38	1.62
Non-red. sug.	12.94	17.22	17.71	16.40
R.S./N.R.S.	0.206	0.122	0.078	0.099

Analysis of Cane.

	Upper	Middle	Lower	Total
Moisture %	75.0	74.1	—	—
Fibre	(11.07)	(10.72)	(12.68)	(11.56)
Total sug.	12.13	14.57	14.06	13.52
Red. sug.	2.06	1.42	1.26	1.56
Non-red. sug.	10.07	13.15	12.80	11.96
R.S./N.R.S.	0.204	0.108	0.098	0.131

Table XLII

Report from Oiwake Tyuzaisyo, Nov. 13th, 1929.

A) Variety: 2714 POJ.

Kind of Garden	Date of ratoonage	Refractive Solids		
		Upper	Middle	Lower
"Hata"	Feb. 28th	13.66	19.06	20 33
"Suiden"	Feb. 28th	14.33	17.50	19.50

B) Variety: 2725 POJ.

"Hata"	Feb. 14th	14.16	18.33	19.66
"Suiden"	Feb. 14th	10.33	18.00	18.33

Remarks:—

1° Three stalks each were examined to obtain the mean value.

2° The moisture of the soils in the gardens were almost identical on the day of examination.

3° The quantity of manure applied to the "Hata-ti" garden was less than that in the case of "Suiden".

these observations are in harmony with the fact that the cane in open fields shows a mean value of 17.4% but that in paddy-fields, 15.5% (See Table XLII.). Such a high refractive solid in the cane juice can not be attributed to the presence of an abnormal quantity of sucrose in the juice unless the nature of the chemical constituents has been examined.

Canes obtained from several badly drained gardens were examined by the usual methods on Oct. 21st–24th to find the content of total sugars, reducing sugars and non-reducing sugars, and the results are given in tables XL and XLI.

The canes in the unripe stage are said to contain a good deal of reducing sugars in their juice and this observation is in harmony with the analytical results shown in Tables XLIII, XLIV and XLV, obtained with canes examined on Nov. 8th, in which the upper part of the stalk has a higher reducing sugar-content than the middle and lower portions.

Thus, we can state that the highly refractive solid in the juice in an early stage of ripening is partly due to the occurrence of a considerable quantity of reducing sugars.

Table XLIII Expt. 2. (v) (cf. Table XLI)

Locality: Kyoatau. Variety: 2725 POJ. "Kao."
Taken: Nov. 8th, 1929.

Sample	Length m.	Internodes
A	3.05	28
B	2.95	30

	Sample	Top	Upper	Middle	Lower
Length (cms.)	A	40	90	81	68.5
	B	66	95	81	82
Diameter (cms.)	A	3.18	3.15	3.12	3.33
	B	2.85	3.48	3.69	3.88
Weight (gms.)	A	240	692	715	610
	B	365	950	905	970
Internodes	A	10	6	6	6
	B	10	9	6	5

Table XLIII

(continued)

Analysis (Juice)

	Top	Upper	Middle	Lower	Total (except top)
Sample (gms.)	585	875	795	840	2510
Juice (c.c.)	210	470	420	460	1350
Yield of J. (c.c./100gms.)	35.9	48.6	52.8	54.8	53.6
Brix	11.30	16.71	17.91	17.63	17.40
Ref. solid	11.34	17.54	18.53	8.13	8.05
Tot. sug.	9.91	16.60	18.47	16.97	17.23
Red. sug.	2.96	1.53	1.29	1.09	1.31
Non-red. sug.	6.95	15.07	17.18	15.88	15.92
R.S./N.R.S.	0.426	0.101	0.075	0.069	0.082

Analysis (Cane)

	Top	Upper	Middle	Lower	Totalo (except t p)
Moisture	82.66	74.89	76.22	77.15	
Fibre	10.40	11.00	14.47	13.70	13.40
Tot. sug.	5.80	11.16	13.42	12.13	12.20
Red. sug.	2.29	1.38	1.26	0.94	1.19
Non-red. sug.	3.51	9.78	12.16	11.19	11.01
R.S./N.R.S.	0.653	0.141	0.103	0.084	0.098

Table XLIV Expt. 2. (vii) (cf. Table XLI)

Locality: Kyoatau. Variety: 2725 POJ. "Koa."
Taken: Nov. 10th, 1929.

Sample	Length m.	Internodes
A	2.78	27
B	2.43	23
C	2.13	22

	Sample	Top	Upper	Middle	Lower
Internodes	A	7	8	6	6
	B	6	7	5	4
	C	7	6	5	5
Length (cms.)	·	24	80	64	90
	B	18	67	74	85
	C	22	59	73	59

Table XLIV (*continued*)

	Sample	Top	Upper	Middle	Lower
Diameter (cms.)	A	2.79	2.85	2.92	3.39
	B	2.61	3.18	3.46	3.42
	C	2.73	2.92	3.09	2.97
Weight (gms.)	A	106	550	625	815
	B	70	505	685	795
	C	105	395	505	405

Analysis (Juice)

	Top	Upper	Middle	Lower	Total (except Top)
Sample (gms.)	275	615	950	1015	2580
Juice (c.c.)	92	330	550	590	1470
Yield of J. (c.c./100gms.)	33.6	53.5	58.0	58.2	57.0
Brix	10.5	17.82	19.62	19.32	19.10
Ref. sol.	9.9	18.92	20.32	19.72	20.17
Tot. sug.	7.54	17.79	19.71	19.04	18.96
Red. sug.	2.07	1.04	1.00	0.89	0.96
Non-red. sug.	5.47	16.75	18.71	18.15	18.00
R.S./N.R.S.	0.381	0.064	0.053	0.049	0.053

Table XLV Expt. 2. (viii) (cf. Table XL)

Locality: Eelung. Variety: 2725 POJ.
Taken: Nov. 21st, 1929. at noon.

Sample	Length m.	Diameter cms.	Internodes
A	1.94	2.58	24
B	1.83	2.61	23
C	1.74	2.67	27
D	1.33	2.18	18

	Sample	Upper	Middle	Lower
Length (cms.)	A	54	56.5	52
	B	51.5	57.5	53.5
	C	46	51	54
	D	35	44	44
Weight (gms.)	A	252	300	275
	B	195	325	307
	C	175	260	330
	D	110	162	160

Table XLV (*continued*)

Analysis (Juice)

	Upper	Middle	Lower	Total
Sample (gms.)	375	535	585	1495
Juice (c.c.)	158	267	290	715
Yield of J. (c.c./100gms.)	42.0	49.8	49.6	47.9
Brix	17.15	20.36	19.26	19.20
Ref. sol.	18.04	20.44	19.44	19.51
Tot. sug.	16.49	19.32	19.13	18.62
Red. sug.	1.50	1.10	0.80	1.07
Non-red. sug.	14.99	18.22	18.33	17.55
R.S./N.R.S.	0.100	0.066	0.044	0.061

Table XLV bis. Expt. 2. (xi) (cf. Table XL)

Locality: Eelung. Variety: 2725 POJ. Ratoon.
Taken: Nov. 29th, 1929. a.m. 10.30.

Sample	Length m.	Diameter cms.	Internodes
A	2.47	3.49	21
B	2.36	3.12	26
C	2.29	2.97	23

	Sample	Upper	Middle	Lower
Length (cms.)	A	77.5	74	82
	B	70	70	55
	C	75	77	66
Diameter (cms.)	A	3.18	3.49	3.28
	B	2.67	3.18	2.97
	C	2.61	2.97	2.82
Weight (gms.)	A	560	680	725
	B	360	520	395
	C	360	500	395
Internodes	A	7	6	6
	B	8	6	7
	C	7	6	6

Table XLV bis.

(continued)

Analysis (Juice)

	Upper	Middle	Lower	Total
Sample (gms.)	700	970	870	2540
Juice (c.c.)	390	580	480	1450
Yield of J. (c.c./100ams.)	55.6	59.6	55.0	57.0
Brix	16.2	17.4	18.2	17.3
Ref. sol.	16.0	17.2	18 0	16.3
Tot. sug.	15.57	17.13	17.55	16.85
Red. sug.	2.47	2.05	1.35	1.92
Non-red. sug.	13.13	15 08	16.20	14.93
R.S./N.R.S.	0.186	0.136	0.083	0.129

B. On the Effect of Drought.

Noël Deerr[1] has noticed that the effect of drought on the cane crop is to reduce tonnage but to increase fibre content, and the latter phenomenon is explained by the restricted length of the internodes and increased transpiration. But the writer is inclined to believe that the high percentage of fibre may, to some extent, be due to the decrease of stored sucrose, since the scantiness of water, as has been remarked above, hinders the formation of sucrose on the one hand, and on the other, accelerates the decomposition of sucrose into water and CO_2 in order to rescue the plant from the danger of desiccation.

It is true that scarcity of water hinders the growth of cane, and it must, in this respect at least, favour the accumulation of sucrose. However, the experimental results shown in Tables XLVI, XLVII, LIII & LV contain some exceptional cases in which the canes grown in the sandy gardens of Tyuryo and in a state of highly suppressed vegetation, show that desiccation has an unfavourable effect on the ripening[2].

1. Cane Sugar: p. 27.
2. Refer Heriot. The manufacture of Sugar from the Cane and Beet (1920) p. 26.

Table XLVI

Report from the Tyuryo Tyuzaisyo. (Nov. 5th, 1929.)
Variety: 2725 POJ. Planted: middle of Sept., 1928.
Kind of Garden: " Hata-ti ".

Condition	Nodes	Length m.	Living leaves	Refractive solids		
				Upper	Middle	Lower
Half dead	16.3	1.61	3.2	13.6	14.2	15.4
Healthy	18.6	1.72	9.0	11.1	14.0	15.8

(Remark: 4 stalks were examined to find the average value.)

Report from the Taito Tyuzaisyo. (Nov. 4th, 1929.)
Variety: 2725 POJ. Planted: Sept. 1928.
Kind of Garden: " Hata-ti ".

Condition	Length m.	Refractive Solids		
		Upper	Middle	Lower
Half dead	1.94	16.5	16.3	21.3
	1.88	14.0	16.5	18.5
	2.15	16.6	16.5	21.5
Healthy	2.02	12.0	17.0	20.0
	2.18	15.0	15.0	19.2
	2.17	12.5	17.2	18.2

Table XLVII Expt. 2. (iv) (cf. Table XLVI.)

Locality: Tyonglyau. Variety: 2725 POJ.
Planting: " Hayaue ", planted in the middle of Sept., 1928.
Sample taken: Nov. 7th, 1929. a.m. 9.00.
Analysed: p.m. 1.00.

Sample	Number of leaves	Length m.	Number of Internodes
A	5	2.29	28
B	4	2.15	31
C	3	1.14	16

	Sample	Top	Upper	Middle	Lower
Internodes	A	9	7	6	6
	B	10	6	6	9
	C	2	5	4	5
Length (cms.)	A	30	72	73	57
	B	38	55	65	60
	C	16	57	52	54

Table XLVII (*continued*)

	Sample	Top	Upper	Middle	Lower
Diameter (cms.)	A B C	2.18 2.82 2.55	3.45 3.34 3.22	3.88 3.03 3.64	3.64 3.03 3.55
Weight (gms.)	A B C	125 205 60	615 570 315	865 565 360	640 510 400

Analysis (Juice)

	Top	Upper	Middle	Lower	Total (except top)
Sample (gms.)	380	695	875	710	2280
Juice (c.c.)	150	310	475	360	1145
Yield of J. (c.c./100gms.)	39.5	44.6	54.3	50.7	49.5
Brix	13.37	14.49	15.58	16.88	15.69
Ref. solid	13.22	14.62	15.52	17.07	15.76
Total sug.	10.82	13.50	15.25	16.45	15.15
Red. sug.	2.57	2.89	2.29	2.04	2.37
Non-red. s.	8.25	10.61	12.96	14.41	12.78
R.S./N.R.S.	0.312	0.272	0.176	0.142	0.168

C. The Inundation.

The canes examined to find the effect of excessive water on the yield of sucrose, had been suffering from inefficient drainage due to the heavy rains in July and August. The high sugar-content of such canes may be partly due to the effect of this long suffering, and such conditions will effect the cane in a way very similar to the ordinary environmental conditions in winter, in which the canes grow normally.

The inundation experiments carried out on 2714 POJ cane at Katokyaku and Saimungkau and the results of the examination of cane juice by the refractometric method are shown in Tables XLVIII and XLIX, and other examples of the effect of inundation on 2725 POJ canes at Saimungkau is shown as control (Table L and LI). The results afford strong support for the writer's assumption that acceleration of ripening by the influence of excessive water is due to the effect upon the physiological state of the whole cane body.

However, the inundation experiment carried with 2725 POJ cane at Rasi Nozyo (Oiwake) may be mentioned as an exceptional case,

(Table XLVIII). Here, the distribution of the refractive solids in the juice obtained from the upper, middle, and lower portions of the stalk separately, is different in each case and a peculiar phenomenon was also noticed when the results obtained with each portion were compared with those obtained with the whole cane. (See Table LII).

Table XLVIII

Report from the Katokyaku Tyuzaisyo. (Nov. 7th, 1929)

Variety	Planting	Expected yield	Duration of irrigation day	Refractive solids		
				Upper	Middle	Lower
2714 POJ	Ratoon	70	0	13.2	15.2	18.2
2714 POJ	Ratoon	90	2	14.4	17.1	18.6
2714 POJ	Ratoon	90	15	15.6	19.3	19.8
2725 POJ	"Hayaue"	260	2	15.7	16.0	16.5
2725 POJ	"Hayaue"	260	18	17.4	17.4	18.2

Results of Inundation Test reported from Oiwake.

Variety: 2725 POJ.

Every internode of nine stalks was examined to find the average values. The inundation began on 1st day of Nov.

Date	XI-19	XI-23	XI-27	XII-21
Control	17.34	19.54	19.97	19.67
Inundation	17.98	17.20	18.32	18.76

Table XLIX

Report from the Syusui Nozyo.

(A) Zaraku :— Saimungkau.
Variety :— 2725 POJ.
Ratooned :— Sept., 1928.

Date	X-30	XI-12	XI-21
Control	15.43	17.89	17.64
Inundation	15.87	18.08	17.64

(B) Zaraku :— Saimungkau.
Variety :— 2725 POJ.
Ratooned :— Feb., 1929.

Date	XI-11	XI-21
Control	18.77	20.06
Inundation		21.68

Remarks :—

1° The canes in (A) were of quite irregular qualities and a good average value was hardly obtainable.

2° The refractive solid of canes ripening under lack of water supply drops constantly from the bottom to the top, while that of canes supplied with abundant water keeps to the middle portion of stalk and then abruptly falls. Since the figures shown above are the results of observations of the middle part of each stalk, some allowance must be given in the values of the control.

Table L Expt. 2. (ix) (cf. Table XLIX. B)

Locality :— Saimungkau. (Inundation.)
Variety :— 2725 FOJ. Ratooned :— Feb., 1929.
Taken :— Nov. 25th, 1929. a.m. 8.00.

Sample	Length m.	Diameter cms.	Internodes
A	2.65	3.64	31
B	2.26	2.85	30
C	1.73	2.61	25
D	1.77	2.61	21
E	1.73	2.31	16

	Sample	Upper	Middle	Lower
Length (cms.)	A	67.0	75.5	82.5
	B	62.5	71.0	65.0
	C	54.0	49.5	40.5
	D	63.0	55.0	45.0
	E	55.0	56.0	56.0
Diameter (cms.)	A	3.18	3.52	4.00
	B	2.43	2.73	3.15
	C	2.62	2.73	2.82
	D	2.49	2.67	2.67
	E	1.76	2.37	2.52
Weight (gms.)	A	530	760	1157
	B	295	430	530
	C	295	310	255
	D	290	325	270
	E	155	240	310

Table L
(*continued*)

	Sample	Upper	Middle	Lower
Internodes	A	8	7	6
	B	8	7	8
	C	6	5	5
	D	6	5	5
	E	5	4	4

Analysis (Juice)

	Upper	Middle	Lower	Total
Sample (gms.)	795	1115	1315	3225
Juice (c.c.)	380	570	680	1630
Yield of J. (c.c./100gms.)	47.7	51.5	51.7	50.4
Brix	18.44	21.54	20.94	20.57
Ref. sol.	17.8	21.4	21.0	20.39
Total sug.	17.04	21.73	20.82	20.27
Red. sug.	1.25	0.68	0.54	0.75
Non-red. sug.	15.79	21.05	20.28	19.52
N.R./N.R.S.	0.079	0.032	0.027	0.038

Table L bis. Expt. 2. (xiii) (cf. Table XLIX. B.)

Locality :— Saimungkau. (Inundation.)

Sample Taken :— Dec. 9th, 1929. a.m. 8.00.

Sample	Length m.	Diameter cms.	Internodes
A	2.06	3.18	25
B	2.425	2.73	29
C	1.65	2.79	16
D	1.73	2.79	22
E	1.32	2.42	14

	Sample	Upper	Middle	Lower
Internodes	A	7	6	5
	B	8	7	7
	C	5	4	3
	D	6	5	4
	E	4	3	3
Length (cms.)	A	63	67	56
	B	74	74	61
	C	49	56	45
	D	57	54	44
	E	43	40	39
Diameter (cms.)	A	2.85	3.15	3.76
	B	2.30	2.66	3.09
	C	2.48	2.79	29.91
	D	2.66	2.60	2.85
	E	2.58	2.36	2.67

Table L bis.
(*continued*)

	Sample	Upper	Middle	Lower
Weight (gms.)	A	415	615	625
	B	340	475	460
	C	210	340	325
	D	315	320	295
	E	175	200	245

Analysis (Juice)

	Upper	Middle	Lower	Total
Sample (gms.)	850	915	880	2645
Juice (c.c.)	460	530	500	1490
Yield of J. (c.c./100gms.)	54.1	57.9	56.8	56.3
Brix	19.95	21.95	21.45	21.17
Ref. sol.	19.98	21.78	21.38	21.09
Tot. sug.	20.15	22.56	21.78	21.56
Red. sug.	1.18	0.69	0.65	0.83
Non-red. s.	18.97	21.87	21.13	20.73
R.S./N.R.S.	0.062	0.032	0.031	0.040
Polarisation	15.82	18.74	19.90	18.23

Table LII Expt. 2. (x) (cf. Table XLIX. B.)

Locality :— Saimungkau. (Control. No irrigation, adjacent to the garden of (ix))
Taken :— Nov. 27th, 1929. a.m. 8.50.

Sample	Length m.	Diameter cms.	Internodes
A	2.98	4.00	35
B	2.28	3.03	22
C	1.79	2.66	18
D	1.93	2.55	19
E	1.88	2.39	18

	Sample	Upper	Middle	Lower
Length (cms.)	A	83.5	87.0	85.0
	B	60.5	57.0	67.0
	C	56.0	49.0	56.0
	D	85.0	51.5	57.0
	E	45.5	63.0	61.0
Diameter (cms.)	A	3.49	4.05	4.05
	B	2.85	3.03	3.15
	C	2.36	2.73	2.91
	D	2.42	2.67	2.79
	E	2.36	2.36	2.58
Weight (gms.)	A	770	1100	1185
	B	370	415	580
	C	255	290	370
	D	285	295	350
	E	205	310	330

Table LII
(*continued*)

	Sample	Upper	Middle	Lower
Internodes	A	10	8	8
	B	6	4	4
	C	6	4	4
	D	6	4	4
	E	4	5	5

Analysis (Juice)

	Upper	Middle	Lower	Total
Sample (gms.)	970	1270	1475	3715
Juice (c.c.)	510	700	810	2020
Yield of J. (c.c./100gms.)	52.4	54.8	54.6	54.1
Brix	16.8	19.4	19.5	18.8
Ref. sol.	16.3	19.0	19.1	18.4
Tot. sug.	16.30	19.45	19.86	18.82
Red. sug.	1.62	1.08	0.78	1.10
Non-red. sug.	14.68	18.37	19.08	17.72
R.S./N.R.S.	0.110	0.059	0.041	0.062

Table LII bis. Expt. 2. (xiv) (cf. Table XLIX. B.)

Locality :— Saimungkau. (Control)
Taken :— Dec. 11th, 1929. a.m. 8.00.

Sample	Length m.	Diameter cms.	Internodes
A	3.00	3.54	30
B	2.12	2.72	24
C	2.23	2.91	26
D	1.64	2.52	21
E	1.76	2.48	22

	Sample	Upper	Middle	Lower
Internodes	A	9	7	6
	B	6	6	5
	C	7	6	6
	D	6	4	4
	E	6	5	5
Length (cms.)	A	82	88	94
	B	57	69	72
	C	58	73	71
	D	48	47	55
	E	54	54	58
Diameter (cms.)	A	3.03	3.54	3.85
	B	2.60	2.82	3.15
	C	2.42	2.76	3.06
	D	2.12	2.42	2.66
	E	2.18	2.42	2.60

Table LII bis.

(*continued*)

	Sample	Upper	Middle	Lower
Weight (gms.)	A B C D E	585 375 265 180 215	895 485 505 250 290	1065 610 560 345 325

Analysis (Juice)

	Upper	Middle	Lower	Total
Sample (gms.)	785	1175	1445	3405
Juice (c.c.)	400	690	820	1910
Yield of J. (c.c./100gms.)	51.0	58.7	56.8	56.1
Brix	16.52	19.22	19.62	18.83
Ref. sol.	16.20	19.21	19.61	18.75
Tot. sug.	14.40	19.05	19.24	18.16
Red. sug.	1.35	0.90	0.65	0.89
Non-red. s.	13.05	18.15	18.59	17.27
R.S./N.R.S.	0.103	0.050	0.035	0.052

Table LIII Expt. 2. (xii) (cf. Table XLVIII.)

Locality :— Oiwake.

Variety :— 2725 I OJ. Ratooned :— Mar., 1929.

Taken :— Dec. 6th, 1929. a.m. 9.00.

	Sample	Length cms.	Diameter cms.	Internodes
Inundation	A B C	281.5 184 188	3.41 2.74 2.68	32 22 19
Control	A B C	218.5 183 190	3.37 2.76 2.62	24 19 21

(Inundation)	Sample	Upper	Middle	Lower
Internodes	A B C	9 7 6	7 5 4	6 5 4
Length (cms.)	A B C	78 65 70	97 55 53	79 57 57
Diameter (cms.)	A B C	3.18 2.61 2.43	3.49 2.85 2.67	3.65 3.18 2.82

Table LIII

(*continued*)

	Sample	Upper	Middle	Lower
Weight (gms.)	A	580	925	835
	B	335	340	460
	C	310	300	330
(Control)				
Internodes	A	7	6	6
	B	5	5	5
	C	6	5	5
Length (cms.)	A	72	72	65
	B	51	64	62
	C	56	62	58
Diameter (cms.)	A	2.92	3.55	3.55
	B	2.37	2.67	2.79
	C	2.37	2.62	2.62
Weight (gms.)	A	410	655	650
	B	240	400	400
	C	260	345	310

Analysis (Juice)

(Inundation)	Upper	Middle	Lower	Total
Sample (gms.)	630	740	815	2185
Juice (c.c.)	330	400	460	1190
Yield of J. (c.c./100gms.)	52.3	53.9	56.3	54.3
Brix	20.42	20.92	20.82	20.74
Ref. sol.	20.17	20.77	20.37	20.45
Tot. sug.	19.91	20.71	20.05	20.24
Red. sug.	1.14	0.77	0.62	0.81
Non-red. s.	18.77	19.94	19.43	19.43
R.S./N.R.S.	0.061	0.039	0.032	0.042
Polarisation	17.08	18.98	18.78	18.38

Table LIII
(*continued*)

(Control)	Upper	Middle	Lower	Total
Sample (gms.)	500	755	665	1920
Juice (c.c.)	275	450	390	1115
Yield of J. (c.c./100gms.)	55.0	59.4	58.5	58.0
Brix	19.82	20.92	21.62	20.90
Ref. sol.	19.57	20.57	21.27	20.46
Tot. sug.	18.60	20.83	21.08	20.37
Red. sug.	1.51	1.36	0.88	1.23
Non-red. s.	17.09	19.47	20.20	19.14
R.S./N.R.S.	0.088	0.070	0.043	0.064
Polarisation	16.24	18.19	19.42	18.14

Results of Analysis; calculated on the weight of fresh cane.

Table LIV

Expt. 2. (vii) Huetuan, Kyoatau. Taken, 1929–11–15.

	Top	Upper	Middle	Lower	Total (except Top)
Moisture	87.46%	79.86%	77.37%	77.55%	77.75%
Fibre	7.30	12.09	11.72	13.27	12.42
Tot. s.	4.12	12.71	15.31	14.50	14.38
Red. s.	1.36	0.85	0.81	0.69	0.77
Non-r.s.	2.76	11.86	14.50	13.81	13.61

Expt. 2. (viii) Pokyunglun, Eelun. 11–21.

	Upper	Middle	Lower	Total (except Top)
Moisture	76.05	75.17	76.26	75.82
Fibre	10.79	10.69	12.70	11.50
Tot. s.	12.97	14.84	14.24	14.17
Red. s.	1.26	0.83	0.64	0.87
Non-r. s.	11.71	14.01	13.60	13.30

Expt. 2. (ix) Saimungkau, Inundation. 11–25.

Moisture	74.68	72.46	71.66	72.21
Fibre	9.71	11.91	11.77	11.23
Tot. s.	12.24	15.90	15.47	14.82
Red. s.	0.99	0.58	0.47	0.64
Non-r.s.	11.25	15.32	15.00	14.18

Table LIV

(*continued*)

Expt. 2. (x) Saimungkau, Control. 11—27.

	Upper	Middle	Lower	Total (except Top)
Moisture	79.56 %	77.95 %	77.01 %	77.98 %
Fibre	11.05	11.60	13.44	12.21
Tot. s.	11.86	14.69	14.41	13.84
Red. s.	1.22	0.83	0.60	0.84
Non-r. s.	10.64	13.86	13.81	13.00

Expt. 2. (xi) Pokxun. Eelun, 11—29.

Moisture	81.13	80.60	80.78	80.74
Fibre	10.30	7.99	9.30	9.08
Tot. s.	12.56	12.48	13.38	12.81
Red. s.	1.96	1.56	1.03	1.49
Non-r. s.	10.60	10.92	12.35	11.32

Expt. 2. (xv) Tyonglyau, 12—16.

Moisture	79.93	76.70	73.61	75.09
Fibre	8.65	9.55	11.23	9.74
Tot. s.	12.96	13.24	12.29	12.84
Red. s.	1.42	1.28	1.03	1.26
Non-r. s.	11.54	11.96	11.06	11.58
Polarisation	11.12	11.41	12.41	11.69
Available sugar				9.72

Polarisation% Cane=(100—Fibre %)÷100 × (Pol'n Test Mill J. × 0.9)
Avail. Sug.% Cane=Pol'n % Cane × (1.4—40) (Purity T.M.J. × 0.966) × 0.925.

Table LV

Expt. (xii) Oiwake. Inundation. 1929—12—6.

	Upper	Middle	Lower	Total (except Top)
Moisture	74.37 %	75.42 %	75.97 %	75.18 %
Fibre	12.56	10.17	12.12	11.59
Tot. s.	15.21	16.22	14.50	15.29
Red. s.	0.96	0.62	0.50	0.67
Non-r. s.	14.25	15.60	14.00	14.62
Polarisation	13.44	15.34	14.84	14.62
Available sugar				12.63

Table LV.

(*continued*)

Expt. (xii) Oiwake. Control. 1--6.

	Upper	Middle	Lower	Total (except Top)
Moisture	74.98 %	77.73 %	73.60	75.62
Fibre	10.42	9.71	12.06	10.50
Tot. s.	14.31	15.89	15.83	15.46
Red. s.	1.39	1.01	1.00	1.00
Non-r. s.	12.92	14.88	14.83	14.46
Polarisation	13.09	14.78	15.37	14.61
Available sugar				12.47

Expt. (xiii) Saimungkau, Inundation. 12—9.

Moisture	73.53	73.19	60.29	69.34
Fibre	10.90	13.17	13.77	12.64
Tot. s.	14.99	16.69	15.99	15.91
Red. s.	1.03	0.64	0.56	0.74
Non-r. s.	13.96	16.05	15.43	15.17
Polarisation	12.68	14.64	15.44	14.33
Available sugar				12.17

Expt. (xiv) Simungkau, Control. 12—11.

Moisture	77.40	77.46	76.88	77.73
Fibre	10.15	10.70	11.27	10.81
Tot. s.	11.69	14.01	13.61	13.31
Red. s.	1.05	0.68	0.50	0.69
Non-r. s.	10.04	13.33	13.10	12.62
Polarisation	10.08	13.96	14.47	13.48
Available sugar				11.68

Expt. (xvi) Saimungkau. Inundation. 12—28.

Moisture	72.92	71.63	72.08	72.75
Fibre	10.29	11.99	13.53	11.83
Tot. s.	12.66	15.41	15.36	14.61
Red. s.	0.52	0.48	0.46	0.48
Non-r. s.	12.14	14.92	14.90	14.13
Polarisation	14.21	15.83	14.68	15.07
Available sugar				13.07

Table LV

(*continued*)

Expt. (xvii) Saimungkau, Control. 12–30.

	Upper	Middle	Lower	Total (except Top)
Moisture	72.44 %	72.92 %	71.68 %	72.33
Fibre	12.38	11.84	14.66	13.13
Tot. s.	13.92	14.39	14.06	14.14
Red. s.	0.73	0.73	0.58	0.67
Non-r. s.	13.19	13.66	13.48	13.47
Polarisation	13.16	14.39	14.13	13.99
Available Sugar				12.04

D. The Practical Significance of Inundation.

Looking over the milling data for the manufacture of sucrose in our factory, we noticed that the maximum yield of sugar is always attained near the close of the milling period of the year. It is clear that if we are able to control the ripening period of the cane by any means, the advantage will be not only to lengthen the milling period, but to reduce the capital cost of the factories in some degree.

Unfortunately we have as yet no informations concerning this question. Considering the actual state of sugar production in our factory, some light was thrown upon the possibility of control by some means of the ripening of cane. It may be easily supposed from the experimental results shown above that if canes were brought under conditions favourable for the ripening before the real ripening season sets in, a high content of cane sugar in the juice would result. Of the environmental conditions such as water and temperature for planting, only the supply of water can be regulated by artificial means.

We noticed the following statement in the "Handboek ten Dienste van be Suikerriet-Cultuur en de Rietsuiker-Fabricage op Java" (V. Deel; p. 1.): "Voor een goede rijping van het riet is een drogere periode wel gewenscht, doch geen geval mag deze intreden voordat de groei zoo goed als voleindigd is. Is dit toch het geval, dan wordt het riet niet rijp, doch begint onrijp af the sterven."

Drying of the soil is one way to attain good ripening of cane, but the process is attended with some difficulty in practice.

A possibility was seen of promoting ripening by inundation, both from theoretical considerations and the experimental results, but how to obtain a crop of good ripe cane, or even only early ripening, is the question.

Supplying water during the crop period will exert an unfavourable effect upon the quality of the crop, but rain water, as Krishnamurti Rao[1] has already noticed, has a somewhat different physiological effect on the vegetation of cane from irrigation water. As to irrigation, Earle[2] has remarked that it is necessary to continue the irrigation just before the harvest when the cane garden is too dry, but in general it must be cut off or stopped in order to reduce the further growth of the cane. On the other hand, Ishida[3] mentions a case where canes irrigated at intervals of one week throughout the crop period gave the same results in sugar yield as cane cultivated in the usual manner.

It is probable that in regions where the atmospheric temperature during the crop period is not too low, the cane may continue its growth if a certain quantity of water be available for it, but in places with a cold winter, the growth of the cane will be suppressed whether there is a supply of water or not.

Actually, the difficulty in the farming conditions in our fields comes from the fact that it is extraordinarily troublesome to dry up the gardens, which suffer from inefficient drainage, rather than from drought.

It is, therefore, considered that in order to attain a higher sucrose-content in the cane, inundation seems to give better results than drainage. Not only has the latter the defect of the practical difficulty of training members of the factory to carry it out, especially in the local situation, but the former has the merit, that the excess of water will have the effect of reducing the vegetable activity which is effected by the temperature of the soil and air, and change of the temperature has a connection with the moisture-content.

It is often noticed that the stalks of cane growing in a garden having an adequate supply of water are seriously injured, showing a high refractivity of juice though escaping death. This is certain to occur in a garden with a poor water supply, and accordingly the supply of an excess of water to the plant can be regarded as a method of reducing the rate of dead cane or as a means of increasing the yield of sugar per unit area of field.

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1. International Sug. Journal, **31**, 488 (1929).
2. Sugar Cane and its Culture: p. 234 (1928).
3. Kansyoto-Seizo-Kagaku, zyokan, p. 98.

In fact, how to control the supply of water to the crop so as to attain the maximum efficiency from the inundation, is a most important question which will be settled by further investigation.

V. The Utilisation of Solar Energy in the Cane.

By

Shinsaku Ozawa

1. Energy-Fixation in Cane-Stalk.

Solar energy falling on the canes is utilized in both transpiration and photosynthesis, and the products of photosynthesis are partly consumed in growth and partly fixed in the cane stalk and the accessory organs such as roots, leaves etc., in the form of sucrose, fibre and other organic constituents.

The portion of solar energy fixed in the cane in the form of sucrose or fibre is important in quantity and in utility for human life and also from the point of view of plant physiology, but substances other than sucrose and fibre are insignificant in quantity, and may be neglected. Of the carbohydrates that occur in the stalk, the reducing sugar should be considered as a transitory form and sucrose and fibre as fixed forms.

The quantities of sucrose and fibre in cane may be expressed in terms of energy in one and the same unit, and if they are considered in that way, the interrelation between the sucrose and fibre-formation can be conveniently dealt with.

The data shown in Table LVI, which are employed in the following discussions on energy-fixation in cane-stalk were obtained from the smoothed curves plotted from the values observed in 2725 POJ and 2878 POJ canes shown in Fig. 15–16, and representing the changes in the sucrose- and fibre-content of the stalk and the weight of a single stalk. From these data the absolute amount of sucrose and fibre in a single stalk was calculated. The results are shown in Table LVII and Fig. 17.

Table LVI

Sucrose- & Fibre-Content, & Fresh Weight of Stalk.

No.	2725 POJ			2878 POJ		
	Sucrose %	Fibre %	Weight gms.	Sucrose %	Fibre %	Weight gms.
1	5.4	7.5	170	6.5	8.6	280
2	5.3	8.0	200	6.6	9.0	320
3	5.0	8.3	300	6.5	9.1	390
4	4.3	8.2	490	5.6	8.8	550
5	3.3	7.5	800	3.1	7.5	860
6	2.7	6.8	1190	2.0	6.8	1240
7	2.7	6.7	1560	2.0	6.9	1600
8	3.2	6.8	1900	2.5	7.8	1900
9	4.1	7.3	2180	3.4	9.1	2110
10	5.2	8.3	2400	4.4	10.2	2200
11	6.6	9.5	2540	5.5	11.0	2270
12	8.0	10.4	2640	6.6	11.5	2320
13	9.5	10.9	2710	7.8	11.9	2360
14	11.0	11.2	2750	9.0	12.2	2380
15	12.5	11.3	2780	10.2	12.4	2390
16	14.1	11.4	2800	11.4	12.5	2400
17	15.3	11.5	2810	12.6	12.6	2405

Fig. 15

Contents of Fibre & Sucrose.

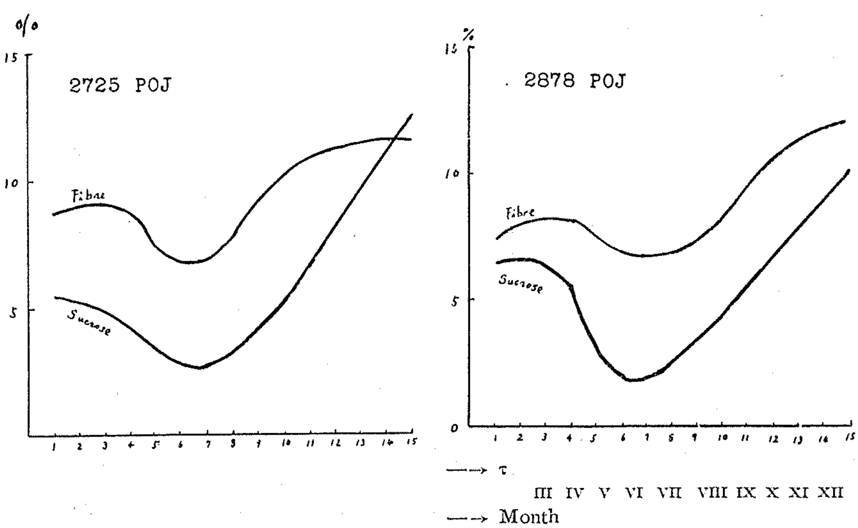


Fig. 16

Fresh Weight.

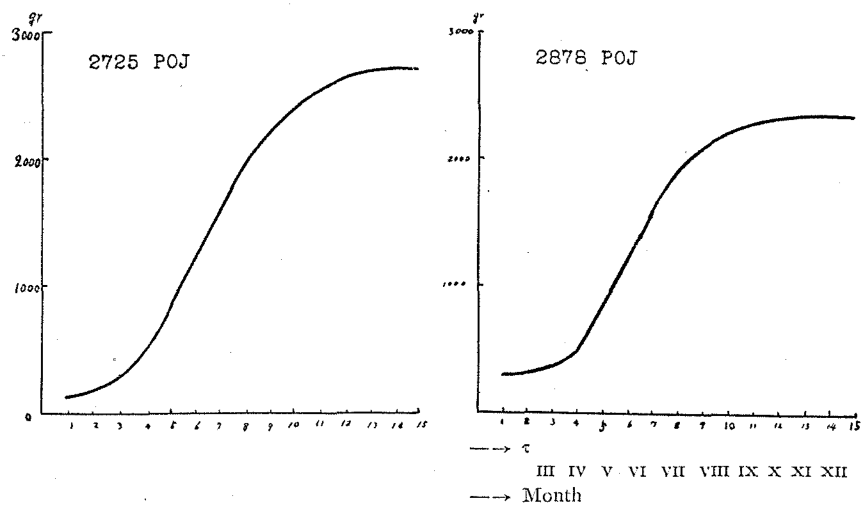


Table LVII

Sucrose & Fibre in a Single Stalk.

No.	2725 POJ		2878 POJ	
	Sucrose gms.	Fibre gms.	Sucrose gms.	Fibre gms.
1	9	13	18	24
2	11	16	21	29
3	15	25	25	35
4	21	40	31	48
5	26	60	27	65
6	32	81	25	84
7	42	103	32	111
8	61	129	46	148
9	89	159	72	192
10	125	199	97	224
11	168	242	125	250
12	212	275	153	267
13	258	296	184	281
14	302	308	214	291
15	348	315	244	297
16	394	319	274	300
17	430	323	303	303

Fig. 17

Fibre & Sucrose in Stalk. Absolute Amount.

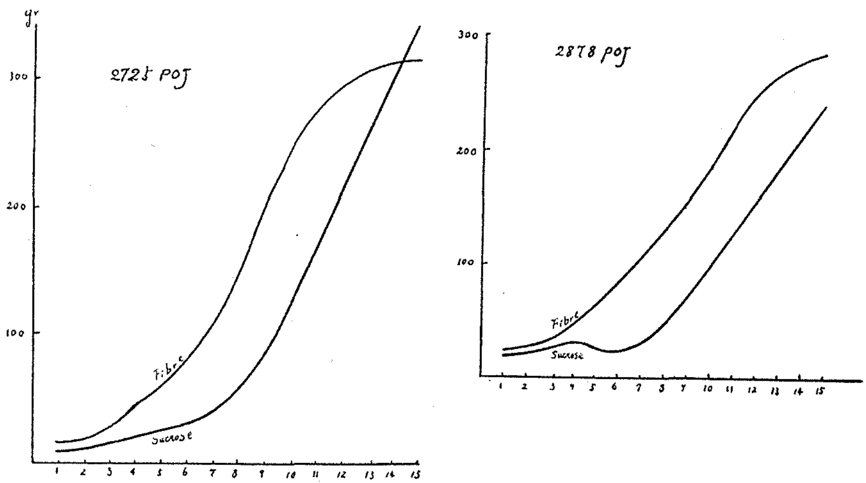


Table LVIII

Energy Fixed as Sucrose (S), as Fibre (F) & Total (E).

No.	2725 POJ			2878 POJ		
	S Cal.	F Cal.	E Cal.	S Cal.	F Cal.	E Cal.
1	35	61	96	71	114	185
2	44	76	120	83	137	220
3	59	118	177	99	169	268
4	84	191	275	123	230	353
5	103(110)	285(278)	388	106(140)	307(273)	413
6	126(140)	385(371)	511	99(160)	401(340)	500
7	166(186)	497(477)	663	127(190)	526(463)	653
8	242(250)	614(606)	856	182(230)	704(556)	886
9	353	756	1109	285(295)	912(902)	1197
10	495	945	1440	384	1066	1450
11	666	1150	1816	495	1186	1681
12	839	1304	2143	605	1268	1873
13	1020	1408	2428	728	1335	2063
14	1195	1462	2657	846	1380	2226
15	1375	1500	2875	965	1410	2375
16	1558	1518	3076	1062	1426	2488
17	1699	1534	3233	1198	1440	2638

Figures in brackets are values corrected for sucrose-consumption.

The heat of the combustion of sucrose and fibre actually occurring in the cane stalk is calculated on the basis of 3955 and 4751 calories per mol of the sugars respectively, and the results are shown in Table LVIII and Figs. 18 and 19.

In order to get clear information as to the energy-fixation in the cane stalk, the rate of the fixation of energy in unit time τ, the interval between any two consecutive samplings (3 weeks) was calculated and the results are shown in Table LIX and Figs. 20 and 21.

The curves for the rate of energy-fixation in unit time $\left(\frac{dS}{d\tau}, \frac{dF}{d\tau}\right.$ and $\left.\frac{dE}{d\tau}\right)$ in 2725 and 2878 POJ canes run parallel, showing the

Fig. 18

Energy fixed in stalk. 2725 POJ
I: Total energy fixed (E)
II: Energy fixed as fibre (F)
III: „ „ „ sucrose (S)
Broken lines represent values corrected for sucrose-consumption.

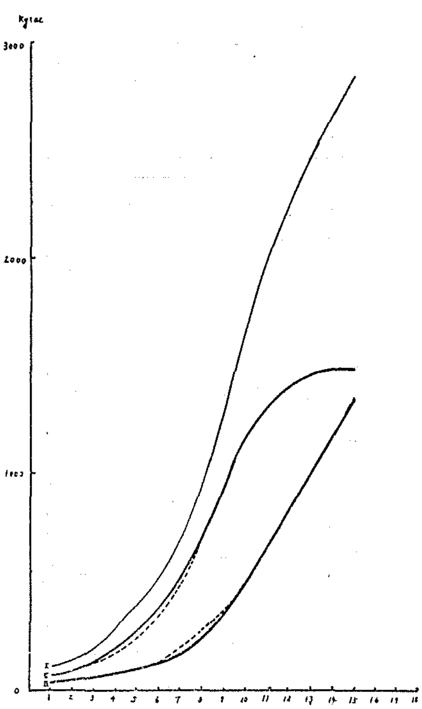


Fig. 19

Energy fixed in stalk. 2878 POJ
I: Total energy fixed (E)
II: Energy fixed as fibre (F)
III: „ „ „ sucrose (S)
Broken lines represent values corrected for sucrose-consumption.

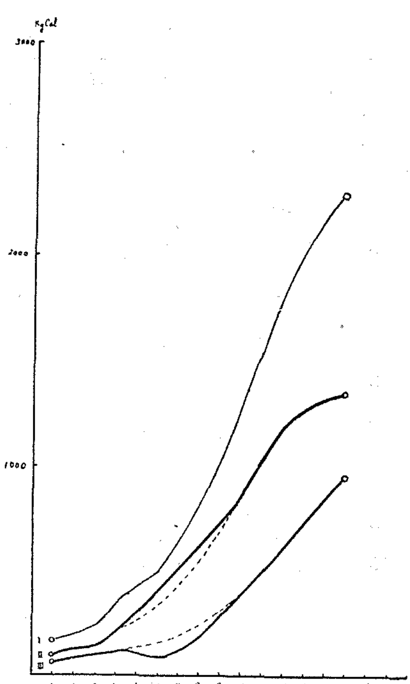


Fig. 20

Rates of Energy-Fixation
2725 POJ

I: Total $\left(\frac{dE}{d\tau}\right)$

II: as Fibre $\left(\frac{dF}{d\tau}\right)$

III: as Sucrose $\left(\frac{dS}{d\tau}\right)$

Broken lines represent the values corrected for sucrose-consumption.

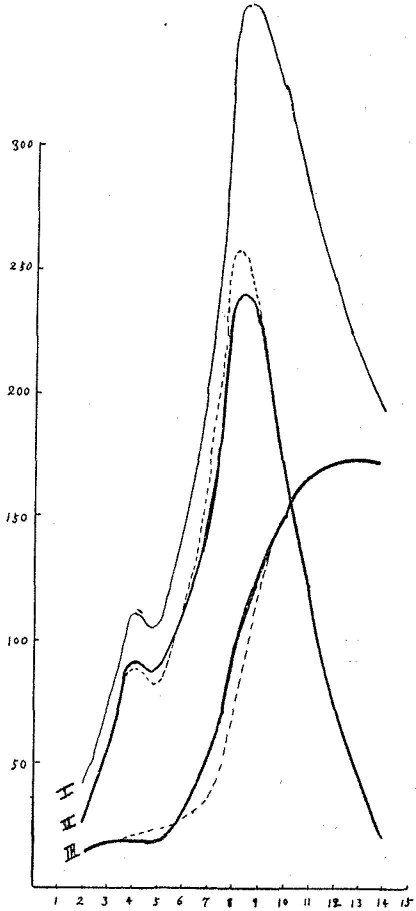


Fig. 21

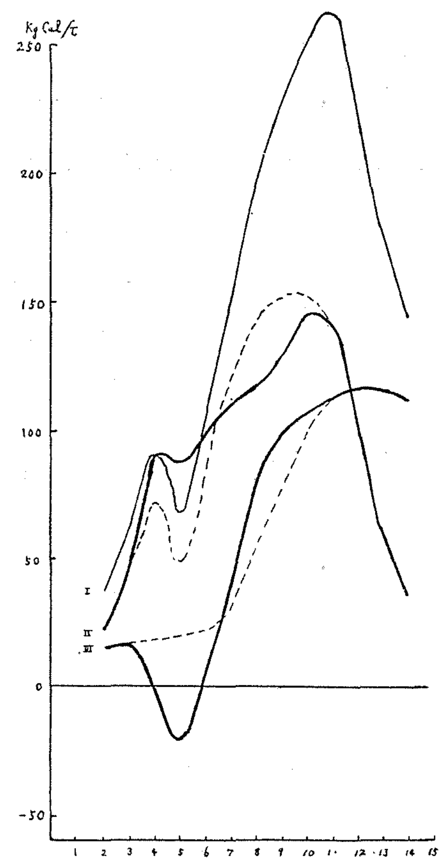
Rates of Energy-Fixation
2878 POJ

I: Total $\left(\frac{dE}{d\tau}\right)$

II: as Fibre $\left(\frac{dF}{d\tau}\right)$

III: as Sucrose $\left(\frac{dS}{d\tau}\right)$

Broken lines represent the values corrected for sucrose-consumption.



minimum and maximum points in similar positions in each curve and three inflection points before the maximum. The only marked difference between the two cases is that in the cane of 2878 POJ, $\frac{dS}{d\tau}$ at its minimum or in May it has a negative value which indicates that the source of energy stored in the form of sucrose has been consumed.

It may seem rather absurd to think that sucrose-consumption is also occurring in the other strain, 2725 POJ cane, in the corresponding stage, since the quantity of sucrose in a single stalk as a whole does not decrease, but a decrease in sucrose-content was actually noticed in the lower part of the stalk due to sucrose being supplied as a source of energy for the upper vigorously growing parts. (cf: Part II.)

A point of inflection in these supposedly meaning the consumption of energy stored in the form of sucrose, slight corrections were applied to the F- and S-curves in Figs. 20 and 21 shown in broken lines, and the corrected values are shown in Table LVIII and LIX (in brackets), and these curves shown in Figs. 20 and 21 respresent the rates of the fixation of energy in the form of fibre and sucrose, which are supposed for simplicity to be formed by the photosynthetic

Table LIX

Rates of Energy-Fixation as Sucrose $\left(\frac{dS}{d\tau}\right)$, as Fibre $\left(\frac{dF}{d\tau}\right)$ & Total $\left(\frac{dE}{d\tau}\right)$

No.	2725 POJ			2878 POJ		
	$\frac{dS}{d\tau}$ Cal./τ	$\frac{dF}{d\tau}$ Cal./τ	$\frac{dE}{d\tau}$ Cal./τ	$\frac{dS}{d\tau}$ Cal./τ	$\frac{dF}{d\tau}$ Cal./τ	$\frac{dE}{d\tau}$ Cal./τ
1	14	16	30	15	20	35
2	15	35	50	16	30	46
3	18	54	72	18	43	61
4	18(22)	75(71)	93	− 5(19)	80(56)	75
5	19(27)	97(89)	116	−10(20)	100(70)	90
6	25(32)	115(108)	140	5(24)	115(96)	120
7	40(40)	130(130)	170	40(34)	145(151)	185
8	80(60)	140(160)	220	80(55)	200(225)	280
9	125(110)	175(190)	300	98(78)	172(192)	270
10	150	190	340	107(101)	128(134)	235
11	170	170	340	113	97	210
12	180	110	290	118	69	187
13	182	68	250	120	48	168
14	180	40	220	120	32	152
15	170	20	190	119	17	136
16	145	15	160	115	5	120
17	100	15	115	105	5	110

Figures in brackets are values corrected for sucrose-consumption.

activity. The $\frac{dF}{d\tau}$-curves as we see in the figures run quite smoothly in both cases and show only one point of inflection.

The ratio of the rate of energy-fixation as fibre to the total fixation, $R=\frac{dF}{d\tau}\Big/\frac{dE}{d\tau}$, was calculated to see what part of the energy is used for fixation as fibre or sucrose and the results are shown in Table LX and Fig. 22.

Table LX

Ratio, $R=\frac{dF}{d\tau}\Big/\frac{dE}{d\tau}$, & Values of $f\left(t, \frac{dt}{d\tau}\right)$.

No.	2725 POJ		2878 POJ	
	R	$f\left(t, \frac{dt}{d\tau}\right)$	R	$f\left(t, \frac{dt}{d\tau}\right)$
1	0.534	0.441	0.572	0.396
2	0.700	0.624	0.652	0.612
3	0.749	0.718	0.705	0.727
4	0.819(0.766)	0.752	1.062(0.750)	0.774
5	0.844(0.770)	0.793	1.111(0.778)	0.823
6	0.823(0.771)	0.807	0.959(0.800)	0.846
7	0.764(0.765)	0.805	0.783(0.816)	0.844
8	0.637(0.739)	0.760	0.714(0.804)	0.792
9	0.583(0.634)	0.699	0.637(0.710)	0.720
10	0.559	0.615	0.544(0.571)	0.623
11	0.500	0.488	0.462	0.475
12	0.378	0.337	0.369	0.300
13	0.272	0.192	0.286	0.192
14	0.182	0.156	0.210	0.078
15	0.105	0.136	0.125	0.054
16	0.094	0.140	0.042	0.048
17	0.130	0.185	0.045	0.102
18		0.305		0.180

Figures in Brackets are Values corrected for Sucrose-Consumption.

For 2725 POJ, $f\left(t, \frac{dt}{d\tau}\right)=0.05(t-12)+0.08\frac{dt}{d\tau}$.

" 2878 " , " $=0.06(t-12)+0.09\frac{dt}{d\tau}$.

These results show quite a difference from each other and in the case of 2878 POJ the utilisation of energy for fixation as sucrose has already occurred early in May to a considerable extent, as is indicated by the fact that R is greater than unity while in the case of 2725 POJ it is not.

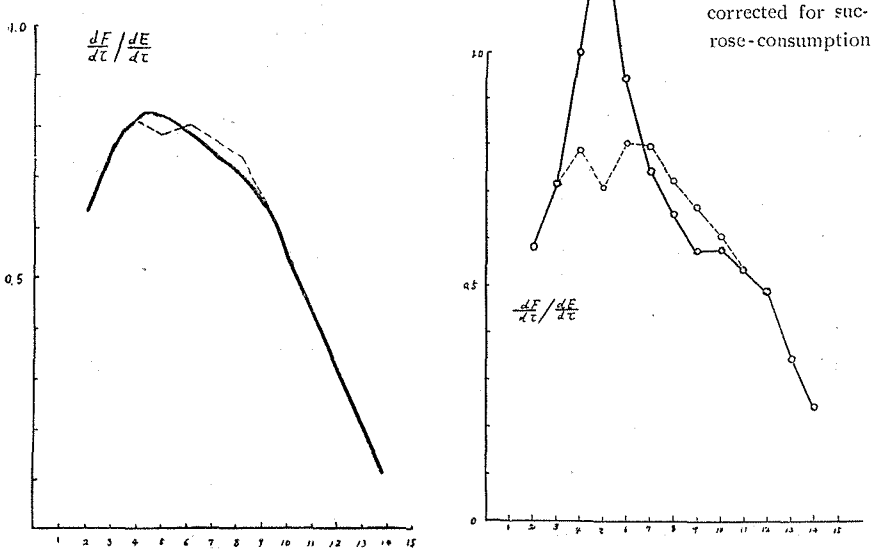
When we compare two values of $R=\frac{dF}{d\tau}\Big/\frac{dE}{d\tau}$ and the rate of growth or the rate or weight-increase, $\frac{dW}{d\tau}$, shown in Table LXI and Fig. 23, we notice there is a maximum of the two ratios in a corresponding stage of two canes and this means that both canes grow in an analogous manner and most rapidly when the largest fraction of energy is fixed as fibre, as may easily be supposed.

It is noteworthy that the maximum of R and of the rate of growth $\frac{dW}{d\tau}$ corresponds to the minimum of energy-fixation as sucrose, $\frac{dS}{d\tau}$, but not the maximum of $\frac{dF}{d\tau}$. In this stage the stalk is quite poor in solid matter but the moisture-content is maximum (See Part II).

Fig. 22.

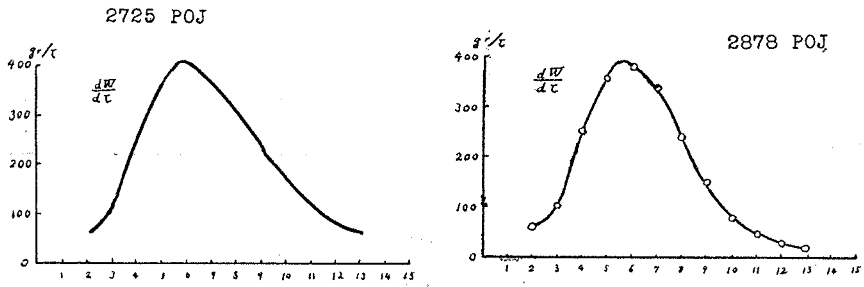
2725 POJ
Broken line represents the values corrected for sucrose-consumption.

2878 POJ
Broken line represents the values corrected for sucrose-consumption



Of the external conditions under which energy-fixation occurs, the temperature of the atmosphere and the water in the soil are considered important factors. In the case where the canes, as we stated in Part I, were grown under good irrigation, and were always able to obtain enough water for their vegetation, temperature was regarded merely as an external condition exerting an influence on the mode of energy-fixation by the plant.

Fig. 23



The temperature and the rate of change in temperature, $\frac{dt}{d\tau}$, during the period when the canes were growing are shown in Table LXI and Fig. 24, which are obtained by interpolation from the data of the Taityu Meteorological Station recorded in the "Togyo-Benran."

Table LXI

Temperature (t) & Rate of Temperature-Rise $\left(\frac{dt}{d\tau}\right)$.

No.	t°C	$\frac{dt}{d\tau}$ °C/τ
1	17.3	2.20
2	20.0	2.80
3	22.6	2.35
4	24.4	1.65
5	26.1	1.10
6	27.1	0.65
7	27.7	0.25
8	27.6	−0.25
9	27 1	−0.70
10	26.3	−1.25
11	24.8	−1.90
12	22.9	−2.60
13	19.8	−2.40
14	18.0	−1.80
15	16.6	−1.15
16	15.6	−0.50
17	15.3	0.25
18	16.1	1.25

Fig. 24

Temperature (t) & Rate of Temperature-Rise $\left(\dfrac{dt}{d\tau}\right)$

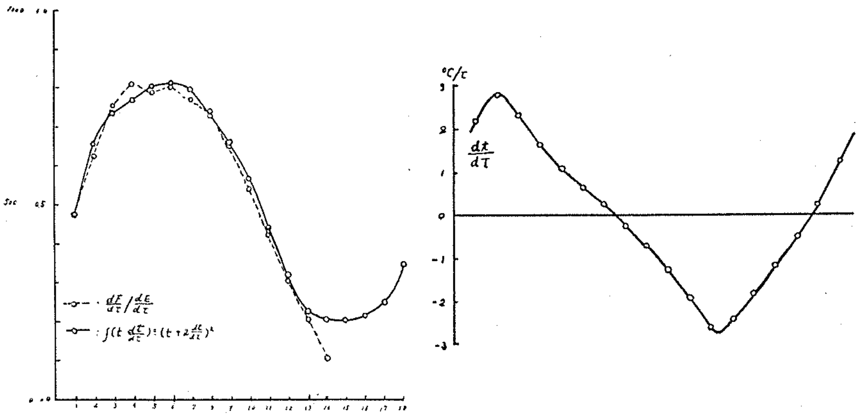
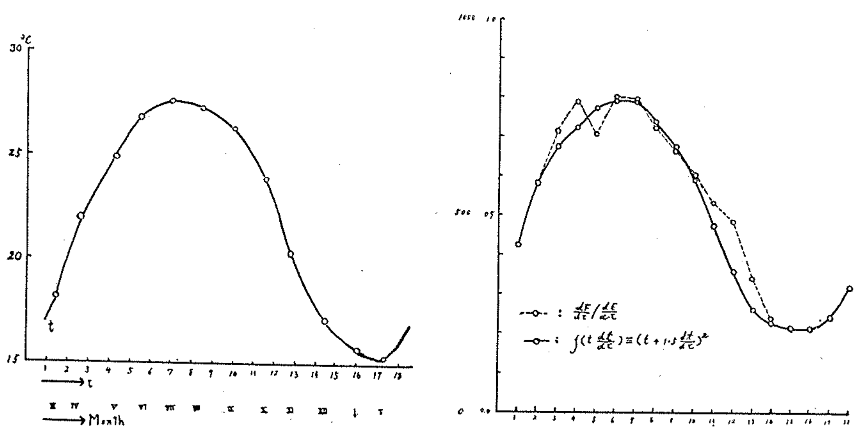


Fig. 25

Ratio $\dfrac{dF}{d\tau} \Big/ \dfrac{dE}{d\tau}$ & $f\left(t, \dfrac{dt}{d\tau}\right)$

2725 POJ 2878 POJ



The maximum of R, as will be seeen in Figs. 23 and 24, occurs before the temperature attains its maximum, and the ratio R can be determined by some function of t and $\dfrac{dt}{d\tau}$, $R=f\left(t, \dfrac{dt}{d\tau}\right)$

$$f\left(t, \frac{dt}{d\tau}\right)=k_1+k_2t+k_3\frac{dt}{d\tau}k_4t^2+k_5\left(\frac{dt}{d\tau}\right)^2+k_6t\frac{dt}{d\tau}+\&c.$$

Fig. 26

A

P: Plane, $R=0.05(t-12)+0.08\frac{dt}{d\tau}$

I: Curre representing t & $\frac{dt}{d\tau}$

II: Curve on P corresponding to I

III: Space-curve representing R corrected for sucrose-consumption

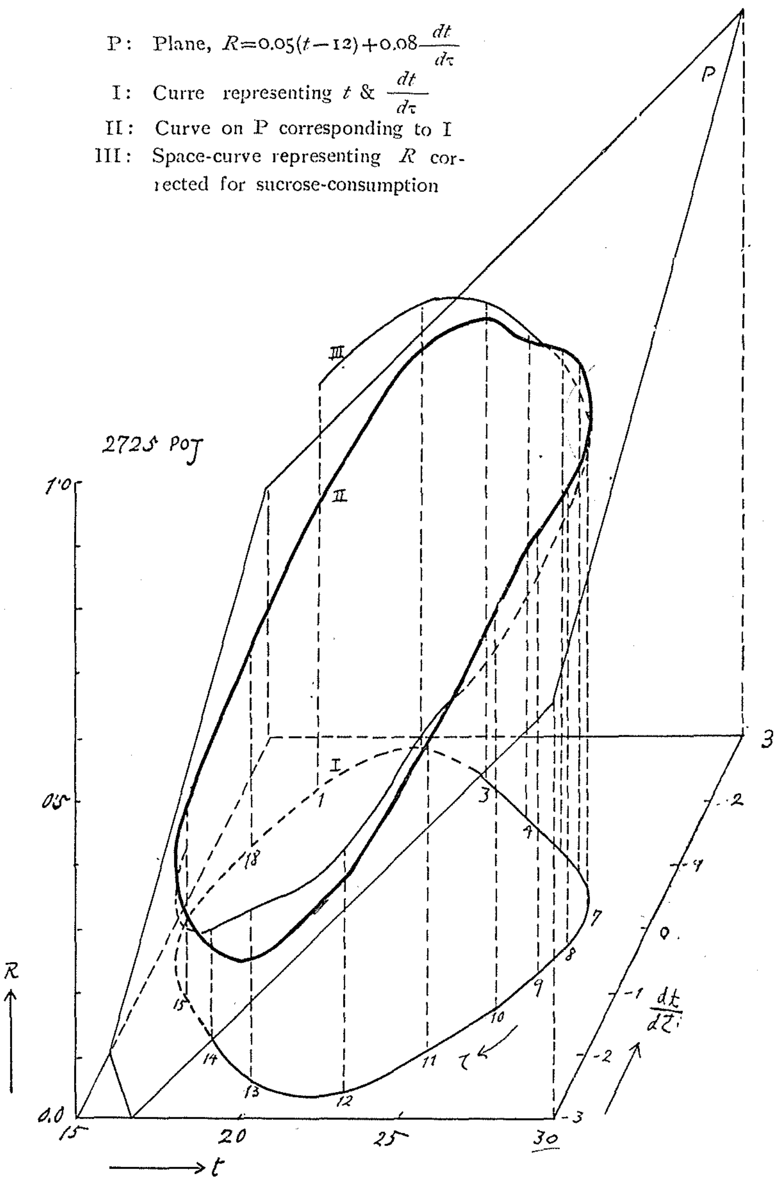


Fig. 26

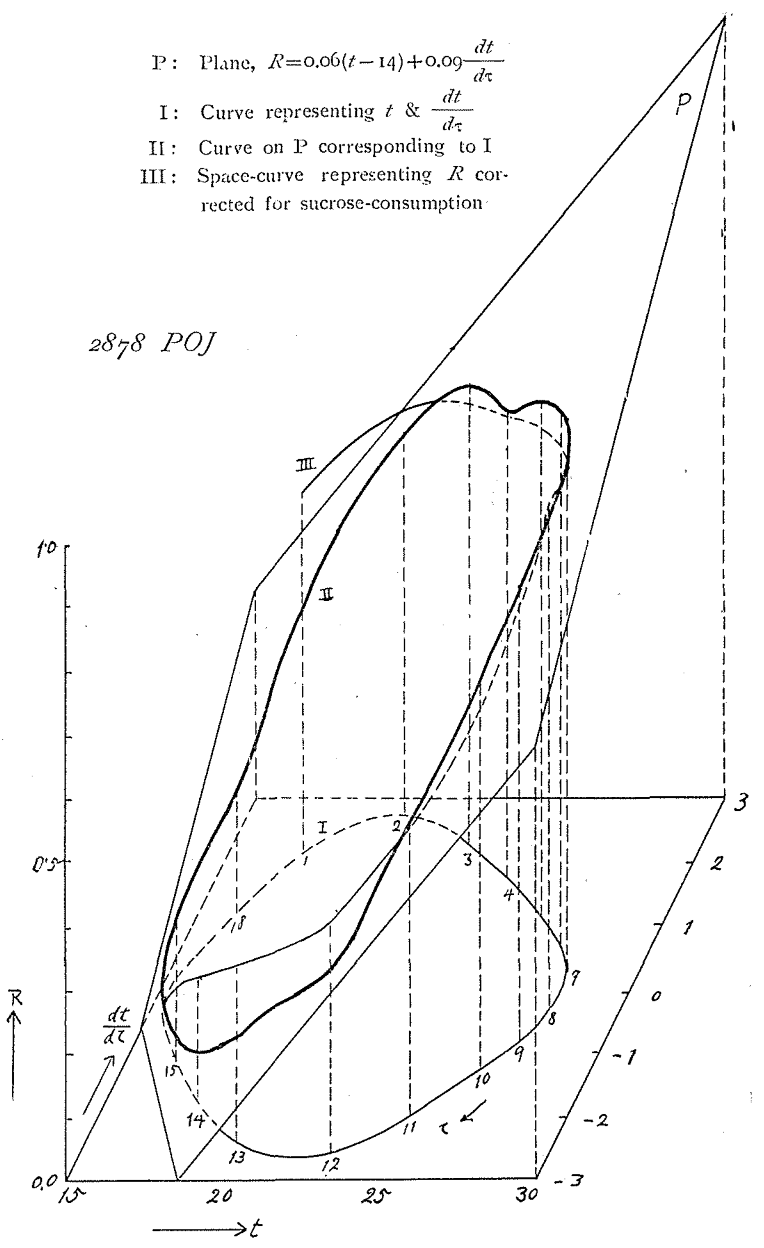
B

P: Plane, $R=0.06(t-14)+0.09\frac{dt}{d\tau}$

I: Curve representing t & $\frac{dt}{d\tau}$

II: Curve on P corresponding to I

III: Space-curve representing R corrected for sucrose-consumption



Assuming that the function is a plane of the form

$$R = a(t - t_0) + b\frac{dt}{d\tau},$$

in which t_0 means the minimum temperature, at which the vegetative activity practically ceases, and a and b the sensitiveness of the plant to variation of temperature, this being characteristic in each variety,

$t_0 = 12$, $a = 0.05$ and $b = 0.08$, for 2725 POJ,

and $t_0 = 14$, $a = 0.06$ and $b = 0.09$, for 2878 POJ.

Applying these data in the above equation, we calculated the values of R and $f\left(t, \frac{dt}{d\tau}\right)$, and these are shown in comparison in Table LX and Figs. 25 and 26.

The deviations of the values of R from those of the plane P indicate that the surface is not a plane. However, in general, these two values agree quite well and this agreement indicates that the mode of energy-fixation in the stalk is influenced by the rate of the change in the temperature and at the same time by the temperature itself.

2. Energy-Fixation in Leaf and Root.

The mode of solar energy-utilisation in the cane will be understood if we know the amount of total energy-fixation in the whole body of the cane. The problem has already been studied in the case of the stalk, and in the present case the question of the leaf- and root-systems will be dicussed.

Solar energy fixed in the leaf- and root-systems can be estimated from the rate of production of solid matter in these organs and also from the study of their heat of combustion.

The solid matter in unit area of the leaf or in the leaf-crown is calculated by interplatation from the smoothed curves representing the weight of unit area and the moisture-content of the leaf, (Part II) since the leaf-crown practically always consists of ten full-grown, healthy leaves. The total solid matter in leaf and leaf-sheath can also be calculated, as may be seen in the Tables LXII, and LXIV by taking their ratio into consideration.

	Weight of leaf gms.	Leaf & leaf-sheath gms.	Ratio
2725 POJ	6082	9232	1.52
2878 POJ	5532	8420	1.52

Table LXII

Dry Matter in Leaf-Crown.

τ	2725 POJ			
	Dry matter in unit area mgms./cm.²	Area of leaf crown without mid-rib m.²	Dry matter in leaf crown without mid-rib gms.	Together with mid-rib gms.
1	7.1	0.38	27.0	36.5
2	7.2	0.45	32.5	44 0
3	7.3	0.51	37.3	50.3
4	7.1	0.57	40.5	54.8
5	6.9	0.63	43.5	58.7
6	6.5	0.68	44.2	59.7
7	6.4	0.71	45.4	61.3
8	6.3	0.71	44.7	60.4
9	6.3	0.70	44.2	59.7
10	6.5	0.67	43.7	59 0
11	6.9	0.63	43.5	58.7
12	7.4	0.58	43.0	58.0
13	7.8	0.54	42.2	57.0

2878 POJ

1	7.3	0.38	27.8	43.5
2	7.4	0.45	33.3	52.0
3	7.3	0.50	36.5	57.1
4	7.0	0.55	38.5	60.2
5	6.5	0.58	37.8	59.0
6	6.3	0.60	37.8	59.0
7	6.1	0.61	37.3	58.3
8	6.1	0.61	37.3	58.3
9	8.2	0.59	39.6	57.2
10	6.4	0.56	35.8	56.0
11	6.7	0.52	34.9	54.6
12	6.9	0.48	33.1	51.7
13	7.1	0.41	29.1	45.5

Table LXIII

Rates of Dry Matter-Production.

2725 POJ

τ	Dry matter per one leaf gms.	Number of leaves produced in unit time.	Dry matter production	
			In leaf-system. gms./τ	In leaf & root. gms./τ
1	5.56	0.6	3 3	6.1
2	6.70	1.1	7.3	13 4
3	7.76	1.5	11.5	21.2
4	8.34	1.9	15.8	29.1
5	8.92	2.2	19.6	36.1
6	9.08	2.5	22.7	41.8
7	9.33	2.8	26.1	48.2
8	9.20	3.0	27.7	51.0
9	9.08	3.0	27.4	50.4
10	8.99	2.7	24.4	45.0
11	8.92	2.3	20.5	37.8
12	8.82	1.8	15.8	29.1
13	8.67	1.3	11.2	20.6

2878 POJ

1	6.62	0.4	2.6	4.8
2	7.91	0.9	7.2	13.2
3	8.70	1.4	12.2	22.5
4	9.16	2.0	18.3	33.8
5	8.99	2.4	21.6	39.8
6	8.99	2.7	24.4	45.0
7	8.88	3.0	26.7	49.2
8	8.88	3.0	26.7	49.2
9	8.70	2.7	23.6	43.5
10	8.56	2.3	19.6	36.2
11	8.30	1.9	15.8	29.1
12	7.86	1.5	11.7	21.6
13	6.92	1.2	8 4	15.5

Table LXIV

Rate of Energy-Fixation.

2725 POJ	In stalk cal./τ	In leaf & root cal./τ	Total cal./τ
1	30	29	59
2	50	64	114
3	72	101	173
4	93	138	231
5	116	171	287
6	140	198	338
7	170	229	399
8	220	242	462
9	300	239	539
10	340	214	554
11	340	180	520
12	290	138	428
13	250	97	347

2878 POJ

1	35	23	58
2	46	63	109
3	61	107	168
4	75	160	235
5	90	189	279
6	120	214	334
7	185	234	419
8	280	234	514
9	270	204	477
10	235	172	407
11	210	138	348
12	187	102	289
13	168	74	242

The product of each two numbers multiplied by 1.84 gives the rate of production of total solid matter in a leaf- and root-systems respectively, where 1.84 is the ratio of total solid matter in leaf- and root-systems to that in the leaf-system alone, and is calculated from the statements found in Noël Deerr's "Cane Sugar" (p. 12).

Thus, the rate of energy-fixation in the leaf- and root-systems is obtained approximately by assuming that the solid matter in both leaves and roots consists of the same constituents as the stalk, and the rate of total energy-fixation in the whole cane and the numerical values are given in Table LXIV and Figs. 27 and 28.

Fig. 27

Rate of Total Energy-Fixation
I: In whole plant
II: In stalk
III: In leaf & root

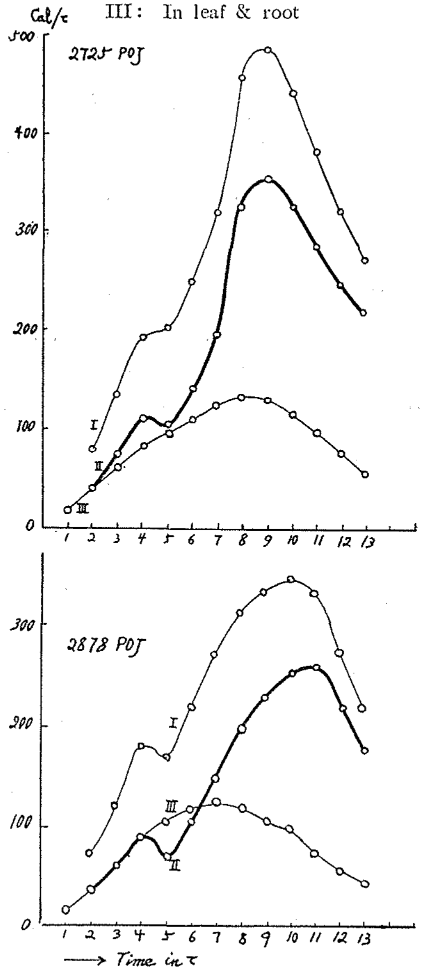
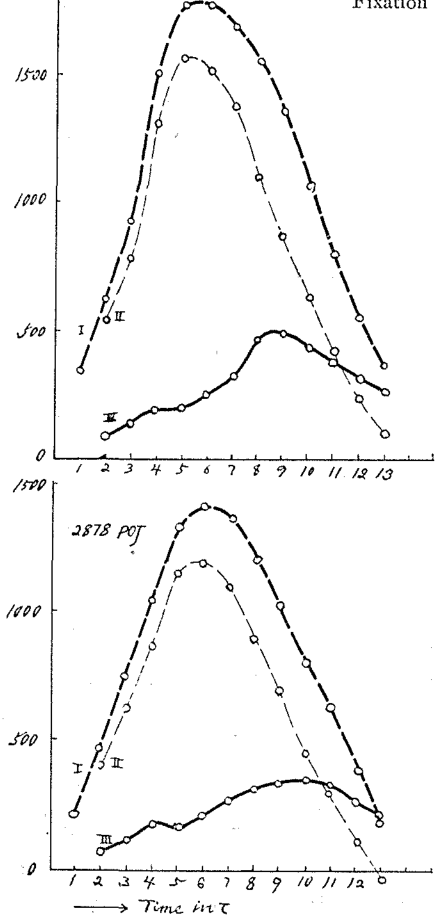


Fig. 28

Rate of Energy-Utilisation
I: In photosynthesis
II: In growth
III: Fixation



3. Utilisation of Energy by Photosynthesis and Consumption of Energy in Growth.

The rate of energy utilised in the photosynthetic activity of chlorophyllous leaves is denoted by $\frac{dP}{d\tau}$, which can be determined as follows:

$$\frac{dP}{d\tau}=k,\ t,\ I,\ C.$$

I. the intensity of the light falling on the leaf,

t. the temperature, which is given by the values stated in § I,

C. the quantity of chlorophyll in the leaf.

I. is calculated from the light-intensity-curve[1] on the assumption that the sun shines 12,600 minutes per τ.

The calculated values for *t. I. C.* are shown in Table LXV.

When the actual values for $\frac{dP}{d\tau}$ are proportional to the calculated ones, the proportional constant is included in the value of k.

The quantity of carbon dioxide taken by the plant from the air can be determined by calculation from the area of the leaf-crown and the chlorophyll-content, (Part II). As the leaves cover the whole area of a cane garden during the period of vigorous vegetation, the area occupied by the leaf-crown is assumed to be constant throughout. There are about 70,000 stalks per ha. in the case of 2725 POJ, and 77,000 stalks in the case of 2878 POJ, and the numerical values for the area of the leaf-crown are found by calculation to be 0.143 $m.^2$ and 0.130 m^2., respectively.

The constant k can be determined as follows:

By assuming that the relation $\frac{dS}{d\tau}=\frac{dF}{d\tau}=\frac{1}{2}\frac{dE}{d\tau}$, at $\tau=11$ holds in the case of energy-fixation in the stalk, for both varieties of cane, we can put some arbitrary value for k, since it has been proved in the case of the stalk that the growth is proportional to the fixation of energy in the form of fibre but not of sucrose, and this principle can be applied to the leaf- and root-systems.

Then, we have at $\tau=11$,

$$\frac{dE(\text{tot})}{d\tau}=\frac{1}{2}\frac{dP}{d\tau},$$

1. Spoehr. Photosynthesis, p. 28.

where $\frac{dE(\text{tot.})}{d\tau}$ means the rate of total energy-fixation in the whole body of the cane, and the value of k is

$k=1.71\times10^{-3}$, for 2725 POJ, and

$k=1.53\times10^{-3}$, for 2878 POJ.

For the sake of simplicity, the value of k is assumed to be identical in the two cases and equals to 1.6×10^{-3}. By means of this value, the numerical values for *k. t. C. I.* were calculated and the results are shown in the last column of Table LXV and in Fig. 29.

Now, the rate of energy-consumption in growth, $\frac{dG}{d\tau}$, must be represented by the difference between $\frac{dP}{d\tau}$ and $\frac{dE(\text{tot.})}{d\tau}$; the results of

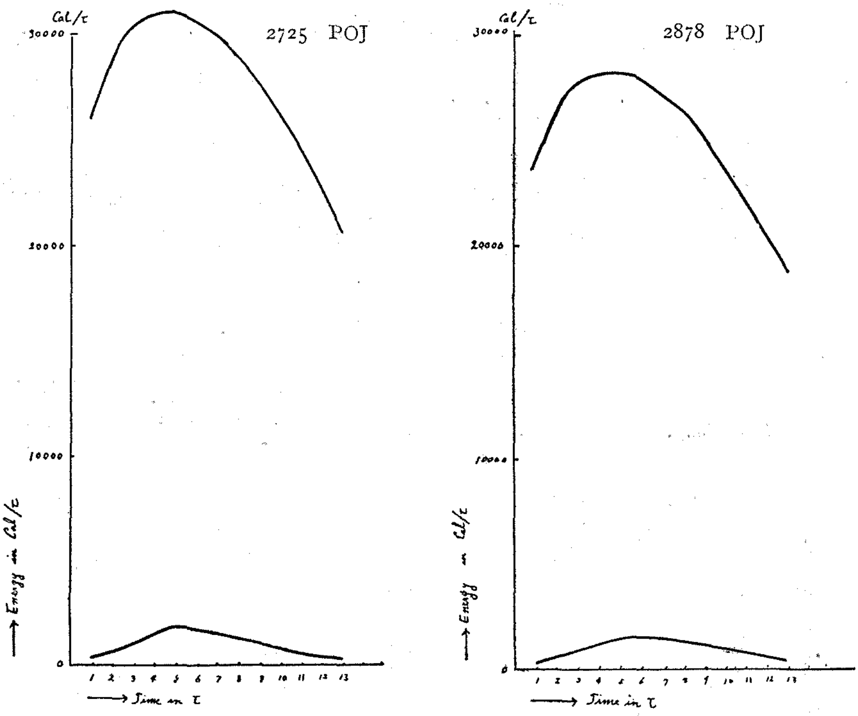
Table LXV

Photosynthetic Utilisation of Solar Energy.

	I 2725 POJ Cal./τ	Chlorophyll in unit area mgms./cm.^{2}	Area of leaf-surface m.^{2}	C gms.	T. C. I. Cal./τ	K.T.C.I. $\left(\frac{dP}{d\tau}\right)$ Cal./τ
1	2.61×10^4	0.115	0.38	0.44	1.99×10^5	3.24×10^2
2	2.89	0.148	0.45	0.65	3.56	5.77
3	3.05	0.185	0.51	0.94	6.50	10.6
4	3.10	0.230	0.57	1.31	9.90	16.0
5	3.12	0.250	0.63	1.58	12.9	20.8
6	3.05	0.250	0.68	1.70	14.1	22.8
7	2.98	0.245	0.71	1.74	13.7	22.2
8	2.90	0.230	0.71	1.64	13.1	21.2
9	2.75	0.210	0.70	1.48	11.0	17.9
10	2.60	0.190	0.67	1.28	8.77	14.2
11	2.43	0.160	0.63	1.01	6.10	9.88
12	2.24	0.135	0.58	0.78	4.01	6.50
13	2.06	0.095	0.54	0.51	2.08	3.37
	2878 POJ					
1	2.37	0.115	0.38	0.44	1.81	2.93
2	2.62	0.145	0.45	0.65	3.41	5.52
3	2.77	0.185	0.50	0.93	5.83	9.44
4	2.81	0.230	0.55	1.27	8.70	14.1
5	2.83	0.250	0.58	1.46	10.8	17.5
6	2.77	0.250	0.60	1.50	11.3	18.2
7	2.71	0.245	0.61	1.50	11.3	18.2
8	2.63	0.230	0.61	1.40	10.2	16.5
9	2.53	0.210	0.59	1.24	8.50	13.8
10	2.36	0.190	0.56	1.06	6.60	10.7
11	2.20	0.160	0.52	0.83	4.54	7.35
12	2.03	0.135	0.48	0.65	3.03	4.91
13	1.87	0.095	0.41	0.39	1.45	2.35

Fig. 29

Photosynthetic Utilisation of Solar Energy
I: Total energy falling on plant
II: Energy utilised in photosynthesis



this calculation are shown in Table LXVI and Fig. 30.

The value of $\frac{dG}{d\tau}$ can be calculated in another way.

The rate of increase in the total weight of the cane-body including the value due to the accumulation of solid matter should rather be regarded as a measure of energy-fixation. Hence, the rate of increase in the total weight of body minus the rate of solid matter accumulation may be considered to represent more precisely the true rate of growth, which is calculated on the assumption that the moisture-content of the leaf- and root-systems is always 75%.

The numerical value of the rate of energy-consumption in growth is obtained from that of the rate of growth by multiplying by 3.62, which is derived from the following equation:

$$\frac{1}{2}\frac{dP}{d\tau}=\frac{dG}{d\tau}=\frac{dE(\text{tot.})}{d\tau}, \text{ at } \tau=11.$$

Table LXVI

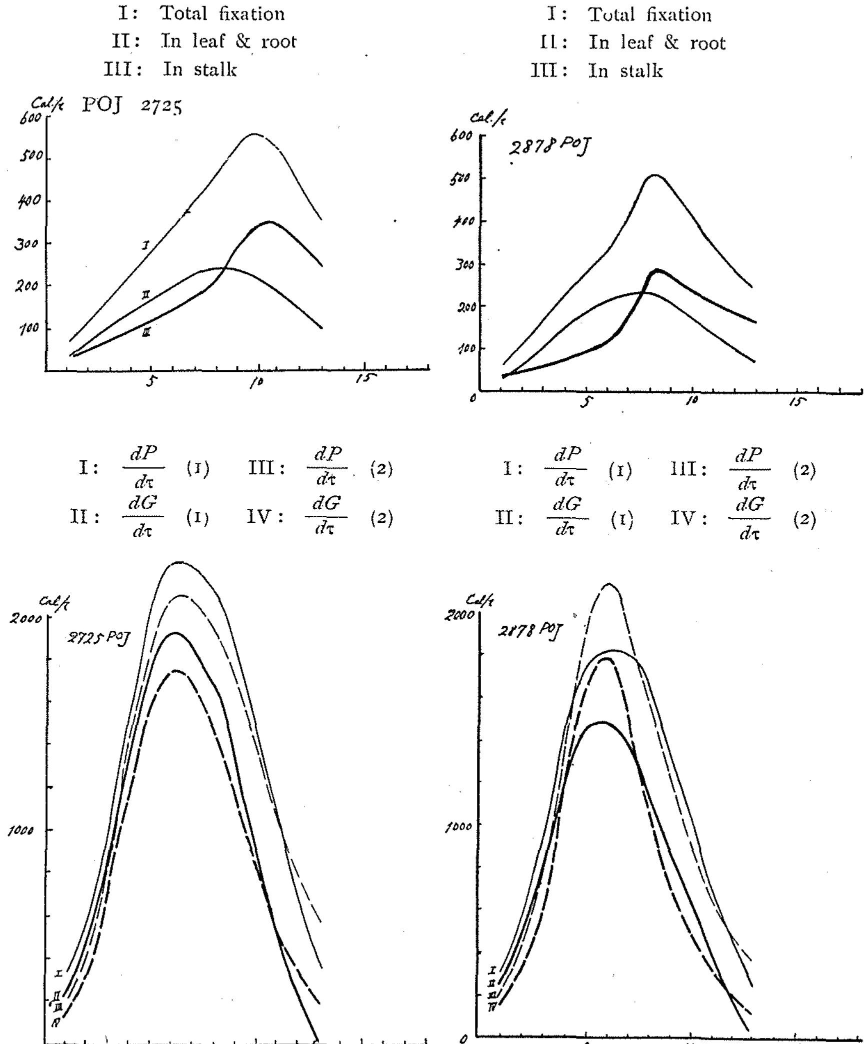
Consumption of Energy in Growth.

2725 POJ	Rates of increase in the weights of: Stalk gms.	Leaf & root gms.	Total gms.	Solid in: Stalk gms.	Leaf & Root gms.	Total gms.	Diff'ce of fresh wt. & solid gms.	$\frac{dG}{d\tau}$ by 2nd method Cal./τ	by Previous method Cal./τ
1	23	24	47	6.7	6.1	13	34	1.2×10^{-2}	2.2×10^{-2}
2	54	54	108	11.2	13.4	25	83	3.0	4.7
3	140	85	225	16.0	21.2	37	188	6.8	8.9
4	254	116	370	20.4	29.1	50	320	11.6	13.7
5	360	144	504	25.2	36.1	61	443	16.0	17.9
6	390	167	557	30.5	41.8	72	485	17.6	19.4
7	350	193	543	37.5	48.2	86	467	16.6	18.2
8	300	204	504	49.8	51.0	101	403	14.6	16.7
9	230	202	432	68.4	50.4	119	313	11.3	12.5
10	170	180	350	78.0	45.0	123	227	8.2	8.7
11	110	151	261	78.8	37.8	117	144	5.2	4.7
12	76	116	192	68.7	29.1	98	94	3.4	2.2
13	55	82	137	60.5	20.6	81	56	2.0	−0.1

2878 POJ

1	30	19	49	8.0	4.8	13	36	1.2	2.3
2	52	53	105	10.4	13.2	24	81	2.9	4.4
3	100	90	190	13.7	22.5	36	154	5.6	7.7
4	230	135	365	15.6	33.8	49	316	11.4	11.7
5	350	159	509	18.6	39.8	58	451	16.3	14.7
6	390	180	570	25.4	45.0	70	500	18.1	14.9
7	310	193	503	40.6	49.2	90	413	14.9	14.0
8	220	193	413	62.5	49.2	112	301	10.9	11.4
9	130	174	304	56.0	43.5	101	203	7.3	9.0
10	85	145	230	54.1	36.2	90	140	5.1	6.6
11	58	116	174	49.0	29.1	78	96	3.5	3.9
12	40	86	126	44.3	21.6	66	60	2.2	2.0
13	26	62	88	40.4	15.5	56	32	1.2	0.0

Fig. 30



The agreement of the values obtained for $\frac{dG}{d\tau}$ in two different ways, as may be seen in Table LXVI and in Fig. 30, can be regarded as a measure of the reliability of the reasoning in the calculation of them. From these data we can learn to what degree the solar energy is utilized in the photosynthetic activity of the plant and also in its growth.

4. The Ripening of the Cane

A. The Rate of Ripening

The ripening or the increase in the sucrose-content of the cane stalks, appears as a result of a number of complicated chemical reactions occurring in the carbohydrates in the stalk.

The most important reactions which have a close connexion with the phenomenon of ripening are on the one hand the polymerisation of the simple sugar formed by the photochemical reaction in the presence of chlorophyll from carbon dioxide and water on the other, the conversion of the sugar into sucrose; the former is intimately connected with the growth or increase in the weight of the stalk and the latter mostly with the ripening of the cane. In the present chapter, the rate of ripening will be dealt with from the physicochemical view point with regard to the chemical reactions occurring in the carbohydrates in the plant tissues, shown in the scheme:

$$C_6H_{12}O_6 \xrightarrow{-xH_2O} (C_6H_{10}O_5)x$$

$$C_6H_{12}O_6 \underset{}{\overset{-H_2O}{\rightleftarrows}} C_{12}H_{22}O_{11}$$

The following notation will be used:—

W: weight of stalk.

$\frac{dW}{d\tau}$: rate of increase in weight of stalk.

s: amount of sucrose in stalk.

V: rate of ripening, i. e., rate of increase in sucrose-content of stalk.

$\frac{s}{W}$: sucrose-content.

$\frac{ds}{d\tau}$: rate of sucrose-accumulation, increase in amount of sucrose present in stalk in unit time.

If the changes in the weight of stalk and the amount of sucrose in time $\Delta\tau$, are represented by ΔW and Δs respectively, the mean rate of increase in sucrose-content during $\Delta\tau$ is given by

$$\left\{\frac{s+\Delta s}{W+\Delta W}-\frac{s}{W}\right\}/\Delta\tau=\left\{\frac{\Delta s}{\Delta\tau}-\frac{s}{W}\cdot\frac{\Delta W}{\Delta\tau}\right\}/(W+\Delta W).$$

The rate of increase in sucrose-content at the moment in question is obtained by taking the limiting case of $\Delta\tau\rightarrow 0$. Accordingly,

$$V=\lim\left(\frac{\Delta s}{\Delta\tau}-\frac{s}{W}\cdot\frac{\Delta W}{\Delta\tau}\right)/(W+\Delta W)=\frac{1}{W}\frac{ds}{d\tau}-\frac{s}{W}\cdot\frac{1}{W}\cdot\frac{dW}{d\tau}.$$

If

$$\frac{ds}{d\tau}\bigg/\frac{dW}{d\tau}\gtreqless\frac{s}{W},\text{ for positive values of }\frac{dW}{d\tau},$$

then, $V\gtreqless 0$.

In other words, the relative magnitude of $\frac{ds}{d\tau}\big/\frac{dW}{d\tau}$ and $\frac{s}{W}$ determines the change in the sucrose-content. The decrease in the sucrose-content which occurs after maximum ripeness will be called the phenomenon of "rejuvenescence," as it is the opposite of ripening. $\frac{ds}{d\tau}$ may have negative values as well as positive, but $\frac{dW}{d\tau}$ cannot be negative so long as the vegetation of the cane continues. When however, the photosynthetic assimilation of carbon and the growth of the plant are completely stopped, both $\frac{ds}{d\tau}$ and $\frac{dW}{d\tau}$ become negative and in that case,

if,

$$\frac{ds}{d\tau}\bigg/\frac{dW}{d\tau}\lesseqgtr\frac{s}{W},$$

then, $V\gtreqless 0$.

Cane-cuttings being kept unsupplied with water, may be taken as an example of the change in sucrose-content under the condition stated above.

Two-eyed cuttings of an average weight of 168 gms. prepared on the 17th of September, 1929, were kept without any water for a week, and the changes in weight and chemical composition observed during that period were as follows:—

Table LXVII

Date	Sept. 17	Sept. 24
Weight gms.	168	128
Moisture %	81.1	76.3
Fibre „	8.34	9.62
Red. sug. „	3.86	4.58
Non-red.s. in %	5.49	5.52
Non-red.s. gms.	9.2	7.0

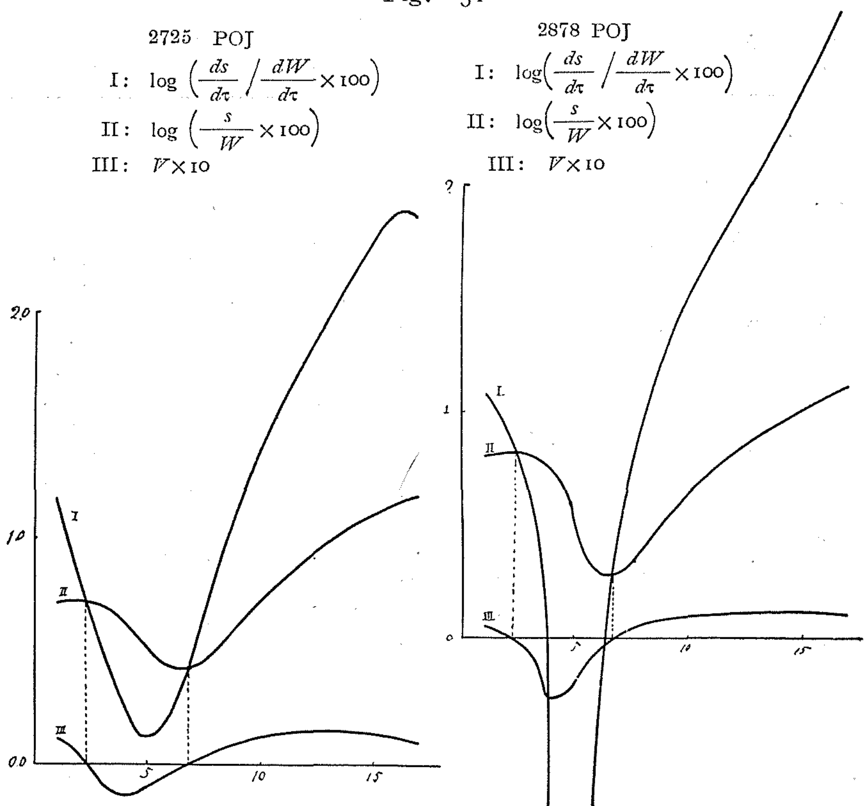
If $\frac{ds}{d\tau}$ be positive when $\frac{dW}{d\tau}$ is negative, then V is of course positive. This case is observed in an artificial ripening of fruit such as the banana, which happens through the conversion of starch into sucrose, as was proved by Bridel and Bourdouil[1].

If $\frac{ds}{d\tau} \Big/ \frac{dW}{d\tau} = \frac{s}{W}$, then $V = 0$.

This is the condition necessary and satisfactory for the occurrence of the maximum and minimum sucrose-content.

The changes in the values of $\frac{ds}{d\tau} \Big/ \frac{dW}{d\tau}$, $\frac{s}{W}$ and V, for both 2725 and 2878 POJ canes, are shown in the following Table LXVIII and figure 31; the experimental details were described in the previous communication.

Fig. 31



1. Loc cit.

Table LXVIII

2725 POJ

τ	$\frac{ds}{d\tau}$	$\frac{dW}{d\tau}$	$\frac{ds}{d\tau} \Big/ \frac{dW}{d\tau}$	$\frac{s}{W}$	V	$\frac{1}{W} \cdot \frac{ds}{d\tau}$	$\frac{1}{W} \cdot \frac{dW}{d\tau}$
1	3.5	23	0.152	0.054	0.013	0.0206	0.135
2	3.8	24	0.070	0.053	0.004	0.0187	0.270
3	4.5	140	0.032	0.050	−0.006	0.0150	0.467
4	4.5	254	0.018	0.043	−0.013	0.0092	0.518
5	4.8	360	0.013	0.033	−0.009	0.0057	0.450
6	6.3	390	0.016	0.027	−0.004	0.0052	0.328
7	10.0	350	0.029	0.027	0.000	0.0064	0.224
8	20.0	300	0.067	0.032	0.005	0.0105	0.157
9	31.3	230	0.136	0.041	0.010	0.0143	0.105
10	37.5	170	0.221	0.052	0.011	0.0156	0.0709
11	42.5	110	0.386	0.066	0.014	0.0167	0.0433
12	45.0	76	0.593	0.080	0.013	0.0170	0.0388
13	45.5	55	0.828	0.095	0.015	0.0168	0.0203
14	45.0	34	1.323	0.110	0.015	0.0164	0.0124
15	42.5	20	2.125	0.125	0.014	0.0153	0.00721
16	36.3	13	2.782	0.141	0.013	0.0130	0.00465
17	25.0	10	2.500	0.153	0.008	0.0089	0.00356

2878 POJ

τ	$\frac{ds}{d\tau}$	$\frac{dW}{d\tau}$	$\frac{ds}{d\tau} \Big/ \frac{dW}{d\tau}$	$\frac{s}{W}$	V	$\frac{1}{W} \cdot \frac{ds}{d\tau}$	$\frac{1}{W} \cdot \frac{dW}{d\tau}$
1	3.8	30	0.127	0.065	0.006	0.0134	0.107
2	4.0	52	0.077	0.066	0.002	0.0125	0.163
3	4.5	100	0.045	0.065	−0.005	0.0115	0.182
4	−1.3	230	−0.006	0.056	−0.026	−0.0023	0.418
5	−2.5	350	−0.007	0.031	−0.016	−0.0030	0.407
6	1.3	390	0.003	0.020	−0.005	0.0010	0.313
7	10.0	310	0.032	0.020	0.002	0.0063	0.194
8	20.0	220	0.091	0.025	0.008	0.0105	0.116
9	24.5	130	0.188	0.034	0.009	0.0116	0.0617
10	26.8	85	0.315	0.044	0.010	0.0120	0.0388
11	28.3	58	0.488	0.055	0.011	0.0124	0.0256
12	29.5	40	0.737	0.066	0.011	0.0127	0.0172
13	30.0	26	1.152	0.078	0.012	0.0127	0.0110
14	30.0	18	1.667	0.090	0.012	0.0126	0.00756
15	29.8	10	2.980	0.102	0.012	0.0124	0.00418
16	28.8	6	4.433	0.114	0.012	0.0120	0.00250
17	26.3	4	6.575	0.126	0.011	0.0109	0.00166

In the formula for the rate of ripening,

$$\frac{1}{W} \cdot \frac{ds}{d\tau} = \frac{s}{W} \cdot \frac{1}{W} \cdot \frac{dW}{d\tau},$$

$\frac{1}{W}\cdot\frac{ds}{d\tau}$ and $\frac{1}{W}\cdot\frac{dW}{d\tau}$ the rate of increase of sucrose and of weight of stalk per unit weight of stalk, and are important for comparison of the modes of ripening of canes of unequal sizes.

The numerical values of these expressions are shown in Table LXVIII.

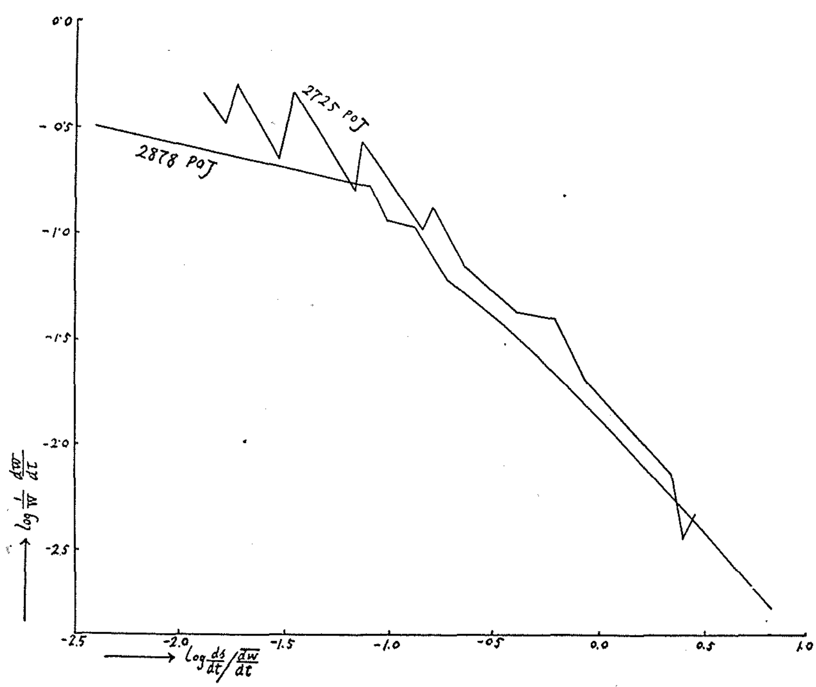
The value of $\frac{1}{W}\cdot\frac{ds}{d\tau}$ does not change so rapidly as the value of $\frac{1}{W}\cdot\frac{dW}{d\tau}$, and remains pretty constant for a short time.

Since, as is shown by the equation

$$\frac{1}{W}\cdot\frac{dW}{d\tau}=\frac{1}{W}\cdot\frac{ds}{d\tau}\left(\frac{ds}{d\tau}\bigg/\frac{dW}{d\tau}\right)^{-1},$$

$\frac{1}{W}\cdot\frac{dW}{d\tau}$ is considered proportional to $\left(\frac{ds}{d\tau}\bigg/\frac{dW}{d\tau}\right)^{-1}$ while $\frac{1}{W}\cdot\frac{ds}{d\tau}$ remains practically constant, the latter, being an important factor in the determination of the rate of ripening, was regarded as the representation of a property that is characteristic in each strain of cane.

Fig. 32



The numerical relation between $\frac{1}{W}\cdot\frac{dW}{d\tau}$ and $\frac{ds}{d\tau}\Big/\frac{dW}{d\tau}$ is illustrated practically in Fig. 32.

Consider now the equation,

$$R=\frac{dF}{d\tau}\Big/\frac{dE}{d\tau}, \qquad \frac{dE}{d\tau}=\frac{dF}{d\tau}\Big/\frac{dS}{d\tau}$$

where $\frac{dF}{d\tau}$ denotes the rate of energy-fixation in the form of fibre,

$\frac{dE}{d\tau}$, the rate of total fixation of energy,

$\frac{dS}{d\tau}$, the rate of energy-fixation in the form of sucrose.

The ratio $\frac{ds}{d\tau}\Big/\frac{dW}{d\tau}$, which manifests itself as a result of the vegeta-

Fig. 33

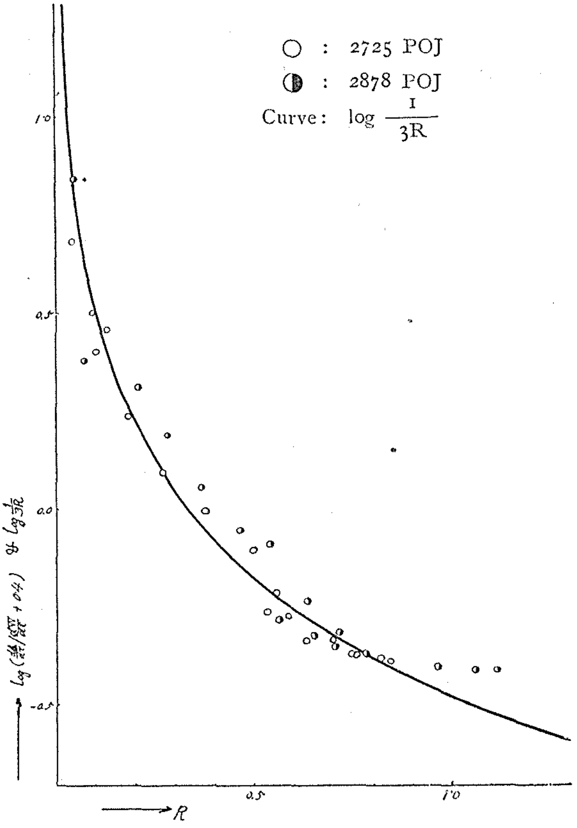


Table LXIX

2725 POJ

τ	R	$\frac{1}{3}\cdot R^{-1}$	$\frac{ds}{d\tau} \Big/ \frac{dW}{d\tau}\cdot 0.4$
1	0.534	0.624	0.552
2	0.700	0.476	0.470
3	0.749	0.445	0.432
4	0.819	0.407	0.418
5	0.844	0.395	0.413
6	0.823	0.405	0.416
7	0.764	0.436	0.429
8	0.637	0.523	0.467
9	0.583	0.572	0.536
10	0.559	0.596	0.621
11	0.500	0.652	0.786
12	0.378	0.883	0.993
13	0.272	1.226	1.228
14	0.182	1.832	1.723
15	0.105	3.175	2.525
16	0.094	3.546	3.182
17	0.130	2.564	2.900

2878 POJ

1	0.572	0.583	0.527
2	0.652	0.511	0.477
3	0.705	0.473	0.445
4	1.062	0.314	0.394
5	1.111	0.300	0.393
6	0.959	0.348	0.403
7	0.783	0.426	0.432
8	0.714	0.467	0.491
9	0.637	0.523	0.588
10	0.544	0.613	0.715
11	0.462	0.722	0.888
12	0.369	0.903	1.137
13	0.286	1.165	1.552
14	0.210	1.587	2.067
15	0.125	2.667	3.380
16	0.042	7.936	4.833
17	0.045	7.407	6.975

tion is supposed to have a close connection with R, and so, if there is some relation between them, $\frac{ds}{d\tau} \Big/ \frac{dW}{d\tau}$ for normal cases, may be expressed as a function of the temperature t and the rate of change in the temperature, $\frac{dt}{d\tau}$, and the value of R for normal cases is already represented by the function of t and $\frac{dt}{d\tau}$.

Comparing the observed values for $\frac{ds}{d\tau} \Big/ \frac{dW}{d\tau}$ and R in the cases of 2725 and 2878 POJ canes, we have the equation

$$\frac{ds}{d\tau} \Big/ \frac{dW}{d\tau} \cdot 0.4 = \frac{1}{3} R^{-1},$$

and the actual values for each term of the equation are shown compared in Table LXIX and Fig. 33.

Hence, $R = f\left(t, \frac{dt}{d\tau}\right)$, where $f\left(t, \frac{dt}{d\tau}\right) \equiv a(t - t_0) + b\frac{dt}{d\tau}$, and the approximate values of $\frac{ds}{d\tau} \Big/ \frac{dW}{d\tau}$ are defined in terms of t and $\frac{dt}{d\tau}$ as follows :—

$$\frac{ds}{d\tau} \Big/ \frac{dW}{d\tau} = \frac{1}{3}\left\{a(t - t_0) + b\frac{dt}{d\tau}\right\}^{-1} - 0.4.$$

B. On the Early-Ripening and Late-Ripening Strains

The maximum position of sucrose-content in the sucrose-content-time-curve, is characteristic in each strain of cane, and a strain is usually called early-ripening or late-ripening according as the maximum content of sucrose is attained early or late in the ripening season. The phenomena observed in these strains will now be considered theoretically.

The sucrose-content is maximum when the equation

$$\frac{ds}{d\tau} \Big/ \frac{dW}{d\tau} = \frac{s}{W}$$

holds with falling values of $\frac{ds}{d\tau} \Big/ \frac{dW}{d\tau}$.

When the vegetation is normal, the value of $\frac{ds}{d\tau} \Big/ \frac{dW}{d\tau}$ is expressed by

$$\frac{ds}{d\tau} \Big/ \frac{dW}{d\tau} = \frac{1}{3}\left\{a(t-t_0) + b\frac{dt}{d\tau}\right\}^{-1} - 0.4.$$

At the maximum of sucrose-content, the equation

$$\frac{1}{3}\left\{a(t-t_0) + b\frac{dt}{d\tau}\right\}^{-1} - 0.4 = \frac{s}{W},$$

holds.

For simplicity we deal with the cases of (1) 2725 and (2) 2878 POJ canes:

Strain	a	b	t_0	$\left(\frac{s}{W}\right)_{max.}$
1	0.05	0.10	10	15
2	0.05	0.10	15	15

and assume that the value of $\frac{dt}{d\tau}$ is constant at $+2.0$ during the time in question and that the initial value of the temperature $t_{\tau=0}=15$. Then the calculated values of $\frac{ds}{d\tau} \Big/ \frac{dW}{d\tau}$ by the formula given above are as follows:—

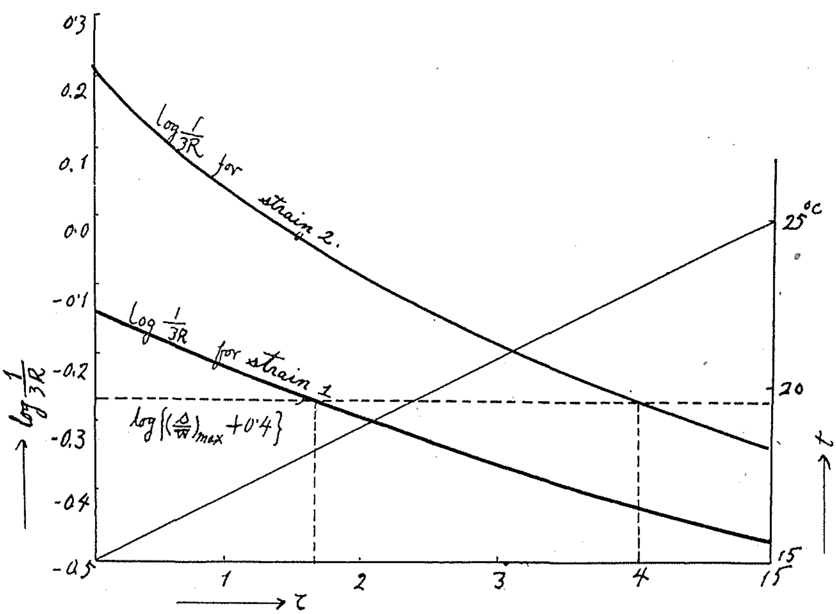
Table LXX

τ	t	$\frac{ds}{d\tau} \Big/ \frac{dW}{d\tau}$ strain 1	$\frac{ds}{d\tau} \Big/ \frac{dW}{d\tau}$ strain 2
0	15	0.340	1.267
1	17	0.206	0.711
2	19	0.125	0.433
3	21	0.044	0.267
4	23	−0.008	0.156
5	25	−0.049	0.076

As is observed in Fig. 34, the maxima for strains 1 and 2 occur at $\tau=\tau_1$, and $\tau=\tau_2$. Accordingly, strain 1 is earlier-ripening than strain 2.

Although in actual cases, the values for a and b differ with every strain and $\frac{s}{W}$ is variable, the difference between the positions of the maximum sucrose-content of 2725 and that of 2878 POJ canes would arise from the difference in the values of the limiting temperature, t_0; the higher the value of t_0, the greater the value of $\frac{ds}{d\tau} \Big/ \frac{dW}{d\tau}$, and the difference between the values of $\frac{ds}{d\tau} \Big/ \frac{dW}{d\tau}$ in the two cane strains is more marked in cooler weather than in

Fig. 34



warmer, which means that the vegetation of the strain with the higher value of t_0 is hindered to a greater extent than that of the other when the temperature is low. Consequently, the value of $\frac{1}{W} \cdot \frac{dW}{d\tau}$ for the first strain must be markedly smaller in a cool season, than that for the second one with a low value of t_0. In case $\frac{1}{W} \cdot \frac{dW}{d\tau}$ is quite small, the rate of increase in the sucrose-content of one strain becomes smaller than that of the other, in spite of the value of $\frac{ds}{d\tau} \Big/ \frac{dW}{d\tau}$ being higher, and the former has a tendency to ripen slower and to show its maximum sucrose-content later than the latter. The facts actually observed in the ripening of 2725 and 2878 POJ canes agree with this statement.

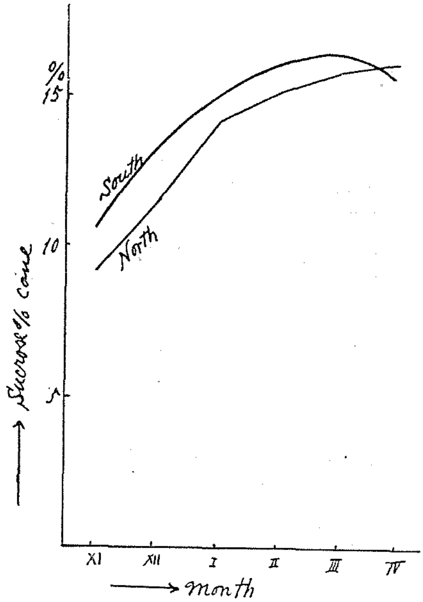
It may also be remarked that if the value of the limiting temperature t_0 is too low for the meteorological conditions under which the cane is cultivated, the rate of ripening must be low owing to the excessively low value of $\frac{ds}{d\tau} \Big/ \frac{dW}{d\tau}$, and the cane cannot show a sufficiently high sucrose-content even at its maximum, which clearly occurs in an early season.

C. Canes cultivated in the Tropical and Subtropical Regions of Formosa

As we mentioned before, the mode of vegetation or ripening of cane is influenced greatly by the climatic conditions, and the biochemical study of canes cultivated in the southern tropical region of Formosa and in the northern subtropical region is interesting as showing the effect of environmental conditions upon the vegetation of cane.

The modes of ripening of 2725 POJ cane in the southern and northern parts of the island, are summarised in the numerical data shown in Table LXXI and Fig. 35, which were obtained from experiments performed at various factories and reported in No. 42 of the Reports of the Agricultural Department, Government Research Institute, Formosa.

Fig. 35



From these data the following conclusions are drawn :—

1° The sucrose-content of southern cane is higher in November than that of northern cane.

2° The rate of increase in sucrose-content is practically the same in both cases.

3° The maximum of the sucrose-content in southern cane occurs somewhere about the beginning of March, while that of the northern cane occurs in April.

Table LXXI

Southern Part

	XI	XII	I	II	III	IV
Toroku	9.16	11.94	15.75	16.77	17.03	15.83
Kobi	8.75	10.59	13.55	13.83	16.11	15.54
Sautan	11.71	14.85	16.25	17.86	17.02	17.00
Nausei	12.72	14.37	15.96	16.67	15.68	16.34
Uzyurin	12.98	14.41	15.61	16.78	17.09	15.31
Soya	9.96	13.07	14.01	14.57	16.27	12.21
Wauri	10.03	13.15	13.98	16.37	17.30	17.40
Saukanten	12.27	14.22	15.94	16.62	17.24	16.69
Ako	8.09	12.14	14.34	15.02	15.02	14.07
Mean	10.63	13.19	15.04	16.05	16.53	15.60

Northern Part

	XI	XII	I	II	III	IV
Sintiku	7.72	11.24	14.02	16.02	15.60	16.15
Taityu	10.59	13.10	16.90	17.61	18.87	19.34
Getubi	7.56	8.35	12.18	14.00	13.26	14.18
Syoka	7.91	10.99	13.57	13.29	15.64	14.80
Keiko	8.82	11.97	14.68	15.31	14.45	14.56
Nauto	11.33	12.90	15.40	15.86	15.74	17.53
Kotobuki	7.29	9.44	12.05	14.80	16.02	15.85
Keisyu	9.18	12.10	14.53	16.37	15.38	16.38
Horisya	12.01	12.87	13.27	12.79	16.10	16.14
Mean	9.16	11.44	14.07	15.12	15.67	16.10

The climatic conditions or the mean monthly atmospheric temperature and rainfall, under which both of southern and northern canes grow are mentioned in Tables LXXII and LXXIII; the northern part is cooler and wetter in winter than the southern part owing to the sequence of rainy days in that season but the southern part has numerous showers in summer, and consequently some marked difference must be noticed between the amounts of solar radiant energy falling upon the leaves of the plant in the two parts.

Now, the chemical changes occurring in the constituents of the cane stalks, must be effected by the temperature and the rate of temperature change, and the values of R and $\frac{ds}{d\tau} \Big/ \frac{dW}{d\tau}$ at any given time, which are calculated by the equations

$$R = a(t - t_0) + b\frac{dt}{d\tau},$$

and

$$\frac{ds}{d\tau} \bigg/ \frac{dW}{d\tau} = \frac{1}{3} R^{-1} - 0.4,$$

Table LXXII

Mean Atmospheric Temperature (°C)

Month	Taihoku	Taityu	Tainan	Kosyun
I	15.2	15.7	16.9	20.3
II	14.7	15.4	16.8	20.2
III	17.0	18.2	19.6	22.1
IV	20.8	21.9	23.3	24.5
V	23.8	24.9	25.9	26.2
VI	26.7	26.8	27.3	27.4
VII	28.1	27.7	27.7	27.5
VIII	27.9	27.3	27.3	27.1
IX	26.1	26.2	26.8	26.6
X	23.0	23.6	24.7	25.2
XI	19.7	20.2	21.5	23.2
XII	16.6	17.0	18.2	21.2
Mean	21.6	22.1	23.0	24.3

Table LXXIII

Monthly Rainfall (m.m.)

Month	Taihoku	Taityu	Tainan	Kosyun
I	84	32	25	23
II	135	68	40	31
III	168	96	41	24
IV	148	116	61	51
V	230	245	181	181
VI	281	349	350	375
VII	215	271	329	433
VIII	304	336	432	572
IX	262	160	164	282
X	132	27	39	163
XI	72	21	20	38
XII	78	23	15	18
Total	2110	1746	1695	2189

were calculated for canes grown at Tainan and Taityu with the following results (Table LXXIV).

The value of $\frac{ds}{d\tau} \Big/ \frac{dW}{d\tau}$ for southern cane, as may be seen in Table LXXIV and Fig. 36 is almost always lower than that for the northern cane. Accordingly, if the rate of growth is effected only by temperature-change, the rate of the relative growth, $\frac{1}{W} \cdot \frac{dW}{d\tau}$, must be higher in the southern cane, but as a matter of fact, the changes in the weight of the stalks of the southern and northern canes, in the

Table LXXIV

Southern Part (Tainan)

Month	$t^0 C$	$\frac{dt}{d\tau} {}^0C/\tau$	R	$\frac{ds}{d\tau} \Big/ \frac{dW}{d\tau}$
I	16.9	−0.7	0.189	1.364
II	16.8	0.7	0.296	0.726
III	19.6	2.2	0.556	0.200
IV	23.3	2.3	0.749	0.045
V	25.9	1.6	0.923	0.005
VI	27.3	0.9	0.837	−0.002
VII	27.7	0.0	0.785	0.025
VIII	27.3	−0.5	0.725	0.060
IX	26.8	−1.0	0.660	0.105
X	24.7	−2.2	0.459	0.326
XI	21.5	−2.3	0.291	0.746
XII	18.2	−1.4	0.198	1.284

Middle Part (Taityu)

I	15.7	−0.5	0.165	1.620
II	15.4	1.1	0.258	0.892
III	18.2	2.3	0.504	0.261
IV	21.9	1.9	0.647	0.115
V	24.9	1.2	0.741	0.050
VI	26.8	0.7	0.796	0.019
VII	27.6	0.0	0.780	0.027
VIII	27.3	−0.3	0.741	0.050
IX	26.2	−0.6	0.662	0.104
X	23.6	−1.3	0.476	0.300
XI	20.2	−2.2	0.234	1.025
XII	17.0	−1.4	0.138	2.015

Fig. 36

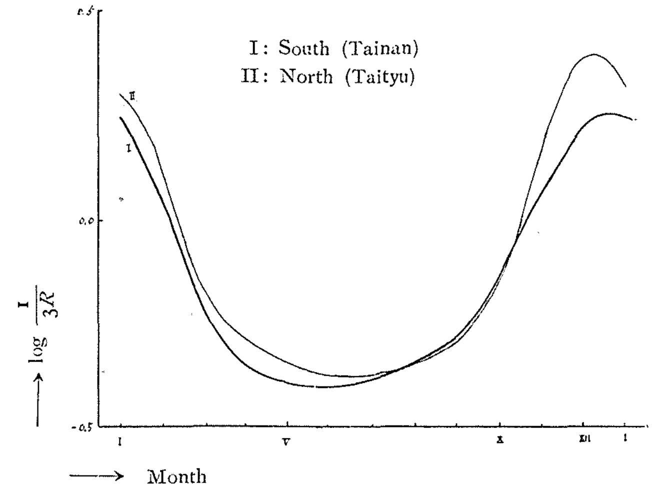
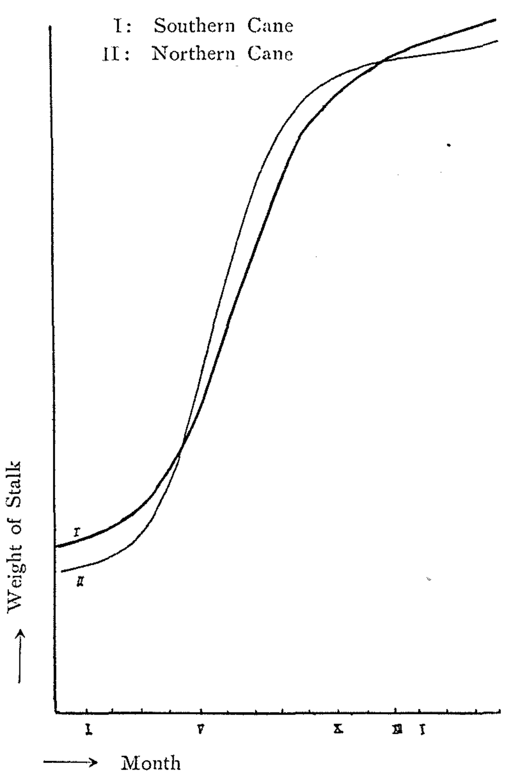


Fig. 37



second year of their life, are as represented schematically in Fig. 37. In other words, the southern cane shows a lower value of $\frac{1}{W} \cdot \frac{dW}{d\tau}$ in the period of most vigorous growth, but a higher value in the ripening season, than the northern cane. The former case is explained by the low rate of rejuvenescence and accordingly the maximum sucrose-content of the southern cane in summer must be higher than that of the northern cane, and the latter case is in harmony with the fact that the rate of ripening in the southern cane with a lower value of $\frac{ds}{d\tau} \Big/ \frac{dW}{d\tau}$ and a higher value of $\frac{s}{W}$, is not slower than that for the northern cane. The effect of the acute coolness on the vegetation of northern cane will be to lower $\frac{1}{W} \cdot \frac{dW}{d\tau}$ and to retard more markedly the rate of ripening.

Finally, when spring returns, the value $\frac{ds}{d\tau} \Big/ \frac{dW}{d\tau}$ for the southern cane will drop below the value of $\frac{s}{W}$ earlier than in the case of the northern cane, and this settles the point of the appearance of the maximum point of sucrose-content.

The deviation of the values of R from the values of $f\left(t, \frac{dt}{d\tau}\right)$ which was actually observed in the study of the life-history of the " Hayaue- " canes remains an interesting subject for future investigation.

D. Rejuvenescence and Over-Ripening.

The phenomenon of the decrease of sucrose-content after the occurrence of the maximum sucrose-content may be called " rejuvenescence"; in this, the chemical composition of the cane-stalk approaches more and more to that observed before the cane has ripened, but it is sometimes called " over-ripening ".

Theoretically, over-ripening will occur in a case where the cane-stalk has no assimilating surface and no growing points. In this case, the composition of the stalk approaches that of the pre-mature stage, just as in the case of the phenomenon of rejuvenescence, and accordingly, it cannot be distinguished from the latter by examination of the changes in the chemical composition of the stalk only. The essential difference between these two phenomena is that in the one, the growth-reaction is occurring and in the other, it is not.

It may be said that the phenomena of growth, ripening, and over-ripening are not essentially different processes, but only different features produced by the combination of various chemical reactions.

The reactions occurring in the cane body are as follows:

$$\begin{array}{ccccc} \text{Outside the System} & \underset{V_5}{\overset{V_1}{\rightleftarrows}} & \text{Red. Sug.} & \xrightarrow{V_2} & \text{Fibre} \\ & & V_4 \uparrow\downarrow V_3 & & \\ & & \text{Sucrose.} & & \end{array}$$

When $v_2 < 2(v_3 - v_4)$ and $v_1 - v_5 > 0$, $v_3 - v_4 > 0$, the ripening-phenomenon appears, and when

$$v_2 > 2(v_3 - v_4) \text{ and } \begin{cases} v_1 - v_5 \gtreqqless 0 \\ v_3 - v_4 \gtreqqless 0, \end{cases}$$

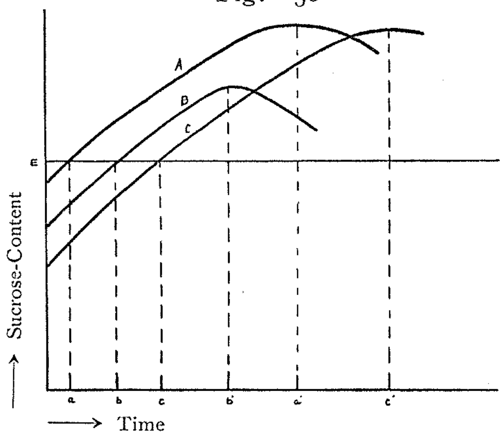
the phenomenon of rejuvenescence occurs.

The phenomenon of over-ripening is to be observed only when $v_1 = 0$, $v_2 = 0$ and $v_3 = 0$, and the transformation of sucrose into reducing sugars and them in turn into some other substances will occur.

E. Comparison of the Early-Ripening and Late-Ripening Strains.

It is said that the 2725 POJ cane is a typical early-ripening strain while 2878 POJ is a late-ripening one, but the true nature of the differences between the two strains is uncertain. For practical purposes, an early ripening cane may be defined as "a variety showing a high sucrose-content earlier than others". There is no theoretical basis for such a view of the maturity of cane.

Fig. 38



Let A, B and C in Fig. 38, be the curves representing the changes in the sucrose-content of three strains and a, b and c the respective points of time at which their sugar content reaches the economic limit, represented by the straight line E, of sucrose-content for sugar-manufacture. According to the definition, A is the earliest-ripening and C is the latest-ripening strain, but their maxima of sucrose-content, as the figure shows, occur at a′, b′ and c′ respectively and therefore the strain B should be called the earliest-ripening of the three because it is the first to attain the maximum sucrose-content.

In fact, 2725 POJ and 2878 POJ canes, as may be seen in Fig. 38, correspond so far as the ripening phenomenon is concerned to the cases A and C, and the latter is called the later-ripening strain.

But the height of E has no theoretical ground, and therefore it seems more convenient and theoretically sound from the mathematical point of view to define early-ripening as follows:

" A strain which reaches the maximum sucrose-content earlier than another is the earlier-ripening strain ".

Now the time when the maximum of the sucrose-content occurs will be discussed.

Since the change in the sucrose-content of the stalk is influenced by numerous internal and external conditions, the definition proposed above becomes practicable only if the relative position of the maximum sucrose-content for all the varieties is the same under any given naturally occurring conditions.

As we have already stated, the maximum of sucrose-content is to be observed when

$$v_2 = 2(v_3 - v_4)$$

within the range of the sucrose-content in cane-stalk.

This equation may be modified as follows:

$$2 = \frac{v_2}{v_3 - v_4}.$$

Hence,

$$\frac{2}{3} = \frac{v_2}{v_2 + (v_3 - v_4)}.$$

The quotient in the right-hand side is none other than " R ", used in the discussions in chapter V, and so we may say that the maximum of sucrose-content is to be observed when the relation,

$$R = \frac{2}{3},$$

holds.

Since the value of R must be influenced by all the internal and external conditions, theoretically, there must exist some relation of the form:

$$R = F(E_1,\ E_2,\ E_3, \ldots\ldots\ ;\ I_1,\ I_2,\ I_3, \ldots\ldots)$$

where E_1, E_2, E_3, &c and I_1, I_2, I_3, &c are external and internal conditions, among which the age of the cane and the temperature of the atmosphere are known to be the most important factors.

The change in atmospheric temperature is the chief factor influencing the vegetative activity, so we have the equation,

$$R=f\left(t, \frac{dt}{d\tau}\right),$$

where, as the first approximation,

$$f\left(t, \frac{dt}{d\tau}\right)\equiv a(t-t_0)+b\frac{dt}{d\tau}$$

may be taken as closely representing the true state of affairs. (cf. V.)

If we neglect the term $\frac{dt}{d\tau}$, which is small compared with the term t, we obtain the following equation as the simplest form of representation.

$$R=a(t-t_0).$$

Consequently, as the first approximation, the time of the occurrence of the maximum may be taken as the time when the value of t satisfies the equation,

$$a(t-t_0)=\frac{2}{3},$$

and, accordingly, the value of t is to be regarded as charcteristic of the strain.

The effect of difference in the moisture-content of the soil will appear in the state of the vegetation and the value of R or it will effect the rate of change in the sugar-content. (cf. II.) But the experimental results shown in Fig. 39 indicate that the position of the maximum of sucrose-content seems not to be appreciably affected by the moisture-content of the soil.

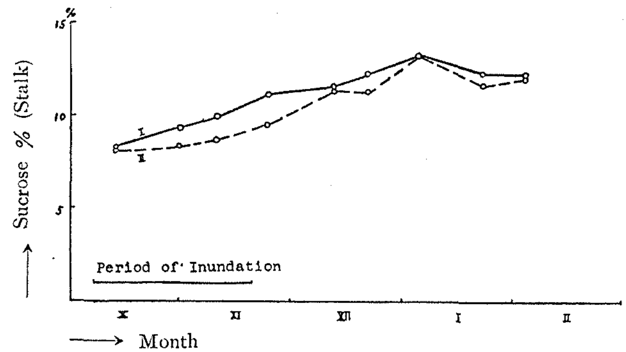
Another example in which the positions of the maxima of sucrose-contents observed in the cases of 2725 POJ cane planted in various months at the Government Research Institute at Sinka are observed to be practically identical, (Togyoka Zigyo Seiseki Gaiyo, (1928) p. 133.) shows that the time of planting exerts little influence upon the value of R, as may be seen in Fig. 39.

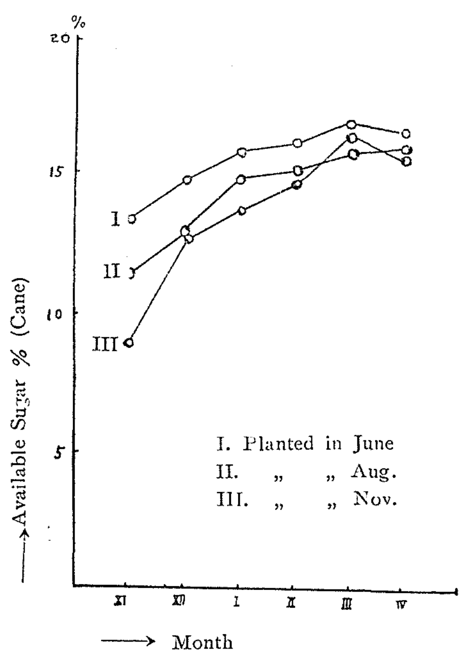
Now, $R=\frac{2}{3}$, being the necessary and sufficient condition for the occurrence of extreme points, satisfies not only the occurrence of the maximum but also of the minimum of sucrose-content.

Fig. 39

"Koa-" Canes

I: Inundation II: Control





Let t_A and t_B denote the temperatures satisfying the equation, $R=\frac{2}{3}$, for the given two strains A and B.

Then if $t_A < t_B$, the minimum in A occurs later than that in B, because the temperature is rising when the maxima occur, but falling in the case of minima. Thus, the position of the minimum value of sucrose-contents is the reverse of that of the maxima, or in other words, the earlier-ripening strain begins to increase its sucrose-content later than the later-ripening one. Fig. 40 is the schematical representation of the state of affairs.

Actual cases which show the changes in sucrose-content in the stalk are exemplified by 2725 and 2878 POJ canes in Fig. 41.

Fig. 40

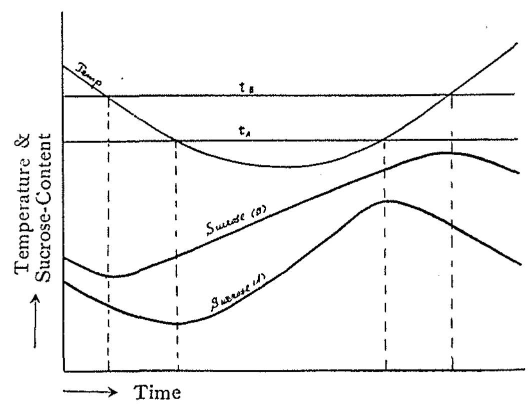
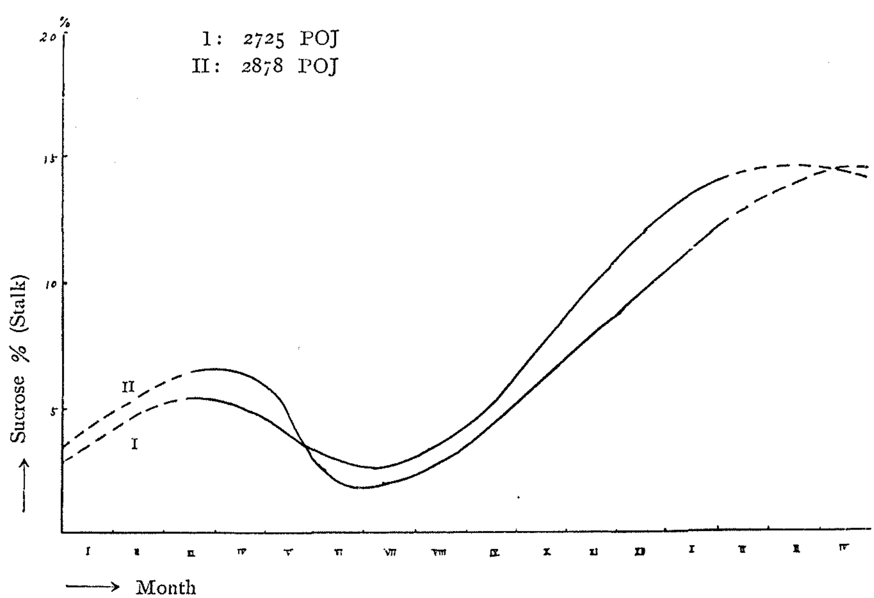


Fig. 41
Sucrose-Contents



VI. Changes in Chemical Composition of Cane Stalks Deprived of Their Leaves

By

Shinsaku Ozawa and **Yasuo Makino**

In the preceding chapter, the fixation of solar energy in the plant body in the case of normally growing canes was discussed, and the disturbances in growth which occur when some anomalous phenomena such as arrowing and the subsequent development of side-shoots and the dying off of leaves happen, have been treated theoretically in the previous communication.

Diminution of the assimilating surface of cane also occurs when some part of the leaf-crown is cut off in order to evade damage by typhoons, as is practised at some places (Handbook, 2nd. (1927) 425), and when the leaves are damaged by some natural causes such as attacks by insects and tearing by wind, etc. The deleterious effects of the artificial damage inflicted on the leaf-system, which has some influence upon the crop of cane-stalk has been examined by some investigators. (Togyoka Zigyo-Seiseki-Gaiyo, (1928) p. 189.) In autumn and winter in Formosa, the north monsoon blows with the force of a gale by which the cane leaf is incessantly damaged and thereby the ripening process seems to be hindered more or less, as it is said that the quality of the harvested cane depends on the strength of the seasonal wind.

If a cane be entirely denuded of its leaves, the supply from the leaf-system of the substances formed by photosynthesis is stopped and the vegetative activities can manifest themselves only by the release of substances already stored in the plant. These chemical changes which occur in the stalk under such conditions must be similar in nature to those observed in the germination of dormant eyes in the case of the preparation of "rajoengans" and in ordinary seed canes (cf. III). In order to see the modes of growth and sugar-accumulation which occur when there is a deficiency of assimilating activity, all the leaves except the topmost folded ones of a certain number of 2725 POJ canes planted on Sept. 20th, 1930 in a cane garden, by the "Kialieng-

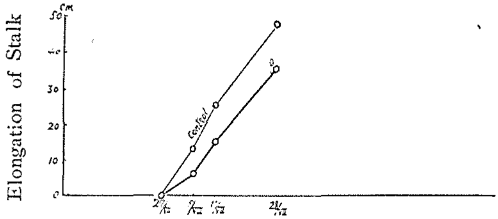
Hantsi" planting system, were completely scissored off on the 27th of July 1931, and the rate of growth of the canes was compared with that of control canes of similar lengths, with the following results. (Table LXXXV Fig. 42).

Table LXXXV

Disturbance in the Rate of Elongation of Stalk.

Date	Treated		Control	
	Stalk-length cms.	Increment cms.	Stalk-length cms.	Increment cms.
VII—27	197	—	193	—
VIII— 5	203	6	206	13
11	212	15	218	25
28	232	35	241	48

Fig. 42



A definite retardation in the rate of elongation of stalk is observed in the treated canes till the newly-formed leaves have reached the normal state, as may be seen in Table LXXXVI and Fig. 43; the leaf-crown reaches its original size again after about fifty days.

Table LXXXVI

Weight of Leaves per Single Stalk.

Date	Treated gms.	Control gms.
VII—27	248	—
VIII—14	100	254
IX—15	210	270
X—15	210	230

The chemical composition of the stalk juice determined by the usual methods, reveals several interesting features with regard to the mechanism of the metabolic changes taking place in the carbohydrates in the stalk. The numerical values for the sugar-content and the rotation of the juice are shown in Table LXXXVII and Figs. 44, 45 and 46.

Fig. 43

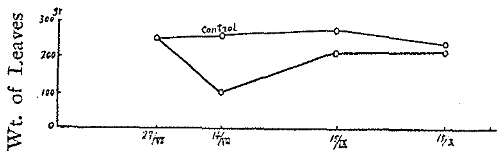


Fig. 44

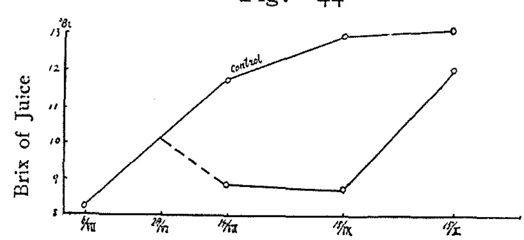


Fig. 45

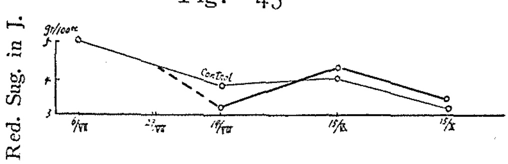
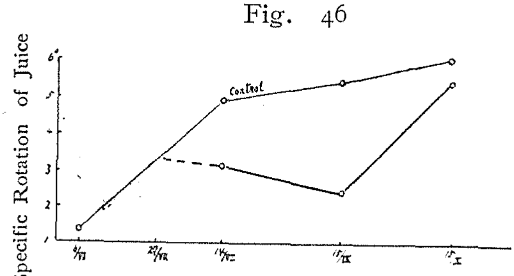


Fig. 46



The degree of brix, which shows the solid-matter content of the juice, keeps constant, and also its specific rotation in the case of a stalk which is deprived of its leaf-system, but both values begin to rise abruptly when the newly-formed leaf-crown reaches the normal size. When the treated cane is compared with the control, there is noticed a marked difference between the two cases in the rotatory power of the juice but not in the content of reducing sugar, probably owing to the difference in the chemical nature of the reducing sugars in it.

Table LXXXVII

Results of Examinations of Juices.

Date	Treated			Control		
	Brix	Rud. sug. in juice	Spec. rot'n of juice	Brix	Red. sug. in juice	Spec. rot'n of juice
	°	gms./100c.c.	°	°	gms./100c.c.	°
VII– 6	8.2	5.00	1.36	8.2	5.00	1.36
VIII–14	8.8	3.13	3.05	11.7	3.76	4.86
IX–15	8.7	4.27	2.38	12.9	3.93	5.37
X–15	12.0	3.40	5.37	13.1.	3.11	6.00

Even although the cane is completely deprived of its leaf-crown it continues to grow at a slow rate, performing the consumption—hydrolysis and oxidation—of carbohydrates such as sucrose already in the stalk without the supply of energy by photosynthesis. When, however, the newly formed leaf-system reaches the normal state again about fifty days after the treatment, the stalk is supplied with carbohydrates produced by the photosynthetic activity, and the inversion of sucrose, which has been utilized for the supply of energy for growth, ceases and an accumulation of sugar begins instead. These phases in the chemical reactions of the sugars in the cane are plainly manifested in the changes in the rotatory power and the content of reducing sugar in the juice.

November, 1931.

Laboratory of Organic & Bio-Chemistry,
Kyoto Imperial University.

Laboratory of Factory Analysis,
Syoka Tyuryo,
Niitaka Seito Kabusiki Kaisya.

Plate I

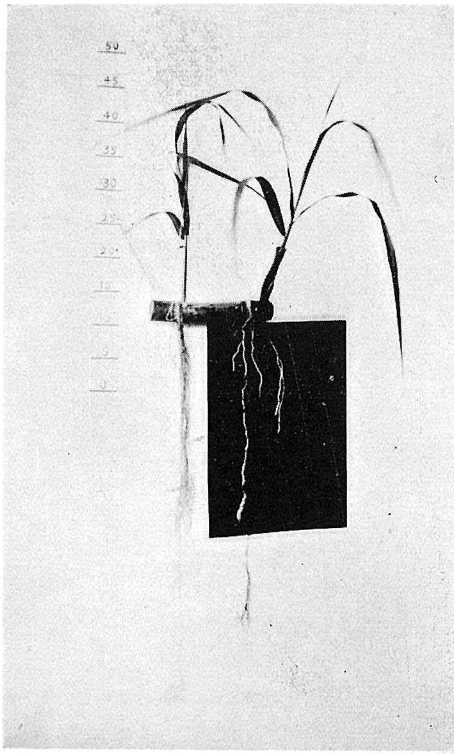


Plate II

No. 1

Canes before topping.

No. 2

Topped stalks.

No. 3

Topped stalks after prodution of sprouts.

Plate III

No. 1

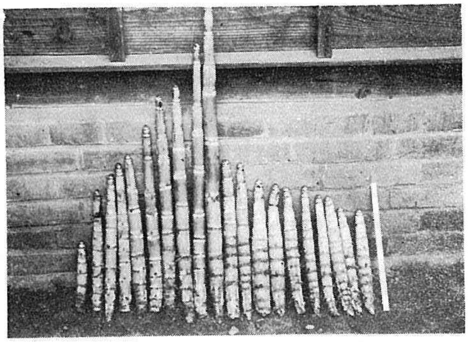
Ratoon cane garden at Geron. Feb. 18th.

No. 2

The same garden on the 13th of June.

Plate IV

No. 1



2878 2725

Mar. 10, 1930

Plate IV

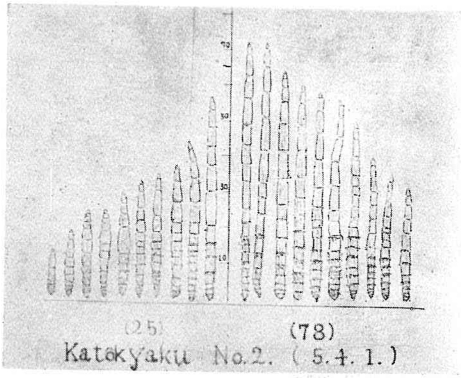
No. 2

2725 POJ
Apr. 1, 1930

No. 3

2878 POJ
Apr. 1, 1930

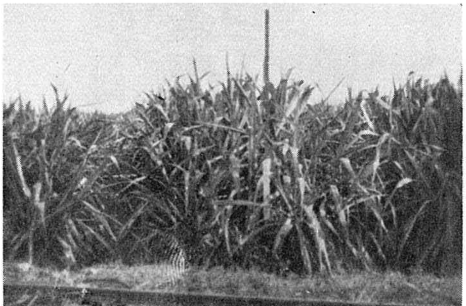
No. 4



(2725) (2878)
Apr. 1, 1930

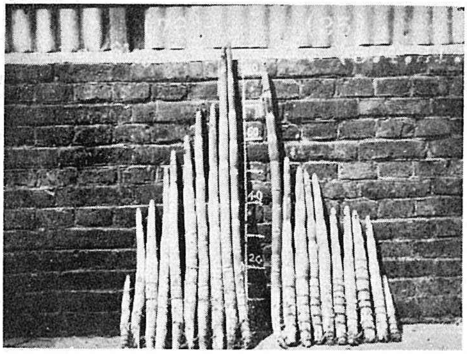
Plate V

No. 1



2725 POJ
Apr. 21, 1930

No. 2



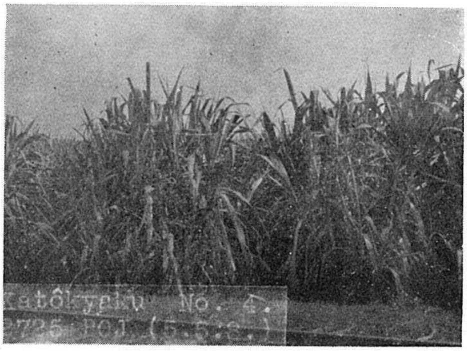
(2878) (2725)
Apr. 21, 1930

Plate VI

No. 1

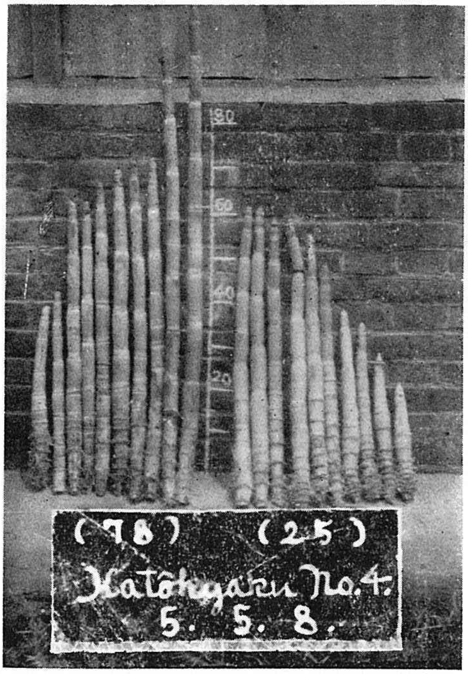
2725 POJ
May 8, 1930

No. 2



2878 POJ
May 8, 1930

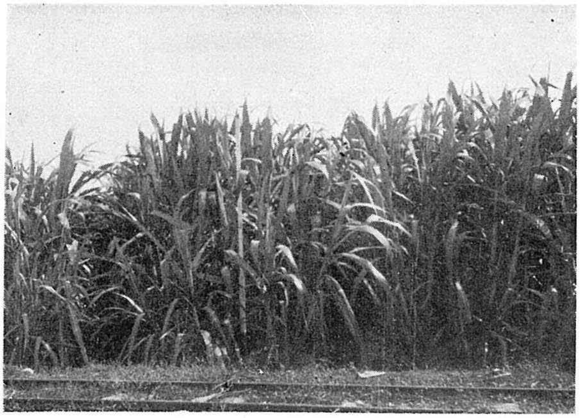
No. 3



May 8, 1930

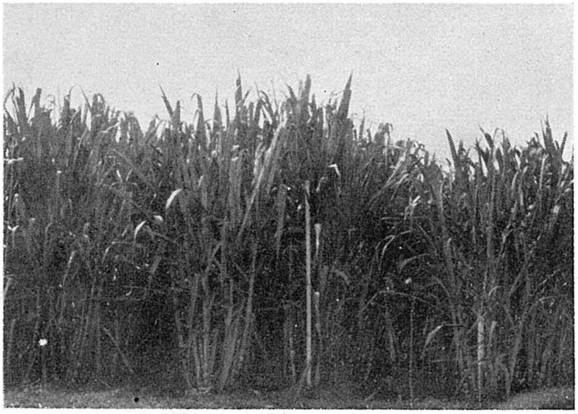
Plate VII

No. 1



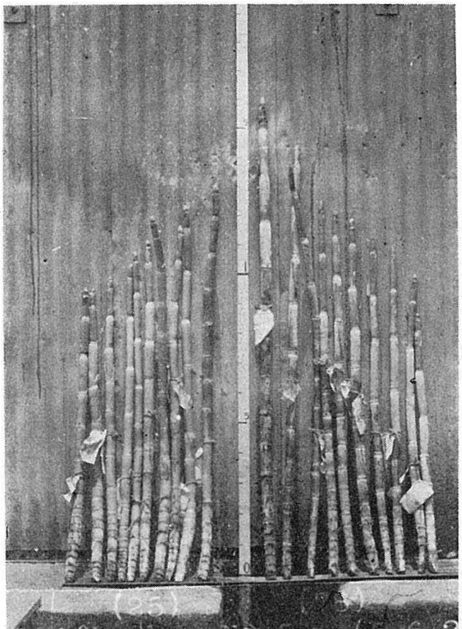
2725 POJ
June 2, 1930

No. 2



2878 POJ
June 2, 1930

No. 3



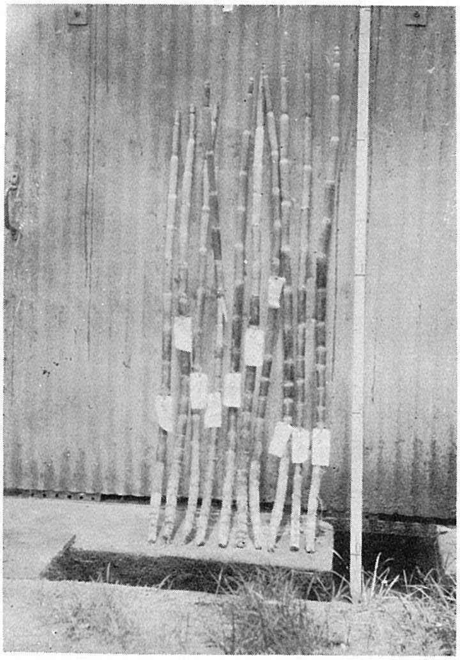
(2725) (2878)
June 2, 1930

Plate VIII

No. 1

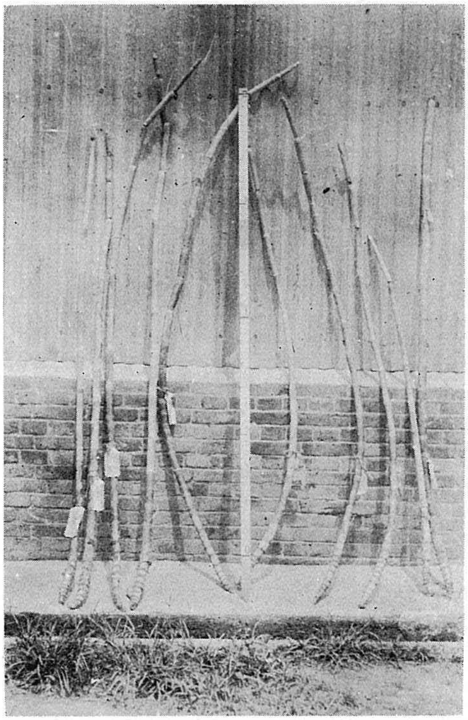
No. 3

No. 2



2725 POJ
June 23, 1930

No. 4



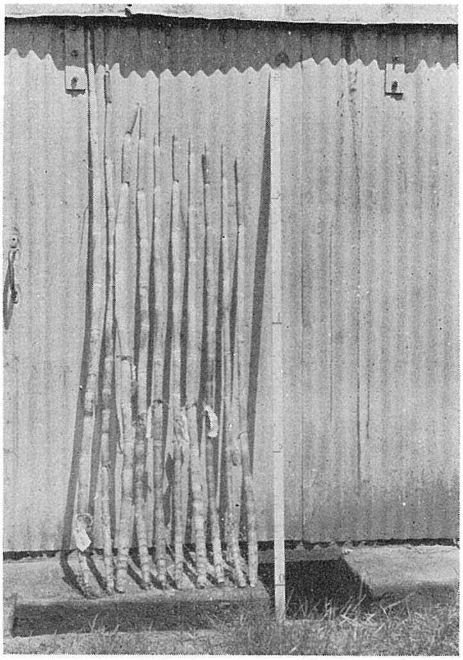
2725 POJ
July 15, 1930

Plate VIII

No. 5

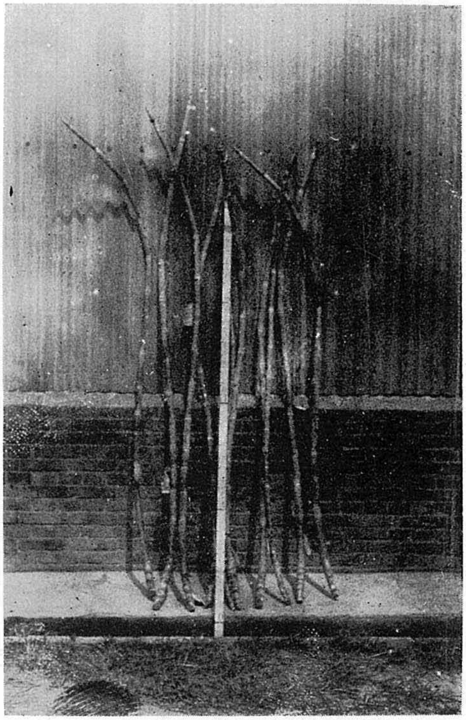
o. 7

No. 6



2878 POJ
June 23, 1930

No. 8

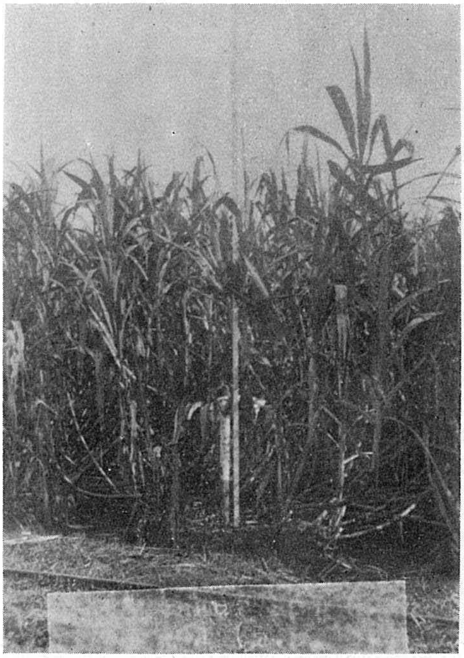


2878 POJ
July 15, 1930

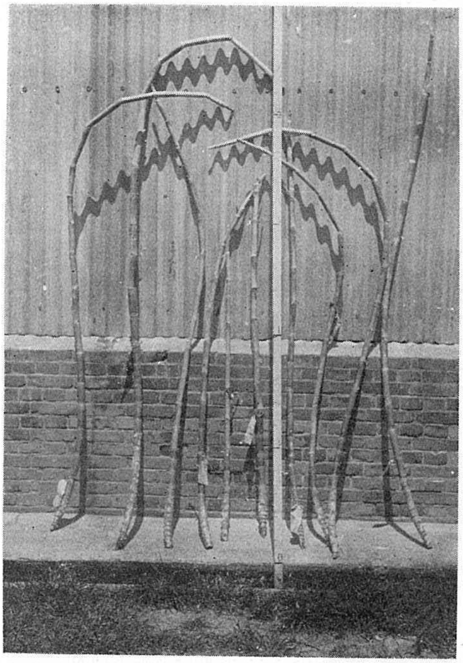
Plate IX

No. 1

No. 3

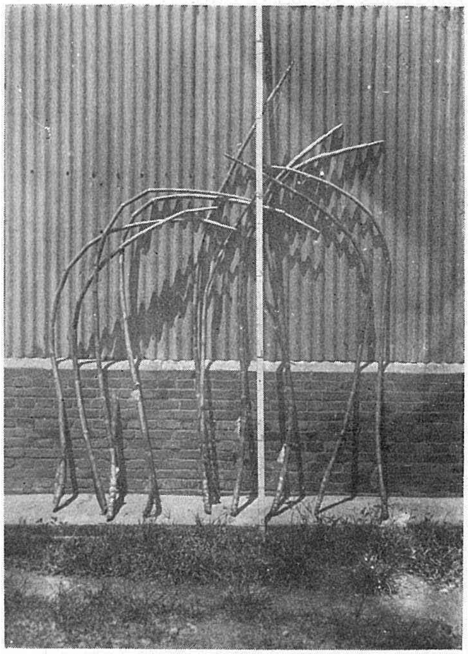


No. 2



2725 POJ
Aug. 4, 1930

No. 4

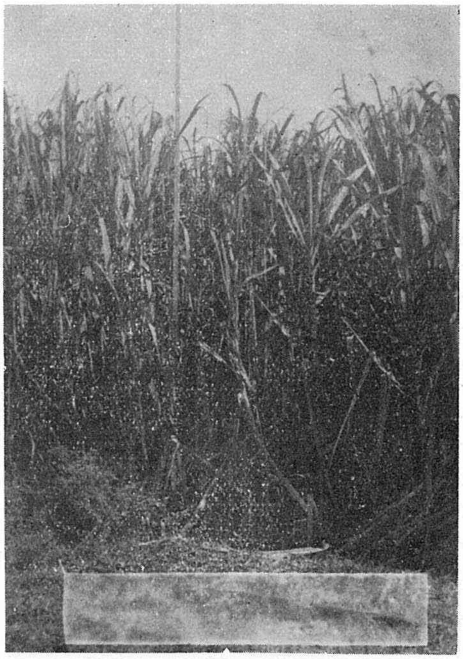


2725 POJ
Aug. 25, 1930

Plate IX

No. 5

No. 7



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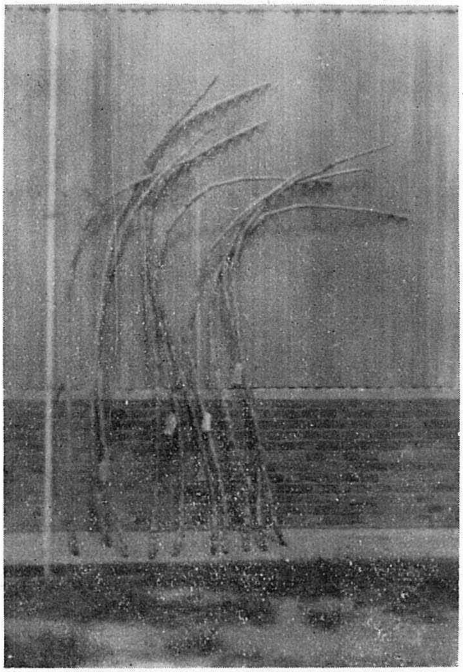
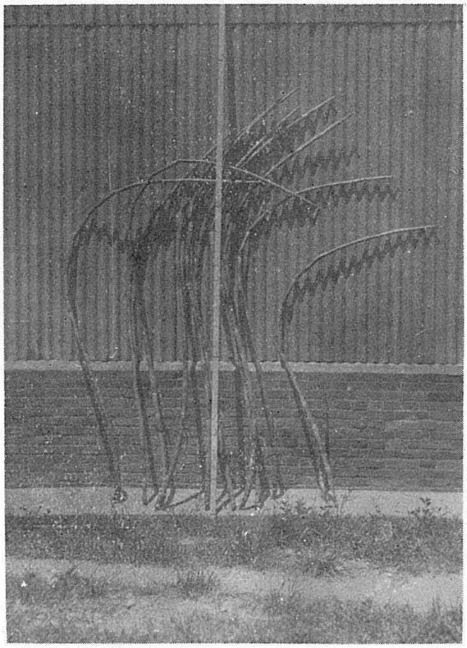


2878 POJ

Aug. 4, 1930.

No. 8

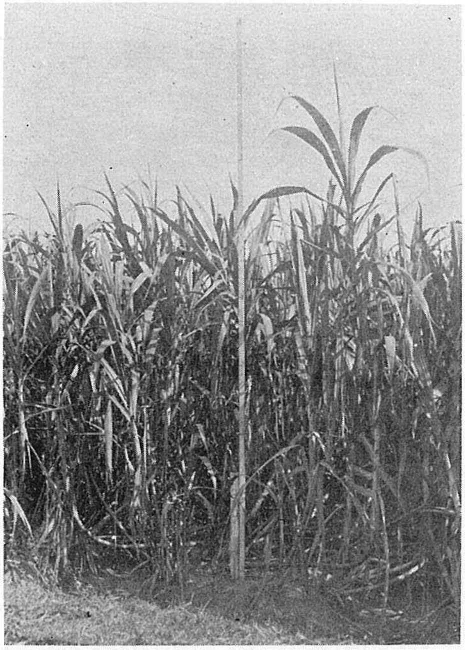


2878 POJ

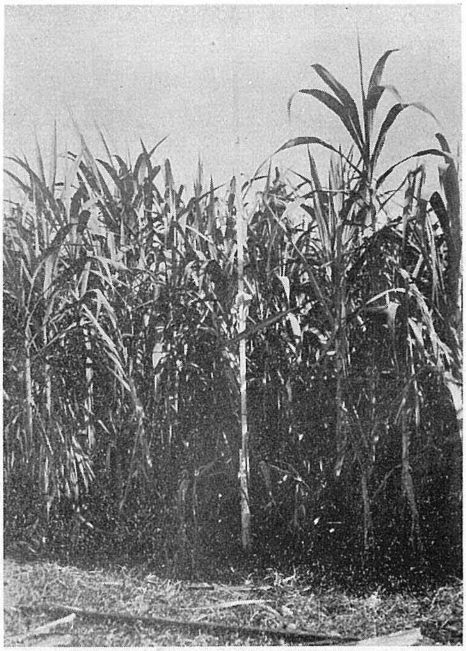
Aug. 25, 1930

Plate X

No. 1



No. 3



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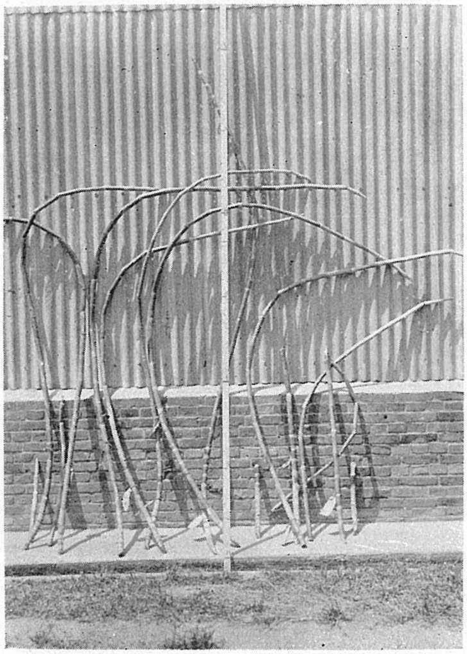
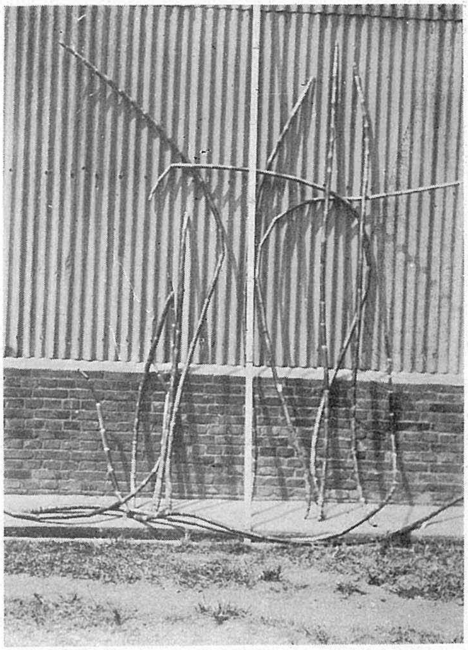


2725 POJ

Sept. 15, 1930

No. 4



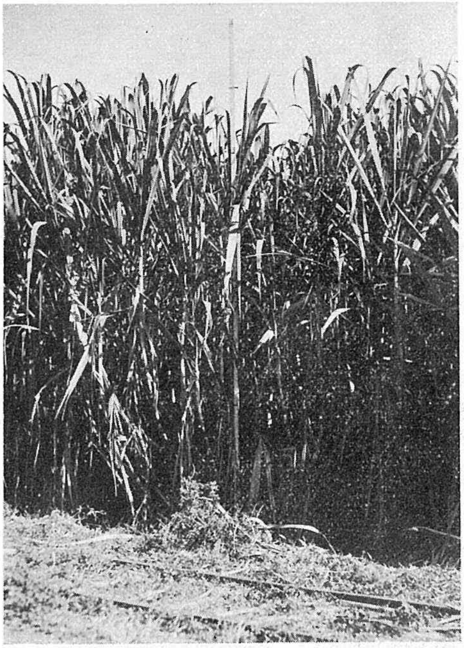
2725 POJ

Oct. 6, 1930

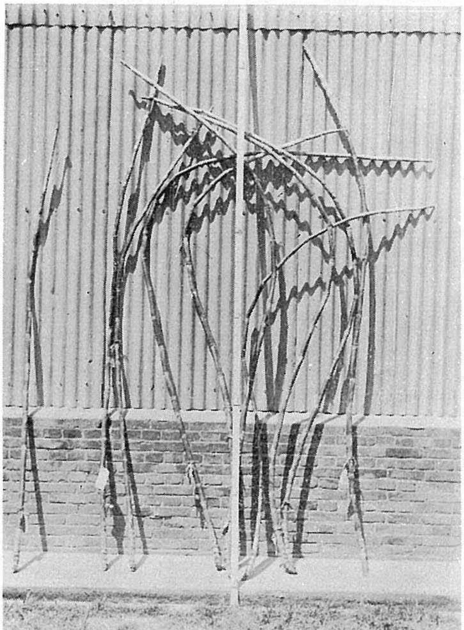
Plate X

No. 5

No. 7

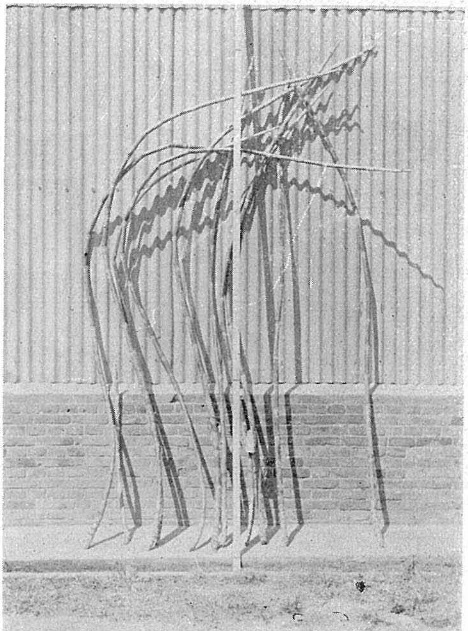


No. 6



2878 POJ
Sept. 15, 1930

No. 8

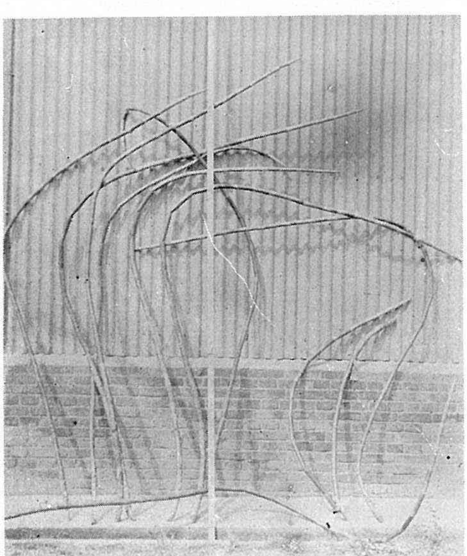


2878 POJ
Oct. 6, 1930

Plate XI

No. 1

No. 2

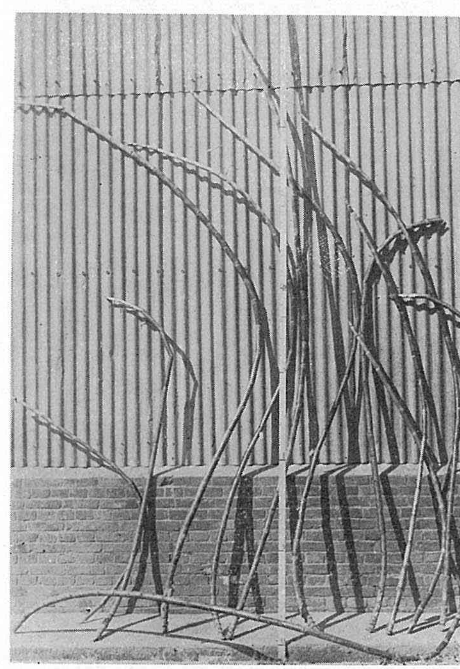


2725 POJ

Oct. 24, 1930

No. 3

No. 4

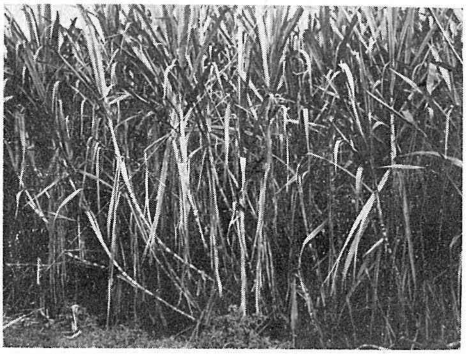


2725 POJ

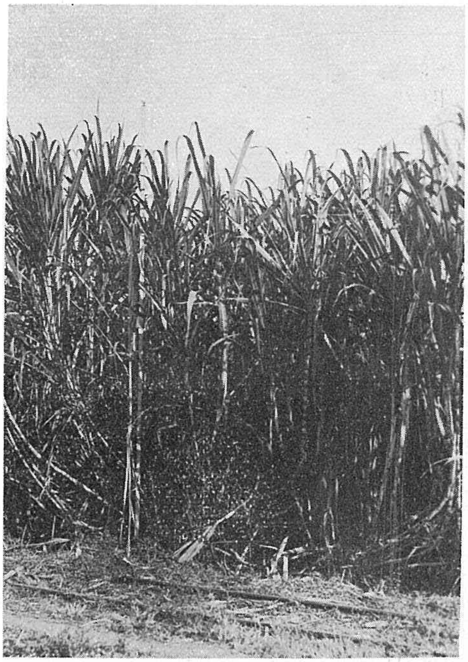
Nov. 17, 1930

Plate XI

No. 5



No. 7



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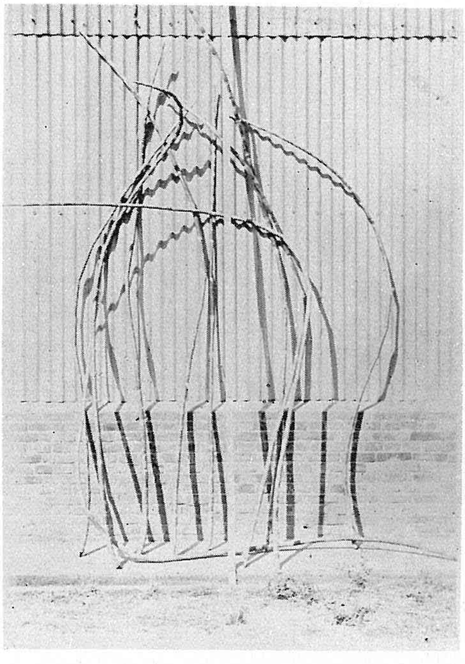
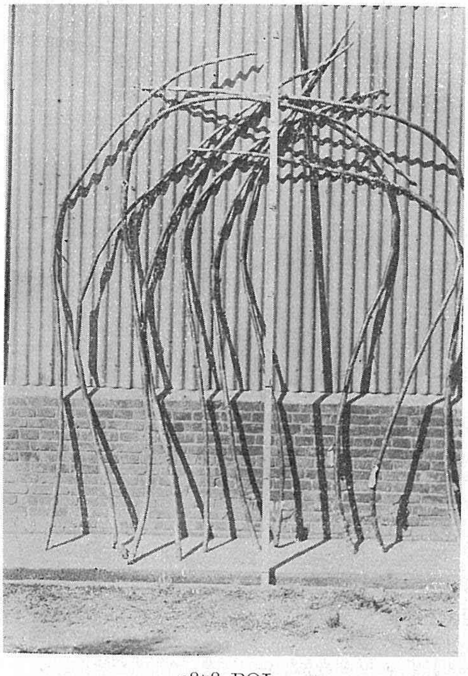


2878 POJ
Oct. 24, 1930

No. 8



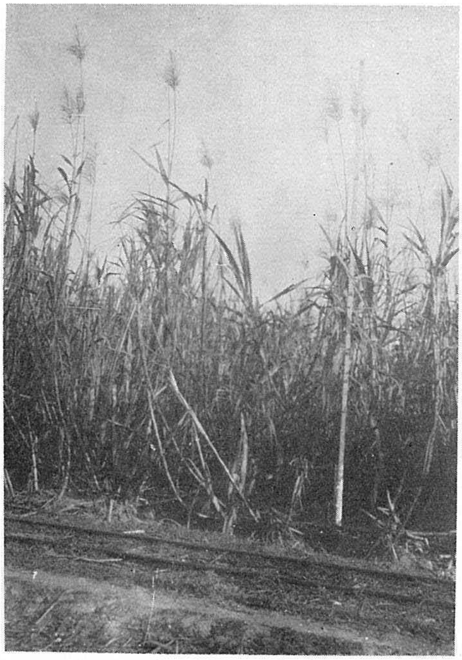
2878 POJ
Nov. 17, 1930

Plate XII

No. 1

2725 POJ
Dec. 5, 1930

No. 3

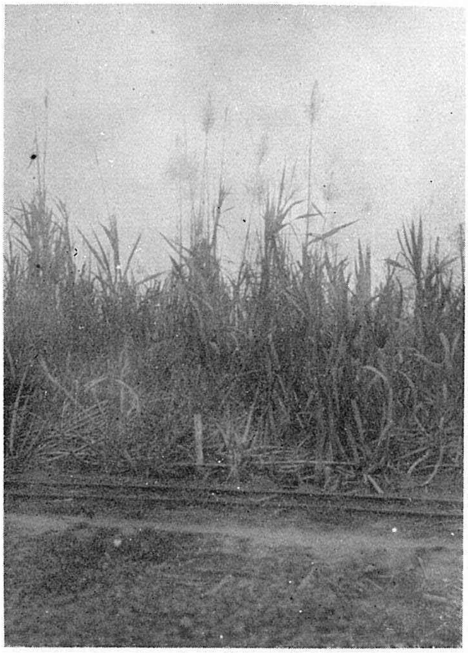


2725 POJ
Jan. 18, 1931

No. 2

2725 POJ
Dec. 28, 1930

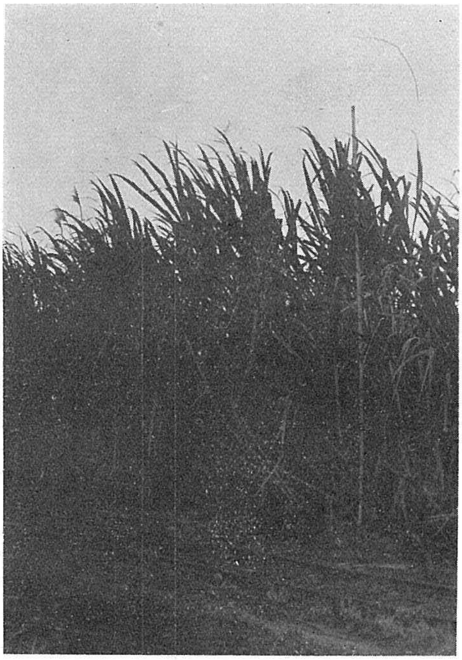
No. 4



2725 POJ
Feb. 10, 1931

Plate XII

No. 5



2878 POJ
Dec. 5, 1930

No. 7

2878 POJ
Jan. 18. 1931

No. 6

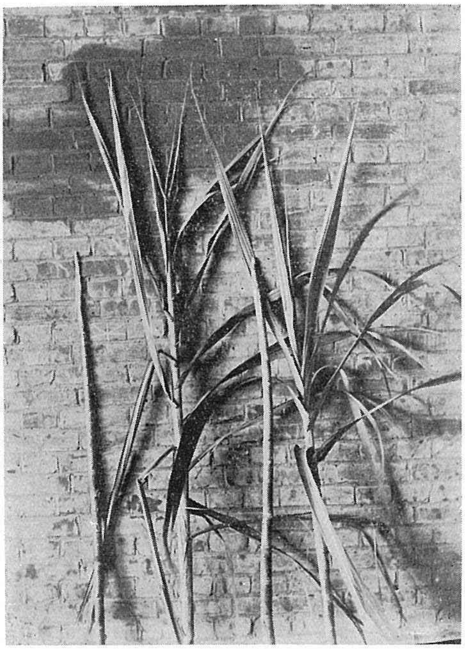
2878 POJ
Dec. 28, 1930

No. 8

2878 POJ
Feb. 10, 1931

Plate XIII

No. 1

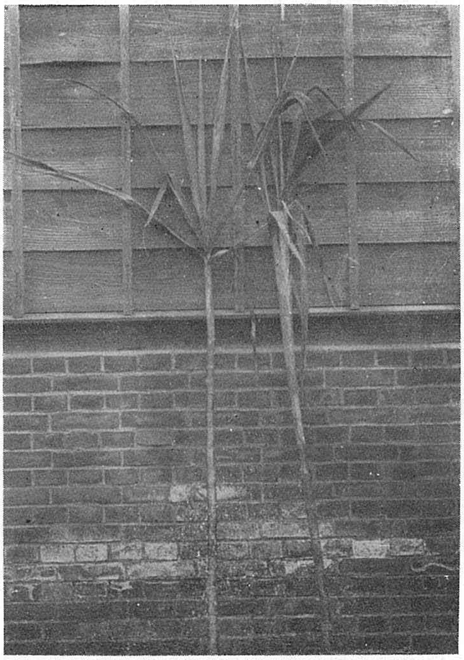


Nov. 6th.

No. 2

Dec. 18th.

No. 3



Feb. 15th.