CYTOGENETICAL STUDIES ON SOME CEREAL AND TUBER CROPS OF NORTH-EASTERN HILLS

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DOCTOR OF PHILOSOPHY

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I certify that the thesis entitled "Cytogenetical studies on some cereal and tuber crops of North-Eastern Hills" submitted by Mr. K.M. Kuruvilla for the degree of Doctor of Philosophy of the North-Eastern Hill University, Shillong embodies the record of original investigation carried out by him under the supervision of Late Dr. Autar Singh. He has been duly registered and the thesis presented is worthy of being considered for the award of the Ph.D. degree. This work has not been submitted for any Degree of any other University.

R.R. Mish

Signature of the Supervisor.

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RESPECTFULLY DEDICATED

TO

MY SUPERVISOR, LATE DR. AVTAR SINGH

C O N T E N T S

A C K N O W L E D G E M E N T S

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INTRODUCTION

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The Indian sub-continent is unique in that its North-Western parts from Punjab, North-Western Province in Pakistan, Kashmir and Afghanistan upto Central Asia happen to be one of the most important centres of origin of a large number of important crop plants, the most important being the wheats. Similarly, the North-Eastern part of India extending from Assam, Sikkim and Meghalaya to Burma and Malayasia is another important centre where several cultivated plants including rice, orange, mango, banana and some tuber crops originated. Meghalaya State falls within this region. It has a wide range of altitudes from 100 metres to approx. 2000 metres and is covered by variable climatic conditions and soil types. Hills are also isolated from one another geographically giving rise to important ecological niches. It is exceptionally rich in germplasm of a large number of plants, viz., cereals, fruits, tubers, etc. The Agricultural Scientists and Institutes quite often organise collections of wild relatives of rice, oranges, bananas, dioscorea, etc. from time to time as these accessions are essential for their studies/improvement programme, but even then inestimable stock of the great variability remains to be explored. It may be stated that Vavilov (1931) while describing Chinese centre of origin of plants mentioned -

"If we take into account the enormous number of wild plants besides the cultivated ones used for food in China, we may better understand how hundreds of millions of people manage to exist on its soil." Similarly, in the North-Eastern region where organised agriculture and cultivation is a recent feature, the original inhabitants sustained themselves on the natural tubers, fruits, cereals and other crops. As an illustration one has to see to believe how hillsides after hillsides in the Assam region wild bananas grow from which through clonal selection or natural hybridisation and polyploidy cultivated varieties could have evolved.

While sustained efforts are being made for the collection, conservation and assessment of the germplasm of major crops like rice, Cicer, Phaseolus, Cucumis, sugarcane, mango, cotton, orange, etc., no worthwhile attention is being paid to spot out and assess the existing variability of lesser known tuberous plants. As mentioned above the role of these tuberous plants in the food chain of the local population cannot be underestimated. It would, therefore, be very useful and rewarding if the locally cultivated tuber crops and their wild relatives be extensively collected and suitably assessed. Such efforts can be of considerable importance for their improvement and wider cultivation so as to contribute substantially to the food granary of the country.

Tuber crops in fact constitute the major staple food for the people in the tropics. Most of these tuber crops are aroids which grow both in plains and hills, and show an array of variable habits. It is with this aim that a number of species of the tuberous crops have been selected which commonly grow in Meghalaya regions. Their cytogenetical aspects and food value need to be properly determined.

A cursary glance at the literature reveals that some attention has been paid to the cytogenetics of tubers growing in other parts of this country as well as in other parts of the world, but there is complete lack of information on the tuberous plants that are found in North-Eastern hills of India.

The whole range of variability with respect to cyto-types, clones, polyploids, natural hybrids, etc. may be expected which could be utilised later in a meaningful manner.

There are a large number of tuberous crops, but for an indepth and fruitful informations the investigation will be restricted to some of the common and cultivated aroids and their wild relatives. The aroids - a monocotyledonous group of plants, comprise of 1400-1500 species belonging to 105 genera (Lawrence, 1961). Vegetative propagation is the primary mode of reproduction in this family,

even if a few of them may be sexually fertile. The genera Colocasia, Gonatanthus, Xanthosoma, Arisaema, Steudnera and Amorphophallus are common in the hills and plains of Meghalaya. Of these, the first three genera belong to the tribe Colocasieae and the remaining three to the tribe Areae, Diffenbachieae and Pythonieae respectively (Hutchinson, 1944).

The genus Colocasia, commonly known as 'Taro' and in West Africa as 'Cocoyam', grows luxuriantly in Meghalaya. The corms and cormels are economically important as they have store of carbohydrate and starch. The starch is amylase and amylopectin and is readily digestible, hence, they are greatly priced as food. Even in protein content it is better than sweet potato or Cassava (Mannihot). The plants propagate vegetatively, hence, there is continuous gradation of characters. The taxonomy of Taro, therefore, presents complications. According to Plucknett (1976) there may be more than 1000 cultivars of Taro. C. esculenta is considered as the most widely cultivated taxon. Mookerjea (1955) studied a number of taxa of the Araceae including Colocasia and reported $2n = 28$. However, a great number of morphological strains/types growing in the plains and hills of Meghalaya were not covered in this study. Similarly, the taxon Gonatanthus sarmentosus which showed $2n = 32$

by the same author, was not collected from Meghalaya.

Sharma and Sircar (1963) reported various cytotypes with different chromosome numbers in North Indian species (not Meghalaya) of Colocasia antiquorum. Another mitotic studies in C. antiquorum and C. esculenta were carried out by Magoon et al. (1971) with a view to bring out the nature and trend of chromosomal variations in Colocasia. These cytological reports on materials collected from another area than Meghalaya confirm that the various species of Colocasia growing in North-East Hill region have not been touched and, therefore, need critical cytological investigation from both basic and applied standpoints to bring out the mechanism of variations and thus may be helpful in selecting suitable clones and cytotypes for multiplication and cultivation.

Similarly, the other genus Amorphophallus comprising of about 90 species of which 14 are reported in India (Wealth of India, 1948) has not been collected to any extent from Meghalaya. Two species, A. companulatus and A. riveri, are cultivated and greatly valued for their edible corms. Two species of Amorphophallus, A. bulbifer and A. titanum were reported to possess $2n = 36$ and $2n = 26$ respectively by Chandler (1943).

Magoon et al. (1970) and

Krishnan *et al.* (1970) studied the pachytene chromosomes in *Amorphophallus*. But in recent years Ramachandran (1977) prepared the karyotypes of the 4 South Indian species of *Amorphophallus*, namely, *A. bohenackeri*, *A. companulatum*, *A. bulbifer* and *A. dubius*. The reported 2n numbers in these are 26, 28, 39 and 28 respectively. These studies and reports indicate the variation in chromosome numbers, existence of cytotypes, polyploids, etc. within the genus. It is, therefore, worthwhile to explore the materials growing in Meghalaya to determine the extent of variability in them.

The other important aroid genus *Xanthosoma* is commonly known as 'Tannia' or 'Cocoyam'. It is generally considered a tropical American genus and was brought in use by the American-Indian of the Carribean Islands (Plucknett, 1976). During the middle and late 19th and early 20th centuries 'Tannia' spread throughout the Pacific and Indo-Asia where it achieved the status of minor crops because of its high resistance to diseases and pests (Massel and Barrow, 1955). Superficially *Xanthosoma* resembles *Colocasia*, but as detailed later they differ from each other in important morphological features. Nutritionally it is similar to *Colocasia*. In fact, the corm of 'Tannia' is composed of 77-86% edible materials. It is

also richer than 'Taro' in mineral elements. Onwueme (1978) reported that between 1965 and 1974 'Tannia' was grown on 6,89,000 hectares of land in the world. Even in Asia 61,000 hectares of land was under 'Tannia' cultivation during this period. The most common cultivated form is X. sagittifolium which appears to have numerous morphological forms (Onwueme, 1978). The species, therefore, is polymorphic. The other species of the genus like X. atrovirens, X. carcau and X. violaceum are grown in West Indies and Philippines. Uptill now the improvement of the group has been limited to the genetic variability present in small numbers of cultivars (Warrid, 1970). It is evident that there is vast scope for collections from the various regions and ecological habitats so as to fully and suitably assess them for selection and cultivation.

The studies in the other genera like Arisaema and Steudnera are equally sketchy.

Thus the importance of these tuberous crops which are used as food can be better and properly appreciated only when it would be recalled that large part of the North-Eastern regions, full of mountains and forests and inhabiting various tribes of local populations whose assured means of food supply through cultivation is of recent introduction. The tubers seen in this light assume special importance. Therefore, from the point of view of the food

values of these tuberous crops and also to explore the range of variations in them in this region of the centre of their origin where most of the dominant genes are expected to be present, form the basis of their inclusion in the present investigation.

The other common cereal, besides rice, which form the favourite crop of the hill tribes, is maize. So much work on maize, both of fundamental and applied nature, has been done throughout the world that even to review them will form a solid book. Why was then maize selected for the present investigation, is the consideration that there is a strong school of thought that the secondary centre of origin (even primary centre) of maize is the North-Eastern India. The relationship of Zea with Tripsacum and Euchlaena may be reviewed and also its relationship with Coix and Sorghum as mentioned by Anderson (1945) and Mangelsdorf (1947) need to be investigated. What is surprising is that some of the primitive types of maize grow in the hills of Sikkim and Meghalaya. These strains still bear 5-6 cobs per plant, the character commonly inherited from Tripsacum. A number of composites and hybrid maize varieties have been evolved in the plains and been exported to the hills for higher yield that many of these primitive varieties are gradually being replaced. It would be a

misfortune if the primitive maize germplasms which could provide important clues to the Asian origin of maize and its relationship with Coix and Sorghum vis-a-vis Tripsacum, are totally replaced by modern hybrid composits. An attempt has, therefore, been made to collect some of the yellow and white kernnel maize types grown in remote areas of Meghalaya and to study their inheritance with a view to know if they throw 'off-types'/'recessive genotypes' which may provide valuable evidence about the origin and development of these primitive hill strains. It is also to stress that more intensive effort is needed to collect on large scale all the available strains of the primitive maize grown in various inaccessible hill areas where improved varieties of maize from the plains have not yet invaded.

In view of this some of the maize varieties grown in the hills were selected for investigation of their inheritance behaviour, growth pattern and cytogenetics so as to utilise these informations to discuss their importance in evolution and breeding.

In addition to the cytogenetical aspect of the tuberous crops and the primitive varieties of maize, another approach, namely, electrophoresis, has been employed to study the carbohydrate and protein profiles in some accessions collected from various regions. Electrophoretic

studies which are greatly helpful in cases where taxa/varieties which have same chromosome number and behaviour, and very similar morphological traits, would reveal different types of protein and carbohydrate profiles. The difference of bands in electrophoretic studies thus bring out the cryptic structural differences in the genetic make-up of the taxa which are otherwise non-detectable in cytological preparations.

Coupling of morphological, cytological, genetical amd electrophoretic studies are thus expected to provide very useful information on the variability pattern and phylogenetic relationship in these groups of plants.

MATERIALS AND METHODS

MATERIALS AND METHODS

The present investigation was carried out on the following species :

Species	Sources
1. *Amorphophallus bulbifer* Bl.	Forests of Meghalaya
2. *Arisaema consanguinum* L. Schott.	"
3. *Gonatanthus ornatus* Klotz.	"
4. *Steudnera colocasioides* Hook. f.	"
5. *Xanthosoma sagittifolium* L. Schott. var. Plain.	Thiruvalla (Kerala)
6. *X. sagittifolium* L. Schott. var. Hill.	Khasi Hills (Meghalaya)
7. *Colocasia esculenta* L. Schott.	
Strain 1	Shillong (Meghalaya)
2	"
3	"
4	"
5	"
6	"
7	"
8	"
9	"
10	"

Strain	11	Ludhiana(Panjab)
	12	Shillong
	13	Thiruvalla
	14	"
	15	Forests of Meghalaya

8. Zea mays L. var. Yellow Shillong — Shillong
9. Z. mays L. var. Garo White — Garo Hills
10. Z. mays L. var. Sikkim Yellow — Sikkim
11. Z. mays L. var. Sikkim White — Sikkim

The Meghalaya strains of 'Taro' were categorised on the basis of size and shape, and the level of ploidy.

Amorphophallus :

A perennial stemless herb. Tubers depressed - globose, brown or dark brownish. Flowering before leafing. Leaves 3-partite; segment pinnatisect. Spadix exserted or included; appendage large, short or long; inflorescence cylindrical; neuters absent.

Arisaema :

Herbaceous tuberous plant. Leaves pedatisect; leaflets whorled; spathe deciduous; tubes convolute; limb often accuminate or tailed usually in curved; spadix included or exserted; appendages long and filiform.

Gonatanthus :

Tuberous herb with branched bulbiferous shoots. Spathe has slender, elongate and convolute limb. Absence of neuters between male and female inflorescences; ovules numerous and basillar.

Steudnera :

Herbs, caudex stout; leaves ovate, long petioled, peltate; spathe shortly convolute at the base; limb ovate - lanceolate, expanded, reflexed, marcescent; spadix very short, dense flaccid.

Xanthosoma :

Rhizomatus herbaceous herb; leaves hastate, dentate; leaf lamina is heart-shaped, lobed. Often seen in the vegetative phase only. Spathes brownish. Spadix longer than spathe.

Colocasia :

An erect rhizomatus herb; leaves are peltate, long petioled; flowering rare; spathes petaloid, pale-brownish, yellow; caudate - accuminate, erect; spadix shorter than spathe, cream-coloured.

Zea mays :

An erect, robust, monoecious grass; leaves are broad lanceolate; spikelets in pairs, one sessile and one pedicelled. Female spikes are axillary, enclosed in the sheath of the leaf and surrounded by bracts.

Tubers and seeds of all varieties were grown in the experimental fields of Botany Department of North-Eastern Hill University, Shillong. Morphological measurements were made from five plants of tuber crops. Ten plants of each varieties of maize were subjected for morphological observations.

For stomatal studies, peels were taken out by the method employed by Roy and Singh (1968). The leaves were cut into pieces and kept in ether for an hour and then in methanol till they became colourless. They were then transferred to the solution of 1.6 gm ammonium oxalate and 0.4 gm of oxalic acid in 100 cc of distilled water, and kept in it for 24 hours. The peels were separated after warming and shaking the solution and were mounted in 1.0% aceto-carmine solution for study. Stomatal index values have been calculated according to the formula given by Meidner and Mansfield (1960).

$$\text{Stomatal index} = \frac{\text{No. of stomata} \times 100}{\text{No. of stomata} + \text{No. of epidermal cells}}$$

Moisture content of the tubers were determined on dry weight basis.

MITOTIC STUDY

Pre-treatment :

For studying the somatic chromosomes of tuberous plants roots were collected from the plants grown in pots. They were thoroughly washed in water with a brush in order to remove the root cap before subjecting them into a saturated solution of 0.002 M 8-hydroxyquinoline for pre-treatment. The pre-treatment was given for four hours, the first two hours at room temperature (20 ± 2°C) and the remaining two hours in refrigerator (8 ± 2°C).

Seeds of different varieties of maize were germinated on a moist filter paper in petridishes kept in an incubator at 22 ± 2°C. The roots were collected from the seeds germinated on the moist filter paper and the root caps were removed with the help of a brush and subjected them to a saturated solution of alpha-bromonaphthalene for four hours at room temperature (20 ± 2°C) for pre-treatment.

Fixation : The fixation procedure was common for the tuber crops as well as the maize varieties. The pre-treated roots were thoroughly washed in distilled water for few minutes.

Then they were soaked in folds of a filter paper and fixed in ethyl alcohol : acetic acid (1:3) mixture with ferric chloride as mordant and kept for 48 hours in the refrigerator.

Staining : After fixing the root tips for 48 hours, roots were taken out from the fixative and hydrolysed in N HCl for 10 minutes at 60°C. The hydrolysed roots were washed in distilled water and soaked in folds of a filter paper and then transferred to the stain. A small portion of the root tip was taken on a slide and squashed in 1.0% aceto-orcein.

Destaining : Acetic acid (45.0%) was used to remove the over-staining of the cytoplasm.

MEIOTIC STUDY

The intact tassels of maize plants were taken out at the booting stage and fixed in Carnoy's fluid, which comprises of ethyl alcohol : chloroform: acetic acid (6:3:1) between 10 and 11.30 A. M. in the months of June-July. Ferric chloride was used as mordant.

Aceto-carmine (1.0%) was used to stain the meiotic chromosomes.

Pollen fertility :

The fertility of the pollen grains was determined based on their stainability in aceto-carmine.

Microphotographs were taken from the temporary preparations. Metaphase chromosomes were measured from the photographic enlargements.

The homologous chromosomes were found on the basis of their length, positions of the constrictions and arm ratio. The chromosomes were categorised following the nomenclature proposed by Levan et al. (1964).

Explanations of abbreviations :

M = median point
m = median region
Sm = sub-median
St = sub-terminal

Chromosome types :

A = above 6.0 μ
B = 4.5 to 6.0 μ
C = 3.0 to 4.5 μ
D = 1.5 to 3.0 μ
E = upto 1.5 μ

The chromosome types have been designated arbitrarily. T. F. % value has been calculated as given by Huziwara (1956).

$$T.F.\% = \frac{\text{Total sum of short arm length} \times 100}{\text{Total sum of chromosome length}}$$

INTERVARIETAL HYBRIDIZATION

Intervarietal hybridization was carried out between the varieties of Yellow Shillong (female) x Sikkim Yellow (male) and Sikkim White (female) x Garo White (male) based on Poehlman and Borthakur (1972). Crosses could not carried out between all the varieties because of the non-uniformity in flowering at higher altitudes of Meghalaya, Shillong. The tassels of the male plants were bagged with a paper envelope (15" x 6") in order to collect viable pollen grains just before the opening of the flowers. The anthesis has taken place between 11.30 to 12.0 A.M. at Shillong conditions. The ears have emerged generally at fourth and fifth internodal region within three to four days after the opening of the male flowers. The tips of the ears were cut with the help of a pair of scissors so as to bring forth uniformity in the emerging silks. The silks were bagged with a butter paper envelope (8" x 6") before it emerges out. The tips of the ear bags were cut with the

help of a pair of scissors in order to dust the pollen grains. As soon as the dusting was over, the bags were stapled and care was taken to prevent the entrance of foreign pollen grains. The seeds were collected from the crosses for further study.

ESTIMATION OF TOTAL PROTEIN AND CARBOHYDRATE

Tubers and seeds of the same age were collected for electrophoretic studies and determination of total protein and carbohydrate contents. Fresh samples were chopped and crushed in a pestle and mortar to which an adequate amount of acetone was added. The supernatant was discarded. This was followed by mixing the crushed sample with an equal amount of acetone and ether and ultimately by ether alone. Again the supernatant was discarded and the sample was kept for drying. The dry powdered sample was used for the determination of protein following the method of Lowry *et al.* (1951). The stock solution A was composed of 2.0 g sodium hydroxide, 10.0 g sodium carbonate and 0.1 g sodium potassium tartarate per litre of distilled water. The solution B was prepared by dissolving 0.1 g of copper sulphate in 100 ml of distilled water. Solution C was made at the time of analysis by mixing 10 ml of solution A with 0.2 ml of solution B. The sample (0.5 mg) was mixed with 5 ml of solution C and shaked well. This mixture was kept for 15 minutes at

room temperature. This was followed by the addition of 0.5 ml of folin-phenol reagent (1 ml of folin-phenol reagent + 2 ml of distilled water) and this mixture was shaken well and kept at room temperature for 30 minutes. The intensity of the colour was measured in a spectrocolorimeter at a wave length 750 nm. Bovine serum albumin was used as standard.

For carbohydrate, 0.5 mg of the dry powdered sample was boiled with 5 ml of distilled water. One ml of this solution was used for analysis according to Anthrone method (cf. Practical Biochemistry by Plummer). The sample solution was mixed with 5 ml of freshly prepared anthrone solution (1gm of anthrone reagent in 100 ml of 90% sulphuric acid was dissolved). This mixture was kept in a boiling water-bath for 10 minutes. Marbles were used in order to prevent the evaporation. The mixture was then taken out of the boiling water-bath, cooled and measured the optical density in a spectrocolorimeter at a wave-length of 620 nm. Glucose was used as standard.

ELECTROPHORESIS

For electrophoretic analysis, chilled fresh tuber samples were crushed with 0.2 M phosphate buffer (pH 7) in a chilled pestle and mortar. The solution was centrifuged for 50 minutes at 10,000 rpm. The supernatant was used for analysis.

The polyacrylamide gels (pH 8.9) were prepared following the formulation given by Davis (1964). Each batch of gels were prepared by mixing one part of stock solution A (composed of 48 ml 1 N HCl, 36.6 g TRIS, 0.23 ml TEMED, made upto 100 ml in distilled water), two parts of stock solution C (composed of 28.0 g acrylamide, 0.735 g Bis-acrylamide, made upto 100 ml in distilled water), one part of distilled water and four parts of 1.4 g/litre ammonium per sulfate (freshly prepared) solution. Tris-glycine (pH 8.4) buffer was used as an electrolyte.

Protein samples were mixed with freshly prepared 40.0% sucrose solution and the mixture was applied to the column. Bromophenol blue (0.1%) was added to the cathode chamber to act as tracking dye. The gels were electrophoresised for 1.5 hours at 2 mA per tube in the remaining time. This allowed the tracking dye to reach the bottom of each gel and resulted in the optimal resolution of bands.

The gels were fixed in 10.0% trichloroacetic acid for 30 minutes and stained in a mixture of (1:1) amido black(1.0% in 7.0% acetic acid) and commassie blue (1.0% in 7.0% acetic acid) for one hour and destained by washing with 7.0% acetic acid and stored in distilled water.

For the staining of peroxidases, hydrogen peroxide (3.0%) was used as a substrate and benzidine as stain. Benzidine solution was prepared by mixing 1 g benzidine powder in 9.0 ml of acetic acid at 45°C and 36 ml of distilled water. The hydrogen peroxide and benzidine were mixed in the ratio of 1:1 and poured on the gels. The isozymes of peroxidases appeared in blue coloured bands.

The bands were categorised as dense, medium and light depending on the intensity of the colour and the gel patterns were compared visually.

Zymograms were made for proteins and peroxidases. Rf values of protein and peroxidase bands were calculated employing the following equation :

$$Rf = \frac{\text{Distance travelled by each band}}{\text{Distance travelled by the tracking dye}}$$

The mean Rf values from five replicates of each of the varieties/strains for proteins and peroxidases were tested by 't' test at 5.0% level.

Statistical analysis :

Mean : $\bar{x} = \frac{\Sigma x}{n}$ where x = number of bands

n = number of observations

Standard Deviation, S.D. = $\sqrt{\frac{\Sigma(x - \bar{x})^2}{n - 1}}$, where,

x = number of bands

$\bar{x}$ = mean number of bands

't'-test - (In the case of two samples)

$$t = \frac{\bar{x} - \bar{y}}{S\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$$ where,

$\bar{x}$ = mean of sample 1

$\bar{y}$ = mean of sample 2

n_1 = size of the sample 1 (Rf)

n_2 = size of the sample 2 (Rf)

S = pooled standard deviation

$$= \sqrt{\frac{S_1^2(n-1) + S_2^2(n_2-1)}{n_1 + n_2 - 2}}$$ where,

S_1 = standard deviation of sample 1

S_2 = standard deviation of sample 2

Test criterion :

If (t) $t_{n_1 + n_2 - 2}(X/2)$, then the samples 1 and 2 are said to be significantly different at x 100% level.

O B S E R V A T I O N S

OBSERVATIONS

Amorphophallus bulbifer Bl.

Tuberous herbs, flowering before leafening. Leaves 3-partite, segments pinnatisect, spathe various, limb companulate infundibular convolute or open. Spadix excerted or included. Inflorescences cylindrical, neuters absent. It is a wild species characterised by bulbils borne at the fork of the leaves. The petiole and peduncle are green streaked with green and black. Leaflets are obovate or lanceolate (Fig. 1).

Somatic counts showed $2n = 26$ chromosomes (Fig. 2). Different chromosome numbers have been reported earlier in the case of *A. bulbifer*. According to Chandler (1942) the chromosome number is $2n = 36$, whereas, Ramachandran (1977) reported $2n = 39$. Chromosome length varied from 3.17 to 6.86 μ and the total chromatin length was 129.56 μ. Secondary constriction was observed in the 12th chromosome pair (Ramachandran, 1977). However, no such constriction was found in the present study. The details of the karyotype analysis are recorded in Table 1 and the chromosome pairs have been represented in the idiogram (Fig. 3). Eleven pairs are median and the remaining two pairs are sub-median with respect to the position of the primary constriction.

Figs 1-6. Amorphophallus bulbifer and Arisaema consanguienum

1-A plant of Amorphophallus bulbifer

2-Somatic Chromosomes (2n = 26) of A.bulbifer(X 2184)

3-Karyotype of A.bulbifer

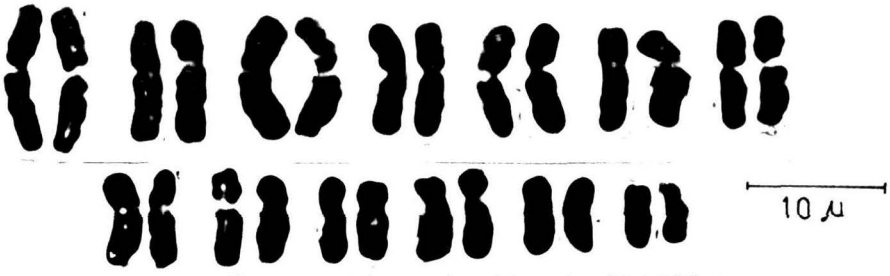
4-A plant of Arisaema consanguienum

5-Somatic chromosomes (2n = 28) of A.consanguienum (X 2184)

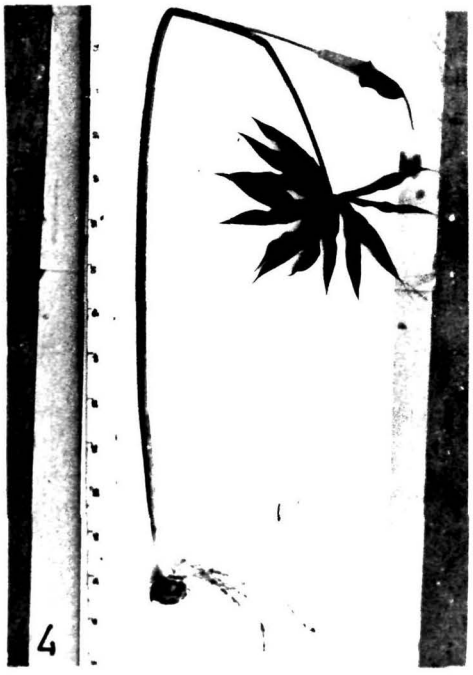
6-Karyotype of A.consanguienum

1

2



3



4

5

6

Figs 7-12. Gonatanthus ornatus and Steudnera colocasioides

7-A plant of Gonatanthus ornatus.

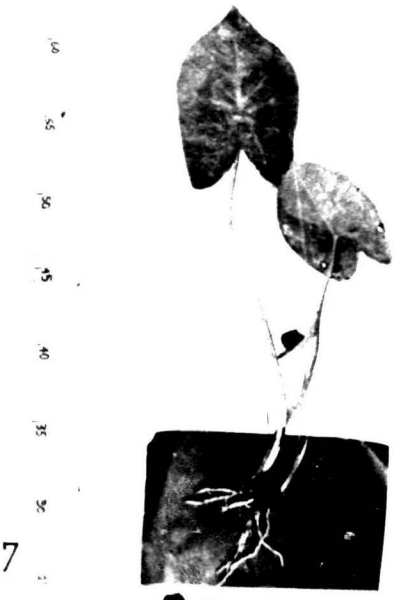
8-Somatic chromosomes(2n = 30) of G.ornatus(X 2184)

9-Karyotype of G.ornatus.

10-A plant of Stendnera colocasioides.

11-Somatic chromosomes (2n = 28) of S.colocasioides (X 2184)

12-Karyotype of S.colocasioides.



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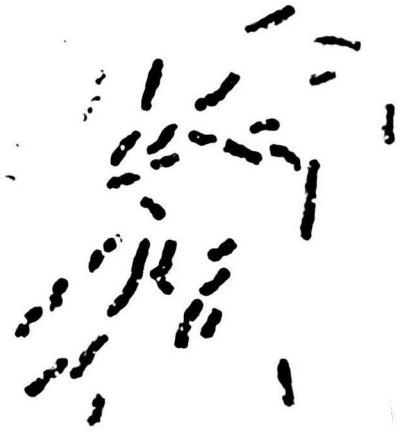

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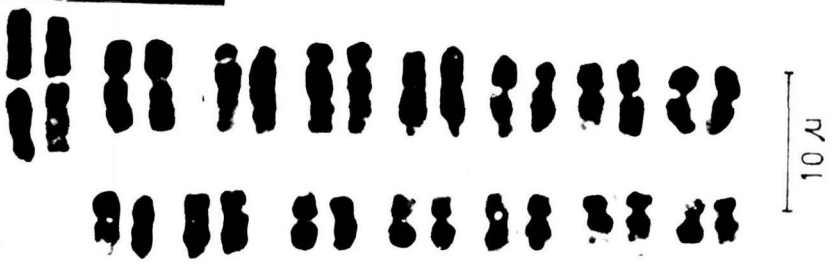
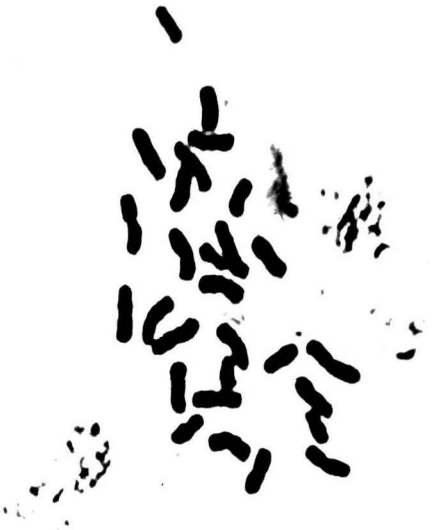


10 μ

9

10



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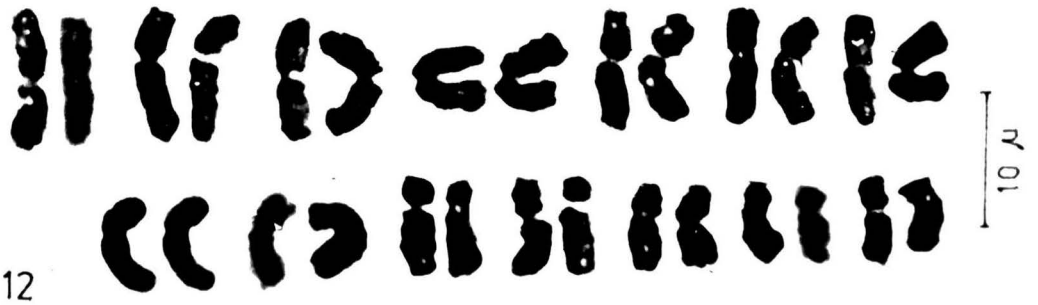


10 μ

12

Table 1 : Chromosomes of Amorphophallus bulbifer.

(2n = 26)

Chromosome pairs	Chromosome type	Position of constriction Primary	Secondary	Arm ratio	Length of the component arms in μ		Total length in μ
1	A	m		1.29	2.99	3.87	6.86
2	B	m		1.13	2.82	3.17	5.99
3	B	m		1.54	2.29	3.52	5.81
4	B	m		1.46	2.29	3.34	5.63
5	B	m		1.38	2.29	3.17	5.46
6	B	m		1.50	2.11	3.17	5.28
7	B	m		1.42	2.11	2.99	5.10
8	B	m		1.45	1.94	2.82	4.76
9	B	m		1.60	1.76	2.82	4.58
10	C	m		1.67	1.58	2.64	4.22
11	C	Sm		2.83	1.06	2.99	4.05
12	C	Sm		1.75	1.41	2.46	3.87
13	C	m		1.57	1.23	1.94	3.17

T. F. % - 41.32

Total chromatin length - 129.56 μ

Karyotype formula - 1(A m) + 8(B m) + 2(C m) + 2(C Sm).

Table 2 : Chromosomes of Arisaema consanguineum.

(2n = 28)

Chromosome pairs	Chromosome type	Position of constriction Primary	Secondary	Arm ratio	Length of component arms in μ		Total length in μ
1	D	m		1.13	1.41	1.58	2.99
2	D	M		1.0	1.41	1.41	2.82
3	D	Sm		2.2	0.88	1.94	2.82
4	D	m		1.14	1.23	1.41	2.64
5	D	Sm		2.0	0.88	1.76	2.64
6	D	Sm		1.80	0.88	1.58	2.46
7	D	m		1.14	1.05	1.41	2.46
8	D	m		1.60	0.88	1.41	2.29
9	D	m		1.40	0.88	1.23	2.11
10	D	m		1.20	0.88	1.06	1.94
11	D	Sm		1.75	0.70	1.23	1.93
12	D	M		1.0	0.88	0.88	1.76
13	D	m		1.25	0.70	0.88	1.58
14	E	M		1.0	0.70	0.70	1.40

T. F. % - 41.64

Total chromatin length - 63.68 μ

Karyotype formula - 2(D M) + 7(Dm) + 4(D Sm) + 1(E M).

Table 3 : Chromosomes of Gonantanthus ornatus.

(2n = 30)

Chromosome pairs	Chromosome type	Position of constriction Prim.	Second.	Arms ratio	Length of the component arms in μ		Total length in μ
1	A	M		1.0	3.52	3.52	7.04
2	B	m		1.25	2.14	2.64	4.78
3	C	Sm		2.13	1.41	2.99	4.40
4	C	St	Sm	3.0	1.06	1.76 + 1.41	4.23
5	C	m	Sm	1.30	1.76	1.94 + 0.35	4.05
6	C	m		1.33	1.58	2.11	3.69
7	C	m		1.11	1.58	1.76	3.34
8	C	m		1.25	1.41	1.76	3.17
9	D	m		1.43	1.23	1.76	2.99
10	D	m		1.13	1.41	1.58	2.99
11	D	M		1.0	1.41	1.41	2.82
12	D	m		1.14	1.23	1.41	2.64
13	D	Sm		1.8	0.88	1.58	2.46
14	D	m		1.6	0.88	1.41	2.29
15	D	Sm		2.0	0.78	1.41	2.19

T. F. % - 40.91

Total chromatin length - 106.16 μ

Karyotype formula - 1(A M) + 1(B m) + 3(C m) + 1(C Sm) + 1(C m Sm) + 1(C St Sm) + 1(D M) + 4(D m) + 2(D Sm).

Table 4 : Chromosomes of Steudnera colocasioides.

(2n = 28)

Chromosome pairs	Chromosome type	Position of constriction Prim.	Second.	Arm ratio	Length of component arms in μ		Total length in μ
1	A	M		1.0	3.34	3.34	6.68
2	A	m		1.53	2.64	4.04	6.68
3	A	m		1.12	2.99	3.34	6.33
4	B	M		1.0	2.99	2.99	5.98
5	B	m		1.43	2.46	3.52	5.98
6	B	m		1.06	2.82	2.99	5.81
7	B	m		1.46	2.29	3.34	5.63
8	B	m		1.06	2.64	2.82	5.46
9	B	m		1.23	2.29	2.82	5.11
10	B	Sm		2.5	1.41	3.52	4.93
11	B	m		1.6	1.76	2.82	4.58
12	C	m		1.27	1.94	2.46	4.40
13	C	m		1.67	1.58	2.64	4.22
14	C	m		1.20	1.76	2.11	3.87

T. F. % - 43.26

Total chromatin length - 151.32 μ

Karyotype formula - 1(A M) + 2(A m) + 1(B M) + 6(B m) + 1(B Sm) + 3(C m).

Table 5 : Karyotypic data on Amorphophallus, Arisaema, Constantinus and Steudnera.

Species	Range of chromosome length in μ	Mean length of chromosomes in μ	Ratio of the longest and shortest chromosome in μ	Total compliment length in μ	T.F. %
A. bulbifer	3.17 - 6.86	5.02	2.16	129.56	41.32
A. consanguinum	1.40 - 2.99	2.20	1.64	63.68	41.64
G. ornatus	2.19 - 7.04	4.62	3.21	106.16	40.94
S. colocasioides	3.87 - 6.68	5.28	1.72	151.32	43.26

Arisaema consanguinum Schott.

Tuberous herbs, leaflets whorled, spathe deciduous, tube convolute, limb often acuminate or tailed usually incurved. Spadix included or excerted. It is a wild species commonly found in the shady places in the forests. Leaves are borne at the tip of the long petioles and it possesses characteristic filiform tips (Fig. 4).

The somatic chromosome number was found to be twentyeight (Fig. 5). This is the first report of somatic number in the species. The chromosome length ranges from 1.40 to 2.99 μ. The total chromatin length is 63.68 μ. Secondary constrictions are absent. The detailed chromosome measurements are summarised in Table 2, and the chromosome pairs have been represented in the idiogram (Fig. 6). Ten pairs are median and the remaining four pairs are submedian with respect to the position of the centromere.

Gonatanthus ornatus Schott.

It is a herb growing wild. Leaves are lanceolate, a fine coppery purple colour is visible between the green nerves and broad green margin (Fig. 7). Absence of neuters between the male and female inflorescence.

The somatic chromosome number was found to be $2n = 30$ (Fig. 8). The somatic count was made for the first time. The chromosome length ranged from 2.19 to 7.04 μ. The total chromatin length was 106.00 μ. Secondary constrictions are present on the fourth and fifth chromosomes of the complement. The details of the karyotype analysis is given in the Table 3 and the chromosome pairs have been represented in the idiogram (Fig. 9). Eleven pairs are median, three sub-median and remaining one is sub-terminal with respect to the position of the centromere.

Steudnera colocasioides Hook. f.

It is a wild species with a rhizome at the base. Leaves are peltate, broadly ovate and acute at the apex (Fig. 10), light green above and glauous beneath. Petioles are green.

Root tips cells showed 28 chromosomes (Fig. 11). Somatic count was made for the first time. The length of the chromosome varies from 3.87 to 6.68 μ. Secondary constrictions are absent. The details of the karyotype analysis are given in the Table 4. The chromosome pairs have been represented in the idiogram (Fig. 12). The total chromatin length is 151.32 μ. Thirteen pairs are median and the

remaining one is sub-median with respect to the position of the primary constriction.

Xanthosoma sagittifolium L. Schott. - Plain Variety.

It is cultivated in plains. Leaves are smaller, hastate, leaf-lamina is heart-shaped(Fig. 13). Tubers are smaller in size. Sprouts absent (Fig. 14). Detailed morphological measurements are recorded in Table 6 and the stomata is represented in Fig. 15. The average height and yield of the plants are comparatively lower than that of the hill variety.

Root tip cells showed $2n = 26$ (Fig. 16). Chromosome counts agree with the earlier reports of Jos and Magoon (1970), Marchant (1971), Magoon et al. (1971). The size of the chromosomes varies from 1.23 to 3.25 μ. The total chromatin length is 60.18 μ. Secondary constrictions are absent. The measurements of the chromosomes are summarised in Table 7 and the chromosome pairs have been represented in the idiogram (Fig. 17). Ten pairs are median and the remaining three pairs are sub-median with respect to the position of the primary constriction. It has a protein value 5.1 mg/g dry wt. and the number of protein and isoperoxidase bands are 7 and 5 respectively.

Figs- 13-17 Xanthosoma sagittifolium var.plain.

13-A plant of X.sagittifolium var.plain

14-Tubers of X.sagittifolium var.plain

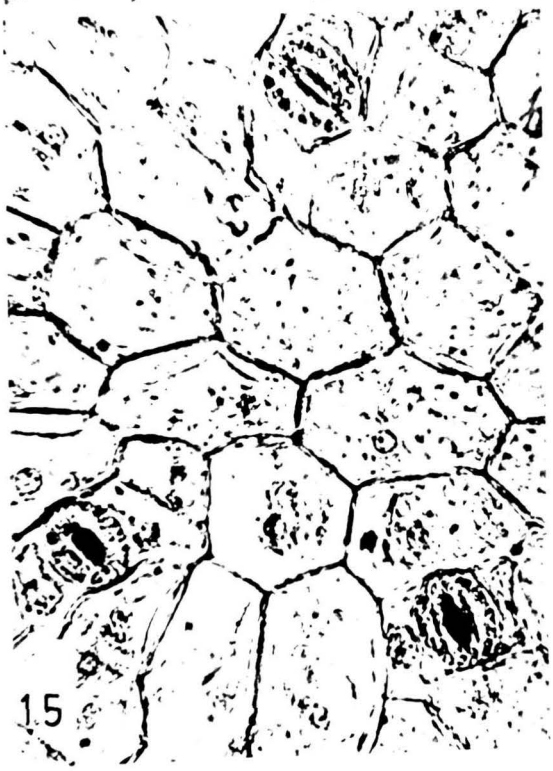
15-Stomata of X.sagittifolium var.plain

16-Somatic chromosomes (2n = 26) of X.sagittifolium (X 2184)

17-Karyotype of X.sagittifolium var.plain

13

14



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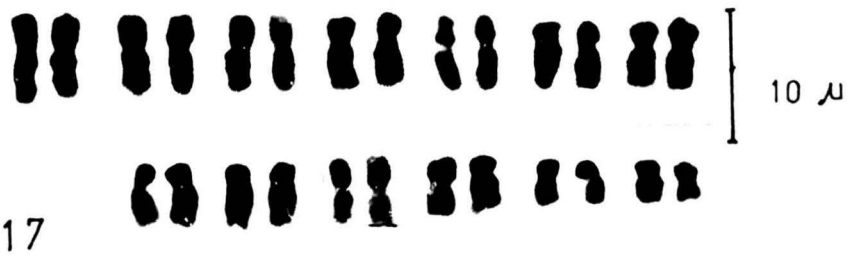


17

Figs 18-22. Xanthosoma sagittifolium var.hill

18-A plant of X.sagittifolium var.hill

19-Tubers of X.sagittifolium var.hill

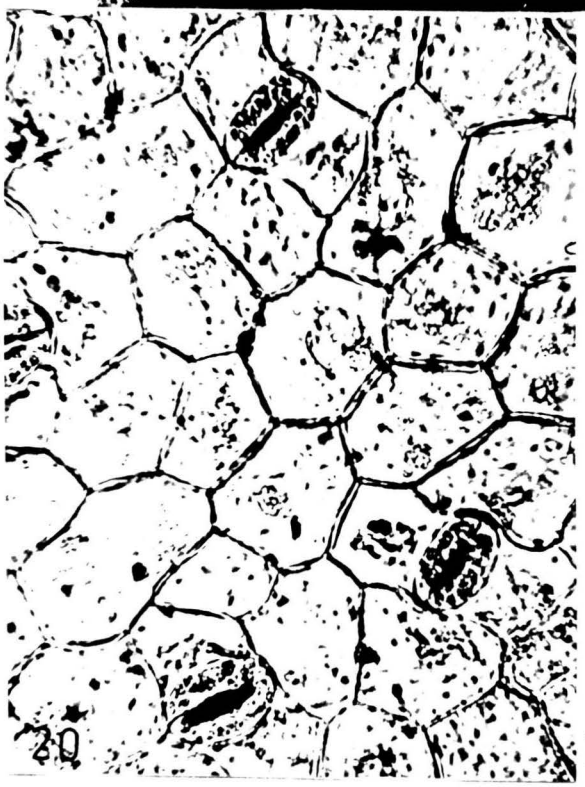
20-Stomata of X.sagittifolium var.hill

21-Somatic chromosomes (2n = 26) of X.sagittifolium var.hill (X 2184)

22-Karyotype of X.sagittifolium var.hill

18

19



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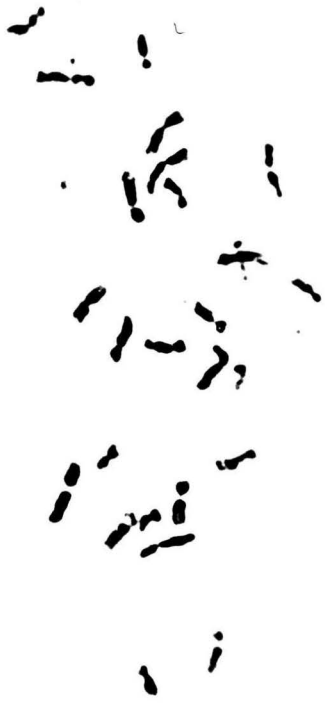

21

10 µ

22

Fig.23 Electrophoretic banding pattern of protein of the two varieties of Xanthosoma

Fig.24 Electrophoretic pattern of peroxidase of the two varieties of Xanthosoma

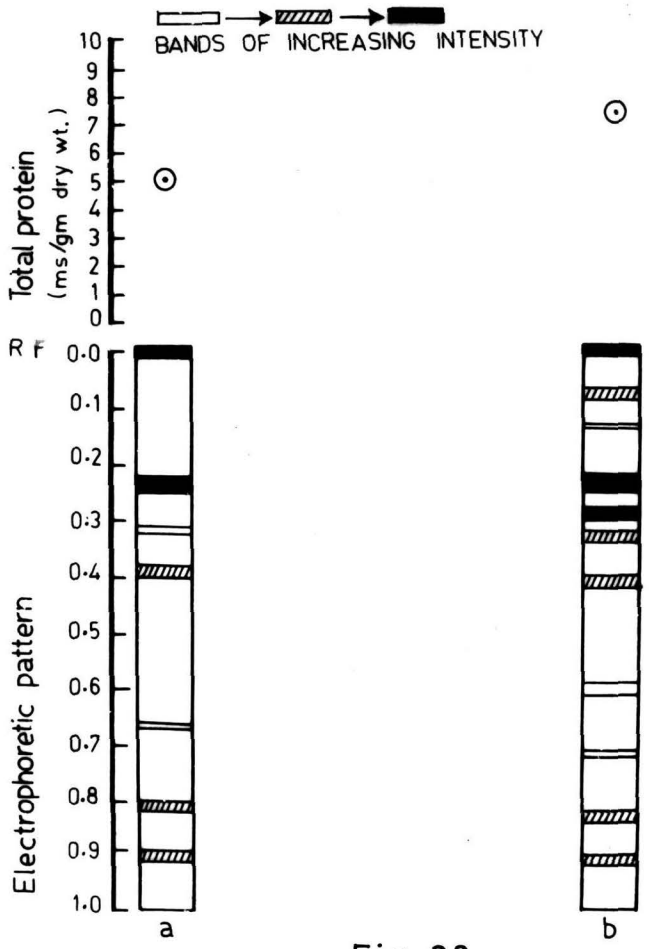

Fig. 23

a Plain variety, b Hill variety

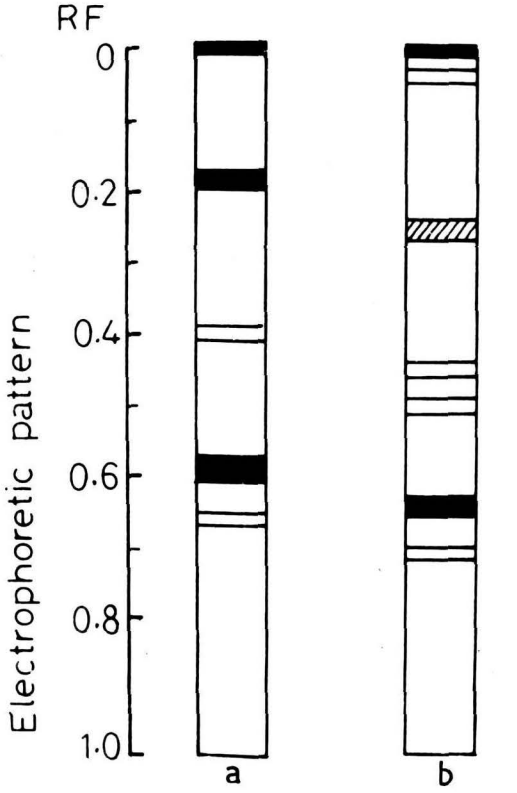

Fig. 24

Xanthosoma sagittifolium L. Schott. - Hill Variety

It is cultivated as a tuber crop in the higher altitudes of Meghalaya. Leaves are bigger in size, hastate and leaf lamina is heart-shaped (Fig. 18). Tubers are bigger in size. Sprouts present throughout the tubers (Fig. 19). The average height of the plants and yield/plant are higher than that of the plain variety and the stomata is represented in Fig. 20.

Somatic counts showed $2n = 26$ (Fig. 21) which confirm the earlier reports of Jos and Magoon (1970), Marchant (1971), Magoon et al. (1971). The length of the chromosomes ranges from 1.84 to 3.87 μ. The total chromatin length is 79.36 μ. Secondary constriction is present on the fourth chromosome of the complement. The detailed analysis of the somatic chromosomes are summarised in Table 8 and the idiogram is presented in the Fig. 22. Six pairs are median, five pairs are sub-median and the remaining two pairs are sub-terminal with respect to the position of the centromere. The total protein content is 8.4 mg/g dry wt. and the number of protein and isoperoxidase bands are 12 and 7 (Figs. 23 & 24) respectively.

Table 6 : Morphological measurements in Tannia.

Variety	Ploidy	Height of the plant (cm) ± S.D.	No. of leaves	Leaf area/ plant (cm^2) ± S.D.	Range of stomata	Mean	Stomatal index	Moisture content (%)	Yield/plant (gms)
Plain	2x	30.90 ± 4.58	4.4	1639.28 ± 528.6	4-7	5.9	9.18	53.8	806.6
Hill	2x	50.1 ± 10.56	5	3112.16 ± 18.54	4-9	6.5	8.75	60.8	1960.0

Table 7 : Chromosomes of K. sagittifolium var. Plain.

(2n = 26)

Chromosome pairs	Chromosome type	Position of constriction Prim.	Second.	Arm ratio	Length of the component arms in μ		Total length in μ
1	C	m		1.30	1.41	1.84	3.25
2	C	m		1.25	1.41	1.76	3.17
3	C	m		1.57	1.23	1.88	3.11
4	D	M		1.0	1.41	1.41	2.82
5	D	m		1.28	1.18	1.52	2.70
6	D	Sm		2.0	0.82	1.72	2.54
7	D	Sm		1.85	0.82	1.52	2.34
8	D	Sm		2.37	0.64	1.52	2.16
9	D	m		1.6	0.76	1.23	1.99
10	D	m		1.3	0.76	1.02	1.78
11	D	m		1.59	0.64	1.02	1.66
12	E	m		1.39	0.56	0.78	1.34
13	E	m		1.41	0.51	0.72	1.23

T. F. % - 40.77

Total chromatin length - 60.18 μ

Karyotype formula - 3(C m) + 1(D M) + 4(D m) + 3(D Sm) + 2(E m).

Table 8 : Chromosomes of X. sagittifolium var. Hill.

(2n = 26)

Chromosome pairs	Chromosome type	Position of constriction Prim.	Second.	Arm ratio	Length of the component arms in μ		Total length in μ
1	C	m		1.36	1.58	2.29	3.87
2	C	Sm		1.75	1.41	2.46	3.87
3	C	m		1.3	1.58	2.11	3.69
4	C	Sm	St	1.85	0.62	2.28+0.62	3.52
5	C	Sm		2.2	1.06	2.36	3.42
6	C	Sm		2.16	1.06	2.28	3.34
7	C	M		1.0	1.58	1.58	3.16
8	D	St		3.5	0.70	2.28	2.98
9	D	St		3.25	0.70	2.11	2.81
10	D	Sm		2.0	0.88	1.76	2.64
11	D	m		1.1	1.16	1.21	2.37
12	D	m		1.4	0.88	1.29	2.17
13	D	m		1.3	0.78	1.06	1.84

T. F. % - 38.48

Total chromatin length - 79.36 μ

Karyotype formula - 1(C M) + 2(C m) + 3 (C Sm) + 3(D m) + 1(C Sm St) + 1(D Sm) + 2(D St).

Table 9 : Karyotypic data on two varieties of *X. sagittifolium*.

Variety	Range of chromosome length in μ	Mean length of chromosomes in μ	Ratio of the longest and shortest chromosomes in μ	Total complement length in μ	T.F.%
Plain	1.23 - 3.25	2.24	2.6	60.18	40.77
Hill	1.84 - 3.75	2.79	2.1	79.36	38.48

Figs.25-28 *Colocasia esculenta*

25- Stomata of diploid plants of *C.esculenta*

26- Stomata of triploid plants of *C.esculenta*

27- Morphology of diploid plants of *C.esculenta*

28- Morphology of triploid plants of *C.esculenta*

27

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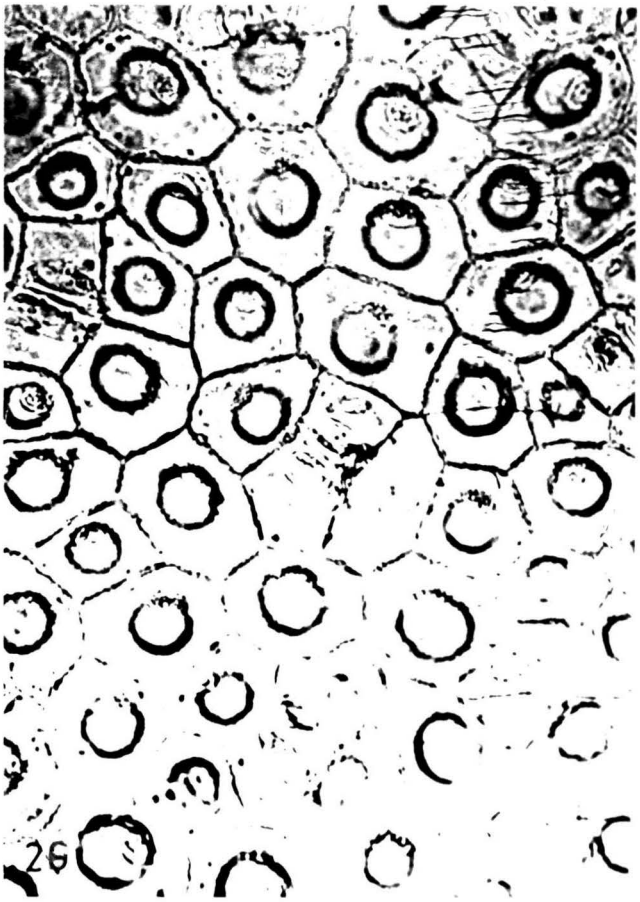
28



26

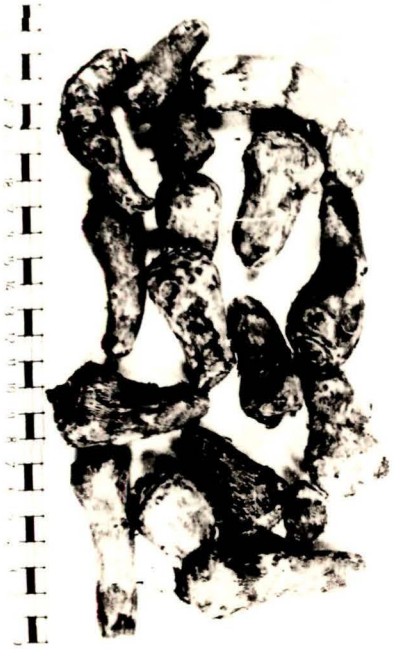
Figs.29-32. Strain 1 of Taro, Colocasia esculenta

29- Tubers of the strain 1 of Taro

30- Plants of the strain 1 of Taro

31- Somatic chromosomes (2n = 42) of the strain 1 (X 2184)

32-Karyotype of the strain 1



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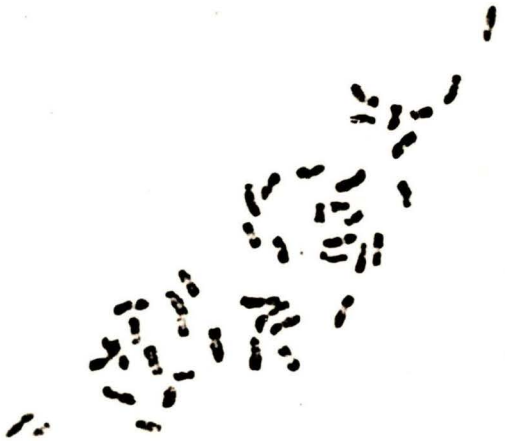

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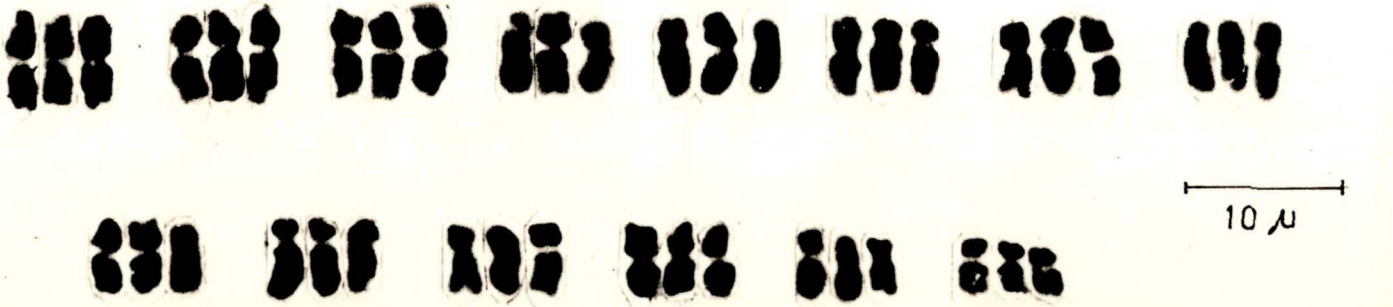


32

10 μ

Figs 33- 36 Strain 2 of Taro

33 Tubers of the strain 2 of Taro

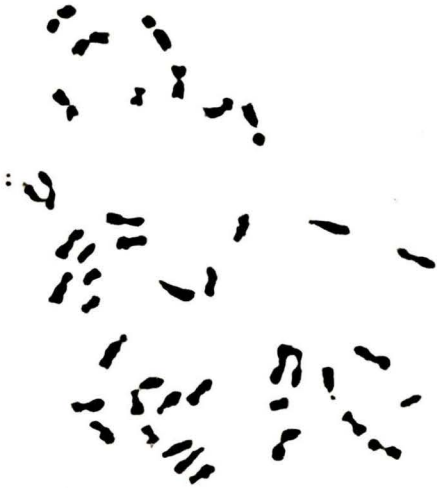
34 Plants of the strain 2 of Taro

35 Somatic chromosomes (2n = 42) of the strain 2 of Taro (X 2184)

36 Karyotype of strain 2 of Taro

33

35



10 μ

36

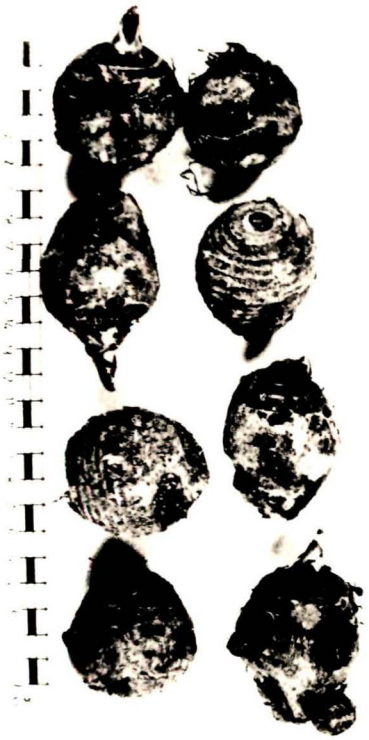
Fig.37-40 Strain 3 of Taro

37 Tubers of the strain 3 of Taro

38 Morphology of the plants of strain 3

39 Somatic Chromosomes (2n = 42)of the strain 3 (X 2184)

40 Karyotype of the strain 3



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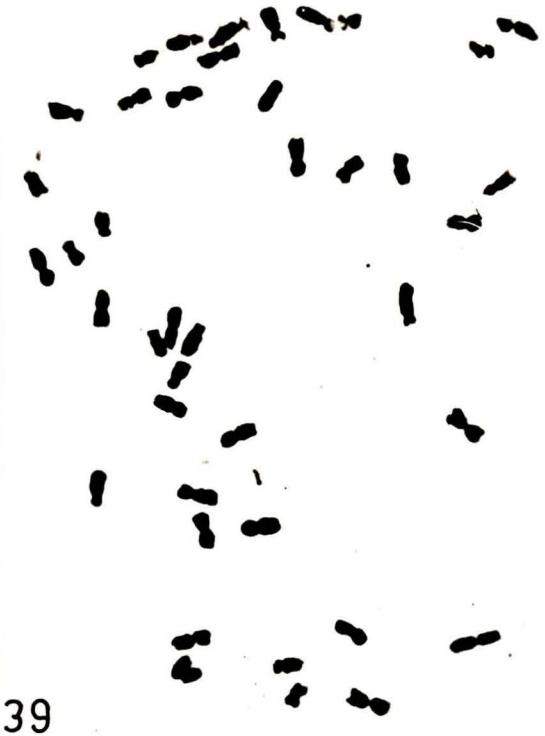

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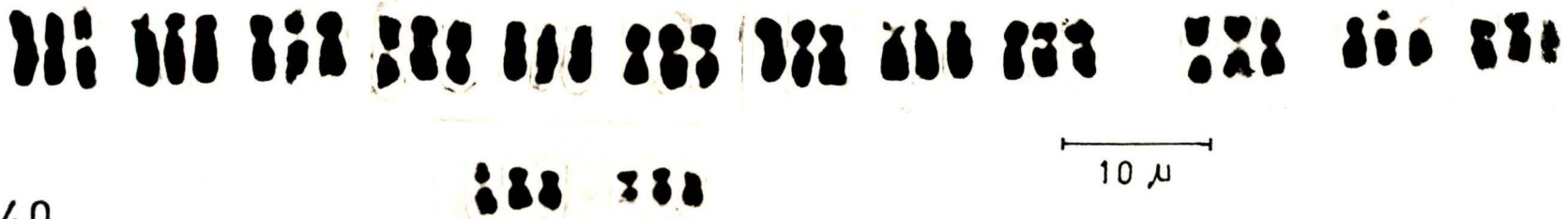


40

10 μ

Colocasia esculenta L. Schott.

It is a herb, cultivated mainly for its starchy corms both in hills and plains. Leaves are peltate. Absence of heart-shaped leaf lamina. Colocasia strains are categorised on the basis of size and shape of tubers and level of ploidy. Detailed morphological observations on all the strains are summarised in Tables 10 and 11. The stomata of both diploids and triploids are represented in Figs. 25 & 26. The average yield/plant is higher in triploids than that in the diploids (Figs. 27 & 28). The diploids are morphologically inferior to triploids and all the strains are diverged from each other morphologically.

The root tip cells of the strains 12, 13, 14 and 15 had $2n = 28$ (Figs. 75, 79, 83 & 86) and all the remaining strains showed $2n = 42$ (Figs. 31, 35, 39, 43, 47, 51, 55, 59, 63, 67 & 71) chromosomes. These counts agree with the earlier reports of Maeda (1932), Sharma and Das (1954), Mookerjea (1955), Sharma and Sarcar (1963), Yen and Wheeler (1968), Jos and Magoon (1970), Plucknett et al. (1970), Marchant (1971), Magoon et al. (1971), Kawhara (1978), Ramachandran (1978), Subramanian (1979). The average length of the chromosomes varied in all strains (Table 27). Secondary constriction is absent in the well contracted metaphase.

Therefore, it is not considered as a consistent feature in the karyotypes of Taro. Sharma and Das (1954), Mookherjea (1955) observed secondary constrictions and satellites in the allied species, Colocasia antiquorum. The total protein, carbohydrate and number of protein bands of all the strains are summarised in Table 28. The electrophoretic banding pattern for proteins are represented in the Zymograms (Fig. 88). The maximum number of protein bands was 12 in Strain 1 (triploid), whereas the minimum of 7 was discovered in Strain 15 (diploid & wild). The Rf values of the characteristic bands of the diploid strains ranged from 0.32 to 0.38 but in the triploids the range was 0.65 to 0.70. Histograms were made to compare total protein and carbohydrate of all the strains (Figs. 89 & 90). The characteristic features of each strain are described as follows :

Strain 1 ($2n = 3x = 42$)

Tubers are small, cylindrical, broad at the base. Absence of ring like structures on the tubers (Fig.29). Petioles and veins are pale green in colour. Yellowish mark present on the leaves (Fig. 30). Stolon is absent.

The chromosome length ranges from 1.80 to 3.63 μ. The total chromatin length is 117.00 μ. The detailed measurements of the somatic chromosomes are summarised in Table 12.

The chromosomes have been arranged in a set of three and are represented in the idiogram (Fig. 32). Thirteen sets are median and the remaining one set is sub-median with respect to the position of the primary constriction.

It has a total protein content value of 11.0 mg/g dry wt. and the value of carbohydrate content is 17.76 mg/g dry wt.

Strain 2 ($2n = 3x = 42$)

Tubers are slightly bigger than that of the Strain 1, not cylindrical, broad at the base. Secondary corms are produced at the base. Rings are very conspicuous at the base (Fig. 33). Petioles and veins are pale yellow in colour. Stolons are absent. Yellowish mark is present on the leaves (Fig. 34).

The chromosome length varies from 2.29 to 4.11 μ. The total chromatin length is 133.60 μ. The detailed measurements of the somatic chromosomes are summarised in Table 13 and the chromosomes have been represented in the idiogram (Fig. 36). Nine sets are median, four sets are sub-median and the remaining one sets are sub-terminal with respect to the position of the primary constriction.

The protein and carbohydrate values are 10.2 and 21.36 mg/g dry wt. respectively.

Strain 3 ($2n = 3x = 42$)

Tubers are small, globose in shape. Rings are prominent at the apical part of the tubers. Secondary corms are produced at the base (Fig. 37). Petioles are long, purplish at the base. Yellow mark is present on the leaves. Stolons are absent (Fig. 38).

The size of the chromosomes varies from 2.05 to 4.17 μ. The total chromatin length is 131.70 μ. The measurements of the somatic chromosomes are summarised in the Table 14 and the chromosomes have been represented in the idiogram (Fig. 40). Nine sets are median, three sub-median and the remaining two are sub-terminal with respect to the position of the centromere.

The protein content is 8.6 mg/g dry wt., whereas the carbohydrate value is 17.52 mg/g dry wt.

Strain 4 ($2n = 3x = 42$)

Tubers are round, rings are prominent at the apex where sprouting takes place. Scales are present on the newly produced secondary corms (Fig. 41). Veins and petioles

are pale-gren in colour. Yellowish mark is present on the leaves. Stolons are absent (Fig.42)

The size of the chromosome varies from 1.70 to 3.70 μ . The total chromatin length is 115.65 μ. The measurements of the somatic chromosomes are given in the Table 15 and idiogram is presented in Fig.44. Nine sets are median and remaining five sets are sub-median with respect to the position of the centromere. The protein value is 8.4 and carbohydrate is 14.44 mg/g wt. respectively.

Strain 5 ($2n = 3x = 42$)

Tubers are oval in shape. Rings are prominent at the base. Secondary corms are produced towards the base (Fig.45.) Petioles are long, purplish at the base. Yellow mark is present on the leaves. Stolons are absent (Fig.46).

The chromosome length ranges from 1.94 to 3.75 μ . The total chromatin length is 122.46 μ . The detailed karyotype analysis is given in the Table 16 and the chromosome pairs have been represented in the idiogram (Fig. 48). The number of median chromosomes are ten, three are submedian and remaining one set is subterminal with respect to the position of the

centromere. The protein and carbohydrate contents are 10.4 and 19.22 mg/g dry wt. respectively.

Strain 6 ($2n = 3x = 42$)

Tubers are round, rings are prominent at the apex. Secondary corms are produced at the base (Fig. 49). Petioles and veins are pale-green in colour and yellow mark is present on the leaves. Stolons are absent (Fig. 50).

The chromosome length ranges from 1.99 to 3.87 μ and the total chromatin length is 125.67 μ. The measurements of the chromosomes are summarised in the Table 17 and the idiogram is presented in the Fig. 52. Eight sets are median and the remaining six sets are sub-median with respect to the position of the centromere. The carbohydrate and protein content is 22.08 and 8.0 mg/g dry wt. respectively.

Strain 7 ($2n = 3x = 42$)

Tubers are big with tapering ends. Apical part is broad whereas the base is narrow. Rings are present on the tubers except in the base. Coloured pigments are present on the tubers. Secondary corms are produced at the base (Fig. 53). Petioles and veins are purplish. Leaves are

dark coloured. Yellowish mark is absent on the leaves (Fig. 54). Stolons are absent.

The size of the chromosome ranges from 2.05 to 4.40 μ. The total chromatin length is 137.43 μ. The detailed analysis of the chromosomes are summarised in Table 18 and the chromosomes have been represented in the idiogram (Fig. 56). Protein content and carbohydrate content is 6.2 and 36.0 mg/g dry wt. respectively.

Eleven sets are median and the remaining three sets are sub-median with respect to the position of the centromere.

Strain 8 ($2n = 3x = 42$)

Tubers are bigger in size with tapering ends, elongated and cylindrical but broad at the base. Rings are prominent at the apex. Secondary corms are produced at the base (Fig. 57). Long petioles and veins are pale-green in colour. Yellowish mark is prominent on the leaves. Stolons are absent (Fig. 58).

The size of the chromosome varies from 1.76 to 3.69 μ. The total chromatin length is 113.46 μ. The measurements of the chromosomes are summarised in Table 19 and the idiogram is presented in the Fig. 60. Ten sets of

chromosomes are median and the remaining four are sub-median with respect to the position of primary constriction. The protein and carbohydrate content is 11.4 and 26.4 mg/g dry wt. respectively.

Strain 9 ($2n = 3x = 42$)

Tubers are very big compared to all other strains studied. They are in aggregate form. Rings are prominent. Coloured pigments are absent (Fig. 61). Petioles and veins are pale-green in colour. Yellowish mark is present on the leaves (Fig. 62). Stolons are absent.

The shortest chromosome has the length of 1.76 μ, whereas the longest one has 3.06 μ. The total chromatin length is 98.70 μ. The detailed karyotype analysis is given in the Table 20 and the chromosomes are represented in the idiogram (Fig. 64). Twelve sets of chromosomes are median and the remaining two sets are sub-median with respect to the position of primary constriction. The protein and carbohydrate content is 6.2 and 14.4 mg/g dry wt. respectively.

Figs 41–44 Strain 4 of Taro

41 Tubers of the strain 4 of Taro

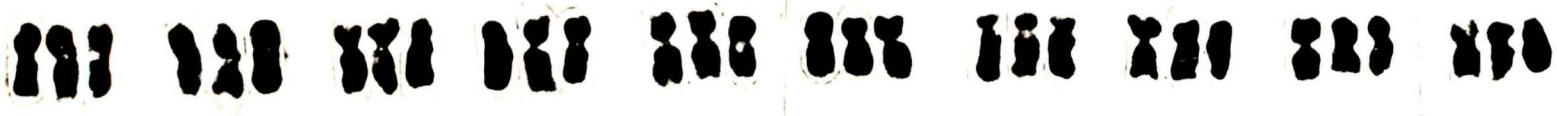
42 Morphology of the plants of strain 4

43 Somatic chromosomes (2n = 42) of the strain 4 (X 2184)

44 Karyotype of the strain 4 of Taro.

41

43



44

10 μ

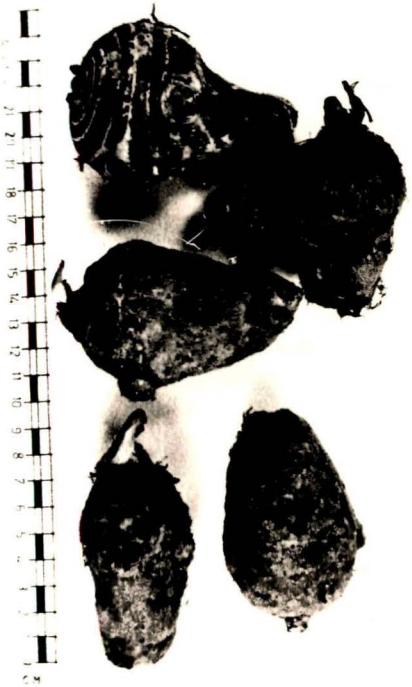
Figs.45–48 Strain 5 of Taro

45– Tubers of the strain 5 of Taro

46– Morphology of the plants of strain 5

47– Somatic chromosomes (2n = 42) of strain 5 (X 2184)

48 – Karyotype of the strain 5 of Taro



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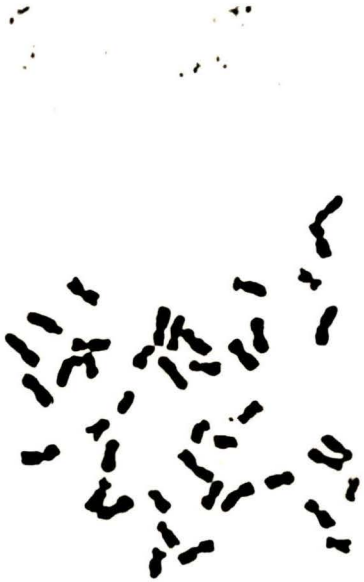


47

48

10 μ

Figs 49-52 Strain 6 of Taro

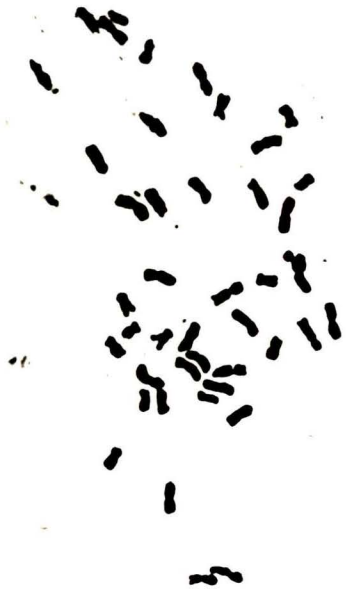
49 Tubers of the strain 6 of Taro

50 Morphology of the plants of strain 6 of Taro

51 Somatic chromosomes (2n = 42) of the strain 6 (X 2184)

52 Karyotype of the strain 6 of Taro

49



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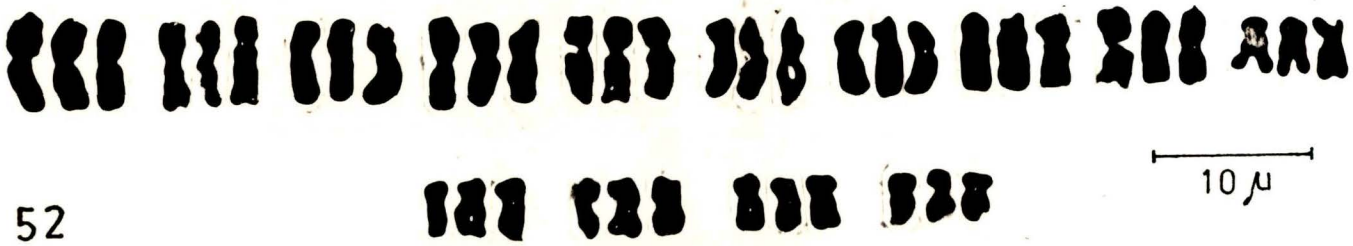


52

10 μ

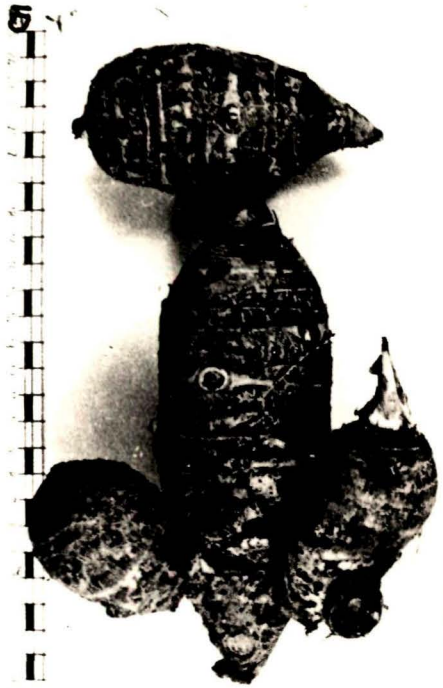
Figs 53- 56 Strain 7 of Taro

53 Tubers of the strain 7 of Taro

54 Morphology of the plants of strain 7

55 Somatic chromosomes (2n= 42) of the strain 7 (X 2184)

56 Karyotype of the strain 7



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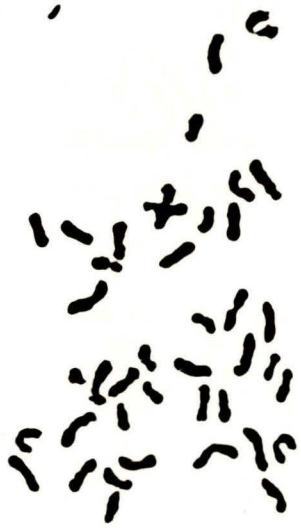

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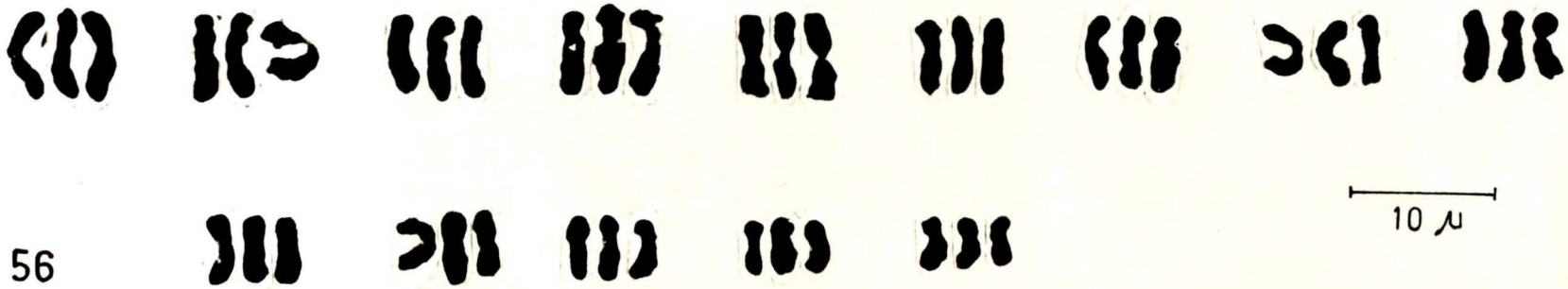


56

10 μ

Table 10 : Morphological measurements on different strains of Taro - *Colocasia esculenta*.

Strain	Ploidy	Mean length of petioles ± S.D.	Mean number of leaves ± S.D.	Leaf size (cm^2) ± S.D.	Range of stomata	Mean number of stomata ± S.D.	Stomatal index
1	3x	72.6 ± 11.21	3.8 ± 0.45	1252.2 ± 383.66	4-8	5.73 ± 1.22	6.45
2	3x	50.5 ± 5.58	3.6 ± 0.55	1227.5 ± 312.47	4-9	6.60 ± 1.57	3.91
3	3x	106.6 ± 14.77	4.4 ± 0.55	2380.1 ± 335.73	5-10	7.60 ± 1.57	5.96
4	3x	113.0 ± 17.16	4.2 ± 0.45	2412.8 ± 220.21	5-8	5.60 ± 1.07	5.76
5	3x	109.7 ± 20.41	4.6 ± 0.89	2860.8 ± 673.08	4-11	8.53 ± 1.88	6.93
6	3x	131.9 ± 7.10	6.8 ± 1.30	1394.8 ± 283.99	6-10	7.40 ± 1.41	8.61
7	3x	40.5 ± 2.82	3.4 ± 0.55	281.7 ± 36.71	3-7	5.40 ± 1.25	4.39
8	3x	124.1 ± 9.80	7.2 ± 0.84	1484.1 ± 235.84	6-12	8.73 ± 2.47	5.29
9	3x	130.5 ± 9.68	6.0 ± 1.22	1443.4 ± 289.06	5-8	6.33 ± 1.11	6.05
10	3x	156.8 ± 15.55	5.6 ± 0.54	3083.5 ± 501.70	8-12	10.7 ± 1.33	7.27
11	3x	62.3 ± 6.46	3.4 ± 1.14	1063.2 ± 164.08	6-12	8.93 ± 1.71	7.41
12	2x	149.8 ± 12.96	5.4 ± 0.55	1983.5 ± 516.11	22-28	22.66 ± 3.01	8.73
13	2x	44.8 ± 9.27	4.25 ± 0.95	546.5 ± 150.23	12-17	14.2 ± 1.54	9.87
14	2x	21.3 ± 3.72	3.2 ± 0.44	214.0 ± 50.23	11-24	17.33 ± 3.46	9.27
15	2x	20.4 ± 0.71	3.75 ± 0.50	111.7 ± 24.14	11-17	13.90 ± 2.13	8.27

Table 11 : Moisture content and yield of different strains of Taro.

Strain	Ploidy	Moisture content (%)	Yield/plant (gms)
1	3x	51.5	683.33
2	3x	48.0	1130.3
3	3x	41.5	1375.0
4	3x	35.0	1382.5
5	3x	43.7	1870.0
6	3x	37.0	895.0
7	3x	41.0	1165.0
8	3x	34.0	685.0
9	3x	61.4	1710.0
10	3x	39.0	920.0
11	3x	42.0	543.83
12	2x	41.0	1090.0
13	2x	24.0	92.0
14	2x	26.0	440.0
15	2x	20.0	-

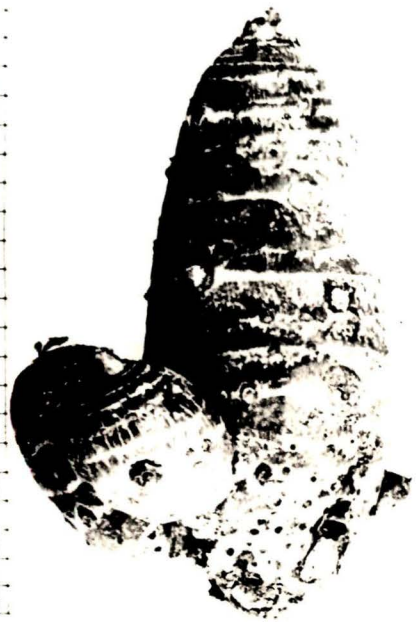
Figs 57-60 Strain 8 of Taro

57 Tubers of the strain 8 of Taro

58 Morphology of the plants of strain 8

59 Somatic chromosomes (2n = 42) of the strain 8 (X 2184)

60 Karyotype of the strain 8 of Taro



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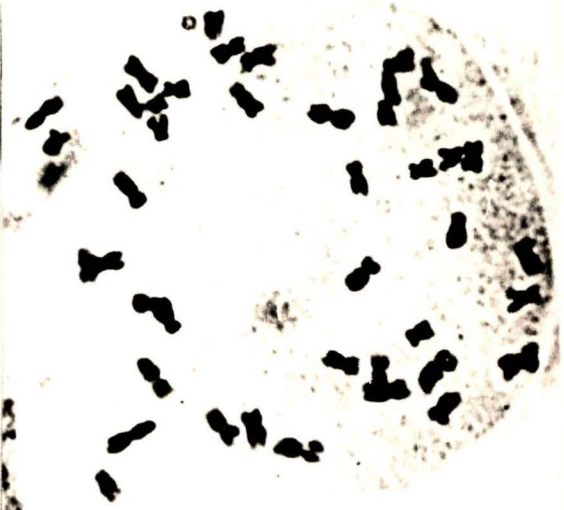

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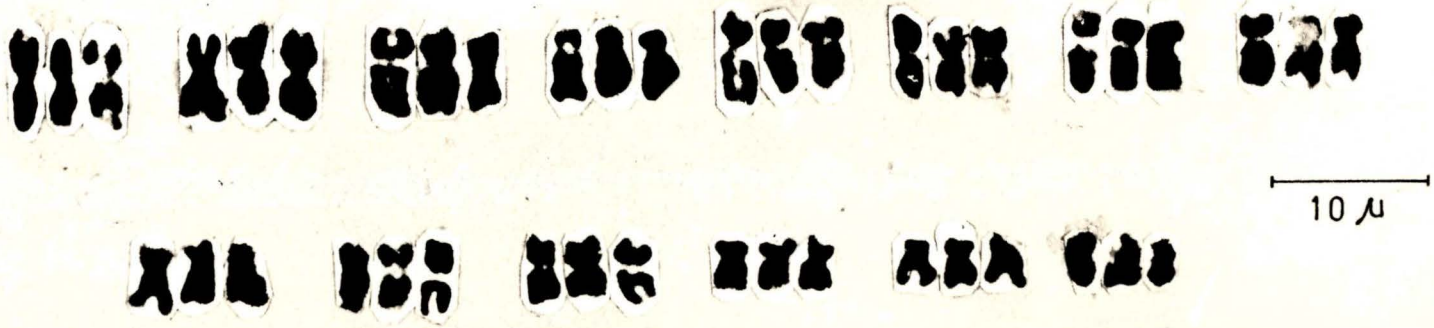


10 μ

60

Figs 61-64 Strain 9 of Taro

61 Tubers of the strain 9 of Taro

62 Morphology of the plants of strain 9

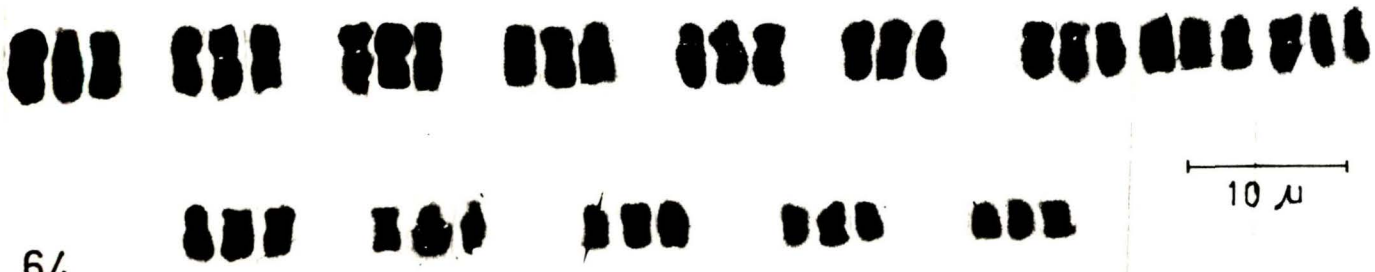
63 Somatic chromosome (2n = 42) of the strain 9 (X 2184)

64 Karyotype of the strain 9

61

62

63



64

10 μ

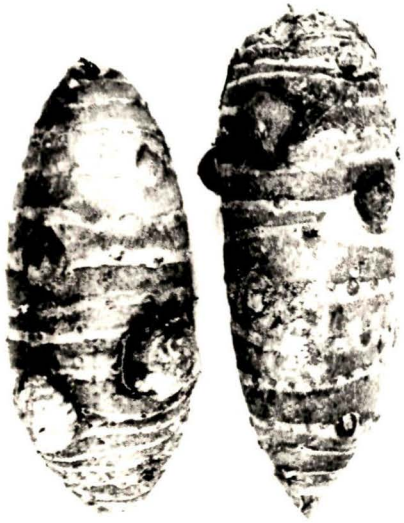
Figs 65-68 Strain 10 of Taro

65 Tubers of the strain 10 of Taro

66 Morphology of the plants of Strain 10

67 Somatic chromosomes (2n = 42) of the strain 10 (×2184)

68 Karyotype of the strain 10



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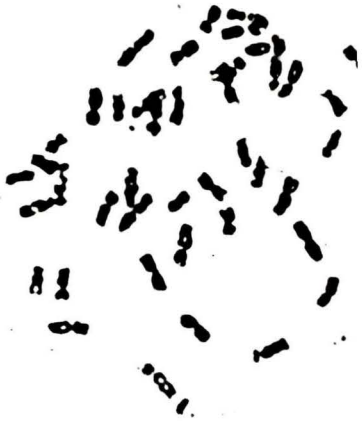

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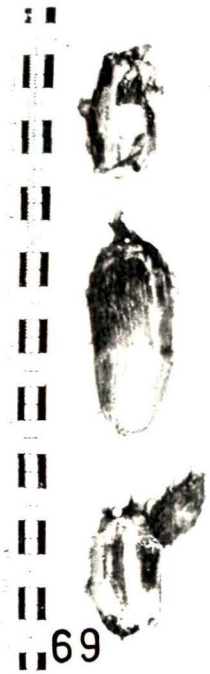
Figs 69-72 Strain 11 of Taro

69 Tubers of the strain 11 of Taro

70 Morphology of the plants of strain 11

71 Somatic chromosomes (2n = 42) of the strain 11(x 2184)

72 Karyotype of the strain 11



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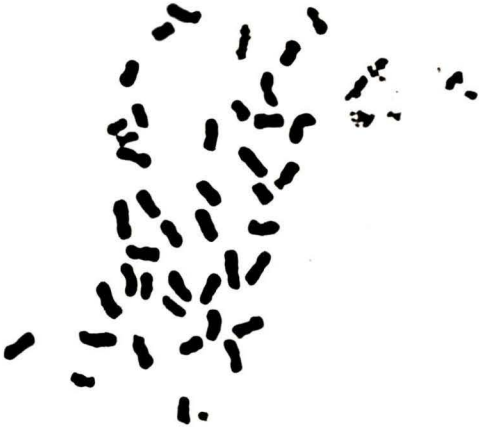


10 μ

72

Strain 10 (2n = 3x = 42)

Tubers are cylindrical, elongated with a tapering end. Scales and rings are present. Secondary corms are produced at the base (Fig. 65); Coloured pigments absent; Long greenish petioles. Yellow mark is absent on the leaves. Stolons are produced at the base (Fig. 66).

The size of the chromosomes vary from 1.82 to 3.87 μ. The total chromatin length is 119.5 μ. The chromosome pairs have been represented in the idiogram (Fig. 68). The measurements of the chromosomes are summarised in the Table 21. Seven sets are median, Six sub-median and the remaining one are sub-terminal with respect to the position of the centromere. The protein and carbohydrate values are 9.0 and 16.8 mg/g dry wt. respectively.

Strain 11 (2n = 3x = 42)

Tubers are small, cylindrical with blunt ends. Rings are absent. Secondary corms are produced at the apex (Fig. 69). Coloured pigments are absent. Petioles and veins are purple in colour. Yellow mark is absent on the leaves. Stolons are absent (Fig. 70).

The size of the chromosomes ranges from 1.94 to 3.87 μ. The total chromatin content is 122.46 μ. The detailed karyotype analysis is given in Table 22 and the chromosomes have been represented in the idiogram (Fig. 72). Twelve sets are median and the remaining two are sub-median. The protein content is 9.8 mg/g dry wt. whereas the carbohydrate value is 28.8 mg/g dry wt.

Strain 12 ($2n = 2x = 28$)

Tubers with tapering ends, broad middle portion. Secondary corms are produced mainly in the centre. Rings are very prominent (Fig. 73). Petioles and veins are light purple. Yellowish mark is absent, but purple mark is present on the leaves. Stolons are absent (Fig. 74).

The length of the chromosomes varies from 2.24 to 4.34 μ. The total chromatin length is 98.97 μ. The measurements of the chromosomes are summarised in Table 23, and the idiogram is presented in the Fig. 76. Ten pairs are median and the remaining four are sub-median with respect to the position of the primary constriction. The protein content is 4.8 mg/g dry wt. whereas the carbohydrate value is 22.0 mg/g dry wt.

Strain 13 (2n = 2x = 28)

Tubers are small. Rings and secondary corms are absent (Fig. 77) Purplish mark is present on the leaves. Coloured pigments and stolons are absent (Fig. 78).

The length of the chromosomes varies from 1.93 to 3.98 μ. The total chromatin length is 86.40 μ. The chromosome pairs have been represented in the idiogram (Fig. 80). The measurements of the chromosomes are recorded in Table 24. Ten pairs are median and the remaining four pairs are sub-median with respect to the position of the centromere. The protein and carbohydrate values are 8.6 and 21.12 mg/g dry wt. respectively.

Strain 14 (2n = 2x = 28)

Tubers are small, elongated with blunt apex and narrow base. Rings are absent. Small secondary corms are produced on the tubers (Fig. 81). Coloured pigments are absent. Petioles and veins are pale-green in colour. Characteristic marks absent on the leaves. Stolons are absent (Fig. 82).

The chromosome length ranges from 2.24 to 3.88 μ. The total chromatin length is 84.40 μ. The chromosome pairs are represented in the idiogram (Fig. 84). The details

of karyotype analysis is given in the Table 25. The number of median chromosomes are 12 and the remaining two are sub-median with respect to the position of the centromere. The protein and carbohydrate values are 4.2 and 17.76 mg/g dry wt. respectively.

Strain 15 ($2n = 2x = 28$)

It is growing as wild in the forests of Meghalaya. Characteristic tubers are absent whereas the root system is well developed. Coloured pigments are absent. Petioles and veins are light green. Leaves are small with an yellowish mid-rib. Absence of yellowish mark on the leaves. Stolons are present (Fig. 85).

The chromosome size ranges from 2.05 to 3.98 μ. The total chromatin length is 86.23 μ. The measurements of the somatic chromosomes are summarised in Table 26 and the chromosome pairs have been represented in the idiogram (Fig. 87). Nine pairs are median and the remaining five pairs are sub-median with respect to the position of the primary constriction.

It has the lowest protein and carbohydrate (4.2 and 12.6 mg/g dry wt. respectively) values among all the strains studied.

Table 12 : Chromosomes of Strain 1 of Taro.

(2n = 3x = 42)

Chromosome pairs	Chromosome type	Position of constriction Prim.	Second.	Arm ratio	Length of component arms in μ		Total length in μ
1	C	m		1.1	1.76	1.87	3.63
2	C	m		1.34	1.52	2.05	3.57
3	C	M		1.0	1.68	1.68	3.36
4	C	m		1.55	1.26	1.96	3.22
5	C	m		1.26	1.38	1.74	3.12
6	C	m		1.6	1.12	1.80	2.92
7	D	m		1.04	1.41	1.48	2.89
8	D	M		1.0	1.41	1.41	2.82
9	D	m		1.27	1.18	1.50	2.68
10	D	Sm		2.2	0.78	1.74	2.52
11	D	m		1.3	1.06	1.38	2.44
12	D	m		1.16	0.98	1.12	2.10
13	D	m		1.51	0.78	1.18	1.96
14	D	m		1.4	0.58	1.22	1.80

T. F. % - 45.33

Total chromatin length - 117.04 μ

Karyotype formula - 1(C M) + 5(C m) + 1(D M) + 6(D m) + 1(D Sm).

Table 13 : Chromosomes of Strain 2 of Taro.

(2n = 3x = 42)

Chromosome pairs	Chromosome type	Position of constrictions Prim.	Position of constrictions Second.	Arm ratio	Length of the component arms in μ		Total length in μ
1	C	m		1.20	1.76	2.35	4.11
2	C	M		1.0	1.98	1.98	3.96
3	C	m		1.2	1.76	2.06	3.82
4	C	St		3.0	0.92	2.76	3.68
5	C	m		1.49	1.41	2.11	3.52
6	C	Sm		2.24	1.06	2.38	3.44
7	C	m		1.25	1.41	1.76	3.17
8	C	Sm		1.83	1.06	1.94	3.00
9	D	Sm		2.28	0.70	2.28	2.98
10	D	m		1.25	1.23	1.58	2.81
11	D	m		1.19	1.23	1.41	2.64
12	D	m		1.33	1.06	1.58	2.64
13	D	Sm		2.02	0.88	1.58	2.46
14	D	m		1.6	0.88	1.41	2.29

T. F. % - 39.28

Total chromatin length - 133.64 μ

Karyotype formula - 1(C M) + 4(C m) + 2(C Sm) + 1(C St) + 4(D m) + 2(D Sm).

Table 14 : Chromosomes of Strain 3 of Taro.

(2n = 3x = 42)

Chromosome sets	Chromosome type	Position of constrictions Prim. | Second.	Arm ratio	Length of the component arms in μ		Total length in μ
1	C	m	1.36	1.76	2.41	4.17
2	C	m	1.31	1.76	2.22	3.98
3	C	St	3.75	0.94	2.82	3.76
4	C	m	1.16	1.68	1.96	3.64
5	C	M	1.0	1.76	1.76	3.52
6	C	Sm	1.93	1.16	2.24	3.40
7	D	m	1.12	1.56	1.76	3.32
8	D	St	3.01	0.76	2.29	3.05
9	D	m	1.20	1.32	1.58	2.90
10	D	Sm	1.87	0.94	1.76	2.70
11	D	m	1.49	1.06	1.58	2.64
12	D	m	1.40	1.06	1.42	2.48
13	D	Sm	1.63	0.87	1.42	2.29
14	D	m	1.07	0.99	1.06	2.05

T. F. % - 40.00

Total chromatin length - 131.70 μ

Karyotype formula - 1(C M) + 3(C m) + 1(C Sm) + 1(C St) + 5(D m) + 2(D Sm) + 1(D St).

Table 15 : Chromosomes of Strain 4 of Taro.

(2n = 3x = 42)

Chromosome sets	Chromosome type	Position of constrictions Prim. / Second.	Arm ratio	Length of the component arms in μ		Total length in μ
1	C	m	1.34	1.58	2.12	3.70
2	C	m	1.15	1.68	1.94	3.62
3	C	Sm	1.76	1.28	2.26	3.54
4	C	m	1.38	1.41	1.94	3.35
5	D	m	1.24	1.41	1.76	3.17
6	D	m	1.43	1.23	1.76	2.99
7	D	Sm	2.75	0.78	2.11	2.89
8	D	m	1.39	1.16	1.62	2.78
9	D	Sm	2.0	0.88	1.76	2.64
10	D	Sm	2.68	0.88	1.48	2.36
11	D	m	1.3	0.94	1.23	2.17
12	D	m	1.29	0.82	1.06	1.88
13	D	Sm	2.33	0.53	1.23	1.76
14	D	m	1.17	0.78	0.92	1.70

T. F. % - 41.50

Total chromatin length - 115.65 μ

Karyotype formula - 1(C Sm) + 3(C m) + 6(D m) + 4(D Sm).

Table 16 : Chromosomes of Strain 5 of Taro.

(2n = 3x = 42)

Chromosome sets	Chromosome type	Position of constrictions Prim. | Second.	Arm ratio	Length of the component arms in μ		Total length in μ
1	C	m	1.28	1.64	2.11	3.75
2	C	m	1.37	1.54	2.11	3.65
3	C	m	1.6	1.32	2.26	3.58
4	C	m	1.49	1.41	2.11	3.52
5	C	m	1.59	1.32	2.11	3.43
6	C	Sm	2.28	0.99	2.26	3.25
7	C	m	1.2	1.41	1.72	3.13
8	C	m	1.6	1.06	1.66	2.72
9	D	m	1.12	1.23	1.41	2.64
10	D	Sm	2.26	0.76	1.72	2.48
11	D	m	1.6	0.88	1.48	2.36
12	D	Sm	2.66	0.60	1.64	2.24
13	D	m	1.20	0.96	1.16	2.12
14	D	St	3.0	0.48	1.46	1.94

T. F. % - 41.01

Total chromatin length - 122.46 μ

Karyotype formula - 7(C m) + 1(C Sm) + 3(D m) + 2(D Sm) + 1(D St).

Figs 73-76 Strain 12 of Taro

73 Tubers of the strain 12 of Taro

74 Morphology of the plants of strain 12

75 Somatic chromosomes (2n = 28) of the strain (X 2184)

76 Karyotype of the strain 12

73

74

75

76

10 μ

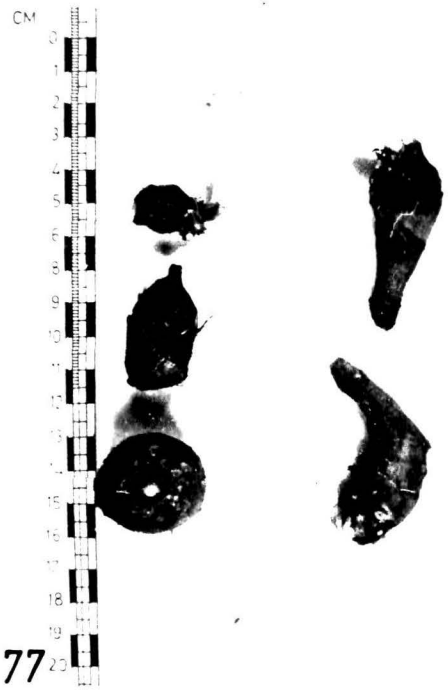
Figs 77 - 80 Strain 13 of Taro

77 Tubers of the strain 13 of Taro

78 Morphology of the plants of strain 13

79 Somatic chromosome (2n = 28) of the strain 13 (X 2184)

80 Karyotype of the strain 13



77

78

79

80

10 μ

Table 17 : Chromosomes of Strain 6 of Taro.

(2n = 3x = 42)

Chromosome sets	Chromosome type	Position of constrictions Prim.	Second.	Arm ratio	Length of the component arms in μ		Total length in μ
1	C	m		1.4	1.58	2.29	3.87
2	C	M		1.0	1.88	1.88	3.76
3	C	Sm		1.76	1.26	2.42	3.68
4	C	m		1.37	1.48	2.04	3.52
5	C	m		1.32	1.54	1.86	3.40
6	C	Sm		2.75	0.88	2.42	3.30
7	D	Sm		2.53	0.88	2.23	3.11
8	D	m		1.12	1.40	1.58	2.98
9	D	m		1.6	1.06	1.72	2.78
10	D	m		1.14	1.23	1.41	2.64
11	D	Sm		1.8	0.88	1.58	2.46
12	D	Sm		2.2	0.71	1.58	2.29
13	D	m		1.4	0.88	1.23	2.11
14	D	Sm		1.75	0.71	1.28	1.99

T. F. % - 41.67

Total chromatin length - 125.67 μ

Karyotype formula - 1(C M) + 3(C m) + 2(C Sm) + 4(D m) + 4(D Sm).

Table 18 : Chromosomes of Strain 7 of Taro.

(2n = 3x = 42)

Chromosome sets	Chromosome type	Position of constrictions Prim.	Second.	Arm ratio	Length of the component arms in μ		Total length in μ
1	C	m		1.08	2.11	2.29	4.40
2	C	m		1.02	1.84	2.29	4.13
3	C	m		1.30	1.76	2.29	4.05
4	C	Sm		2.83	1.06	2.86	3.92
5	C	M		1.0	1.94	1.94	3.88
6	C	m		1.5	1.41	2.11	3.52
7	C	m		1.3	1.52	1.84	3.36
8	C	m		1.24	1.41	1.76	3.17
9	C	Sm		1.67	1.16	1.94	3.10
10	C	m		1.28	1.24	1.58	2.82
11	D	m		1.5	1.24	1.41	2.65
12	D	m		1.3	1.06	1.41	2.47
13	D	m		1.6	0.88	1.41	2.29
14	D	Sm		1.75	0.78	1.27	2.05

T. F. % - 41.19

Total chromatin length - 137.43 μ

Karyotype formula - 1(C M) + 7(C m) + 2(C Sm) + 3(D m) + 1(D Sm).

Table 19 : Chromosomes of Strain 8 of Taro.

(2n = 3x = 42)

Chromosome sets	Chromosome type	Position of constrictions Prim.	Second.	Arm ratio	Length of the component arms in μ		Total length in μ
1	C	m		1.05	1.80	1.89	3.69
2	C	m		1.23	1.56	1.93	3.49
3	C	m		1.3	1.41	1.93	3.34
4	C	m		1.6	1.23	1.98	3.21
5	C	M		1.0	1.58	1.58	3.16
6	C	Sm		2.9	0.76	2.23	2.99
7	D	Sm		2.08	0.93	1.94	2.87
8	D	m		1.28	1.23	1.41	2.64
9	D	Sm		2.0	0.88	1.58	2.46
10	D	M		1.0	1.12	1.12	2.24
11	D	m		1.4	0.88	1.23	2.11
12	D	m		1.4	0.76	1.23	1.99
13	D	Sm		2.0	0.64	1.23	1.87
14	D	M		1.0	0.88	0.88	1.76

T. F. % - 40.75

Total chromatin length - 113.46 μ

Karyotype formula - 1(C M) + 4(C m) + 1(C Sm) + 2(D M) + 3(D m) + 3(D Sm).

Table 20 : Chromosomes of Strain 9 of Taro.

($2n = 3x = 42$)

Chromosome sets	Chromosome type	Position of constrictions Prim.	Second.	Arm ratio	Length of the component arms in μ		Total length in μ
1	C	m		1.07	1.48	1.58	3.06
2	C	m		1.40	1.26	1.76	3.02
3	D	m		1.49	1.18	1.76	2.94
4	D	M		1.00	1.36	1.36	2.72
5	D	m		1.15	1.23	1.41	2.64
6	D	Sm		2.24	0.74	1.66	2.40
7	D	m		1.10	1.12	1.23	2.35
8	D	M		1.00	1.12	1.12	2.24
9	D	Sm		1.92	0.74	1.42	2.16
10	D	m		1.40	0.88	1.23	2.11
11	D	m		1.26	0.84	1.06	1.90
12	D	m		1.36	0.78	1.06	1.84
13	D	M		1.00	0.88	0.88	1.76
14	D	m		1.51	0.70	1.06	1.76

T. F. % - 42.21

Total chromatin length - 98.70 μ

Karyotype formula - 2(C m) + 3(D M) + 7(D m) + 2(D Sm).

Table 21 : Chromosomes of Strain 10 of Taro.

(2n = 3x = 42)

Chromosome sets	Chromosome type	Position of constrictions Prim.	Second.	Arms ratio	Length of the component arms in μ		Total length in μ
1	C	m		1.2	1.76	2.11	3.87
2	C	m		1.33	1.52	2.11	3.63
3	C	M		1.0	1.76	1.76	3.52
4	C	St		3.47	0.76	2.64	3.40
5	C	Sm		2.1	1.06	2.23	3.29
6	D	Sm		2.48	0.94	2.23	3.17
7	D	M		1.0	1.52	1.52	3.04
8	D	m		1.14	1.33	1.52	2.85
9	D	Sm		1.83	0.94	1.72	2.66
10	D	Sm		2.88	0.64	1.84	2.48
11	D	Sm		2.00	0.76	1.52	2.22
12	D	m		1.27	0.88	1.12	2.00
13	D	m		1.69	0.70	1.18	1.88
14	D	Sm		1.84	0.64	1.18	1.82

T. F. % - 41.63

Total chromatin length - 119.49 μ

Karyotype formula - 1(C M) + 2(C m) + 1(C St) + 1(C Sm) + 1(D M) + 3(D m) + 5(D Sm).

Table 22 : Chromosomes of Strain 11 of Taro.

(2n = 3x = 42)

Chromosome sets	Chromosome type	Position of constrictions Prim. | Second.	Arm ratio	Length of the component arms in μ		Total length in μ
1	C	m	1.20	1.76	2.11	3.87
2	C	m	1.34	1.58	2.11	3.69
3	C	m	1.02	1.76	1.80	3.56
4	C	m	1.26	1.54	1.94	3.48
5	D	m	1.19	1.48	1.76	3.24
6	D	M	1.00	1.54	1.54	3.08
7	D	Sm	2.40	0.88	2.11	2.99
8	D	m	1.28	1.23	1.58	2.81
9	D	m	1.15	1.24	1.42	2.66
10	D	Sm	2.77	0.70	1.94	2.64
11	D	M	1.00	1.23	1.23	2.46
12	D	m	1.16	1.06	1.23	2.29
13	D	m	1.40	0.88	1.23	2.11
14	D	m	1.20	0.88	1.06	1.94

T. F. % - 40.37

Total chromatin length - 122.46 μ

Karyotype formula - 4(C m) + 2(D M) + 6(D m) + 2(D Sm).

Table 23 : Chromosomes of Strain 12 of Taro.

(2n = 28)

Chromosome pairs	Chromosome type	Position of constrictions Prim. / Second.	Arm ratio	Length of component arms in μ		Total length in μ
1	C	m	1.06	2.11	2.23	4.34
2	C	m	1.4	1.76	2.46	4.22
3	C	Sm	1.96	1.41	2.76	4.17
4	C	m	1.2	1.76	2.35	4.11
5	C	Sm	1.75	1.41	2.56	3.97
6	C	m	1.44	1.58	2.28	3.86
7	C	M	1.0	1.86	1.86	3.72
8	C	Sm	1.71	1.23	2.28	3.51
9	C	m	1.37	1.46	1.94	3.40
10	C	m	1.25	1.58	1.66	3.24
11	D	M	1.0	1.58	1.58	3.16
12	D	m	1.5	1.41	1.54	2.95
13	D	m	1.3	1.09	1.48	2.57
14	D	Sm	2.2	0.70	1.54	2.24

T. F. % - 43.15

Total chromatin length - 98.92 μ

Karyotypic formula - 1(C M) + 6(C m) + 3(C Sm) + 1(D M) + 2(D m) + 1(D Sm).

Figs 81 - 84 Strain 14 of Taro

81 Tubers of the strain 14 of Taro

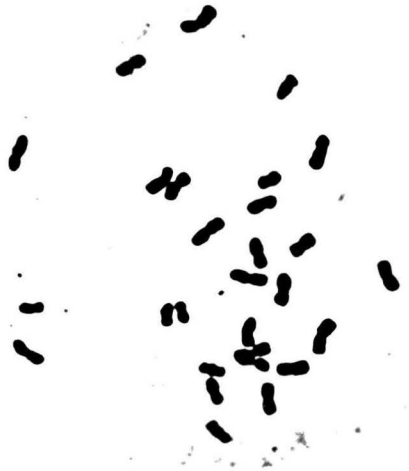
82 Morphology of the plants of strain 14

83 Somatic chromosomes (2n = 28) of the strain 14 (× 2184)

84 Karyotype of the strain 14

81

82



83

84

10 μ

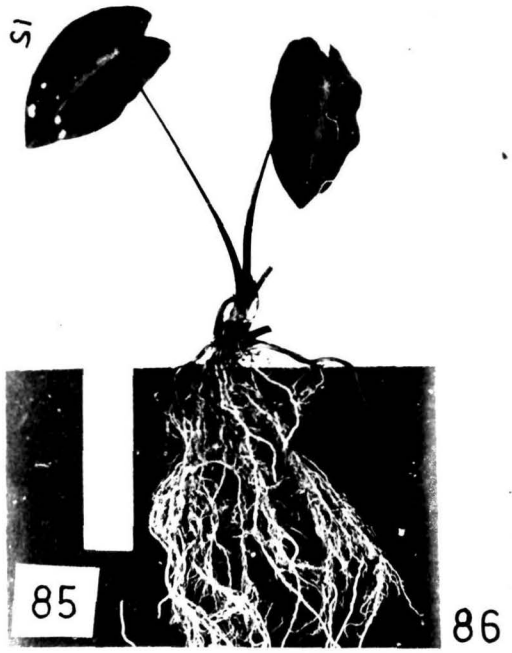
Figs 85 - 87 Strain 15 of Taro

85 Morphology of the strain 15 of taro

86 Somatic chromosome (2n = 28) of the strain 15 (× 2184)

87 Karyotype of the strain 15

STRAIN 15



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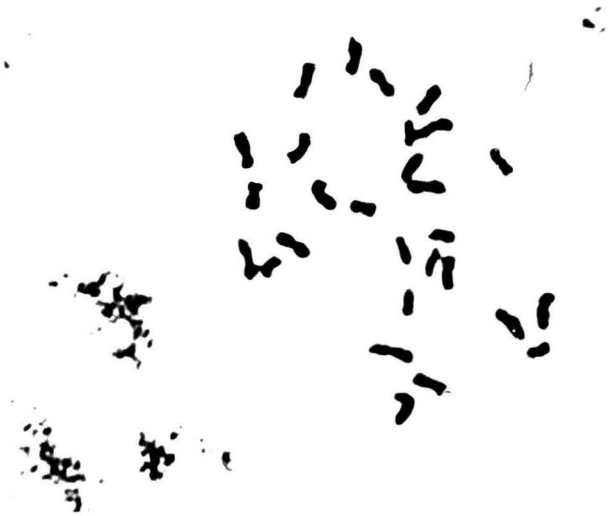


87

10 μ

Table 24 : Chromosomes of Strain 13 of Taro.

(2n = 28)

Chromosome pairs	Chromosome type	Position of constrictions Prim. | Second.	Arm ratio	Length of the component arms in μ		Total length in μ
1	C	m	1.3	1.76	2.22	3.98
2	C	m	1.2	1.76	2.12	3.88
3	C	m	1.5	1.48	2.28	3.76
4	C	Sm	2.0	1.23	2.46	3.69
5	C	Sm	1.85	1.23	2.29	3.52
6	C	M	1.0	1.73	1.73	3.46
7	D	m	1.51	1.23	1.86	3.09
8	D	m	1.43	1.23	1.76	2.99
9	D	m	1.6	1.05	1.76	2.81
10	D	Sm	2.75	0.76	1.94	2.70
11	D	m	1.14	1.23	1.41	2.64
12	D	Sm	1.8	0.88	1.58	2.46
13	D	m	1.6	0.88	1.41	2.29
14	D	m	1.2	0.88	1.05	1.93

T. F. % - 41.98

Total chromatin length - 86.40 μ

Karyotype formula - 1(C M) + 3(C m) + 2(C Sm) + 6(D m) + 2(D Sm).

Table 25 : Chromosomes of Strain 14 of Taro.

(2n = 28)

Chromosome pairs	Chromosome type	Position of constrictions Prim. | Second.	Arm ratio	Length of the component arms in μ		Total length in μ
1	C	m	1.2	1.76	2.12	3.88
2	C	M	1.0	1.86	1.86	3.72
3	C	Sm	2.0	1.23	2.46	3.69
4	C	M	1.0	1.76	1.76	3.52
5	D	m	1.12	1.56	1.76	3.32
6	D	m	1.24	1.41	1.76	3.17
7	D	M	1.0	1.56	1.56	3.12
8	D	m	1.43	1.23	1.76	2.99
9	D	m	1.26	1.23	1.56	2.79
10	D	m	1.5	1.06	1.58	2.64
11	D	m	1.3	1.06	1.41	2.47
12	D	M	1.0	1.18	1.18	2.36
13	D	m	1.16	1.06	1.23	2.29
14	D	Sm	2.2	0.66	1.58	2.24

T. F. % - 43.07

Total chromatin length - 84.40 μ

Karyotype formula - 2(C M) + 1(C m) + 1(C Sm) + 2(D M) + 7(D m) + 1(D Sm).

Table 26 : Chromosomes of Strain 15 of Taro.

(2n = 28)

Chromosome pairs	Chromosome type	Position of constrictions Prim. / Second.	Arm ratio	Length of the component arms in μ		Total length in μ
1	C	m	1.2	1.80	2.18	3.98
2	C	m	1.33	1.58	2.12	3.70
3	C	Sm	2.0	1.23	2.46	3.69
4	C	M	1.0	1.76	1.76	3.52
5	C	m	1.5	1.41	2.11	3.52
6	C	m	1.3	1.41	1.93	3.34
7	C	m	1.4	1.32	1.93	3.25
8	C	Sm	2.0	1.05	2.12	3.17
9	D	m	1.12	1.41	1.58	2.99
10	D	Sm	2.2	0.88	1.93	2.81
11	D	m	1.28	1.23	1.41	2.64
12	D	m	1.5	0.94	1.41	2.35
13	D	Sm	2.0	0.70	1.41	2.11
14	D	Sm	2.3	0.64	1.41	2.05

T. F. % - 38.32

Total chromatin length - 86.24 μ

Karyotype formula - 1(C M) + 5(C m) + 2(C Sm) + 3(D m) + 3(D Sm).

Fig. 88 Electrophoretic banding patterns of the total soluble proteins of different strains of taro.

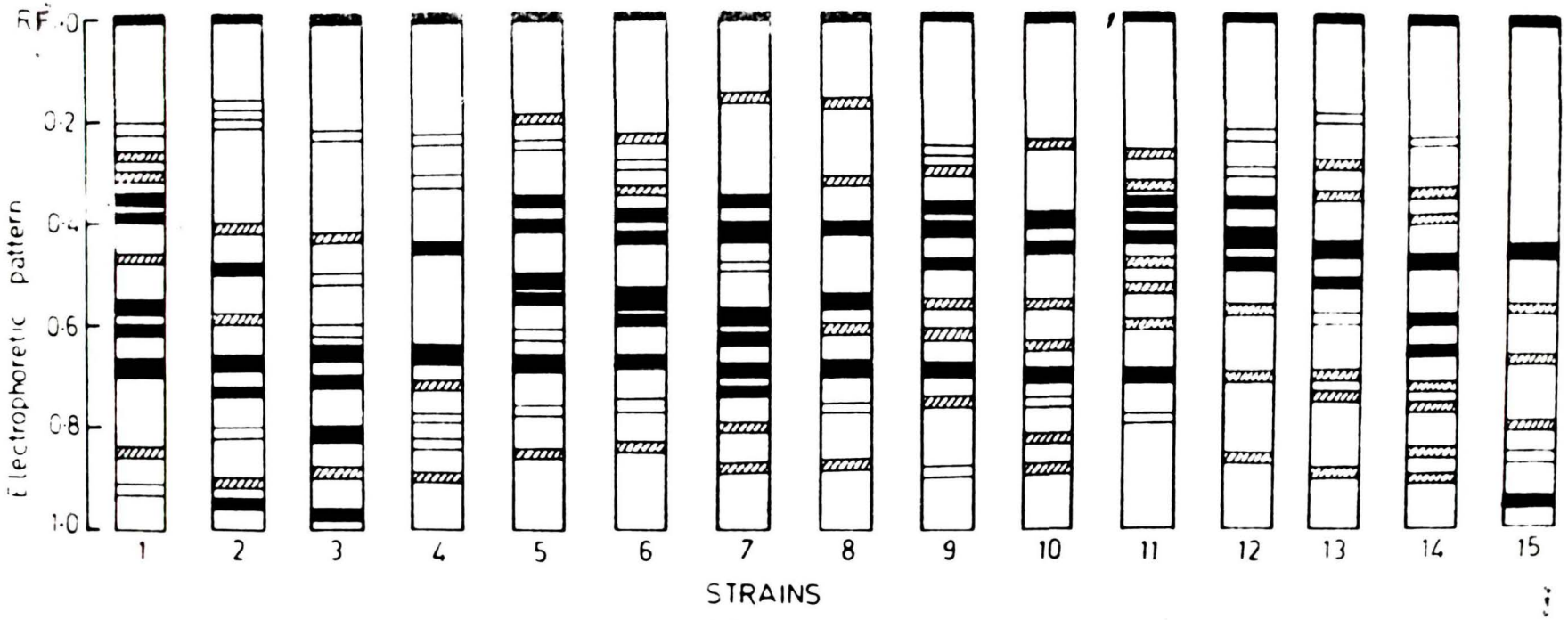

RF
0·0
0·2
0·4
0·6
0·8
1·0
Electrophoretic pattern
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
STRAINS

Fig 88

Figs. 89 Histogram representing the total soluble portion contents of taro.

90 Histogram representing the total carbohydrate contents of taro.

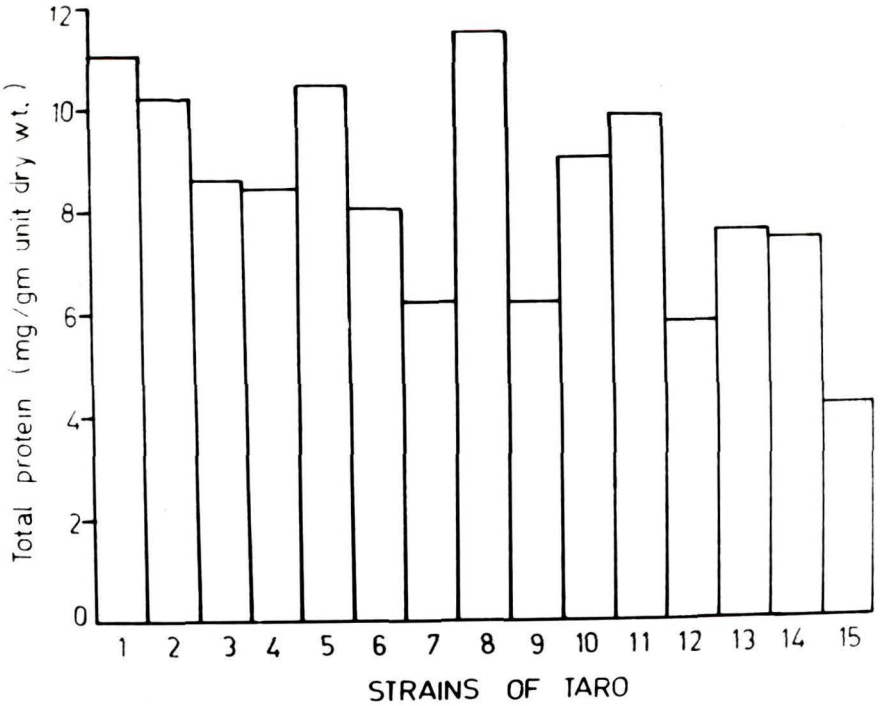

Total protein (mg/gm unit dry wt.)
0
2
4
6
8
10
12
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
STRAINS OF TARO

Fig.89

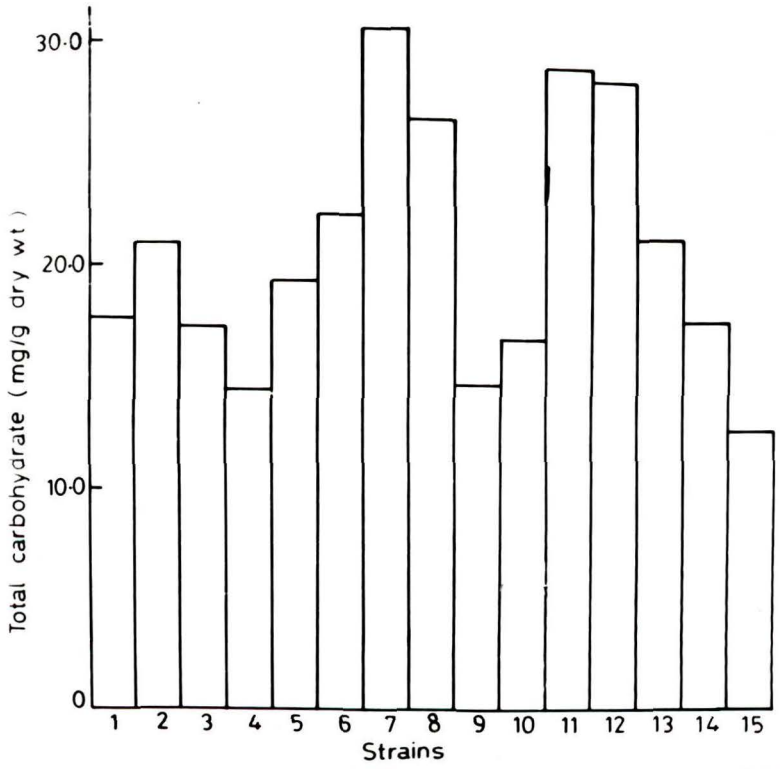

Total carbohydrate (mg/g dry wt)
0
10·0
20·0
30·0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Strains

Fig.90

Table 27 : Somatic chromosomes of different strains of Taro.

Strain	Ploidy	Range of chromosome length in μ	Mean length of chromosome in μ	Ratio of the longest and shortest chromosomes in μ	Total chromatin length in μ	T.F.%
1	3x	1.80 - 3.63	2.71	2.01	117.00	45.33
2	3x	2.29 - 4.11	3.20	1.79	133.60	39.28
3	3x	2.05 - 4.17	3.11	2.03	131.70	40.00
4	3x	1.70 - 3.70	2.70	2.21	115.60	41.50
5	3x	1.94 - 3.75	2.85	1.93	122.46	41.01
6	3x	1.99 - 3.87	2.94	1.94	125.67	41.67
7	3x	2.05 - 4.40	3.23	2.15	137.43	41.19
8	3x	1.76 - 3.69	2.73	2.09	113.46	40.75
9	3x	1.76 - 3.06	2.42	1.73	98.70	42.21
10	3x	1.82 - 3.87	2.84	2.12	119.50	41.63
11	3x	1.94 - 3.87	2.90	1.99	122.46	40.37
12	2x	2.24 - 4.34	3.29	1.85	98.92	43.15
13	2x	1.93 - 3.98	3.00	1.67	86.40	41.98
14	2x	2.24 - 3.88	3.06	1.71	84.40	43.07
15	2x	2.05 - 3.98	3.02	1.94	86.24	38.32

Table 28 : Total carbohydrate, protein content and protein bands of Taro.

Strain	Ploidy	Total protein (mg/g dry wt.)	Total carbohydrate (mg/g dry wt.)	No. of protein bands
1	3x	11.0	17.76	12
2	3x	10.2	21.36	11
3	3x	8.6	17.52	10
4	3x	8.4	14.44	9
5	3x	10.4	19.2	11
6	3x	8.0	22.08	11
7	3x	6.2	36.0	10
8	3x	11.4	26.4	9
9	3x	6.2	14.4	11
10	3x	9.0	16.8	10
11	3x	9.8	28.8	11
12	2x	4.8	28.0	9
13	2x	8.6	21.12	10
14	2x	8.4	17.76	11
15	2x	4.2	12.6	4

Figs. 91-94 *Zea mays* var.yellow Shillong

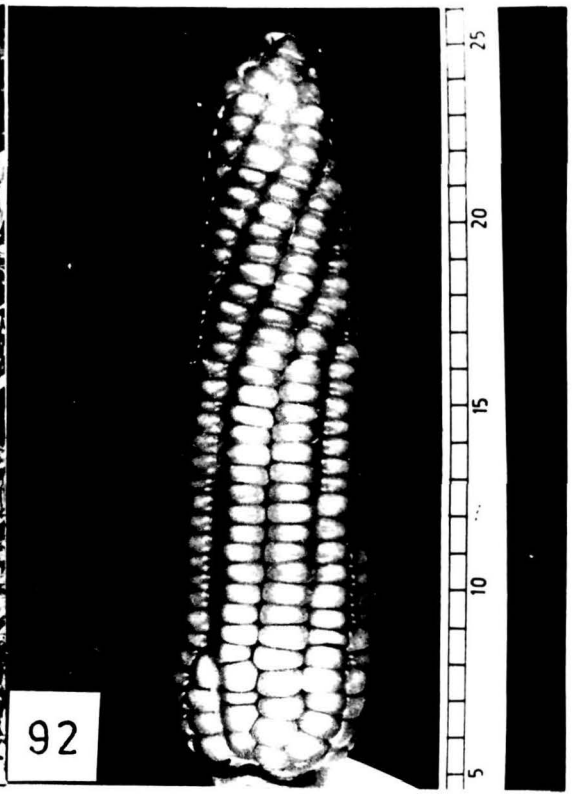
91-*Zea mays* - Habit.

92-Ear of *Zea mays* var. yellow Shillong

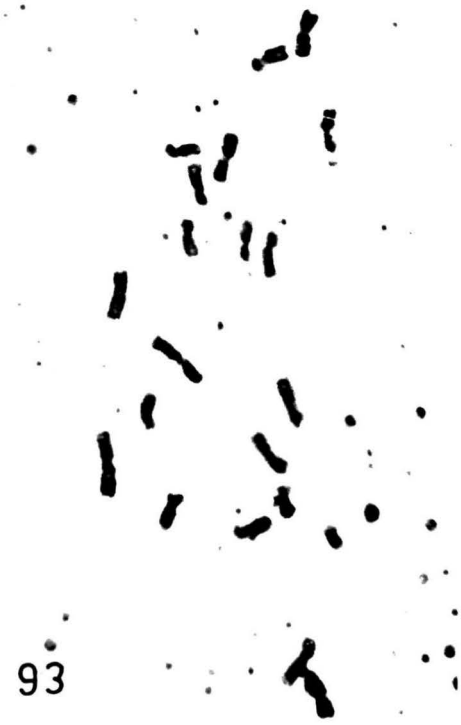
93-Somatic Chromosome (2n = 20) of *Z.mays* var. yellow Shillong(X 2100)

94-Karyotype of *Z.mays* var. yellow, Shillong

91



92



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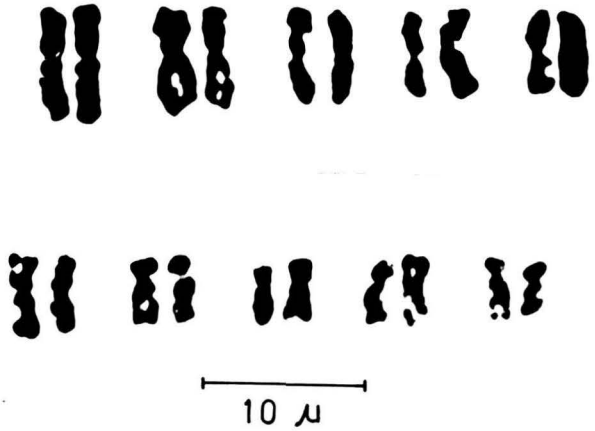

10 μ

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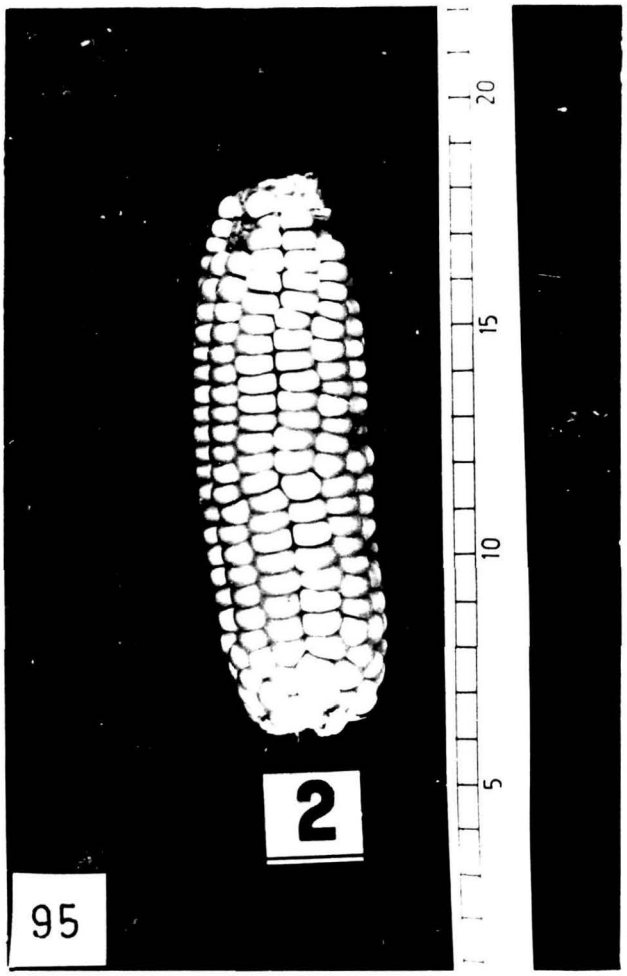
Figs 95-97 Zea mays var. gar[illegible] white

95 Ear of Z. mays var. gero white.

96 Somatic chrom[illegible]mes (2n = 20) of Z. mays var gero white (x 2184)

97 Karyotype of Z. mays var. gero white



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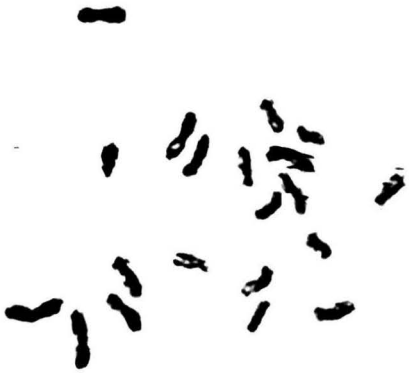

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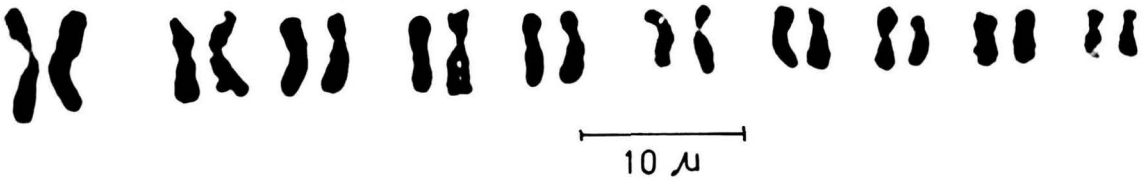

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Zea mays

It is a monotypic genus, unique among all the grasses, in that the staminate flowers borne in a tassel are separated from the pistillate flowers borne in the lateral position on the stem. Leaves are broad, lanceolate, spikelets in pairs, one sessile and one pedicelled. The female spikes are axillary, enclosed in the sheath of the leaf and surrounded by bracts. Suckers are produced from the lower nodes of stem (Fig. 91). Detailed morphological measurements were recorded in Table 29.

The root tip cells of all the varieties showed the chromosome number as $2n = 20$ (Figs. 93, 96, 100 & 104) which confirms the earlier reports of Kuwada (1911, 1919), Longley (1924), Kiesselbach and Peterson (1925), Fisk (1925, 1927), Humphrey (1933), Ono and Suzuki (1956), Chen (1969). Varied number of B chromosomes were reported in maize by various workers (Randolph, 1928; McClintock, 1933). However, extra chromosomes were not observed in the present investigation. Cytological marker and satellites were not observed whereas secondary constriction was found on the 6th chromosome pairs of the Sikkim Yellow variety. Ono and Suzuki (1956) and Chen (1969) reported the presence of satellites on the 6th chromosomes of the somatic complement. The average length of the chromosomes varied in all the varieties

(Table 34).

In pollen mother cells, 10 bivalents were observed both at diakinesis (Fig. 106) and metaphase (Fig. 107) and occasionally 9 bivalents and two univalents were also noticed (Fig. 108). Meiosis was regular (Figs. 109 & 110) and the chromosome distribution was equal at anaphase I (Fig. 112). Spindle shaped chromosomes were noticed at metaphase I (Fig. 111). Meiotic abnormalities like lagging, stickiness, bridges, etc. were not observed. The second anaphase was also regular with tetrads and pollen grains (Fig. 113). The pollen fertility and chiasmata frequency values are recorded in the Table 35. The characteristic features of all the varieties are described as follows :

1. Zea mays var. Yellow Shillong

Stem cylindrical; leaves are not compactly arranged. Flag leaf is erect and glabrous. Anthers and silks are white in colour. Kernels are yellowish, unshrunken, compactly arranged. Absence of sterile appendage at the tip of the ear (Fig. 92). The number of kernel layer is 9 and the mean length of the ear is 17.7 cm.

The length of the chromosomes varies from 2.80 to 5.80 μ. The total chromatin length is 81.32 μ. The measurements of the somatic chromosomes are summarised in the Table 30 and the chromosome pairs have been represented in the idiogram (Fig. 94). Six pairs are median and the remaining four pairs are sub-median with respect to the position of the primary constriction.

Protein and carbohydrate values are 8.4 and 8.7 mg/g dry wt. respectively.

2. *Z. mays* var. Garo White

Stem cylindrical, leaves are compactly arranged. Flag leaf is not erect but glabrous. Anthers are purple whereas the silk is white in colour. Kernels are small, white coloured arranged regularly, unshrunken. Sterile appendage is present. The number of kernel layers is 12 and the mean length of the ear is 11.2 cm (Fig. 95).

The size of the chromosomes ranges from 2.82 to 4.92 μ. The total chromatin length is 74.94 μ. The details of the karyotypic analysis are given in the Table 31, and the chromosome pairs have been represented in the idiogram (Fig. 97). Seven pairs are median and the remaining three are sub-median with respect to the position of the primary constriction.

The values of total protein and carbohydrate are 9.2 and 9.6 mg/g dry wt. respectively.

3. Z. mays var. Sikkim Yellow

Stem cylindrical, flag leaf is not erect but glabrous. Mid-rib is purple. A number of two ears were noticed in the same internode (Fig. 98). Kernels are yellowish, unshrunken, arranged regularly in 10 layers. Sterile appendages are absent at the tipe of the ears. The average length of the ear is 16.8 cm (Fig. 99).

The chromosome size varies from 1.76 to 3.16 μ. The total chromatin length is 50.04 μ. Secondary constrictions are present on the 6th chromosomes of the somatic complement. The details of the karyotype analysis is recorded in the Table 32 and the chromosome pairs have been represented in the idiogram (Fig. 101). The number of median chromosomes are eight and the remaining two are submedian with respect to the position of the primary constriction.

Carbohydrate and protein values are 13.4 and 5.4 mg/g dry wt. respectively.

4. Z. mays var. Sikkim White

Stem cylindrical, leaves are not compactly arranged. Flag leaf is erect but glabrous. Anthers and silks are white coloured. Kernels are whitish, unshrunken and regularly arranged in 10 layers. Rudiments of sterile appendage is present. The mean length of the ear is 15.7 cm (Fig. 103).

The length of the chromosomes ranges from 1.76 to 4.22 μ and the total chromatin length is 57.94 μ. The measurements of the somatic chromosomes are summarised in Table 33, and the chromosome pairs have been represented in the idiogram (Fig. 105). Seven pairs are median and the remaining three are sub-median with respect to the position of the primary constriction.

The protein content is 6.0 mg/g dry wt. whereas the carbohydrate content is 11.3 mg/g dry wt.

Table 29 : Morphological measurements on different varieties of maize.

Variety	Average height of plants (cm)	No. of internodes (mean)	Length of the 5th internode (cm)	Flag leaf length (cm)	Tassel length (cm)	Weight/1000 grains (gm)
Zea mays var. Yellow Shillong	353.32	13.0	23.7	36.72	46.32	375.0
Z. mays var. Garo White	179.58	13.5	12.43	35.26	43.53	210.0
Z. mays var. Sikkim Yellow	216.67	12.8	14.27	39.62	45.97	385.95
Z. mays var. Sikkim White	275.5	14.4	19.8	40.68	46.68	439.5

Table 30 : Chromosomes of Z. mays var. Yellow Shillong.

(2n = 20)

Chromosome pair	Chromosome type	Position of constrictions Prim.	Second.	Arm ratio	Length of the component arms in μ		Total length in μ
1	B	m		1.20	2.64	3.16	5.80
2	B	m		1.33	2.11	2.81	4.92
3	B	M		1.00	2.28	2.28	4.56
4	C	m		1.27	1.93	2.46	4.39
5	C	Sm		1.87	1.40	2.64	4.04
6	C	m		1.20	1.76	2.11	3.87
7	C	Sm		2.14	1.23	2.64	3.87
8	C	Sm		2.33	1.05	2.41	3.46
9	D	Sm		1.83	1.05	1.93	2.98
10	D	M		1.00	1.40	1.40	2.80

T. F. %. - 36.33

Total chromatin length - 81.32 μ

Karyotype formula - 2(B m) + 1(B M) + 2(C m) + 3(C Sm) + 1(D M) + 1(D Sm).

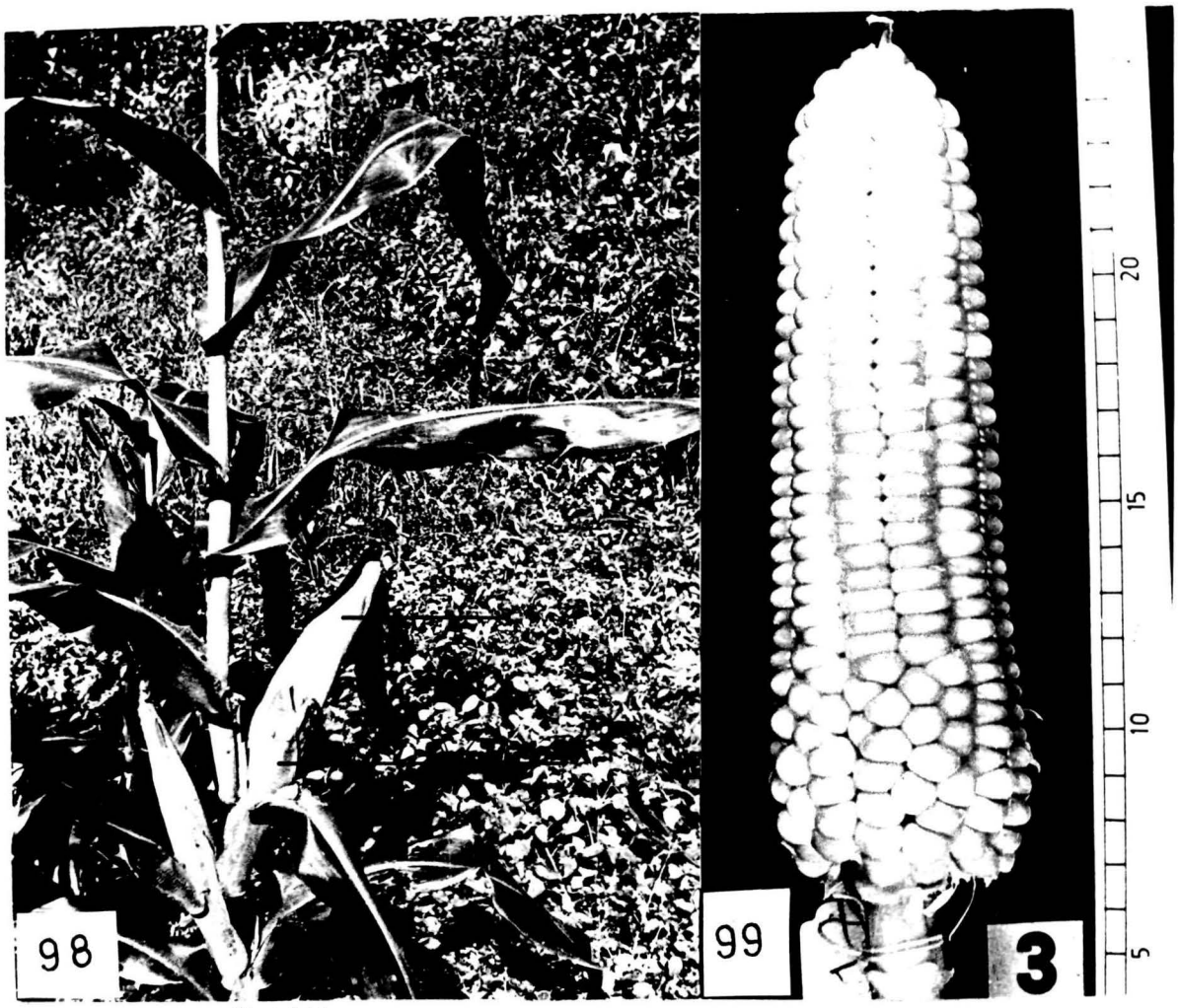
Figs 98-101 *Zea mays* var. Sikkim yellow

98 A plant of *Z.mays* var.Sikkim yellow

99 Ear of *Z.mays* var.Sikkim yellow

100 Somatic chromosomes(2n = 20) of *Z.mays* var.Sikkim yellow (X 2184)

101 Karyotype of *Z.mays* var.Sikkim yellow.



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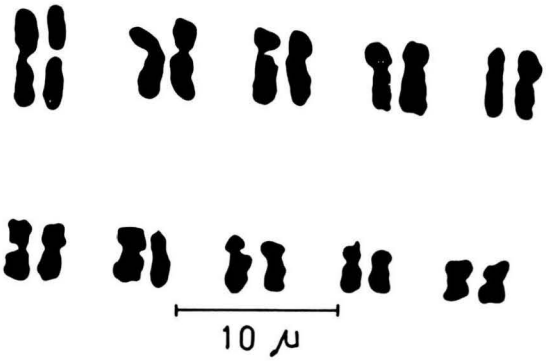

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Figs. 102-105-*Zea mays* var. Sikkim white

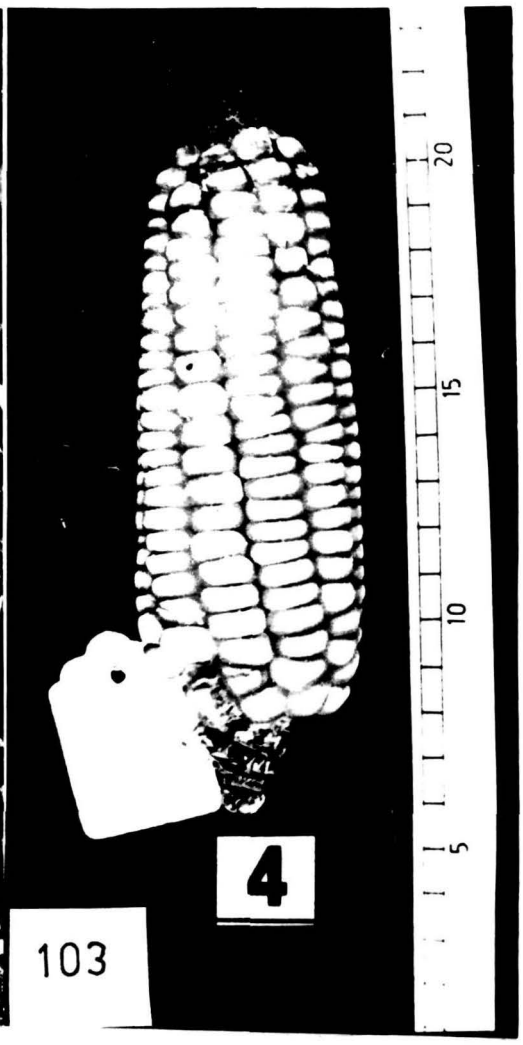
102-A maize plant showing bagged tassel

103-Ear of *Z.mays* var. Sikkim white

104-Somatic Chromosomes (2n = 20) of *Z.mays* var. Sikkim white. (× 2184)

105-Karyotype of *Z.mays* var. Sikkim white

102



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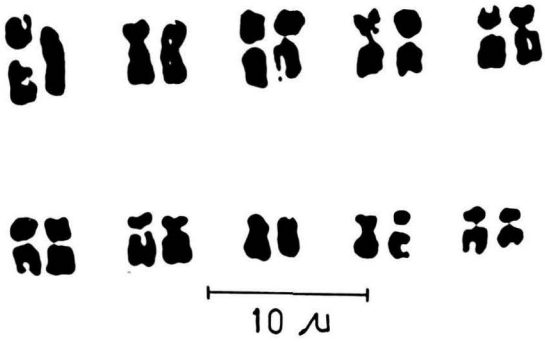

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Figs. 106–113 Meiosis in Parental *Zea mays* plants

106–A PMC showing diakinesis with 10 II

107–A PMC showing metaphase 1 with 10_{II}

108–A PMC showing diakinesis with $9_{II} + 2_{I}$

109–A PMC at diplotene

110–A PMC at Pachytene

111–A PMC at metaphase 1 showing spindle-shaped fivalents.

112–Pollen mother cell showing equal distribution of chromosomes at anaphase 1.

113–Fertile pollen grains.

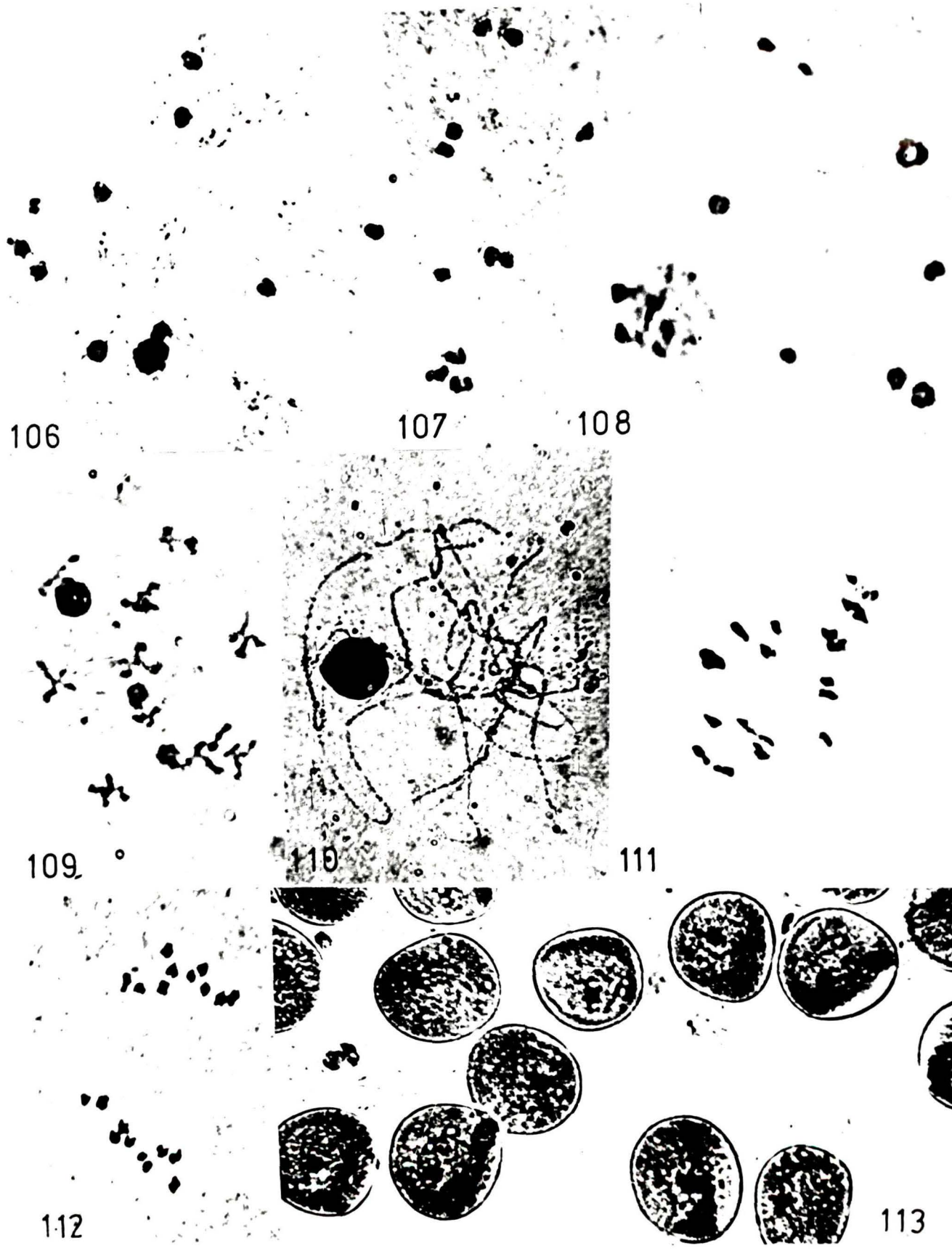
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Table 31 : Chromosomes of Z. mays var. Garo White.

(2n = 20)

Chromosome pairs	Chromosome type	Position of constrictions Prim.	Second.	Arm ratio	Length of the component arms in μ		Total length in μ
1	B	M		1.0	2.46	2.46	4.92
2	B	m		1.36	1.94	2.64	4.58
3	C	m		1.4	1.76	2.46	4.22
4	C	m		1.55	1.58	2.46	4.04
5	C	m		1.2	1.76	2.11	3.87
6	C	Sm		2.33	1.06	2.46	3.52
7	C	Sm		2.17	1.06	2.28	3.35
8	C	Sm		2.0	1.06	2.11	3.17
9	D	m		1.12	1.40	1.58	2.98
10	D	m		1.67	1.06	1.76	2.82

T. F. % - 39.73

Total chromatin length - 74.94 μ

Karyotype formula - 1(B M) + 1(B m) + 3(C m) + 3(C Sm) + 2(D m).

Table 32 : Chromosomes of Z. mays var. Sikkim Yellow.

(2n = 20)

Chromosome pairs	Chromosome type	Position of constrictions Prim.	Second.	Arm ratio	Length of the component arms in μ		Total length in μ
1	C	M		1.0	1.58	1.58	3.16
2	C	m		1.25	1.40	1.76	3.16
3	D	M		1.0	1.40	1.40	2.80
4	D	m		1.6	1.05	1.74	2.79
5	D	m		1.5	1.05	1.58	2.63
6	D	m	Sm	1.33	0.35 + 0.75	1.40	2.40
7	D	Sm		2.25	0.70	1.58	2.28
8	D	m		1.4	0.88	1.23	2.11
9	D	Sm		1.75	0.70	1.23	1.93
10	D	M		1.0	0.88	0.88	1.76

T. F. % - 42.75

Total chromatin length - 50.04 μ

Karyotype formula - 1(C M) + 1(C m) + 2(D M) + 3(D m) + 1(D m Sm) + 2(D Sm).

Table 33 : Chromosomes of Z. mays var. White Sikkim.

(2n = 20)

Chromosome pair	Chromosome type	Position of constrictions Prim.	Second.	Arm ratio	Length of the component arms in μ		Total length in μ
1	C	M		1.0	2.11	2.11	4.22
2	C	m		1.44	1.58	2.28	3.86
3	C	Sm		1.85	1.23	2.28	3.51
4	C	Sm		2.16	1.05	2.28	3.33
5	D	m		1.28	1.23	1.58	2.81
6	D	Sm		2.0	0.88	1.76	2.64
7	D	m		1.33	1.05	1.40	2.45
8	D	m		1.60	0.88	1.40	2.28
9	D	m		1.40	0.88	1.23	2.11
10	D	M		1.0	0.88	0.88	1.76

T. F. % - 38.84

Total chromatin length - 57.94 μ

Karyotype formula - 1(C M) + 1(C m) + 2(C Sm) + 1(D M) + 4(D m) + 1(D Sm).

Table 34 : Karyotypic data on different varieties of maize.

Variety	Range of chromosome length in μ	Mean length of chromosomes in μ	Ratio of the longest and shortest chromosomes in μ	Total compliment length in μ	T.F.%
Z. mays var. Yellow Shillong	2.80 - 5.80	4.3	2.07	81.32	36.33
Z. mays var. Garo White	2.82 - 4.92	3.87	1.74	74.94	39.73
Z. mays var. Sikkim Yellow	1.76 - 4.22	2.99	2.40	57.94	38.84
Z. mays var. Sikkim White	1.76 - 3.16	2.46	1.86	50.04	42.75

Table 35 : Mean chiasma frequency at diakinesis and metaphase I in different varieties of maize.

Variety	Pollen fertility (%)	No. of PMCs analysed	Diakinesis			Metaphase I		
			Range	Mean	± S.E.	Range	Mean	± S.E.
Z. mays var. Yellow Shillong	90.20	40	19 - 28	23.02	0.33	17 - 23	20.12	0.21
Z. mays var. Garo White	90.60	40	21 - 29	24.50	0.33	19 - 24	20.13	0.19
Z. mays var. Sikkim Yellow	87.39	40	20 - 27	22.55	0.25	17 - 23	20.37	0.24
Z. mays var. Sikkim White	86.28	40	20 - 25	21.61	0.22	16 - 23	19.50	0.26

Figs. 114– 120 F_1 hybrids of *Z. mays* var. yellow Shillong X *Z. mays* var. Sikkim yellow

114– Ear of F_1 hybrids of *Z. mays* var. yellow Shillong X *Z. mays* var. Sikkim yellow.

115– Somatic chromosomes (2n = 20) of the F_1 hybrids of *Z. mays* var. yellow Shillong X *Z. mays* var. Sikkim. (× 2184)

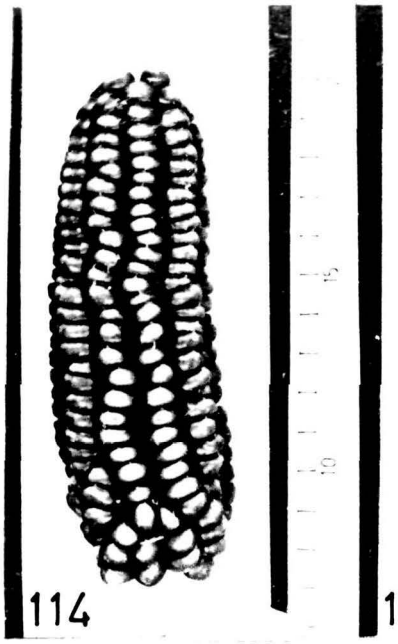
116– Karyotype of the F_1 hybrid of *Z. mays* var. yellow Shillong X *Z. mays* var. Sikkim.

117– A pollen mother cell showing 10_{II} at diakinesis

118– A pollen mother cell showing 10_{II} at metaphase 1

119– A PMC showing equal distribution of chromosomes at anaphase 1

120– Fertile pollen grain



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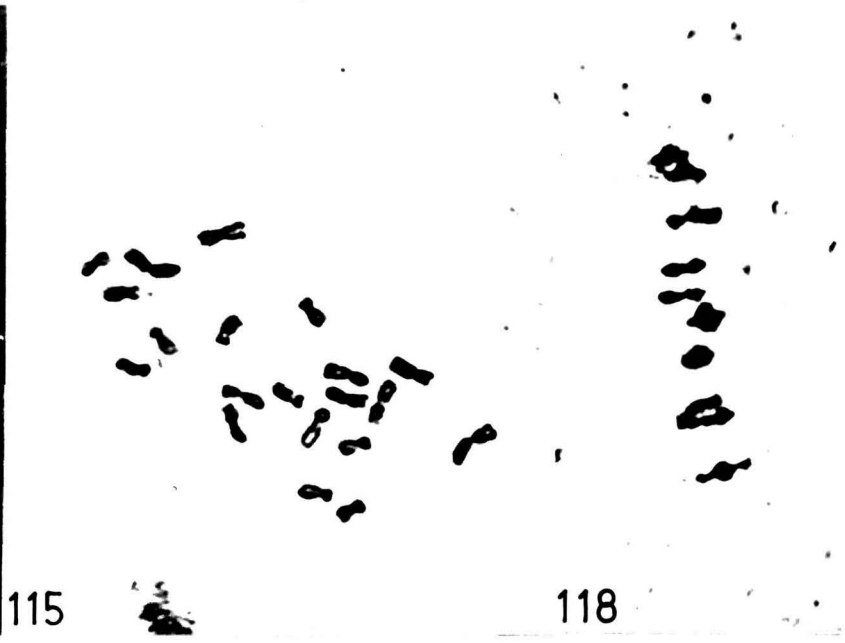

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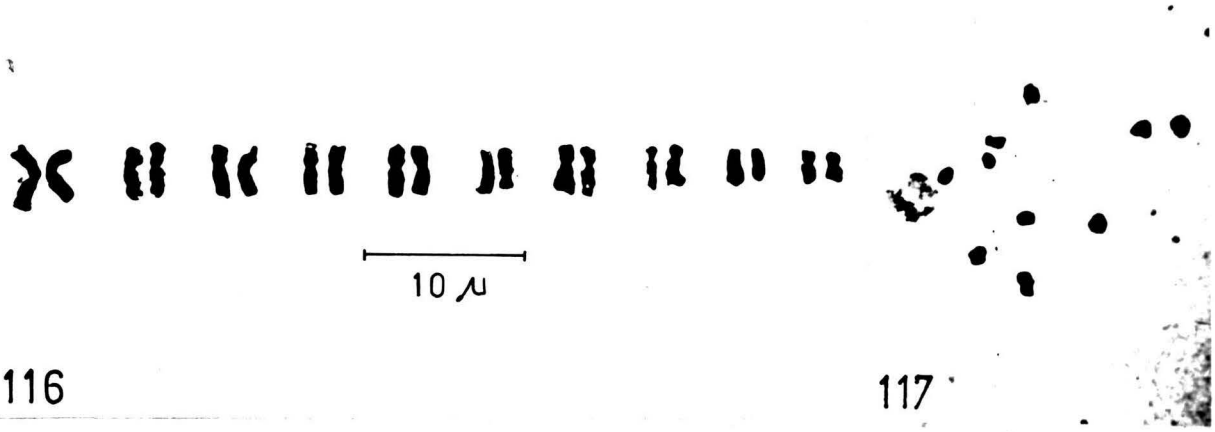

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Figs.121-126 F_1 hybrids of *Z.mays* var.Sikkim white X *Z.mays* var Garo white

121- Ear of F_1 hybrids of *Z.mays* var.Sikkim white X *Z.mays* var. Garo white.

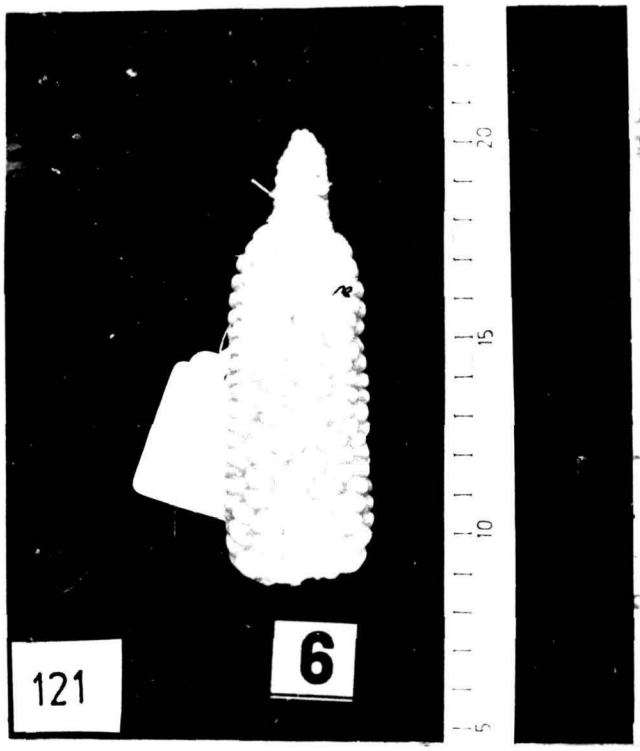
122- Somatic chromosomes ($2n = 20$) of the F_1 hybrids of *Z.mays* var. Sikkim white X *Z.mays* var. Garo white(X 2184)

123- Karyotype of the F_1 the hybrids of *Z.mays* var. Sikkim white X *Z.mays* var. Garo white.

124- A pollen mother cell showing 10_{II}

125- A pollen mother cell showing equal distribution of chromosomes at anaphase I .

126- Fertile pollengrains.



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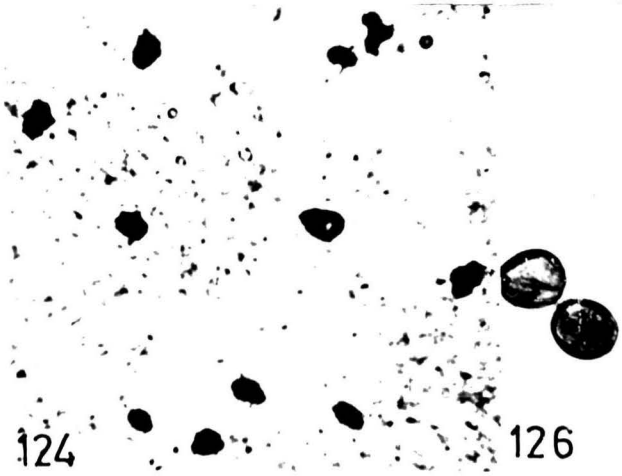

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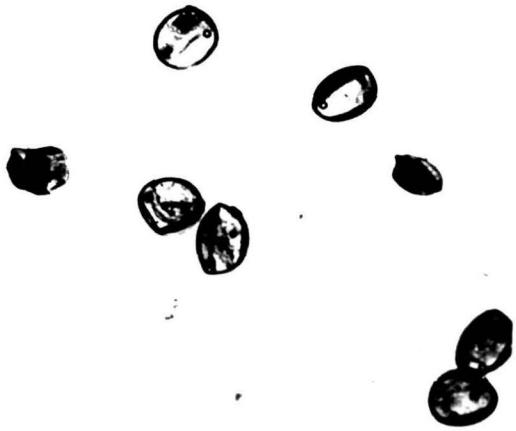

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Intervarietal hybrids

1. *Z. mays* var. Yellow Shillong x *Z. mays* var. Sikkim Yellow

The stem is cylindrical. Flag leaf is erect and glabrous. Mid-rib purplish. Anthers and silks are also purplish. Kernels are purplish, shrunken and regularly arranged in 10 layers (Fig. 114) and the mean length of the year is 12.8 cm. The hybrids are intermediate to their parents with respect to other morphological characters (Table 36).

The somatic chromosome number was found to be twenty (Fig. 115). The size of the chromosomes ranges from 1.40 to 2.99 μ. The total chromatin length is 46.32 μ. Secondary constrictions are present on the fifth chromosomes of the complement. The measurements of the somatic chromosomes are summarised in Table 37 and the chromosome pairs have been represented in the idiogram (Fig. 116). Seven pairs are median, two are sub-median and the remaining one is sub-terminal with respect to the position of the primary constriction.

In pollen mother cells, 10 bivalents were observed both at diakinesis and metaphase I (Figs. 117 & 118). Occasionally 9 bivalents and two univalents were observed. The course of meiosis was regular. Meiotic abnormalities

were absent. Chromosome distribution was equal at anaphase I (Fig. 119). The second anaphase was also regular. Pollen grains were normal and complete (Fig. 120).

The protein and carbohydrate values are 8.0 and 8.9 mg/g dry wt. respectively.

2. Z. mays var. Sikkim White x Z. mays var. Garo White

Stem is cylindrical, Flag leaf is not erect but glabrous. Anthers and silks are whitish. Kernels are whitish, comparatively bigger than the male parental ones, irregularly arranged in 8 layers. Sterile appendage is present (Fig. 121). The mean length of the ear is 6.8 cm. The hybrid plants are intermediate to their parents in all other morphological parameters analysed.

The root tip cells showed the chromosome number as $2n = 20$ (Fig. 122). Chromosome length varies from 2.28 to 4.22 μ. The total chromatin length is 64.62 μ. Secondary constrictions are absent. The measurements of the somatic chromosomes are summarised in the Table 38 and the chromosome pairs have been represented in the idiogram (Fig. 123). Eight pairs are median and the remaining two are sub-median with respect to the position of the constriction.

In pollen mother cells, 10 bivalents were noticed (Fig. 124). The course of meiosis was regular. Meiotic abnormalities were absent, and the chromosome distribution was equal at anaphase I (Fig. 125). The second anaphase was also regular. The pollen fertility and chiasma frequency values are recorded in Table 40. The pollen grains were normal and complete (Fig. 126).

The protein value is 7.8 mg/g dry wt. whereas the carbohydrate content is 8.8 mg/g dry wt.

Table 36 : Morphological measurements on the F_1 hybrids of maize.

Hybrids	Mean height of the plants (cm)	No. of inter-nodes	Length of the 5th internode (cm)	Flag leaf length (cm)	Tassel length (cm)	Weight/1000 grains (gm)
Z. mays var. Yellow Shillong x Z. mays var. Sikkim Yellow	283.7	12.6	19.8	38.3	52.16	350.0
Z. mays var. Sikkim White x Z. mays var. Garo White	252.1	13.6	17.92	34.0	43.18	430.0

Table 37 : Chromosomes of the F_1 hybrid

Z. mays var. Yellow Shillong x *Z. mays* var. Sikkim Yellow. ($2n = 20$)

Chromosome pairs	Chromosome type	Position of constriction Prim.	Second.	Arm ratio	Length of the component arms in μ		Total length in μ
1	D	m		1.42	1.23	1.76	2.99
2	D	m		1.28	1.23	1.58	2.81
3	D	m		1.14	1.23	1.40	2.63
4	D	M		1.0	1.23	1.23	2.46
5	D	m	Sm	1.33	0.17+0.88	1.40	2.45
6	D	Sm		2.25	0.70	1.58	2.28
7	D	m		1.40	0.88	1.23	2.11
8	D	Sm		2.0	0.70	1.40	2.10
9	D	m		1.2	0.88	1.05	1.93
10	E	St		3.0	0.35	1.05	1.40

T. F. % - 40.91

Total chromatin length - 46.32 μ

Karyotype formula - 1(D M) + 5(D m) + 1(D m Sm) + 2(D Sm) + 1(E St).

Table 38 : Chromosomes of F_1 hybrid *Z. mays* var. Sikkim White x *Z. mays* var. Garo White.

(2n = 20)

Chromosome pairs	Chromosome type	Position of constrictions Prim.	Position of constrictions Second.	Arm ratio	Length of the component arms in μ		Total length in μ
1	C	M		1.0	2.11	2.11	4.22
2	C	m		1.4	1.76	2.46	4.22
3	C	m		1.33	1.58	2.11	3.69
4	C	m		1.5	1.40	2.11	3.51
5	C	m		1.57	1.23	1.93	3.16
6	D	m		1.42	1.23	1.76	2.99
7	D	M		1.0	1.40	1.40	2.80
8	D	m		1.66	1.04	1.76	2.80
9	D	Sm		2.0	0.88	1.76	2.64
10	D	Sm		2.25	0.70	1.58	2.28

T. F. % - 42.08

Total chromatin length - 64.62 μ

Karyotype formula - 1(C M) + 4(C m) + 1(D M) + 2(D m) + 2(D Sm).

Table 39 : Karyotypic data on F_1 hybrids of maize.

Variety	Range of chromosome length in μ	Mean length of chromosomes in μ	Ratio of the longest and shortest chromosomes in μ	Total compliment length in μ	T.F.%
Z. mays var. Yellow Shillong x Z. mays var. Sikkim Yellow	1.40 - 2.99	2.20	2.16	46.32	40.91
Z. mays var. Sikkim White x Z. mays var. Garo White	2.28 - 4.22	3.25	1.85	64.62	42.08

Table 40 : Mean chiasma frequency at diakinesis and metaphase I of intervarietal hybrids of maize.

Hybrid	Pollen fertility (%)	No. of PMCs analysed	Diakinesis			Metaphase I		
			Range	Mean ±	S.E.	Range	Mean ±	S.E.
Z. mays var. Yellow Shillong x Z. mays var. Sikkim Yellow	83.27	40	18-29	23.90	0.34	17-24	20.05	0.26
Z. mays var. Sikkim White x Z. mays var. Garo White	82.46	40	21-27	23.08	0.25	16-22	19.75	0.21

Table 41 : Chromosome numbers in *Amorphophallus*.

Species	n	2n	Authors
A. bulbifer	-	36	Chandler (1943)
	-	39	Ramachandran (1977)
	-	26	Present study
A. campanulatus Bl.	-	26	Asana & Sutaria (1939)
	14	28	Krishnan *et al.* (1970)
	14	28	Ramachandran (1977)
A. dubium	-	28	Ramachandran (1977)
A. hohenackeri Engl.	-	26	Ramachandran (1977)
A. linumana	-	26	Kishimoto (1941)
A. kiusiana	-	26	Kishimoto (1941)
A. konjac	-	26	Ho (1942)
	-	26	Nakajima (1955)
A. rivieri	-	39	Tjio (1948)
A. satzumaensis	-	26	Kishimoto (1941)
A. titanum	-	26	Tjio (1948)
	-	26	Chandler (1943)

Table 42 : Chromosome numbers in Arisaema.

Species	n	2n	Authors
A. quinatum	-	28	Bowden (1940)
A. japonicum	14	28	Kishimoto (1941)
A. taihokensis	-	28	"
A. kiushianum	-	56	Ito (1942)
A. ovale	-	56	Ito (1942)
A. robustum	-	56	"
A. rigens	14	28	Chuang et al. (1963)
A. cucullatum	14	28	Hotta (1963)
A. consanguineum	-	28	Present study

Table 43 : Chromosome numbers in *Gonatanthus*.

Species	n	2n	Authors
G. sarmentosus	-	28	Sharma & Das (1954)
G. sarmentosus	-	32	Mookerjea (1955)
G. ornatus	-	30	Present study

Table 44 : Chromosome numbers in *Steudnera*.

Species	n	2n	Authors
S. discolor	-	32	Jos *et al.* (1971)
	-	56	Ramachandran (1978)
S. colocasioides	-	28	Present study.

Table 45 : Chromosome numbers in *Xanthosoma*.

Species	n	2n	Authors
X. sagittifolium	-	26	Jos & Magoon (1970)
	8	26	Magoon *et al.* (1970)
	-	26	Marchant (1971)
	-	26	Present study.
X. atrovirens	13	26	Pfitzer (1957)
	-	26	Marchant (1971)
X. robustum	13		
X. lindeinii	13	26	Pfitzer (1957)
X. violaceum	13		
X. carcay	-	26	Marchant (1971)

Table 46 : Chromosome numbers in *Colocasia*.

Species	n	2n	Authors
C. antiquorum	14	28	Maeda (1932)
	12	36, 48	Rao (1947)
	-	48	Delay (1951)
	-	28	Sharma & Das (1954)
	-	28	Mookerjea (1955)
	-	28, 42	Rattenbury (1957)
	-	42	Fukushima *et al*. (1962)
	-	28, 42	Bhattacharya (1971)
	-	42	Kawhara (1978)
	-	28, 42	Ramachandran (1978)
	-	28, 42	Choudhari & Sharma (1979)
	-	22, 36, 42, 44, 46, 52 & 58	Subramanian (1979)
C. esculenta	-	28, 42	Yen & Wheeler (1968)
	-	28, 42	Marchant (1971)
	-	28, 42	Ramachandran (1978)
	-	28, 42	Present study.

Table 47 : Chromosome numbers in *Zea mays*.

Species	Gametic number	Sporophytic number	Authors
Zea mays	9, 12	-	Kuwada (1911)
	10	20	Kuwada (1919)
	10	-	Longley (1924)
	10	-	Kiesselbach & Peterson (1925)
	-	20	Fisk (1927)
	10	-	Randolph (1927)
	10	-	McClintock (1929)
	-	20	Humphrey (1933)
	-	20	Ono & Suzuki (1953)
	-	20	Lima-de-Faria & Sarvella (1962)
	-	20	Chen (1969)
	10	20	Present study.

D I S C U S S I O N

DISCUSSION

In the previous section detailed observations on morphological variations, chromosome number, cyto-types and,carbohydrate and protein profiles of some members of tuberous species, both cultivated and wild, of the family Araceae, have been embodied. It was stressed that the investigation on these aroids was primarily taken up to explore the range of variations, both morphological and cytological, among the common tuberous aroids of Meghalaya. Informations about these plants are either sketchy or almost non-existent, especially the types growing in the North-East region of the country. A systematic study of a few of the species that have been carried out indicates considerable scope for the domestication of some of these tuberous aroids either directly or through clonal selections, spontaneous or induced. But any such programme of useful exploitation of these natural food resources needs a reliable inventory of the totality of the gene pool found in the high and low altitudes of Meghalaya. The importance of tuberous crops has a supplement or substitute of cereals cannot be underestimated in a growing population of the country. These considerations, namely, lack of knowledge of the almost completely unexplored tuberous flora of Meghalaya, and a systematic attempt to exploit them as minor or subsidiary food crop justify a thorough investigation

of these plants.

Similarly, one of the most common cereals cultivated by the original population of the State, is maize. It has been stated earlier that primitive strains of maize are still cultivated in the hilly tract of Sikkim and North-East regions. The existence of these strains in this area offers a suitable opportunity to study them in depth with a view to determine the exchange of gene pool in them and also to explore their relationship and origin of this important cereal. Why this is necessary, has been stressed earlier, in that there is a school of thought that North-East India and South-East Asia may be the centre of origin of maize besides the American centre. Whether North-East India or South-East Asia is the primary centre of origin of maize or not is keenly debated, but the existence of primitive strains in the area does offer support to the view that at least this region may be the secondary centre of its origin. Once the range of variability of this primitive maize is fully screened they may be utilized in the production of high yielding hybrid synthetics or composite strains. Therefore, the morphological variations of the maize strains and their cytological behaviour and the inheritance pattern have been included in the investigation.

For the sake of clarity, however, studies on the aroids and that of maize strains and their hybrids will be discussed separately.

I

To begin with, the six genera of the tuberous aroids may be critically discussed in view of their morphological and cytological variations and behaviour.

The six genera of the tuberous aroids are - Amorphophallus, Arisaema, Gonatanthus, Steudnera, Xanthosoma and Colocasia. As mentioned earlier these materials have been collected from various locations of low and high altitudes. They exhibit considerable morphological variations in regard to height of the plant, leaf size, number of stomata and yield per plant, namely, the size of the corm and cormels etc. (Tables 6, 10 and 11; Figs. 14, 19, 29, 33, 37, 41, 45, 49, 53, 57, 61, 65, 69, 73, 77 & 81). For instance, in Xanthosoma sagittifolium collections from the plain and the hill, the morphological data bring out clearly great variability. Similarly, in Colocasia esculenta, 15 strains collected from various locations show amazing array of variability in morphological features. Out of the 15 accessions of this taxon,

11 are triploids and 4 are diploids. But even within triploid cyto-types the wide variations exist in respect of the various morphological features summarised in Tables 10 & 11; Figs. 29, 33, 37, 41, 45, 49, 53, 57, 61, 65 & 69. Similarly, among its 4 diploid accessions considerable variations have been scored (Tables 10 & 11; Figs. 73, 77, 81 & 85). These two examples fully justify that in this unexplored region very rich repository of germ-plasms exists which needs systematic collection, assessment and utilisation. If limited effort could bring out so many strains exhibiting wide divergence from one another, the extensive collections from different ecological niches of the plains and the hills of the State are bound to provide rich store of germ-plasm which through clonal selection, spontaneous or induced, would greatly add to the tuber wealth of the State.

In the other 4 genera, Amorphophallus, Arisaema, Gonatanthus and Steudnera, only limited collections have been made and it would be very profitable if these species are also collected from the whole range of their habitats and their variabilities are suitably assessed.

For an objective evaluation of the evolutionary trends, its tempo and direction in any group of plants, the chromosome numbers have proved to be a very valuable

tool. Not only the chromosome number is fairly constant in a species, but even minor alterations in the individual chromosome structure, through deletion, duplication, translocation, inversions, can be detected and their role in speciation be ascertained. The addition or deletion of a few chromosomes or whole set of haploid number, thus raising the ploidy of the species, can also be established through the study of chromosome numbers. Even within a species intraspecific chromosome variations have been detected in a number of plants, such as, in barley (Hagberg & Tijo, 1950), Polianthus tuberosa (Sharma & Ghosh, 1956), Caladium bicolor (Sharma & Sarkar, 1964), Oryza sativa (Sharma & Mukhopadhyaya, 1965), Brassica campestris (Mookherjee, 1977), etc. Thus the alterations in the chromosome number and structure are looked upon as a very reliable parameter in phylogenetic considerations. Stebbins (1950) stressed that "Studies of chromosome morphology often provide to the students of evolution and phylogeny valuable sign posts indicating the nature of evolutionary process at work and trends which evolution has taken." It is generally accepted that primitive species are characterised by symmetrical karyotype, i.e., metacentric or sub-metacentric chromosomes, and advanced species have asymmetrical karyotypes with sub-median to sub-terminal chromosomes.

A number of workers have studied several members of the family Araceae and reported the chromosome numbers, namely, Bowden (1940), Darlington and Janaki-Ammal (1945), Sharma and Das (1954), Mookherjea (1955), Ramachandran (1978). Among the six taxa of the Araceae included in the present investigation, 4 taxa - Amorphophallus bulbifer, Arisaema consanguineum, Gonatanthus ornatus and Steudnera colocasioides, grow almost wild in Meghalaya. The previous work on these genera including the present determination are summarised in Tables 41 to 44. The 2n numbers are 26, 28, 30 and 28 respectively and all are at the diploid level. Among the 4 species, the chromosome sizes in A. bulbifer and S. colocasioides are almost similar which range from 3.17 to 6.86 μ (Table 5). In the other two species, Arisaema consanguineum and Gonatanthus ornatus, the chromosomes are much smaller, 1.40 to 2.99 μ in the former and 2.19 to 7.04 μ in the latter. A great variation in the size range of individual pairs in Gonatanthus ornatus may be noted. The karyotype of Amorphophallus bulbifer (Table 1; Fig. 3), indicates that 11 pairs of chromosomes of different sizes, A, B and C types, have median centromeres and only 2 pairs have sub-median centromeres. The T.F. value is 41.32. From these chromosome measurements and karyotype the species appear to have a symmetrical karyotype. The other species Arisaema

consanguineum has much smaller chromosomes, but in this case also out of 14 pairs, 10 pairs have median centromeres and 4 pairs have sub-median centromeres with T. F. value 41.64. On the whole, this species also has a symmetrical karyotype. The third species Gonatanthus ornatus has 15 pairs of chromosomes, of which 10 pairs of chromosomes with A, B, C and D types have median centromeres and 5 pairs of different sizes have sub-median centromeres. The T. F. value is 40.94. This species tends towards asymmetry although majority of the chromosomes are still metacentric. Steudnera colocasioides has 13 pairs of A, B and C types of chromosomes with median centromeres and only one pair has sub-median centromere with T. F. value 43.26. Thus, this species also has a symmetrical karyotype. Therefore, from the idiogram, T. F. value and karyotypes of these four species which are at the diploid level can be classified as primitive types chromosomally.

From the determination of 2n number, the haploid number in them is 13, 14 and 15 respectively. A perusal of the basic chromosome number in the family (c.f. Darlington & Wylie, 1955) indicates x = 7, 8, 9, 11, 12, 13, 14 and 17. The species with a haploid number 14 can easily arise as a multiple of 7. In fact, the haploid number which is found in the largest number of species, is generally taken as the primary basic number. It is quite

likely that 7 may be the basic number from which even 8 or 9 can be derived through duplication of one chromosome by non-disjunction at anaphase. Thus, from the primary mode of 7, 8 or 9 could arise. Similarly, 7 could give rise to the number 14 by duplication from which 13 or 15 could arise by addition or deletion of one chromosome at anaphase. Once these numbers, 13, 14 or 15, are established, their mere doubling would give rise to the 2n number 26, 28 and 30. Most of the species are vegetatively propagated and sexual sterility even if encountered, has no relevance. The previous report of Mookherjea (1955) also stresses the basic number as 7, 8 or 9 which are found in several genera of Araceae, such as, n = 9 in Acorus (Darlington & Wylie, 1955) and n = 8 & 9 in Typhonium (Sharma & Mukhopadhyaya, 1965). The ten species of Amorphophallus listed in Table 41 have all 2n = 26 or 39. It is, therefore, quite reasonable to assume that the secondary stable basic number for the genus is 13 from which the species with 26 or 39 have arisen through doubling or tripling. However, it might be possible that x = 13 in Amorphophallus and x = 15 in Gonatanthus may themselves be a derived number from a lower number as suggested above. Krishnan et al. (1970) held the same view while studying the number of chromosomes in Amorphophallus. The presence of supernumerary constrictions (Fig. 8) in the chromosomes

of Gonatanthus ornatus also indicate that structural changes in chromosomes have taken place.

Secondary constrictions have not been observed in the chromosomes of Amorphophallus, Arisaema and Steudnera, but two pairs of chromosomes of Gonatanthus show secondary constrictions. Ramachandran (1977) reported secondary constriction in a triploid A. bulbifer. It is a common feature that in the same species some workers have reported secondary constrictions, whereas, others have not observed it. According to some workers secondary constrictions are important chromosome markers and it imparts individuality to chromosome pairs, but it is not considered important in over all considerations of karyotype. There is considerable divergence of opinion about the relevance of secondary constrictions as a chromosome marker and reliable tool in phylogenetic studies. Stebbins (1950) mentioned that "nucleolar organisers with its satellites may be gained or lost during evolution and that the size may increase or decrease." Lewis and John (1963) stated that chromosome regions which are devoid of coiling present a different picture than a totally coiled arm and, therefore, secondary constrictions are not always constant in appearance and have to be considered with utmost care and attention. So far these four species are concerned, secondary constrictions are absent in 3 and present in two

chromosomes of one species and thus it does not provide any valuable information either on the symmetry or phylogeny of these taxa.

The other two species Xanthosoma sagittifolium and Colocasia esculenta are cultivated for their nutritious corms and cormels. These two show great diversity in their morphological features as well as other characteristics. In particular, X. sagittifolium collected from plains and the same species collected from the hills differ markedly. The tubers of the plain variety are smaller in size than those of the hill variety. The height of the plants in the hill variety is higher (50.1 cm) than that of the plain variety (30.90 cm), but these two varieties are identical in their leaf shape. Their leaf size differs. Percentage of moisture content and yield per plant are high in the hill variety as compared to the plain ones. The stomatal index is high in the former. The hill variety is found to be morphologically superior to plain variety in all the morphological parameters analysed. The species is popularly known as 'Tannia' and the varieties collected from the hills and the plains are both diploids ($2n = 26$). Thus, in spite of great differences in the morphological features of the two varieties they have the same chromosome number and are at the diploid level. The somatic number

corroborates the earlier report of Jos and Magoon (1970), Magoon et al. (1971) and Marchant (1971). The chromosome complements in both the varieties are almost similar with slight differences, namely, in the plain variety it ranges from 1.23 μ to 3.25 μ and in the hill variety from 1.84 to 3.87 μ. The individual length of chromosomes and the types to which they belong are given in Tables 7 and 8. In the plain variety 10 pairs of chromosomes are metacentric and they are of the C, D and E types. Only 3 pairs have sub-median centromeres. In the hill strain, however, 6 pairs of chromosomes of C and D types are metacentric, 4 pairs of C type and one pair of D type have sub-median centromeres. The remaining 2 pairs are of D types and have sub-terminal centromeres. Thus the T. F. value in the plain variety is 40.77 and in the hill variety it is 38.48. On the basis of these measurements it is evident that the karyotype of the plain variety is more symmetrical than that of the hill variety. If wider areas in the hills including all niches are covered for collections possibly we may get far more variations both morphologically and karyotypically.

The 2n number being 26, the haploid number is 13, which may be looked upon as the basic number. It has been discussed above in the case of the other species like

A. bulbifer that even x = 13 could have arisen from a lower number. The variation in the karyotypes of the plain and the hill varieties possibly indicate that the original basic number 13 is a derived number. Based on pachytene studies (Table 45) it was suggested that Xanthosoma has a low base number like 7 or 8.

Thus, on the whole, the differences in the T. F. values of the plain and the hill varieties and their karyotypes, indicate that factors responsible for the loss or gain in the chromatin matter and mechanism like pericentric inversions and translocations could be operative possibly shifting the position of the centromeres and altering the size of the chromosomes. Two trends in the chromosome morphology and size appear to be evident, namely, evolution of the basic number 13 from a lower number and karyotypic differences in the plain and the hill variety through aberrations.

The species, Colocasia esculenta, is popularly called 'Taro' and is cultivated for its nutritious corms. Fifteen strains have been collected from the plains of South and North India, and also from the hills of Meghalaya. The distinctive morphological features of the corms and cormels have been summarised in Tables 10 and 11. The accessions from South India are diploid with 2n = 28 and

those from North India are triploids with 2n = 42. The collections made from the hills of Meghalaya have both diploids and triploids. The triploid strains on the whole are bigger in size and morphologically superior to diploids. The triploids from Meghalaya also showed more variations in size than diploids. The leaf size in the diploids ranges from 111.7 cm^2 (Strain 15) to 1983.5 cm^2 (Strain 12). In triploids, however, it ranges from 281.7 cm^2 (Strain 7) to 3083.5 cm^2 (Strain 10). It is interesting that the wild strains had a lower leaf area, namely, 111.7 cm^2 and the stomatal index 8.27. The increase of chromosome number from 28 to 42 decreases the stomatal index which ranges from 3.91 to 8.61. A similar tendency in the reduction of stomatal index frequency was reported in Zea mays (Randolph, 1932, 1935), Tradescantia (Sax & Sax, 1937) and Sedum (Smith, 1943). The triploids gave much higher yield than the diploids. Even the diploid strains growing in the higher altitude gave better yield performance than the strains cultivated in the plains. Thus even in the diploids there is strain difference. This great variability, therefore, in the diploid and triploid accessions in Colocasia esculenta can be meaningfully exploited for higher and more production.

The genus Colocasia appears to possess different chromosome numbers. The present report of 2n = 28 and 42

confirms the earlier reports by a number of workers (Table 46). However, Rao (1947) and Delay (1951) also reported $2n = 36$ and 48 respectively. But the majority of the reports from various accessions confirm $2n = 28$ and 42.

The detailed measurements of chromosomes and their karyotypes are given in Tables 12 to 26. Taking the Strains 1 to 11 (Tables 12 to 22), all of which are triploids, there is some degree of variations in the size of individual chromosome and correspondingly in the mean length of the chromosomes. Some differences in the size of individual chromosome can also be ascribed to differential fixation and staining on different locations and dates, but intrinsic differences in the size of the individual chromosomes cannot altogether be ignored. Among the triploids the smallest chromosome is 1.70 μ (Strain 4) and the longest is 4.40 μ (Strain 7) in size. Naturally the total chromatin length among the triploids also shows variation with the lowest factor 98.70 μ in Strain 9 and the highest 137.43 μ in Strain 7. The karyotypes of the individual strains also show variations. For instance, Strain 1 to 11, which are all triploids, have different number of metacentric chromosomes, 13, 9, 9, 9, 10, 7, 11, 10, 12, 7 and 12, respectively. Most of the metacentric

chromosomes are of C and D types. However, there is variation in the number of chromosomes with sub-median and sub-terminal centromeres in these strains. Besides the metacentric chromosomes, the remaining pairs are mostly sub-metacentric. Only in 4 strains some chromosomes show sub-terminal centromeres (Tables 13, 14, 16 & 21). Thus, basically the karyotype is symmetrical with some chromosomes showing tendency towards sub-terminal centromeres. This is also evident from the T. F. value which is only 39.28 in Strain 2 and the highest 45.33 in Strain 1 with most of the strains having 40-41 as the T. F. value.

Among the four diploid strains (Tables 23 to 26) the smallest chromosome is 1.93 μ in Strain 13 and the biggest 4.34 μ in Strain 12. However, the mean length of the chromosomes is 3.0 μ. Among these 4 strains also the pairs of metacentric chromosomes are from 12 to 15 and most of these metacentric chromosomes are of C and D types. The reamining pairs have sub-metacentric centromeres but no pair has been found to possess sub-terminal centromere. Accordingly, the highest T. F. value is 43.15 in Strain 12 and the lowest 38.32 in Strain 15. In the diploid strains also, therefore, the karyotype is mostly symmetrical only showing a shift of the position of centromere towards sub-median position. But a comparative look

of the triploids and the diploids, indicate that there are individual sets of triploid chromosomes where the centromere shifted to sub-median position, but that type of situation has not been found in the diploid accessions. It indicates that the triploids showing greater variability not only in regard to the number but also in intra-chromosomal shifts of segments. One would, therefore, expect the triploids to provide a much richer material for clonal selection and cultivation than the diploids.

The above discussions have established the existence of cultivation of a number of diploid and triploid strains, some suited to South India, some to North India, whereas both diploid and triploid to Meghalaya State. These strains of Colocasia (Taro) are propagated exclusively by vegetative means and, therefore, one strain is completely isolated from another without any chance of gene exchange among them. Thus the karyotypic changes and random mutations arising in each strain would gradually lead them to divergence. This is not only true for Colocasia, but equally true for Tannia (X. sagittifolium) as reported by Kuruvilla and Singh (1980). These divergences are also reflected in the diploid and triploid strains cultivated in the higher altitude of Meghalaya which have longer chromosomes than those cultivated in the plains. Stebbins (1950)

critically discussed the adaptive significance of longer chromosomes at higher altitude. Thus the general pattern of the evolutionary dynamics, i.e., through structural changes in chromosomes in Taro and Tannia is the same as described in other groups like Hordeum (Sharma, 1956; Sharma & Mookherjea, 1956), Sorghum (Sharma & Bhattacharjee, 1957) and Brassica campestris (Mookherjee, 1977).

The occurrence of the triploid strains which are karyologically arranged into 14 sets, each set of 3 chromosomes, confirm their autoploid nature. But the number 28 with $n = 14$ itself appears to be a derived number from the basic number 7 because in a large number of the taxa of Araceae $x = 7$ is the dominant number. Thus through doubling in the remote past the secondarily derived base number 14 was established in this genus. The polyploids in the genus appear to have been derived from the basic set of 7 and wherever numbers other than 28 and 42 are found, they may be deviations from the basic set of 7 (Choudhari & Sharma, 1979). The meiotic studies of Abraham and Ramachandran (1960) and, Sharma and Sarcar (1963) showing 14 regular bivalents corroborate that the chromosomal sets are homogenous and have arisen through doubling in the remote past. It is now well known that the autopolyploids, after a few generations, fail to form

multivalents (Randolph & Giles, 1951), hence, the occurrence of regular 14 bivalents does not preclude the chance of the autoploid nature of the polyploid strains of Colocasia.

Electrophoresis, i.e., electrophoretic mobility of protein fractions, is proving to be a very effective tool in the analysis of genetic variance. Similar varieties of a taxon possess almost similar/identical bands which are considered a reflection of their genetic homogeneity. In accessions which have the same chromosome number as well as very few distinguishing features, protein and enzymatic bands may prove informative to bring out the intrinsic differences among them. Singh et al. (1973) and Sanyal and Sharma (1980) stressed this point in their report. In this backdrop the two accessions of Xanthosoma sagittifolium, one from the plain and the other from the hills, have been analysed electrophoretically to bring out the nature of intrinsic differences between them. It may be recalled that the same chromosome number and their chromosomal complements are very similar except that in the hill accessions the karyotype has several pairs of chromosomes with sub-median centromeres and show a tendency towards asymmetry. How far these intra-chromosomal variations are reflected in their protein and enzymatic profiles may provide

useful information. The total protein content in the plain and the hill accessions is 5.1 and 8.4 mg/g dry wt. respectively. The number of protein bands are 7 in the plain accession and 12 in the hill accession. Fig. 23 indicates that the number of dense bands vary in the two accessions which are 2 in the plain and 3 in the hill variety. However, statistical analysis of the Rf values of the 5 bands in the two accessions shows that they are not significantly different from each other and, therefore, be considered homologous. The homologous bands are characterised - (a) dense and (b) medium, but none of the light bands are homologous in the two accessions. Shecter and de Wet (1975) mentioned that in spite of morphological and ecological differences, taxonomic categories below the species level possess the same protein profile. However, in several cases different bands have been encountered among different varieties or sub-species of the same species complex. For the enzymatic profiles peroxidases are easily screened. These are oxidative enzymes which oxidise a number of substrates but not hydrogen peroxide (H_2O_2). They catalyse the oxidation of phenolic compounds and aromatic amines into quinones in the presence of H_2O_2 (Bonner, 1950). These enzymes are universal in the plant kingdom and are generally associated

with the electron transport chain from $NADH_2$ to cytochrome as reported in cabbage and cucumber mitochondria (Ivanova et al., 1967). It is seen from Fig. 24 that peroxidase bands afe 5-7 in the plain and hill varieties but the number of dense bands are the same in both the accessions. Thus electrophoretic pattern shows characteristic banding pattern for protein and enzyme. The minor differences in the two patterns may be taken to indicate the differences in their genetic make-up.

Summarising the situation in X. sagittifolium it may be stated that the minor differences in the karyotype of the two accessions may be due to intra-chromosomal changes and mutations which are also reflected in addition to their total protein and electrophoretic patterns of isoperoxidases. Quite likely the hill variety with higher protein content may be the result of human selection for more nutritious corms. The hill variety growing in remote areas is comparatively not so disturbed and represent the pattern of intra-chromosomal changes that are taking place in the species.

Onwueme (1978) holds that 'Tannia' originated and was brought into cultivation first in Tropical America from where it spread to other continents including South-East Asia. In Meghalaya it is likely to have been brought

from the South-East Asian countries and reached the Khasi hills. The plain variety may be a direct introduction from the original American strains.

Ethnic relationships of some tribes of North-East India to the natives of South-East Asia lend support to this view. Even if the two accessions may have a common origin, some cytogenetic divergences are expected because of their migration from the original place via different routes. Perhaps the performance of the Khasi variety and the plain variety, and vice versa, and also their in-depth assessment of protein and peroxidase profiles may provide additional information about their origin.

The electrophoretic studies in respect of total protein profiles and carbohydrate contents have been made in all the 15 strains of Colocasia esculenta, 11 of which are triploids and 4 are diploids. The protein values in these strains range from 4.2 to 11.4 mg/g dry wt. The maximum protein value is found in one of the triploid Strain 8 (11.4 mg/g dry wt.) and the minimum (4.2 mg/g dry wt.) in the wild diploid Strain 15 (Table 28). The highest carbohydrate content 36.0 mg/g dry wt. is regarded in triploid Strain 7 and the lowest in the diploid Strain 15. Electrophoretic banding patterns also show variable numbers among the different strains of 'Taro'. Generally the

number of bands is 9 in the wild strains and 12 in the cultivated Strain 1 (Table 28, Fig. 88). The number of dense bands also differ in diploids and triploids. Even in triploids, Strain 4 has two bands, whereas Strain 7 has six bands. The other strains like 1, 2, 3, 9 and 11 of the triploids, have 4 bands each. Only two triploid strains 5 & 6 have 5 bands. Among the diploid strains the number of bands ranges from 2 to 3. For instance, Strains 12 and 14 have 3 bands and Strains 13 and 15 have 2 bands. Like the dense bands the medium bands also vary in all the strains. Danimihardja and Sastrapradja (1978) reported maximum of six bands in the cultivated and three bands in the wild. In the present collections both in wild and cultivated 'Taro' the number of bands are higher than in the reports of the previous workers.

From these electrophoretic studies and carbohydrate contents indications become evident that these strains differ at the genotypic level. The wild strain with tendency towards asymmetrical karyotype, which obviously has not been subjected to human selection, has lost carbohydrate and protein content. Human selections have always been in favour of strains which have more food value. This is all the more evident that the triploid strains have more total protein content than the diploid strains

although collected from the same area and altitude. Their protein bands are almost similar. Minor karyotypic changes in the wild strains may only be the device for adaptation in the natural environment whereas the cultivated strains are pampered and safeguarded under human care.

In conclusion it may be generalised that these 'Taro' strains are not only morphologically divergent but also karyotypically and genotypically. The triploid strains have greater variability than the diploid ones. The occurrence of both diploid and triploid forms in the hills of Meghalaya, whereas the diploid forms restricted to the plains of South India may be taken to suggest that triploid arose in response to the demand of the climatic situations of the Meghalaya region. Several workers like Löve and Löve (1943, 1949 & 1957) stress that the polyploidy is one of the responses of the organism to higher altitude. Since these strains flower very rarely, their meiosis is unknown and no critical comment on the nature of triploidy is possible although karyotypes suggest their autoploid origin.

De Candolle (1886) mentioned that Colocasia originated in the Indo-Malayan regions. According to Pena (1970) cultivars of C. esculenta might have originated

either in the North-Eastern regions of India or Upper Burma. Plucknett (1972), on the other hand, holds that Southern Asia is the native place for Colocasia. Onwueme (1978) stated that 'Taro' varieties might have originated from South Central Asia. The greater diversity in the hill strains of C. esculenta than in the plain varieties suggests that there is greater probability that these strains originated in the North-Eastern India. According to Vavilov (1931) the species in the area of its origin has larger number of variations or diversity. From this angle the North-Eastern region of India may be considered the centre of origin of C. esculenta. To settle the matter wider collections from the whole hill regions of North-East India as well as from the South-East Asia would be rewarding, hence, is essential.

Thus the cytological data of the wild and cultivated species of Araceae have provided useful clue to the trend of speciation among them and also throws light on the status of their ploidy and the basic chromosome number. The study of total protein content, enzyme profiles and carbohydrate content in the wild and cultivated strains have also indicated the role of human and natural selection in the spread of the varieties. It has also highlighted the necessity for in-depth collections

of the rich germplasm of the tuber crops which can be meaningfully utilised to supplement the food chain of the population. The maximum diversity of some of these aroids also indicates North-East region of India to be their probable centre of origin. These informations underline how necessary it is to have a systematic and intensive cytogenetic study of the local flora, both cultivated and the wild, of the almost unexplored region of Meghalaya.

II

The choice of selecting some local varieties of maize of Meghalaya as the experimental material for investigation was stressed in the earlier chapter, on the basis that the North-East region of India is considered as the secondary centre of origin of maize. In fact primitive maize varieties are cultivated in Sikkim and other hill States of the North-East region showing all the features of the Tripsacum in having several cobs from a large number of nodes, but each cob of small size. There is also a group of cytogeneticists who hold that maize originated in South-East Asia from Coix and Sorghum (Anderson, 1945; c.f. Mangelsdorf, 1947). Be that as it may, in the present investigation several local varieties have been

studied for their morphological diversities and behaviour of the intervarietal hybrids in the F_1 and succeeding generations. It is well known that in inheritance studies hybrids do produce 'throw-backs' and 'off-types' of recessive genes which are important, if not economically, at least from the phylogenetic angle. It is in this background that data on the various varieties included in the investigation and their hybrid performance is considered here.

The chromosome number is very stable ($2n = 20$) and confirms all the previous work (Table 47). The n and the basic number, therefore, is 10 which is accepted by most maize workers. However, Anderson (1945) holds that the basic number in maize is 5 like Coix and some other species of Maydeae. According to these latter views maize is a tetraploid which has got diploidised as a result of getting filtered through thousands of sexual generations after its origin. The process of diploidisation in maize appears to be rather fast which was evident from the work of Randolph and Giles (1951) in which only during 10 generations the experimentally produced tetraploid maize with $2n = 40$ began to show only 1-2 quadrivalents in the 10th generation when it had an average of 9 quadrivalents in the first generation.

In view of this if Zea mays arose from a progenitor with 2n = 10, it would be a polyploid but behaves today as perfect diploid. This could be a probable hypothesis. It is true that in Z. mays inheritance studies have shown duplicate factors (Huskins & Smith, 1934; Powers & Clark, 1937), but even in strictly diploid species deletion and duplication do arise spontaneously. The individuals with deleted segment may be eliminated but the one with duplicated segments may have a survival value in natural selection and would thus be retained. In this light mere presence of duplicated genes cannot be a strong ground for a polyploid origin of a taxon. Das (1970) holds that maize might have originated as a result of hybridisation between two very closely related genera with n = 10 of a basic number 5 in Poaceae (Graminae) in which an array of basic numbers like 5, 7, 9, 10, 11, 12, 13, etc. are common. Several genera have dibasic number 7 or possible 5. But no conclusive evidences have been forthcoming to establish the derivation of n = 10 in Z. mays from basic number 5.

It is interesting that 2n = 20 is a common number in all the four varieties - Yellow Shillong, Garo White, Sikkim Yellow and Sikkim White, but the total chromatin length in them are different from one another, namely,

81.32 μ, 74.94 μ, 57.94 μ and 50.04 μ respectively. The length of chromosome itself is not a decissive factor to interpret wide divergences, yet, the difference like 81.32 μ and 50.04 μ cannot be altogether ignored, especially when all these varieties are almost endemic to the hilly tract of the North-East region.

Looking to the karyotype of the four varieties some interesting features emerge. The karyotypes of Yellow Shillong have the maximum sub-median chromosomes, i.e., 4 pairs are sub-median and 6 pairs are metacentric; whereas, in Sikkim Yellow there are only 3 sub-median pairs and 7 pairs are metacentric (Tables 30 & 32). The difference in the number of chromosome pairs having median and sub-median centromeres is reflected in the T. F. value which is 36.33 in Yellow Shillong and 42.75 in Sikkim Yellow. It thus shows that the intra-chromosomal shifting of centromere and chromosomal segments have taken place in these varieties which are well adapted to local climatic situations. In each of these varieties there are some chromosomes which are longer and others are shorter. The ratio between the longest and the shortest chromosomes are 2.07 μ and 2.40 μ in Yellow Shillong and Sikkim Yellow respectively. The occurrence of long and short chromosomes in one cell have been generally interpretted as having been

contributed from two different progenitors. Thus Kuwada (1919) postulated that longer chromosomes in Z. mays are derived from Euchalena and shorter through other hypothetical progenitor supposed to be an unknown species of Andropogonae. It was on this postulate that he based his idea of hybrid nature of Zea mays. This view has, however, very little support and even in the present primitive varieties no such indication can be ascertained.

Meiosis in a taxon and hybrid provides a very useful source of information on the homology, structural pattern, linearity of genes, chromosomal aberrations, etc. Therefore, meiosis occupies a very important aspect of investigation of species hybrids to understand their ancestory and phylogenetic relationship. There are important research publications showing that the meiotic pairing is under genetic control (Swanson, 1957; Rees, 1961; Ved Brat, 1965). Basic chromosome number and chiasmata per nucleus constitute the recombination index of a species. In several cases chiasma frequencies have been found to be influenced by environmental factors, such as, temperature, rainfall (Elliott, 1955; Dorwick, 1957; Henderson, 1962, 1963). But in the present instance all the varieties have been grown and studied under uniform environmental conditions having the same temperature, soil types, etc., hence,

the influence of environmental factor is ruled out . The chiasma frequency may, therefore, be safely taken as true index of genetic expression. At meiosis all the varieties show 10 bivalents mainly of ring types. Rod bivalents were scarce. At times a few PMCs in an anther did have 9 bivalents and 2 univalents which may have been precociously separated or they may be true univalents. The scoring of ring, rod or spindle shaped bivalents in different frequencies determine the number of chiasmata per nucleus and per chromosome. In this respect, the four varieties have different chiasma frequency at diakinesis and metaphase I and they significantly differ from one another (Table 35). For instance, Garo White has 24.50 chiasmata at diakinesis but the Sikkim White has 21.61. On the other hand Sikkim Yellow has 20.37 and Sikkim White 19.50 at metaphase I. Of course the chiasmata value always decreases from diakinesis to metaphase I due to terminalisation, yet between the two varieties of the same locality, if they differ in chiasmata frequency that may amount to an intrinsic genetic difference between them. It is also held that a variety which is highly homologous has a high chiasma frequency with the result that the recombination index is raised through reshuffling of genes at recombination. Thus the chiasma frequency at diakinesis and metaphase I in these varieties may be taken to reflect some amount of genetic

divergence that have arisen in them to maintain varietal identity.

Pollen fertility is very high in all the four varieties, namely, 90.20%, 90.60%, 87.39% and 86.28% in Yellow Shillong, Garo White, Sikkim Yellow and Sikkim White respectively. Since there were no chromosomal abnormalities at any stage of meiosis, the high fertility of pollen is an expected expression.

From the standpoint of nutritive value, such as, the carbohydrate and protein contents, the four varieties differ from one another. Garo White has the maximum protein content (9.2 mg/g dry wt.) and the minimum value is 5.4 mg/g dry wt. in Sikkim Yellow. But Sikkim Yellow has the highest carbohydrate content (13.4 mg/g dry wt.) and the lowest value in Yellow Shillong (8.7 mg/g dry wt.). These differences in the total protein and carbohydrate contents should be taken to reflect their genetic divergence. The same is true about other two varieties.

In the hybridisation programme among these four primitive varieties, the procedure adopted has been that one variety from the Sikkim area and one from the Shillong area have been hybridised. Since these two States grow their own maize varieties the crossing experiments

could bring out through the hybrid and segregating generations the differences in their genetic make-up. The hybrids raised are : Yellow Shillong (female) x Sikkim Yellow (male) and Sikkim White (female) x Garo White (male). In both these crossings the size of the F_1 hybrids was vigorous and intermediate of the two parents. The colour of the kernels in the first cross Yellow Shillong x Sikkim Yellow was purplish. This indicates that the factors for yellowish kernels in the two varieties are not the same, hence, instead of producing additive effect, the phenotypic expression of the kernel colour has been through genic interaction producing a new genotype, purplish.

In the second cross Garo White x Sikkim White, the F_1 kernel was whitish. But in all other respects the first hybrid, Yellow Shillong x Sikkim Yellow was superior to the Garo White x Sikkim White (Table 36).

The F_1 hybrids were meiotically quite stable in number as well as in pairing behaviour. The karyotype in the hybrid also remained more or less the same as for the parent varieties (Tables 37 & 38). However, due to hybridisation a mixture of chromosome complements may sometime lead to more pairs of chromosomes with sub-median centromeres or less with median or vice versa. Thus the

shift in the symmetry of the karyotype may take place as a result of the hybridisation between the two distinct varieties. Secondary constrictions are absent in the Sikkim White x Garo White but is present in the Yellow Shillong x Sikkim Yellow.

The mean length of chromosomes differ in the two hybrids. The hybrid Sikkim White x Garo White has longer chromosomes (3.25 μ), whereas, Yellow Shillong x Sikkim Yellow has the mean chromosome length of 2.02 μ (Table 39). As in the parents, Garc White x Sikkim White hybrid has a pair of long chromosomes when compared to other chromosomes in the complement and the ratio between the longest and the shortest is 2.16 μ. In Yellow Shillong x Sikkim Yellow hybrid, however, longer chromosomes have not been observed. But little difference exists between the chromosomes as the ratio is 1.85 μ.

Chromosome pairing being quite normal not much information on the internal make up of the chromosomes could be made out. The chiasma frequency is higher at diakinesis than at metaphase (Table 40) in both the hybrids. The value of chiasmata in Yellow Shillong x Sikkim Yellow is 23.90 μ and 20.05 μ at diakinesis and metaphase I respectively. At these two stages the chiasma frequency in the F_1 hybrid Sikkim White x Garo White is 23.08 and 19.75 respectively.

Pollen fertility is high which is expected because of the regular meiosis, but in the two hybrids the value slightly differ (82.27% in the Yellow x Yellow and 82.20% in the White x White). However, in comparison to the parent varieties the pollen fertility is lower. This may be due to cryptic structural differences in the chromosomes of the varieties brought together in the hybrid. Such minute cryptic differences do not hamper normal pairing but result in disharmonious gene combinations giving rise to production of some aberrant and sterile pollen grains. To that extent the pollen fertility data suggest that these primitive maize varieties are distinct and isolated, and possess different set of genes in their chromosome complements. Magoon et al. (1967) interpretted the reduction in pollen fertility and seed set on the basis of such cryptic structural differences in varietal hybrids which grow in geographically distant areas.

Protein and carbohydrate contents in the F_1 hybrids are intermediate of the two parents which again suggest that these two profiles are under genetic control and, hence, acquire the intermediate value between parents and the hybrids.

Summarising the study of the four hill varieties of maize it may be stated that they are distinct and

established primitive varieties well adapted to these hill regions. More and more isolated pockets of the tribal and hill areas need to be covered and all available primitive varieties of maize be collected to ascertain their variability and gene pool. Quite likely some of them still possess more genes of other progenitors and may thus hold the key to illustrate their origin. Even in this collection of four varieties only there is indication of cryptic structural differences in the chromosomes. Similarly, they have features which point to other genera from which they have originated. However, more in-depth collections and modern techniques of chromosomal assay in these primitive varieties and their comparison with the primitive varieties of the New World can be worthwhile to see how much North-Eastern region has contributed to the origin of maize. In this connection it may be stressed that Jain and his associates (personal communication) studied a number of primitive varieties of North-Eastern region, especially their chromosomal make up and recombination index. They found that the DNA content of these primitive maize significantly differ from the New World maize which is also reflected in their different recombination frequencies. On this basis they concluded that these primitive maize varieties of the North-Eastern region are the original progenitors of the

modern maize. They thus supported the views of Anderson and others that maize arose in North-Eastern region of India including Upper Burma. Mangelsdorf (1947) held that the South-East Asian origin of maize is an open question and need to be probed thoroughly. In view of these findings it becomes imperative that more and more collections of the primitive maize varieties of Sikkim, North-Eastern region including Upper Burma be made and suitably assessed with regard to their chromosomal and DNA organisation, meiotic behaviour and recombination in the parents and their hybrids and compare them with the New World maize as well as with the allied genera of Poaceae to elucidate their origin.

S U M M A R Y

SUMMARY

Collections of some cultivated and wild tuberous species of the family Araceae and primitive native strains of maize being cultivated in the remote areas of Meghalaya were made. To suitably assess these accessions, their morphometric, cytological, electrophoretic and inheritance studies have been carried out, the results of which are compiled in the thesis. Such a systematic collection and evaluation of the above mentioned wild germplasms of Meghalaya is almost a new attempt in the study of the rich flora of the region.

1. The tuberous taxa comprise of the genera Amorphophallus, Arisaema, Gonatanthus, Steudnera, Xanthosoma (plain and hill varieties) and Colocasia (15 strains).

2. Amorphophallus bulbifer, Arisaema consanguineum, Gonatanthus ornatus and Steudnera colocasioides grow wild. The 2n number in these species are 26, 28, 30 and 28 respectively. These numbers have been determined for the first time. There is wide range in the size of chromosomes - 1.4 μ to 7.04 μ. The smallest chromosomes are found in A. consanguineum. The detailed measurements of the chromosomes show that they have a

symmetrical karyotype. However, in G. ornatus a few of the chromosomes tend towards asymmetry. Cytologically these species appear to be primitive.

Somatic number suggests basic number as 13, 14 and 15 respectively. But the possibilities of these basic numbers having been derived from a lower number 7 or 8 cannot be precluded. These points of evolutionary importance have been discussed.

3. The two cultivated tuberous species belong to Xanthosoma and Colocasia. Xanthosoma is cultivated in the hills as well as in the plains. The leaf shape in the plain and the hill strains are identical, but they greatly differ in size. Both the varieties of Xanthosoma have $2n = 26$ and are considered diploid. Detailed chromosome measurements indicate that the plain variety has more symmetrical karyotype than the hill variety. The role of chromosomal aberrations in creating karyotypic differences has been stressed.

4. Colocasia esculenta has a large number of strains, 15 of which were collected and studied. Eleven of the accessions are triploids with $2n = 42$ and four are diploids with $2n = 28$. Triploid strains are morphologically and in yield far superior than the diploid strains. The

detailed measurements of the chromosomes and the karyotypes have indicated greater divergence in the position of the centromeres of the chromosome pairs in triploid strains than in the diploid ones. Thus triploids showing greater diversity in morphology, yield and karyotype, provide a richer material for clonal selection and cultivation than the diploids. There is also significant difference in the mean length of the chromosomes of the different strains of Colocasia esculenta. The adaptive significance of the difference in the chromosome length with respect to lower and higher altitudes have been projected. The study has brought out the role of karyotypic changes and random mutations on the divergence of these strains.

5. Using Lowry's method (1951) total protein content in the plain and hill varieties of Xanthosoma sagittifolium was determined, the values being 5.1 and 8.4 mg/g dry wt. respectively. Electrophoretic studies showed characteristic banding pattern with respect to protein and isoperoxidase. In Colocasia esculenta triploid strains have more protein and carbohydrate contents than the diploids. The number of protein bands also are more in triploids than the diploids. The electrophoretic data have provided an insight into the genetic make-up of the

varieties (plain and hill) and strains of Xanthosoma sagittifolium and Colocasia esculenta respectively.

6. The cytological and morphological data, when compared with other works of these genera from other regions of the world indicate that the hill variety of Xanthosoma sagittifolium probably reached Meghalaya and other North-Eastern regions of India from South-East Asia. The plain variety of the species, on the other hand, appear to be a direct introduction from the original American strains. Thus the presence of the hill and plain varieties of this species has two sources of introduction in Meghalaya and, therefore, their cyto-genetic divergence is a result of their having been originated from different centres.

7. Similarly, the diploid forms of Colocasia esculenta are restricted to South India, whereas both diploid and triploid forms are found in Meghalaya, the triploid strains being more wide-spread. It is believed that the triploid strains arose in response to the climatic conditions and ecological demands of the hills of Meghalaya.

8. North-Eastern India including Sikkim still grow primitive maize varieties in remote areas. Anderson (1945) held that North-Eastern India and Western China are probably

the centres of origin of the cultivated maize, the contributing parents being Coix and Sorghum. Be that as it may, the primitive strains of maize of this area do possess several features of Tripsacum, one of the important contributors to the genome of Zea mays. Four varieties of maize - Yellow Shillong, Garo White, Sikkim Yellow and Sikkim White, all with $2n = 20$, were collected and grown for their morphological and cytological studies along with the hybridisation programme. The total chromatin length in these four primitive varieties differ widely from one another. It is significant that Jain (personal communication) pointed out the great difference in DNA contents of these primitive varieties of maize with that of the American maize varieties. Detailed karyotype and the position of centromeres among these varieties indicate intra-chromosomal shiftings, presumably as an adaptation to the ecological niches. At meiosis the chiasma frequency in these varieties differ from one another indicating the different recombination index. The recombination index in these varieties is again quite different from the cultivated varieties brought from the American continent.

In protein and carbohydrate contents also the four varieties differ indicating their genetic divergence. F_1

hybrids between Yellow Shillong x Sikkim Yellow and Garo White x Sikkim White showed intermediateness in the expression of characters. In the seed colour the hybrids showed gene interaction than simple dominant and recessive relationship indicating that the different varieties carry different loci for seed colour. Although meiosis was normal in the hybrids, the pollen fertility was slightly lower than in the parents. The lower fertility of pollen may be due to cryptic structural differences in the chromosomes of primitive strains.

The data on these four primitive maize varieties indicate that they are distinct and well established varieties, well adapted to these hill regions. More in-depth collections and modern technique of chromosome assay, namely, DNA hybridisation, etc. with the new world maize may prove rewarding about their relationship as well as their separate or identical origin. Further, the conservation of these primitive varieties of maize growing in all the hill areas of North-Eastern India need to be maintained as they are definitely more ancient germplasms and are expected to possess many dominant and useful genes not found in the improved varieties.

9. Similarly, wider and systematic collections of other tuberous crops of the genera mentioned above as well as of other genera need to be made, screened and assessed for fuller utilisation.

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