STUDIES IN THE GENUS *Areca* L.

(CYTOGENETICS AND GENETIC DIVERSITY OF *A. catechu* L. AND *A. triandra* Roxb.)

By

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CERTIFICATE

This is to certify that work for the thesis entitled "STUDIES IN THE GENUS Amaranthus L. (CYTOGENETICS AND GENERIC DIVERSITY OF *A. caudatus* L. AND *A. frumentaceus* Roxb.)" submitted by Shri K.V. Ahamed Devaypa for the Degree of DOCTOR OF PHILOSOPHY in the University of Mysore, Mysore, was carried out at the Central Plantation Crops Research Institute, Regional Station, Vittal, South Kanara, Karnataka State, under my guidance.

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DECLARATION

I do hereby declare that the thesis entitled "STUDIES IN THE GENUS *ANNONA* L. (CYTOGENETICS AND GENETIC DIVERSITY OF *A. squamosa* L. AND *A. hybrida* Hort.)" which I am submitting for the Degree of DOCTOR OF PHILOSOPHY, in the University of Mysore, Mysore, is the result of work carried out by me at the Central Plantation Crops Research Institute, Regional Station, Vittal, South Kanara, Karnataka State, under the guidance of Dr. K.N. Narayan, M.Sc.,Ph.D.(Calif.), Professor and Head of the Department of Botany, University of Mysore. I further declare that this work has not been previously submitted for any Degree either in this or in any other University.

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CONTENTS

INTRODUCTION

The genus ARECA L. belongs to the tribe Areceae of the family Palmae. Different authors have recognised varying number of species in the genus (Bentham and Hooker, 1883; Ridley, 1925; Blatter, 1926 and Murthy and Bavappa, 1962). Among the ARECA species, A. catechu L. popularly known as betelnut palm, is the only cultivated one.

The nut of areca palm is used as a masticatory in India, the Middle East and the Far East. India is the biggest producer and consumer of arecanuts. It has been estimated that over four million people are connected with this industry in India. The crop is commercially important to the states of Kerala, Karnataka, Assam, West Bengal, Maharashtra and Tamil Nadu.

The breeding system of the palm, the perennial habit and the long juvenile phase constitute the chief barriers in undertaking cytogenetical and breeding investigations in this crop. Intraspecific variability existing in A.catechu has been reported from Philippines, Malaya, Ceylon and India (Beccari, 1919; Sands, 1926; Malegede, 1944 and Raghavan, 1957) based mostly on fruit size and certain anatomical characteristics.

In the genus ARECA, cytological work done in the past has been confined to the reporting of chromosome

numbers, their morphology and meiotic analyses of a few cultivars and species (Venkatasubban, 1945; Raghavan, 1957 and Devappa and Raman, 1965). From cytomorphological studies, Devappa (1965) inferred that structural changes in the chromosomes, alterations in chromosome size and gene mutations have played a part in the differentiation of cultivars and species.

The role of cytogenetic investigations in determining phylogenetic relationships among the species has been well recognised (Anderson, 1951; Levitsky, 1951; Babcock, 1947; Grant, 1971 and Stebbins, 1971). In the family Palmae, the first such large scale attempt at using the cytological information such as chromosome number, size and morphology as an aid in the classification was made by Sharma and Sarkar (1956).

In recent years, newer and sophisticated techniques have been employed in phylogenetic studies. The usefulness of multivariate analysis to classify biological populations based on genetic divergence has been established in several plant species (Nair and Mukherjee, 1960; Rao, 1960; Murty and Arunachalam, 1962; Gannie, 1963; Jeswani, Murty and Mehra, 1970). Similarly, protein and enzyme variations have been found to provide additional clues for a better understanding of species relationships (Johnson and Hall, 1965; Gottlieb, 1971 and Peirce and Brewbaker, 1973).

In the present investigation, an attempt has been made to study the differentiation and relationship between the three Avena species viz., A. sativa L., A. brevis Roth. and A. sterilis Linn. using morphological cytogenetical, biometric and biochemical techniques. The genetic divergence in 13 cultivars of A. sativa and four ecotypes of A. brevis have been determined using the D^2 statistic of Mahalanobis (1936). Hybrids involving A. sativa and A. brevis have been studied for the first time. The species relationships have been corroborated through electrophoretic analysis of isoenzymes.

Based on the morphologic and cytogenetic data obtained in respect of parents and their hybrids the causes of sterility in the parents and hybrids, mode of reproduction in the parents and the extent and direction of differentiation among and between the two species have been examined. The significance of these results in widening our knowledge on the phylogeny of the genus Avena and in aiding breeding programmes are presented in this thesis.

PREVIOUS WORK

Bentham and Hooker (1883) in their treatise "Species Plantarum" treat the genus *Areca* as the first one in the family Palmae under the tribe Areceae. Hooker (1894) and Ridley (1925) follow the same order in the treatment of the genus in their "Flora of British India" and "Flora of Malaya Peninsula" respectively. The disagreement existing among the taxonomists on the correct specific epithet of the betelnut palm was clarified by Davappa (1964).

Watt (1889) mentions 24 species of *Areca* but has given description of only *A. catechu* L., *A. concinna* Thw. and *A. gracilis* Roxb. Hooker (1894) also recognised only 24 species and has described in detail *A. catechu*, *A. triandra* Roxb., *A. concinna* and *A. gracilis* Griff. According to Beccari (1919) there are 36 species in the genus. Ridley (1925) described six species occurring in the Malay Peninsula. According to him the number of species in the genus is only ten. Blatter (1926) however visualises the number of species as 40. Kirtikar and Basu (1933) endorse this number. The Royal Horticultural Society (Anon., 1956) however has recognised only 15 species. Davappa (1963) after a critical review has listed 66 species of *Areca* spread over 25 countries.

Rao (1915) based on the sweet kernel of mature fruit has described a new "variety" of arecanut from

Mysore as A. catechu var. deliciosa. Roxburgh (1919) has also used the term "variety" in describing the areccanuts of Philippines. According to him there are four varieties in the Philippines, namely, A. catechu var. communis, A. catechu var. silvestris, A. catechu var. intermedia and A. catechu var. longicarpa, the distinguishing characters being the size and shape of the fruits and their kernels. Sands (1926), Grist (1926), Molegode (1944), Iyer (1950) and Rumbier (1954) have referred to the variations in A. catechu occurring in Malaya, Ceylon and South India as "varieties" and designated them by local names. According to Kasasagara (1941) there are apparently no distinct varieties in Mysore. Raghavan and Baruah (1956 b) have used the term "type" while describing the variations of areccanut occurring in Assam stating that "type" is used in a restricted sense and does not necessarily indicate distinct types based on botanical characters. They have used size, shape, weight, volume and colour of fruits; weight, volume and thickness of husk, and endosperm and embryo characters for the study. The same authors (1958) reported similarity in the anatomy of the fruit stalk of these types. However, Roxburgh (1919) used features such as disposition of vascular bundles in the fruit for classification of varieties of A. catechu. Murthy and Bavappa (1962) employed the term "ecotype" (cultivar) in attempting to study the variation pattern

of the palm in South India based on length and breadth of nuts.

Ramappa (1966 a) conducted detailed morphological and anatomical studies in A. eichleri and A. triandra and identified certain characters such as the number of offshoots, number of nuts per palm, mean weight of nut, number of stomata per unit area and the stomatal index that could be used to distinguish between the two species of A. eichleri and A. triandra as well as the different varieties of A. eichleri. The presence of thicker cuticle in A. triandra and its bearing on the relative resistance of this species to the infestation by mites has also been brought out by him. Detailed studies on floral biology and dispersal of pollen in A. eichleri have been made by Murthy and Ramappa (1960 a, 1961). Observations on the common abnormalities in arecanut (Murthy and Ramappa, 1959) and those with special reference to floral parts (Ramappa and Murthy, 1961) showed that the number of stamens in A. eichleri ranged from zero to six.

The chromosome number of 2n = 32 for the species was first determined by Venkatasubban (1945) and subsequently confirmed by Sharma and Sarkar (1956), Raghavan and Ranga (1958), Abraham, Mathew and Nair (1961) and Ramappa and Rama (1965). Sharma and Sarkar (1956) reported that they could get meiotic stages in flower buds collected from fully emerged spadix where the component spikes were covered by

their hybrids. The authors have also recorded certain meiotic irregularities such as non-disjunction and lagging of bivalents and univalents and pentads. Sarkar (1956) in the course of his observations made on meiosis with reference to male sterility has also observed similar irregularities. He also found that 15.8 per cent of the pollen grains from these anthers were inviable as judged from the germination percentage. Raghavan and Baruah (1956 a) have reported varying frequencies of pollen sterility ranging from three to 100% in the different types of arecanuts of Assam investigated by them. The sterility in respect of the female flowers of these types was however found to vary from 34 to 54 per cent. The probable causes of female sterility according to these authors are (i) dichogamy, (ii) presence of sterile pollen grains, (iii) failure of pollen grains to germinate, (iv) length of pollen tubes being insufficient to reach the ovule, (v) a shorter longevity of pollen grains and the receptivity of stigma and (vi) effect of temperature on the germination of pollen grains. Iyengar and Raman (1935) after a detailed study of the different stages of meiosis recorded a number of phenomena in the nature of (a) segmental interchange, (b) chromatin bridge and fragment, (c) precocious separation of bivalents, (d) non-synchronised anaphase plates, (e) delayed disjunction bridges, (f) chromosome meiotic cells and (g) cytomixis, which culminate as they

should in the ultimate formation of inviable pollen. Based on the observation that unpollinated flowers of the female plants in dioecious palms develop into fruits with normal seed and embryo, Sharma and Sarkar (1956) suspected apomictic development in such palms.

The chromosome morphology of a few cultivars of A. sakuntala from Assam studied by Raghavan (1957) showed that minor variations in structure and length of individual chromosomes, in the total length of the complement and presence, absence or position of the constrictions, existed among the types and that the chromosome size varied from 0.7 μ to 4.0 μ. On the basis of morphology the individual chromosomes in these types could be demarcated into nine groups.

Based on the chromosome morphology Banerjee (1963) could classify 16 chromosome of an ecotype of A. sakuntala from South Kanara into seven groups. He also studied its prophytosis chromosomes and compared the same with somatic chromosomes. Based on secondary association and the seven groups into which the chromosomes could be classified on the basis of morphology, it has been deduced that the cultivated A. sakuntala is a secondary allotetraploid having a basic number of seven. Based on the gross differences between the karyotypes of A. sakuntala and A. triandra, Sharma and Sarkar (1956) suggested separate generic status for the two species and emphasized the need for a thorough

study of the morphological and anatomical characters of the various species of Areca.

Biometrical methods have been extensively used in the improvement of arecanut crop. Phenotypic and genotypic correlations of various growth characters of seedlings recorded at the time of transplanting to the main field and at the end of first and second year thereafter with yield during first, second, third and fourth years of bearing and cumulative yield for these four years have been worked out by Nayeppa and Ramachander (1967 a, b). Among the various growth characters studied by them the number of leaves at the time of planting and girth at collar, and number of nodes after one and two years after planting respectively were found to have high heritability as well as positive significant phenotypic and genotypic correlations with yield. As the heritability of yield in arecanut was low (Nayeppa and Ramachander, 1967 c) a search for characters having high heritability and correlation with yield was made. Among various characters examined, age at first bearing alone was found to have high heritability and negative correlation with yield. Percentage of nut set was observed to have high correlation with yield but medium heritability (Nayeppa and Ramachander, 1967 c and 1968 b). A mass-pedigree selection programme for arecanut has been drawn up by Nayeppa and Ramachander (1967 c, 1968 a).

Using 17 growth characters and 12 yield components Ramachander and Iruvappa (1972) worked out selection indices for different groups of characters following Smith's method of discriminant function (Smith, 1936). An index based on all the 29 characters was five times more efficient than the straight selection based on yield alone. The major contribution to this efficiency was by 17 growth characters of which those characters having high heritability at the time of planting were most important. An index based on only two characters viz. number of leaves and height was found to be three times more efficient than straight selection (Iruvappa, 1970).

Literature available on the genetic diversity of palms is meagre. The only reported study of genetic divergence using Mahalanobis' D^2 statistic is in coconut (Cocos nucifera L.) by Iruvappa, Subramonian and Jacob Mathew (1975). They found that the individual cross combinations of West Coast Tall x Dwarf Green differed significantly for all the 13 characters studied and that 9 cross combinations could be grouped into four clusters depending on the similarities of their D^2 values. Their study also indicated that phenotypic uniformity can involve considerable genetic diversity and that proper choice of palms even among Tall and Dwarf varieties of coconut may be necessary for the efficient exploitation of these hybrids. Iruvappa and Pillai (1974), while studying the yield components in a

germplasm collection of arecanut observed that there is significant variation between the different cultivars and ecotypes of *A. catechu* and *A. triandra* for various characters. Barring this, no attempt to classify them based on large number of characters or groups of characters has been made so far.

MATERIALS AND METHODS

The two species of *A. sativum* and *A. javanica* used in the present investigation are from the germplasm collection maintained at the Central Plantation Crops Research Institute, Regional Station, Vittal. Since the material included 19 forms of the cultivated *A. sativum* and four forms of wild *A. javanica* (Table 1), the term "cultivar" has been used for the forms of the former and "ecotypes" for those of the latter in the light of the definition by Turesson (1922). They were planted in a randomised block design with four replications and single tree plots, in 1961 and were utilised along with the local cultivar grown in bulk at the Institute farm.

The validity of nomenclature was checked up in respect of each of the introduction when it was observed that VTL-21 (Ceylon-5) did not conform to the description of *A. sativum*. This was found to be *A. javanica*. This identification was confirmed by Dr. Harold, E. Moore Jr. of Bailey Hortorium, Ithaca, New York and Dr. Robert W. Read, Department of Botany, Smithsonian Institution, Washington D.C. (1973, personal communication).

Crossing between *A. sativum* and *A. javanica* was done following the method described by Murthy and Ravappa (1960 b). The portion of rachillae bearing the male flowers in the pistil parent were clipped off before the commencement of the female phase and the inflorescence bagged

Table 1. Details of the cultivars of *A. esculentus* and ecotypes of *A. tricuspis*

Sl. No.	Accession No.	Place of collection	Name of species
1.	VEL-5	Ceylon-1	*A. esculentus*
2.	VEL-15	Ceylon-2	"
3.	VEL-11	Indonesia-6	"
4.	VEL-12	Saigon-1	"
5.	VEL-13	Saigon-2	"
6.	VEL-14	Saigon-3	"
7.	VEL-16 a	Br. Sol. Islands-1*	"
8.	VEL-16 b	Br. Sol. Islands-2	"
9.	VEL-16 c	Br. Sol. Islands-3	"
10.	VEL-3	China	"
11.	VEL-17	Singapore	"
12.	VEL-1	Fiji	"
13.	VEL-6	Indonesia-1	*A. tricuspis*
14.	VEL-7	Indonesia-2	"
15.	VEL-2	Mauritius	"
16.	VEL-21	Ceylon-3**	"
17.	VEL	Local	*A. esculentus*

* British Solomon Islands

** Introduced as *A. esculentus*

When the female flowers started opening, the inflorescence was partially exposed and fresh male flowers collected from the pollen parents were brought and the pollen dusted on the stigmatic lobes. The inflorescence was bagged soon after the pollination which was normally done between 8 and 10 a.m. Pollination was continued every day morning till all the female flowers of the inflorescence were pollinated which usually took five to seven days. One week after the completion of pollination, the bag was removed and the bunch labelled. The details of crosses made are given in Table 2.

The ripe nuts were harvested and immediately sown in primary nursery. The sixth month old sprouts were transplanted to the secondary nursery, where they remained for one year. The hybrid seedlings from secondary nursery were transplanted during June 1968 to the main field at a spacing of 2.7 m x 2.7 m.

In order to gather evidence in support of the occurrence of apomixis, inflorescences of both A. guineense and A. kingianum were emasculated prior to the opening of female flowers and bagged. The nut set (percentage of female flowers set two months from the date of pollination) was recorded. Pollen germination on the stigmatic surface of both the crosses was also studied in vivo using aniline blue lacto-phenol method (Darlington and La Cour, 1960).

Table 2. Details of interspecific crosses involving *A. sativum* and *A. hirsutum*

Sl. No.	Female parent	Male parent	No. of female flowers crossed	Set after two months	Nut set %	Maturity* period of nuts (days)
I	*A. hirsutum* x *A. sativum*					
1.	Ceylon-3 (70)	Local (342)	483	128	26.5	163
2.	Indonesia-2 (154)	Local (511)	1864	369	19.8	161
II	*A. sativum* x *A. hirsutum*					
3.	Local (717)	Mauritius (109)	120	27	22.5	287
4.	Local (739)	Mauritius (109)	149	5	3.4	302
5.	Local (690)	Mauritius (109)	360	7	1.9	287
6.	Local (471)	Ceylon-3 (70)	220	18	8.2	334
7.	Local (677)	Ceylon-3 (70)	126	24	19.0	291
8.	Local (761)	Ceylon-3 (70)	271	29	10.7	288
III	Open pollinated					
9.	Ceylon-3 (70)		53	32	60.4	163
10.	Local (717)		86	11	22.5	287

*Number of days taken by nuts from the date of pollination to ripening.

The morphology of the two parents involving two cultivars of A. sativa and three ecotypes of A. brevis and their interspecific hybrids including a spontaneous hybrid was studied for the following important characters which distinguish A. sativa and A. brevis:

1. Number of anthers including main stem
2. Internodal distance at fixed mark (cm)
3. Girth of stem at fixed mark (cm)
4. Number of leaves per main stem
5. Number of leaves per clump
6. Length of leaf (cm)
7. Length of spadix (cm)
8. Number of female flowers per bunch
9. Length x breadth of female flowers (cm)
10. Number of male flowers per bunch
11. Length x breadth of male flowers (cm)
12. Number of stamens
13. Arrangement of male flowers
14. Length x breadth of fruit (cm)

Note:- Character 6 - mean of four observations

Characters 9, 11 and 14 - mean of 10 observations

Two cultivars of A. sativa (local and China) three ecotypes of A. brevis and their hybrids were studied for their meiotic behaviour. In the A. brevis x A. sativa hybrids the study was confined

to a single plant due to their close similarity to the A. brizantha parent. For the study of meiosis, the inflorescence was split open to expose the enclosed male flowers. Flower buds collected between 10.30 and 11.30 a.m. from inflorescences 80 to 90 days prior to the leaf fall were found to be most suitable. They were fixed in Carnoy's fluid (6 parts ethyl alcohol, 3 parts chloroform, 1 part glacial acetic acid), retained in the fixative for 4 hours and later washed and stored in 70 per cent ethyl alcohol. The anthers were squeezed in 1 per cent iron-aceto-carmine. The course of meiosis was studied mostly from temporary preparations and these were also made permanent wherever necessary following the method of Swaminathan, Magoon and Mehra (1954).

For the study of pollen fertility, flowers from the middle of the rachilla were collected and anthers which were about to dehisce were squeezed in 1 per cent aceto-carmine - glycerine (1 : 1). Well filled and well stained pollen grains were scored as normal while unstained and shrivelled ones were scored as sterile. Pollen germination studies were taken up in vitro adopting the hanging drop technique. As it was found that the stainability and germination data are in agreement, pollen stainability has been taken as pollen viability.

In addition to the karyotype of the parents and hybrids studied for meiosis, karyotypes of six cultivars

of *A. gabonica* and one ecotype of *A. brianica* were also analysed. The chromosome morphology was studied from the root tip squashes following the method developed by Jagathesan and Rathnambal (1967). The technique in brief consists of pre-treating the root tips in a saturated solution of alpha bromonaphthalene at low temperature (5°C) for two hours, fixing in "Ostergren and Hansen's (1962)" fixative (60 ml methyl alcohol, 30 ml chloroform, 20 ml water, 1 gm picric acid and 1 gm mercuric chloride) for 24 hours, hydrolysing in 1N HCl for 32 minutes, staining in 0.5% leuco basic fuchsin for 30 minutes and squashing in 1 per cent aceto-carmine. The maximum divisions were obtained in root tips fixed between 11 and 12 a.m. under Vittal conditions. Well spread and intact metaphase plates alone were considered for study. All the drawings were made at table level using Carl-Zeiss microscope with x 100 objective x 15 ocular and a Beck Lucedi drawing apparatus. Five well spread metaphase plates were drawn for each parent/hybrid and the chromosomes were numbered and measured. The measurements of long and short arms were done separately excluding the primary constrictions. The chromosomes were paired and the average values for five cells arrived at for chromosome length and arm ratio (long/short). In the case of satellite chromosome, the length of satellite was included in the arm bearing it. The chromosome length was expressed as percentage of total chromatin length in each cell.

In representing the karyotype diagrammatically, the chromosomes were arranged in the decreasing order of length. Chromosomes falling within the same length were arranged in the decreasing order of arm indices (Hansen, 1962), the end of the long arm always directing downwards. The primary constrictions were represented by a gap of 2 mm and secondary constrictions by a gap of 4 mm (Malik and Thomas, 1966).

The photographs were taken with a Carl-Zeiss bellow camera on orthochromatic film of 2 b size and enlarged to the magnification specified in the legend.

For electrophoretic studies sheets of two month old seedlings were ground in a cold mortar and pestle with 0.05 M Tris-HCl buffer. The cell paste suspension was centrifuged at 20,000 x g for 30 minutes and the supernatant crude extract was used for electrophoresis after determining the protein content as per the method described by Lowry et al. (1951).

Polyacrylamide gel electrophoresis technique outlined by Davis (1964) and Ornstein (1964) was employed to study the isoenzyme pattern of esterase in A. sativum and A. triandra. Samples, containing 150 mg of protein, were applied to each gel column over spacer gel and electrophoresis was carried out using Tris-glycine buffer (pH 8.3) for 90 minutes at 3 mA current per gel column, using bromophenol blue as the tracking dye.

After electrophoresis, the gels were removed from the tubes and incubated in the staining mixture at 20°C till the bands of enzyme activity appeared on the gel. The staining mixture contained per ml of phosphate buffer (pH 5.9), 0.5 mg of diazotised product of 4 benzoylamino-2, 5- dimethoxy aniline - zinc chloride and 25 mg alpha naphthyl acetate. The reaction was stopped with 7 per cent acetic acid and the gels were stored in 7 per cent acetic acid. Rf values were calculated and the densitographs of the isoenzyme patterns were prepared by scanning the gels on chromoscan (Joyce Loebl, England). The similarity index was calculated as

$$\frac{\text{number of pairs of similar bands}}{\text{number of dissimilar bands} + \text{number of pairs of similar bands}}$$

The band homology between the two species was established by running co-electrophoresis with the mixed extract (50:50) of the two species.

Growth measurements and anatomical observations of all the cultivars and ecotypes were recorded for estimating the genetic divergence. During 1963, before the plants commenced flowering, observations in respect of six characters were recorded. After the commencement of flowering detailed observations were taken in respect of 40 characters, including anatomical features, during 1966. Recording of observations were repeated in respect of 24 out of 40 characters in 1972. The data for the years 1963, 1966 and 1972 were

analysed independently. The pooled data for the 24 common characters of 1966 and 1972 were also analysed. Separate analysis was also carried out with the 24 characters of 1966 used in pooled analysis. The following were the characters on which observations were recorded in different years:-

1963

1. Number of suckers, including main stem
2. Total height (cm)
3. Girth at collar (cm)
4. Girth below crown (cm)
5. Number of functioning leaves
6. Number of nodes

1966 and 1972

1. Height, above fixed mark (cm)
2. Girth at fixed mark (cm)
3. Girth below crown (cm)
4. Internodal distance at fixed mark (cm)
5. Internodal distance at last node (cm)
6. Number of bunches harvested during the year
7. Number of inflorescence
8. Number of functioning leaves
9. Angle of leaf to the stem (°)
10. Number of leaflets
11. Number of mid-rib
12. Length of longest leaflet (cm)
13. Breadth of broadest leaflet (cm)

14. Length of leaf without sheath (cm)
15. Length of leaf sheath (cm)
16. Breadth of leaf sheath (cm)
17. Length of fruit (cm)
18. Breadth of fruit (cm)
19. Weight of nut (gm)
20. Mean volume of nut (cc)
21. Length of kernel (cm)
22. Breadth of kernel (cm)
23. Weight of kernel (gm)
24. Volume of kernel (cc)

1966 only

25. Intensity of selfing or crossing
26. Number of female flowers produced during the year
27. Stomatal index
28. Length of stomatal pore (μ)
29. Length of epidermal cells (μ)
30. Length of guard cells (μ)
31. Breadth of guard cells (μ)
32. Breadth of epidermal cells (μ)
33. Length of spathe (cm)
34. Breadth of spathe (cm)
35. Longevity of leaves (days)
36. Interval between successive leaf fall (days)
37. Duration of male phase (days)

38. Duration of female phase (days)

39. Number of epidermal cells per unit area

40. Number of stomata per unit area

Note:- Characters 9 to 14 - mean of 4 observations

" 17 to 24 - mean of 12 observations

" 28 to 32 and 39 and 40 - mean of 15 observations

" 33 to 38 - varying number depending on number of leaves and bunches

Of the different aspects of floral biology the breeding mechanism is of considerable importance. In arecanut which is a monoecious palm with unisexual flowers this is generally studied by recording the duration of the male and female phases as well as their overlapping. As these data will not individually represent the extent of selfing or crossing taking place in a cultivar, the three independent observations had to be pooled to make it meaningful. Since the index thus obtained has to effectively represent inter-spadix and intra-spadix pollination taking place within a palm, the data on the number of days on which there was overlapping of male and female phases both within the bunch and between bunches were converted into relative variables using a scale of 0 to 1, 0 being complete out crossing and 1 being complete selfing. Intermediate figures for selfing were arrived at by dividing the number of days

for which the female flowers were exposed to the male phase by the total number of days taken for completion of female phase. Values thus obtained were totalled and divided by the maximum value for complete selfing and multiplied by 100 to obtain the percentage of selfing. If there are n bunches continuously on a tree and if the selfing intensity values within the bunch are $ww_1, ww_2, \ldots\ldots\ldots, ww_n$ and between bunches $bw_1, bw_2, \ldots\ldots\ldots, bw_{n-1}$ the selfing intensity of the tree will be

$$\frac{(ww_1 + ww_2 \ldots\ldots\ldots + ww_n + bw_1 + bw_2 \ldots\ldots bw_{n-1}) \times 100}{n+n-1}$$

The epidermal pattern of leaf in the cultivars and ecotypes was studied following the method of Clarke(1960). The method involved immersion of leaf samples collected from top leaflet of 8th leaf between 8 and 8.30 a.m. in a beaker of boiling water for three to five minutes and thereafter transferring to 70 per cent ethyl alcohol. The decolourised leaf sample was again transferred to 50 per cent warm lactic acid for 10-15 minutes to clear the cells and stored in cold lactic acid. A portion of the treated leaf is placed on a black tile and the surface scraped carefully with a surgical scalpel held at an angle. The midrib is extracted by splitting the cuticle and carefully dissecting it away. The vascular tissues are also scraped until single cell layer of epidermal tissue is left behind. This strip is stained with 1% solution of

cotton blue, destained in 1:1 lactophenol and finally mounted in glycerine. The leaf sampling technique, was standardised using the local cultivar based on samples collected from all leaves on the crown at three locations (first, middle and last leaflets of each leaf). Observations on the number of epidermal cells and stomata per unit area, length of stomatal pore and length and breadth of guard cells and epidermal cells were recorded. From the mean values and c.v. it was observed that the sample from the top leaflet of the 8th leaf had the least variability when all the characters were considered together. Leaf samples from this portion of the leaf were, therefore, collected for the study. Stomatal index (I) was arrived at using the formula $I = \frac{S}{S+E} \times 100$ (Salisbury, 1927) where S = number of stomata per unit area and E = number of epidermal cells per unit area.

The differences between cultivars for each year of observation was tested using analysis of variance taking the individual characters separately. The character means of the cultivars were transformed to uncorrelated variables, by the pivotal condensation of the common dispersion matrix (Rao, 1952) and then transformed into standardised uncorrelated variables. After transformation to uncorrelated variables, the actual values of D^2 (square of Mahalanobis' generalised distance) between any two cultivars based on all the

characters were calculated. Thus for each year there were 136 values.

With a view to determining constellations, all the cultivars were grouped into a number of clusters on the basis of D^2 values using Tocher's method (Rao, 1952). On the basis of intra- and inter-cluster distances spatial diagrams were drawn. The grouping obtained using D^2 statistic was confirmed by canonical analysis. The relative positions of the different cultivars were depicted in a two dimensional plane taking the first two canonical vectors as co-ordinate axes. All the analyses excepting that of 40 characters were carried out on the IBM-1620 Electronic Computer of the Institute of Agricultural Research Statistics, New Delhi. In respect of 40 characters recorded during 1966 the analysis was done on the IBM 360/44 computer of the Delhi University.

RESULTS

I. MORPHOLOGY

Two cultivars of *A. sativum*, three ecotypes of *A. brizantha* and their interspecific hybrids including a spontaneous hybrid obtained (*A. sativum* China x *A. brizantha*) were studied for the 14 important characters. The results are presented in Table 3.

1. Number of suckers including main stems: The number of stems in both the cultivars of *A. sativum* was only one each (Plate I, Fig. 1) while in the different ecotypes of *A. brizantha* it varied from two to sixteen (Plate I, Fig. 2) due to its suckering habit. In the *A. sativum* x *A. brizantha* hybrid the stem number was one (Plate I, Fig. 3) while in the reciprocal hybrid the number of stems varied from six to 10 (Plate I, Fig. 4). In respect of this character the hybrids in all the cases were similar to the female parent.

2. Internodal distance at fixed points: The internodal distance recorded 75 cm above the bole ranged from 5.5 to 18 cm in *A. sativum* while in *A. brizantha* it was 3 to 22 cm. In the *A. sativum* x *A. brizantha* hybrids the internodal distance exceeded both the parents. In the reciprocal hybrid the internodal distance ranged from 11 to 18 cm.

Table 3. Morphological characteristics of *A. sativum*

Sl. No.	Characters	*A. sativum*			
		Local		China	
		777	471	173 (Plate II, Fig. 1)	111
1.	Number of stems	1	1	1	1
2.	Internodal distance at fixed mark (cm)	16.0	18.0	5.5	6.0
3.	Girth of stem at fixed mark (cm)	47.0	57.0	40.0	37.0
4.	Number of leaves per main stem	10	10	9	9
5.	Number of leaves per clump	10	10	9	9
6.	Mean length of leaf (cm)	211.0	200.0	195.6	188.0
7.	Mean length of spadix (cm)	53.0	57.0	64.0	51.0
8.	Number of female flowers per bunch	416	351	306	472
9.	Mean length x breadth of female flowers (cm)	1.63x0.89	1.85x1.03	1.61x1.17	1.94x1.02
10.	Number of male flowers per bunch (appx.)	37934	26784	36112	35257
11.	Mean length x breadth of male flower (cm)	0.44x0.23	0.45x0.23	0.44x0.22	0.48x0.23
12.	Number of stamens	6	6	6, occasionally 5	6, rarely 5
13.	Arrangement of male flowers	Single biseriate alternate	Single biseriate alternate	Single biseriate alternate	Single biseriate alternate
14.	Mean length x breadth of fruit (cm)	5.6x3.9	5.6x3.5	5.5x4.7	5.7x4.5

. A. brianica and their hybrids

A. ambigua x A. brianica				
248	257 (Plate II, Fig. 3)	258	307	Sp. hybrid
1	1	1	1	1
22.0	25.0	14.0	18.0	21.0
40.0	40.0	37.0	39.0	31.0
10	9	9	10	10
10	9	9	10	10
208.0	195.0	215.0	193.0	188.0
80.0	96.0	90.0	91.0	46.0
2469	2274	2879	3005	1006
1.08x0.64	1.15x0.52	1.09x0.33	1.29x0.55	1.08x0.85
44919	40256	52724	57385	48270
0.20x10	0.30x0.15	0.33x0.14	0.20x0.09	0.37x0.16
3 to 5	Mostly 5 rarely 4	Mostly 4 occasionally 3 or 5	mostly 5 occasionally 4	mostly 6 rarely 5
Pairs bisseriate alternate	Pairs bisseriate alternate	Pairs bisseriate alternate	Pairs bisseriate alternate	Pairs bisseriate alternate
4.4x2.1	4.2x1.8	4.3x2.4	4.1x2.3	4.8x2.8

Table 3. Morphological characteristics of *A.*

Sl. No.	Characters	*A. balbisiana* x *A. schizocarpa*		
		249 (Plate II, Fig. 4)	252	267
1.	Number of stems	7	6	6
2.	Internodal distance at fixed mark (cm)	18.0	18.0	17.0
3.	Girth of stem at fixed mark (cm)	24.0	23.1	23.1
4.	Number of leaves per main stem	9	8	8
5.	Number of leaves per clump	36	32	28
6.	Mean length of leaf (cm)	169.0	186.0	184.0
7.	Mean length of spadix (cm)	50.5	52.5	51.0
8.	Number of female flowers per bunch	549	402	449
9.	Mean length x breadth of female flowers (cm)	0.92x0.54	0.75x0.90	0.89x0.92
10.	Number of male flowers per bunch (appx.)	22155	35690	37574
11.	Mean length x breadth of male flower (cm)	0.25x0.10	0.22x0.10	0.25x0.10
12.	Number of stamens	3	3	3
13.	Arrangement of male flowers	Pairs, uniseriate	Pairs, uniseriate	Pairs, uniseriate
14.	Mean length x breadth of fruit (cm)	Not available	2.92x1.48	Not available

[redacted] hybrids (Contd.)

A. Intercross					
271	Ceylon-3 55	70	87 (Plate II, Fig.2)	Mauritius 109	Indonesia-2 154
19	11	16	16	4	2
11.0	3.0	22.0	11.0	17.0	15.0
24.1	15.0	20.0	16.0	20.0	20.0
8	7	8	7	8	7
44	30	92	74	27	14
176.0	101.0	187.0	168.0	205.0	138.0
47.0	40.0	51.0	38.0	45.0	41.0
299	340	421	206	864	910
0.77±0.42	0.87±0.48	0.44±0.21	0.95±0.47	0.98±0.54	0.95±0.38
25990	27762	22845	19994	30452	26964
0.23±0.10	0.22±0.10	0.21±0.10	0.[illegible]2±0.10	0.23±0.10	0.22±0.10
3	3	3	3	3	3
Pairs, uni-seriate	Pairs, uni-seriate	Pairs, uni-seriate	Pairs, uni-seriate	Pairs, uni-seriate	Pairs, uni-seriate
2.9±1.41	2.7±1.5	2.8±1.4	2.8±1.5	3.3±1.4	2.8±1.3

PLATE I

Parents and hybrid calyx

Fig.1 : A. subulata

Fig.2 : A. bidentata

Fig.3 : A. subulata x A. bidentata

Fig.4 : A. bidentata x A. subulata

PLATE I


ARECA CATECHU
VTL 3
1


ARECA TRIANDRA
2


A.CATECHU+ATRIANDRA
3


ATRIANDRA+A.CATECHU
4

3. Girth of stem at first month:- A. brisaeka ecotypes are thin stemmed as compared to A. galeeka. The girth in A. brisaeka ranged from 15 to 20 cm while in A. galeeka it was 37 to 57 cm. The A. galeeka x A. brisaeka hybrids had a stem girth almost intermediate to both the parents and ranged from 31 to 40 cm. In the reciprocal hybrid the girth ranged from 23.1 to 25.1 cm.

4. Number of leaves per main stem:- The cultivars of A. galeeka had more number of leaves (9-10) compared to A. brisaeka (7-8). The number of leaves in A. galeeka x A. brisaeka hybrids was similar to those of A. galeeka and ranged from 9 to 10. In the reciprocal hybrid the number of leaves varied from 8 to 9.

5. Number of leaves per clump:- Since A. galeeka cultivars and the A. galeeka x A. brisaeka hybrids were single stemmed the number of leaves per clump and per stem were the same. In the case of A. brisaeka and A. brisaeka x A. galeeka hybrid the total number was much higher as compared to A. galeeka and ranged from 14 to 92 and 28 to 44 respectively.

6. Length of leaf:- A. galeeka cultivars had longer leaves (188-211 cm) compared to A. brisaeka (198-205 cm). In the A. galeeka x A. brisaeka hybrid (208), leaf length exceeded both the parents while in the reciprocal hybrid the leaf length was similar to A. brisaeka.

7. Length of spadix:- The length of spadix in A. sahuhu ranged from 51 to 64 cm and in A. brianiza from 38 to 51 cm. In all the A. sahuhu x A. brianiza hybrids excepting the spontaneous hybrid the spadices were longer than both the parents. The length of spadix in the A. brianiza x A. sahuhu hybrid was similar to the female parent.

8. Number of female flowers per bunch:- The range of female flowers in both the parents was from 206 to 910. In the A. sahuhu x A. brianiza hybrids the number ranged from 1806 to 3805, thus showing considerable hybrid vigour. In the reciprocal hybrid the range of number of female flowers was similar to A. brianiza.

9. Length x breadth of female flowers:- The size of female flowers in A. sahuhu ranged from 1.63 x 0.89 cm to 1.94 x 1.02 cm and in A. brianiza from 0.44 x 0.21 cm to 0.95 x 0.58 cm. The A. sahuhu x A. brianiza hybrids were intermediate for this character compared to parents and had a range of 1.03 x 0.55 cm to 1.68 x 0.85 cm. The range in the reciprocal hybrid was 0.73 x 0.50 cm to 0.92 x 0.54 cm and was thus similar to A. brianiza.

10. Number of male flowers per bunch:- In the two parents the number of male flowers ranged from 19994 to 38452. In the A. sahuhu x A. brianiza hybrids there was considerable increase in the number of male flowers

which ranged from 40256 to 57525 indicating hybrid vigour for this character also. The number of male flowers in the reciprocal hybrid ranged from 22155 to 37574.

11. Length x breadth of male flowers: The size of male flowers in A. sativum ranged from 0.45 x 0.25 cm to 0.42 x 0.23 cm and in A. triandra from 0.21 x 0.10 cm to 0.23 x 0.10 cm. In the A. sativum x A. triandra hybrid the flower size was intermediate and ranged from 0.20 x 0.09 cm to 0.37 x 0.16 cm while in the reciprocal hybrid the size was similar to A. triandra parent.

12. Number of stamens: While the local cultivar of A. sativum had flowers with six stamens, (Plate II, Fig. 5) the cultivar, China, had mostly six and rare to occasionally five stamens. In all the ecotypes of A. triandra the number of stamens was only three (Plate II, Fig. 7). The A. sativum x A. triandra hybrids were intermediate for this character with stamens ranging from 3 to 6 (Plate II, Fig. 6). The number of stamens in A. triandra x A. sativum hybrid was same as in the female parent.

13. Arrangement of male flowers: In A. sativum, male flowers were single biseriate and alternate (Plate II, Fig. 1) while in A. triandra they were in pairs and uniseriate (Plate II, Fig 4). In the A. sativum x A. triandra hybrids they were in pairs biseriate and alternate (Plate II, Fig 2). The reciprocal hybrid had an arrangement similar to A. triandra (Plate II, Fig. 3).

PLATE XI

Arrangement and variation of male flowers

Fig.1 : Arrangement of male flowers in A. sativa

Fig.2 : " " " " " A. sativa x A. brianica

Fig.3 : " " " " " A. brianica x A. sativa

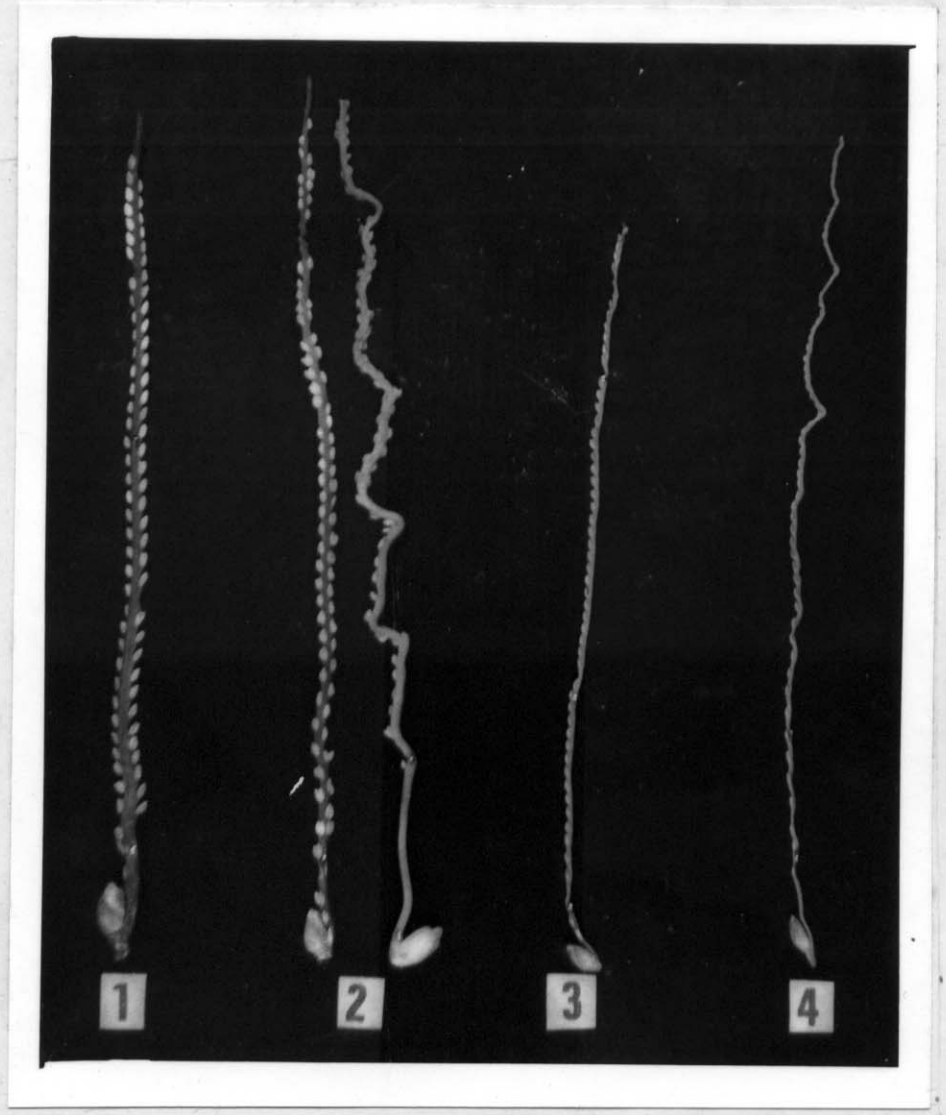
Fig.4 : " " " " " A. brianica

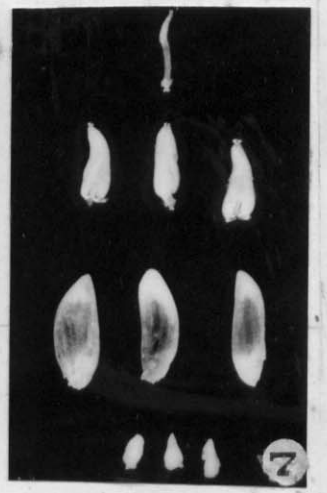
Fig.5 : Dissected male flowers of A. sativa

Fig.6 : " " " " A. sativa x A. brianica

Fig.7 : " " " " A. brianica

PLATE II





14. Length x breadth of fruit:- The size of fruit in the cultivars of A. satania ranged from 5.6 x 3.5 to 5.5 x 4.7 cm and in A. triandra from 2.5 x 1.4 cm to 3.3 x 1.4 cm. The fruit size of the A. satania x A. triandra F_1 hybrids was intermediate and ranged from 4.2 x 1.8 cm to 4.8 x 2.8 cm (Plate III, Fig. 2A). The fruit size of the A. triandra x A. satania F_1 hybrid was similar to the female parent (Plate III, Fig. 2B).

It was noted that the maturity period for A. satania and A. satania x A. triandra F_0 nuts ranged from 287 to 334 days while that of A. triandra and A. triandra x A. satania (F_0) ranged from 161 to 163 only (Table 2). The maturity period of A. satania x A. triandra F_1 hybrid nuts ranged from 258 to 284 days. The hybrid nuts (F_0) obtained from A. satania x A. triandra cross, showed considerable differences in size and shape as compared to the open pollinated nuts of A. satania. This was not, however, apparent in the case of the nuts obtained from the cross in which A. triandra was used as female parent (Table 4, Plate III, Fig. 1A - D).

XI. CYTOLOGY

a. Meiosis

The maximum and minimum meiotic associations of chromosomes and the pairing with highest frequency at diakinesis and metaphase-I for all the parents and their interspecific hybrids are given in Table 5. The average

Table 4. Mean size and weight of nuts of *A. subulata*, *A. bilimbia* and their hybrids (F_0)

Sl. No.	Parents/hybrids	Length (cm)	Breadth (cm)	Weight (gm)
1.	*A. subulata*	5.3 ± 0.33	4.2 ± 0.33	43.6 ± 1.39
2.	*A. subulata* × *A. bilimbia* (F_0)	5.5 ± 0.50	5.3 ± 0.22	34.2 ± 1.96
3.	*A. bilimbia* × *A. subulata* (F_0)	2.7 ± 0.11	1.5 ± 0.08	5.9 ± 0.31
4.	*A. bilimbia*	2.7 ± 0.13	1.5 ± 0.11	5.9 ± 0.34

PLATE XXI

Buts of parents, F_0 and F_1

Fig.1A : A. sativum

Fig.1B : A. sativum x A. brianskum (F_0)

Fig.1C : A. brianskum x A. sativum (F_0)

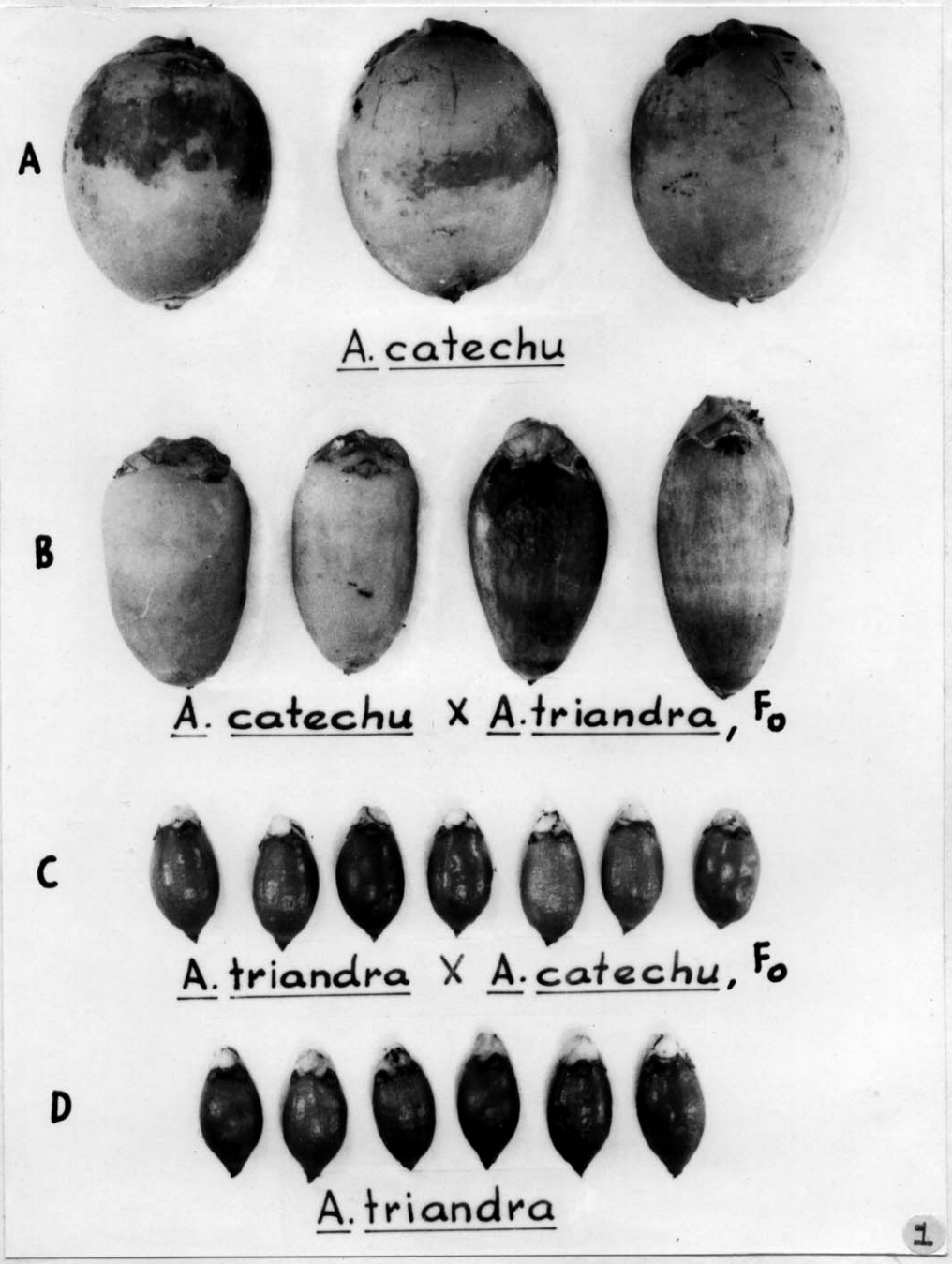
Fig.1D : A. brianskum

Fig.2A : A. sativum x A. brianskum (F_1)

Fig.2B : A. brianskum x A. sativum (F_1)

(3/4 of the natural size)

PLATE III


A
A. catechu
B
A. catechu X A. triandra, F0
C
A. triandra X A. catechu, F0
D
A. triandra
1


A
B
A. catechu x A. triandra, F1
A. triandra x A. catechu, F1
2

chiasmata per cell and per bivalent at diakinesis are given in Table 6. The range and mean pairing at diakinesis and metaphase-I are given in Tables 7 and 8 respectively. Abnormalities at anaphase-I and II, micronuclei and supernumerary spores at spored stage, pollen fertility and nut set of the parents and hybrids are given in Table 9. Data relating to intra individual variation in chromosome numbers at meiosis in respect of the above are given in Table 10.

(i) Annona squamosa

1. Kanal (471):- Of the 82 PMCs examined 22.0 per cent had higher associations, the maximum being $2_{IV} + 12_{II}$ (Plate IV Fig. 1). Of the remaining cells 54.9 per cent had 16 bivalents (Plate IV, Fig. 2). In metaphase-I, the highest association was $1_I + 1_{IV} + 9_{II}$ (Plate IV, Fig. 3). A maximum of five quadrivalents and six bivalents was observed in about 2 per cent of the cells (Plate IV, Fig. 4). There was clumping of chromosome in 50 per cent of the cells. At anaphase-I, 9.0 per cent of the cells had laggards varying from one to five (Plate IV, Fig. 5). At anaphase-II, the separation was abnormal in 9.5 per cent of the cells resulting in tripolar and pentapolar orientation. Only 1.2 per cent of the cells had laggards. At tetrad stage 12.5 per cent of the cells were triads. The pollen fertility was 95.4 per cent (Plate IV, Fig.6).

PLATE IV

Meiosis in *A. sativum* Local (471)

Fig.1 : Diakinesis, $2_{IV} + 12_{II}$

Fig.2 : Diakinesis, 16_{II}

Fig.3 : Metaphase-I, $1_{X} + 1_{IV} + 9_{II}$

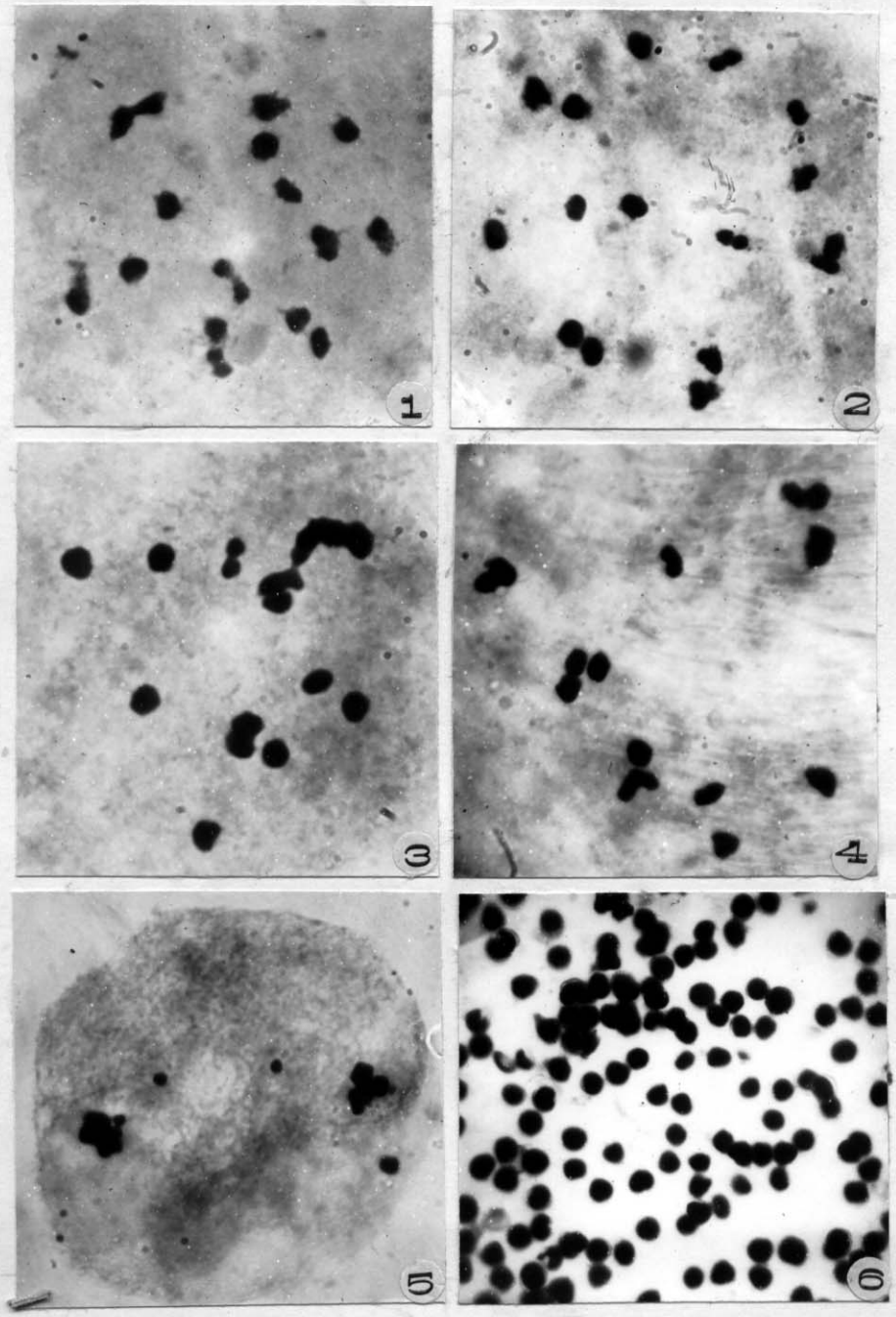
Fig.4 : Metaphase-I, $3_{IV} + 16_{II}$

Fig.5 : Anaphase-I; 3 laggards

Fig.6 : Pollen grains

(Figs.1 to 5, x 1350; 6, x 1120)

PLATE IV



2. Local (717):- Of the 100 pollen mother cells of this variety examined 73.0 per cent had 16 bivalents (Plate V, Fig. 1) and the remaining cells showed 11-15 bivalents. At metaphase-I, 95.4 per cent out of the 87 pollen mother cells examined showed complete pairing with 16_{II} and the remaining 4.6 per cent had two univalents, including those resulting from the precocious separation of a bivalent (Plate V, Fig. 2). The cells with chromosome stickies was 2.0 per cent. Clumping and disorientation of the chromosomes at metaphase-I was met with in 1.8 per cent of the cells.

Anaphase-I was normal (Plate V, Fig. 3) in 88.6 per cent of the 123 cells observed, the abnormalities being limited to lagging chromosomes varying from one to five (Plate V, Fig. 4). At anaphase-II the separation was normal (Plate V, Fig. 5) excepting for one cell out of 67 which had one laggard. At tetrad stage the abnormalities included micronucleus in one, died in two and triad in three out of 144 cells. The pollen fertility was 82.7 per cent (Plate V, Fig. 6).

3. China (111):- The chromosome configurations observed in this cultivar at diakinesis varied from a maximum of $1_{VI} + 13_{II}$ (Plate VI, Fig. 1) to $14_{II} + 4_{I}$. The highest frequency however was that of 16_{II} (Plate VI, Fig. 2). A maximum association of $1_{VI} + 2_{IV} + 9_{II}$ was

PLATE V

Meiosis in A. sativa var. Local (VII)

Fig. 1 : Diakinesis, 16_{II}

Fig. 2 : Metaphase-I, $15_{II} + 2_{I}$

Fig. 3 : Anaphase-I, 16/16 separation

Fig. 4 : Telophase-I; one laggard

Fig. 5 : Anaphase-II; lagging chromosome

Fig. 6 : Pollen grains

(Figs.1, 2, 3, 5 and 6, x 1350; 4, x 1800)

PLATE V

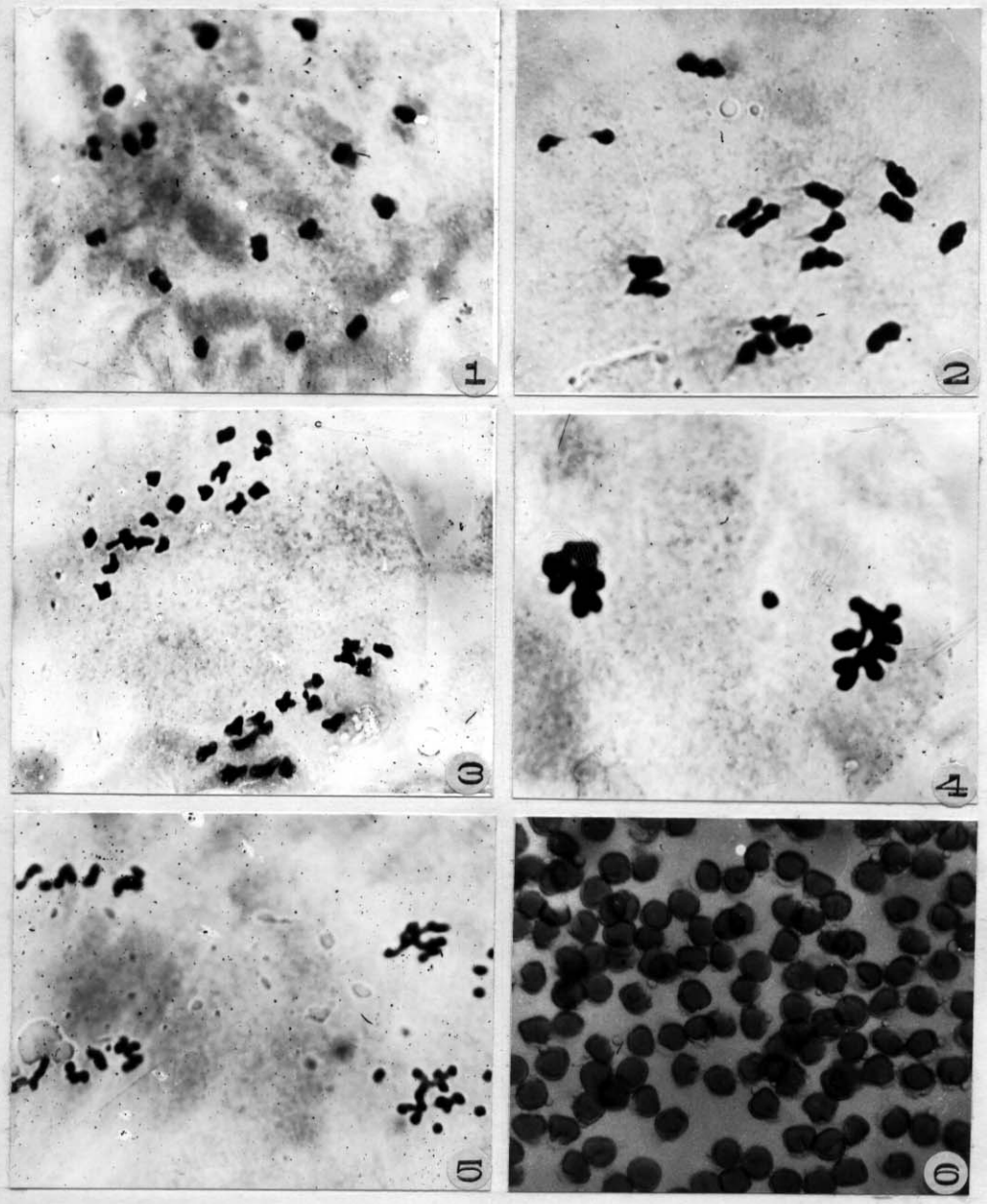


PLATE VI

Meiosis in A. sativum China (111)

Fig.1 : Diakinesis, $^{1}_{VI} + ^{15}_{II}$

Fig.2 : Diakinesis, $^{16}_{II}$

Fig.3 : Metaphase-I, $^{16}_{II}$

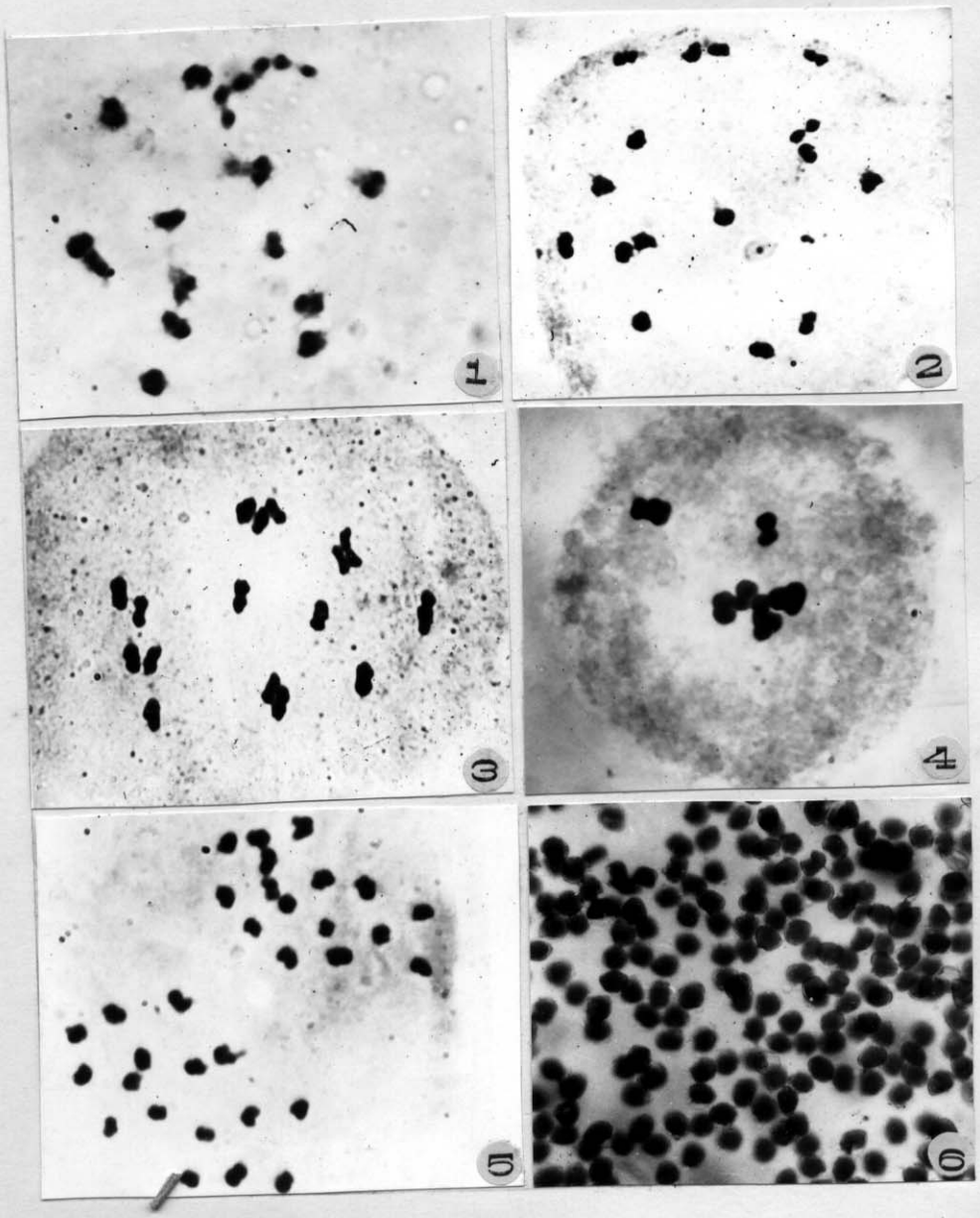
Fig.4 : Metaphase-I; clumping of chromosomes

Fig.5 : Anaphase-I, 16/16 separation

Fig.6 : Pollen grains

(Figs.1 to 5, x 1200; 6, x 1150)

PLATE VI



found at metaphase-I, 16_{II} being the most frequent ones (Plate VI, Fig. 3). Chromosome meanies were observed at diakinesis and metaphase-I in 6.8 and 4.5 per cent of the cells respectively. There was clumping of chromosomes at metaphase-I in 2.5 per cent of the cells (Plate VI, Fig. 4). At anaphase-I the separation was normal (Plate VI, Fig. 5) except in one cell out of 163 which had a laggard. Anaphase-II was normal. At tetrad stage triads were observed in 3.0 per cent of the cells. Pollen fertility was 98.2 per cent (Plate VI, Fig. 6).

4. China (175):- Of the 80 cells studied, 72.5 per cent had 16 bivalents (Plate VII, Fig. 1), the maximum association of $2_{IV} + 12_{II}$ was observed in 2.5 per cent of the cells (Plate VII, Fig. 2). At metaphase-I, 76.7 per cent of the PMCs had 16 bivalents. The maximum association of $1_{VI} + 13_{II}$ was observed in 2.5 per cent of the cells (Plate VII, Fig. 3). Clumping at metaphase-I was observed in 42.7 per cent of the PMCs (Plate VII, Fig. 4). The anaphase-I abnormalities consisted of laggards and disorientation of chromosomes in 6.5 per cent of the cells (Plate VII, Fig. 5). Laggards were also observed along with tripolar orientation at anaphase-II to the extent of 4.8 per cent. At tetrad stage triads and/diads to the extent of 13.2 per cent were observed (Plate VII, Fig. 6). Pollen fertility was 95.7 per cent.

PLATE VII

Meiosis in A. sativum China (175)

Fig.1 : Diakinesis, 16_{II}

Fig.2 : Diakinesis, $2_{IV} + 12_{II}$

Fig.3 : Metaphase-I, $1_{VI} + 13_{II}$

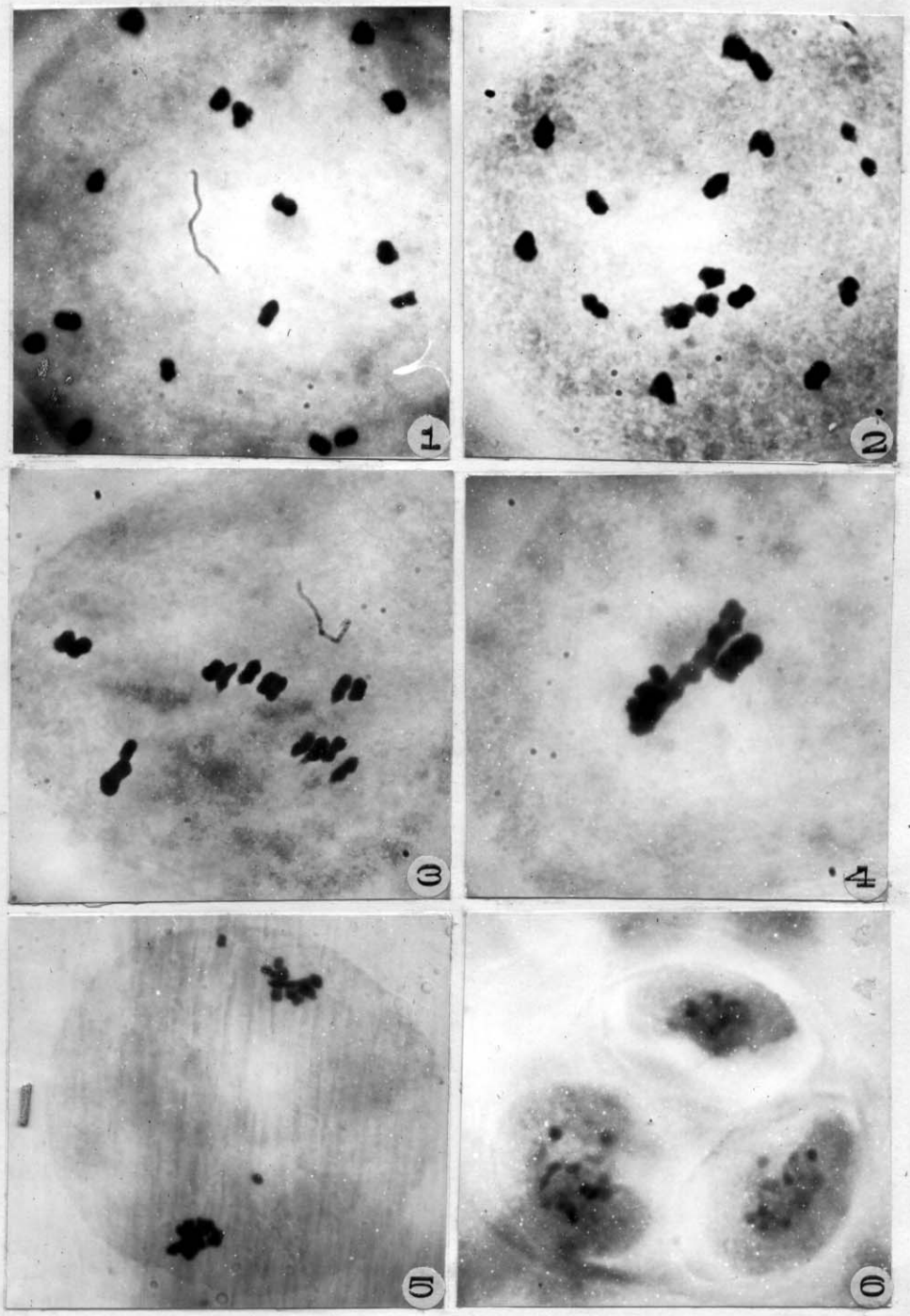
Fig.4 : Metaphase-I; clumping of chromosomes

Fig.5 : Late anaphase-I; two lagging chromosomes

Fig.6 : Triad

(Figs. 1 to 5, x 1350; 6, x 1950)

PLATE VII



(11) Arenga Saccharifera

5. Ceylon - 3 (55):- At diakinesis, higher association than bivalent was not observed. Only 9.1 per cent of the 55 cells analysed had 16 bivalents. The association in the remaining cases ranged from eight to fifteen bivalents (Plate VIII, Figs. 1 and 2). At diakinesis 25.6 per cent of the cells had chromosome numbers varying from $5_{II} + 1_I$ to 17_{II} and at metaphase-I 14.3 per cent of the cells had $27_{II} + 1_I$ (Plate VIII, Fig. 3) to $1_{II} + 1_I$ (Plate VIII, Fig. 4). At metaphase-I there was higher association (trivalents) in 1.2 per cent of the 84 cells observed. In 73.8 per cent of the cells, 16 bivalents were observed (Plate VIII, Fig. 5) the remaining cells having 15 bivalents and two univalents. There was clumping at metaphase-I in 6.5 per cent of the cells (Plate VIII, Fig. 6). Anaphase-I was normal (Plate IX, Fig. 1) in 73.6 per cent of the cells. Cytomixis to the extent of 26.0 per cent was observed at metaphase-I (Plate IX, Fig.2).

There were laggards in 26.4 per cent at anaphase-I (Plate IX, Fig. 3) and 11.1 per cent at anaphase-II (Plate IX, Fig. 4) in the cells studied. At tetrad stage microcytes (1.7 per cent), monads (0.3 per cent), diads (1.7 per cent) and triads (2.0 per cent) were observed (Plate IX, Fig. 5). The pollen fertility was 75.3 per cent (Plate IX, Fig. 6).

PLATE VIII

<u>Meiosis in A. triandra Ceylon-3 (3X)</u>

Fig.1 : Diakinesis, $10_{II} + 12_{I}$

Fig.2 : Diakinesis, $15_{II} + 2_{I}$

Fig.3 : Chromosome mosaic; $27_{II} + 1_{I}$

Fig.4 : Chromosome mosaic; $1_{II} + 1_{I}$

Fig.5 : Metaphase-I, 16_{II}

Fig.6 : Metaphase-I, clumping of chromosomes

(Figs., x 1350)

PLATE VIII

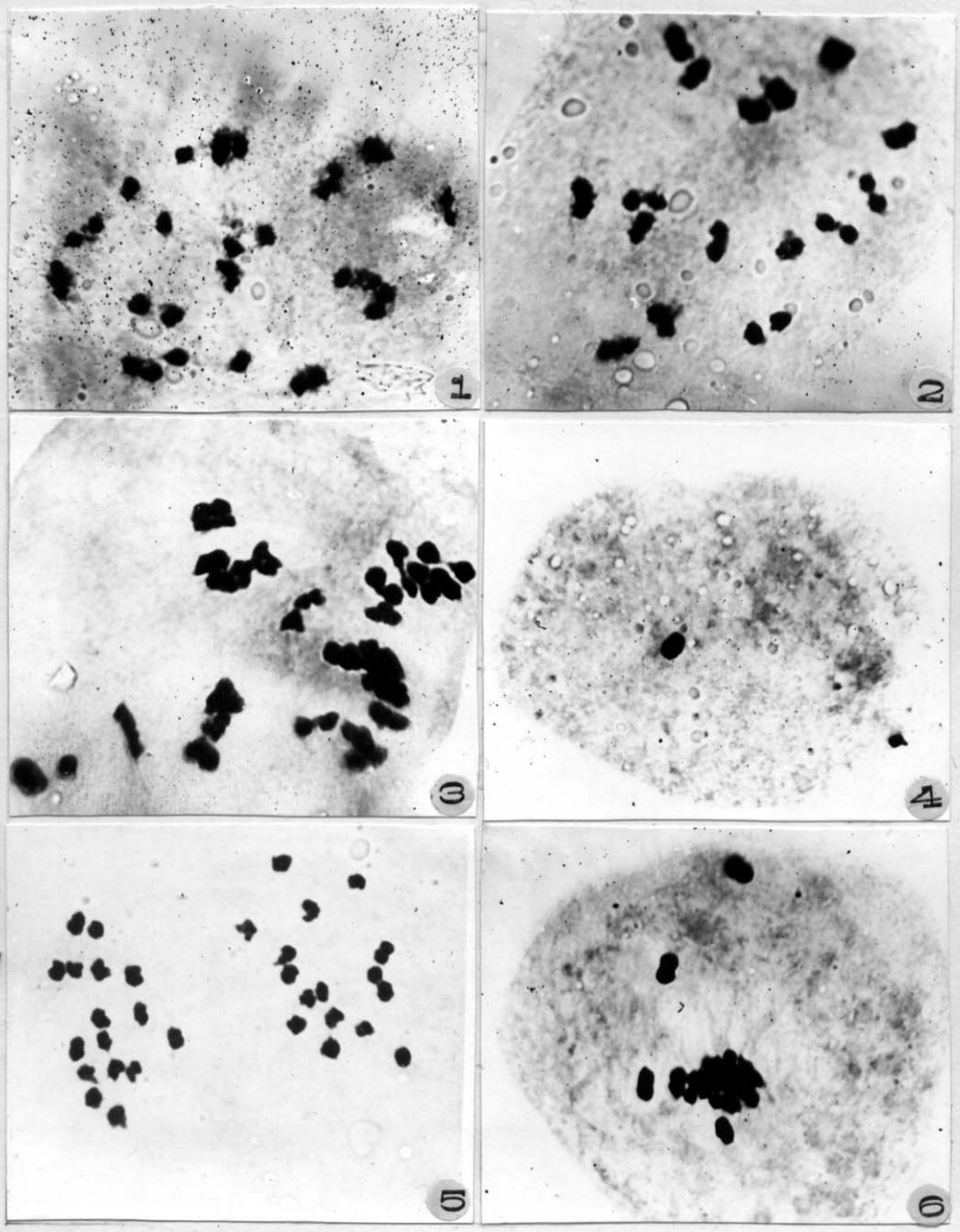


PLATE IX

Meiosis in A. brandisii Gamble-3 (55) (Contd.)

Fig.1 : Anaphase-I, 16/16 separation

Fig.2 : Cytomixis

Fig.3 : Anaphase-I; lagging chromosomes

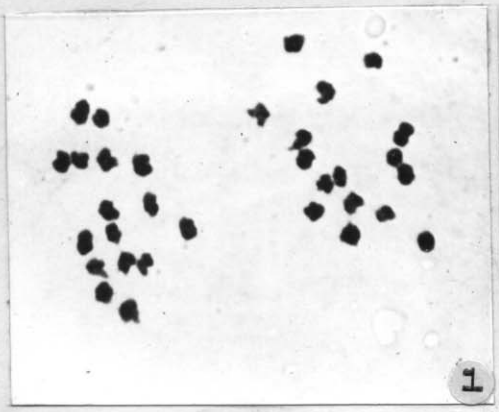
Fig.4 : Anaphase-II; lagging chromosomes

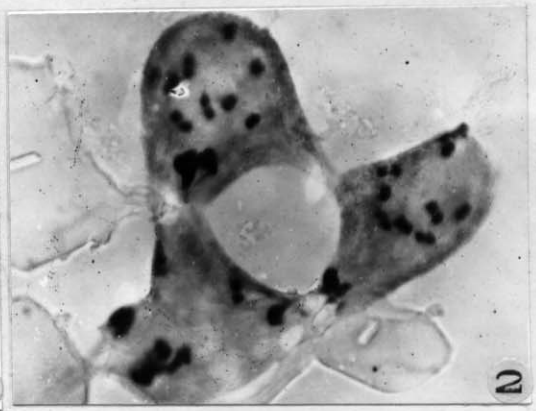
Fig.5 : Normal tetrad and a triad

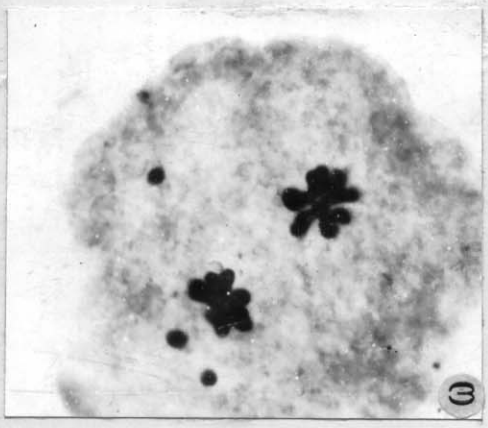
Fig.6 : Pollen grains

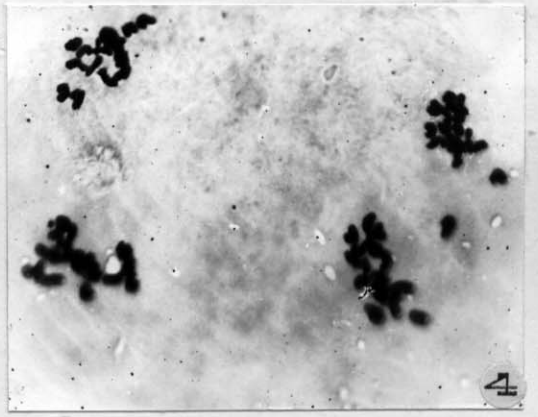
(Figs.1, 3 and 4, x 1350; 2, 5 and 6, x 1150)

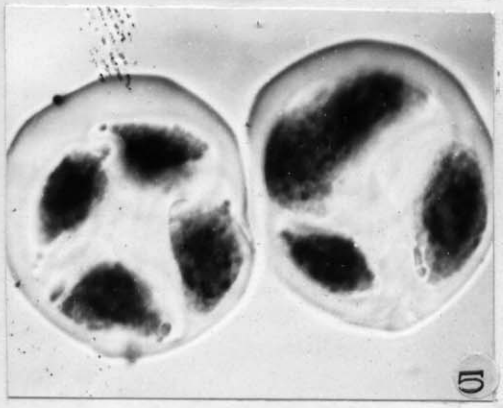
PLATE IX

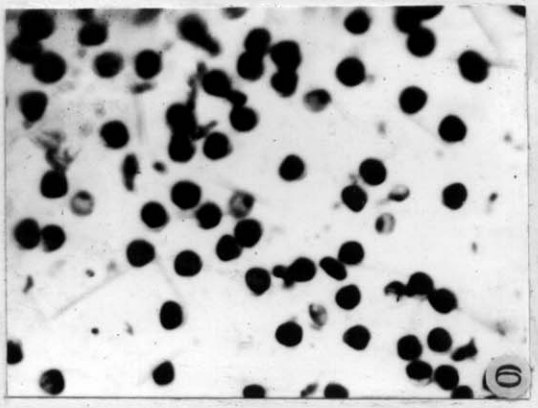












6. Ceylon x 3 (72):- At diakinesis, 31.3 per cent of the cells had 16_{II} (Plate X, Fig. 1) while the rest of the cells had association ranging from $6_{II} + 20_{I}$ to $15_{II} + 2_{I}$. Sixteen bivalents were observed in 77.6 per cent of the cells at metaphase-I (Plate X, Fig.2), the association in the remaining cells ranging from $13_{II} + 6_{I}$ to $15_{II} + 2_{I}$. There were chromosome monads in 8.0 per cent of the pollen mother cells at diakinesis (Plate X, Fig. 3) and 6.2 per cent at metaphase-I. Cytomixis was observed in 33.7 per cent of the cells at metaphase-I (Plate X, Fig. 4).

At anaphase-I, there was 16/17 separation (Plate X, Fig. 5) and laggards in 8.2 per cent of the cells (Plate X, Fig. 6). At metaphase-II there was clumping (Plate XI, Fig. 1) and disorientation of chromosomes (Plate XI, Fig. 2) in 6.2 per cent of the cells. At anaphase-II 98.5 per cent of the cells were normal (Plate XI, Fig. 3), the rest of the cells having laggards and disorientation of the chromosomes resulting in tripolar (Plate XI, Fig. 4) and pentapolar separation. At tetrad stage 14.3 per cent of the cells showed irregularities such as diads, triads (Plate XI, Fig. 5) and pentads. The pollen fertility was 65.4 per cent (Plate XI, Fig. 6).

7. Ceylon x 3 (87):- The chromosome association ranged from $1_{IV} + 14_{II}$ to $7_{II} + 18_{I}$ which included $1_{IV} + 13_{II} + 4_{I}$ (Plate XII, Fig. 1) and $1_{III} + 12_{II} + 5_{I}$ (Plate XII, Fig. 2). Out of 96 cells analysed at

PLATE X

Meiosis in A. triandra Series-3 (70)

Fig. 1 : Diakinesis, 16_{II}

Fig. 2 : Metaphase-I, 16_{II}

Fig. 3 : Chromosome mosaic, 11 bivalents

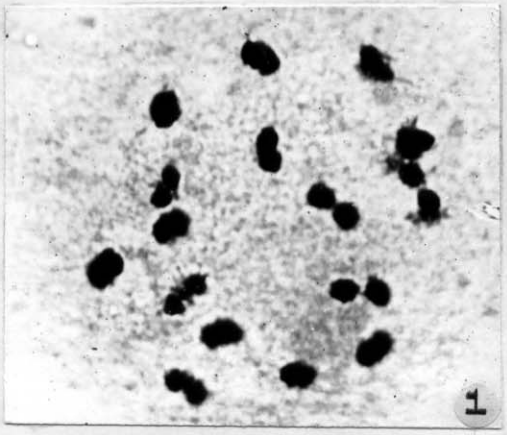
Fig. 4 : Cytomixis

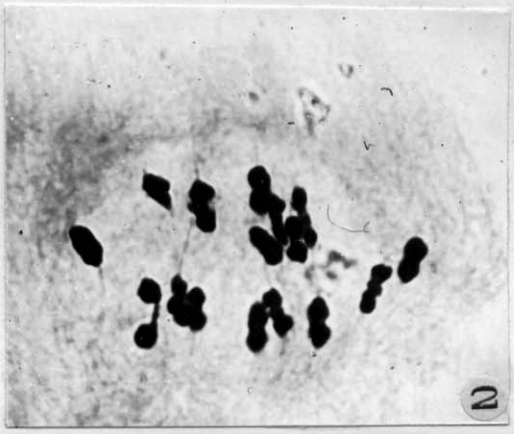
Fig. 5 : Anaphase-I, 16/17 separation

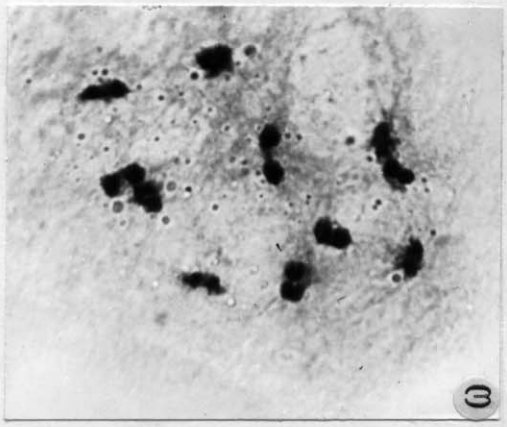
Fig. 6 : Anaphase-I, a lagging chromosome

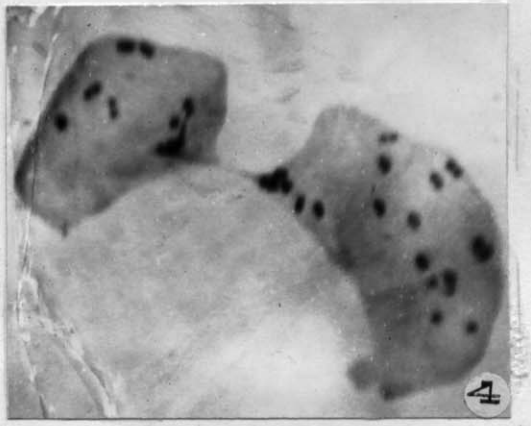
(Figs.1, 2 and 3, x 1500; 4, x 1400; 5 and 6, x 1350)

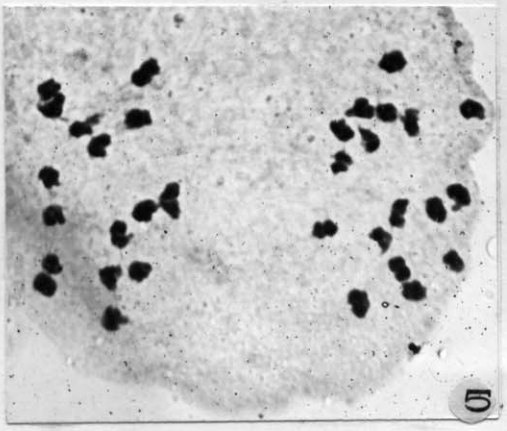
PLATE X











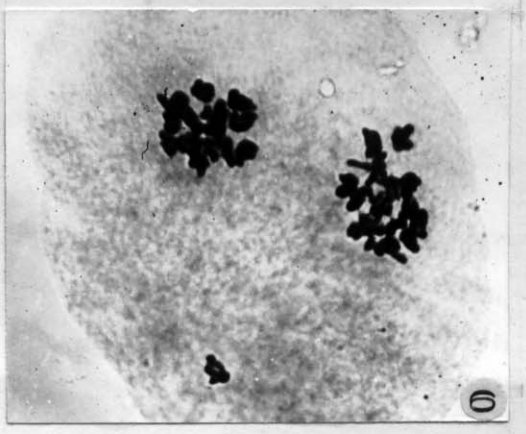


PLATE XI

<u>Meiosis in A. triandrum Ceylon-1 (70) (Contd.)</u>

Fig. 1 : Metaphase-II; clumping of chromosomes

Fig. 2 : Metaphase-II; disorientation and laggards

Fig. 3 : Anaphase-II; normal separation

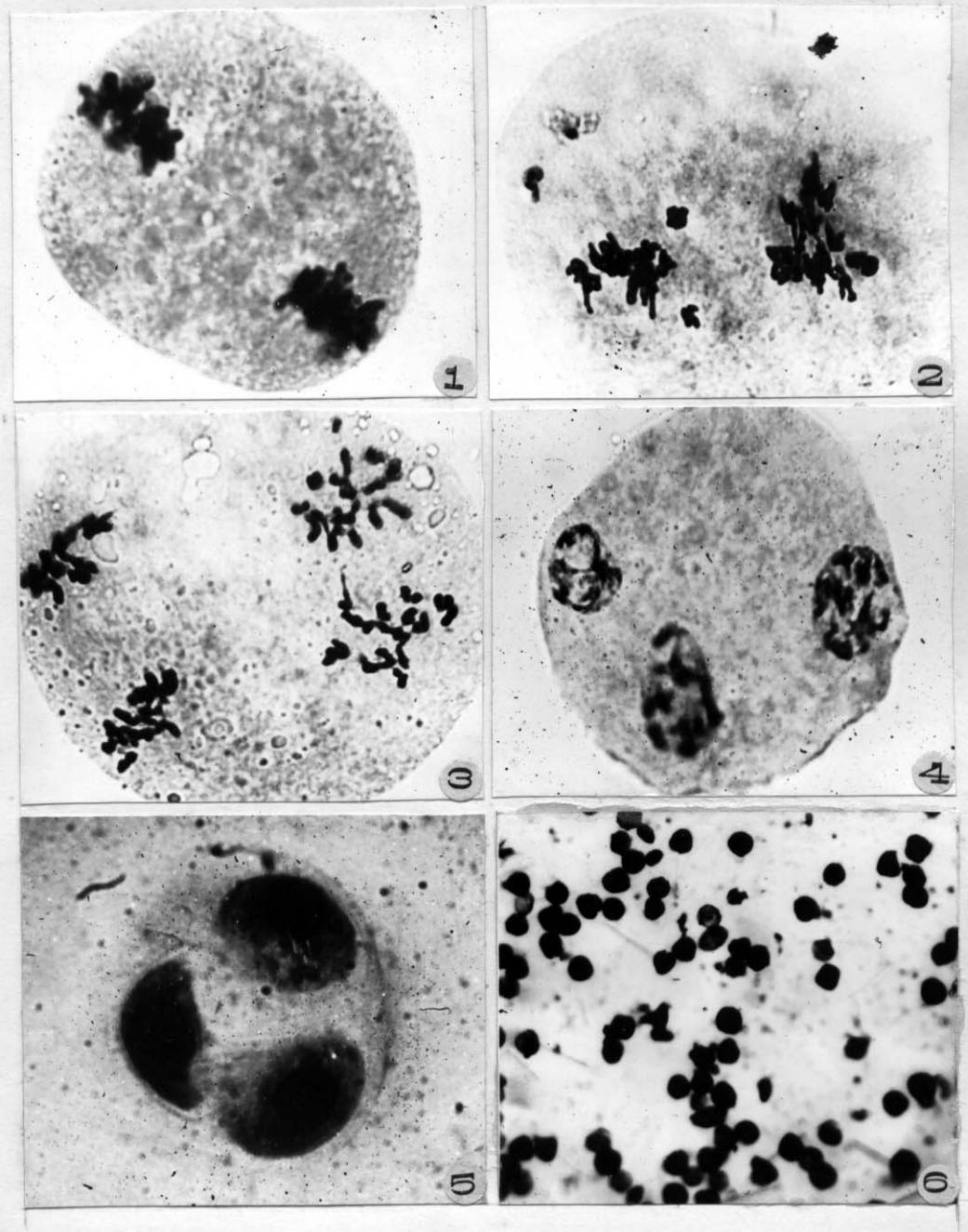
Fig. 4 : PMC showing three nuclei

Fig. 5 : Triad

Fig. 6 : Pollen grains

(Figs.1 and 4, x 1350; 2, 3 and 5, x 1500; 6, x 1150)

PLATE XI



diakinesis, cells with 16_{II} had the highest frequency. Chromosome mosaics ranging from $5_{II} + 5_{I}$ to 15_{II} were observed in 6.8 per cent of the cells at diakinesis. At metaphase-I, 63.6 per cent of the cells had 16_{II} (Plate XXI, Fig. 3) and the remaining had $15_{II} + 2_{I}$ to $8_{II} + 16_{I}$. In 9.6 per cent of the cells, chromosome mosaics ranging from 18_{II} + 1 fragment (Plate XXI, Fig. 4) to 2_{II} were met with. At metaphase-I, 22.6 per cent and 19.1 per cent of the cells had stickiness and cytomixis respectively (Plate XXI, Fig. 5). At anaphase-I 17.9 per cent of the cells had laggards, while at anaphase-II 15.6 per cent of cells showed the same abnormality. The remaining cells were normal. At tetrad stage 4.1 per cent had micronuclei while 2.7 per cent had supernumerary spores (Plate XII, Fig. 6), besides diads (0.7 per cent) and triads (13.6 per cent). The pollen fertility was 63.3 per cent.

8. Mauritius (102):- The 32 chromosomes at diakinesis associated themselves into a maximum of $1_{III} + 14_{II} + 1_{I}$. Plate XXII, Fig. 1 shows an association of $1_{III} + 13_{II} + 3_{I}$. Fifteen bivalents and two univalents formed the class of highest frequency. The number of univalents at diakinesis ranged from 0 (Plate XXII, Fig. 2) to 22. Pollen mother cell, with $7_{II} + 18_{I}$ is shown in Plate XXII, Fig. 3. Chromosome mosaics at

PLATE XXI

Meiosis in A. triandra Boriss-3 (87)

Fig. 1 : Diakinesis, $1_{IV} + 15_{II} + 2_{I}$

Fig. 2 : Diakinesis, $1_{III} + 12_{II} + 5_{I}$

Fig. 3 : Metaphase-I, 16 bivalents

Fig. 4 : Chromosome mosaic; 16 bivalents and a fragment

Fig. 5 : Cytomixis

Fig. 6 : Normal and partial

(Figs. 1 to 4, x 1500; Fig. 5, x 1500; Fig. 6, x 1100)

PLATE XII

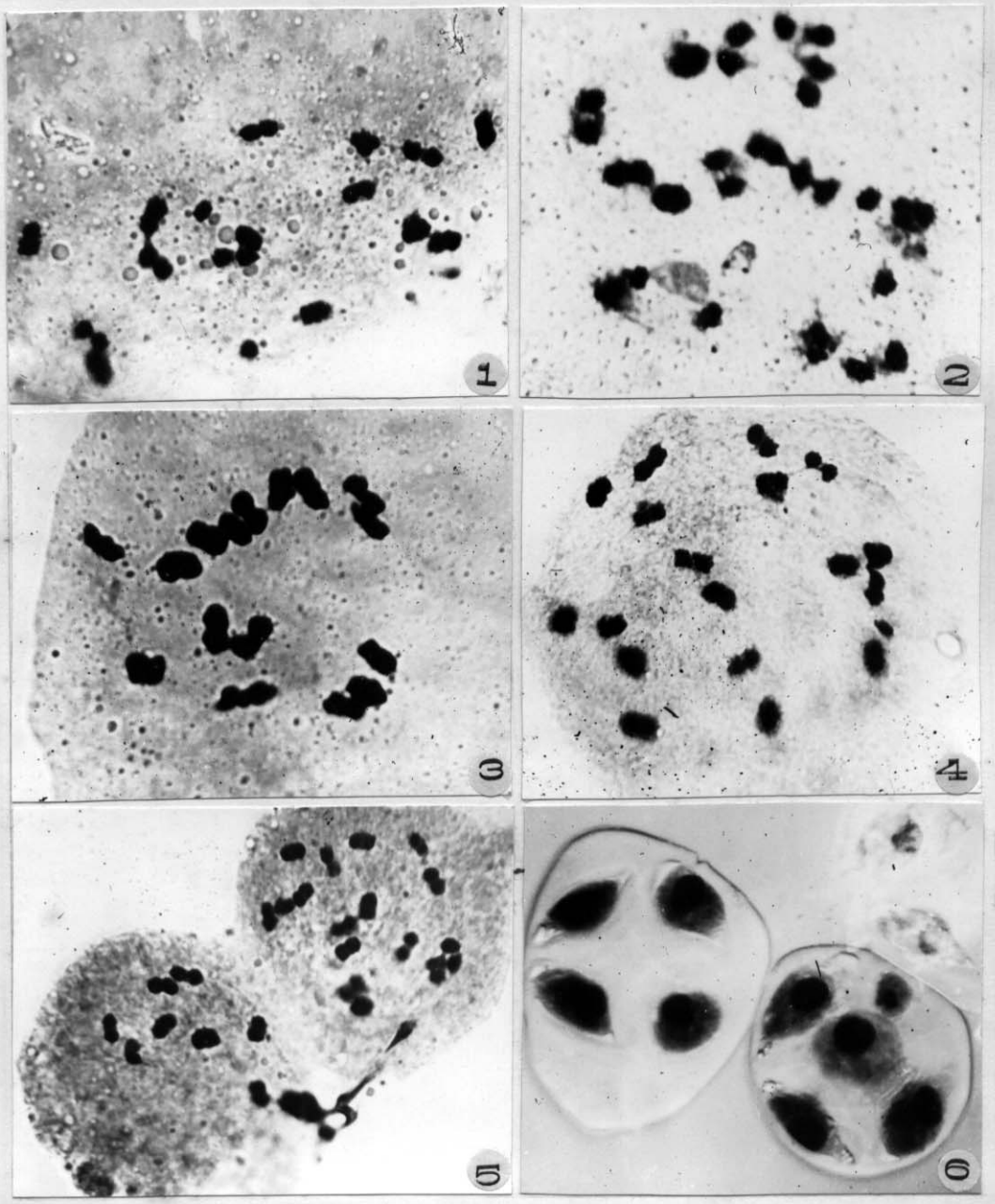


PLATE XIII

Meiosis in *A. triandra* Mauritius (109)

Fig.1 : Diakinesis, $1_{III} + 13_{II} + 3_{I}$

Fig.2 : Diakinesis, 16_{II}

Fig.3 : Diakinesis, $7_{II} + 18_{I}$

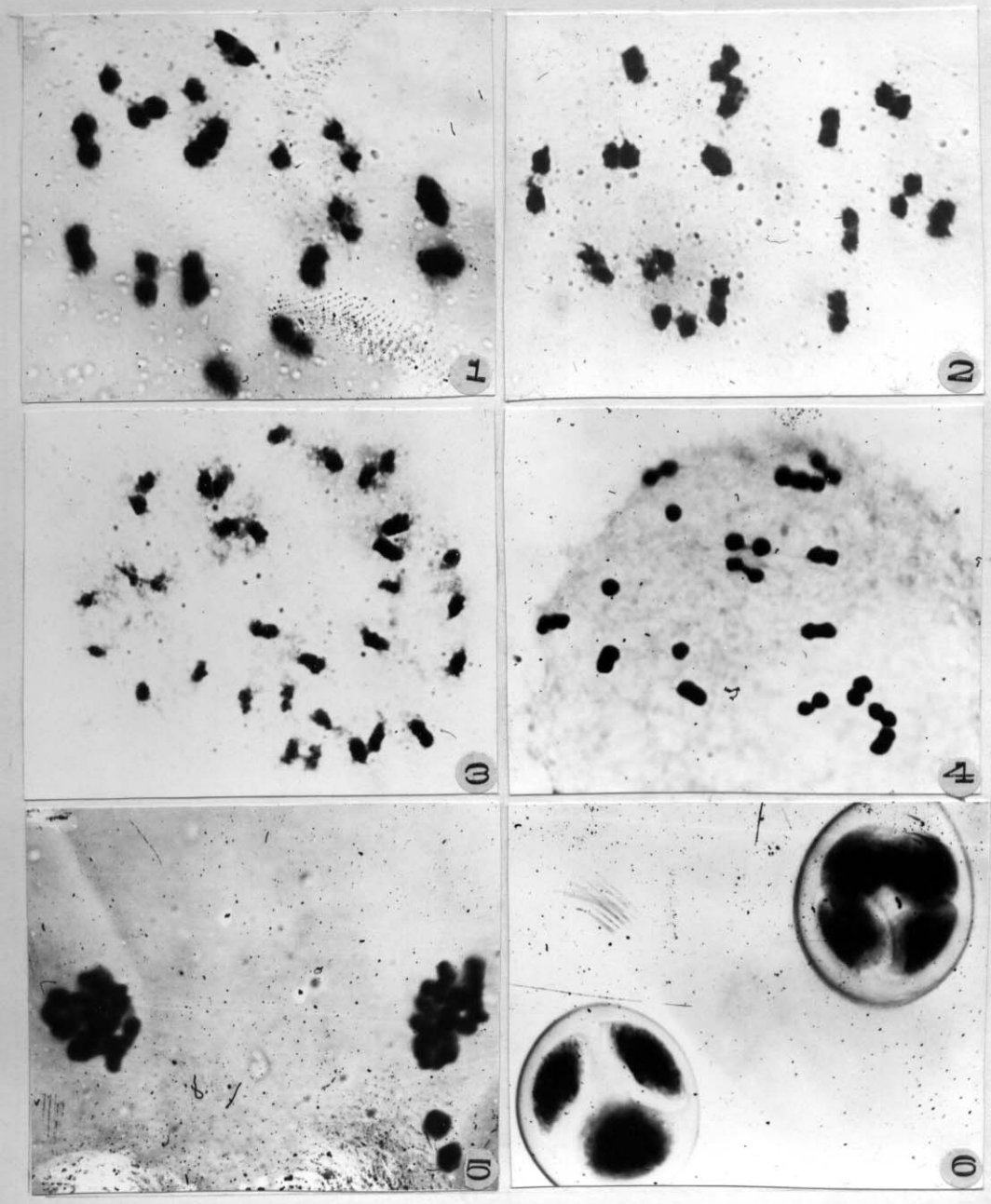
Fig.4 : Metaphase-I, $1_{III} + 13_{II} + 3_{I}$

Fig.5 : Telophase-I; two lagging chromosomes

Fig.6 : Tetrad and triad

(Figs.1, 2 and 5, x 1400; 3 and 4, x 1300; 6, x 1100)

PLATE XIII



diakinesis were observed in 12.5 per cent of the cells, the association ranging from $1_{IV} + 1_{III} + 7_{II} + 13_{I}$ to $4_{II} + 3_{I}$. At metaphase-I, the configurations ranged from $2_{III} + 9_{II} + 8_{I}$ to $4_{II} + 24_{I}$. Plate XXII, Fig. 4 shows an association of $1_{III} + 15_{II} + 3_{I}$. At metaphase-I 10.1 per cent of the cells studied had varying chromosome numbers and the association ranged from $1_{III} + 9_{II} + 15_{I}$ to 7_{II}. Stickiness was observed in 28.3 per cent of the cells. At anaphase-I, 29.3 per cent of the cells had laggards (Plate XXII, Fig. 5) while at anaphase-II, 26.8 per cent of the cells had similar abnormality. At tetrad stage 14.9 per cent of the cells had microcytes, 1.7 per cent had monads, 4.6 had dyads and 6.8 had triads (Plate XXII, Fig. 6). The pollen fertility was 53.1 per cent.

9. Indosaccia - 2 (154):- Diakinesis revealed no higher association or cells with 16_{II}. The association ranged from $4_{II} + 24_{I}$ to $15_{II} + 2_{I}$. Plate XIV, Fig. 1 shows an association of $10_{II} + 12_{I}$. At metaphase-I, 55.6 per cent of the cells had 16_{II} (Plate XIV, Fig. 2) while the remaining had $8_{II} + 16_{I}$ to $15_{II} + 2_{I}$. Quadrivalents and trivalents (Plate XIV, Fig. 3) were observed in 2.8 per cent of the cells each. At metaphase-I, 2.7 per cent of the PMCs had chromosome mosaics and the chromosome association observed in this case was $15_{II} + 1_{Fr}$ (Plate XIV, Fig. 4). At anaphase-I there were laggards in

PLATE XIV

Meiosis in *A. javanica* Indonesia (154)

Fig. 1 : Diakinesis, $10_{II} + 12_{I}$

Fig. 2 : Metaphase-I, 16_{II}

Fig. 3 : Metaphase-I, $1_{III} + 14_{II} + 1_{I}$

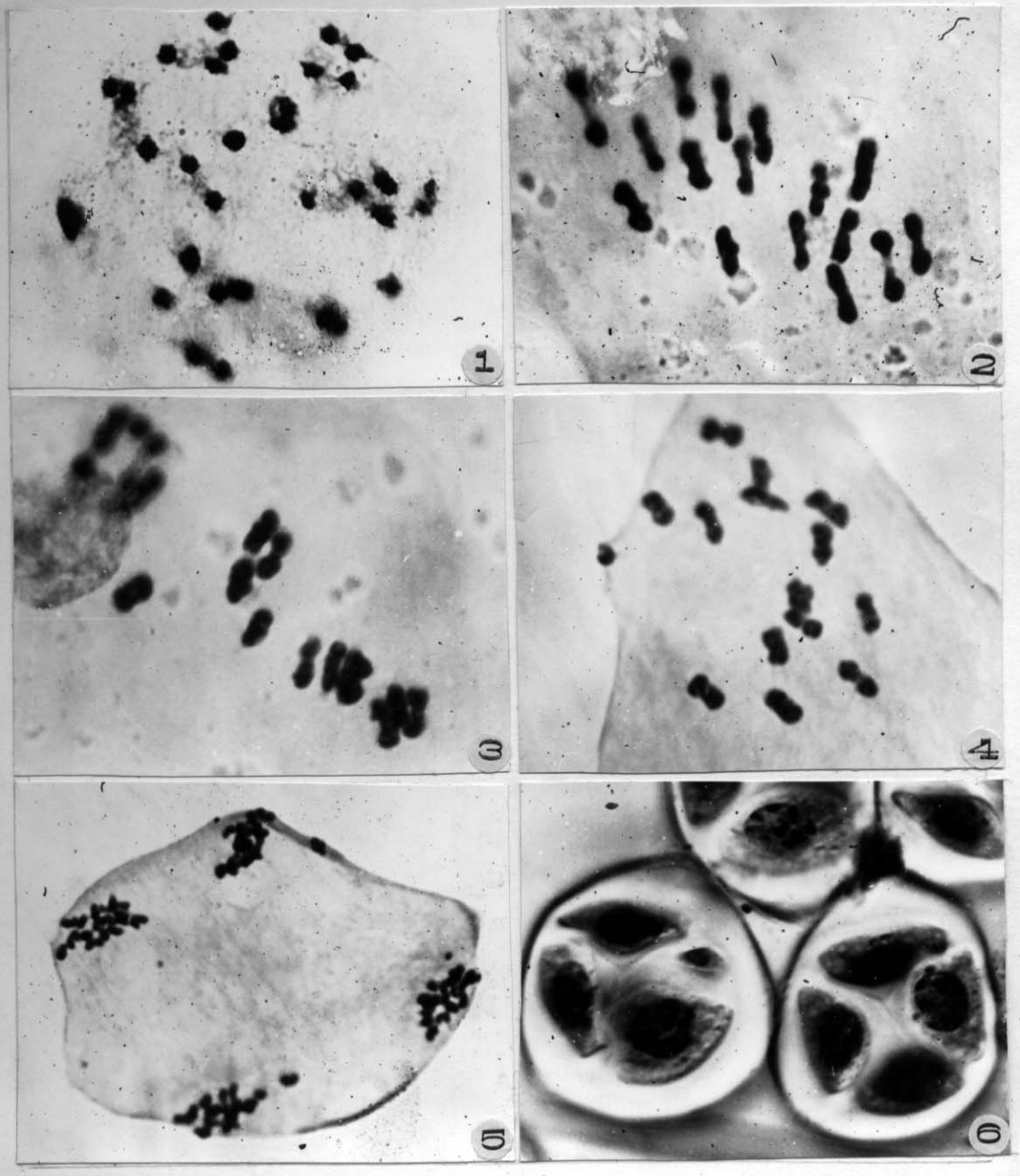
Fig. 4 : Chromosome mosaic - PMC with 15 bivalents and a fragment

Fig. 5 : Anaphase-II; laggards

Fig. 6 : A tetrad and a triad with micronuclei

(Figs.1 to 5, x 1350; 6, x 1100)

PLATE XIV



18.8 per cent of the cells and at anaphase-II in 24.6 per cent (Plate XIV, Fig. 5). At tetrad stage 1.8 per cent had micronuclei (Plate XIV, Fig. 6) while 5.5 per cent had monads and triads. The pollen fertility was 45.2 per cent.

(iii) Interspecific hybrids

10. *A. sphaeno* x *A. brianum* (248):- At diakinesis, the chromosome association ranged from $1_{VIII} + 1_V + 1_{III} + 5_{II} + 6_I$ (Plate XV, Fig. 1) to $8_{II} + 28_I$. Plate XV, Fig. 2 shows $1_{IV} + 2_{III} + 9_{II} + 4_I$ while Fig. 3 shows $2_{III} + 11_{II} + 4_I$ and Fig. 4, $10_{II} + 12_I$. The most frequent associations was $8_{II} + 16_I$. Out of 107 pollen mother cells analysed, higher associations varying from trivalent to octavalent were observed in 35. Chromosome mosaics were observed in 1.0 per cent of the cells which included presence of fragment and higher associations (Plate XV, Figs. 5 & 6). Fragments were also observed in normal cells (Plate XVI, Fig. 1). Cytomixis was observed in 6.7 per cent of the cells.

At metaphase-I, the chromosome association ranged from $1_{VI} + 13_{II}$ to $11_{II} + 10_I$. In 14.8 per cent of the cells, higher associations were observed. Stickiness of chromosomes was observed in 33.7 per cent of the cells. Pollen mother cells having $13_{II} + 2_I$ as well as $14_{II} + 4_I$ were of the highest frequency (21.7 per cent each).

PLATE XV

Meiosis in A. ambrosia x A. trifida (248)

Fig. 1 : Diakinesis, $1_{VIII} + 1_{V} + 1_{III} + 3_{II} + 6_{I}$

Fig. 2 : Diakinesis, $1_{IV} + 2_{III} + 9_{II} + 4_{I}$

Fig. 3 : Diakinesis, $2_{III} + 11_{II} + 4_{I}$

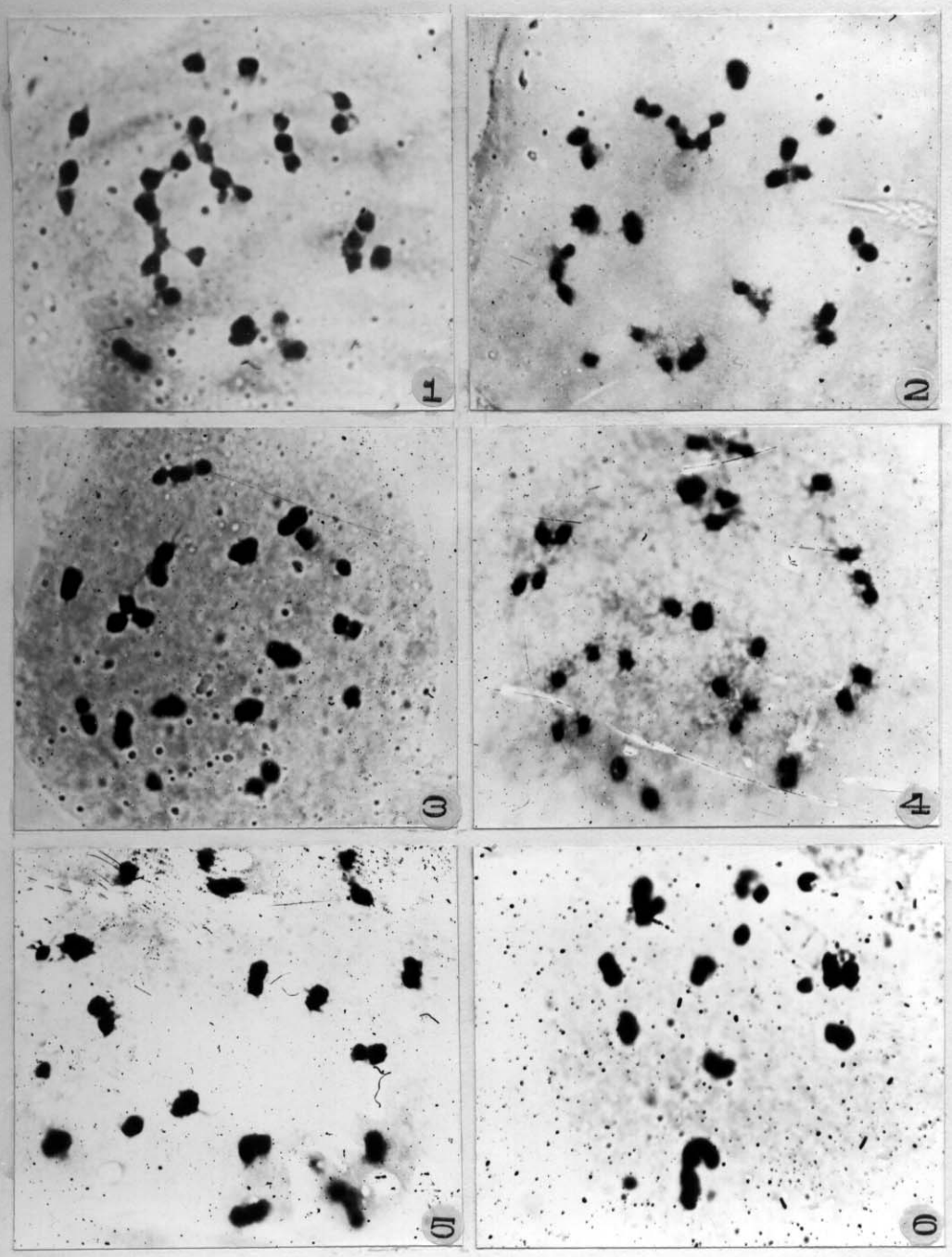
Fig. 4 : Diakinesis, $10_{II} + 12_{I}$

Fig. 5 : Chromosome mosaic; $15_{II} + 4_{I} + 1_{Fr.}$

Fig. 6 : Chromosome mosaic; $1_{IV} + 11_{II} + 4_{I}$.

(Figs., x 1350)

PLATE XV



Sixteen bivalents were observed in 19.7 per cent of the pollen mother cells (Plate XVI, Fig. 2). Chromosome mosaics were observed in 4.6 per cent of the cells.

The abnormalities at anaphase-I and II included bridges (2.2 and 2.3 per cent respectively) and laggards (87.5 and 90.0 per cent respectively) (Plate XVI, Figs. 3 and 4). In addition to normal tetrads, tetrads with micronuclei (22.6 per cent) (Plate XVI, Fig. 5), diads (2.2 per cent) and triads (16.1 per cent) were also observed. In addition, failure of cytokinesis in one half of the tetrads resulting in two normal and one binucleate spread was observed in 2.9 per cent of the cells. The pollen fertility was 3.7 per cent (Plate XVI, Fig. 6).

11. A. sativa x A. brizantha (287):- At diakinesis, 5.5 per cent of the cells had trivalents (Plate XVII, Fig. 1) with varying numbers of bivalents and univalents and invariably one fragment. Fragment was also observed in cells with bivalents and univalents (Plate XVII, Fig. 2). There were cells with 32 univalents. Plate XVII, Fig. 3 shows an association of $1_{II} + 30_{I}$. However, the maximum frequency of 13.3 per cent was observed in respect of $12_{II} + 8_{I}$. Chromosome mosaics were observed in 7.2 per cent of the cells, the association ranging from $1_{III} + 2_{II} + 8_{I}$ to $4_{II} + 3_{I}$. At metaphase-I, 2.7 per cent of the cells had trivalents

PLATE XVI

Meiosis in *A. sativum* x *A. bisulcum* (2A2) (Contd.)

Fig. 1 : Late diakinesis; 16 bivalents and 2 fragments

Fig. 2 : Metaphase-I, 16_{II}

Fig. 3 : Anaphase-I; unequal separation and laggards

Fig. 4 : Anaphase-II; lagging chromosomes

Fig. 5 : Tetrads with micronucleus in one of them

Fig. 6 : Pollen grains

(Figs. 1, 3 and 4, x 1350; 2, x 1500; 5 and 6, x 1100)

PLATE XVI

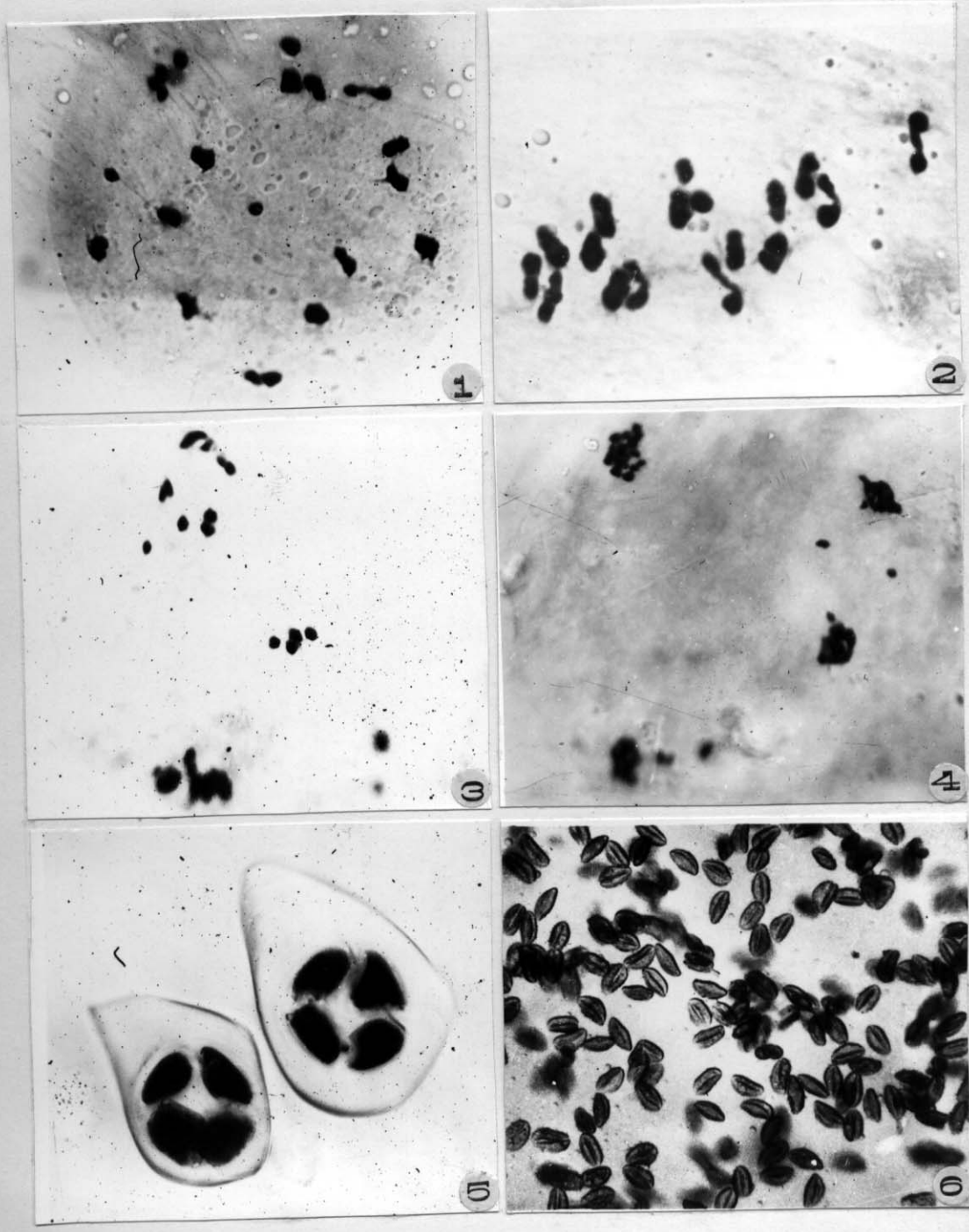


PLATE XVII

Meiosis in *A. sativum* × *A. triandrum* (287)

Fig. 1 : Diakinesis, $1_{III} + 13_{II} + 3_{I} + 1_{Fr.}$

Fig. 2 : Diakinesis, $14_{II} + 4_{I} + 1_{Fr.}$

Fig. 3 : Diakinesis, $1_{II} + 30_{I}$

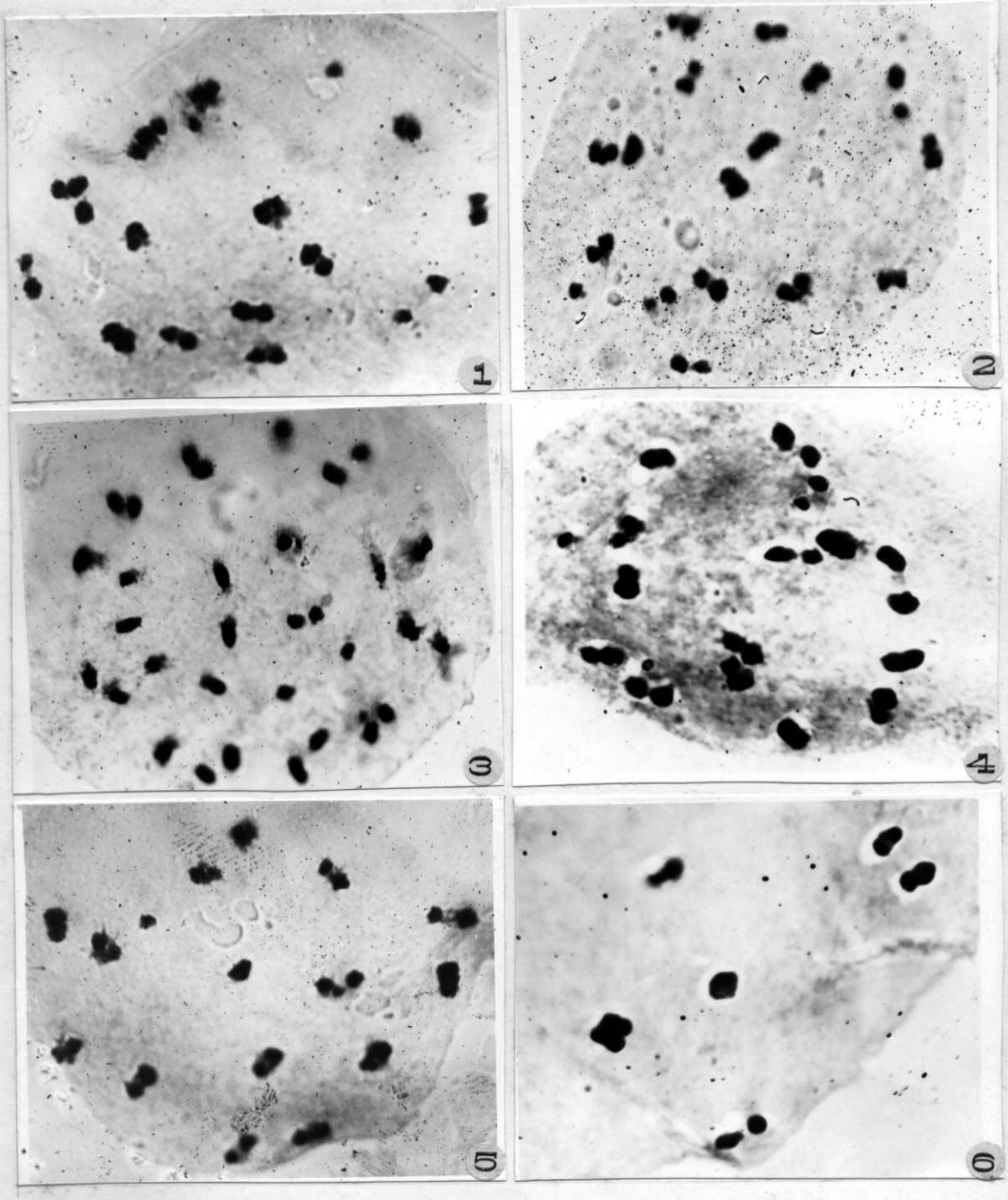
Fig. 4 : Metaphase-I, $15_{II} + 2_{I} + 1_{Fr.}$

Fig. 5 : Chromosome mosaic; $1_{III} + 13_{II} + 2_{I}$

Fig. 6 : Chromosome mosaic; 8_{II}

(Figs., x 1490)

PLATE XVII



and five out of 114 cells had fragments (Plate XVII, Fig. 4). Pollen mother cells with chromosome association of $15_{II} + 2_{I}$ were found to have the highest frequency (41.2 per cent). At metaphase-I, 2.6 per cent of the cells had chromosome mosaics, with association ranging from $1_{III} + 13_{II} + 2_{I}$ (Plate XVII, Fig. 5) to 8_{II} (Plate XVII, Fig. 6). Clumping of chromosomes at metaphase-I was observed in 8.2 per cent of the cells studied (Plate XVIII, Fig. 1).

At anaphase-I, 14.7 per cent of the cells had laggards and bridges. The abnormalities included the division of lagging univalent (Plate XVIII, Fig. 2), chromatin bridge and fragment (1.8 per cent) (Plate XVIII, Fig. 3) and lagging trivalents and univalents (12.9 per cent) (Plate XVIII, Fig. 4). Separation in the remaining 85.3 per cent of the cells was normal. At anaphase-II, the abnormalities consisted of laggards in 16.2 per cent of the cells. At telophase-II lagging univalents and division of fragments were also observed. The tetrad abnormalities included micronuclei (4.7 per cent), diads (0.7 per cent) and triads (8.8 per cent) (Plate XVIII, Fig. 5). The pollen fertility was 8.5 per cent (Plate XVIII, Fig. 6).

12. *A. sativa* x *A. brizantha* (253):- The chromosome association at diakinesis ranged from $1_{IV} + 1_{III} + 12_{II} + 1_{I}$ to $8_{II} + 14_{I}$. Pollen mother cells

PLATE XVIII

Meiosis in *A. sativum* × *A. triandrum* (2EI) (Contd.)

Fig. 1 : Diakinesis-I; clumping of chromosomes

Fig. 2 : Anaphase-I; bivalent and univalent laggards. The univalent is in the process of division

Fig. 3 : Anaphase-I; a chromatin bridge and a fragment

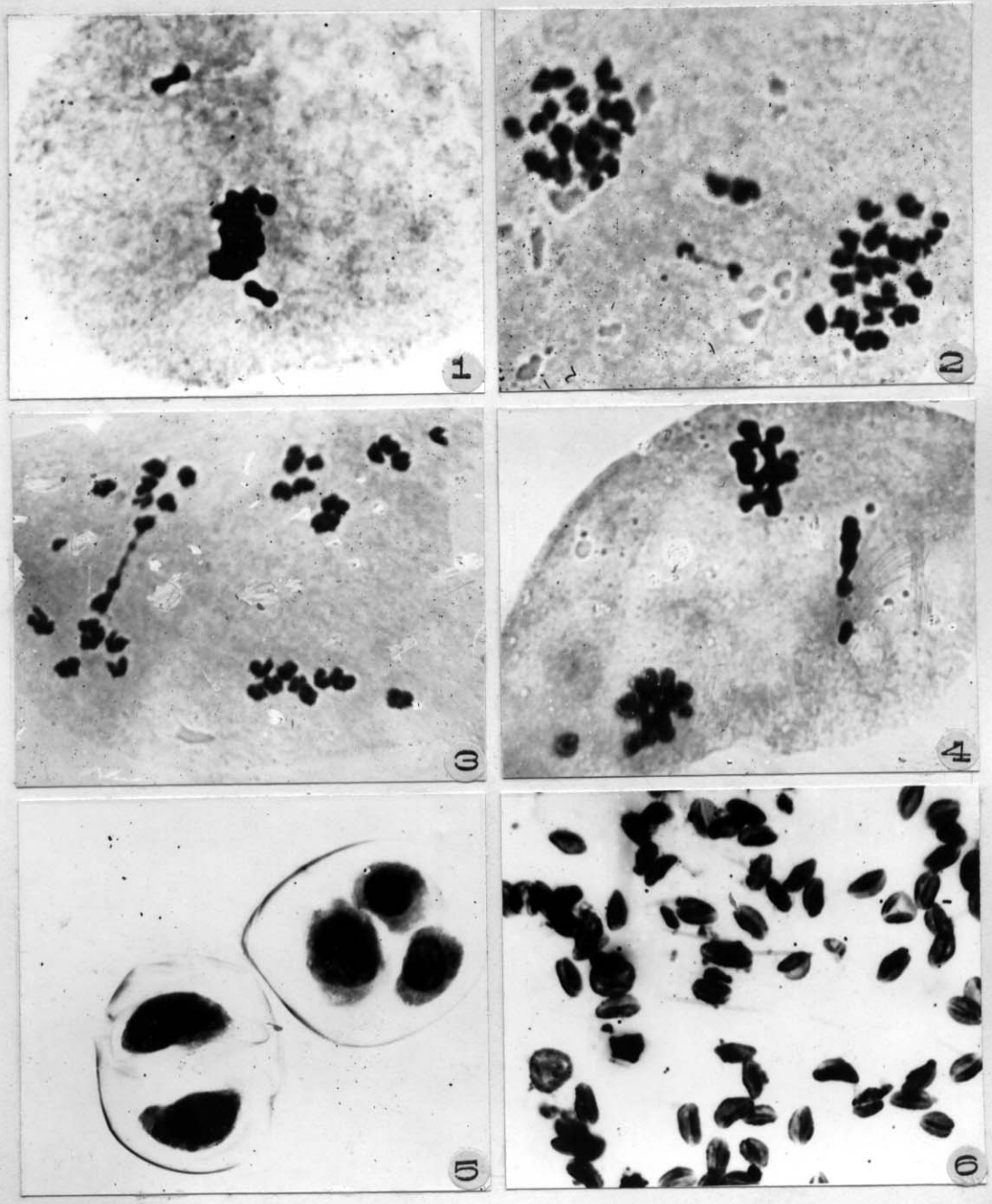
Fig. 4 : Late anaphase-I; 1 trivalent and 2 univalents lagging.

Fig. 5 : Dimi and trimi

Fig. 6 : Pollen grains

(Figs. 1 to 4, × 1400; 5 and 6, × 1100)

PLATE XVIII



with sixteen bivalents had the highest frequency (30.5 per cent) (Plate XIX, Fig. 1). At metaphase-I, the chromosome configuration ranged from $1_{IV} + 1_{III} + 11_{II} + 3_{I}$ to $13_{II} + 6_{I}$. Plate XIX, Fig. 2 shows an association of $1_{III} + 14_{II} + 1_{I}$ and Fig. 3 an association of $1_{IV} + 14_{II}$. Cells with 16_{II} were of the highest frequency (28.0 per cent). Chromosome meanies were observed in 5.7 per cent of the pollen mother cells at diakinesis and 4.7 per cent at metaphase-I (Plate XIX, Figs. 4 and 5). The clumping of chromosomes at metaphase-I was observed in 24.3 per cent of the pollen mother cells. Cytomixis was observed in 33.6 per cent of the cells (Plate XIX, Fig. 6). At anaphase-I, laggards varying in number from one to eight were observed in 29.9 per cent of the cells. Anaphase-II was also characterised by laggards (26.9 per cent) (Plate XIX, Fig. 7) as well as irregular orientations and separation into tripolar and pentapolar configurations. In tetrad stage, microcytes (4.6 per cent), diads (3.2 per cent), triads (11.8 per cent) and pentads (4.8 per cent) were observed. The pollen fertility was 8.3 per cent (Plate XIX, Fig. 8).

13. A. ambosinum x A. bulbosum (307):- The chromosome association at diakinesis ranged from 16_{II} to $1_{II} + 30_{I}$, the highest frequency of 13.8 per cent of cells having 16 bivalents. At diakinesis 3.7 per cent

PLATE XIX

Meiosis in A. sativum x A. triandrum (2n=28)

Fig. 1 : Diakinesis, 16_{II}

Fig. 2 : Metaphase-I, $1_{III} + 14_{II} + 1_{I}$

Fig. 3 : Metaphase-I, $1_{IV} + 14_{II}$

Fig. 4 : Chromosome mosaic; 14_{II}

Fig. 5 : Chromosome mosaic; $17_{II} + 1_{IV}$.

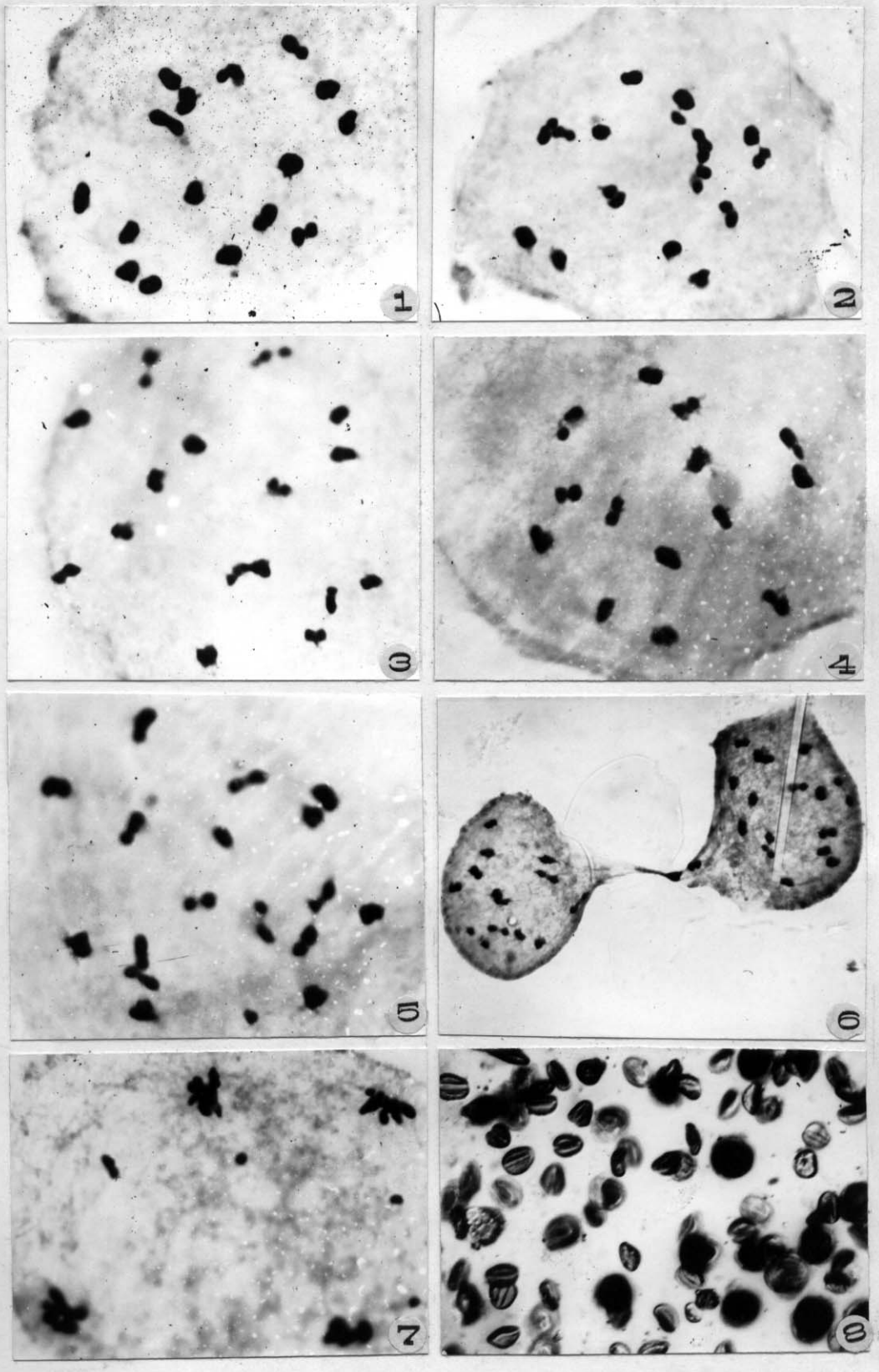
Fig. 6 : Cytomixis

Fig. 7 : Anaphase-II, lagging chromosomes

Fig. 8 : Pollen grains

(Figs.1, 6 and 7, x 1450; 2-5, x 1350; 8, x 1100)

PLATE XIX



of the cells had interplant variation ranging from 6_{II} to $27_{II} + 2_{I}$. At metaphase-I, the chromosome configurations ranged from $1_{III} + 14_{II} + 1_{I} + 1_{Fr}$ (Plate XX, Fig.1) to $13_{II} + 6_{I}$. Cells with 16 bivalents had the highest frequency (22.5 per cent) (Plate XX, Fig.2). Chromosome mosaics observed in 7.6 per cent of the cells had also higher association (Plate XX, Fig. 3). Cytomixis was observed in 39.5 per cent of the cells. Abnormalities at anaphase-I and II included laggards (Plate XX, Fig.4) (69.6 and 35.0 per cent respectively) and chromatin bridges (2.1 and 2.5 per cent respectively). At metaphase-II, there was clumping and disoriented organisation in 84.5 per cent of the cells (Plate XX, Fig. 5). Irregular separation of chromosomes at anaphase-II was also observed in 3.6 per cent of the cells (Plate XX, Fig. 6). At tetrad stage abnormalities like microcytes (10.9 per cent), monads, diads, triads and pentads (3.8 per cent) were also observed. The pollen fertility was 6.1 per cent.

14. A. sativum x A. triandra (Spontaneous hybrid)- At diakinesis, the chromosome association ranged from $1_{IV} + 9_{II} + 10_{I}$ to $4_{II} + 24_{I}$ (Plate XXI, Fig. 1). Plate XXI, Fig. 2 shows an association of $1_{III} + 12_{II} + 5_{I}$. Pollen mother cells with $9_{II} + 14_{I}$ were of the highest frequency (24.6 per cent). Three cells with chromosome mosaics were observed out of the 60 cells studied. At

PLATE XX

Meiosis in *A. ambigua* × *A. triandra* (307)

Fig. 1: Metaphase-I, $1_{III} + 14_{II} + 1_{I} + 1_{pr}$.

Fig. 2: Metaphase-I, 16_{II}

Fig. 3: Chromosome mosaic; $1_{III} + 13_{II} + 4_{I}$

Fig. 4: Late anaphase-I, lagging chromosome

Fig. 5: Disorientation of chromosomes at metaphase-II

Fig. 6: Tripolar separation with unequal chromosome numbers at anaphase-II.

(Figs.1 and 3 to 6, × 1350; 2, × 1500)

PLATE XX

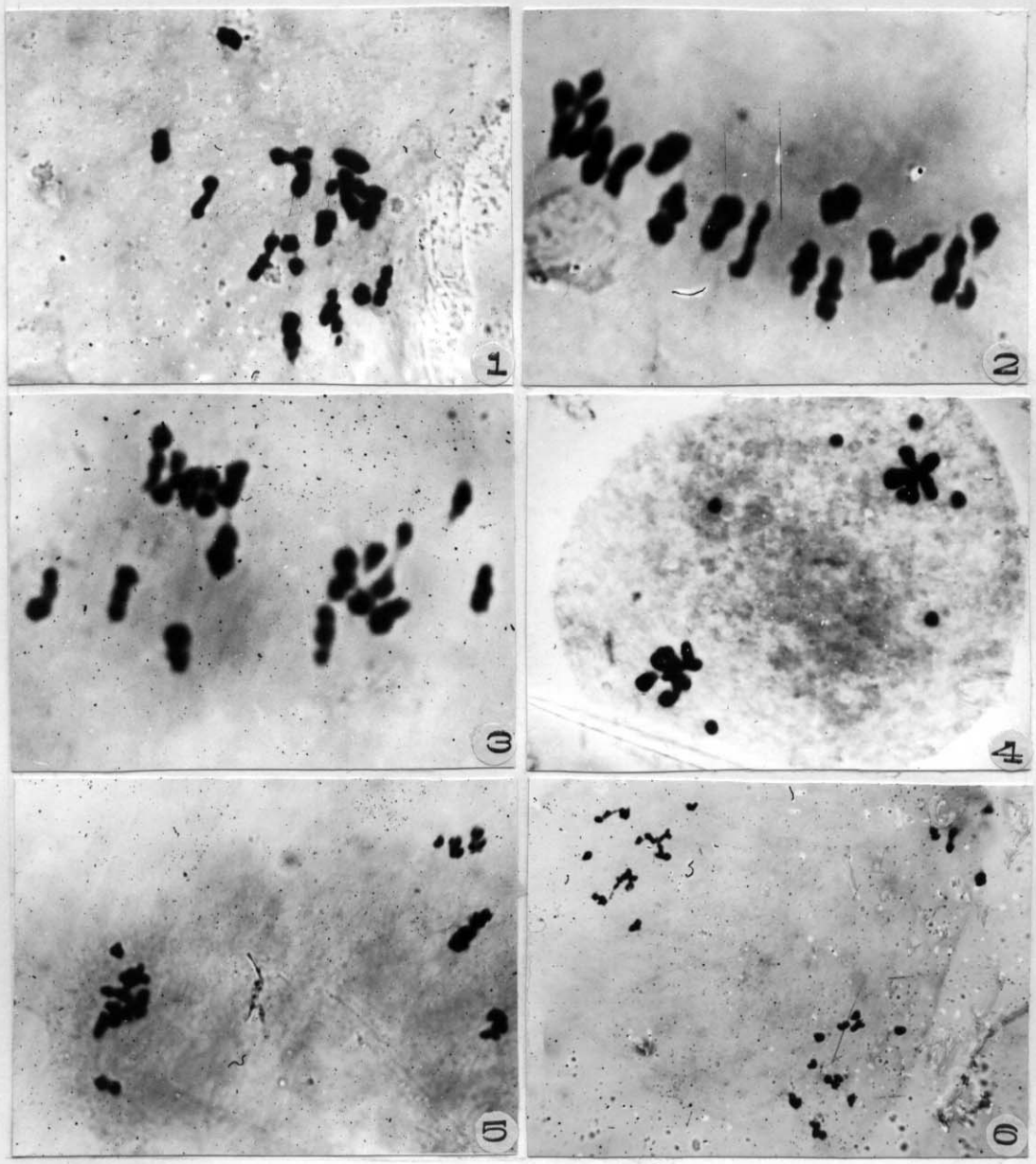


PLATE XXI

Meiosis in *A. asiaticum* × *A. triandra* spontaneous hybrid

Fig. 1: Diakinesis, $4_{II} + 24_{I}$

Fig. 2: Diakinesis, $1_{III} + 12_{II} + 5_{I}$

Fig. 3: Metaphase-I, 16_{II}

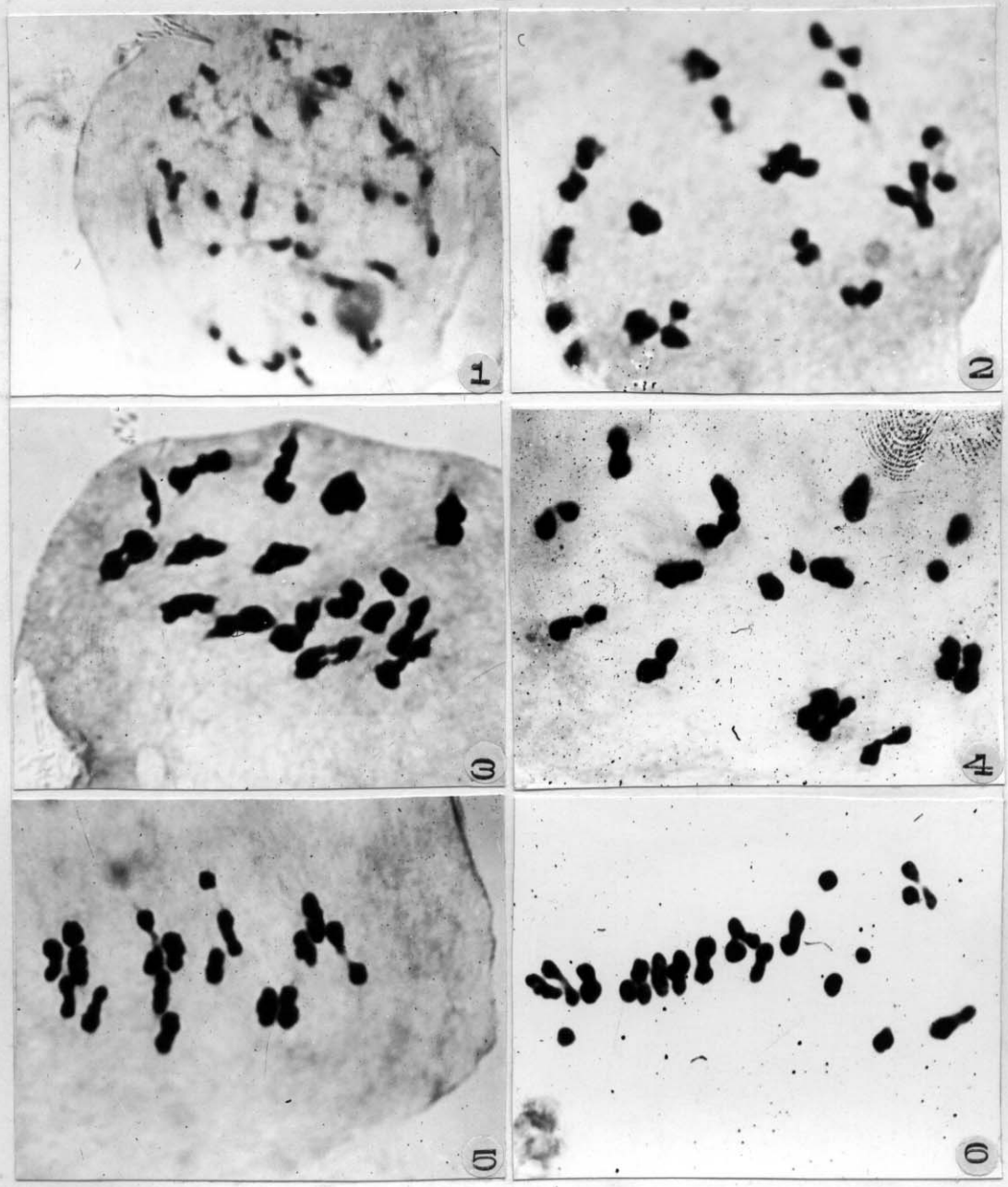
Fig. 4: Metaphase-I, $1_{IV} + 11_{II} + 6_{I}$

Fig. 5: Metaphase-I, $1_{III} + 14_{II} + 1_{I}$

Fig. 6: Metaphase-I, $1_{III} + 11_{II} + 7_{I}$

(Fig.1, × 1550; 2 to 6, × 1450)

PLATE XXI



metaphase-I, the chromosome association ranged from $^{1}_{IV} + 11_{II} + 6_{I}$ to $11_{II} + 10_{I}$ (Plate XXI, Figs. 3, 4, 5 & 6). Chromosome mosaics were observed in four out of 44 cells studied. Laggards were observed in 46.5 per cent of the cells at anaphase-I (Plate XXI, Fig. 1) and 31.8 per cent at anaphase-II (Plate XXI, Fig. 2). Disorientation of chromosomes and subsequent formation of multipolar groups were noticed (Plate XXI, Figs. 3 and 4). Besides normal tetrads, monads (6.3 per cent), diads (9.8 per cent), triads (15.8 per cent) and tetrads with micronuclei (Plate XXI, Fig. 5) (12.6 per cent) were also noticed. The pollen fertility was 0.1 per cent (Plate XXI, Fig. 6).

15. A. triantha x A. sativa (249):- At diakinesis as well as at metaphase-I, 16 bivalents were of the highest frequency (31.1 and 82.3 per cent of the pollen mother cells respectively, Plate XXIII, Fig. 1). The higher association was limited to trivalents only in 1.6 per cent of the cells at diakinesis and 2.5 per cent at metaphase-I (Plate XXIII, Fig.2). The average number of univalents per cell were more at diakinesis (7.5) than at metaphase-I (0.45). Chromosome mosaics were observed in 1.6 per cent of the pollen mother cells at diakinesis and 13.0 per cent at metaphase-I (Plate XXIII, Fig.3). Chromosome mosaics at metaphase-I included two cells with a fragment each,

PLATE XXII

Meiosis in *A. sativa* x *A. strigosa* Spontaneous hybrid (Contd.)

Fig. 1 : Anaphase-I; 15/15 separation and delayed division of two univalents

Fig. 2 : Unequal separation and laggards at anaphase-II

Fig. 3 : Anaphase-II with three groups of chromosomes and laggards

Fig. 4 : Anaphase-II, showing unequal groups of chromosomes and laggards

Fig. 5 : Tetrad with 2 micronuclei

Fig. 6 : Pollen grains

(Figs. 1 to 4, x 1450; 5, x 1900; 6, x 1100)

PLATE XXII

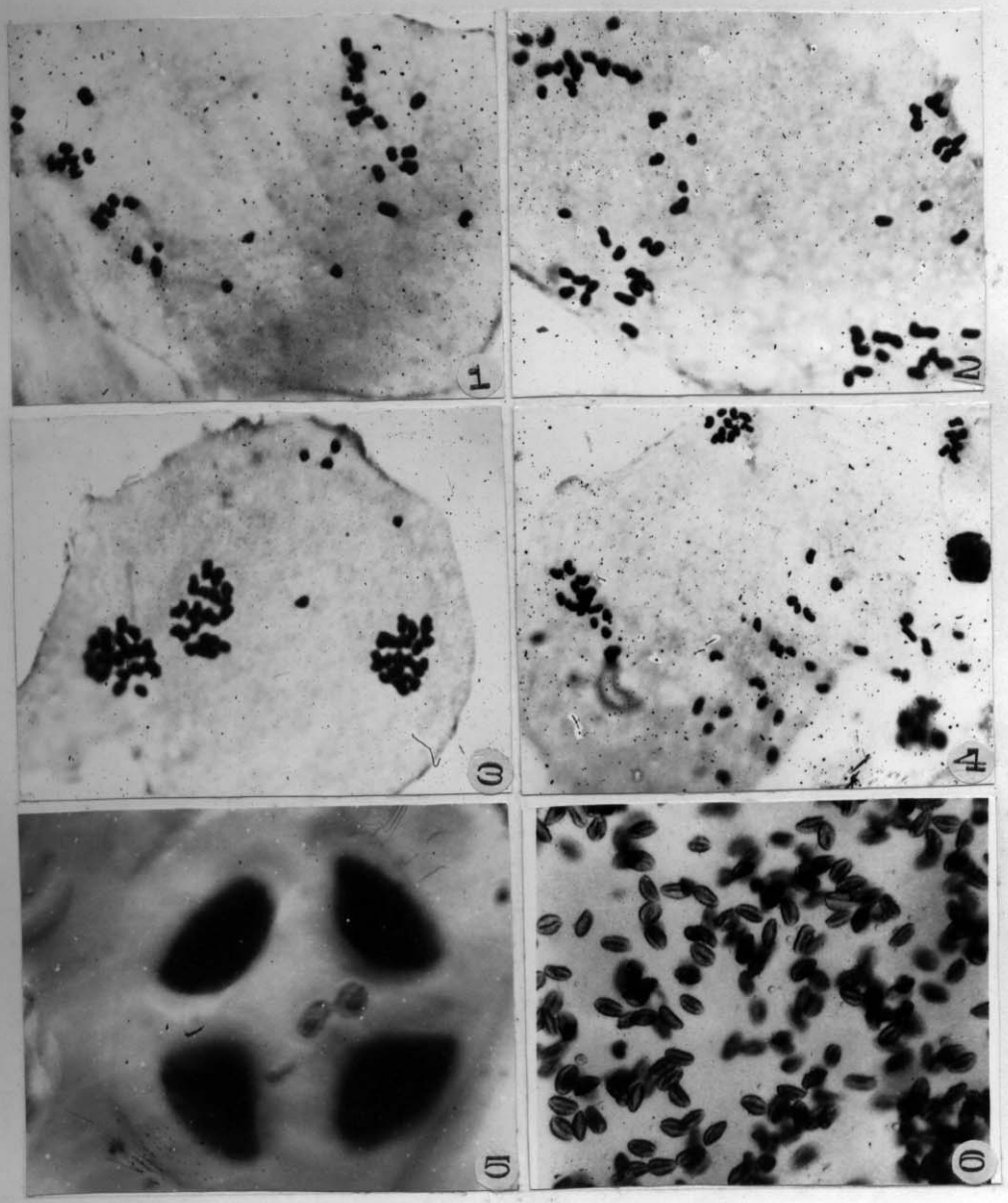


Table 5. Maximum and minimum chromosome association and association with hi
A. catechu, *A. triandra* and their interspecific hybrids

Sl. No.	Parents/Hybrids			No. of PMCs studied	Maximum association								
					X	VIII	VI	V	IV	III	II	I	Fr.
	(i) *A. catechu*												
1.	Local	(471)	Diakinesis	82					2	-	12	-	-
			Metaphase-I	53	1	-	-	-	1	-	9	-	-
2.	"	(717)	Diakinesis	100							16	-	-
			Metaphase-I	87							16	-	-
3.	China	(111)	Diakinesis	82			1	-	-	-	13	-	-
			Metaphase-I	63			1	-	2	-	9	-	-
4.	"	(175)	Diakinesis	80					2	-	12	-	-
			Metaphase-I	43			1	-	-	-	13	-	-
	(ii) *A. triandra*												
5.	Ceylon-3	(55)	Diakinesis	55							16	-	-
			Metaphase-I	84						1	14	1	-
6.	"	(70)	Diakinesis	80							16	-	-
			Metaphase-I	76							16	-	-
7.	"	(87)	Diakinesis	96					1	-	14	-	-
			Metaphase-I	66							16	-	-
8.	Mauritius	(109)	Diakinesis	49						1	14	1	-
			Metaphase-I	71						2	9	8	-
9.	Indonesia-2	(154)	Diakinesis	38							15	2	-
			Metaphase-I	56					1	-	14	-	-
	(iii) Hybrids												
10.	*A. catechu* x *A. triandra*	(248)	Diakinesis	107		1	-	1	-	1	5	6	-
			Metaphase-I	61				1	-	-	13	-	-
11.	"	(287)	Diakinesis	90						1	13	3	1
			Metaphase-I	114						1	12	5	1
12.	"	(288)	Diakinesis	82					1	1	12	1	-
			Metaphase-I	81					1	1	11	3	-
13.	"	(307)	Diakinesis	65							16	-	-
			Metaphase-I	97						1	14	1	1
14.	Spontaneous hybrid		Diakinesis	57					1	-	9	10	-
			Metaphase-I	40					1	-	11	6	-
15.	*A. triandra* x *A. catechu*	(249)	Diakinesis	61						1	14	1	-
			Metaphase-I	80						1	14	1	-

* Fragments

ighest frequency at diakinesis and metaphase-I in

Minimum association				Association with highest frequency			
Percentage of PMCs	II	I	Percentage of PMCs	II	I		Percentage of PMCs
22.0	16	-	54.9	16	-		54.9
1.9	16	-	52.8	16	-		52.8
73.0	11	10	1.0	16	-		73.0
95.4	15	2	4.6	16	-		95.4
1.2	14	4	1.2	16	-		74.4
1.6	16	-	87.3	16	-		87.3
2.5	15	2	5.0	16	-		72.5
2.3	16	-	76.7	16	-		76.7
9.1	8	6	3.6	15	2		20.0
1.2	15	2	25.0	16	-		73.8
31.3	6	20	1.3	16	-		31.3
77.6	15	6	1.3	16	-		77.6
2.1	7	18	6.3	16	-		21.9
63.6	8	16	3.0	16	-		63.6
2.0	5	22	2.0	15	2		22.4
1.4	4	24	1.4	16	-		45.1
10.5	4	24	2.6	15	2		10.5
2.8	8	16	5.6	16	-		55.6
0.9	2	28	1.9	8	16		15.9
1.7	11	10	1.7	{15 / 14}	{2 / 4}	and	21.7 each
2.2		32	1.1	12	8		13.3
5.5	12	8	0.9	15	2		41.2
1.2	8	14	1.2	16	-		30.5
1.2	15	6	1.2	16	-		98.8
13.8	1	30	3.1	16	-		13.8
1.0	15	6	2.1	16	-		82.5
1.8	4	24	7.0	9	14		24.6
1.2	11	10	2.5	14	4		90.8
1.6	4	24	1.6	16	-		31.1
2.5	10	12	1.3	16	-		82.5

Table 6. Chiasma frequency at diakinesis in *A. sativa*, *A. byzantina* and their interspecific hybrids

Sl. No.	Parents/Hybrids	Chiasma per cell		Chiasma per bivalent	
		Mean	Standard error	Mean	Standard error
	(i) *A. sativa*				
1.	Local (471)	25.900	0.241	1.619	0.015
2.	" (717)	21.833	0.832	1.365	0.052
3.	China (111)	25.933	0.249	1.621	0.016
4.	" (175)	25.333	0.290	1.576	0.018
	(ii) *A. byzantina*				
5.	Ceylon-3 (55)	14.333	0.480	0.896	0.030
6.	" (70)	15.767	0.397	0.985	0.025
7.	" (87)	14.533	0.632	0.909	0.040
8.	Mauritius (109)	15.790	0.658	0.899	0.041
9.	Indonesia-2 (154)	15.530	0.562	0.846	0.035
	(iii) Hybrids				
10.	*A. sativa* x (248) *A. byzantina*	9.300	0.505	0.581	0.032
11.	" (287)	12.660	0.700	0.792	0.044
12.	" (288)	17.630	0.582	1.102	0.036
13.	" (307)	11.200	2.209	0.700	0.043
14.	Spontaneous hybrid	9.300	0.525	0.581	0.033
15.	*A. byzantina* x (249) *A. sativa*	14.673	0.572	0.889	0.036

Table 7. Chromosome pairing at diakinesis their hybrids

Sl. No.	Parents/Hybrids	2n	Cells	VIII Range	VIII Mean	VI Range	VI Mean
	(i) *A. sativa*						
1.	Local (471)	32	82				
2.	" (717)	32	100				
3.	China (111)	32	82			0-1	0.01
4.	" (175)	32	80				
	(ii) *A. brizantha*						
5.	Ceylon-3 (55)	32	55				
6.	" (70)	32	80				
7.	" (87)	32	96				
8.	Mauritius (109)	32	49				
9.	Indonesia-2 (154)	32	58				
	(iii) Hybrids						
10.	*A. sativa* x *A. brizantha* (248)	32	107	0-1	0.01	0-1	0.01
11.	" " (287)	32	90				
12.	" " (288)	32	82				
13.	" " (307)	32	65				
14.	Spontaneous hybrid	32	57				
15.	*A. brizantha* x (249) *A. sativa*	32	61				

s in *A. catechu*, *A. triandra* and

DIAKINESIS									
V		IV		III		II		I	
Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
		0–2	0.67	–	–	12–16	14.66	–	–
		–	–	–	–	11–16	15.64	0–10	0.72
–	–	0–2	0.15	–	–	12–16	15.55	0–4	0.24
		0–2	0.24	0–1	0.01	12–16	14.45	0–2	0.11
						8–16	12.67	0–14	7.[illegible]
						6–16	13.74	0–20	4.[illegible]
		0–1	0.03	–	–	7–16	12.85	0–18	6.17
				0–1	0.06	5–16	12.12	0–22	7.[illegible]
						4–15	11.05	1–24	9.[illegible]
0–1	0.01	0–2	0.10	0–3	0.40	2–14	8.92	0–[illegible]	12.37
		–	–	0–1	0.08	0–16	11.24	0–32	9.[illegible]
		0–1	0.13	0–1	0.05	8–16	14.34	0–14	2.66
		–	–	–	–	0–16	10.34	0–30	11.[illegible]
		0–1	0.04	0–1	0.09	4–16	9.91	5–24	11.77
				0–1	0.02	4–16	12.22	0–24	7.38

Table 8. Chromosome pairing at metaphase-I and their hybrids

Sl. No.	Parents/Hybrids	2n	No. of PMC's studied	X Range	X Mean	VIII Range	VIII Mean	Range
(i)	A. sativa							
1.	Local (471)	32	53	0-1	0.02	0-1	0.02	0-2
2.	" (717)	32	87					
3.	China (111)	32	65					0-1
4.	" (175)	32	43					0-1
(ii)	A. byzantina							
5.	Ceylon-3 (55)	32	84					
6.	" (70)	32	76					
7.	" (87)	32	66					
8.	Mauritius (109)	32	71					
9.	Indonesia-2 (154)	32	36					
(iii)	Hybrids							
10.	A. sativa x (248) A. byzantina	32	61					0-1
11.	" (287)	32	114					
12.	" (288)	32	81					
13.	" (307)	32	97					
14.	Spontaneous hybrid	32	39					
15.	A. byzantina x (249) A. sativa	32	80					

in A. [illegible], A. triandra

VI	IV		III		II		I	
Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
0.17	0-5	0.60	0-2	0.16	4-16	15.55	0-2	0.08
					15-16	15.95	0-2	0.08
0.02	0-2	0.21	-	-	9-16	15.63	-	-
0.02	0-2	0.21	-	-	13-15	15.52	-	-
			0-1	0.01	14-16	15.73	0-2	0.31
					13-16	15.71	0-6	0.58
					8-16	14.65	0-16	2.49
			0-2	0.10	4-16	13.46	0-24	4.77
	0-1	0.05	0-1	0.05	8-16	14.69	0-16	2.42
0.02	0-1	0.02	0-2	0.12	5-16	14.07	0-10	3.35
			0-1	0.06	10-16	14.83	0-9	2.15
	0-1	0.09	0-1	0.06	11-16	15.33	0-6	0.90
			0-1	0.01	13-16	15.73	0-6	0.31
			0-1	0.05	11-16	14.35	0-10	3.18
			0-1	0.05	10-16	15.73	0-12	0.45

Table 9. Abnormalities at later stages of meiosis in *A. sativa* and their hybrids

Sl. No.	Parents/Hybrids	Anaphase I			Anaphase II	
		Normal cells (%)	Cells with bridges and laggards and dis-orientation (%)	Total number of cells	Normal cells (%)	Cells with bridges and laggards and dis-orientation (%)
	(i) *A. sativa*					
1.	Local (471)	90.9	9.1	121	89.3	10.7
2.	" (717)	88.6	11.4	123	98.5	1.5
3.	China (111)	99.4	0.6	163	100.0	0
4.	" (173)	93.7	6.3	93	95.2	4.8
	(ii) *A. brizaeformis*					
5.	Ceylon-3 (55)	73.6	26.4	148	88.9	11.1
6.	" (70)	91.8	8.2	110	98.5	1.5
7.	" (87)	82.1	17.9	106	84.4	15.6
8.	Mauritius (109)	70.5	29.5	44	73.2	26.8
9.	Indonesia-2 (154)	81.2	18.8	80	75.4	24.6
	(iii) Hybrids					
10.	*A. sativa* x (248) *A. brizaeformis*	30.3	69.7	89	47.7	52.3
11.	" (287)	85.3	14.7	109	83.8	16.2
12.	" (288)	70.1	29.9	87	73.1	26.9
13.	" (307)	28.3	71.7	46	62.5	37.5
14.	Spontaneous hybrid	53.5	46.5	71	68.2	31.8
15.	*A. brizaeformis* x (249) *A. sativa*	85.8	14.2	147	97.4	2.6

* Returns with failure

pollen fertility and nut set in *A. saltuaria*.

Total number of cells	Tetrads: Normal cells (%)	Tetrads: Micronuclei (%)	Tetrads: Monads (%)	Tetrads: Diads (%)	Tetrads: Triads (%)	Tetrads: Supernumerary spores (%)	Total number of cells	Pollen fertility (%)	Nut set (%)
84	87.7	0	0	0	12.3	0	171	99.4	26.4
67	95.8	0.8	0	1.4	2.0	0	144	82.7	36.9
70	97.0	0	0	0	3.0	0	67	98.2	42.2
63	86.8	0	0	2.8	10.4	0	106	95.7	12.0
81	93.3	1.7	0.5	1.7	2.8	0	178	75.5	36.4
67	85.7	0	0	0.7	12.9	0.7	140	85.4	42.1
77	78.9	4.1	0	0.7	13.6	2.7	147	63.3	28.1
41	72.0	14.9	1.7	4.6	6.8	0	175	33.1	33.8
57	92.7	1.8	1.2	0	4.3	0	164	45.2	41.5
44	56.2	22.6	0	2.2	16.1	2.9*	137	3.7	0.5
117	85.8	4.7	0	0.7	8.8	0	148	0.5	0.28
93	75.6	4.6	0	3.2	11.8	4.8	185	8.3	Nil
80	85.3	10.9	0.7	0.4	2.3	0.4	733	6.1	Nil
66	55.9	12.6	6.3	9.8	15.4	0	143	0.1	Not available
77	90.4	0	0.6	3.9	4.5	0.6	177	67.0	Not available

* cytokinesis in one half.

Table 10. Intra individual variation in chromosome numbe
A. sativum, A. brizantha and their interspecific

Sl. No.	Parents/Hybrids		Number of PMCs observed	Number of PMC with chromosome mosaic
	(i) A. sativum			
1.	Local (471)	Diakinesis	82	-
		Metaphase-I	53	-
2.	" (717)	Diakinesis	102	2
		Metaphase-I	87	-
3.	China (111)	Diakinesis	88	6
		Metaphase-I	66	3
4.	" (175)	Diakinesis	80	-
		Metaphase-I	43	-
	(ii) A. brizantha			
5.	Ceylon-3 (55)	Diakinesis	72	17
		Metaphase-I	93	14
6.	" (70)	Diakinesis	87	7
		Metaphase-I	81	5
7.	" (87)	Diakinesis	103	7
		Metaphase-I	73	7
8.	Mauritius (109)	Diakinesis	56	7
		Metaphase-I	79	8
9.	Indonesia-2 (154)	Diakinesis	38	-
		Metaphase-I	37	1
	(iii) Hybrids			
10.	A. sativum x A. brizantha (248)	Diakinesis	119	12
		Metaphase-I	64	3
11.	" (287)	Diakinesis	97	7
		Metaphase-I	117	3
12.	" (288)	Diakinesis	87	3
		Metaphase-I	85	4
13.	" (307)	Diakinesis	72	7
		Metaphase-I	105	8
14.	Spontaneous hybrid	Diakinesis	80	3
		Metaphase-I	44	4
15.	A. brizantha x A. sativum (249)	Diakinesis	82	1
		Metaphase-I	98	98

r at meiosis in
e hybrids

Percentage	Range of chromosome association in PMCs with meiosis
-	-
-	-
2.0	15_{II}
-	-
6.8	6_{II} to $1_{IV} + 13_{II}$
4.5	6_{II} to 15_{II}
-	-
-	-
23.6	$5_{II} + 1_{I}$ to 17_{II}
14.3	$1_{II} + 1_{I}$ to $27_{II} + 1_{I}$
8.0	$8_{II} + 3_{I}$ to 15_{II}
6.2	12_{II} to 19_{II}
6.8	$5_{II} + 5_{I}$ to 15_{II}
9.6	2_{II} to $18_{II} + 1$ Fr
12.5	$4_{II} + 3_{I}$ to $1_{IV} + 1_{III} + 7_{II} + 13_{I}$
10.1	7_{II} to $1_{III} + 9_{II} + 13_{I}$
-	-
2.7	$13_{II} + 1$ Fr
1.0	$1_{II} + 3_{I}$ to $1_{VI} + 8_{II} + 4_{I}$
4.6	$12_{II} + 6_{I}$ to $1_{XX} + 10_{II} + 3_{I}$
7.2	$4_{II} + 3_{I}$ to $1_{III} + 2_{II} + 8_{I}$
2.6	8_{II} to $1_{III} + 13_{II} + 1_{I}$
3.7	$8_{II} + 2_{I}$ to $1_{III} + 14_{II} + 3_{I}$
4.7	14_{II} to $1_{III} + 13_{II} + 2_{I}$
9.7	6_{II} to $27_{II} + 2_{I}$
7.6	11_{II} to $1_{III} + 13_{II} + 2_{I}$
5.0	$15_{II} + 15_{I}$ to $1_{III} + 9_{II} + 9_{I}$
9.1	$15_{II} + 1_{II}$ to 9_{II} to 12_{I}
1.6	$3_{II} + 4_{I}$
13.0	$2_{II} + 5_{I}$ to $15_{II} + 1$ Fr

PLATE XXXXI

Meiosis in *A. tricandra* x *A. sativum* (249)

Fig. 1 : Metaphase-I, 16_{II}

Fig. 2 : Metaphase-I, $1_{III} + 14_{II} + 1_{I}$

Fig. 3 : Chromosome mosaic, 15_{II}

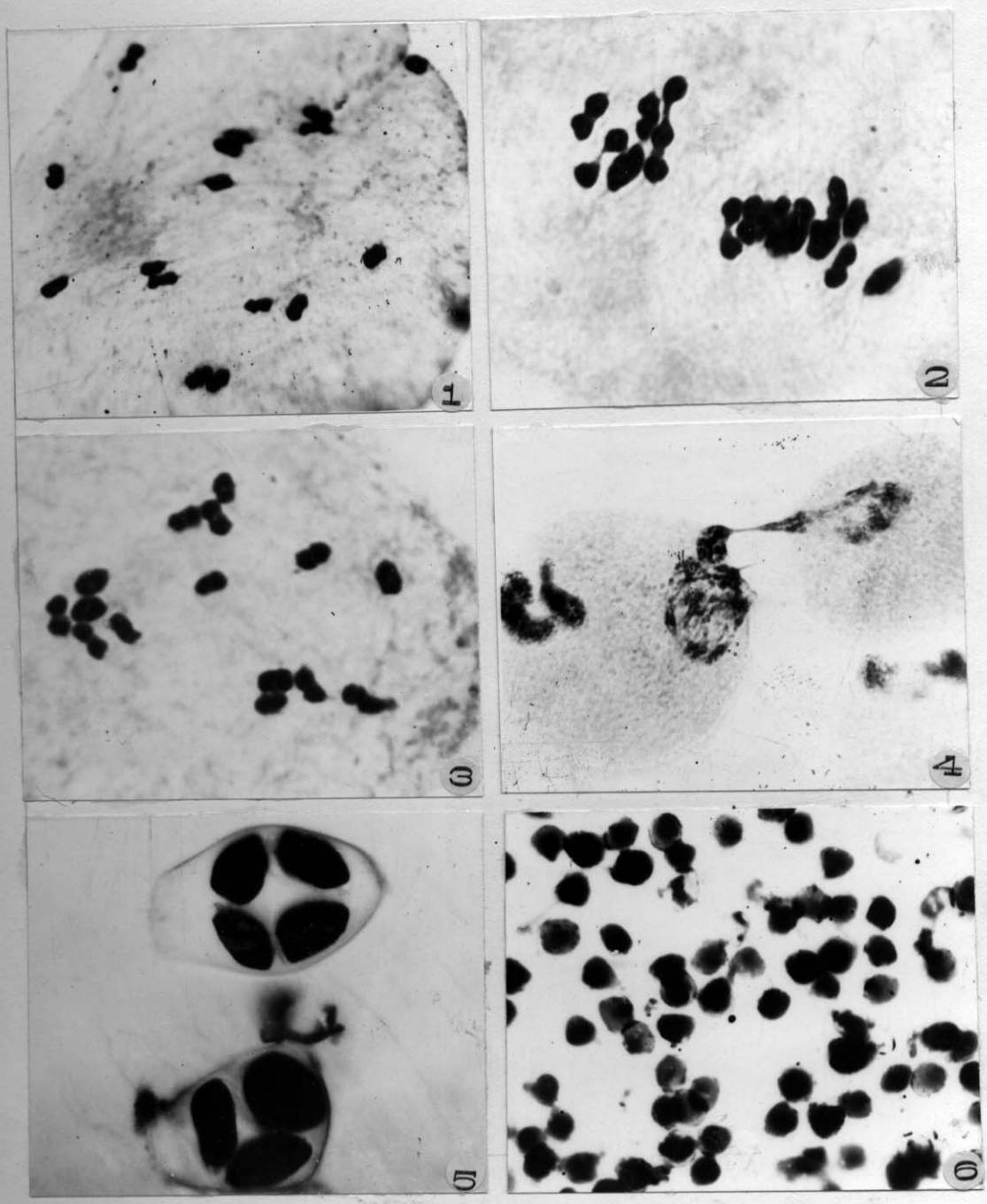
Fig. 4 : Cytomixis

Fig. 5 : Triad and tetrad

Fig. 6 : Pollen grains

(Figs. 1, 3 and 5, x 1450; 2, x 1500; 4, x 1500; 6, x 1100)

PLATE XXIII



cytomixis was observed in 35.2 per cent of the pollen mother cells (Plate XXXII, Fig. 4). At metaphase-I, stickiness and clumping of the chromosomes were observed in 15.5 per cent of the cells. Anaphase-I and II had laggards in 14.2 and 2.6 per cent of the cells respectively. Misorientation of the metaphase-II plates were observed in 29.2 per cent of the cases. The abnormalities observed at tetrad stage were monads (0.6%), diads (3.9%), triads (4.5%) (Plate XXXII, Fig. 5) and pentads (0.6%). Pollen fertility was 67.0 per cent (Plate XXIII, Fig. 6).

b. Lawsonia

The 2n chromosome number of *L. spinosa*, *L. inermis* and their hybrids was found to be 32. The morphology of chromosomes of the parents and hybrids is described from the somatic (root tip) divisions. For convenience of description of karyotype the chromosomes were paired and numbered according to the order of decreasing length. The paired chromosomes were classified as median (long arm/short arm = 1.00 - 1.33), submedian (long arm/short arm = 1.34 - 1.66) and subterminal (long arm/short arm = 1.67 and above) based on their arm ratio. The total chromatin length, range of absolute length of individual chromosomes and type of symmetry based on Stebbins (1958) are given in Table 11. Each

category of chromosomes which did not show significant differences for their relative length were further grouped together (Table 12). As the main consideration in grouping has been the relative length, it is likely that chromosomes with the same arm ratio fall under different groups. Detailed observations on morphological characteristics of the individual chromosomes of parents and hybrids are given in Appendix I.

(1) Arman catechu

1. Local (471):- Among the 16 pairs of chromosomes (Plate XXIV, Fig. 1; Plate XXVIII, Fig. 1), six were submedian and the remaining 10 pairs were subterminal. The absolute length of the chromosomes in the complement varied from 2.18 μ to 4.13 μ and the arm ratio varied from 1.43 to 2.38. Based on the relative length, the 16 pairs were classified into the following eight groups.

Group I (Chromosome 1):- The longest chromosome in the complement with submedian centromere; arm ratio = 1.43; relative length = 8.31.

Group II (Chromosome 2):- This has subterminal centromere with the arm ratio of 1.94 and relative length of 7.64.

Group III (Chromosomes 3 - 5):- Chromosome 3 had submedian centromere while 4 and 5 have subterminal centromere. The arm ratios ranged from 1.49 to 2.27 and relative lengths ranged from 7.29 to 6.90. Chromosome 3 had satellite on the short arm.

PLATE XXIV

Somatic chromosomes in *A. esculenta multivora*

Fig. 1 : Local (471), 2n = 32

Fig. 2 : Local (717), 2n = 32

Fig. 3 : China (111), 2n = 32

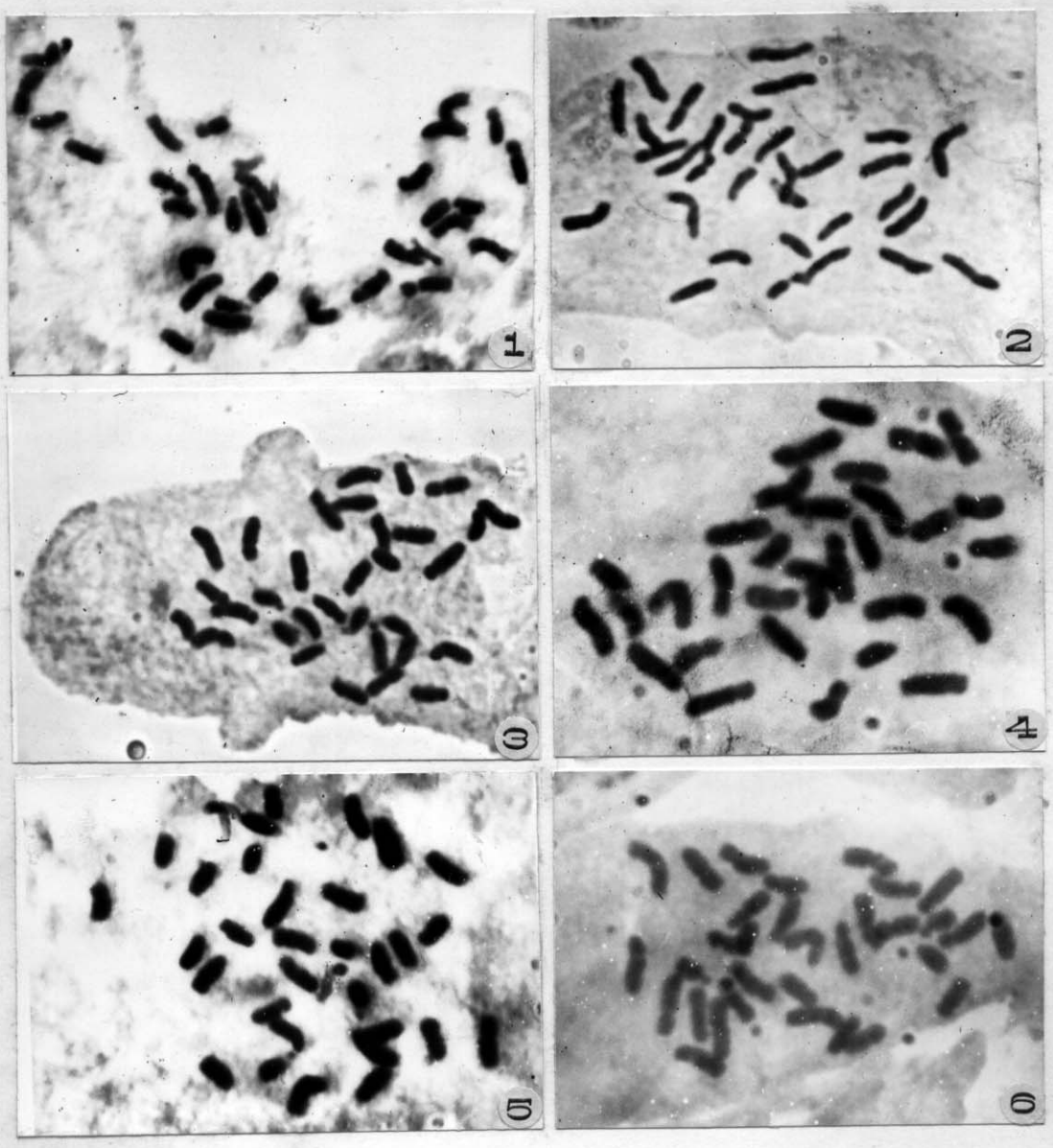
Fig. 4 : Ceylon-1 (191), 2n = 32

Fig. 5 : Indonesia-6 (61), 2n = 32

Fig. 6 : Saigon-1 (176), 2n = 32

(Figs. 1 and 2, x 1900; 3, 5 and 6, x 2450; 4, x 2700)

PLATE XXIV



Group IV (Chromosomes 6 and 7):- Both were subterminal chromosomes. Arm ratio - 1.74 and 2.38; relative length - 6.73 and 6.44.

Group V (Chromosomes 8 - 10):- Chromosomes 8 and 9 had subterminal centromere and 10 had submedian centromere. The arm ratios ranged from 1.63 to 2.25 and relative length from 6.37 to 6.01.

Group VI (Chromosomes 11 and 12):- Chromosome 11 was submedian with satellite on the long arm. Chromosome 12 had subterminal centromere. Arm ratio - 1.61 and 1.82; relative length - 5.81 and 5.60.

Group VII (Chromosomes 13 and 14):- Chromosome 13 was subterminal with the arm ratio of 2.06 and chromosome 14 was submedian with the arm ratio of 1.47. The relative lengths were 5.30 and 5.18 respectively.

Group VIII (Chromosomes 15 and 16):- Chromosome 15 was subterminal and 16 was submedian. The latter had satellite on the long arm. The arm ratios were 1.83 and 1.99 and relative lengths were 4.83 and 4.42 respectively.

2. Local (717):- Out of the 16 pairs of chromosomes (Plate XXIV, Fig. 2; Plate XXVIII, Fig. 2), five were median and 11 were submedian. No satellites were observed in the chromosome complement. The maximum and minimum length of chromosomes were 3.78 μ and 1.83 respectively. The arm ratios of the chromosomes varied fr 1.29 to 1.51. The 16 pairs of chromosomes were classified into the following nine groups.

Group I (Chromosome 1):- This was the longest chromosome of the complement with submedian centromere. Arm ratio - 1.51; relative length - 8.57.

Group II (Chromosomes 2 and 3):- Submedian chromosomes; arm ratio - 1.46 and 1.41; relative length - 7.79 and 7.57.

Group III (Chromosomes 4 and 5):- Both the chromosomes had submedian centromere with arm ratios of 1.42 and 1.49 and relative lengths of 7.23 and 6.95.

Group IV (Chromosomes 6 and 7):- Both the chromosomes had median centromere. The arm ratios were 1.31 and 1.29 and relative lengths 6.77 and 6.58.

Group V (Chromosomes 8 and 9):- Both the chromosomes had submedian centromere with arm ratios of 1.45 and 1.41 and relative lengths of 6.23 and 6.05.

Group VI (Chromosomes 10 and 11):- Of the two chromosomes one was median and the other submedian with the arm ratios of 1.30 and 1.34 and relative lengths of 5.90 and 5.61.

Group VII (Chromosomes 12 and 13):- Submedian chromosomes; arm ratio - 1.34 and 1.44; relative length - 5.33 and 5.15.

Group VIII (Chromosomes 14 and 15):- One chromosome had submedian and the other had median centromere with arm ratios of 1.35 and 1.32 and relative lengths of 4.90 and 4.52.

Group IX (Chromosome 16):- This was the smallest chromosome of the complement and had an arm ratio of 1.31 and relative length of 4.13.

3. China (111):- Of the 16 pairs of chromosomes (Plate XXIV, Fig. 3; Plate XXVIII, Fig. 3), one was submedian and the remaining 15 were subterminal. Chromosome 15 in the complement had satellite. The maximum and minimum lengths of chromosomes were 3.39 μ and 1.72 μ respectively. The arm ratios of the chromosomes ranged from 1.64 to 2.63. The 16 pairs of chromosomes were classified into the following nine groups.

Group I (Chromosome 1):- This was the largest chromosome of the complement and had subterminal centromere. The arm ratio was 1.98 and relative length 8.59.

Group II (Chromosomes 2 and 3):- Both the chromosomes had subterminal centromere with arm ratios of 1.99 and 2.40 and relative lengths of 7.90 and 7.45.

Group III (Chromosomes 4 and 5):- Subterminal chromosomes with arm ratios of 2.06 and 1.83 and relative lengths of 7.09 and 6.99.

Group IV (Chromosome 6):- Subterminal; arm ratio - 2.04; relative length - 6.75.

Group V (Chromosomes 7 - 10):- This was the longest group with all the chromosomes having subterminal centromere. Arm ratios ranged from 2.63 to 2.04 and relative lengths from 6.39 to 5.99.

Group VI (Chromosomes 11 and 12):- Both the chromosomes had subterminal centromere with arm ratios of 2.11 and 2.37 and relative lengths of 5.74 and 5.49.

Group VII (Chromosome 13 and 14):- Subterminal chromosome with arm ratios of 1.69 and 1.88 and relative lengths of 5.33 and 4.93.

Group VIII (Chromosome 15):- Subterminal chromosome with satellite in the short arm; arm ratio - 2.00; relative length - 4.33.

Group IX (Chromosome 16):- This is the only submedian chromosome of the complement having an arm ratio of 1.64 and relative length of 4.12.

4. Ceylon-1 (191):- Of the 16 pairs of chromosomes, five were median, nine submedian and two subterminal (Plate XXIV, Fig. 4; Plate XXVIII, Fig. 4). Chromosome 12 had satellite on the short arm. The absolute length of the chromosomes ranged from 4.41 μ to 2.14 μ. The chromosomes were classified into the following 10 groups for descriptive purpose.

Group I (Chromosome 1):- Submedian chromosome; arm ratio - 1.40; relative length - 8.54.

Group II (Chromosome 2):- This chromosome was submedian with an arm ratio of 1.38 and relative length of 8.05.

Group III (Chromosome 3 and 4):- Chromosome 3 had submedian centromere and 4 had median centromere. Arm ratio - 1.57 and 1.23; relative length - 7.60 and 7.48.

Group IV (Chromosome 5):- This had submedian centromere with an arm ratio of 1.48 and relative length of 7.14.

Group V (Chromosomes 6 - 8):- Chromosomes 6 and 7 had subterminal centromeres and 8 submedian centromere. Arm ratio - 1.58 - 1.84; relative length - 6.85 - 6.46.
Group VI (Chromosome 9):- Submedian; arm ratio - 1.61; relative length - 6.14.
Group VII (Chromosomes 10 and 11):- Submedian chromosomes; arm ratio - 1.45 and 1.53; relative length - 5.86 and 5.58.
Group VIII (Chromosomes 12 and 13):- Chromosome 12 was median with an arm ratio of 1.33 and relative length of 5.35. It was satellited on the short arm. Chromosome 13 had submedian centromere with an arm ratio of 1.49 and relative length of 5.02.
Group IX (Chromosomes 14 and 15):- Both were median chromosomes with the arm ratios of 1.24 and 1.14 and relative lengths of 4.76 and 4.48 respectively.
Group X (Chromosome 16):- This also had median centromere with an arm ratio of 1.28 and relative length of 4.11.

5. Indonesian (61):- Among 16 pairs of chromosomes 13 had subterminal centromere and the remaining three had submedian (Plate XXIV, Fig. 5; Plate XXVIII, Fig. 5). Chromosome 6 has satellite on its short arm. The length of the largest and shortest chromosomes is 4.12 μ and 1.93 μ

respectively. The arm ratio of the chromosomes ranged from 1.62 to 2.51. The 16 pairs of chromosomes are described under nine groups.

Group I (Chromosome 1):- The longest chromosome in the complement and had an arm ratio of 1.98 and relative length of 8.83.

Group II (Chromosomes 2 and 3):- Both were subterminal chromosomes with the arm ratios of 2.51 and 2.11 and relative lengths of 7.78 and 7.45 respectively.

Group III (Chromosomes 4 and 5):- Both had subterminal centromere. Arm ratio - 2.30 and 2.24; relative length - 7.16 and 7.02.

Group IV (Chromosomes 6 and 7):- Subterminal chromosomes; arm ratio - 2.15 and 1.72; relative length - 6.79 and 6.57. Chromosome 6 had satellite on its short arm.

Group V (Chromosomes 8 and 9):- Both were submedian chromosomes with the arm ratios of 1.62 and 1.65 and relative lengths of 6.39 and 6.19 respectively.

Group VI (Chromosomes 10 - 12):- Chromosomes 10 and 11 were subterminal and 12 was submedian. Arm ratio - 1.65 - 2.35; relative length - 5.87 - 5.42.

Group VII (Chromosomes 13 and 14):- Subterminal chromosomes; arm ratio - 1.79 and 1.74; relative length - 5.21 and 4.96.

Group VIII (Chromosome 15):- This had subterminal centromere with the arm ratio of 1.68 and relative length of 4.68.

Group II (Chromosome 16):- Subterminal; arm ratio - 1.79; relative length - 4.12.

6. Saisam-1 (176):- Nine chromosomes had submedian centromere and the remaining seven had subterminal centromere (Plate XXIV, Fig. 6; Plate XXVIII, Fig. 6). Chromosome 4 had satellite on its short arm. The arm ratio of the chromosomes in the complement ranged from 1.45 to 2.25. The maximum and minimum length of the chromosomes were 3.67 μ and 1.92 μ respectively. The 16 pairs of chromosomes fell under the following nine relative length groups.

Group I (Chromosome 1):- The longest chromosome in the complement with an arm ratio of 2.25 and relative length of 8.24.

Group II (Chromosome 2 and 3):- Chromosome 2 was subterminal and 3 submedian. The arm ratios of the chromosomes were 1.71 and 1.59 and relative lengths 7.82 and 7.53 respectively.

Group III (Chromosome 4):- The chromosome is submedian with satellite on the short arm. The arm ratio was 1.46 and relative length 7.23.

Group IV (Chromosome 5 - 7):- Chromosome 5 and 6 were submedian and 7 subterminal. The arm ratios of the chromosomes ranged from 1.54 to 1.72 and relative lengths from 6.83 to 6.49.

Group V (Chromosomes 8 - 10):- Chromosomes 8 and 9 had submedian centromere and 10 had subterminal. Arm ratio - 1.61 - 2.23; relative length - 6.33 - 5.90.
Group VI (Chromosomes 11 and 12):- Both were subterminal chromosomes. Arm ratio - 1.69 and 1.73; relative length - 5.77 and 5.57.
Group VII (Chromosomes 13 and 14):- Chromosome 13 was submedian and 14 subterminal. The former had an arm ratio of 1.51 and relative length of 5.24 and the latter had an arm ratio of 1.70 and relative length of 5.01.
Group VIII (Chromosome 15):- Submedian chromosome; arm ratio - 1.52; relative length - 4.81.
Group IX (Chromosome 16):- This was the smallest chromosome of the complement and had submedian centromere. Arm ratio - 1.45 and relative length - 4.33.

7. Saisree-2 (180):- Thirteen out of the 16 pairs of chromosomes in this cultivar had subterminal centromere. The remaining three chromosomes had submedian centromere (Plate XIV, Fig. 1; Plate XXVII, Fig. 7). One of the shorter chromosomes (chromosome 14) had satellite. The absolute length of the chromosome in the complement varied from 4.15 μ to 2.15 μ and the arm ratio ranged from 1.64 to 2.16. The chromosomes were tentatively grouped into the following nine categories.

PLATE XIV

Somatic chromosomes in *A. satsuma* cultivars and *A. latandica* varieties

Fig. 1 : *A. satsuma* Saigon-2 (100), 2n = 32

Fig. 2 : " " Ceylon-2 (192), 2n = 32

Fig. 3 : " " Singapore (163), 2n = 32

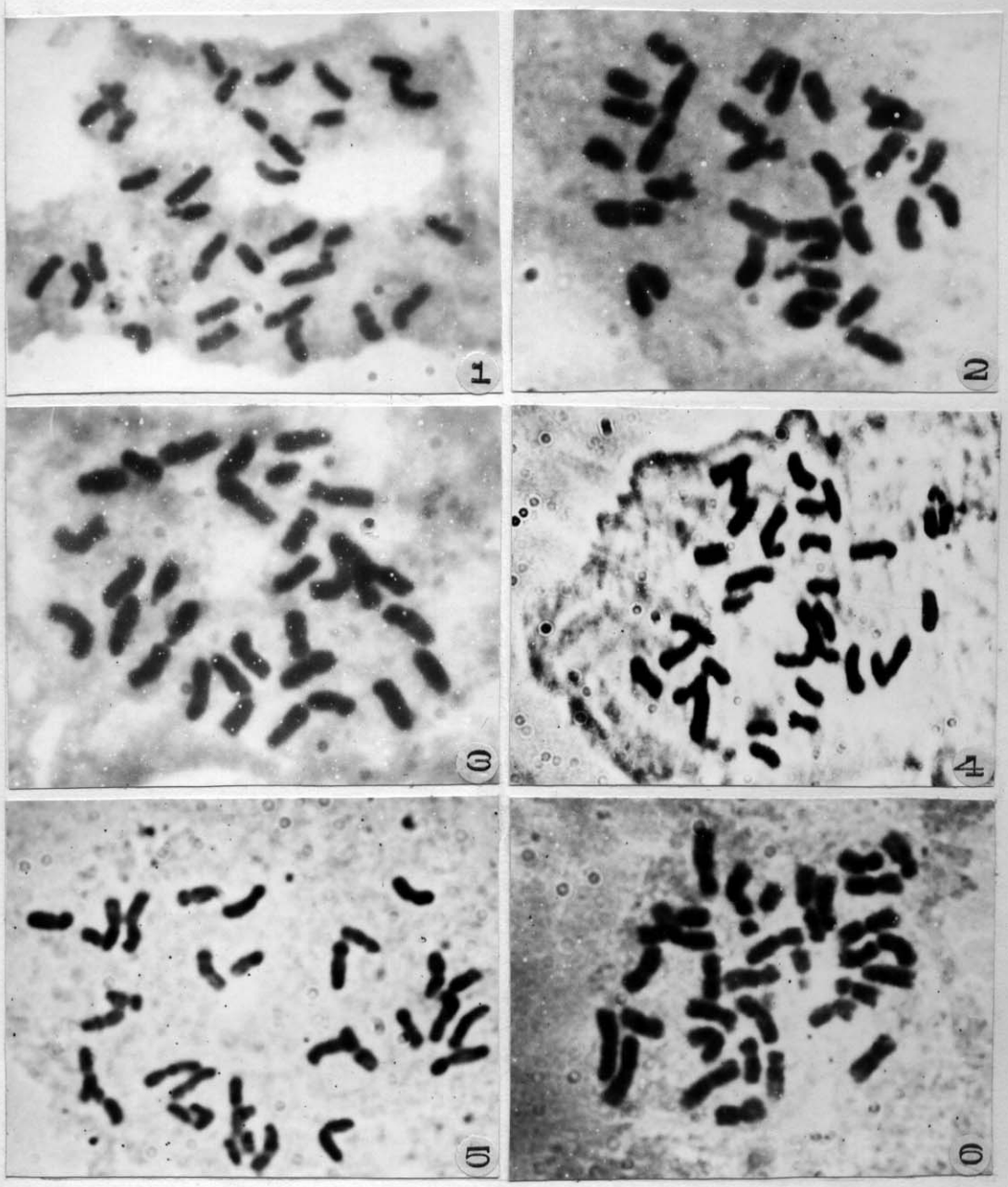
Fig. 4 : *A. latandica* Mauritius (109), 2n = 32

Fig. 5 : " " Indonesia-1 (125), 2n = 32

Fig. 6 : " " Indonesia-2 (74), 2n = 32

(Figs.1 and 3, x 1900; 2, 3 and 6, x 2600; 4, x 2450)

PLATE XXV



Group I (Chromosome 1):- This was the longest chromosome in the complement with subterminal centromere. Arm ratio - 1.69 and relative length - 8.18.

Group II (Chromosomes 2 and 3):- Subterminal chromosomes with the arm ratios of 1.82 and 2.10 and relative lengths of 7.80 and 7.43 respectively.

Group III (Chromosomes 4 and 5):- Subterminal chromosomes; arm ratio - 1.87 and 1.91; relative length - 7.29 and 7.06.

Group IV (Chromosomes 6 and 7):- Both had subterminal centromere. The chromosomes had the arm ratio of 1.97 and 2.05 and relative length of 6.81 and 6.58 respectively.

Group V (Chromosomes 8 - 10):- Chromosomes 8 and 10 were subterminal and 9 was submedian. The arm ratio ranged from 1.64 to 2.16 and relative length ranged from 6.33 to 5.94.

Group VI (Chromosomes 11 and 12):- Chromosome 11 was subterminal and 12 submedian. Arm ratio - 1.86 and 1.65; relative length 5.74 and 5.51.

Group VII (Chromosomes 13 and 14):- Both had subterminal centromere. Chromosome 14 had satellite on its short arm. The chromosomes had the arm ratio of 1.89 and 1.84 and relative length of 5.19 and 5.05 respectively.

Group VIII (Chromosome 15):- Submedian; arm ratio - 1.64; relative length - 4.68.

Group IX (Chromosome 16):- Subterminal chromosome with an arm ratio of 1.89 and relative length of 4.21.

8. Sarlam-2 (192):- Among the 16 pairs of chromosomes, 13 had subterminal centromere and the remaining three had submedian centromere (Plate XXV, Fig. 2 and Plate XXVIII, Fig. 8). The absolute length of the individual chromosomes in the complement varied from 4.43 μ to 1.88 μ. The arm ratio of the individual chromosomes ranged from 1.41 to 2.31. Chromosome 4 had satellite on the short arm. Based on the relative length the 16 pairs of chromosomes were grouped into the following 11 classes.

Group I (Chromosome 1 and 2):- Both were subterminal chromosomes with arm ratios of 2.02 and 2.16 respectively. The relative lengths of the chromosomes were 9.30 and 8.96 respectively.

Group II (Chromosome 3):- The chromosome was subterminal with an arm ratio of 2.29 and relative length of 8.50.

Group III (Chromosome 4):- The chromosome was subterminal with an arm ratio of 1.73 and relative length of 7.98. This was the only satellited pair in the complement.

Group IV (Chromosome 5):- Subterminal chromosome; arm ratio - 2.05; relative length - 7.61.

Group V (Chromosome 6):- Subterminal; arm ratio - 2.31; relative length - 6.93.

Group VI (Chromosome 7):- This had subterminal centromere with an arm ratio of 1.70 and relative length of 6.78.

Group VII (Chromosome 8):- The chromosome was submedian with an arm ratio of 1.54 and relative length of 6.10.
Group VIII (Chromosome 9):- Subterminal centromere; arm ratio - 1.72; relative length - 5.61.
Group IX (Chromosome 10 - 12):- Chromosome 10 and 12 were subterminal and 11 was submedian. The arm ratio of the chromosomes ranged from 1.41 to 2.08 and the relative length ranged from 5.30 to 4.93.
Group X (Chromosome 13 and 14):- Chromosome 13 was submedian and 14 was subterminal. Arm ratio - 1.59 and 2.18; relative length - 4.47 and 4.40.
Group XI (Chromosome 15 and 16):- Both had subterminal centromeres. The chromosome had the arm ratios of 2.20 and 2.12 respectively and the relative lengths of 3.94 each.

9. Rhesus (163):- Among the 16 pairs of chromosomes in the complement six had submedian centromere and the rest subterminal (Plate XV, Fig. 3; Plate XVIII, Fig. 9). The length of the largest and shortest chromosome was 3.62 μ and 2.11 μ respectively. The arm ratio of the individual chromosomes ranged from 1.36 to 2.18. Two pairs of chromosomes were satellited. The chromosomes were grouped into eight categories based on their relative length.
Group I (Chromosome 1):- Subterminal chromosome; arm ratio - 1.87; relative length - 8.12.

Group II (Chromosome 2):- Subterminal chromosome; arm ratio - 1.79; relative length - 7.59.

Group III (Chromosomes 3 and 4):- Both the chromosomes had subterminal centromere with the arm ratios of 1.67 and 2.07 and relative lengths of 7.33 and 7.10 respectively.

Group IV (Chromosomes 5 - 7):- Chromosome 6 was submedian and the remaining two subterminal. The arm ratios ranged from 1.57 to 2.18 and relative lengths ranged from 6.88 to 6.41.

Group V (Chromosomes 8 - 10):- Chromosomes 8 and 10 were subterminal and 9 submedian. Arm ratio - 1.62 - 2.14; relative length - 6.31 - 5.95.

Group VI (Chromosomes 11 - 13):- Chromosomes 11 and 13 were submedian with the former having satellite on its short arm. Chromosome 12 was subterminal. The arm ratios ranged from 1.48 to 1.80 and relative lengths from 5.68 to 5.42.

Group VII (Chromosomes 14 and 15):- Chromosome 14 was subterminal and 15 submedian, the latter having satellite on its short arm. Arm ratio - 2.05 and 1.49; relative length - 5.16 and 4.96.

Group VIII (Chromosome 16):- Submedian chromosome; arm ratio - 1.36; relative length - 4.75.

ii) Areca triandra

10. Mauritius (102):- Of the 16 pairs of chromosomes (Plate XXV, Fig. 4; and Plate XXVIII, Fig. 10), four had median centromere while three had submedian and nine subterminal. The largest chromosome had a length of 5.24 μ and the smallest 2.52 μ. The arm ratios ranged from 1.00 to 2.20. The chromosomes were classified into eight groups as described below.

Group I (Chromosome 1):- This was the longest chromosome with the satellite on the long arm. The centromere was submedian; arm ratio 1.40; relative length 8.23.

Group II (Chromosome 2):- Subterminal centromere; arm ratio - 1.93; relative length - 7.56.

Group III (Chromosomes 3 and 4):- Both the chromosomes had subterminal centromere. Arm ratio - 1.80 and 1.93; relative length - 7.20 and 7.03.

Group IV (Chromosomes 5 - 8):- Three chromosomes had median centromere, while the fourth had subterminal. Arm ratios ranged from 1.00 to 1.67 and relative lengths from 6.52 to 6.86.

Group V (Chromosomes 9 and 10):- One chromosome was submedian and the other subterminal. Arm ratio - 2.00 and 1.50; relative length - 6.17 and 6.00.

Group VI (Chromosome 11 - 14):- Excepting chromosome 14, which had submedian centromere, others were subterminal.

Chromosome 12 had satellite in its long arm. Arm ratios ranged from 1.46 to 2.20 and relative lengths from 5.66 to 5.49.

Group VII (Chromosome 15):- Subterminal; arm ratio - 1.80; relative length - 4.90.

Group VIII (Chromosome 16):- The smallest chromosome in the complement with median centromere; arm ratio - 1.10; relative length - 4.12.

11. Indonesia-1 (12S):- Among 16 pairs of chromosomes, nine were submedian and the remaining subterminal (Plate XIV, Fig. 5; Plate XXI, Fig. 1). The second chromosome had a satellite on the long arm. The absolute length of the chromosomes ranged from 4.04 μ to 2.02 μ. The chromosomes were grouped into the following nine categories.

Group I (Chromosome 1):- The chromosome was submedian with an arm ratio of 1.64 and relative length of 8.43.

Group II (Chromosomes 2 and 3):- Chromosome 2 was submedian with the satellite on the long arm and chromosome 3 subterminal. The arm ratio and relative lengths were 1.43 and 1.79 and 7.78 and 7.41 respectively.

Group III (Chromosomes 4 and 5):- Chromosome 4 was subterminal and 5 submedian. Arm ratio - 1.92 and 1.57; relative length - 7.17 and 7.02.

Group IV (Chromosomes 6 and 7):- Both had submedian centromere. Arm ratio - 1.56 and 1.63; relative length - 6.74 and 6.57.

Group I (Chromosome 8 - 10):- All the chromosome had submedian centromere. The arm ratios ranged from 1.38 to 1.60 and relative lengths ranged from 6.38 to 5.99.

Group II (Chromosome 11 and 12):- Both were subterminal chromosome. The arm ratios were 2.05 and 1.76 and relative lengths 5.74 and 5.49 respectively.

Group III (Chromosome 13 and 14):- Chromosome 13 had submedian centromere and 14 had subterminal. Arm ratio - 1.66 and 1.96; relative length - 5.24 and 4.94.

Group IIIA (Chromosome 15):- This had subterminal centromere with an arm ratio of 1.71 and relative length of 4.75.

Group IV (Chromosome 16):- Subterminal chromosome; arm ratio - 1.83; relative length - 4.22.

12. Indermimal (74):- Among 16 pairs of chromosomes, two were median, eight submedian and six subterminal (Plate XXV, Fig. 6; Plate XXIX, Fig. 2). None of them had satellites. The absolute length of individual chromosome varied from 4.68 μ to 2.40 μ. The arm ratios ranged from 1.29 to 2.11. The chromosome were grouped into the following eight categories for descriptive purpose.

Group I (Chromosome 1):- This was a median chromosome with an arm ratio of 1.32 and relative length of 8.70.

Group II (Chromosome 2 and 3):- Chromosome 2 was median and 3 was submedian with the arm ratios of 1.29 and 1.42 respectively. The relative lengths of the chromosome were 7.86 and 7.54 respectively.

Group III (Chromosome 4 and 5):- Two submedian chromosomes with the arm ratio of 1.60 and 1.61 and relative length of 7.18 and 6.97 respectively.

Group IV (Chromosome 6):- Subterminal centromere; arm ratio - 1.68; relative length - 6.69.

Group V (Chromosome 7 - 9):- Submedian chromosome; arm ratio - 1.43 - 1.65; relative length - 6.36 - 5.95.

Group VI (Chromosome 10 - 12):- The chromosome had subterminal centromere. The arm ratio ranged from 1.69 to 2.11. The chromosome varied for their relative length from 5.76 to 5.51.

Group VII (Chromosome 13 and 14):- Chromosome 13 had subterminal centromere and 14 submedian. Arm ratio - 1.67 and 1.59; relative length - 5.32 and 5.09.

Group VIII (Chromosome 15 and 16):- Chromosome 15 was subterminal and 16 submedian. The chromosome had the arm ratio of 1.76 and 1.60 and relative length of 4.82 and 4.48 respectively.

13. Indomonas2 (154):- Out of the 16 pairs of chromosomes (Plate XXVI, Fig. 1; Plate XXIX, Fig. 3), three were median, seven submedian and six subterminal.

PLATE XXVI

Somatic chromosomes in *A. triandra* centrum

Fig. 1 : Indonesia-2 (154), 2n = 32

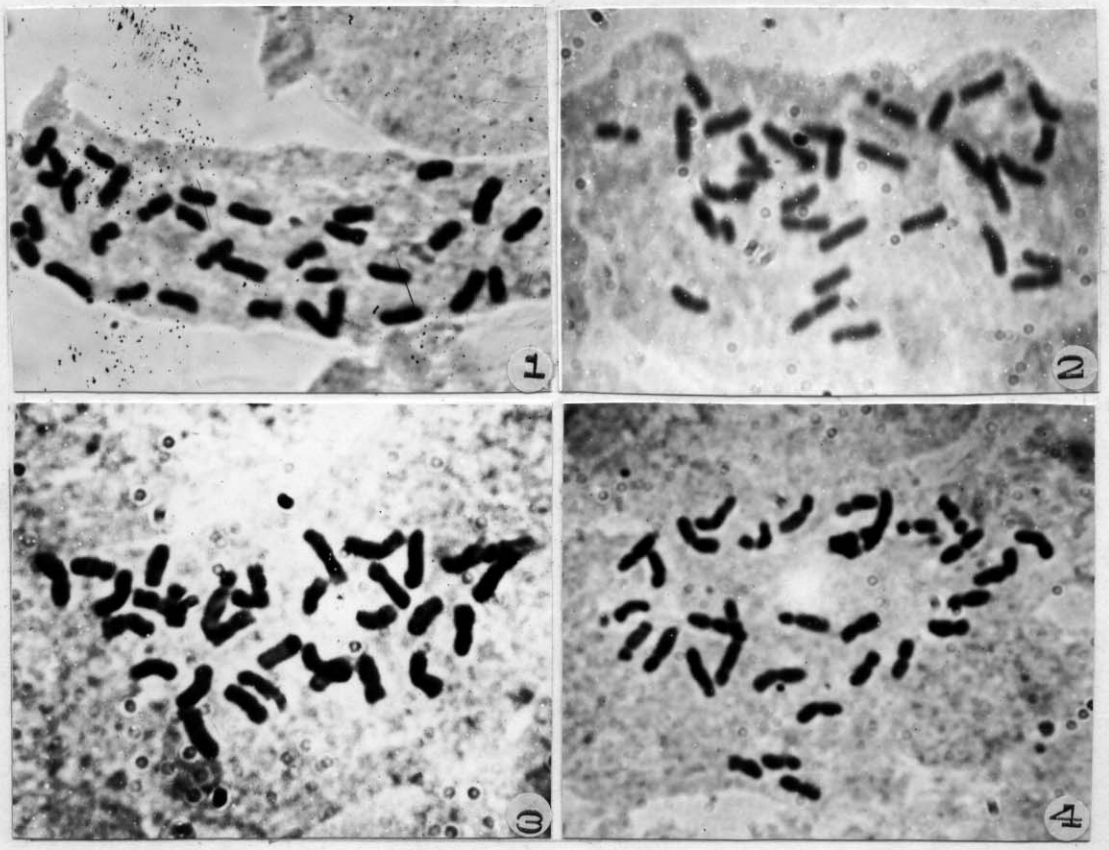
Fig. 2 : Ceylon-3 (55), 2n = 32

Fig. 3 : Ceylon-3 (70), 2n = 32

Fig. 4 : Ceylon-3 (87), 2n = 32

(Figs.1, 2 and 4, x 1900; 3, x 2100)

PLATE XXVI



There were no satellited chromosomes in the complement. The longest chromosome was 4.41 μ and the shortest 2.44 μ. The arm ratios ranged from 1.21 to 2.29. The chromosomes were classified into nine groups. The description of groups is given below.

Group I (Chromosome 1):- This was the largest chromosome with median centromere. Arm ratio - 1.21; relative length - 8.15.

Group II (Chromosomes 2 and 3):- One chromosome was median and the other submedian. Arm ratio - 1.51 and 1.25; relative length - 7.71 and 7.45.

Group III (Chromosome 4):- This had median centromere with an arm ratio of 1.28 and relative length of 7.17.

Group IV (Chromosomes 5 - 7):- Two chromosomes were submedian and one subterminal. Arm ratios ranged from 1.40 to 1.70 and relative lengths from 6.52 to 6.83.

Group V (Chromosomes 8 and 9):- One chromosome was submedian and the other subterminal. Arm ratios - 1.72 and 1.61; relative lengths - 6.25 and 6.09.

Group VI (Chromosomes 10 - 12):- All the chromosomes were subterminal. Arm ratios ranged from 1.77 to 2.29 and relative lengths from 5.51 to 5.09.

Group VII (Chromosomes 13 and 14):- One chromosome was submedian and the other subterminal. Arm ratios - 1.68 and 1.45; relative length - 5.32 and 5.24.

Group VIII (Chromosome 15):- This chromosome had submedian centromere with an arm ratio of 1.57 and relative length of 4.39.

Group IX (Chromosome 16):- Submedian chromosome with an arm ratio of 1.57 and relative length of 4.29. This was the smallest chromosome in the complement.

14. Garlend (55):- Of the 16 pairs of chromosomes (Plate XXVI, Fig. 2; Plate XXIX, Fig. 4), one was median, 10 submedian and five subterminal. No satellited chromosome was observed in the complement. The maximum and minimum lengths of chromosomes were 4.72 μ and 2.46 μ respectively. The arm ratios of the chromosomes varied from 1.30 to 1.74. The 16 pairs of chromosomes were classified into nine groups.

Group I (Chromosome 1):- This was the largest chromosome of the complement and had subterminal centromere. The arm ratio was 1.68 and relative length 6.79.

Group II (Chromosome 2 and 3):- One chromosome was subterminal and the other submedian. Arm ratio - 1.74 and 1.47; relative length - 7.76 and 7.57.

Group III (Chromosome 4 and 5):- One chromosome subterminal and the other submedian; arm ratio - 1.71 and 1.53; relative length - 7.27 and 7.08.

Group IV (Chromosome 6 and 7):- One subterminal and the other submedian; arm ratio - 1.70 and 1.54; relative length - 6.75 and 6.45.

Group V (Chromosomes 8 - 10):- One chromosome was median and the other two submedian. Arm ratios ranged from 1.30 to 1.62 and relative lengths 6.26 to 5.93.

Group VI (Chromosomes 11 and 12):- One chromosome subterminal and the other submedian; arm ratio - 1.73 and 1.46; relative length - 5.59 and 5.41.

Group VII (Chromosomes 13 and 14):- Both chromosomes had submedian centromere. Arm ratio - 1.47 and 1.51; relative length - 5.26 and 4.96.

Group VIII (Chromosome 15):- Submedian centromere. Arm ratio - 1.46; relative length - 4.77.

Group IX (Chromosome 16):- Submedian; arm ratio - 1.79; relative length - 4.56.

15. Saylam-3 (70):- Of the 16 pairs of chromosomes of the complement (Plate XXVI, Fig. 3; Plate XXIX, Fig.3), 11 were submedian and five subterminal. The length varied from 4.09 μ to 2.62 μ. The arm ratios ranged from 1.40 to 1.81 and the relative lengths from 4.79 to 8.18. There were no satellited chromosomes in the complement. The 16 pairs of chromosomes were grouped further into eight groups and described below.

Group I (Chromosome 1):- This was a submedian chromosome with an arm ratio of 1.40 and relative length of 8.18.

Group XI (Chromosomes 2 and 3):- One chromosome was submedian and the other subterminal. Arm ratio - 1.77 and 1.49; relative length - 7.62 and 7.44.

Group XII (Chromosomes 4 and 5):- Both had submedian centromere with arm ratios of 1.64 and 1.43 and relative lengths of 7.23 and 7.02.

Group IV (Chromosomes 6 and 7):- One chromosome was subterminal and the other submedian, with arm ratios of 1.71 and 1.48 and relative lengths of 6.78 and 6.53.

Group I (Chromosomes 8 and 9):- Both had submedian centromere. Arm ratio - 1.54 and 1.52; relative length - 6.25 and 6.11.

Group VI (Chromosomes 10 - 12):- Two had subterminal centromere and the third submedian. Arm ratios ranged from 1.63 to 1.81 and the relative lengths from 5.55 to 5.83.

Group VII (Chromosomes 13 - 15):- One chromosome had subterminal centromere and the other two submedian. Arm ratios ranged from 1.50 to 1.68 and relative lengths from 4.91 to 5.37.

Group VIII (Chromosome 16):- The smallest chromosome in the complement with submedian centromere. Arm ratio - 1.55; relative length - 4.79.

16. Gerlach-1 (GT):- The complement consisted of 16 pairs of chromosomes (Plate XXVI, Fig. 4; Plate XXIX, Fig. 6). The chromosome lengths ranged from

4.20 μ to 2.14 μ . Three chromosomes had median centromere while 12 had submedian and one had subterminal. Two chromosomes were satellited. The 16 chromosomes were divided into nine groups. The details of the groups are given below.

Group I (Chromosome 1):- This was the largest chromosome of the complement with median centromere and also satellited on the long arm. Arm ratio - 1.22; relative length - 8.30.

Group II (Chromosome 2):- This was the second satellited chromosome with satellite on the long arm and had submedian centromere. Arm ratio - 1.57; relative length - 7.47.

Group III (Chromosome 3):- Submedian with arm ratio of 1.65 and relative length of 7.14.

Group IV (Chromosome 4 and 5):- The chromosome had submedian centromere with arm ratios of 1.48 and 1.57 and relative lengths of 6.81 and 6.68.

Group V (Chromosome 6 - 8):- All the chromosome were submedian with arm ratios ranging from 1.50 to 1.65 and relative lengths from 6.79 to 6.02.

Group VI (Chromosome 9 - 12):- Three chromosome were submedian while fourth was subterminal. The arm ratios ranged from 1.40 to 1.77 and relative lengths from 5.89 to 5.48.

Group VII (Chromosome 13 and 14):- Submedian chromosomes; arm ratio - 1.34 and 1.38; relative length - 5.06 and 4.94.

Group VIII (Chromosome 15):- Median; arm ratio - 1.15; relative length - 4.73.

Group IX (Chromosome 16):- Smallest chromosome with median centromere; arm ratio - 1.27; relative length - 4.53.

(iii) Interspecific hybrids

17. A. sativa x A. brianica (2n=28):- Of the 16 pairs of chromosomes (Plate XXVI, Fig. 1; Plate XXIX, Fig. 7), six had median centromere, four submedian and six subterminal. There were no satellited chromosomes in the complement. The longest chromosome had a length of 6.19 μ and the shortest 2.21 μ. The arm ratios of the chromosomes varied from 1.04 to 2.75. The 16 pairs of chromosomes have been grouped into 12 groups for descriptive purpose.

Group I (Chromosome 1):- This was the longest chromosome in the entire material studied and had a length of 6.19 μ. The centromere was submedian. Arm ratio - 1.42; relative length - 10.72.

Group II (Chromosome 2):- Subterminal; arm ratio - 2.06; relative length - 9.06.

Group III (Chromosome 3):- Median centromere; arm ratio - 1.04; relative length - 8.69.

PLATE XXVII

Somatic chromosomes in *A. sativa* × *A. byzantina*

Fig. 1 : *A. sativa* × *A. byzantina* (248), 2n = 32

Fig. 2 : " (287), 2n = 32

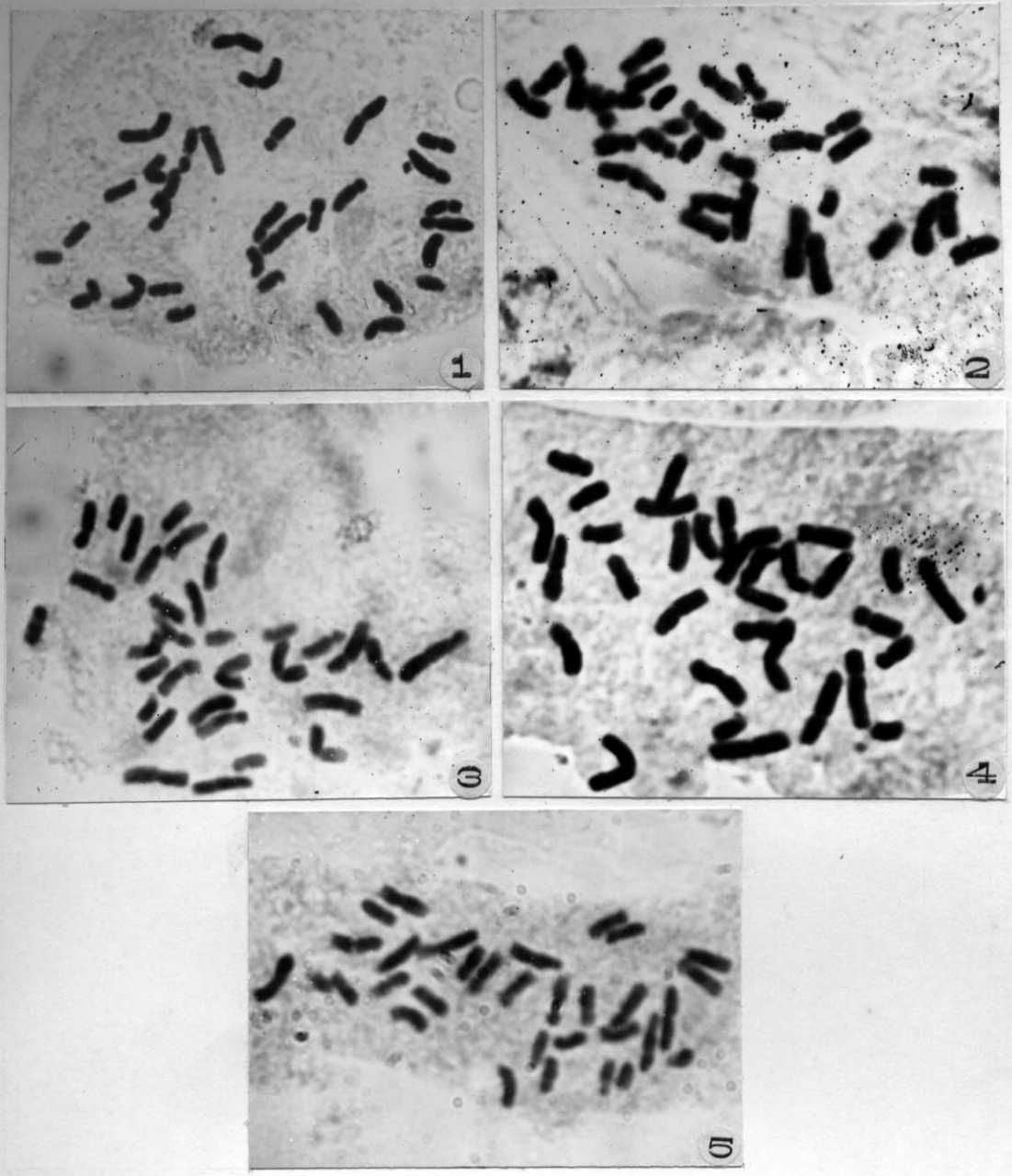
Fig. 3 : " (288), 2n = 32

Fig. 4 : " (307), 2n = 32

Fig. 5 : " Spontaneous hybrid, 2n = 32

(Figs.1 and 5, x 1900; 2 and 3, x 2500; 4, x 2900)

PLATE XXVII



Group IV (Chromosome 4):- Median chromosome; arm ratio - 1.20; relative length - 8.13.

Group V (Chromosome 5):- Chromosome with subterminal centromere; arm ratio - 2.07; relative length - 7.59.

Group VI (Chromosome 6):- Submedian chromosome with an arm ratio of 1.47 and relative length of 6.84.

Group VII (Chromosome 7 and 8):- Both median chromosomes with arm ratios of 1.29 and 1.13; relative length - 5.91 each.

Group VIII (Chromosome 9 and 10):- Both chromosomes had subterminal centromere. Arm ratio - 2.73 and 1.73; relative length - 5.55 each.

Group IX (Chromosome XI):- Median chromosome; arm ratio - 1.25; relative length - 4.99.

Group X (Chromosome 12 and 13):- Chromosome 12 was submedian and 13 median; arm ratio - 1.36 and 1.18; relative length - 4.81 and 4.44.

Group XI (Chromosome 14 and 15):- Both were subterminal chromosomes; arm ratio - 2.67 and 1.75; relative length - 4.07 each.

Group XII (Chromosome 16):- Smallest chromosome with submedian centromere; arm ratio - 1.63; relative length - 3.88.

10. A. satanica x A. kelaartica (287):- The 16 pairs of chromosomes in the complement (Plate XXVII, Fig. 2; and Plate XXIX, Fig. 8), consisted of nine median and seven submedian chromosomes. The length of the longest chromosome was 4.80 μ and that of the shortest 1.68 μ. The arm ratios varied from 1.00 to 1.61. The chromosomes are grouped into nine groups and described below.

Group I (Chromosomes 1 and 2):- Both had median centromere. The chromosome 1 was satellited on its short arm. Arm ratio - 1.00 and 1.21; relative length - 8.87 and 8.60.

Group II (Chromosomes 3 and 4):- Submedian; arm ratio - 1.43 and 1.61; relative length - 7.76 and 7.41.

Group III (Chromosome 5):- Median centromere; arm ratio - 1.29 and relative length - 6.92.

Group IV (Chromosome 6):- Submedian; arm ratio - 1.34; relative length - 6.65.

Group V (Chromosomes 7 and 8):- Both had submedian centromere. Arm ratio - 1.52 and 1.45; relative length - 6.25 and 5.99.

Group VI (Chromosomes 9 - 11):- One chromosome submedian and the other two median; arm ratio ranged from 1.25 to 1.38 and relative length from 5.90 to 5.50.

Group VII (Chromosomes 12 and 13):- One chromosome submedian and the other median; arm ratio - 1.37 and 1.24; relative length - 5.56 and 5.28.

PLATE XXVIII

Idiograms of *A. satsuba* and *A. brandza*

Fig. 1 : *A. satsuba* Local (471)

Fig. 2 : " " (717)

Fig. 3 : " China (111)

Fig. 4 : " Ceylon-1 (191)

Fig.5 : " Indonesia-6 (61)

Fig. 6 : " Saigon-1 (176)

Fig. 7 : " Saigon-2 (180)

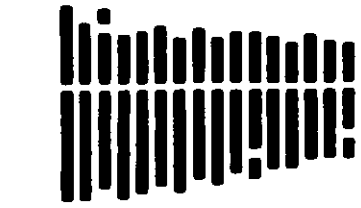
Fig. 8 : " Ceylon-2 (192)

Fig. 9 : " Singapore (163)

Fig. 10 : *A. brandza* Mauritius (109)

PLATE XXVIII

IDIOGRAMS OF A. CATECHU AND A. TRIANDRA



1

2

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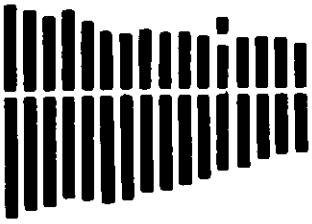
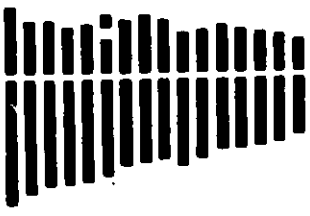
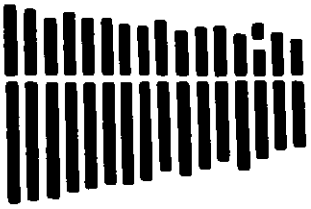


4



5

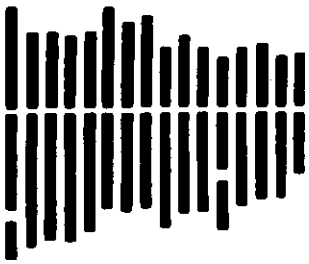
6



7

8

9



10

PLATE XXIX

Inflorescence of *A. brunnea* and *A. setosa* x *A. brunnea*

Fig. 1 : *A. brunnea* Indonesia-1 (125)

Fig. 2 : " Indonesia-2 (74)

Fig. 3 : " " (154)

Fig. 4 : " Ceylon-3 (55)

Fig. 5 : " " (70)

Fig. 6 : " " (87)

Fig. 7 : *A. setosa* x *A. brunnea* (248)

Fig. 8 : " (287)

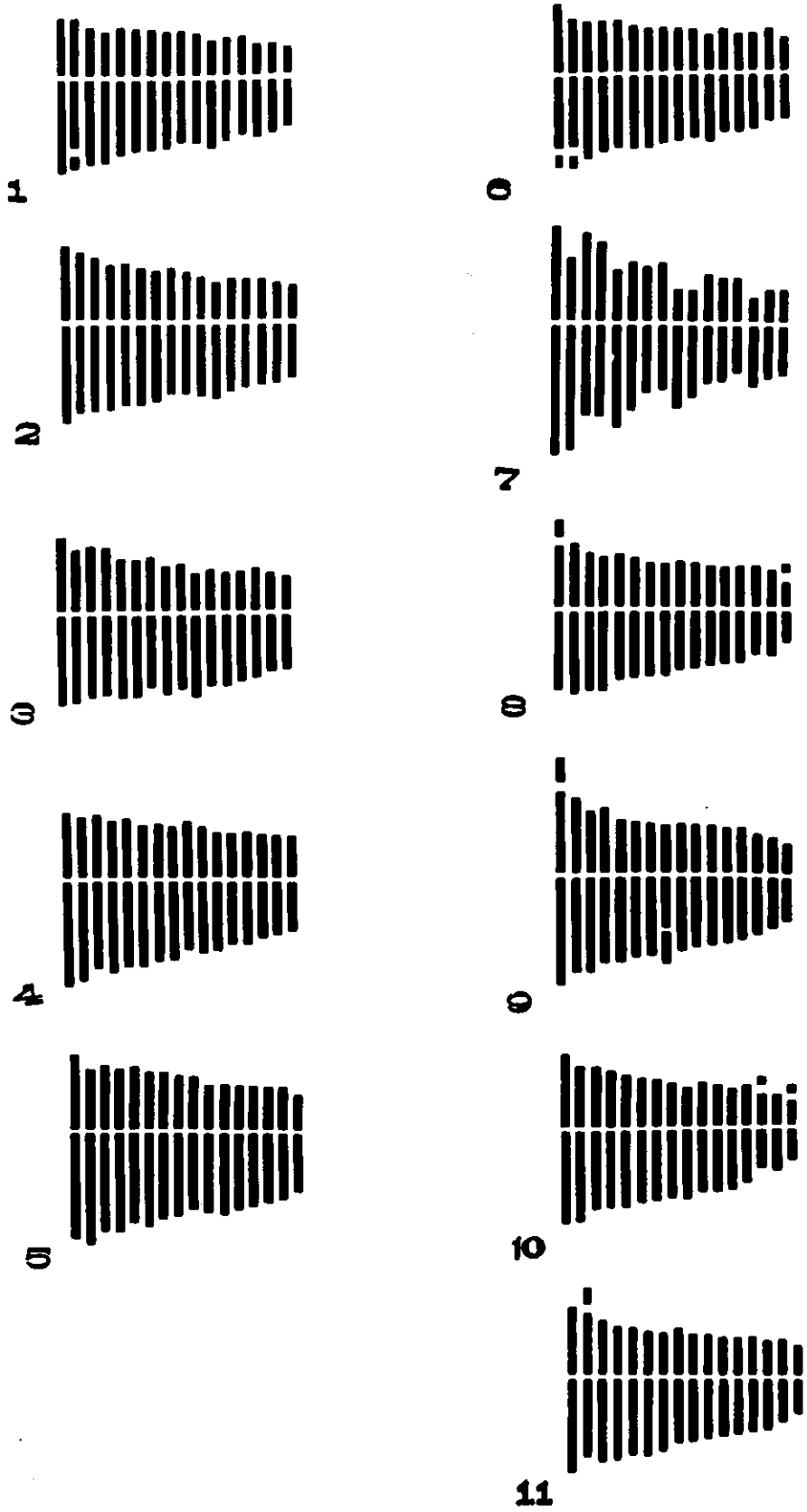
Fig. 9 : " (288)

Fig. 10 : " (307)

Fig. 11 : " Spontaneous hybrid

PLATE XXIX

IDIOGRAMS OF *A. TRIANDRA* AND *A. CATECHU* × *A. TRIANDRA*



Group VIII (Chromosomes 14 and 15):- Median chromosome; arm ratio - 1.11 and 1.24; relative length - 4.86 and 4.48.

Group IX (Chromosome 16):- Smallest chromosome satellited on the short arm; arm ratio - 1.00; relative length - 3.33.

19. A. sativum x A. triandra (255):- Out of the 16 pairs of chromosomes (Plate XXVII, Fig. 3 and Plate XXIX, Fig. 9), two had median centromere, 11 submedian and three subterminal. The largest chromosome had a length of 5.77 μ while the shortest 1.99 μ. The arm ratios ranged from 1.04 to 3.00. Two chromosomes were satellited. The chromosomes are grouped into the following 11 groups.

Group I (Chromosome 1):- Longest chromosome with the satellite on the short arm; median centromere; arm ratio - 1.04; relative length - 10.33.

Group II (Chromosome 2):- Median centromere; arm ratio - 1.26; relative length - 8.42.

Group III (Chromosome 3):- Submedian; arm ratio - 1.56; relative length - 7.70.

Group IV (Chromosome 4):- Submedian; arm ratio - 1.35; relative length - 7.33.

Group V (Chromosomes 5 and 6):- Both had submedian centromere. Arm ratio - 1.58 and 1.52; relative length - 6.88 and 6.54.

Group VI (Chromosome 7 - 9):- Chromosome 8 and 9 had subterminal centromere and chromosome 7 submedian. Chromosome 8 was satellited on its long arm. Arm ratios ranged from 1.62 to 3.00 and relative lengths from 6.31 to 6.81.

Group VII (Chromosomes 10 and 11):- Both had submedian centromere. Arm ratio - 1.54 and 1.50; relative length - 5.82 and 5.62.

Group VIII (Chromosomes 12 and 13):- Both submedian; arm ratio - 1.60 and 1.42; relative length - 5.57 and 5.19.

Group IX (Chromosome 14):- Submedian centromere; arm ratio - 1.56; relative length - 4.62.

Group X (Chromosome 15):- Submedian; arm ratio - 1.49; relative length - 4.21.

Group XI (Chromosome 16):- Shortest chromosome with subterminal centromere; arm ratio - 1.71; relative length - 3.57.

20. A. sativum x A. triandrum (307):- The 16 pairs of chromosomes in the complement (Plate XXVI, Fig. 4; Plate XXIX, Fig. 10), consisted of five median, 10 submedian and one subterminal chromosomes. Two chromosomes were satellited. The maximum and minimum length of chromosomes were 4.31 μ and 1.88 μ respectively. The arm ratios varied from 1.00 to 1.76.

The 16 pairs are classified into the following 11 groups.

Group I (Chromosome 1):- Longest chromosome with median centromere; arm ratio - 1.22; relative length - 9.27.

Group II (Chromosome 2):- Submedian; arm ratio - 1.42; relative length - 8.45.

Group III (Chromosome 3):- Median centromere; arm ratio - 1.53; relative length - 8.02.

Group IV (Chromosome 4):- Submedian centromere; arm ratio - 1.45; relative length - 7.72.

Group V (Chromosome 5):- Submedian centromere; arm ratio - 1.44; relative length - 7.16.

Group VI (Chromosome 6 and 7):- Both had submedian centromere. Arm ratio - 1.44 and 1.46; relative length - 6.73 and 6.47.

Group VII (Chromosome 8):- Submedian with arm ratio of 1.53 and relative length of 6.21.

Group VIII (Chromosome 9 - 12):- Chromosome 9 had sub-terminal centromere while others had submedian. Arm ratios ranged from 1.43 to 1.76 and relative lengths from 5.43 to 5.26.

Group IX (Chromosome 13):- Submedian; arm ratio - 1.30; relative length - 5.26.

Group I (Chromosome 14 and 15):- Both had median centromere. Chromosome 14 was satellited on its short arm. Arm ratio - 1.00 and 1.23; relative length - 4.31 and 4.01.

Group II (Chromosome 16):- The smallest chromosome with median centromere, satellited on its short arm; arm ratio - 1.00; relative length - 3.45.

21. A. sativa x A. strigosa (Spontaneous hybrid):- In the chromosome complement which consisted of 16 pairs of chromosomes (Plate XXVII, Fig. 5 and Plate XXII, Fig. 11), two were median, 12 submedian and two subterminal. The maximum and minimum length of chromosome were 4.43 μ and 1.83 μ respectively. One chromosome was satellited. The arm ratios of the chromosomes varied from 1.00 to 1.80. The 16 pairs are grouped into 10 groups and described below:

Group I (Chromosome 1):- Longest chromosome with submedian centromere; arm ratio - 1.37; relative length - 9.19.

Group II (Chromosome 2):- Satellited on the short arm; median centromere; arm ratio - 1.00; relative length - 8.71.

Group XIX (Chromosome 3):- Submedian chromosome; arm ratio - 1.54; relative length - 7.76.

Group XV (Chromosomes 4 and 5):- Both had submedian centromere. Arm ratio - 1.64 and 1.58; relative length - 7.36 and 6.97.

Group I (Chromosome 6 and 7):- Both were subterminal. Arm ratio - 1.80 and 1.76; relative length - 6.71 and 6.49.

Group VI (Chromosomes 8 and 9):- Both were submedian. Arm ratio - 1.40 and 1.49; relative length - 6.27 and 5.97

Group VII (Chromosomes 10 and 11):- Both had submedian centromere. Arm ratio - 1.42 and 1.60; relative length - 5.79 and 5.43.

Group VIII (Chromosomes 12 and 13):- Both submedian; arm ratio - 1.57 and 1.58; relative length - 5.27 and 5.10.

Group XI (Chromosomes 14 and 15):- Chromosome 14 was submedian, while chromosome 15 had median centromere. Arm ratio - 1.57 and 1.27; relative length - 4.71 and 4.44.

Group X (Chromosome 16):- Smallest chromosome with submedian centromere; arm ratio - 1.42; relative length - 3.79.

Table 11. Karyotype differences in *A. sativa*

Sl. No.	Species	Chromosome number 2n	Total chromatin length (μ)	Length of longest chromosome (μ)	Length of shortest chromosome (μ)	I
	A. sativa					
1.	Local (471)	32	49.42	4.15	2.18	
2.	" (717)	"	43.97	3.78	1.83	
3.	China (111)	"	41.64	3.59	1.72	
4.	Ceylon-1 (191)	"	51.79	4.41	2.14	
5.	Indonesia-6 (61)	"	46.81	4.12	1.93	
6.	Saigon-1 (176)	"	44.48	3.87	1.92	
7.	Saigon-2 (180)	"	50.78	4.15	2.13	
8.	Ceylon-2 (192)	"	47.60	4.43	1.88	
9.	Singapore (163)	"	44.32	3.82	2.11	
	A. byzantina					
10.	Mauritius (109)	"	61.21	5.24	2.92	
11.	Indonesia-1 (125)	"	48.04	4.04	2.02	
12.	Indonesia-2 (74)	"	53.73	4.88	2.48	
13.	Indonesia-2 (154)	"	54.14	4.41	2.44	
14.	Ceylon-3 (53)	"	56.32	4.72	2.46	
15.	Ceylon-3 (70)	"	59.77	4.89	2.62	
16.	Ceylon-3 (87)	"	50.59	4.20	2.14	
	Hybrids					
17.	*A. sativa* x *A. byzantina* (248)	"	56.80	6.19	2.21	
18.	" (287)	"	47.35	4.80	1.68	
	" (288)	"	55.82	5.77	1.99	
	" (307)	"	48.69	4.91	1.68	
	[illegible] hybrid	"	48.19	4.43	1.83	

H. A. Iridaceae and their hybrids

Number of chromosomes			Number of satellited chromosomes	Types of symmetry (Stebbins, 1950)
Median	Sub median	Sub terminal		
-	6	10	3	2 A
3	11	-	-	1 B
-	1	15	1	3 B
3	9	2	1	1 B
-	3	13	1	2 B
-	9	7	1	2 A
-	3	13	1	2 A
-	3	13	1	3 B
-	6	10	2	2 A
4	3	9	2	2 B
-	9	7	1	2 B
2	8	6	-	2 A
3	7	6	-	2 A
1	10	5	-	1 A
-	11	5	-	1 A
3	12	1	2	1 A
6	4	6	-	2 B
9	7	-	2	1 B
2	11	3	2	2 B
3	10	1	2	1 B
2	12	2	1	1 B

Table 12. Chromosome frequencies of *A. sativum*, *A.* different relative length classes

Sl.No.	Species/Hybrids	10.9	10.4	9.9	9.4	8.9
	A. sativum					
1.	Local (471)					
2.	Local (717)					
3.	China (111)					
4.	Ceylon-1 (191)					
5.	Indonesia-6 (61)					
6.	Saigon-1 (176)					
7.	Saigon-2 (180)					
8.	Ceylon-2 (192)					2
9.	Singapore (163)					
	A. ledebourianum					
10.	Mauritius (109)					
11.	Indonesia-4(125)					
12.	Indonesia-5 (74)					
13.	Indonesia-7 (154)					
14.	Ceylon-3 (55)					
15.	Ceylon-5 (70)					
16.	Ceylon-3 (87)					
17.	*A. sativum* x *A. ledebourianum* (248)	1	-	-		1
18.	" (287)					2
19.	" (288)		1	-		-
20.	" (307)					1
21.	Spontaneous hybrid					1

Triticum and interspecific hybrids in

8.4	7.9	7.4	6.9	6.4	5.9	5.4	4.9	4.4	3.9	3.4
	1	1	3	2	3	2	2	2	-	-
1	-	2	2	2	2	2	2	2	1	-
1	-	2	2	1	4	2	2	1	1	-
1	1	2	1	3	1	2	2	2	1	-
1	-	2	2	2	2	3	2	1	1	-
	1	2	1	3	3	2	2	1	1	-
	1	2	2	2	3	2	2	1	1	-
1	1	1	1	1	1	1	3	2	2	-
	1	1	2	3	3	3	2	1	-	-
	1	1	2	4	2	4	-	1	1	-
1	-	2	2	2	3	2	2	1	1	-
1	-	2	2	1	3	3	2	2	-	-
	1	2	1	3	2	3	2	1	1	-
	1	2	2	2	3	2	2	1	1	-
	1	2	2	2	2	3	3	-	1	-
	1	1	1	2	3	4	2	1	1	-
1	1	-	1	1	2	2	1	2	2	1
-	-	2	1	1	2	3	2	2	-	1
1	-	1	1	2	3	2	2	1	1	1
1	1	1	1	2	1	4	1	-	2	1
1	-	1	2	2	2	2	2	2	-	1

XXI. ELECTROPHORETIC STUDIES

Marked differences were observed between the two species in respect of the number of isoenzymes of esterase (Plate XXI, A). *A. sativum* had only three bands with Rf values of 0.200, 0.530 and 0.996. In addition to the two bands at Rf 0.200 and 0.996, *A. tricuspis* exhibited two slow moving bands (Rf. 0.059 and 0.080) and 3 fast moving bands (Rf. 0.622, 0.870 and 0.897) which were absent in *A. sativum*. The similarity index was thus found to be 0.25. The co-electrophoresis with mixed extract revealed as expected eight bands - a hybrid pattern of the two species. The band at Rf 0.200 was very intense, those at 0.059, 0.870 and 0.897 were very light and the rest were medium intense (Plate XXI, B).

XV. GENETIC DIVERGENCE

a. Analysis of Variance

Analysis of variance of the data for the characters under study for different years revealed considerable differences between cultivars for most of the characters. The results for 1983, presented in Table 13, showed that the differences between cultivars were highly significant for all the six

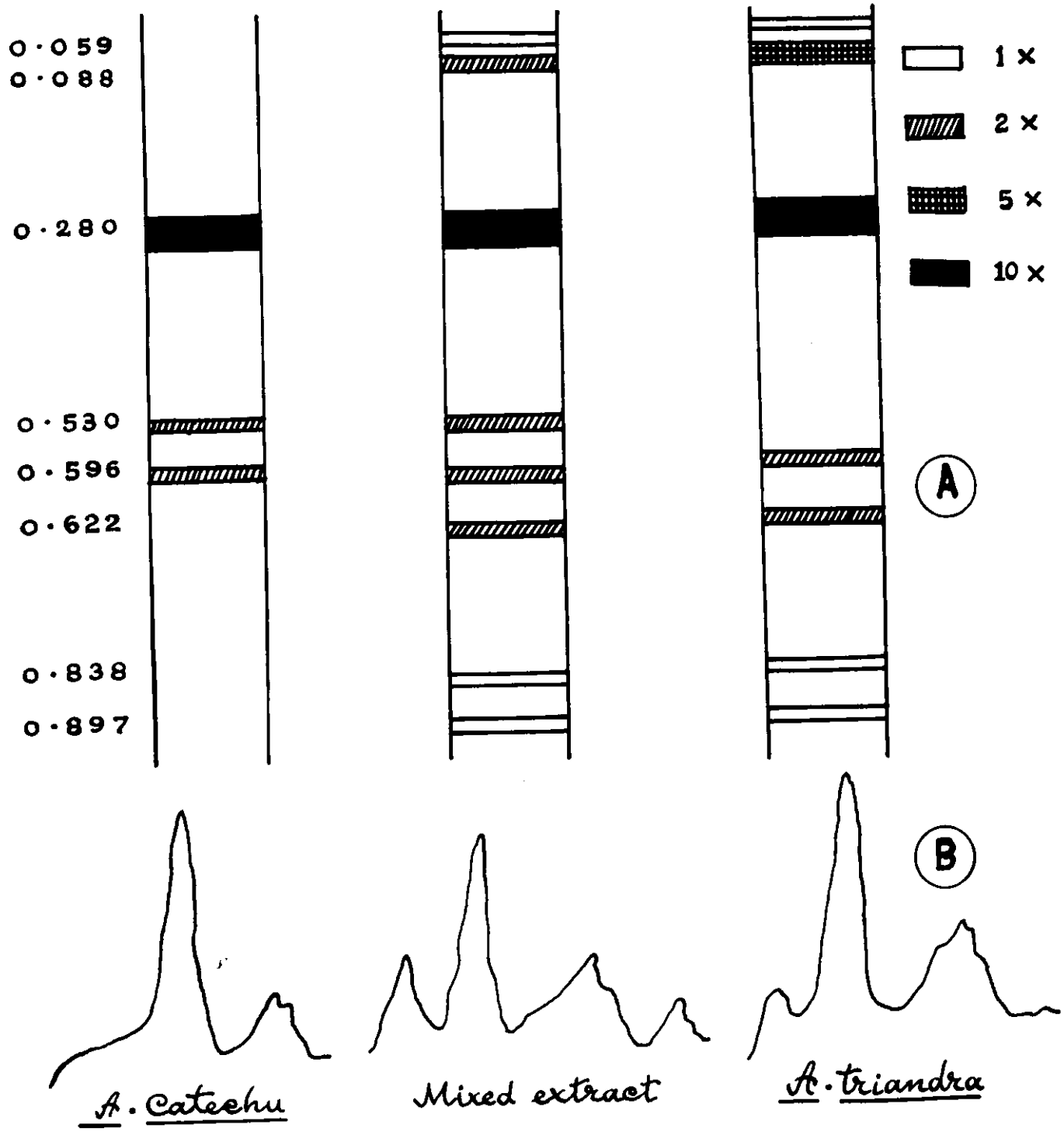
PLATE XXX

Electrophoretic pattern of extracts isoenzymes

A. Electrophoregrams for *A. spinulosa*, *A. triandra* and the mixed extract.

B. Densitographs of the electrophoregrams

PLATE XXX. ELECTROPHORETIC PATTERN OF ESTERASE ISOENZYMES IN *A. Catechu* and *A. triandra*



morphological characters. Table 14 shows the results for 1966 and 1972. Out of the 40 morphological, yield and anatomical characters studied in 1966, all except one, viz., mean length of longest leaflet, showed significant differences between cultivars. In the case of 35 of these characters, the differences were highly significant. During 1972, all the 24 characters studied (from among the 40 characters studied in 1966), had given significant differences between cultivars. A combined analysis of data, for the 24 common characters recorded during 1966 and 1972 (Table 15) also revealed significant differences between cultivars for all characters excepting length of longest leaflet. Differences between years were also noticed for some of the morphological characters like height, girth, internodal distance, number of bunches and inflorescences, length and breadth of leaf sheath, length and volume of nut and length, breadth, weight and volume of kernel. Significant interaction between years and cultivars was seen in the case of height above fixed mark, internodal distance at fixed mark and at last exposed node, number of bunches and inflorescence on the palm, angle of leaf to the stem, mean length of leaf without sheath, mean breadth of leaf sheath and weight and volume of kernel.

b. D^2 analysis

All possible D^2 values (136) were worked out between cultivars, the number of characters being unequal in the different years. During 1963, the values ranged from 0.29 to 162.80. In 1966, the range of D^2 for the 40 characters was from 53.88 to 6251.55 while for 24 characters it ranged from 12.42 to 621.67 only. During 1972, the corresponding limits were 24.85 and 822.29. For the pooled data the values ranged only between 8.82 and 309.89. The D^2 values for the different years are presented in Table 16. The magnitude of D^2 values indicates that considerable divergence exists between many of the cultivars in all the years. Using Tocher's method, the 17 cultivars could be grouped into 6 clusters each for the independent years 1963, 1966 (24 characters) and 1972. Though the number of clusters were the same, the constituents in the different clusters were slightly different in the different years. For the 40 characters of 1966, the number of clusters increased to seven. In the case of pooled data, there were only five clusters. The intra and inter-cluster D^2 values for the different years are given in Table 17. The cluster means for the characters under study are presented in Tables 18 and 19.

Plates XXXI and XXXII show the disposition of clusters in the different years.

PLATE XXXI

Spatial diagrams showing the distribution of climates in 1963 and 1966

1. 1963 (6 characters)

2. 1966 (40 characters)

PLATE XXXI SPATIAL DISTRIBUTION OF CLUSTERS

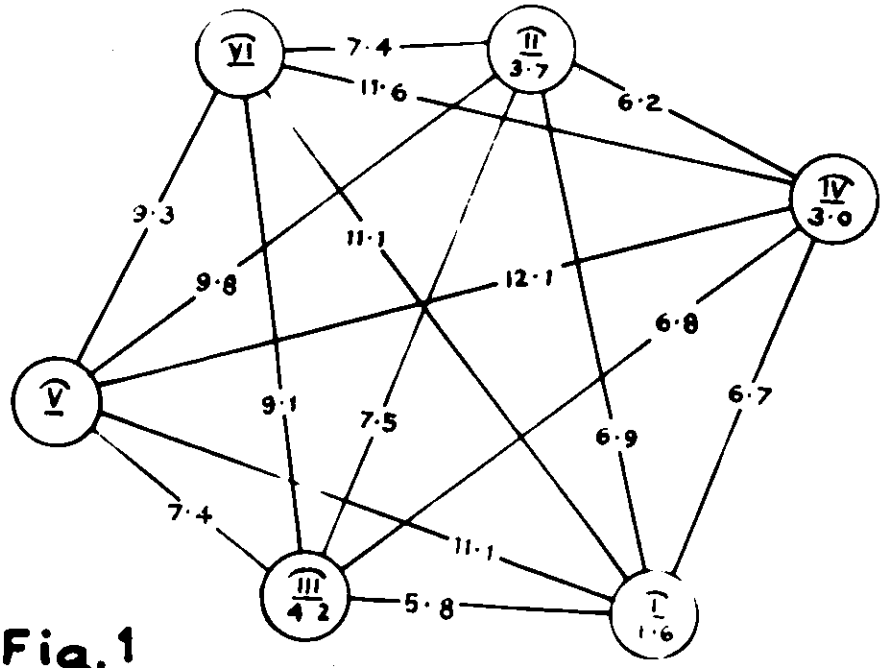


Fig. 1

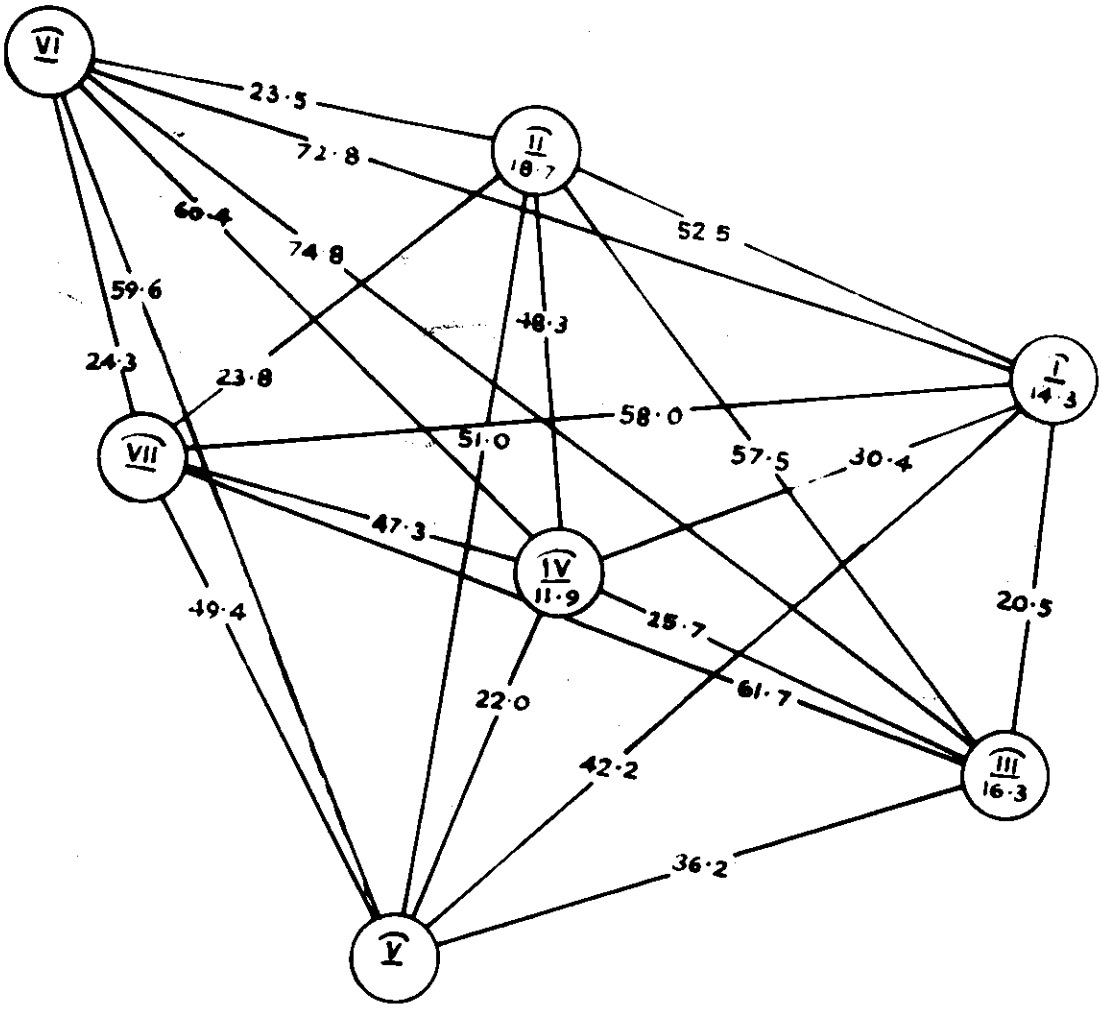


Fig. 2

PLATE XXXI

Spatial diagram showing the distribution of Chelonia in 1966 and 1972

1. 1966 (24 characters)

2. 1972 (")

3. 1966 and 1972, pooled

PLATE XXXII SPATIAL DISTRIBUTION OF CLUSTERS

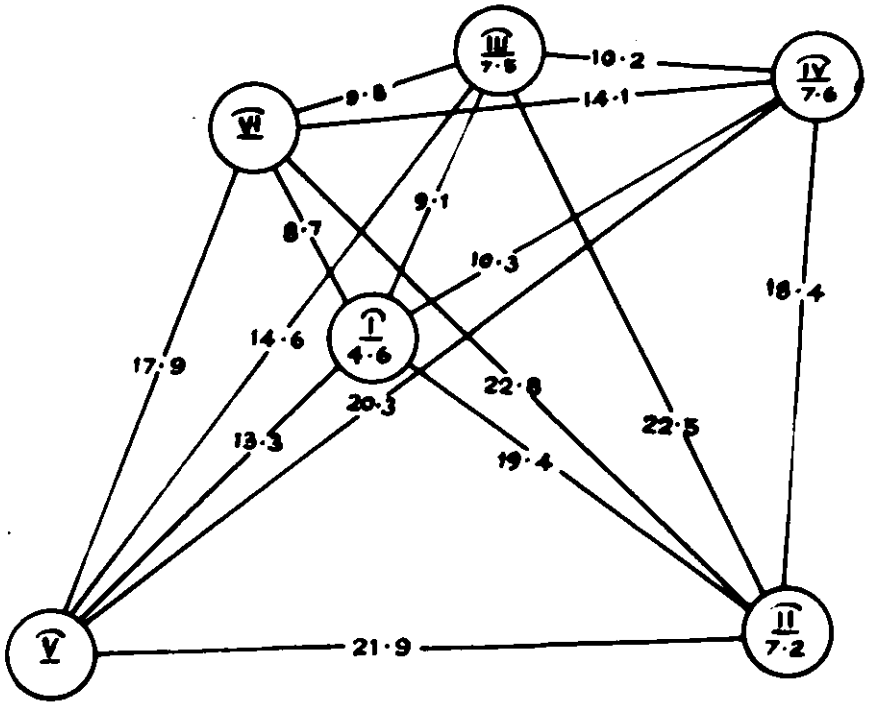


Fig. 1

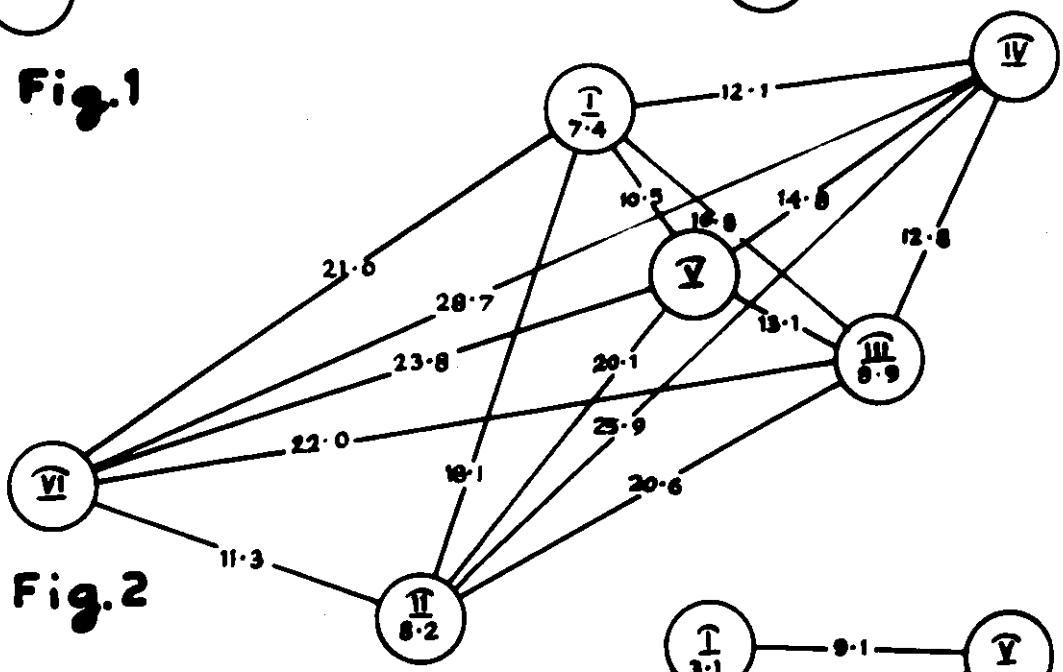


Fig. 2

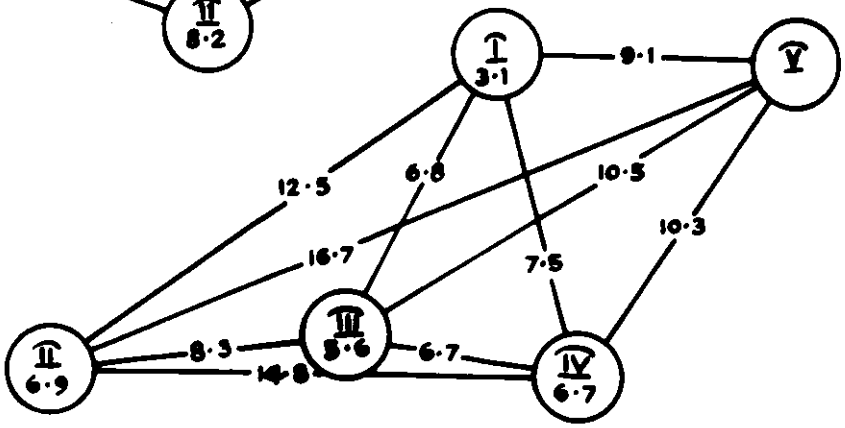


Fig. 3

e. Canonical analysis

Canonical analysis was also carried out for the data for different years to confirm the clustering obtained from D^2 analysis. The first three canonical roots were found to account for 91.7 per cent of the total variation in 1963, 93.5 per cent in 1966 (40 characters) and 83.6 per cent in the same year with 24 characters. In respect of the 24 characters of 1972, the first three canonical roots accounted for 81.9 per cent of the total variation while in the pooled data for 1966 and 1972 (24 common characters) the variation accounted was 81.4 per cent. As, in all the years, about three-fourth of the total variation was shared by the first two roots themselves, a two-dimensional presentation of the cultivars was attempted. Plates XXXIII, XXXIV and XXXV show the relative positions of the cultivars, using the first two canonical vectors as coordinate axes. The pattern of clustering was similar to those obtained from D^2 analysis, except for minor deviations at three instances. In 1963, cultivar Ceylon-1 was found to slightly move away from cultivars Saigon-2, 3 and Nr. Sel. Kalimpong-1. In 1966, for both the sets of characters, there were hardly any differences in the two groupings obtained. In 1972, differences could be seen with respect to cultivars Ceylon-2 and Fiji. In respect of pooled data for 1966 and 1972, the groupings obtained under the two methods were in broad agreement. Canonical vectors for the different years are given in Tables 20 and 21.

PLATE XXXIX

Geometrical analysis of differences in ornament

1. 1963 (6 characters)

2. 1966 (40 characters)

PLATE XXXIII

CANONICAL ANALYSIS OF DIVERGENCE IN ARECANUT

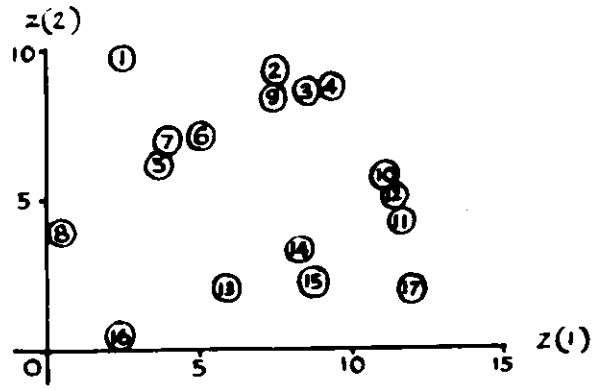


Fig. 1

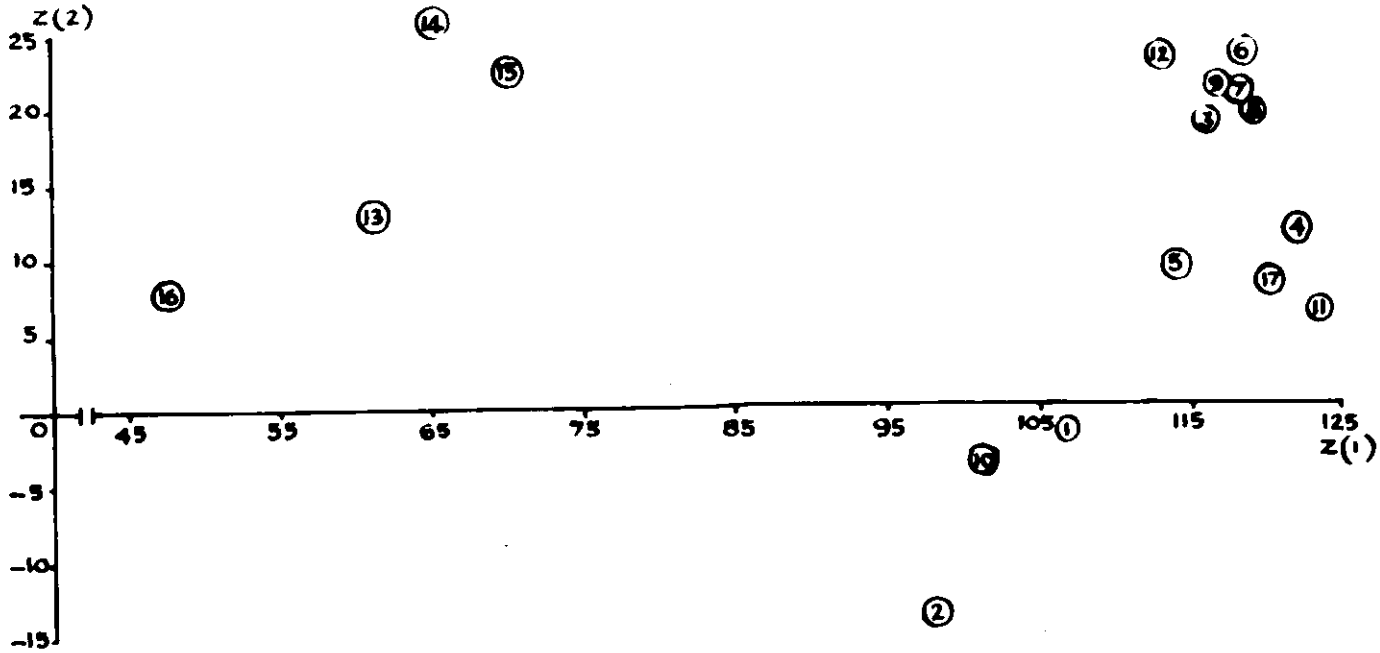


Fig. 2

PLATE XXXIV

Canonical analysis of divergence in sequence

1. 1966 (24 characters)

2. 1972 (")

PLATE XXXIV

CANONICAL ANALYSIS OF DIVERGENCE IN ARECANUT

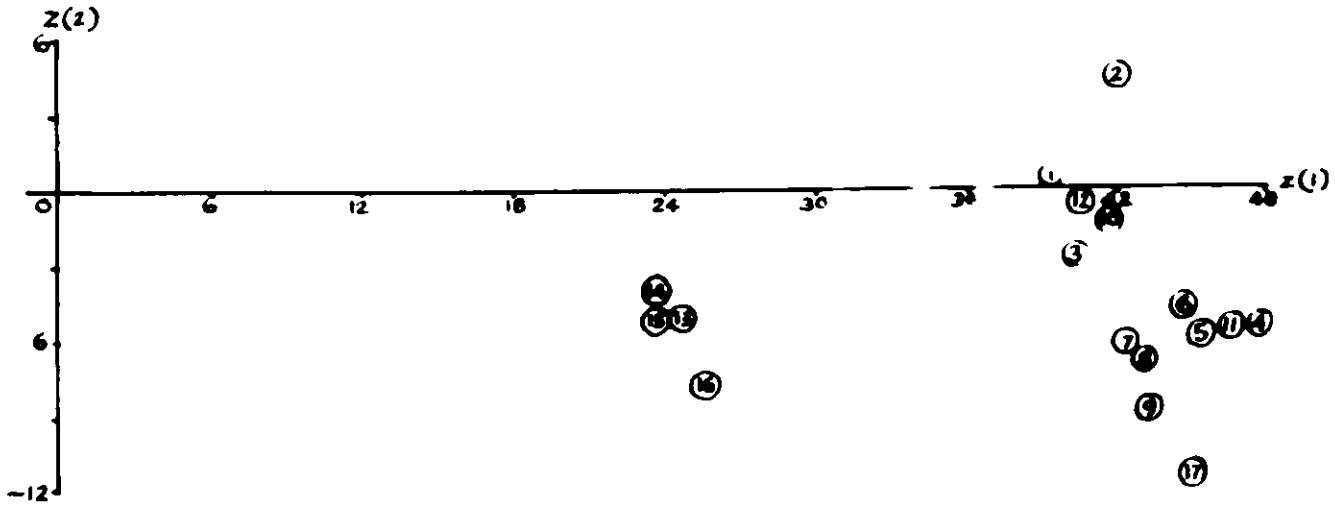


Fig.1

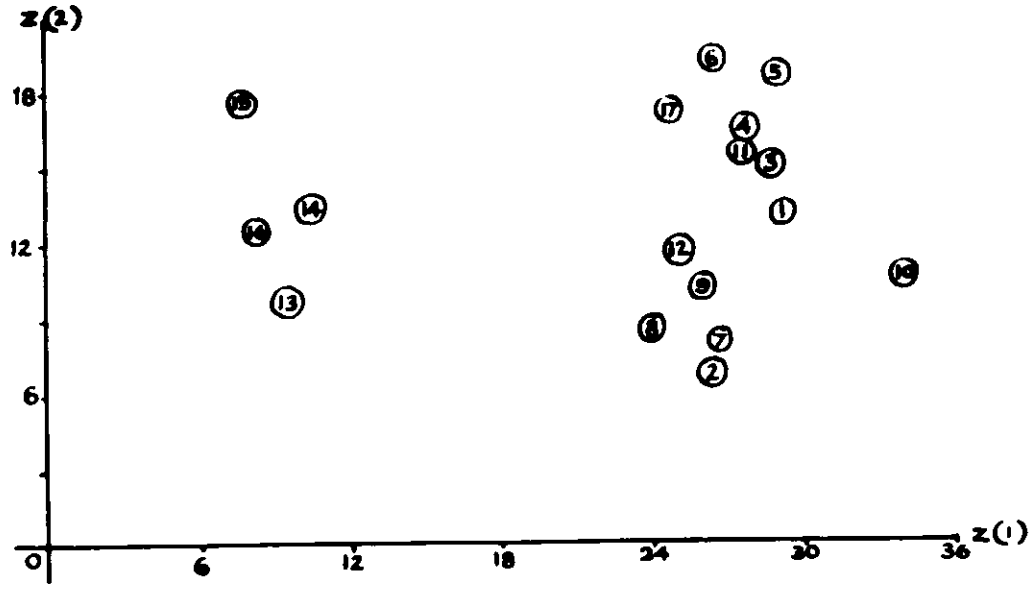


Fig.2

PLATE XXXV

Canonical analysis of divergence in argument

1966 and 1972, pooled

PLATE XXXV

CANONICAL ANALYSIS OF DIVERGENCE IN ARECANUT

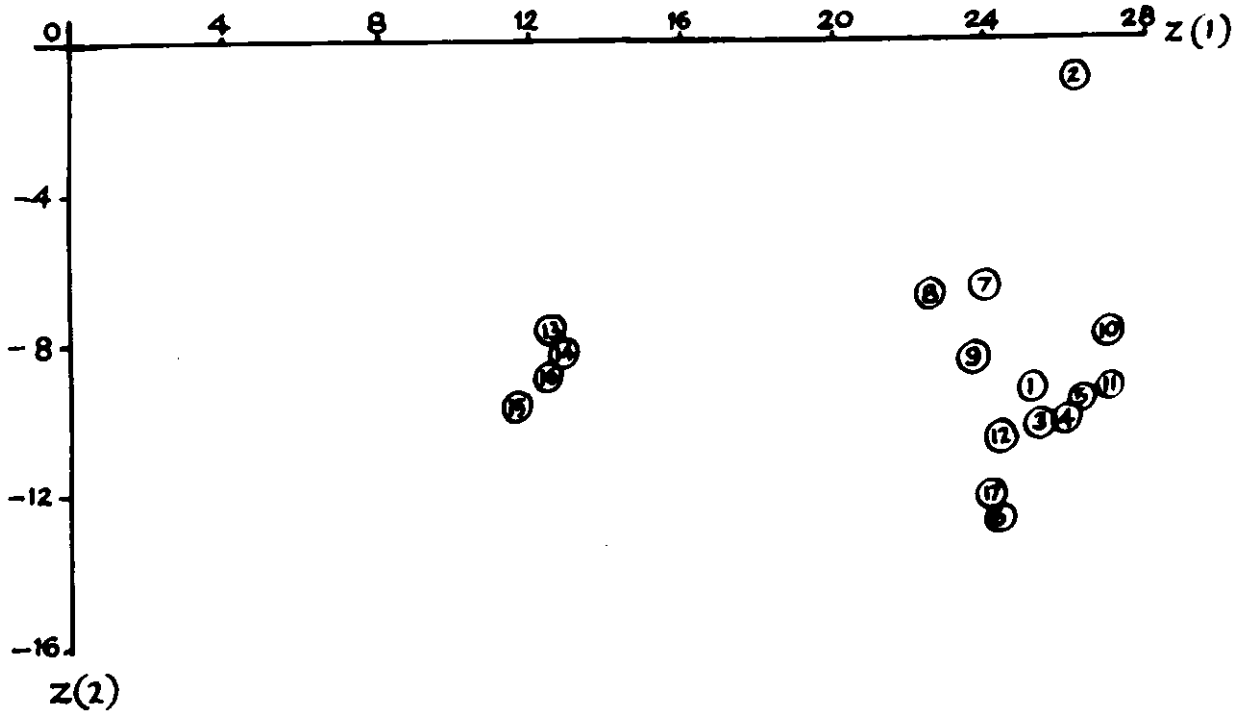


Fig.1

Table 13. ANOVA of means for six characters in Arecanut (1965)

Sl. No.	Characters	Replications (3 d.f.) Mean sum of squares	Cultivars (16 d.f.)	Error (48 d.f.)
1.	Total number of suckers	1.02	8.51**	1.14
2.	Height	531.53	5165.12**	422.83
3.	Girth at collar	38.43	879.78**	55.13
4.	Girth below crown	4.23	322.06**	11.65
5.	Number of leaves	0.33	7.22**	0.85
6.	Number of nuts	1.06	54.82**	3.98

**Significant at P = 0.01

Table 14. ANOVA of plot means for morphological and yield

Sl. No.	Characters	Replications (3 d.f.)	
		1966	1972
			(M e a n
1.	Height above fixed mark	1220.00	406.44**
2.	Girth at fixed mark	20.67	21.30
3.	Girth below crown	41.87	5.27
4.	Internodal distance at fixed mark	16.13**	6.49
5.	Internodal distance at last node	19.33	0.67
6.	Number of bunches per palm	7.94*	4.41
7.	Number of inflorescence on the palm	13.23*	1.69
8.	Total number of leaves on the palm	1.43	0.84
9.	Angle of leaf to the stem	62.33	109.22
10.	Number of leaflets	20.87	37.37
11.	Number of midribs	38.53	51.18
12.	Length of longest leaflet	990.00	253.61
13.	Breadth of broadest leaflet	3.87	1.26
14.	Length of leaf without sheath	36.87	395.60
15.	Length of leaf sheath	24.00	96.72
16.	Breadth of leaf sheath	104.98	51.90
17.	Mean fruit length	0.08	0.19
18.	Mean fruit breadth	0.10	0.40
19.	Mean weight of nut	128.97	24.97
20.	Mean volume of nut	95.47	26.13
21.	Mean kernel length	0.06	0.04
22.	Mean kernel breadth	0.01	0.17
23.	Mean weight of kernel	11.08	8.29
24.	Mean volume of kernel	13.57	4.94
25.	Intensity of selfing	135.95	
26.	Number of female flowers	497.33	
27.	Stomatal Index	0.89	
28.	Length of stomatal pore	0.02	
29.	Length of epidermal cells	0.37	
30.	Length of guard cells	0.04	
31.	Breadth of guard cells	0.03	
32.	Breadth of epidermal cells	0.01	
33.	Length of spathe	108.33	
34.	Breadth of spathe	17.17	
35.	Mean longevity of leaves	1000.00	
36.	Interval between successive leaf fall	192.33	
37.	Mean number of days for male phase	3.37	
38.	Mean number of days for female phase	20.87	
39.	Number of epidermal cells per unit area	111.33	
40.	Number of stomata per unit area	1.30	

* Significant at P = 0.05
** Significant at P = 0.01

Square root to multip

l characters in Assessment (1966 & 1972)

Cultivars (16 d.f.)		Error (48 d.f.)	
1966	1972	1966	1972
(sum of squares)			
285.38[2]**	142.48[3]**	2126.25	9215.81
461.69**	539.69**	16.46	28.55
548.07**	287.00**	23.31	14.98
28.00**	21.87**	3.43	3.90
65.16**	11.84**	14.96	2.51
8.94**	27.84**	2.80	6.15
8.65*	242.74**	4.22	19.79
2.22**	4.53**	0.75	0.71
608.75**	185.91**	78.58	72.12
357.53**	315.61**	24.41	28.99
321.17**	406.02**	23.42	69.82
1078.36	699.09**	1373.57	117.79
18.16**	17.67**	3.19	3.64
3681.25**	2991.52**	491.46	674.71
701.44**	733.07**	110.77	86.57
254.48**	469.66**	43.88	54.10
5.70**	4.56**	0.13	0.16
5.54**	4.03**	0.08	0.56
1191.53**	935.71**	67.86	88.01
1825.95**	1450.92**	52.05	43.61
0.88**	0.53**	0.10	0.06
2.56**	2.52**	0.04	0.13
125.73**	140.65**	8.82	5.08
150.66**	104.77**	9.74	5.79
691.25**		152.59	
457.54[4]**		741.50[3]	
4.31**		0.90	
0.14**		0.01	
4.76**		0.16	
0.35**		0.05	
0.56**		0.01	
0.08**		0.02	
486.15**		62.75	
82.49**		9.50	
7068.75**		1308.33	
421.94**		174.19	
696.85**		28.52	
611.67**		37.83	
4991.25**		215.83	
77.06**		6.15	

Note 2, 3 and 4 indicate that the figures should
plied by 10^2, 10^3 and 10^4 respectively.

Table 15. Pooled ANOVA of means for 24 characters over two years (1966 & 1972) in Arecanut

Characters	Years (1 d.f.)	Replication (3 d.f.)	Years x Replication (3 d.f.)	Cultivars (16 d.f.)	Years x cultivars (16 d.f.)	Error (96 d.f.)
	(M e a n			s u m	o f	s q u a r e s)
1	598.00^{4}**	272.00**	147.00^{2}	140.46^{3}**	305.62^{2}**	5698.35
2	59.00	37.33	5.00	985.13**	16.31	21.00
3	720.00**	26.67	20.67	623.75**	11.38	19.15
4	34.00**	17.43**	5.20	43.06**	6.81*	3.46
5	670.60**	7.23	12.53	57.27**	18.11*	8.60
6	154.60**	11.91**	0.44	16.99**	18.99**	4.48
7	855.01**	9.81	5.11	106.97**	144.41**	11.99
8	0.90	1.53	0.43	6.13**	1.09	0.68
9	1266.96**	67.05	184.21*	537.08**	315.57**	75.26
10	28.00	29.00	9.67	643.56**	15.38	23.06
11	27.00	32.33	55.33	701.63**	35.23	59.83
12	1.30	123.33	656.67	1003.75	772.50	745.10
13	1.20	4.40	0.83	34.29**	1.54	3.34
14	282.70^{2}**	173.33	360.00	5098.12**	1508.12**	412.71
15	478.00*	26.62	92.67	1598.00**	75.56	90.95
16	6196.00**	12.67	198.00*	556.69**	90.56*	44.55
17	1.49**	0.18	0.13	10.20**	0.17	0.15
18	0.25	0.11	0.11	10.24**	0.14	0.09
19	64.00	58.67	101.33	2178.56**	69.94	50.51
20	624.00**	93.33	38.00	3213.12**	68.75	47.54
21	0.39*	0.08	0.02	1.10**	0.11	0.08
22	0.41*	0.12	0.06	4.96**	0.12	0.09
23	47.20*	18.07	1.23	240.24**	24.13**	6.91
24	172.40**	16.80	1.67	221.65**	33.78**	6.74

(Note: For character names, refer Table 14)

* Significant at P = 0.05

** Significant at P = 0.01

Superscripts 2, 3 and 4 indicate that the figures should be multiplied by 10^2, 10^3 and 10^4 respectively.

Table 16. D^2 values for 17 cultivars

1	2	3	4	5	6	7	8	9
	25.31 494.78	35.40 609.88	40.70 625.98	36.77 358.39	13.77 899.94	17.82 815.35	70.69 761.71	47.97 849.15
114.42 148.75 66.75		3.18 1628.94	4.59 1528.91	53.65 1012.36	14.73 1942.91	24.05 1000.51	113.27 1675.72	0.21 1008.68
72.14 [illegible] [illegible] 11.82	167.31 122.05 94.88		0.29 272.64	57.49 256.61	18.90 171.50	33.41 191.47	180.19 210.20	3.16 261.77
[illegible] [illegible] 34.09	237.07 170.44 105.75	98.70 84.78 20.59		61.18 134.58	20.98 285.97	35.86 276.57	134.76 271.55	3.84 294.82
107.48 [illegible] 97.67	184.92 104.59 93.15	65.82 71.50 24.78	40.23 34.09 13.42		17.97 305.75	18.30 356.69	33.38 286.29	55.10 314.25
91.84 84.19 55.75	206.55 266.26 143.94	38.21 102.46 90.95	74.81 27.42 32.92	42.78 80.13 29.40		3.73 217.55	49.78 194.16	14.10 218.94
[illegible] [illegible] 41.62	163.37 107.91 77.51	85.55 109.90 41.55	85.04 112.15 55.06	66.59 171.01 50.07	90.27 161.20 63.95		30.66 66.28	22.78 85.68
[illegible] [illegible] 57.41	140.44 105.14 74.70	85.68 135.43 44.82	86.06 91.19 41.46	38.39 198.17 58.74	83.88 153.58 55.98	18.42 55.10 9.50		116.84 55.88
[illegible] [illegible] [illegible]	226.86 84.14 96.15	104.29 [illegible] 30.08	109.82 [illegible] 32.20	70.27 [illegible] 48.78	82.69 [illegible] 40.14	26.37 [illegible] 10.41	24.24 [illegible] 8.82	
[illegible] [illegible] 29.52	177.42 [illegible] 82.46	60.43 [illegible] 51.24	[illegible] [illegible] 26.75	73.89 [illegible] 29.90	101.71 [illegible] [illegible]	[illegible] [illegible] 24.53	[illegible] [illegible] 55.61	113.[illegible] [illegible] 30.59
[illegible] [illegible] 53.57	222.66 [illegible] 97.88	78.76 80.44 25.85	70.99 [illegible] 25.49	51.58 [illegible] 27.82	[illegible] [illegible] 98.25	[illegible] [illegible] 97.31	[illegible] [illegible] 68.18	[illegible] [illegible] 97.74
[illegible] [illegible] [illegible]	199.48 143.98 127.74	73.55 84.81 38.31	163.31 81.50 45.40	146.83 135.08 65.19	77.84 131.72 46.92	[illegible] [illegible] 89.95	[illegible] [illegible] 95.78	[illegible] [illegible] 55.89
[illegible] [illegible] 189.65	[illegible] [illegible] 262.48	307.55 [illegible] 195.02	[illegible] [illegible] 205.90	[illegible] [illegible] 217.79	[illegible] [illegible] 184.96	[illegible] [illegible] 182.51	[illegible] [illegible] 151.84	[illegible] [illegible] 196.36
211.00 [illegible] [illegible]	470.95 401.45 259.90	350.39 [illegible] 182.47	621.67 271.39 204.87	478.31 490.14 219.84	[illegible] [illegible] 182.89	404.17 [illegible] 183.29	401.70 [illegible] 128.91	[illegible] [illegible] 198.00
[illegible] [illegible] [illegible]	461.78 384.67 509.89	317.34 [illegible] 206.54	285.73 474.16 234.88	466.92 [illegible] 244.98	466.81 425.76 197.67	[illegible] [illegible] 192.92	761.31 [illegible] 192.66	[illegible] [illegible] 174.85
[illegible] [illegible] [illegible]	505.05 [illegible] 281.56	700.11 466.00 190.55	507.99 [illegible] 201.08	407.25 [illegible] 216.65	415.92 [illegible] 182.29	319.90 [illegible] 185.82	[illegible] [illegible] [illegible]	[illegible] [illegible] [illegible]
211.14 [illegible] 55.58	321.97 189.19 147.17	158.47 [illegible] 29.60	114.66 42.04 29.50	73.36 75.35 35.49	107.78 46.96 17.98	95.95 [illegible] 56.78	81.96 92.41 48.11	48.77 [illegible] 52.65

Values for 1965 (6 characters) and 1966 (40 characters) are given above below the diagonal.

s of [illegible]

10	11	12	13	14	15	16	17
90.29 142.80	116.21 559.89	107.97 755.35	76.25 2444.88	77.18 2667.82	95.21 2197.17	101.18 3953.05	143.18 705.76
33.94 471.98	54.09 1245.44	48.38 1772.18	61.00 2457.38	38.33 2905.09	32.32 2257.47	124.65 3548.94	73.30 1455.06
21.39 932.79	41.52 382.15	36.69 207.05	61.84 3502.75	35.03 2684.86	48.69 2404.86	126.70 5252.54	38.63 590.06
18.60 811.16	37.73 318.31	34.10 509.84	60.88 3935.37	38.84 3798.38	45.80 3130.80	126.18 5782.49	32.93 288.35
64.28 467.25	66.98 278.90	60.78 414.06	53.99 3057.21	31.78 2890.47	73.61 2368.05	90.24 4711.49	97.12 265.69
42.94 1171.78	34.74 528.29	33.72 156.78	36.24 3526.22	39.93 3107.90	43.38 2622.00	69.72 5545.64	73.18 626.35
60.93 1057.31	88.23 557.48	67.54 358.97	38.30 3360.38	37.33 3086.49	36.68 2645.42	70.84 5311.95	88.97 475.11
179.74 1077.40	143.47 412.88	127.73 365.76	97.48 3532.75	21.16 3223.14	109.35 2697.98	97.03 5494.04	168.80 398.85
31.66 1113.08	50.73 498.53	46.79 361.04	56.28 3458.24	36.04 3118.21	47.98 2529.98	117.96 5246.34	66.98 327.31
	4.98 840.42	4.60 1038.88	27.26 2050.95	38.66 2400.24	33.23 2048.65	121.98 3356.15	14.35 953.89
97.13 [illegible] 94.88		2.28 648.87	37.80 4231.88	19.21 4097.42	23.98 3326.97	134.87 6251.95	8.80 553.79
87.92 [illegible] 45.40	143.87 141.25 99.88		65.05 3068.76	25.19 2565.33	44.78 2225.21	122.76 4966.14	19.93 851.79
372.17 [illegible] 298.48	150.96 185.38 293.04	346.21 311.34 182.97		17.38 510.95	19.74 621.45	32.79 952.12	38.61 4044.96
379.64 [illegible] 155.05	360.65 311.90 245.98	306.82 [illegible] 171.85	74.98 [illegible] 95.48		4.61 348.96	62.93 1114.55	17.11 3064.19
286.30 [illegible] 289.14	343.29 [illegible] 277.94	366.37 416.97 218.15	44.57 180.26 55.27	42.88 72.88 52.54		38.25 1154.75	23.34 3095.55
379.78 [illegible] 251.59	481.94 [illegible] 258.98	377.97 342.35 177.07	19.23 18.80 16.86	64.47 97.23 45.44	37.12 [illegible] 55.92		117.36 5624.95
199.07 400.99 75.95	97.61 158.29 56.40	235.74 73.41 56.27	223.34 286.60 179.04	277.92 265.65 175.21	229.94 262.73 180.87	160.11 180.98 182.71	

the diagonal and 1966, 1972 and pooled (24 characters)

Table 17. Intra and inter cluster D^2 values (1963-'72)

Clusters		I	II	III	IV	V	VI	VII
I	a	2.6	47.9	53.9	44.2	123.4	123.7	..
	b	205.6	2752.3	419.1	923.6	1784.3	5905.7	5364.8
	c	21.1	376.6	82.3	106.6	176.9	75.9	..
	d	54.8	388.3	117.0	142.6	109.8	440.2	..
	e	9.3	198.3	44.8	56.6	82.8	..	..
II	a		14.0	56.6	38.0	96.1	54.3	..
	b		348.9	3706.2	2386.0	2956.3	1124.6	566.2
	c		52.2	304.0	157.3	480.5	517.3	..
	d		67.4	422.9	671.8	404.1	128.2	..
	e		47.8	68.3	217.8	270.4	..	..
III	a			18.0	78.6	55.2	83.0	..
	b			266.2	659.8	1510.3	5588.1	3812.3
	c			56.2	104.2	212.8	96.9	..
	d			79.9	164.3	173.0	485.3	..
	e			31.0	45.3	109.9	..	..
IV	a				8.9	145.8	135.0	..
	b				142.8	483.4	3644.6	2238.0
	c				58.2	411.1	198.9	..
	d				..	217.9	822.3	..
	e				45.4	105.1	..	..
V	a					..	87.0	..
	b					..	3548.9	2437.4
	c					..	321.9	..
	d					..	564.7	..
	e					..	..	..
VI	a						..	..
	b						..	598.1
	c						..	..
	d						..	..
	e						..	..
VII	a							..
	b							..
	c							..
	d							..
	e							..

(For composition of clusters in individual years, refer Table 22)

a - 1963 (6 characters) b - 1966 (40 characters)

c - 1966 (24 characters) d - 1972 (24 characters)

e - 1966 & 1972 pooled (24 characters)

Table 18. Cluster means (1965)

Characters	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI
1	1.00	1.00	4.00	1.00	1.00	4.00
2	62.66	77.85	33.90	72.03	31.05	0.00
3	47.75	55.43	28.52	48.78	41.20	10.13
4	32.96	34.61	22.67	32.75	32.18	0.00
5	8.19	9.06	7.08	8.50	7.25	5.00
6	7.38	9.50	4.58	8.50	5.75	0.00

Table 19. Cluster means (1966-'72)

Characters		Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI	Cluster VII
1	a	167.50	72.63	264.75	112.75	58.00	80.00	88.50
	b	140.25	78.44	250.25	138.25	58.00	314.75	
	c	485.43	268.75	763.14	413.00	389.25	600.50	
	d	319.25	252.56	908.40	266.25	223.62		
2	a	43.83	25.13	44.81	42.38	43.25	18.50	16.25
	b	42.33	21.25	44.50	43.63	45.25	47.50	
	c	47.81	19.50	46.86	39.25	46.75	26.00	
	d	44.25	21.19	45.60	45.50	45.00		
3	a	39.42	26.38	43.31	40.88	40.75	17.00	16.00
	b	37.38	21.44	42.36	41.75	40.75	41.50	
	c	33.63	17.42	37.18	34.50	34.00	22.25	
	d	34.29	20.05	39.71	40.25	37.37		
4	a	9.71	12.50	11.94	7.00	6.25	12.00	9.50
	b	9.85	11.62	10.31	8.31	6.25	16.00	
	c	10.31	11.17	11.54	8.00	8.75	17.50	
	d	9.87	12.19	11.25	8.31	7.50		
5	a	12.21	14.25	12.75	6.50	6.00	15.00	7.25
	b	14.17	12.69	13.00	7.19	6.00	14.00	
	c	7.19	6.92	6.89	5.00	4.75	11.00	
	d	10.96	10.31	9.41	5.44	5.37		
6	a	1.96	3.08	3.19	4.50	3.50	0.00	2.00
	b	1.33	2.06	3.38	3.31	3.50	2.75	
	c	2.75	7.50	4.32	2.25	4.00	11.50	
	d	2.17	3.88	3.91	2.31	3.75		
7	a	3.42	4.00	4.31	5.75	4.50	0.75	4.25
	b	2.50	3.25	4.25	5.00	4.50	4.75	
	c	5.31	22.53	5.96	2.75	5.00	13.75	
	d	4.12	11.78	5.30	4.00	4.75		
8	a	9.39	9.13	10.06	10.00	7.95	8.50	8.75
	b	9.50	8.88	10.00	9.88	7.75	9.75	
	c	9.63	8.00	10.50	10.00	9.25	8.50	
	d	9.54	8.50	10.25	9.75	8.50		

Contd....

Table 19. Cluster means (1966-'72) (Contd.)

Characteristics		Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI	Cluster VII
9	a	51.22	35.41	61.68	49.97	42.75	46.75	32.75
	b	64.04	37.98	53.85	45.87	42.75	39.80	
	c	55.87	48.42	59.77	61.98	58.47	44.10	
	d	60.95	42.55	56.13	57.83	50.70		
10	a	26.21	17.80	36.82	34.99	19.37	24.82	18.42
	b	18.83	19.21	38.31	33.47	19.37	24.65	
	c	23.56	20.26	24.54	33.05	20.60	17.87	
	d	18.42	19.43	35.22	37.69	19.98		
11	a	55.76	49.25	62.01	62.98	55.80	51.80	38.45
	b	48.42	47.18	64.00	63.14	55.80	52.75	
	c	54.47	44.54	63.13	63.45	53.62	48.37	
	d	49.11	46.54	64.32	64.25	53.71		
12	a	82.32	80.40	89.22	86.25	91.30	61.15	137.15
	b	86.86	69.77	84.04	86.78	91.30	81.22	
	c	92.82	70.66	88.58	92.10	96.19	85.22	
	d	90.32	81.79	86.53	90.51	93.70		
13	a	11.30	12.89	10.65	10.74	16.67	8.32	8.90
	b	12.00	10.65	10.39	10.67	16.67	11.82	
	c	12.05	9.82	11.21	9.37	15.77	12.97	
	d	12.44	10.65	11.15	9.37	16.22		
14	a	164.00	115.88	180.88	175.90	137.25	142.50	124.00
	b	151.25	124.56	186.44	179.19	137.25	142.25	
	c	178.81	164.67	197.12	216.30	183.75	202.90	
	d	165.12	149.34	188.59	186.44	160.50		
15	a	82.25	67.25	89.56	85.38	87.00	55.75	51.50
	b	80.88	60.44	87.15	85.50	87.00	67.75	
	c	88.56	62.50	91.87	91.35	73.75	66.00	
	d	85.04	61.50	89.75	85.75	80.57		
16	a	34.46	25.75	34.19	37.13	34.00	17.25	18.75
	b	27.50	20.88	38.38	39.75	34.00	34.75	
	c	44.38	33.82	51.34	49.00	37.00	42.75	
	d	34.21	22.50	44.11	45.96	35.50		

Contd....

Table 19. Cluster means (1966-'72) (Contd.)

Characteristics		Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI	Cluster VII
17	a	5.32	2.96	5.30	5.50	6.65	2.72	3.02
	b	5.51	2.98	5.58	5.35	6.65	4.65	
	c	5.00	2.86	5.17	5.60	5.57	2.00	
	d	5.17	2.88	5.29	5.26	6.26		
18	a	3.64	1.40	4.28	4.13	4.62	1.42	1.47
	b	3.63	1.43	4.30	3.82	4.62	3.62	
	c	3.44	1.59	3.98	4.30	4.20	1.25	
	d	3.53	1.46	4.01	3.92	4.41		
19	a	30.93	4.28	39.47	48.20	55.02	3.52	4.70
	b	33.04	4.19	39.97	38.37	55.02	47.27	
	c	28.04	4.21	38.42	43.70	47.73	3.02	
	d	30.49	4.04	38.32	36.30	51.40		
20	a	37.44	4.25	52.41	51.11	68.27	3.57	4.80
	b	36.91	4.22	54.36	43.26	68.27	55.27	
	c	30.88	4.06	43.93	48.10	53.02	2.42	
	d	33.89	3.43	45.87	42.52	61.65		
21	a	2.48	1.93	2.69	2.55	3.05	1.62	1.70
	b	2.52	1.81	2.72	2.49	3.05	2.30	
	c	2.33	1.81	2.47	2.45	2.90	2.45	
	d	2.59	1.79	2.53	2.49	2.97		
22	a	2.51	1.11	3.10	2.62	3.10	1.10	0.97
	b	2.48	1.07	3.11	2.52	3.10	2.67	
	c	2.20	1.05	2.79	2.58	2.79	0.98	
	d	2.33	1.04	2.83	2.76	2.98		
23	a	11.88	2.96	13.34	11.12	22.75	1.40	2.02
	b	12.61	2.34	12.74	10.46	22.75	11.25	
	c	7.92	1.86	13.34	11.10	16.80	1.17	
	d	10.29	1.78	12.99	9.98	19.77		
24	a	10.56	2.24	13.21	11.72	26.87	4.12	2.17
	b	11.52	2.60	13.29	10.15	26.87	11.35	
	c	6.88	1.29	11.65	10.45	14.20	1.00	
	d	9.25	1.95	11.92	9.20	20.75		

Contd....

Table 19. Cluster means (1966-'72) (Contd.)

Character- ers		Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI	Cluster VII
25	a	25.31	54.30	24.06	32.64	35.56	37.61	26.75
26	a	1006.75	4098.62	908.31	2272.25	636.00	906.25	1299.15
27	a	9.75	9.55	8.82	8.90	7.54	8.14	7.79
28	a	1.46	1.96	1.62	1.52	1.49	1.79	1.54
29	a	3.12	5.82	5.52	3.05	3.17	5.72	4.00
30	a	2.91	3.65	3.05	2.95	2.71	3.38	3.11
31	a	2.00	1.31	2.08	2.05	1.87	0.99	1.83
32	a	1.77	2.12	1.72	1.76	1.75	1.89	1.92
33	a	54.10	36.84	61.05	62.02	39.57	38.00	34.30
34	a	13.76	11.31	15.33	21.17	11.22	8.00	8.77
35	a	429.61	496.16	404.65	394.89	351.42	467.90	445.38
36	a	44.13	59.30	38.39	35.79	46.33	55.22	62.88
37	a	25.99	44.14	22.09	21.33	32.07	69.52	21.17
38	a	14.02	30.77	12.92	13.85	19.40	17.75	18.92
39	a	188.14	110.06	191.71	185.73	190.00	116.25	115.87
40	a	20.49	11.56	18.49	18.38	18.30	10.25	9.75

(Note: For composition of clusters in individual years, refer Table 18)

a : 1966 (40 characters) b : 1966 (24 characters)

c : 1972 (24 characters) d : 1966 & 1972 (pooled)

Table 20. Canonical vectors (1963)

Elements	Vector (1)	Vector (2)	Vector (3)
1	-0.0657	-0.3053	-0.3221
2	0.0904	-0.0854	0.7156
3	0.6317	-0.0913	0.2091
4	0.6969	0.1781	-0.0090
5	0.2496	0.3915	-0.5364
6	-0.2145	0.8402	0.2291
Values of canonical roots	205.29	139.07	68.06
Percentage contribution to total variation	45.7	30.9	15.1

Table 21. The first three canonical vectors, roots and their contribution to total variation in Assessment (1966-1972)

Elements		Vector (1)	Vector (2)	Vector (3)
1	a	0.0491	0.0128	0.0489
	b	0.1410	-0.2280	-0.1672
	c	0.0984	0.4106	-0.0279
	d	0.1478	-0.4684	0.1546
2	a	0.0830	0.0430	0.0851
	b	0.2430	0.2066	0.0202
	c	0.1262	-0.1108	0.0025
	d	0.2476	0.0851	0.2901
3	a	0.0249	-0.0131	0.0251
	b	0.0714	-0.0105	-0.0716
	c	0.1691	-0.0763	0.0864
	d	0.2030	-0.0149	0.2035
4	a	-0.0399	0.0635	-0.0561
	b	-0.1204	-0.3469	0.0072
	c	-0.0995	0.0634	-0.0822
	d	-0.1506	-0.1968	-0.1588
5	a	-0.0121	0.0412	-0.0121
	b	0.0396	0.1284	0.1049
	c	-0.1827	-0.0574	-0.1775
	d	-0.1355	-0.0068	-0.1996
6	a	-0.0181	-0.0342	-0.0178
	b	0.0516	0.1390	0.0814
	c	-0.1484	-0.0262	-0.0926
	d	-0.0900	-0.0789	-0.1082
7	a	-0.0164	-0.0160	-0.0163
	b	-0.0500	0.2165	0.0405
	c	-0.0993	-0.1101	0.2714
	d	-0.1181	0.0787	-0.1253
8	a	0.0021	0.0226	0.0020
	b	0.0806	-0.0594	-0.1182
	c	0.1011	0.1309	-0.0413
	d	0.1088	-0.1317	0.1080
9	a	0.0344	-0.0089	0.0344
	b	0.1092	-0.2438	0.2338
	c	0.0190	0.0884	0.0088
	d	0.0935	-0.0534	0.0928
10	a	0.0965	-0.0415	0.0965
	b	0.1264	0.1444	-0.3012
	c	0.1783	0.4393	0.1167
	d	0.2457	-0.4870	0.2475

Contd.....

Table 21. The first three canonical vectors, roots and their contribution to total variation in Arecanut (1966-1972) (Contd.)

Elements		Vector (1)	Vector (2)	Vector (3)
11	a	0.0025	-0.0401	0.0025
	b	0.0803	0.3299	-0.1975
	c	-0.0142	-0.0903	0.0190
	d	0.0436	0.0934	0.0425
12	a	0.0055	-0.0078	0.0054
	b	0.0141	-0.0143	-0.0182
	c	0.0871	-0.1475	0.1090
	d	0.0201	0.1056	0.0801
13	a	-0.0008	-0.0297	-0.0007
	b	-0.0061	0.0949	0.3901
	c	-0.0180	-0.0058	0.0142
	d	-0.0656	0.2218	-0.0667
14	a	0.0538	-0.0071	0.0540
	b	0.1055	-0.0105	-0.2519
	c	0.0035	0.0955	0.2808
	d	0.0491	-0.0066	0.0490
15	a	0.0245	-0.0800	0.0245
	b	0.0734	-0.0780	0.0744
	c	0.1578	-0.0800	-0.1480
	d	0.1728	-0.0501	0.1729
16	a	0.0535	-0.0184	0.0539
	b	0.1521	0.1610	-0.3119
	c	-0.2060	0.2780	-0.0531
	d	-0.0275	-0.2250	-0.0267
17	a	0.1055	-0.1180	0.1061
	b	0.3292	0.2418	[illegible]
	c	0.3168	-0.0482	[illegible]
	d	0.4461	0.2009	0.4434
18	a	0.1152	-0.1118	0.1152
	b	0.3688	-0.0475	0.2997
	c	0.4576	-0.3734	0.3002
	d	0.5599	0.2168	0.5296
19	a	-0.0261	-0.0461	-0.0262
	b	-0.0681	0.0805	0.1708
	c	-0.0161	-0.2558	0.2979
	d	-0.0046	0.1117	-0.0050
20	a	-0.2055	0.0405	-0.2088
	b	-0.3776	0.1973	0.1274
	c	-0.1691	0.2536	0.1667
	d	-0.4096	0.2159	-0.4085

Contd....

Table 21. The first three canonical vectors, roots and their contribution to total variation in Arcesant (1966-1972) (Contd.)

Elements		Vector (1)	Vector (2)	Vector (3)
21	a	0.0765	-0.0450	0.0768
	b	0.2532	0.0856	-0.1448
	c	-0.9982	-0.3429	0.0468
	d	-0.0589	0.1923	-0.0998
22	a	0.1280	-0.0317	0.1219
	b	0.3879	-0.3098	0.1989
	c	0.0644	-0.1476	-0.0796
	d	-0.0057	0.0812	-0.0881
23	a	0.0023	-0.0490	0.0023
	b	0.0175	0.2271	0.1809
	c	-0.1884	0.2105	0.7144
	d	0.0922	0.3161	0.0989
24	a	0.0590	-0.1756	0.0793
	b	0.1929	0.4554	0.2598
	c	0.2110	0.0858	-0.0443
	d	0.1700	0.2852	0.1791
25	a	0.0402	-0.0466	0.0401
26	a	0.0058	0.0497	0.0058
27	a	-0.0885	0.1519	-0.0884
28	a	0.0229	0.1275	0.0229
29	a	-0.1766	0.1655	-0.1759
30	a	0.0374	0.1296	0.0373
31	a	0.4656	-0.0033	0.4655
32	a	-0.0476	0.1327	-0.0684
33	a	-0.0865	0.0917	-0.0867
34	a	-0.0495	-0.3695	-0.0490
35	a	0.0503	-0.0975	0.0509
36	a	0.6238	0.4162	0.6290
37	a	-0.3665	-0.0885	-0.3687
38	a	0.0191	0.0519	0.0189
39	a	0.1290	-0.4990	0.1297
40	a	-0.2851	0.5017	-0.2817
Value of canonical roots	a	9869.02	1988.96	1000.29
	b	1142.62	234.79	133.64
	c	1133.05	245.30	164.60
	d	524.88	105.77	69.66
Percentage contribution to total variation	a	71.7	14.5	7.3
	b	63.2	13.0	7.4
	c	60.2	13.0	8.7
	d	61.0	12.5	8.1

a : 1966 - 40 characters; b : 1966 - 24 characters;
c : 1972 - 24 characters; d : Pooled

DISCUSSION

The genus *Musa* is found to be a habitant of certain regions, extensively distributed over the tropical belt. Among the species reported in this genus, *M. sapientum*, the only cultivated species, has received some attention of the botanists, while *M. ingens* has not so far been investigated to any appreciable extent. The diversity in this genus has also not been assessed except for the attempts made on classifying some of the cultivars of *M. sapientum* based on few characters (Baccari, 1919; Raghavan and Baruah, 1956b, Murthy and Bavappa, 1962).

MORPHOLOGY

A study of literature shows that *M. sapientum* has single stem, larger number of leaves per stem, larger number of male flowers arranged in single uniseriate alternate rows with six stamens and large sized female flowers and fruits, whereas *M. ingens* is characterised by multiple thin stems, the off-shoots emerging from the base, less number of leaves and male flowers with three stamens arranged in uniseriate pairs, smaller female flowers and fruits (Matter, 1926; Bavappa, 1966a, b). Morphological characters of the two cultivars of *M. sapientum* and three ecotypes of *M. ingens* studied in the present investigation largely confirmed the earlier

reports cited, though variations in the number of stamens in *A. galeata* as well as distinct difference in maturity of nuts between the two species which have not been reported so far were observed. However, the important distinguishing characters of these two species are the number of stem and leaves per clump, arrangement of male flowers, number of stamens, size of female flower and size and maturity period of nuts.

The F_1 hybrids of *A. galeata* x *A. triandra* had only one stem as in *A. galeata* indicating the dominance of single stem. The reciprocal hybrid had varied number of suckers as in *A. triandra*. While the possibility of cytoplasmic inheritance cannot be ruled out, for establishing the same, it will be necessary to do a series of backcrosses and prove the consistency in inheritance (Cesperi, 1948). In this connection it is also pertinent to point out that evidences as are discussed elsewhere show that *A. triandra* is synaristic.

The values for internodal distance at fixed mark in the two species showed considerable overlapping. The hybrids mostly equalled the parents in the above character as well as in leaf length. It appeared that a dosage effect of gene, as was reported in sugarcane by Chun-Fu-Chen (1953) for leaf length is operating with respect to internodal distance and leaf length.

As regards the number of leaves per main stem, neither the two species nor their hybrids showed any marked difference. However, there was distinct difference for number of leaves per clump. The similarity of the hybrids to their respective female parents in respect of leaves per clump indicated that this character might be maternal in inheritance.

A. sativum x A. trianum exhibited hybrid vigour for number of male flowers per bunch. The difference in size of the male flowers (length x breadth) in the two parents was distinct. In the hybrids, the size of the male flower, though was intermediate in most cases, also showed extreme variations as compared to the parents. The smallest size of male flowers observed in one of the hybrid plants (307) might be partly due to the larger number of flowers per bunch produced by this hybrid. Such extreme variation was observed for none of the other characters.

As the very name indicates A. trianum has three stamens while A. sativum has six. This is one of the most important characteristics distinguishing the two species. The present study has confirmed that the number of stamens of A. trianum is three. However, the number of stamens in A. sativum seems to show some

variability as against the six recorded by earlier workers (Koehne, 1894; Hutter, 1926). A more detailed study of the cultivars of A. spinosa seems to be necessary for assessing the variability existing for this character. The number of stamens in the A. spinosa x A. triandra hybrids varied from three to six. In this respect the spontaneous hybrid was distinctly different from the artificial hybrids, the former having mostly six stamens and rarely five as compared to others which were intermediate. The inheritance of number of stamens seems to be quantitative.

Arrangement of male flowers is another important character which distinguishes A. spinosa from A. triandra. In A. spinosa the male flowers are single and alternate, and arranged on either side of the rachilla. In A. triandra, on the other hand the male flowers are in pairs and arranged only on one side of the rachilla. In all the hybrids of A. spinosa x A. triandra they are in pairs arranged on either side of the rachilla alternating with each other. It may be reasonable to assume that the paired and single nature of the male flowers and their arrangement follow Mendelian inheritance and that the biseriate is dominant over uniseriate and paired condition over singleness.

The other two distinguishing characters of A. sativum and A. orientale are the maturity period and size of fruits. The maturity period of fruits of the F_1 hybrids was tending towards A. sativum. Fruits of A. sativum were about eight times larger than those of A. orientale. The fruit size in all the artificial hybrids was generally intermediate. However, the fruit size in the spontaneous hybrid was larger and tending towards that of A. sativum. The inheritance of fruit size would appear to be quantitative.

Thus the two species, A. sativum and A. orientale differed by a series of clear-cut morphological attributes, the pattern of variation being attributable to dominance-recessive relationships with respect to quantitative characteristics and different types of gene action in the case of quantitative traits.

In the reciprocal cross involving A. orientale x A. sativum, all the hybrids showed considerable morphological similarity with the female parent in respect of characters such as number of stem, internodal distance, length of leaf, girth of stem at fixed mark, number of leaves per clump, length of spadix, number and size of female flowers, number and size of male flowers, arrangement of male flowers and size of fruits. While clear evidences for heterosis and dominance were available in the F_1 of A. sativum x A. orientale, the reciprocal cross did not show any

such genetic effects. The similarity of A. brizantha x A. sativum hybrids to their female parent in respect of the above characters indicates the probable asexual mode of reproduction in A. brizantha. This aspect has been elaborated elsewhere.

CYTOLOGY

In the genus Arachis, the existing cytological information is confined to the report of chromosome numbers and their morphology in A. sativum and A. brizantha and meiotic analysis in the former. The reported somatic chromosome number of 32 for the two species (Venkatasubban, 1945; Sharma and Sarkar, 1956; Abraham, Mathew and Kinna, 1961 and Devappa and Ramam, 1965) has been confirmed in eight cultivars of A. sativum, four ecotypes of A. brizantha and five hybrids now studied. Attempts were made to evaluate the variability existing in the two species and to study their inter-relationship based on meiotic behaviour and karyo-morphology in the present study.

Meiosis

Study of meiosis in the two cultivars of A. sativum showed that there was considerable intra-cultivar differences in their meiotic behaviour. While meiosis was normal in pair 717, chromosome

associations as high as $1_X + 1_{IV} + 9_{II}$ were observed in the other palm (471) of the same cultivar. Howard (1948) while studying the different plants of the variety Pieton which was bred from a cross between winter and spring oats, found similar differences in meiotic behaviour of the different plants. Differences in meiotic behaviour have also been reported to exist in the various strains of Secale kuprianovii (Krishi and Muntzing, 1960), in which individuals heterozygous for a segmental interchange was found to be very pronounced. They suggested the probability of heterozygotes being superior to homozygotes and co occurrence of heterozygosy, as the two methods for the maintenance of the same.

In spite of the relatively high variability in the multivalent association (0 - 14.8%) observed in A. sativa, pollen fertility in all the palms was high. Similar lack of specific relation between meiotic aberrations and sterility has also been observed in rice (Ruglo, Chang and Ramirez, 1969). In this connection, it is pointed out that the multivalents observed in all the cases were of the chain type indicating terminal homology of the pairing chromosomes. The probability of balanced disjunction is known to increase when the interchanged chromosomes tend to be equal armed and are

associated only terminally (Sax and Anderson, 1933; Darlington, 1937). It is now clear that fertility is influenced not only by the presence or absence of multivalents but also by other kinds of genic control (Manning, 1956).

Lawrence (1938) has shown that selection can be effectively practised, in a segregating population of interchange heterozygotes, to increase the frequency of disjunction. It has been shown that heterosis is maintained in plant species through various means such as amphidiploidy, apomixis, chromosomal interchanges and balanced lethal systems. If not by nature such chromosome heterozygotes by virtue of their expressing heterotic vigour might probably be perpetuated by man through selection of vigorous plants. A consideration of the selection pressure applied in the nursery of A. sativum may be relevant in this context. Only vigorous seedlings, to the extent of about 70 per cent of the total population, were being selected and the remaining destroyed (Narayya, Patel and Mohiyuddin, 1958). In this cross fertilised crop this will mean that selection was always for hybrid vigour. It is also possible that in attempt an increase in the frequency of normal disjunction might have been inadvertently achieved as a consequence of the above mentioned selection practice.

Based on cytomorphologic evidences Devappa (1963) has identified distinct cultivars in *A. sahasim* occurring in South India. It appears that being a perennial crop, crops fertilised to the extent of about 85 per cent (Murthy and Devappa, 1960b), these cultivars got hybridised freely and under intensive selection large number of individual palms with differential chromosomal make up got built up in the population. This view is supported by the finding that in the tall variety of cocount, cross fertilised to a more or less similar extent, individual palms crossed with a relatively homozygous variety, Dwarf Green, gave genetically distinct F_1 plants (Devappa, Sukumaran and Jacob Mathew, 1973).

Love (1951) designated the percentage of normal pollen quartets as the "meiotic index". When the index of a variety was 90 per cent or above, it was thought that the variety was sufficiently stable for practical breeding purposes. In the light of this observation, the two cultivars of *A. sahasim* which have a meiotic index of 96.8 to 97 per cent may be considered as stable.

As against the highest association of $1_X + 1_{IV} + 9_{II}$ observed in *A. sahasim* the highest association in *A. triandra* was $1_{IV} + 14_{II}$ (Table 5). The anaphase-I and II and tetrad abnormalities in all the palms of *A. triandra* were much higher as compared to *A. sahasim*.

The percentage of higher association observed in A. triandra (Tables 7 and 8) seems to be too low to account for the high sterility (25 - 67%) observed. It may also be mentioned that palm number 70 which had no such higher association also showed a high pollen sterility (33%) compared to palms which had higher association. Though there exists a regular positive association between pollen fertility and 'meiotic index' in A. triandra, there are palms which show about 55 per cent sterility in spite of the low meiotic index of 7.3. It, therefore, appears that at least in this case pollen sterility is not entirely due to the higher chromosome associations or to the related meiotic abnormalities.

The chromosome pairing observed in A. triandra showed that there is partial desynapsis of varying degrees in the different plants. Among the recorded deviations from normal chromosome pairing, desynapsis constitutes one of the most important meiotic phenomenon. It has been reported by Riley and Law (1965) that the chromosome pairing can be widened or narrowed by gene action. More recently, it has been inferred that chromosome pairing and in fact all events of meiosis including desynapsis may be under some form of genetic control (Riley, 1966). The genetics of desynapsis in several plant species is now fairly well known.

Since Beadle (1930) reported that desynapsis in Zea mays is due to a recessive gene, several other studies have shown similar inheritance pattern in Drosophila melanogaster (Gowen, 1933), Secale cereale (Rudloff, 1943), Leucanthemum maximum (Scott, 1951), Zinnia pattiva (Gottschalk, 1968) and Gallinsia bicolor (Mehra and Rai, 1972) to mention a few examples. In addition, two recessive genes in Oenothera (Emsweller and Brown, 1935) and a dominant gene in Secale cereale (Hollingshed, 1930) and polygenic inheritance in Secale cereale (Rees, 1961) have also been reported to cause this abnormality.

As A. brianica is apomictic, this character can be expected to be maintained in the population. The extent of desynapsis is higher in the F_1 hybrid of A. sativa and A. brianica as compared to A. brianica, suggesting that the gene controlling this character may be dominant. But a larger number of univalents were observed in the hybrid as compared to the A. brianica parent. This may be due to the non-homology of certain of the parental chromosomes.

However, a great deal of variation was observed in the synaptic behaviour of chromosomes both in the A. brianica parent and the F_1hybrids. This variation presumably arises from the differential expressivity of

the gene controlling the process (Jauhar, 1969) or due to environmental factors (Id., Pao and Id., 1965; Wang et al., 1965 and Mehra and Rai, 1972).

The increased pairing and consequent regularisation of meiosis from metaphase-I onwards observed in A. brianica and its F_1 hybrids do not seem to have been reported so far. However a similar desynapsis accompanied by orientation of chromosomes at metaphase plate and further blockage of meiotic course has been reported in Dasypyrum orientale (Jauhar and Singh, 1969) resulting in about 85 per cent pollen sterility. It is generally agreed that the pairing of chromosome at metaphase-I is essential for their proper segregation. In the absence of proper pairing the question whether or not a corrective mechanism exists which keeps such chromosomes in the paired condition at metaphase-I, thus assuring normal segregation, arises. The formation of pseudobivalents at metaphase-I might act, as such a corrective mechanism. This assumption is also supported by observations of Grell (1967). She has provided elegant evidence that in Drosophila melanogaster the chromosomes which fail to undergo exchange pairing are involved in the so called distributive pairing. Distributive pairing may involve homologous or non-homologous chromosomes. Such distributively paired chromosomes undergo proper segregation. Distributive pairing has also been reported in Gallinsia bimaculata (Mehra and Rai, 1972). In A. brianica as well as in

the A. sativum x A. fatuum hybrid, the observed increase in pairing at metaphase-I and the regular orientation of the chromosomes indicate that the phenomenon of distributive pairing is in operation. This view has also been confirmed by Sybenga (1973, personal communication).

Meiotic abnormalities such as chromosome mosaics, stickiness, cytomixis, bridges and fragments were met with in the parents as well as the hybrids to varying extent. For these characters, A. sativum was relatively normal, except for the stickiness of chromosomes.

Sachs (1952) thought that the chromosome mosaics are due to defects in spindle mechanism which was genic. The view that genetic factors are responsible for the chromosome mosaics is supported by the presence of pollen mother cells with altered chromosome numbers in one of the strains of autotetraploid rye (O'Mara, 1942) and their absence in another strain (Muntzing, 1931). Secretion of tapetal cells has been reported to be responsible for initiation of meiosis in aneuploid cells of experimental amphiploids of Triticinae (Sachs, 1952) resulting in chromosome mosaics. The presence of pollen mother cells with more or less bivalents than the expected seven in female gametes has been explained by Muntzing and Prakken (1941) as due to the exchange of chromosomal material between archesporial cells in

the premeiotic mitosis. In A. brizantha and A. guineense - A. brizantha hybrids cytomixis met with to a maximum extent of 39 per cent seems to have contributed for the intraplant variation of chromosome numbers observed. A similar origin of chromosome mosaics in Setaria has been reported by Sarvella (1958). From the evidences on hand it appears that cytomixis has played a major role compared to other likely causes mentioned above, in the origin of chromosome mosaics in Arachis.

The high percentage of chromosome stickiness met with in certain plants of A. guineense has neither affected the later course of meiosis, nor the pollen fertility. It is likely that cells showing stickiness of chromosomes degenerate and do not participate in the formation of microspores. In the case of A. brizantha and the hybrids, chromosome stickiness, which had affected in certain cases as high as 84.3 per cent of the cells (Hybrid 307), was invariably associated with fragments, chromosome mosaics, cytomixis, disorientation of chromosomes and chromatin bridges.

Beadle (1932) in Zea mays and more recently Martini and Rossini (1965) in Triticum sp. reported stickiness of chromosomes due to a single recessive gene. On the other hand Shepova (1966) attributed chromosome clumping and

pycnosis observed in Gautieria to have "resulted from the process of inbreeding which must have been involved in the origin of cultivated peppers". Mehra and Rai (1970) have shown that in Gallinsia bimacrocia excessive chromosome stickiness during various stages of meiosis is attributable to a recessive gene.

Stern and Hotta (1966) have concluded that if the continuity of the DNA of the chromosomes is interrupted by gaps and if such gaps are not repaired, the structure of chromosome would be abnormal in the region of the gaps resulting in fragmentation, and stickiness. There are many cytological similarities between the present work and that of Stern and Hotta (1966) and Mehra and Rai (1970). The stickiness observed in A. triandra and the hybrids suggests to a more or less some extent that this abnormality is genetically controlled.

It will be relevant to examine the chromosome fragments along with cases of bridges recorded in the parents and hybrids. No instance of inversion bridge was observed indicating that the fragments had their origin either from chromosome breakages in the early stages of meiosis (Stern and Hotta, 1966) or due to the unequal division of univalents at anaphase. This view is supported by the presence of fragments at metaphase-I, and anaphase-I and II.

It has been shown in Gallinsia bimaculata by Mehra and Rai (1970) that chromosomal clumping increased heterogyngesis of chromosomes, distorting of the normal location of chromosomes at metaphase-I, occasional abnormal synapsis of chromosome, prevention of chromosomal movement and chromosomal fragmentation, all of which resulting in a high degree of male sterility. The pollen sterility in A. brimuina which ranged from 24.5 to 66.9 per cent seems to be due to the meiotic abnormalities observed at various stages as in Gallinsia bimaculata.

Pollen sterility in the F_1 hybrids ranged from 91.7 to 99.9 per cent. The meiotic abnormalities observed in the hybrids were higher than those in the A. brimuina parent at diakinesis, anaphase-I and II as well as at the tetrad stages. Failure of chromosome to pair at meiosis may be caused either by lack of structural homology, lack of synchronization of the various metabolic processes which take place at the early stages of meiosis, or by both of these conditions existing together (Stebbins, 1950). Genetically conditioned synapsis associated with partial lack of homology was demonstrated by Sears (1941) in amphidiploids of Aegilops, as well as Aegilops x Triticum and Aegilops x Haynaldia by Love and Love (1952). The meiotic behaviour of the A. sativum - A. brimuina hybrids suggests a similar situation. Disharmony arising

from the non-homology of the parental genomes or disharmonious interaction between the genotype of one species and the cytoplasm of the other (Rana and Swaminathan, 1964) contributing to the extreme sterility in this interspecific hybrid cannot also be ruled out. Such cases of extreme sterility which could not be accounted entirely due to meiotic abnormalities have been reported in Bambusa bamboos (McNaughton, 1975) and Paspalum species hybrids (Burson and Bennett, 1972) and have been attributed to genetic imbalance.

Observations on pollen and female fertility show that in A. galapium which has a high pollen fertility, the nut set is less than 50 per cent (Table 9). The average fruit set in this species has been reported to be 37.6 per cent (Murthy and Bavappa, 1960b). Various events that prevent pollination and fertilisation have been listed by Raghavan and Baruah (1956a) as possible causes contributing to female sterility in this species. The present observation on fruit set in two cultivars of A. galapium confirms the earlier reports on lower female fertility in this species.

Even though, the pollen fertility in A. triandrum was considerably lower than that of A. galapium, the nut set was higher than the latter. There were cases in which the percentage of pollen fertility and nut set were equal.

Assuming that the conditions that have prevented pollination and fertilisation in A. sativum are also applicable to this species, a comparatively high fruit set, in spite of low pollen fertility seems to indicate the operation of other modes of restoring the female fertility in A. bulbosum.

In the A. sativum - A. bulbosum hybrids the nut set was less than one per cent in most of the cases (Table 9). It, therefore, appears that the factors which have been responsible for pollen sterility are also in operation on the female side. Similar case of extreme male and female sterility has been observed in the interspecific hybrid of Iridaea (Crooks and Khosra, 1973).

From the cytological behaviour of A. sativum, A. bulbosum and their interspecific hybrids, it is observed that higher chromosome associations to varying extent are met with in them. While 16 bivalents were of the highest frequency in most of them, the maximum configuration observed was decavalent in A. sativum, quadrivalent in A. bulbosum and octavalent in the hybrids. While autosyndesis may explain the observed chromosomal association in the hybrid to a certain extent, it does not account for the highest frequency of sixteen bivalents as well as the maximum association. It, therefore, appears that there is homology between certain chromosomes of the two species.

Summary

Karyotype of the different cultivars of *A. sativum* studied showed considerable differences in their gross morphological characteristics. Most of them had subterminal or submedian chromosomes. However, in one plant (717) there were only median and submedian chromosomes. The karyotype of the *A. hirsutum* ecotypes showed a higher frequency of submedian and median chromosomes as compared to *A. sativum* (Table 11). A classification of the karyotype of the two species according to the degree of their asymmetry which recognises three grades of size differences and four grades of asymmetry in centromere position (Stebbins, 1938) showed that karyotypes 1B, 2A, 2B and 3B are represented in *A. sativum* cultivars and only 1A, 2A and 2B are represented in the ecotypes of *A. hirsutum*. It is interesting to note that even within the same cultivar of *A. sativum* two different types of asymmetry in karyotype is observed, while there was no such variation in *A. hirsutum* ecotypes. It is, therefore, evident that *A. hirsutum* has a more symmetrical karyotype than that of *A. sativum*. This is in conformity with the observations made by Ramappa and Raman (1965). Delineating the cultivars of *A. sativum* on the basis of standard karyotype seems to be rather difficult.

The use of karyotype symmetry-asymmetry in the study of species evolution is well known and in the Zingiberaceae (tribe Hellieboreae), Levitsky (1931) showed that the most primitive species tend to have chromosomes possessing median centromeres and of equal size. The total chromatin matter in all the ecotypes of A. kriandra was higher than that of the cultivars of A. subulata (Table 11). Delaunay (1926) demonstrated the gradual reduction in chromatin matter from primitive to advanced forms. Similar observations have been made in the different genera and tribes of palms (Sharma and Sarkar, 1956). The fact that A. subulata has lesser chromatin matter and asymmetrical karyotype compared to A. kriandra shows that the latter is the primitive among the two species.

The karyotype of A. subulata x A. kriandra hybrid showed wider variability in chromosome size than that of both the parents (Table 12). Various workers have investigated how the phenotypic appearance of the parental chromosomes is changed under the influence of the hybrid genotype. Simonet (1931) in Iris, Navashin (1934) and Tokgy (1943, 1949) in Crepis, Levan (1935) in Allium, Darlington (1937) in Tradescantia, Hakansson (1943) in Salsola, Hansen (1962) in Aegilops, and Singh (1972) in Rumex observed

varied responses of the hybrids to the new genotype with regard to retaining or changing the chromosome dimensions of the parental sets. In *A. sativum* and *A. brandzae* the relative length of chromosomes ranged from 4.12 to 8.99 whereas in the hybrids the variation was from 3.45 to 10.72. This clearly indicates that compensation effect has brought about a reduction in the length of the shortest chromosome and an increase in that of the longest chromosome.

The number of satellites in *A. sativum* varied from zero to three whereas in *A. brandzae* and in the hybrid it varied from zero to two. The maintenance or disappearance of secondary constrictions in the hybrid has been reported by Navashin (1934). In the present study no consistency in the presence/absence, number and position of the satellite could be observed either in the parents or in the hybrids. Baryagwia and Jordinsky (1971) have reported differences in the mode of phenotypic variability of satellited chromosomes in clones of interspecific hybrids of *Allium nutans* x *A. fistulosum*. In the light of the above, the usefulness of this character seems to be limited in the classification of karyotypes in *Allium* species.

APPENDIX II *A. triandra*

The interspecific hybrids involving *A. sativum* and *A. triandra* showed considerable reciprocal differences. While *A. sativum* x *A. triandra* hybrids were intermediate for some characters and showed heterosis and dominance for certain other characters and were highly sterile, *A. triandra* - *A. sativum* hybrids showed considerable morphological similarities to *A. triandra* and did not indicate any evidence of hybridity. The pollen fertility in this hybrid was also similar to that of *A. triandra* parent. The hybrid nuts (F_0) obtained also showed reciprocal differences. While the nuts from *A. sativum* x *A. triandra* cross showed the influence of pollen on the maternal tissue, no such effect was observed in the reciprocal cross (Table 4). Failure of *A. sativum* pollen to germinate on the stigma of *A. triandra* shows that the *A. triandra* x *A. sativum* 'hybrid' nuts (F_0) may not be of sexual origin.

Disturbance in meiotic divisions of many amphiotic plants are characterised by slight abnormalities such as small number of univalent and multivalent formation, irregular distribution of chromosomes, laggards and micronuclei formation in tetrad stages in microsporogenesis (Gustafsson, 1947; Stebbins, 1950; Snyder, 1961).

In the apomictic Brassicetum Zingaidum Chatterji and Timothy (1969) observed two to three quadrivalents at diakinesis with some early disjunction laggards and micronuclei. The pollen sterility was 22.8 per cent. Similar meiotic irregularities and pollen sterility met with in A. brizantha supports the apomictic nature of reproduction in this species.

In addition to the low pollen fertility in A. brizantha, there was also an accompanying reduction in the quantity of pollen per anther. Difficulty was also observed in getting the pollen extracted from the flowers. Similar variation in pollen fertility as well as reduction in the quantity of pollen has been reported in the reversion types of the apomictic species Paharitilla salina (Manning, 1958). Gerstel and Mishenco (1960) also observed that the sexual parent in Parthenium argentatum had normal meiosis, abundant pollen production and high seed and pollen fertility, while the apomictic type differed from the sexual in having lower chiasma frequency per cell, scarce pollen and reduced male and female fertility. The female fertility was, however, high enough to produce sizable number of progenies.

While positive evidence for the presence of apomixis can be obtained only from laborious and time consuming studies of megaspore, embryosac and embryo

development, properly conducted breeding tests on a sufficiently large scale should in most groups provide reasonably decisive indirect evidence (Stebbins, 1950). The limited extent of meiotic irregularities, reduced pollen viability, low quantity of pollen and low chiasma frequency (Table 6) together with the morphological and genetical evidences obtained from the reciprocal crosses, strongly support the apomictic reproduction in A. brizantha. The fact that the pollen of A. sphaelata does not germinate on the stigma of A. brizantha indicates that apomixis in this species is autonomous. The fruit set obtained under emasculated and bagged conditions both in respect of A. brizantha (9.2%) and of A. brizantha x A. sphaelata (20.3%) lends further support to this view.

The variation observed in morphological attributes of A. brizantha ecotypes suggests that there are distinct differences between them. However, the variations have not been adequately strong enough to place them in distinct groups as revealed by the D^2 statistic. One of the reasons for bringing about polymorphy in a group where apomixis occurs is the gene changes within the apomictic clones themselves (Stebbins, 1950). The variation observed in the A. brizantha complex seems to be the result of genic changes between the ecotypes.

There is general agreement that genetic factors control the mechanism of apomixis (Ostenfeld, 1910; Andersson-Kotte, 1932; Hunting and Hunting, 1945 and Gildenhuys and Brix, 1959). Hunting (1940) in Zea Bergman (1935) in Leontodon and Narayan (1951) in Ipomoea observed that apomixis is generally controlled by special constellations of genes and chromosomes rather than by single gene. Stebbins (1950) observed that the apomictic condition is generally recessive to sexuality. The observation in the present study that the A. sativum - A. brizantha hybrid is asexual indicates the recessive nature of apomixis in A. brizantha.

It will be of interest to consider as to how this species became apomictic. In the absence of any definite evidence on the origin of A. brizantha, it is probable that acquisition of apomixis in this species is through genetic factors causing a disturbance of meiosis. This is supported by the presence of both meiotic disturbance and partial sterility in this species to varying extents. Further, A. brizantha also possesses vegetative means of propagation through suckers. Stebbins (1950) points out that, just as in the case of polyploidy, the evolutionary line which is acquiring apomixis must pass through a bottle-neck of partial sterility and efficient vegetative means of growth and reproduction preadopting plants to these conditions.

ELECTROPHORETIC STUDIES

Variation in protein and enzyme has been taken in the recent years as one of the criteria to study the species relationships in plants (Fox et al., 1964; Gerber, 1965; Johnson and Hall, 1965; Vaughan et al., 1966; Desborough and Peloquin, 1966; Hart and Mattia, 1967 and Siddiq, Nerkar and Mehta, 1972). In the present study, representative samples of A. sativum and A. tricuspis were studied for electrophoretic patterns with respect to the esterase isoenzymes. It appeared from the study that these isoenzymes of the two species were similar in only two bands and differed in 6 bands, A. sativum showing lesser number of bands than A. tricuspis. The variation in banding pattern, therefore, can be used as an ancillary demarcating character between A. sativum and A. tricuspis.

GENETIC DIVERGENCE

Results obtained from the cyto-morphological studies indicate that considerable diversity exists in the two species, A. sativum and A. tricuspis. The extent of outbreeding in A. sativum was 54 to 85 per cent whereas in A. tricuspis it varied from 35 to 75 per cent. Consequently in the absence of well defined crossability barriers, there can be a large number of forms in these two species. Their classification thus

become extremely difficult. The difference in the cultivars of A. guineense and ecotypes of A. triandra were, therefore, examined by using the generalised distance (D^2 statistic) of Mahalanobis (1936).

The 13 cultivars and four ecotypes from nine countries fell into six clusters when 24 characters were considered (Table 22). The number of clusters and pattern of clustering were more or less similar for the years 1966 and 1972. During 1966 the four ecotypes of A. triandra were found to be in the same cluster (cluster II) and the divergence of this cluster from the others was of a high order. This was because of the fact that the ecotypes included in the above cluster were conspicuous for their thin stem, low angle of leaf to the stem, short leaves, short and narrow leaf sheath and small size and weight of the fruit and kernel. The divergence of Ceylon-2 which is the only constituent of cluster V was also high due to its short stature, low internodal distance, broad leaflets and large size of fruit and kernel (Table 19).

Table 22. Composition of clusters in different years

Cluster No.	1963 (6 characters)	1966 (40 characters)	1966 (24 characters)	1972 (24 characters)	1966 & 1972 pooled (24 characters)
I	2,3,4,9	5,6,7,8,9,12	7,8,9	7,8,9,12	7,8,9
II	13,14,15	14,15	13,14,15,16	13,14,16	13,14,15,16
III	1,5,6,7	4,5,11,17	4,5,6,11	1,3,4,5,6,11,17	1,3,4,5,6,11,17
IV	10,11,12,17	1,10	1,3,10,12	10	10,12
V	8	2	2	2	2
VI	16	16	17	15	
VII		13			

1. Ceylon-1; 2. Ceylon-2; 3. Indonesia-6; 4. Saigon-1; 5. Saigon-2;
6. Saigon-3; 7. Mr. Sel. Islands-1; 8. Mr. Sel. Islands-2;
9. Mr. Sel. Islands-3; 10. China; 11. Singapore; 12. Fiji;
13. Indonesia-4; 14. Indonesia-5; 15. Mauritius; 16. Ceylon-3; 17. Local

Note:- Numbers 1 to 12 and 17 - A. subtilis
Numbers 13 to 16 - A. latumia

When the analysis was repeated with the observations recorded for the same set of characters, six years later, the group constellations were found to be more or less similar. The pattern of clustering was the same in respect of Kr. Sel. Islands-1, 2 and 3; Ceylon-1 and Indonesia-6; Saigon-1, 2, 3 and Singapore; Indonesia-1, 2 and Ceylon-3; and Ceylon-2, Mauritius, one of the four ecotypes of A. intermedia was found to be different from the rest and formed a separate cluster (cluster VI). This was because of the tall stature, thick stem, large internodal distance, less number of inflorescence and long leaf of the ecotype. The maximum divergence was between clusters IV and VI, which can be attributed to the differences in girth and internodal distance, number of bunches and inflorescence, orientation of leaves, number of leaflets, breadth of leaf sheath and size and weight of nut and kernel. Clusters II and IV also differed between them for all the above characters in addition to the length of leaf and leaf sheath (Table 19).

In the pooled analysis for 1966 and 1972, the number of clusters got reduced from six to five. However, it was interesting to note that the pattern of clustering was more or less in conformity with the groups obtained for the individual years (Table 22). The groups

obtained for 1972 and the pooled data were similar except in the case of cultivars China, Fiji and Mauritius. The pooled data showed that cultivars Ceylon-1, Indonesia-6, Saigon-1, 2, 3, Singapore and Local were in a single cluster whereas in 1966 they were in three different clusters. All the four ecotypes of A. brizantha were in one cluster (cluster IX) in the pooled analysis and this cluster continued to show maximum divergence from the rest. The divergence between clusters IV and V were due to the differences in nut and kernel characters, breadth of leaf sheath, breadth of leaflets and number of leaflets (Table 19). A comparison of the groups obtained during 1966 and 1972 showed that the deviations observed were in respect of China, Fiji, Mauritius and Local. A closer study of the deviations revealed that the instability was restricted to those, the divergence between which was quite low, whereas the widely divergent clusters remained distinct in both the years (Table 22). It was also observed that the D^2 values slightly increased during 1972. Due to the perennial nature of the crop and consequent changes in the morphological characteristics of the population, such variation in the D^2 values can be expected. However, such variation has not materially affected the classification. As indicated earlier, detection of the genetic divergence in the

early years of productive phase is of considerable advantage in formulating breeding programmes. In the light of this, groupings obtained in 1966, five years after planting, can be preferred over later years.

In the present study it has been possible to examine the effect of additional characters on the divergence since observations on 40 characters had been recorded during one of the years (1966). The following effects in the pattern were observed when the results were compared with those of 1966 and 1972: (i) the magnitude of the D^2 values increased considerably; (ii) the number of clusters went up to seven; (iii) the four ecotypes of A. brianica fell into three different clusters, viz. II, VI and VII (Table 22); (iv) cultivar Saigon-3 was found to move away from Saigon-1 and 2; and (v) cultivars Ceylon-1 and Indonesia-6 were found to be in two different groups. These are attributable to the additional characters such as interval between successive leaf fall, breadth of guard cells and number of stomata. However, in view of the fact that the stability of these characters over years has not been tested, these results are not discussed further.

The rankings obtained by the different characters during 1966 for their contribution towards overall genetic divergence showed that the mean volume of nut

and breadth of kernel were the characters of primary importance. When the differentiation within A. sabdariffa cultivar alone was considered, height of the palm above the first mark, was also found to assume importance. For divergence between A. hirsutum and A. sabdariffa, mean length of fruit was found to be second in importance, next only to volume of nut. Ranking of characters for 1972 and the pooled data also revealed the importance of nut and kernel characters in differentiation within A. sabdariffa cultivars and between A. sabdariffa and A. hirsutum types. It was also evident that characters such as length of the longest leaflet and number of leaves on the palm do not contribute to any appreciable extent to the divergence. When the 40 characters were considered together, it was observed that the characters added, such as duration of male phase, number of stomata and number of epidermal cells were gaining importance. It therefore appears that there is scope for appropriate choice of characters in such divergent studies.

Nature of divergence in relation to environments

Unlike annuals, perennials are in the field over years subjecting themselves to the environmental changes which may influence them to varying degrees. Besides, they have distinct growth phases in which not only the number of characters get added but also show differential

expressivity. Under these circumstances one would prefer to choose those sets of characters (from seedling stage onwards) which would give stability for classification.

The grouping obtained for 1965 (juvenile phase) showed considerable difference as compared to that obtained in 1966 and 1972 (productive phase). The main deviations noticed are in the grouping of cultivars Ceylon-2, Saigon-1, Hr. Sel. Islands-1, 2, 3, Singapore, and Ceylon-3. It may be pointed out that in a perennial crop like arecanut identification of the genetic divergence in the early years has tremendous advantage in that breeding programmes could be planned in advance which otherwise would take a number of years. Thus the observations recorded in the juvenile phase assume importance. But the results of the present study indicate that identification of genetic divergence in the juvenile phase in arecanut may not give the correct picture.

A critical examination of the data for the years 1966 and 1972 in respect of height, girth, internodal distance, number of bunches and inflorescences, length and breadth of leaf sheath, length and volume of nut, and length, breadth, weight and volume of kernel, showed certain differences (Table 15). In arecanut, the height

goes on increasing and the girth below crown reduces with age. The internodal distance also gets sharply reduced with advance in age due to the reduction in growth rate, thus giving differences between years (Murthy and Ramayya, 1968a). The length and breadth of leaf sheath get increased due to the increased crown size which is normally observed with advancement in age in the early growth phase. This character however is likely to show a decline as the plants grow older. While it may not be possible to explain the reduction in the size of nut with increase in the age of the palm, it will be of interest to relate this behaviour with the reported observation that the quality of arecanuts improves with age.

The year x cultivar interaction has been significant for some of the characters. In respect of height, cultivars Ceylon-2, China, Indonesia-2 and Mauritius have recorded a much higher rate of growth during the period 1966-72 as compared to the rest. The internodal distance at the last node showed a general decrease of 39 per cent during 1972 as compared to 1966. However, cultivars Ceylon-1, 2, China, Fiji, Indonesia-1 and 2 had relatively low rate of decrease. This is because of the fact that their internodal distance was originally low.

As regards the number of bunches per palm, there has been a general increase of 36 per cent in the population during 1972 as compared to 1966. However, cultivars Guigne-2, China, Singapore, Indonesia-2 and Mauritius have lesser number of bunches during 1972. This is possible in a crop like arecanut, where wide fluctuations in the number of bunches produced are observed over years due to irregular bearing habit (Anon, 1969). It may not be advantageous therefore to include such characters in divergence study, unless they are the means of at least two consecutive years.

The reduction in the angle of leaf by six degrees has a special significance. The reduction in the spread of the crown which will result as a consequence of reduced leaf angle will bring about an overall compactness of the crown. Such an effect has been reported in coconut as a phenomenon which is related to age of the trees (Anon, 1975). This is also further supported by the general reduction in the mean length of leaf observed with increase in age. The reduction in the length of leaf should normally influence the leaf orientation. It is therefore apparent that these two characters together bring about considerable change in the canopy of the plant.

The results obtained from canonical analysis are also in broad agreement with the clustering pattern found from D^2 analysis.

From a perusal of the first three canonical vectors presented in Table 20, it can be seen that in 1965, girth below crown and girth at collar are the two most important characters operating at the first stage of differentiation and number of nodes at the second stage of differentiation. In 1966, when 40 characters were studied, mean interval between successive leaf fall and breadth of guard cells were the main characters differentiating the cultivars in the first stage and number of stomata and number of epidermal cells per unit area differentiated the cultivars in the second stage (Table 21). When only 24 characters were considered, volume of nut, volume of kernel and number of leaflets were found to contribute maximum for the first, second and third roots respectively. The primary characters responsible for differentiation at successive stages in 1972 were length of kernel, number of leaflets and kernel weight. The vectors for the pooled data (Table 21) have also thrown light on the importance of breadth and length of fruit and number of leaflets as characters in the differentiation of cultivars. In the present study it appears that canonical analysis can be

of only limited utility in view of the fact that the first two canonical roots accounted for only 85 per cent of the variation or less.

In spite of the fact that there are peculiarities in perennial crops as compared to annuals, consistent results obtained over years from the present study show that Mahalanobis' D^2 statistic can be a powerful tool in the hands of the breeder to study genetic divergence among perennial crops like arecanut.

Geographic diversity

While the importance of genetic diversity had been widely appreciated, the basic difficulty had always been of recognising and estimating such diversity. Some workers regarded ecogeographic diversity as reasonable index of genetic divergence (Mail, Salhuana and Robinson, 1962). The ecogeographic diversity is only an inferential criterion, which obviously cannot always be used for discrimination among populations inhabiting the same or similar agroclimatic regions.

The groupings obtained in the present study revealed that the three cultivars each from Saigon and British Solomon Islands, and the two ecotypes of A. javanica from Indonesia were invariably in one cluster each. As against this, close similarity between the cultivars from different countries has also been observed. The cultivar

from Singapore got grouped with the three cultivars from Saigon in one cluster. A similar affinity between the two geographically distant cultivars is shown by Ceylon-1 and Indonesia-6, both always coming within the same cluster. The local cultivar (17) has been found to be invariably associated with the cultivar from Singapore in forming the cluster. Of the two cultivars of A. esculentus from Ceylon, Ceylon-2 was always forming a separate cluster indicating its distinct nature of divergence. Murty, Mathur and Arunachalam (1965) in Eleusine, Murty and Anand (1966) in linseed, Arunachalam and Jawahar Ram (1967) in Sorghum, Singh and Raina (1968) in cotton, and Gupta and Singh (1970) in green gram found that there was no relationship between geographic and genetic diversity. However, a definite relationship between the above two has been reported in Pennisetum typhoides (Upadhyay and Murty, 1970) and in Zizania palustrissima (Jeswani, Murty and Mehra, 1970). The clustering pattern of cultivars and ecotypes obtained in the present study revealed that geographic diversity need not always be related to genetic diversity.

BREEDING POSSIBILITIES IN ABELMOSCHUS

Studies of the inter cluster divergence showed that the genetic distance between A. moschatus and the local (A. esculentus) is wide. The interspecific hybrids

between A. sativum and A. brianium studied showed high sterility and hybrid vigour for different characters as can be expected in an interspecific cross involving genetically divergent parents. Since it has been possible to backcross the hybrids to A. sativum, the possibilities of transferring the mite resistance and high fruit set reported in A. brianium (Ramappa, 1966a, b) to A. sativum are bright. As the sterility observed in the hybrids appeared to be due to the meiotic abnormalities in A. brianium and the disharmonious interaction between the genotype and cytoplasm of the parents, restoration of fertility through repeated backcrosses with A. sativum may be feasible. Among the A. sativum cultivars clusters IV and VI were highly divergent from cluster V. Crosses of Ceylon-1, Indonesia-6, China, Fiji and Local with Ceylon-2 (which fall under the above mentioned groups) should prove useful. It may be mentioned in this context that a natural hybrid of China and Ceylon-2 has shown hybrid vigour for different characters.

EVOLUTIONARY SIGNIFICANCE

The clustering of certain cultivars of A. sativum from countries such as India, Ceylon, Singapore, Indonesia and Saigon throws some light about their relationship. Probably both A. sativum and A. brianium had their origin in the group of islands now represented by Indonesia (Ramappa, 1963; Corner, 1966) and have moved

to west through Malaysia to India, Ceylon and as far west as Mauritius, although maintaining their species identity while A. galeatum found its way to north (Saigon) as well.

A careful study of the material obtained from Ceylon under the name Arenga saccharina has shown that the number of stamens was three as against six reported by previous workers (Hooker, 1894 and Hatter, 1926). The material was identified as A. trianderum by Dr. Reeds (1973, personal communication). While identifying this species, Reeds mentioned that A. trianderum had often been misidentified as A. saccharina. He had also observed A. saccharina in its native home "in a swamp in Ceylon". According to him as well as Hooker (1894) this species has solitary stem and six stamens. However, the illustration given by Hatter (1926) does not conform to the above description of the stem.

The evolutionary course of A. galeatum, A. trianderum and A. saccharina can be deduced from (i) their distribution, (ii) similarities of synthetic hybrid between A. galeatum and A. trianderum to A. saccharina and (iii) the natural occurrence of A. galeatum x A. trianderum hybrids. It is possible that A. galeatum and A. trianderum have got hybridised to give rise to A. saccharina. The fact that the spontaneous hybrid obtained and studied showed characteristics similar to that of A. saccharina such as

single stem, arrangement of male flowers, number of stamens, shape of sepals, striation of petals, and fruit colour (Table 23) lends support to this view. The synthetic and spontaneous hybrids which were highly sterile produced limited number of nuts. The sterility barrier and consequent limitation on seed production seem to have forced this species to be highly endemic. The endemic nature of A. gemmiana in Ceylon may also be due to its low economic importance. Even though A. gemmiana has been reported as endemic to Ceylon, it is likely that a closer search for this species may show its presence in places such as Indonesia and India where A. sahniana and A. triandra occur in proximity. The fact that A. triandra had been collected from at least two new centres shows that the existing knowledge on the distribution of the species of this genus is very limited, and that a more thorough search can be very much rewarding in locating the different species and their inter-relationships.

Genetic divergence shown by Ceylon-2 also deserves special consideration in this context.

Table 23. Morphological comparison of *A. sativus*, *A. triandra*, *A. sanguinus* and *A. sativus* - *A. triandra* spontaneous hybrid

Characters	*A. sativus*	*A. triandra*	*A. sanguinus* (Hooker, 1894; Blatter, 1926)	*A. sativus* - *A. triandra* spontaneous hybrid
Trunk:	Solitary	Throws off cuts at the base	Solitary	Solitary
Spathe:	Smooth	Minutely rough	Smooth	Milky rough
Rachis:	Stout, compressed	Compressed	Stout, compressed	Stout, compressed
	Branches not spreading	Spreading	Branches terminating in pendulous male spikes	Branches partially spreading
Male flowers:				
Arrangement	Biseriate	Biseriate	Biseriate	Biseriate
Sepals	Three connected	Ovate oblong	Oblong	Ovate oblong
Petals	Broadly lanceolate	Oblong	Obliquely ovate	Oblong
	Striated	Smooth	Striated	Striated
Number of stamens	6	3	6	Mostly 6
Female flowers:				
Sepals	Free	Free	United to form a cup	Free, Cup shaped
Fruits:				
Length	5.3 to 5.7 cm	2.5 to 3.5 cm	3.0 to 3.8 cm	4.1 to 4.8 cm
Colour on ripening	Orange or scarlet	Orange turning to red	Scarlet	Scarlet

The synthetic hybrids are similar to the spontaneous hybrid except for the number of stamens which ranges from 3 to 5.

this has been the most divergent among the cultivars of *A. guineense*, being in a separate cluster in all the years (Table 22), and is similar to *A. triandra* in height, number and length of leaves and leaflets, and orientation of leaves. It appears that *A. guineense* got backcrossed repeatedly to *A. palmata* in localities where the two species had an overlapping distribution and considerable variability was released for different characters. In this connection, it may be pointed out that the synthetic hybrids when backcrossed to *A. palmata* gave a nut set to the extent of nine per cent. In the light of the hybrid vigour obtained for certain characters in the *A. guineense* - *A. triandra* hybrids, types with favourable gene combinations can be expected to be realised. This coupled with the selection which has invariably been for longer and heavier fruit in arecanut might have given Ceylon-2 the observed genetic diversity.

SUMMARY

In the present investigation an attempt has been made using cytogenetical, morphological, biometric and biochemical techniques to study the inter and intra specific differences and relationships among the cultivated *A. sativum* and the two allied species, *A. triandrum* and *A. sativum*.

The important distinguishing characteristics of *A. sativum* and *A. triandrum* are in the number of stems per clump, arrangement of male flowers, number of stamens, size of female flowers and fruits and maturity period of nuts. They also differ markedly in the electrophoretic pattern of the esterase isoenzymes.

The morphological study of the hybrids between *A. sativum* and *A. triandrum* indicate the dosage effect of genes for internodal distance and leaf length. It has been inferred that inheritance of stem thickness, number of stamens and fruit size is quantitative. The number of leaves per clump appears to be maternal in inheritance. The paired nature of the male flowers is dominant over singleness and the biseriate arrangement is dominant over uniseriate.

Variation in hybrid vigour expression was observed in crosses involving different cultivars of *A. sativum* and ecotypes of *A. triandrum* for length of spadix,

girth of stem at fixed mark, number of male and female flowers per bunch, and length and breadth of female flowers. The maximum hybrid vigour observed was for number of female flowers. The hybrids also exhibited extreme variation in the size of male flowers.

Intracultivar variation for meiotic behaviour was very high in A. sanderi. While certain trees showed normal bivalent formation, others exhibited as high as decavalent associations. In spite of the high degree of multivalent associations obtained in A. sanderi, pollen fertility was high. The possibility of the frequency of multivalent formation and disjunction being under genotypic control and being subjected to selection has been indicated. The two cultivars studied in A. sanderi had a meiotic index of 86.8 to 97.0 per cent and are, therefore, considered stable.

The maximum chromosome association observed in A. triandra was one quadrivalent and 14 bivalents. The abnormalities at anaphase-I and II in all the palms of this species were higher than those in A. sanderi. Studies on chromosome pairing in A. triandra and A. sanderi - A. triandra hybrid revealed that partial desynapsis occurs to varying degrees in both. It has been suggested that desynapsis is controlled by a dominant gene. The higher number of univalents in the interspecific hybrid is proposed to be the result of nonhomology of certain of the parental chromosomes.

Meiotic abnormalities such as chromosome mosaics, stickiness, cytomixis, bridges and fragments were met with in A. triandra and the hybrids to varying extent. Meiosis in A. gatanka was relatively normal except for the occasional stickiness of chromosomes in a few palms. Such abnormalities as cytomixis appear to have played a major role in the origin of chromosome mosaics. The fragments seemed to have had their origin either from chromosome breakages in the early stages of meiosis or due to unequal division of univalents at anaphase-I.

The observed increase in pairing at metaphase-I in A. triandra and A. gatanka x A. triandra has been attributed to distributive pairing, a mechanism that has been possibly adopted for ensuring their regular segregation.

Pollen sterility in A. triandra which varied from 25 to 67 per cent is believed to be caused by meiotic abnormalities at various stages. The higher percentage of meiotic abnormalities of one of the parental species and the disharmonious interaction between the genotype of one and the cytoplasm of the other appeared to be the possible cause of the high sterility in the hybrid. In A. gatanka - A. triandra hybrids, the nut set was even less than one per cent indicating that the factors responsible for pollen fertility possibly operate on the female side also.

Studies on the karyotypes of eight cultivars of *A. sativum* and four ecotypes of *A. brandzaea* revealed considerable differences in their gross morphological characteristics. Using Stebbin's classification, the karyotypes 1B, 2A, 2B and 3B were represented in *A. sativum* and 1A, 2A and 2B in *A. brandzaea*. *A. brandzaea* is considered primitive of the two species, as it has a more symmetrical karyotype and also possesses more chromatin matter.

A compensation effect due to the differential dimensions of the parental chromosome was observed in *A. sativum* - *A. brandzaea* hybrids. No consistency in the presence/absence, number and position of the satellite could be observed either in the parents or hybrids and it is inferred that the usefulness of this character in the classification of *Avena* karyotype is very limited.

Unlike the F_2 nuts of *A. sativum* - *A. brandzaea* hybrid, those from the reciprocal cross were similar to nuts of *A. brandzaea*. Based on this as well as on the similarities of *A. brandzaea* x *A. sativum* to *A. brandzaea* in morphological characteristics and pollen fertility, absence of heterosis for any character in the reciprocal cross & failure of *A. sativum* pollen to germinate on stigmatic surface of *A. brandzaea*, it is proposed that apomictic reproduction in *A. brandzaea* is possible. This

is further supported by the occurrence of only limited extent of meiotic irregularities, reduced pollen fertility, low quantity of pollen and nut set obtained without pollination. It has been inferred that apomixis in *A. hirsutum* is recessive.

The genetic distance between the 13 cultivars of *A. sativum* and four ecotypes of *A. hirsutum* was estimated using the Mahalanobis' D^2 statistic. Results obtained from a study of 24 characters recorded in the productive phase for two years and the pooled data for both these years were more or less consistent. The cultivars could be grouped into six clusters in both the years and into five for the pooled data. The four ecotypes of *A. hirsutum* were found to be grouped into one cluster and its divergence from the rest was the maximum. This is mainly due to the small size and weight of the nut and kernel and thin stem of this species. Ceylon-2 was found to be distinct from the other cultivars of *A. sativum*. A comparison of the groupings obtained during the two different years showed that the widely divergent clusters remained distinct in both the years whereas in the case of less divergent groups there were slight deviations in the clustering pattern.

It is concluded that detection of genetic divergence is possible in the early years of productive phase.

this is of considerable advantage in formulating breeding programmes. Estimates of the genetic divergence made during the juvenile phase do not give a true picture of divergence. The rankings obtained by the different characters for their contribution towards genetic divergence revealed the importance of nut and kernel characters in differentiation within *A. saltatia* group and between *A. saltatia* and *A. hirsutum* types.

When the analysis was carried out with 40 characters there was not only an overall increase in D^2 values but also an increase in the number of clusters from six to seven. It was also observed that out of the characters added, interval between successive leaf fall, breadth of guard cells and number of stomata per unit area were gaining importance.

The results obtained from canonical analysis were also in broad agreement with the clustering pattern found from D^2 analysis. The first three canonical roots were found to account for nearly 90 per cent of the total variation. Clustering pattern of cultivars and ecotypes obtained in the present study revealed that geographic diversity need not always be related to genetic diversity. However, the three cultivars each of *A. saltatia*

from Saigon and Mr. Solomon Islands and the two ecotypes of A. brizantha from Indonesia were invariably in one cluster each.

Based on genetic divergence the advantage of crossing Ceylon-2 with Ceylon-1, Indonesia-6, China and Fiji has been pointed out. The possibilities of transferring mite resistance and high fruit set from A. brizantha to A. gabonica through interspecific hybridisation and back crossing have been indicated. Based on the similarity of the synthetic and spontaneous hybrids of A. gabonica and A. brizantha to A. sanguinea, the distribution of these three species and the presence of a suspected introgressive derivative (Ceylon-2) from A. gabonica and A. brizantha, the probable origin of A. sanguinea has been discussed.

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*Original not seen

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Appendix I. Morphological characteristics of karyotypes of

Sl.No.	Species/Hybrids		1	2	3	4	5	6
(i) A. subulata								
1.	Local (471)	1 M	8.21	7.64	7.27*	6.92	6.90	6.73
		S.E.	0.163	0.207	0.059	0.076	0.072	0.089
		2 M	1.43	1.24	1.48	2.27	2.04	1.74
		S.E.	0.184	0.314	0.201	0.181	0.176	0.200
2.	" (717)	1 M	8.57	7.79	7.37	7.23	6.95	6.77
		S.E.	0.142	0.156	0.078	0.182	0.063	0.146
		2 M	1.31	1.46	1.41	1.42	1.42	1.31
		S.E.	0.100	0.102	0.082	0.178	0.124	0.205
3.	China (111)	1 M	8.39	7.90	7.45	7.09	6.99	6.75
		S.E.	0.427	0.059	0.049	0.074	0.099	0.128
		2 M	1.96	1.99	2.40	2.06	1.83	2.04
		S.E.	0.366	0.173	0.195	0.142	0.084	0.303
4.	Ceylon (191)	1 M	8.54	8.05	7.60	7.48	7.14	6.85
		S.E.	0.204	0.106	0.060	0.069	0.048	0.067
		2 M	1.40	1.38	1.27	1.23	1.48	1.84
		S.E.	0.111	0.087	0.314	0.081	0.155	0.291
5.	Indonesia-6 (61)	1 M	8.83	7.78	7.45	7.16	7.02	6.72*
		S.E.	0.214	0.141	0.800	0.087	0.099	0.070
		2 M	1.98	2.31	2.11	2.38	2.24	2.15
		S.E.	0.197	0.361	0.181	0.282	0.300	0.300
6.	Saigon-1 (176)	1 M	8.24	7.83	7.33	7.17*	6.83	6.79
		S.E.	0.100	0.074	0.153	0.150	0.053	0.077
		2 M	2.25	1.71	1.38	1.44	1.66	1.34
		S.E.	0.291	0.217	0.156	0.117	0.164	0.177
7.	Saigon-2 (180)	1 M	8.18	7.80	7.43	7.29	7.06	6.81
		S.E.	0.118	0.165	0.147	0.121	0.085	0.097
		2 M	1.62	1.83	2.19	1.87	1.91	1.87
		S.E.	0.154	0.246	0.346	0.301	0.351	0.345
8.	Ceylon-2 (192)	1 M	8.30	8.06	8.00	7.88*	7.61	6.82
		S.E.	0.100	0.054	0.046	0.053	0.150	0.084
		2 M	2.08	2.16	2.32	1.73	2.05	2.21
		S.E.	0.147	0.081	0.208	0.181	0.199	0.082
9.	Singapore (163)	1 M	8.12	7.29	7.23	7.10	6.88	6.71
		S.E.	0.152	0.085	0.076	0.084	0.092	0.056
		2 M	1.97	1.79	1.67	2.07	2.18	1.77
		S.E.	0.111	0.056	0.195	0.353	0.269	0.117
(ii) A. brandza								
10.	Mauritius (109)	1 M	8.25*	7.36	7.20	7.03	6.86	6.86
		S.E.	0.188	0.127	0.089	0.104	0.083	0.091
		2 M	1.40	1.87	1.88	1.87	1.67	1.80
		S.E.	0.269	0.173	0.081	0.141	0.118	0.219
11.	Indonesia-1 (185)	1 M	8.15	7.78*	7.41	7.17	7.08	6.74
		S.E.	0.182	0.070	0.089	0.092	0.086	0.083
		2 M	1.64	1.43	1.78	1.88	1.87	1.86
		S.E.	0.160	0.173	0.214	0.087	0.165	0.129

7	8	9	10	11	12	13	14	15	16
6.44 0.365	6.37 0.098	6.13 0.076	6.01 0.100	5.81* 0.044	5.60 0.050	5.30 0.065	5.18 0.053	4.85 0.080	4.42* 0.157
2.38 0.175	1.68 0.194	2.25 0.276	1.63 0.112	1.60 0.234	1.82 0.155	2.06 0.190	1.47 0.058	1.85 0.201	1.32 0.105
6.38 0.128	6.23 0.111	6.05 0.111	5.90 0.660	5.61 0.080	5.33 0.051	5.15 0.087	4.80 0.061	4.58 0.061	4.13 0.106
1.29 0.154	1.43 0.086	1.41 0.087	1.30 0.085	1.34 0.110	1.34 0.048	1.44 0.061	1.35 0.056	1.32 0.077	1.31 0.075
6.39 0.071	6.39 0.111	6.09 0.129	5.99 0.120	5.74 0.118	5.49 0.126	5.33 0.118	4.95 0.040	4.33* 0.159	4.12 0.207
2.04 0.193	2.31 0.149	2.63 0.117	2.13 0.115	2.11 0.224	2.27 0.285	1.69 0.194	1.88 0.297	2.00 0.193	1.64 0.158
6.37 0.049	6.46 0.040	6.14 0.082	5.96 0.115	5.88 0.127	5.72* 0.150	5.08 0.051	4.76 0.079	4.48 0.061	4.11 0.010
1.80 0.147	1.38 0.278	1.61 0.225	1.45 0.156	1.33 0.196	1.37 0.282	1.49 0.246	1.24 0.150	1.14 0.044	1.38 0.157
6.37 0.065	6.38 0.090	6.18 0.094	5.87 0.049	5.64 0.078	5.42 0.089	5.21 0.058	4.96 0.053	4.60 0.140	4.12 0.208
1.72 0.207	1.62 0.225	1.65 0.177	2.32 0.187	1.98 0.252	1.68 0.280	1.78 0.201	1.74 0.159	1.68 0.152	1.78 0.256
6.42 0.070	6.33 0.075	6.13 0.051	5.92 0.088	5.77 0.090	5.57 0.077	5.34 0.089	5.01 0.072	4.61 0.045	4.17 0.119
1.72 0.125	1.61 0.189	1.64 0.116	2.25 0.305	1.69 0.208	1.77 0.172	1.51 0.101	1.70 0.265	1.52 0.078	1.45 0.158
6.38 0.052	6.35 0.052	6.17 0.117	5.94 0.800	5.74 0.119	5.51 0.125	5.13 0.101	5.05* 0.150	4.68 0.154	4.21 0.156
2.05 0.202	1.98 0.120	1.64 0.148	2.16 0.325	1.95 0.145	1.85 0.284	1.82 0.182	1.84 0.172	1.64 0.155	1.88 0.219
6.38 0.056	6.19 0.085	5.61 0.080	5.39 0.049	5.27 0.070	4.97 0.058	4.47 0.056	4.18 0.165	3.84 0.059	3.36 0.152
1.78 0.171	1.84 0.072	1.77 0.177	1.92 0.181	1.41 0.101	2.08 0.117	1.72 0.120	2.18 0.346	2.20 0.156	2.18 0.256
6.41 0.086	6.21 0.086	6.11 0.100	5.95 0.091	5.68* 0.089	5.51 0.070	5.42 0.072	5.16 0.085	4.96* 0.097	4.72 0.154
2.10 0.252	2.14 0.181	1.68 0.087	1.72 0.152	1.68* 0.196	1.80 0.058	1.46 0.050	2.03 0.244	1.42* 0.074	1.36 0.151
6.52 0.074	6.32 0.061	6.17 0.087	6.00 0.064	5.66 0.111	5.42* 0.118	5.42 0.050	5.42 0.074	4.80 0.100	4.12 0.148
1.24 0.186	1.11 0.155	2.00 0.109	1.32 0.084	1.75 0.117	2.20 0.509	1.67 0.157	1.46 0.084	1.92 0.128	1.38 0.078
6.27 0.060	6.38 0.040	6.11 0.077	5.88 0.081	5.74 0.071	5.42 0.074	5.24 0.076	4.94 0.050	4.72 0.052	4.11 0.110
1.68 0.213	1.88 0.155	1.54 0.208	1.72 0.144	2.08 0.328	1.76 0.193	1.66 0.255	1.96 0.156	1.71 0.140	1.88 0.159

Continued

Appendix I. Morphological characteristics of karyotypes of A.

Sl.No.	Species/Hybrids			1	2	3	4	5	6
12.	Indonesia-2 (74)	1	M	8.70	7.86	7.24	7.18	6.27	6.62
			S.E.	0.241	0.156	0.181	0.184	0.098	0.097
		2	M	1.32	1.29	1.12	1.09	1.01	1.05
			S.E.	0.096	0.075	0.082	0.115	0.297	0.274
13.	Indonesia-2 (154)	1	M	8.15	7.71	7.45	7.17	6.83	6.38
			S.E.	0.256	0.172	0.088	0.089	0.050	0.097
		2	M	1.21	1.31	1.25	1.28	1.19	1.09
			S.E.	0.110	0.134	0.089	0.071	0.096	0.105
14.	Ceylon-3 (55)	1	M	8.39	7.76	7.37	7.27	7.08	6.72
			S.E.	0.125	0.165	0.153	0.143	0.144	0.071
		2	M	1.68	1.74	1.47	1.71	1.55	1.70
			S.E.	0.137	0.049	0.086	0.100	0.170	0.141
15.	Ceylon-3 (70)	1	M	8.18	7.62	7.44	7.22	7.08	6.78
			S.E.	0.109	0.091	0.056	0.081	0.130	0.127
		2	M	1.40	1.77	1.48	1.64	1.43	1.71
			S.E.	0.197	0.090	0.301	0.159	0.152	0.196
16.	Ceylon-3 (87)	1	M	8.30*	7.47*	7.14	6.81	6.68	6.32
			S.E.	0.270	0.119	0.044	0.082	0.051	0.101
		2	M	1.22	1.27	1.15	1.18	1.17	1.11
			S.E.	0.105	0.224	0.148	0.156	0.154	0.072
(111)	A. sativum x A. ursinum								
17.		(248)	1	10.72	9.06	8.69	8.13	7.32	6.84
			S.E.	0.246	0.115	0.095	0.178	0.126	0.052
		2	M	1.42	2.06	1.04	1.09	2.07	1.47
			S.E.	0.085	0.205	0.098	0.110	0.142	0.126
18.		(287)	1	8.67*	8.60	7.76	7.41	6.92	6.65
			S.E.	0.176	0.230	0.088	0.080	0.108	0.111
		2	M	1.09	1.31	1.13	1.11	1.22	1.24
			S.E.	0.044	0.049	0.151	0.138	0.084	0.054
19.		(288)	1	10.35*	8.42	7.79	7.33	6.88	6.54
			S.E.	0.257	0.255	0.545	0.126	0.051	0.045
		2	M	1.04	1.26	1.16	1.23	1.28	1.32
			S.E.	0.059	0.059	0.129	0.056	0.204	0.124
20.		(307)	1	9.37	8.45	8.02	7.72	7.16	6.72
			S.E.	0.208	0.190	0.180	0.159	0.075	0.084
		2	M	1.22	1.42	1.33	1.45	1.44	1.44
			S.E.	0.115	0.122	0.188	0.156	0.051	0.087
21.	Spontaneous Hybrid	1	M	9.19	8.71*	7.76	7.26	6.87	6.71
			S.E.	0.115	0.197	0.045	0.056	0.041	0.056
		2	M	1.37	1.33	1.14	1.14	1.18	1.18
			S.E.	0.156	0.085	0.169	0.117	0.156	0.152

*Satellited chromosome 1 - Relative length 2 - Long arm/

7	8	9	10	11	12	13	14	15	16
6.36 0.117	6.16 0.103	5.95 0.099	5.76 0.080	5.62 0.080	5.51 0.070	5.32 0.087	5.03 0.080	4.82 0.102	4.48 0.201
1.57 0.181	1.43 0.185	1.48 0.100	1.37 0.272	2.11 0.244	1.58 0.145	1.47 0.159	1.38 0.158	1.36 0.215	1.30 0.152
6.52 0.112	6.25 0.118	6.08 0.082	5.92 0.150	5.57 0.108	5.21 0.025	5.22 0.078	5.24 0.098	4.92 0.181	4.52 0.194
1.40 0.158	1.32 0.067	1.41 0.140	2.29 0.075	1.37 0.255	1.25 0.202	1.28 0.174	1.25 0.117	1.27 0.170	1.27 0.127
6.43 0.054	6.26 0.025	6.12 0.067	5.93 0.101	5.59 0.109	5.41 0.157	5.26 0.087	4.96 0.155	4.77 0.104	4.36 0.067
1.54 0.115	1.42 0.150	1.30 0.142	1.32 0.208	1.32 0.157	1.46 0.151	1.47 0.157	1.31 0.127	1.46 0.078	1.32 0.057
6.53 0.042	6.25 0.068	6.11 0.096	5.83 0.094	5.69 0.068	5.35 0.117	5.27 0.072	5.02 0.096	4.81 0.079	4.32 0.129
1.48 0.180	1.34 0.182	1.22 0.122	1.21 0.155	1.32 0.125	1.27 0.210	1.28 0.161	1.21 0.149	1.32 0.184	1.35 0.152
6.32 0.196	6.02 0.128	5.89 0.089	5.77 0.116	5.52 0.057	5.48 0.053	5.06 0.053	4.94 0.062	4.72 0.218	4.32 0.195
1.42 0.128	1.30 0.124	1.42 0.208	1.44 0.155	1.37 0.142	1.40 0.085	1.34 0.053	1.28 0.099	1.12 0.081	1.27 0.149
5.21 0.089	5.21 0.128	5.35 0.109	5.23 0.088	4.99 0.071	4.81 0.181	4.44 0.086	4.07 0.175	4.07 0.146	3.88 0.189
1.22 0.084	1.13 0.085	2.72 0.205	1.72 0.065	1.25 0.019	1.36 0.112	1.18 0.105	2.67 0.119	1.78 0.109	1.62 0.159
6.25 0.073	5.92 0.105	5.90 0.089	5.76 0.071	5.50 0.104	5.36 0.109	5.28 0.150	4.96 0.106	4.48 0.182	3.85* 0.079
1.82 0.216	1.42 0.088	1.25 0.080	1.28 0.227	1.38 0.101	1.37 0.117	1.24 0.071	1.11 0.082	1.24 0.088	1.00 0.101
6.31 0.095	6.01* 0.155	6.01 0.111	5.82 0.077	5.62 0.076	5.37 0.128	5.12 0.127	4.62 0.125	4.81 0.092	3.87 0.098
1.68 0.085	1.67 0.070	3.00 0.275	1.54 0.258	1.30 0.221	1.60 0.120	1.42 0.209	1.36 0.284	1.12 0.155	1.71 0.145
6.47 0.075	6.21 0.096	5.86 0.094	5.86 0.088	5.62 0.108	5.42 0.088	5.26 0.075	4.71* 0.172	4.01 0.174	3.45* 0.189
1.46 0.140	1.33 0.086	1.76 0.150	1.42 0.122	1.49 0.091	1.63 0.183	1.30 0.078	1.00 0.157	1.23 0.089	1.00 0.129
6.42 0.094	6.27 0.121	5.97 0.064	5.79 0.091	5.45 0.103	5.27 0.068	5.10 0.079	4.71 0.089	4.44 0.102	3.78 0.130
1.76 0.175	1.40 0.172	1.42 0.104	1.42 0.117	1.60 0.121	1.57 0.165	1.38 0.186	1.27 0.084	1.27 0.085	1.12 0.185

*Short arm M - Mean S.E. - Standard error of mean