Contributions to the Cytology of the Genus *Saccharum*. IV. Studies of chromosomes in wild *Saccharum* species in Formosa

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Introduction

Among the wild sugar canes found in Formosa, the studies of chromosomes in the plants belonging to *Saccharum spontaneum* were reported preliminarily by the present writer (1940 b, 1941). He also reported briefly on the chromosomes of *S. Narenga* (= *Narenga porphyrocoma*) (1941). The circulation of the publications in which these two reports appeared, however, was quite restricted, so that the entire data in these reports as well as the new data found thereafter will be included in the present paper. All these studies were worked out at the former Japanese Government Sugar Experiment Station, Tainan, Formosa.

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I. Short remarks on wild *Saccharum* plants in Formosa

1) *Saccharum spontaneum* L. According to Honda (1930), Masamune and others (1936), two varieties have been found in Formosa. The first is slender, within 10^{mm} in stem diameter and nearly 2^m in height even in larger types. The leaf blade is extremely narrow and has a glabrous ligule. This is classified under the name *S. spontaneum* L. subsp. *indicum* Hackel var. *genuinum*¹ Hackel (Japanese name, Wase-Obana). This is found distributed also in the middle area of Japan proper, Malay and also in India. The second variety has a thick stem, in some larger types the diameter reaching more than 10^{mm}. It is usually more than 2^m in height, in some cases exceeding 3^m. The leaf blade is broader than the former type and has a ciliate ligule. This is named *S. spontaneum* L. subsp. *indicum* Hackel var. *Roxburghii*¹ Honda

¹ Artschwager (1942) reports very detailed comparative morphology of *S. spontaneum* including two clones of Formosa. It seems quite probable to the present writer that his clone Formosa 4 (Importation Number 719) is *Roxburghii* and the clone Formosa (Imp. No. 928) is *genuinum*, though the latter has more or less broader blades.

(Japanese name, Kansho-Gaya), which is not found in Japan proper (Honda 1930).

These two varieties are found in wild state all over the plains and mountains of the island of Formosa at the elevation below 500^m, especially abundantly on sand-bars of riverside or ashore. *Roxburghii* seems to be more low-land habitant which, along the sea-shores of northern or middle-parts of the island, serves as the hedge to prevent the monsoon during the winter season. Both plants are sometimes growing in close contact with each other, but *Roxburghii* grows more abundantly near the water, often in muddy places. Two varieties can be distinguished from each other by a distant glance as they grow in separated brake even in the case of contact. One may usually be able to judge with certainty that the plants taller than 2^m with stout appearance are *Roxburghii*. But the plant height is not always constant if the plants are transplanted, and in a case the relation in height of the two varieties became converse when transplanted to Tainan from the original habitat. In an exceptional case, a plant which showed the appearance similar to *genuinum* was found to have the chromosome number same as *Roxburghii*. However, the discrimination of two varieties by the general appearance is conveniently be made at the original habitat, though of course it is anything but the decisive one. More detailed comparative studies in morphology and anatomy are necessary.

To say about the florescence, a small type of *genuinum*, nearly 1^m high commonly seen in Tainan, flowers earliest, and a type of *Roxburghii* found in Karenkō blooms as latest in the latter part of September. Generally speaking, *genuinum* flowers earlier than *Roxburghii* beginning with July and lasts to August¹. The latter usually comes into flower from August, blooming most abundantly in September, and rarely it flowers at the end of October (a clone from Karenkō). Anyhow, under natural condition, Formosan *spontaneum* can never be crossed with cultivated cane varieties, since the former bear flowers quite earlier than the latter.

2). *Narenga porphyrocoma* Hance (Bor) = *Saccharum Narenga* Wallich (Japanese name, Murasaki-Waseobana). This plant has been known as *Saccharum Narenga*, and is recently separated from *Saccharum* in a new genus *Narenga* (Bor 1940). The habitat of this plant is the foot of mountains all over the island. Morphological differences in characteristics that were experienced in *S. spontaneum* have not been observed in this plant.

¹ The northern extremity of distribution of *S. spontaneum* (var. *genuinum*) in Japan proper is considered to be near Chōshi City, Chiba Prefecture, where it flowers from the middle of August to the end of the same month.

II. Habitat of the material plants

Spontaneum and *Narenga* were collected from 32 localities in the island and preserved in the field of the former Japanese Government Sugar Experiment Station, Tainan. The plants in which the chromosomes were investigated are listed in Table 1 and their original homes are mapped out in Fig. 1.

Materials marked with * showed extraordinary characteristics, so that they will be further explained. Two kinds of *spontaneum*, large and small, were brought from Bantan to Tainan where they had been planted. The plants sprouted next year, however, and they showed a conversed relation in plant size; i.e., the larger clone (No. 5 in Table 1) grew to about 1^m high, while the smaller one which was below 1^m in height in Bantan developed to about 2^m in height in Tainan. Regrettably, the comparative studies on their morphology have not been made yet, except for the general appearance. This plant (No. 5) seems to the writer to be properly assigned to a clone of *genuinum*, since its chromosome number was revealed to be $n=56$, same as that of other *genuinum* clones.

Fūkikaku is a district located at the extremely northern part of the island. On a grass land near the lighthouse there, small brakes consisted of the *genuinum* type of *spontaneum* (No. 7 in Table 1) were found here and there. This *spontaneum* is the smallest, the feeblest and the most grass-like among the writer's collection which was assembled from Formosa, Amami-Ōshima and Japan proper. Chromosome number is $n=56$ in spite of its small body size.

From Anpin, suburb of Tainan City, three types of *spontaneum* have been collected by the present writer. The first type shows $n=56$, having small (1^m high) and slender stature as seen in Table 1 (No. 1), and is

Fig. 1. Original homes of the material plants.

Table 1. List of the materials

(1) *S. spontaneum* subsp. *indicum* var. *genuinum*

No.	Locality	Plant height	Remarks
1	Anpin (Tainan)	About 1 ^m	Slender, common type
2	Tanpansen (, ,)	About 2 ^m	Intermediate type
3	Sugar Expt. Station (, ,)	Below 1 ^m	Slender, common type
4	Bank of Sobun-Kei River (, ,)	Below 1 ^m	Common type
5*	Bantan (Takao)	About 2 ^m	Large type in Bantan, small type in Tainan
6	Taitō (Taitō)	Below 1 ^m	Slender, common type
7*	Fūkikaku (Taihoku)	About 60 ^{cm}	Most slender, leaf sheath very hairy, lower surface of blade whitish, blade narrow, mostly grass like appearance

(2) *S. spontaneum* subsp. *indicum* var. *Roxburghii*

8	Anpin (Tainan)	About 3 ^m	Stout
9*	,, (, ,)	About 1 ^m	Slender, stem waxy, larger at Sug. Expt. Stat.
10	Sug. Expt. Stat. (, ,)	About 2 ^m	In muddy soil of pond-side
11	Karenkō (Karenkō)	Larger than 2 ^m	Stout
12*	Banshiryō (Nantō, Taichū)	About 3 ^m	Largest, stoutest, leaf sheath bristled, on brook-side

(3) *N. porphyrocoma*

13	Taikōzan (Takao)	About 2 ^m	At the elevation about 300 ^m
14	Kotōhi (Tainan)	,,	On the foot of a mountain

found very commonly on road-side. The second one (No. 8) with the chromosome number $n=48$ is 3^m high and stout, being abundantly found along the Anpin Canal. The last one (No. 9) is noticeable. It coexistents with the material No. 1, though with a smaller number of individuals, and comes into flower somewhat later than No. 1. Its stem is waxy differing clearly from No. 1. This is classified as *Roxburghii*, because the chromosome number is $n=48$, and in the field of the Sugar Experiment Station, it grew on to about 2^m in height, the waxy nature of stem being indistinct, and the florescence delayed to the date as same as that of No. 8.

The plant No. 12, showing a fine contrast in its morphology compared with the plant No. 7 which is the smallest, was brought from the suburb of Nantō, near Taichū. It has the most robust, thickest and tallest culms in the writer's collection, and its leaf sheath is bristled.

III. Methods

1) *Somatic chromosomes* Root tips were taken from the sand-

cultured stems laid for root development in a thermostat, and also from the stocks planted in earthen pots. For the fixation, Flemming's solution of Bonn was applied for 24 hours. Sections $15\ \mu$ thick were made through the usual paraffine method and stained with Heidenhain's iron-alum haematoxylin.

2) *Meiosis* Studies were made exclusively in PMC-s. Materials were fixed with Carnoy's solution (6:3:1) and Farmer's solution (6:0:1) in the original habitat or in the field in Tainan where the materials were transplanted. The fixed materials were preserved in 70% alcohol and examined with Belling's iron aceto-carmin.

Figures were drawn using Abbe's Camera lucida with Zeiss Ocular K15 $\times$ and Zeiss Objective apochromat 120 $\times$. The original magnification is 2750 times being reduced to $\times 1465$ in reproduction except Figs. 10, 12.

IV. Observations

1) *Chromosomes of genuinum* Observations on PMC-s revealed 56 as the haploid chromosome number in all the materials examined. Very fine nuclear plates were commonly observed at MI, later a normal course having been taken (Figs. 2-6). But univalents were, in some cases,

Figs. 2-6. Regular meiosis of var. *genuinum*. 2, Polar view of MI of No. 7, Fūkikaku, showing 56II. 3-6, No. 3, Sug. Expt. Stat. 3, Side view of MI. 4, Heterotypic telophase. 5, Homotypic metaphase. 6, Pollen tetrad. 7-9. Irregular meiosis of var. *genuinum*. 7, Side view of MI of No. 5, Bantan, with some univalents. 8, Heterotypic anaphase of the same material, 6 univalents are seen lagging. 9, Abnormal pollen tetrad of No. 7, Fūkikaku. ca. $\times 1465$.

observed at MI (Fig. 7), and lagging univalents were also seen during first ana- and telophases. The largest number of lagging univalents was found to be 6 in all the types of *genuinum* (Fig. 8). Table 2 shows the univalent frequency during the reduction division of PMC-s of the

Table 2. Univalent frequency of *genuinum*

No. of materials	Locality	No. of univalents in first ana- and telophases
1	Anpin	ca. 4
2	Tanpansen	1-3
3	Sug. Expt. Stat.	0
4	Bank of Sobun-Kei River	1-3
5	Bantan	1-6
6	Taitō	—
7	Fūkikaku	0-3

genuinum plants. The numbers ranging 1-3 were most frequently counted. These univalents lagged during the heterotypic division, and were enclosed in both poles after splitting into two halves. The material plants in which univalents were seen in the heterotypic division, usually showed some chromosomes again, which irregularly behaved in the subsequent homotypic division. At the pollen tetrad stage, chromatin clumps were often observed outside the nuclei, and some tetrads contained no nuclei (Fig. 9). In the average, 3.2% of pollen grains from the plants collected, from 6 plots were abortive, while a clone brought from Niketsu, near Karenkō, presented an exceptionally high sterility of pollen reaching to 47.7%.

Somatic chromosomes were studied only in the material No. 1 from Anpin. As seen in Fig. 10, fine figures showing $2n=112$ were observed. No difference in the morphology of chromosomes could be detected between this material and sugar cane varieties in cultivation.

Figs. 10-12. 10, Somatic chromosomes of var. *genuinum*, No. 1, Anpin. $2n=112$. $\times 2750$. 11-12, var. *Roxburghii*, 11, Polar view of MI of No. 10, Sug. Expt. Stat. 48H. ca. $\times 1465$: 12, Somatic chromosomes of No. 8, Anpin. $2n=96$. $\times 2750$.

2) *Chromosomes of Roxburghii* All the materials showed $n=48$ in PMC-s, the course of meiosis being more regular than in *genuinum*. So that, only one nuclear plate of MI is given here (Fig. 11). The occurrence of univalents was also less frequent than in *genuinum*, 4 being the highest number, which was observed very rarely. Homotypic division also proceeded, in general, almost normally. At interkinesis and in pollen tetrad, fewer chromatic bodies were seen in comparison with *genuinum*. Nevertheless, pollen sterility was higher than in *genuinum*, 5.3% having been found as an average percentage of abortive pollen of 4 clones.

As to the somatic chromosomes, only No. 8 from Anpin was studied, and it showed clearly $2n=96$ (Fig. 12).

Figs. 13-21. 13-18, Regular meiosis of *Narenga porphyrocoma*, No. 13, Taikozan. 13, Diakinesis showing 15_{II}. 14, 15 complements, side view. 15-18, Heterotypic anaphase, telophase, homotypic metaphase and pollen tetrad. 19-21, Irregular meiosis of *Narenga*, No. 14, Kotōhi. 19, 8_{II}+2_{IV}+1_{VI}, 20, 12_{II}+1_{VI}. 21, Regular disjunction of chromosomes in the same inflorescence. $\times$ ca. 1465

3) *Chromosomes of Narenga* $n=15$ was the haploid number counted in both materials. In the material No. 13, which was brought from Taikōzan, comparatively regular meiosis of PMC-s was observed. 15 bivalents were exactly counted 8 times (Figs. 13, 14), and only in one case a conjugation 13_{II} + 1_{IV} was found. After anaphase, the course proceeded normally, resulting in regular pollen tetrads (Figs. 15-18).

Dissimilar was the case of material No. 14 from Kotōhi. In some inflorescences, 15_{II} were normally observed (10 cases) with a few other modes of conjugation such as 13_{II} + 1_{IV} or 13_{II} + 4_I. But in other in-

fluorescence of the same stock fixed at the same time, 15 μ was rather rare and nearly all spikelets observed showed complicated conjugations (Figs. 19, 20). Once a multivalent chromosome, possibly an octavalent, was observed. Univalents appeared only when accompanied by tri- or heptavalent chromosomes, as far as the present material was concerned. Despite of these complicated conjugations, the disjunction of chromosomes took place commonly in the manner 15:15 (Fig. 21), developing good pollen grains, abortive ones being merely 0.3%.

V. Discussion

1) *S. spontaneum* Generally speaking, two types of *S. spontaneum* have been discovered in the plains and mountains of Formosa. The smaller type is var. *genuinum*, which is considered identical with that found in Japan proper. The larger one is var. *Roxburghii*, and is not found in Japan proper. Chromosome numbers of these two plants were previously reported by the present writer (1940 b) to be $n=56$ ($2n=112$) and $n=48$ ($2n=96$) respectively. The fact that *spontaneum* with 96 chromosomes in diploid is growing in Formosa is confirmed by Suzuki (1940, 1941) and Nishiyama and others (1942). Their materials were collected in the vicinity of Karenkō where a large number of *Roxburghii* plants are growing, so that the material No. 11 in the present study may probably be the same with the plants reported by these workers.

The chromosome numbers described above for the two types goes entirely against the supposition of Bremer (1924) which is accepted by Santos (1937). Regarding this problem a discussion will be made later.

As to the relation between the plant height and the chromosome number, we have the reports of Bremer (1928) on self descendants of Glagah Tabongo, Singh (1934) on *spontaneum* of Sumatra, and Janaki Ammal and Singh (1936) on selfed seedlings from Burmese *spontaneum*. In the writer's case, however, the relation is just on the contrary compared to the facts found by them, i.e., the smaller type shows a larger number of chromosomes.

In regard to the plant height, it was found, by studying many individuals in various districts all over the island, that some were of intermediate in size between two types (Material No. 2), and in some other cases the size relation of the two types seen in the original habitat was converted in the transplanted field (No. 5). But even in these cases, the clear difference in plant height was seen in the field in Tainan between the groups of 48 (haploid) chromosomed larger clones and 56 chromosomed smaller ones. Exception to this rule has never been experienced in the field of Tainan.

During the winter season, numerous *spontaneum* seedlings are seen on some sand-bars, where adult *genuinum* plants are growing abundantly,

along the banks of rivers in Formosa. Among these seedling individuals, considerable differences in morphology are observable, some being supposed to die in due time owing to poor vigor in growth. In spite of such a large number of natural seedlings, the individuals in which the number of chromosomes differs from $n=48$ or 56 have never been met with. Morphological differences seen in clones belonging to *genuinum* or *Roxburghii* may perhaps be caused by the genetical constitution of chromosome complements involved in each individual, as is suggested by the differences of univalent frequency in meiosis shown in Table 2. But no datum on the genom constitution of *spontaneum* plant has been available to date.

As a second question, let us discuss on the relationship between the Formosan *spontaneum* and that of other places. Table 3 is a list of the chromosome numbers of so-called *S. spontaneum* which have been reported so far.

Table 3. List of the chromosome numbers in various types of *S. spontaneum* (Moriya 1941, revised)

Locality	Types or forms	Chromosome No.		Authors***
		<i>n</i>	<i>2n</i>	
Java	Glagah Djatirotol	56		Bremer 1922
	„ Kependjen	56		„ „
		54*		Starrett unpublished ²
	„ alas Kletak III	56		Bremer 1922
	„ alas Kloet	$\frac{112^3)}{2}$	112 ⁴ -114	„ 1931a
		60*	118*-122*	Starrett unpublished
	„ Pasoeroean		126*-130*	„ „
	„ Sempol	56		Bremer 1928b
	„ Soekapoera	56		„ „
	„ alas Soemberpoetih	56		„ „
	„ alas Troeno	56		„ 1922
Soembawa isl.	„ Soembawa	$\frac{112}{2}$	113-119	„ 1931a
Krakatau isl.	„ Krakatau	$\frac{123-125}{2}$	125-130 (126)	„ „
Sumatra	„ Prapat		111*-112	„ 1934
	Thick form	64		Singh 1934a
	Thin form	54		„ „
Borneo	Glagah I Djantoer		112	Bremer 1934
	„ M Moentai		ca. 112	„ „
	Kinggoerang Oewis		109-111 (112)	„ „
	Teboe Salah II Belajan**		60-61	„ „
	„ „ Melak**		60	„ „
	„ „ M. Kaman**		59-60	„ „

Locality	Types or forms	Chromosome No.		Authors
		<i>n</i>	<i>2n</i>	
Gelebes	„ Tigoe Tenggaron**		81	„ „
	„ Troeboeg**		81-82	„ „
	Biroh Bewoeloeh Koelawi		96-97*	„ „
	„ Goenoeng Torimanoe		96	„ „
	„ Koelawi A		ca. 96	„ „
	„ Soengi Moepanga		95*-96	„ „
	Glagah Koelawi A		96-97*	„ „
	„ „ B	46II+1I*		„ „
	„ „ C		96-98*	„ „
	„ Paloe		80-81	„ „
New Guinea	„ Tabongo	40		„ 1924b
			80-84	„ 1931a
			90*	Starrett unpublished
		40		Moriya unpublished
	Teboe Salah Toewa**		89-90	Bremer 1934
	28 NG 292, from near Port Moresby		80-84	Brandes & others 1939
	<i>S. spontaneum</i>		80-116	„ „ „
	28 NG 101	48	96	Starrett unpublished
	28 NG 291	58	114-116	„ „
	28 NG 292		84-88	„ „
Philippine	28 NG 293		88-94	„ „
	Talahib		8C-82	Bremer 1934
	<i>S. spontaneum</i> subsp. <i>indicum</i>	40		Santos 1937
North Africa	<i>S. biflorum</i> = <i>S. spontaneum</i>	$\frac{112}{2}$	112-118	Bremer 1931a
	<i>Aegyptiacum</i>	45	90-92*	Starrett unpublished
India	Bihar form	32	64	Janaki Ammal 1936
	SH 244 (Bihar)		80	Starrett unpublished
	SH 249 („)		70*	„ „
	Cochin form		64	Janaki Ammal 1936
	Coimbatore form	32	64	Dutt & Subba Rao 1933
			61*-62* (60)*	Bremer 1934
			55*-57*	„ „
		32		Singh 1934a
		32	64	Janaki Ammal 1936
		40*	92*	Starrett unpublished
	Dacca (Bengal) form		72-73	Bremer 1934
		39*		Singh 1934a
		40	80	Janaki Ammal 1936
		42*		Starrett unpublished
	Dehra Dun form	27*		Singh 1934a
		28	56	Janaki Ammal 1936
	Lahore form		48	„ „ „

Locality	Types or forms	Chromosome No.		Authors
		<i>n</i>	<i>2n</i>	
Turkmenistan	Godavary (Madras) form		80	Starrett unpublished
		32		Singh 1934a
		32	64	Janaki Ammal 1936
	Amu Darya No. 59		86*	Starrett unpublished
			60	Brandes & others 1939
Burma	„ „ No. 60		50-52	„ „ „
	US 4520 (Amu Darya)	25		Starrett unpublished
	US 4523 (Amu Darya)	25	48-50	„ „
	Mandalay form		96-97	Bremer 1934
Formosa	Imported from India		96	Janaki Ammal & Singh 1936a
			80-84*	Starrett unpublished
	<i>S. spontaneum</i> subsp. <i>indicum</i> var. <i>genuinum</i>	56	112	Moriya 1940b
	<i>S. spontaneum</i> subsp. <i>indicum</i> var. <i>Roxburghii</i>	48	96	„ „
	<i>S. spontaneum</i> from Karenkō	48II		Suzuki 1940, 1941
Okinawa	<i>S. spontaneum</i> , Amami-Oshima form		96	Nishiyama & others 1942
			104	Moriya 1940b
Japan	<i>S. spontaneum</i> from Kamakura		ca. 68*	Kuwada 1915, 1919
	<i>S. spontaneum</i> from Ichinomiya (Chiba Pref.)	52-56		Moriya unpublished
Ponape	<i>S. spontaneum</i> from Matalaneum	40II		Nishiyama & others 1942

1 Types are classified with the name of localities for identification.

2 Cited from Artschwager (1942); some are doubtful in chromosome number.

3 Chromosome numbers counted at meiotic anaphase.

4 Numbers believed to be typical by the original authors are shown in gothic type.

* Numbers doubtful to the present writer.

** Teboe Salah = Tananggé = *Saccharum robustum*? (Bremer 1924b, 1930b). Teboe Tigoe Tenggaron = Teboe Troeboeg = *S. robustum*? (Bremer 1934). Teboe Troeboeg = *S. edule* (Grassl 1946).

*** cf. Moriya 1941.

The distribution of *S. spontaneum* is mapped in Fig. 22, in which the numbers of chromosomes marked with * in Table 3 and the plants marked with ** in the same Table are excluded. In the map, chromosome numbers are shown in diploid and the numbers reported in haploid are doubled in the figure. Types from Africa are also excluded here.

Now, the distribution of *S. spontaneum* will be discussed taking the map as a reference. Brandes and Sartoris (1937) thought that “in general, the forms with the higher numbers of chromosomes are confined to the tropics and the forms with a lower chromosome number extend

Fig. 22. Distribution of *S. spontaneum* in South-eastern Asia and vicinity. (Moriya 1941, revised).

into the subtropical and temperate zones. Thus, the forms with 112 and 124 somatic chromosomes are found in Java and the islands nearby. The forms with 80 somatic chromosomes extend northward to the Philippines and Taiwan."

This opinion is constructed based on the assumption of Bremer (1924), which is accepted by Santos (1937), that the

wild sugar canes in Formosa and Japan may have 80 chromosomes as the somatic number. However, the actual survey worked out by the present writer discloses that the fact is quite different from this assumption.

On the other hand, Janaki Ammal (1939) proposed another conception that the chromosome number of *S. spontaneum* increases according to the extent of distribution from west to east ($2n=48 \rightarrow 112$). This seems also improper if the chromosome numbers found in Formosa, Japan, New Guinea and Ponape are taken into consideration.

In dealing with this question, the writer presents the following propositions which were previously (1941) published in Japanese and are here somewhat revised.

(1) In regard to the distribution of *S. spontaneum* in South-eastern region of Asia and vicinity, three Sections may be divided, from the point of view of chromosome number:

I, Malay Archipelago and South Seas Section....Philippines, Micronesia, New Guinea involved.

II, India-Burma Section.....Turkmenistan involved.

III, Japan Islands Section.....Formosa and Okinawa involved.

(2) The clones having the highest chromosome number are restricted to the southern part of Sumatra and the western part of Java. In general, the chromosome number becomes less according to the distance from there.

(3) The clones having the lower chromosome numbers are found in India, where the widest variation in the chromosome number of *S. spontaneum* is seen. In the area at the farther north in India, we can find a clone having the lowest chromosome number known in this plant.

In India, main sugar cane plantations are located in its northern

parts, where the varieties of cultivated canes are thought to belong mainly to *S. sinense* and *S. Barberi* (Okade 1942), and the chromosome numbers of the latter species are very variable as in the case of *spontaneum* (cf. Moriya 1940a, 1941). Janaki Ammal (1940) found *Sclerostachya fusca*, which is closely related to *S. spontaneum* and coexistent with it, in Orissa and Assam, north-eastern parts of India. These two regional types of *Sclerostachya* had 48 and 96 somatic chromosomes respectively, the numbers same as those of some *spontaneum* forms.

Judging from these facts together with the writer's propositions given above, one of the keys which can unlock the question of unknown ancestral sugar cane form seems to be concealed in the northern part of India, as Barber (1920) supposed.

The above mentioned propositions may be ascertained by the further cytological studies, especially in chromosome number, of *S. spontaneum* distributed in the eastern and southern parts of the Asian Continent, particularly in South China, Hainan island, French Indo-China, Siam and Malay Peninsula.

Next, the phylogenetical relationship between *spontaneum* of Formosa and those of other places will be discussed. As obviously seen from Fig. 22, types of *S. spontaneum* showing $2n=96$ have been found in Burma, Celebes and in New Guinea; while the clones showing $2n=112$ in Soembawa, Sumatra, Borneo and Java, the last named being the center of the distribution.

S. spontaneum of Burma ($2n=96$) may be judged to be much taller than Formosan *Roxburghii* ($2n=96$) (see Photos in Janaki Ammal and Singh 1936, and in Brandes and others 1939). On the other hand, a clone of Celebes ($2n=96$) also seems to be very large in general appearance, according to Brandes and others (1939). Thus, *Roxburghii* in Formosa seems smaller in plant body than those 96 chromosomed *spontaneum* plants found in these places, and it may be said that the 96 chromosomed *spontaneum* is distributed without direct connection in various regions. In view of this, it seems to the writer that *Roxburghii* is not always the same with *spontaneum* plants found in Burma, Celebes, and New Guinea.

As to *genuinum* which shows $2n=112$, the following facts may be worth while to be noticed.

i) We had preserved several forms of Javanese Glagah (*S. spontaneum*, $2n=112$) in Tainan. They were larger in plant height than Formosan *genuinum* ($2n=112$), and some variations in their morphology were seen. Javanese Glagah came into flower in Formosa in November or December, somewhat earlier than the cultivated cane varieties and extremely later than two kinds of Formosan *spontaneum*. Dr. Rümke of Java investigated the writer's collection of *spontaneum* in Tainan in

1947, and told the writer that he thought they were different in appearance from Javanese Glagah.

Brandes and others (1939) reported that the varieties of Formosan *spontaneum* (Imp. Nos. 719 and 928)¹ are somewhat smaller than those of the same species from the lower latitude. Thus, *genuinum* may be recognized to be much smaller than Javanese Glagah.

Differences in meiotic behavior between Formosan *genuinum* and Javanese Glagah (Bremer 1922) are, however, not so clear as to be specially touched, except that in the former it seems to be slightly more irregular than in the latter.

ii) Various types of *spontaneum* having different numbers of chromosomes are found in areas located between Formosa and Java and other habitats of *spontaneum* showing $2n=112$. Thus, there can be found no geographical connection regarding the distribution of Formosan *genuinum* and Javanese Glagah.

iii) *Spontaneum* plants found in nearly lying Hainan and the Philippine islands seem to the writer to be different from *genuinum* in Formosa, seeing from the time of flowering and plant size. The flowering season of *spontaneum* in Formosa is specially earlier than that found in above stated islands. For example, the Herbarium of the former Taihoku Imperial University informed the writer, that a *spontaneum* plant collected by a Japanese taxonomist in the southern part of Hainan island, which was very poor in general appearance being below 1^m in height, and was much resembling the writer's material No. 7, was found blooming in the end of December. This late flowering nature is quite different from *genuinum* in Formosa, in spite of the similarity in plant stature. On the so-called Talahib (*S. spontaneum*) in the Philippine islands, it is reported (Santos 1937) that it is $n=40$ and the fixing of PMC-s was made during August to September, a period which is much later than in Formosa for that purpose. According to an information from one of the writer's friends who had once stayed there, Talahib culms had been customary to be used as arrows by the savage, which suggests us the stem size of Talahib may be larger than that of *genuinum* in Formosa. Talahib plant which is $n=40$, therefore, seems quite different from *genuinum* in Formosa. Thus, Formosan *genuinum* may be considered isolated geographically even from the nearest islands.

From the above stated reasons, the writer believes that Formosan *genuinum* may be phylogenetically different from Glagah in Java. It is the writer's regret, however, that no detailed studies of the morphology and taxonomy about these questions can be made further, as the writer was repatriated from Formosa leaving there the materials for the study.

¹ cf. p. 237 foot note.

Let us now turn our attention to the relationship between polyploidy and the distribution of this plant. Both Javanese Glagah and Formosan *genuinum* have 112 chromosomes in diploid, but, as described above, they are assumed phylogenetically of different origin. Thus it may not be concluded in general, that the types with the same chromosome number are always the same. However, it can be easily recognized from Fig. 22, that the plants having 112, 96 and 80 chromosomes are distributed most widely. To say on Formosan island only, higher polyploid *genuinum* are spread wider on the low lands as well as on mountains, and the individuals found there are more numerous than lower polyploid *Roxburghii*, just corresponding to the facts reported by Shimotomai and others (Shimotomai 1947). It may be noted here that, in the writer's material, the higher polyploid *genuinum* is earlier in flowering time and is smaller in plant size than the lower polyploid *Roxburghii*, an interesting example regarding the relationship between polyploidy and ecology of plant.

Janaki Ammal and Singh (1936) used the name subsp. *indicum* var. *genuinum* for *S. spontaneum* showing $2n=56$ and 64, which were found in India. The Formosan *genuinum* has the chromosome number just twice that of one of these Indian forms, although we have no sufficient datum to make a discussion on their relationship.

2) *Narenga porphyrocoma* Every person who has a chance to glance at this plant may easily understand its difference from either cultivated sugar canes (*S. officinarum*, *S. sinense*, *S. Barberi*) or wild sugar canes (*S. spontaneum*, *S. robustum*). The characters discriminating it from *S. officinarum* are shown distinctly by Janaki Ammal (1942). Bremer (1924) stated about this plant of Java, that the leaf blade is nearly 2^m long and hairy on the upper surface. But the Formosan *Narenga* reaches to about 2^m high in its full growth.

Bremer (1924) counted 15 gemini at diakinesis of this plant in Java, but after metaphase the counting was difficult due to the clumping of the chromosomes. The pollen tetrad and pollen grains were, however, observed to be regularly formed. In the writer's case, each chromosome was clearly distinguished from diakinesis to the heterotypic anaphase. Bremer compared the size of nuclei of PMC-s of this plant with that of other *Saccharum* species, and thought that this plant might not belong to genuin *Saccharum*, supporting Jeswiet's opinion which was based on the morphological studies.

Janaki Ammal (1942) counted 30 somatic chromosomes in Indian *Narenga* and reported that the reduction division was regular showing 15II. Pollen fertility was nearly 100%. He concluded that this plant is hexaploid with the basic number 5 instead of 10.

Singh (1934) studied the chromosomes of a hybrid plant between

Vellai (*S. officinarum*) and *Narenga*, but the chromosomes of *Narenga* seem not to have been observed.

The chromosome number of Formosan *Narenga* is also $n=15$, and the frequent occurrence of polyvalents of high degree seems sufficient to let us suppose its complicated origin, though the number of chromosomes is rather small. This may be interesting if referred to the Janaki Ammal's observation (1942), that only a single pair of chromosomes among 30 somatic ones have trabants. Bremer (1924) found that the chromosomes in PMC-s of *Narenga* were larger than those of other *Saccharum* plants at the same meiotic stage. The present writer observed, however, no difference among them.

VI. Summary

1) Various forms of *Saccharum spontaneum* collected from different parts of Formosa can be, in general, divided into two categories, small and large. The smaller plant, below 2^m in height with a glabrous ligule, is *S. spontaneum* subsp. *indicum* var. *genuinum*, the chromosome numbers being $n=56$, $2n=112$. The larger one, taller than 2^m in height with a ciliate ligule, is *S. spontaneum* subsp. *indicum* var. *Roxburghii*, the chromosome numbers of which are $n=48$, $2n=96$. The relation between the plant height and the chromosome number shows a sheer contrast compared to the cases in *S. spontaneum* reported by some investigators to date. In Formosa, both kinds of *spontaneum* are found on the plains and mountains below the elevation 500^m, especially on the banks of rivers or seashores.

2) Any number of chromosomes other than above mentioned two was found in naturally grown *spontaneum* of Formosa, though a considerable difference in morphological characteristics was seen within each variety.

3) The distribution map of *S. spontaneum* in South-eastern Asia and its vicinity was presented, and the area was divided as follows according to the number of chromosomes of the plants growing:

- I. Malay Archipelago and South Seas SectionPhilippines, Micronesia, New Guinea involved.
- II. India-Burma Section.....Turkmenistan involved.
- III. Japan Islands Section.....Formosa, Okinawa involved.

4) Speciality in the mode of distribution and chromosome numbers of *S. spontaneum* in India, as well as the existence of abundant kinds of cultivated sugar cane there, suggests us that at least one of the keys to unlock the question of unknown ancestral sugar cane forms seems to be concealed in the northern part of India.

5) *S. spontaneum* subsp. *indicum* var. *genuinum* of Formosa and Glagah of Java, appear to be phylogenetically different, though the

number of chromosomes is the same ($2n=112$). This conclusion may be drawn from the facts that: (1) they are different in external aspects, (2) two islands under consideration seem to have no geographical connection concerning the distribution of *S. spontaneum*, other kinds of *spontaneum* with different numbers of chromosomes being found in the districts between Formosa and Java, and (3) *S. spontaneum* in Hainan and Philippine islands, lying nearest to Formosa, are considered to be different from *genuinum* of Formosa, making the distribution of *genuinum* in Formosa isolated from near lying islands.

6) *Narenga porphyrocoma* in Formosa is $n=15$, which is the same as Javanese and Indian materials. This plant shows sometimes high degree of polyvalent conjugation in meiosis of PMC-s.

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Addendum

After the manuscript had been sent to the editor, *Cytologia*, the writer received a report 'Chromosome numbers of wild sugarcane in Micronesia' by Nishiyama and others (Rept. Kihara Inst. B. R. No. 3. 1947). In this paper *S. spontaneum* of Palau ($2n=80$), Truk (96), Ponape (78), Kusaie (96) are discussed.