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CYTOLOGY OF DEVELOPMENT OF ABNORMAL ENDOSPERM IN PHILIPPINE MAKAPUNO COCONUTS

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During the course of extensive investigations on the cytology of endosperm in coconuts, an interesting case of endosperm abnormality in the Philippine makapuno coconuts has been studied. « The makapuno is a special type of coconut in which the meat almost fills the cavity of the shell. Instead of the hard crispy meat and milk found inside ordinary coconuts, there are in the makapuno nuts an outer portion which is white and soft substance corresponding to the meat of ordinary nuts and in the inner portion a viscous liquid somewhat transparent or pellucid » (TORRES 1937).

The makapuno nuts are in great demand in the Philippines, as the buttery kernel of these nuts is used in the preparation of certain delicacies. Though the makapuno nuts contain apparently normal embryos, they do not germinate *in vivo* and hence completely makapuno bearing trees do not exist. The makapuno nuts are borne amidst normal ones in makapuno bearing trees and are indistinguishable from the latter in external appearance. Mature makapuno nuts could however be identified with some experience.

Though there is essential similarity in early stages of development of normal and makapuno nuts, the latter could be distinguished by the presence of small outgrowths which develop on the inner surface of the young endosperm. These by unlimited growth almost fills the cavity of the shell in the mature nut. This situation being reminescent of the development of tumours and neoplasms in plants and animals, it was thought desirable to make a critical study of the cytology of development of the makapuno endosperm.

MATERIAL AND METHODS

Endosperm materials used in this study were fixed by the senior author during a visit of the Philippines in November 1963. Several bunches from makapuno bearing trees were cut down and ' would be ' makapuno nuts in various stages of development were selected and their endosperm fixed in Carnoy's fluid. Nineteen graded stages

in order of maturity were fixed and brought to Trivandrum, and stored in a refrigerator. Microtome sections of successive stages of endosperm development were taken and these were supplemented with acetocarmine smear preparations.

OBSERVATIONS

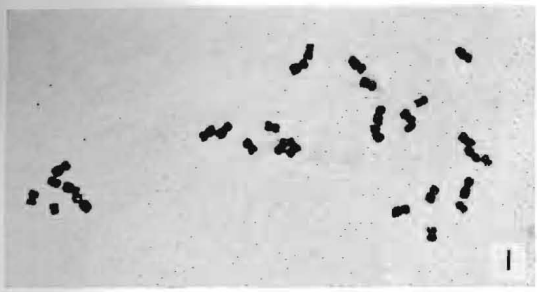
The early stages of development of the makapuno endosperm are similar to those in the Laccadive Tall variety reported earlier (ABRAHAM *et al.* 1965). The first recognisable stage in endosperm formation is the appearance of free nuclei, mostly of uniform size in a thin film of cytoplasm on the endothelial wall. This is followed by the appearance of a cell layer which by rapid growth results in the formation of regular cell rows.

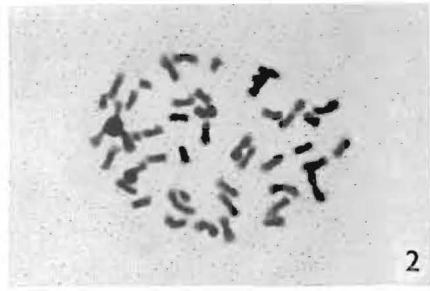
From the sixth bunch (counting from the top inflorescence that has just opened), it is possible to scrape off the endosperm tissue for making smear preparations of chromosomes. The endosperm at this stage is about 40 cell layers thick and exhibits marked variations in the size of the nuclei. Some cells showed more than one nucleus. Examination of smear preparations at this stage showed large numbers of dividing nuclei. Though less than one per cent of the cells exhibited the diploid number of 32 chromosomes (Fig. 1), majority of the dividing cells (78.44%) showed the normal triploid number of 48 chromosomes (Fig. 2). Nearly 6% of cells showed a hypotriploid constitution with numbers varying from 38 to 47. Fourteen per cent of dividing cells showed the hexaploid number of 96 chromosomes (Fig. 3). In addition, 0.44% of cells showed the 9*n* number of 144 chromosomes (Fig. 4) and a similar proportion of cells showed the 12*n* number of 192 chromosomes (Fig. 5). The highest grade of ploidy met with in the endosperm from the 6th bunch was the 12*n* condition. Similar study of endosperm tissues upto the ninth bunch was possible and the details are presented in Table I.

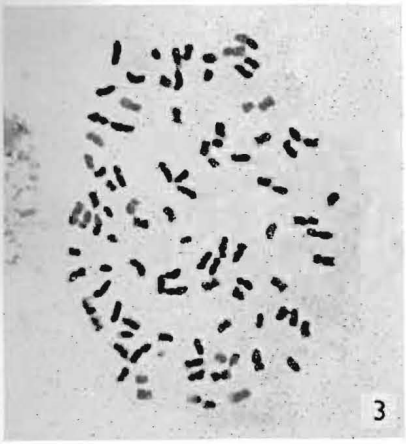
TABLE I

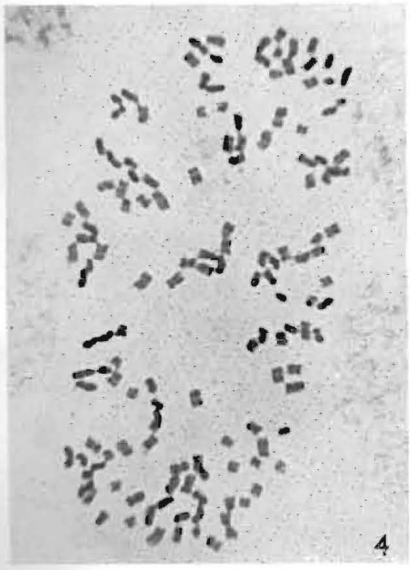
Chromosome situation in the cellular endosperm of the Philippine makapuno coconut.

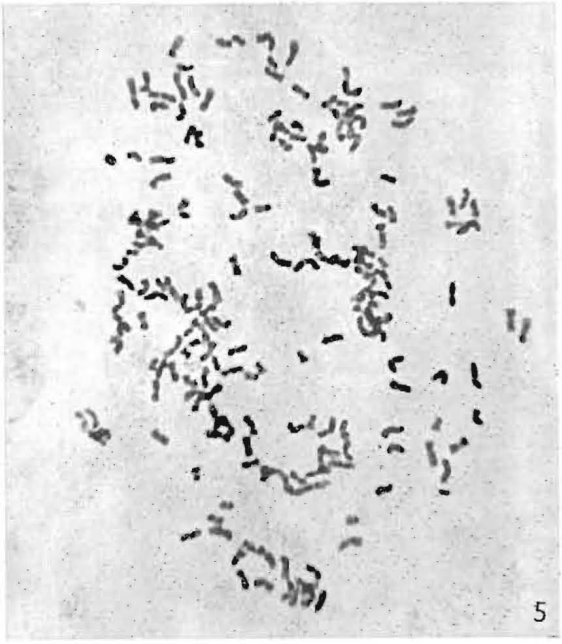
No. of bunch (from top)	Total No. of cells studied	Percentage of cells with									Percentage of polyploid cells
		2*n*	3*n*	6*n*	9*n*	12*n*	24*n*	48*n* & above	Aneuploidy ca. 3*n*	Aneuploidy ca. 6*n*	
6	450	0.89	78.44	14.00	0.44	0.44	0.00	0.00	5.79	0.00	14.88
7	450	0.00	71.79	23.55	0.22	3.11	0.22	0.00	1.11	0.00	27.10
8	450	0.00	59.33	31.56	0.44	5.78	0.44	1.11	0.89	0.45	39.78
9	450	0.67	44.90	41.56	0.89	5.11	1.55	4.65	0.22	0.45	54.21

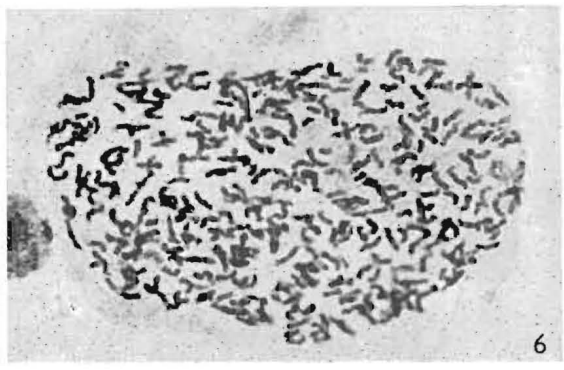












Figs. 1-6. — Cytology of the cellular endosperm of Philippine makapuno coconut. All figures ×750.

Fig. 1. A diploid cell showing 32 chromosomes. *Fig. 2.* Triploid cell with 48 chromosomes. *Fig. 3.* A cell with 96 chromosomes (6*n*). *Fig. 4.* Metaphase showing 144 chromosomes (9*n*). *Fig. 5.* Metaphase showing 192 chromosomes (12*n*). *Fig. 6.* A cell showing ca. 24*n*.

Perusal of data in the above table reveals that the frequency and grade of polyploidy increase as the endosperm matures. Thus from 14% in the sixth bunch, the proportion of $6n$ nuclei rises to 41.56% in the ninth bunch and that of $12n$ nuclei from 0.44% to 5.11%. From 0.22% in the seventh bunch frequency of $24n$ nuclei (Fig. 6) goes upto 1.55% in the ninth bunch. Cells with $48n$ nuclei and above (Fig. 7) are first noted in the endosperm from the eighth bunch and their frequency rises from 1.11% to 4.65% in the ninth bunch.

Examination of division stages in the endosperm of the sixth to the ninth bunch showed several types of mitotic abnormalities. These included disturbances in the spindle mechanism leading to c-metaphases (Figs. 8 and 9), stickiness (Fig. 10) which considerably increased in the ninth bunch, metaphase groups, unequal and multipolar anaphase separation (Fig. 11), lagging (Fig. 12), sticky and restitution bridges (Fig. 13), micronuclei (Fig. 14) etc. The frequency of abnormalities considerably increases as the endosperm matures (see Table II).

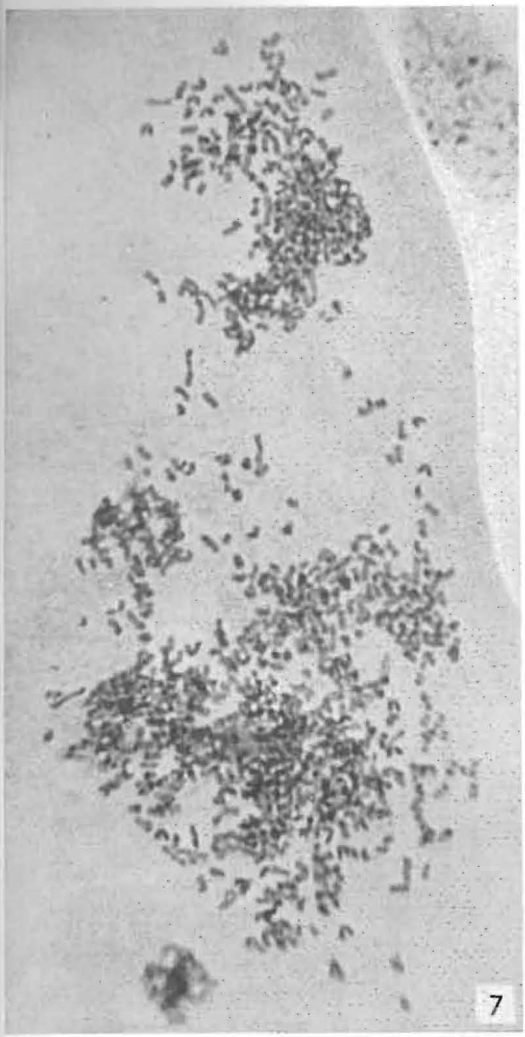
TABLE II

Cytological abnormalities in the endosperm of makapuno coconut.

No. of bunch (from top)	In percentage of cells examined							
	C-metaphase	Sticky associations at metaphase	Metaphase groups	Micronuclei	Laggards and unequal separation	Sticky bridges	Restitution bridges	Total abnormalities
6	3.20	2.35	3.22	0.42	2.70	0.20	0.00	12.09
7	3.14	6.70	4.91	0.00	3.14	1.30	0.00	19.19
8	8.80	1.94	0.60	0.60	2.46	1.20	0.60	16.20
9	3.49	42.40	0.00	4.23	4.80	0.70	0.70	56.32

Figs. 7-14. — Cytological abnormalities in the cellular endosperm of Philippine makapuno coconut. All figures ×750.

Fig. 7. A cell showing over $48n$ chromosomes. *Fig. 8.* c-metaphase in a triploid cell. Note the ringlike shapes of chromosomes. *Fig. 9.* A cell showing 96 diplochromosomes. *Fig. 10.* A triploid cell showing scattered, sticky chromosome groups. *Fig. 11.* A cell showing multipolar seperation. *Fig. 12.* Anaphase with laggards. *Fig. 13.* Telophase showing restitution. *Fig. 14.* A cell showing micronuclei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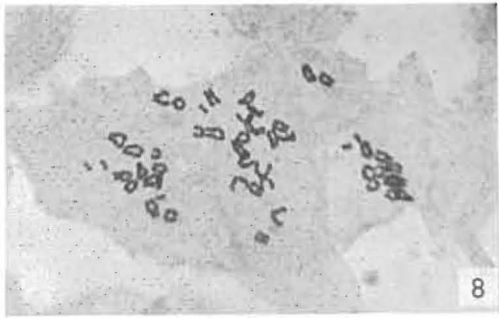
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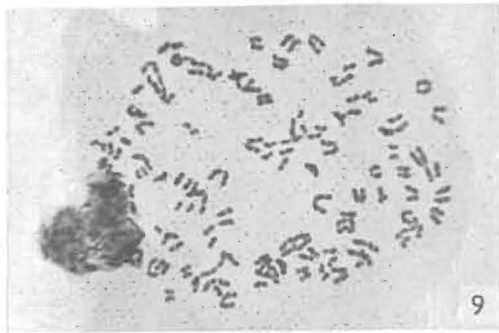
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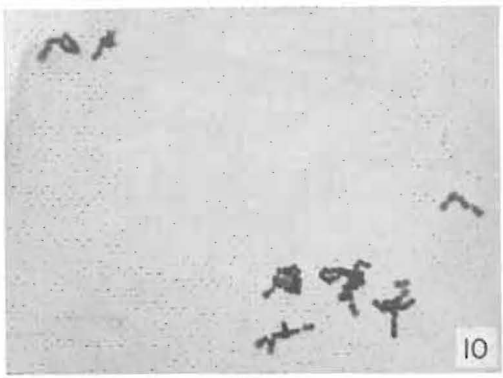
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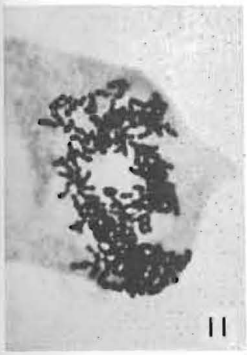
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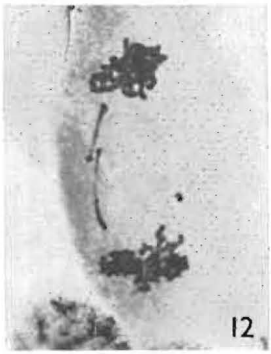
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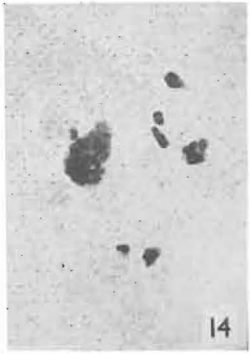
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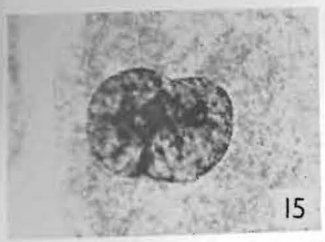
From the endosperm from the tenth bunch onwards, there is almost complete breakdown of the mitotic process and division figures are rarely seen. Due to the high polyploidy attained and the greater incidence of mitotic abnormalities, further divisions are possibly impeded. The endosperm however continues growth mostly through amitotic type of division (Figs. 15 and 16). Multinucleate cells arise through budding and fragmentation of nuclei without cytokinesis (Figs. 17 and 18). Single or multilobulate giant nuclei (Figs. 19 and 20) are commonly seen at this stage and the polymorphism of nuclei increases very much.

In sections of endosperm from the thirteenth bunch onwards, inclusions of various sizes and shapes are seen in some cells (Fig. 21). At first these inclusions appear as crystalline bodies of hexagonal or rectangular shape distributed mostly one in each cell. The basal 15-20 cell layers adjacent to the endothelium in these sections do not show these inclusions. The nuclei in these cell layers are deeply stained. In the cell layers with inclusions, however, the nuclei take only faint stain. In sections of the endosperm from the fifteenth bunch onwards, the cell inclusions show increase in size and are seen in almost every cell, except in the 15-20 cell layers adjacent to the endothelium. The inclusions in the inner cell layers then break up into particles of varying sizes and shapes (Figs. 22 and 23) and most of the cell space is filled with these bodies. In the region of cell layers away from the endothelium, these bodies are conspicuously smaller and fewer.

The later stages of development of the endosperm are characterised by disorganised growth and proliferation. Distinct cell wall formation ceases. The irregular mass thus formed gets detached from the basal column of regular cells. These masses show scanty cytoplasm and pycnotic and degenerating nuclei of varying sizes and shapes (Fig. 24). The chromatin of the nuclei condenses and shrinks, and only solid spheres of deeply stained chromatin (Fig. 25) are left. Such bodies sometimes collect together and form large pycnotic masses. These appear to undergo haryorrexis followed by karyolysis. This is accompanied by the appearance of characteristic raphide like bodies (Fig. 26) which constitute the chief cell components in the later formed endosperm mass.

Figs. 15-26. — Cytological abnormalities in the cellular endosperm of Philippine makapuno coconut. All figures × 750.

Figs. 15 and 16. Stages in amitosis. *Fig. 17.* Budding of giant nucleus and separation of buds. *Fig. 18.* A giant nucleus undergoing fragmentation. *Fig. 19.* A giant nucleus with five lobes. *Fig. 20.* A multi-anisolobulate giant nucleus. *Fig. 21.* Cell inclusions of various sizes and shapes. *Figs. 22 and 23.* Stages in division of cell inclusions. *Fig. 24.* A pycnotic, degenerating nucleus. *Fig. 25.* A spherical mass of highly condensed chromatin. *Fig. 26.* Raphide like inclusions.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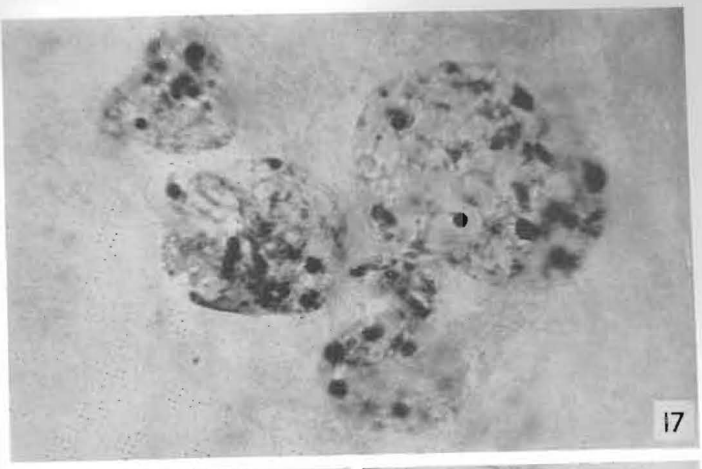
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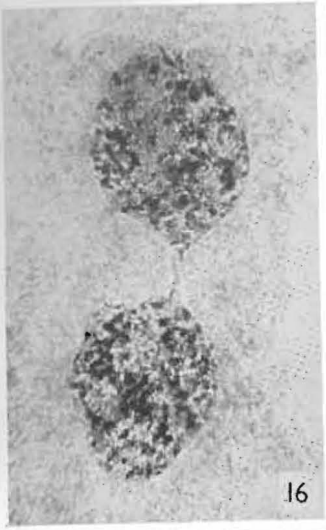
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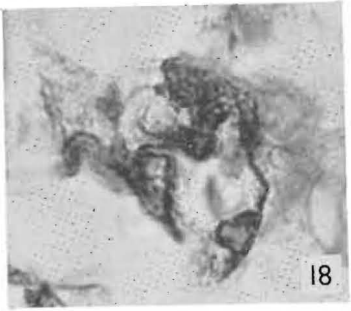
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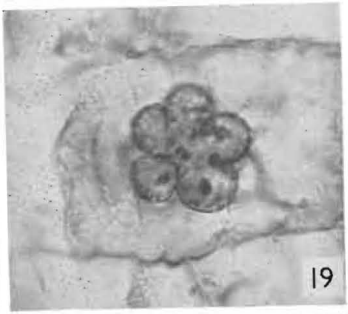
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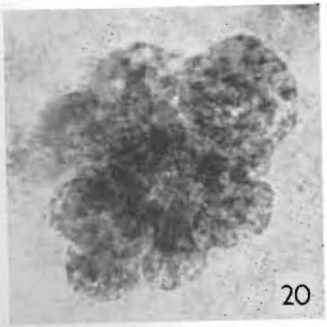
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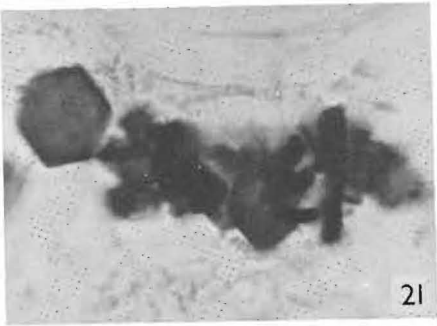
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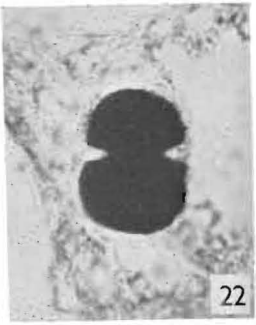
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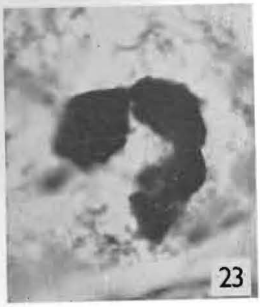
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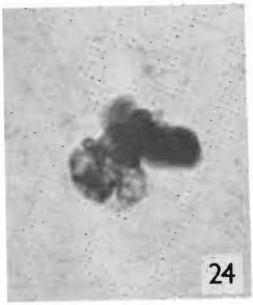
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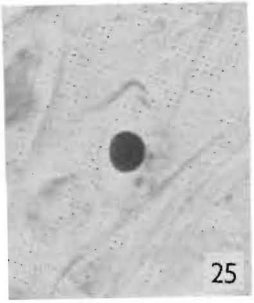
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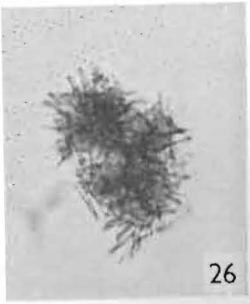
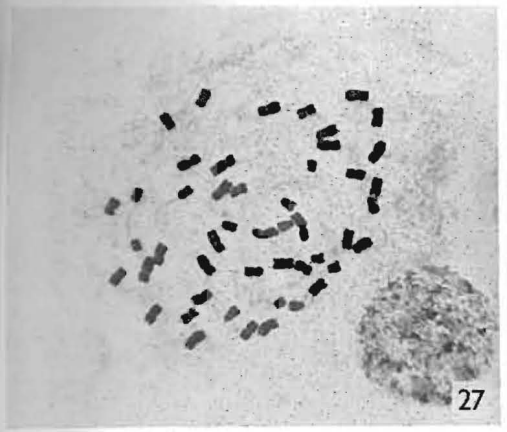

26

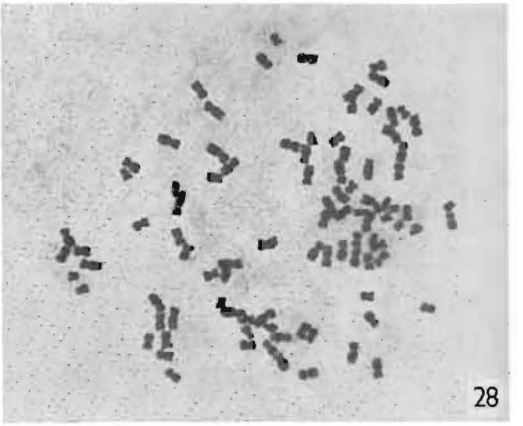
DISCUSSION

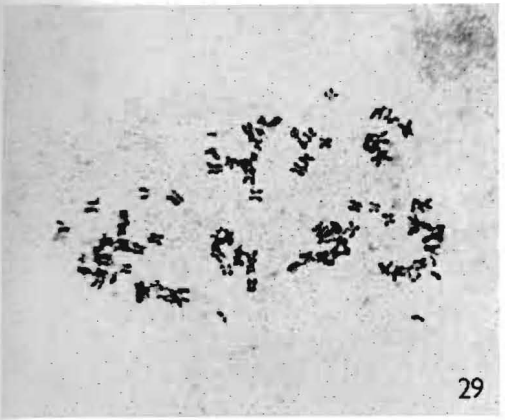
The initial stage of development of the makapuno endosperm are similar to those in the normal coconuts reported earlier (Abraham *et al.* 1965). The first formed cellular endosperm shows nuclei of almost uniform size and dividing cells are predominantly triploid (78.4%) with 48 chromosomes. As development of the endosperm proceeds, polyploid cells with $6n$, $9n$, $12n$, $24n$, $48n$ (and higher numbers that could not be clearly counted) appear and their frequency increases with increasing maturity. As in the other coconut varieties already reported (Abraham and Mathew 1963, Abraham *et al.* 1965), this increase in chromosome number is brought about through a c-mitotic type of division, restitution or fusion of nuclei, the former two processes resulting in polyploid numbers like $6n$, $12n$, $24n$, $48n$ etc. and the latter resulting in the $9n$ condition. Aneuploid numbers mostly near $3n$ and $6n$ and the diploid condition noted in a small proportion of cells probably result from errors in mitotic divisions. The early stages of development of the makapuno endosperm shares this cytological situation with other varieties of coconuts especially dwarfs with which they share in common the higher percentage of polyploid cells, occurrence of $2n$ and $9n$ numbers etc. (see Figs. 27-40).

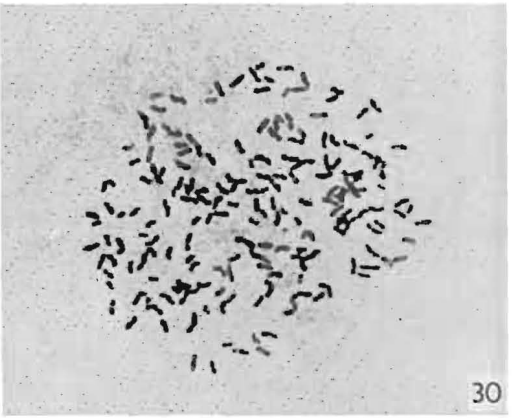
Comparison of the mitotic abnormalities in makapuno with that in other coconut varieties reveals that the former shows higher frequency of the different types of abnormalities, particularly stikiness, and clumping of chromosomes. There is also increase in the frequency of abnormalities as the maturity of the endosperm proceeds, whereas in the normal endosperm of the Laccadive tall variety studied, the frequency of mitotic abnormalities is less and the chromosome situation is more stabilised in the mature endosperm (Abraham *et al.* 1965). The higher frequency of abnormalities in the makapuno endosperm appears to be associated with the abnormal (tumour like) development of the endosperm. Reisman *et al.* (1964) produced evidence for an association between neoplastic transformation and gross chromosomal abnormalities mainly aneuploidy. Ranadive *et al.* (1963) reported chromosomal abnormalities like clumping of chromosomes, laggards, multipolarity, micronuclei formation etc., in carcinogen treated cultures of mouse skeletal muscle fibroblasts. Available evidence on endosperm cytology on other plants shows that mitotic abnormalities play an important role in the failure of the endosperm and are characteristic of degenerating endosperms (Boyes and Thompson 1937, Beaudry 1951, Brock 1954*a*, 1954*b*, 1955, Tandon and Kapoor 1962, 1963).

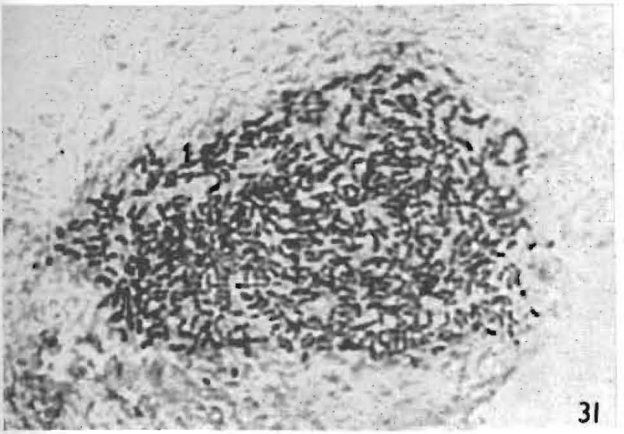
The attainment of high levels of polyploidy in greater frequencies as well as the increasing incidence of abnormalities in the makapuno endosperm appear to impede further mitotic divisions, which are replaced by an altered mechanism of cell division, namely amitosis. It is of considerable significance





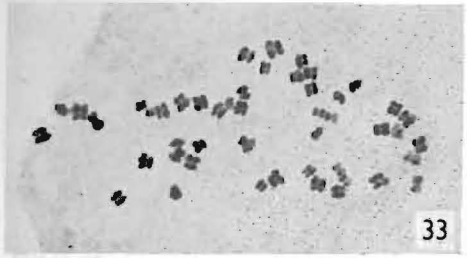


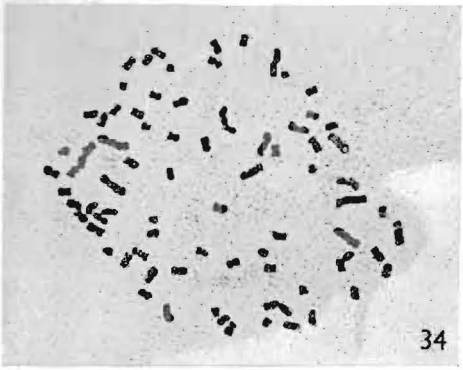


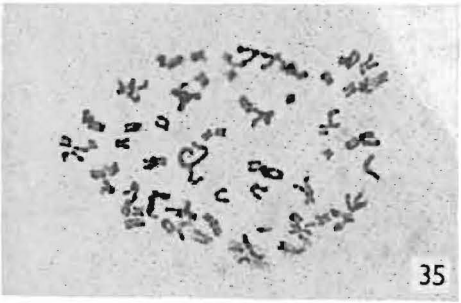


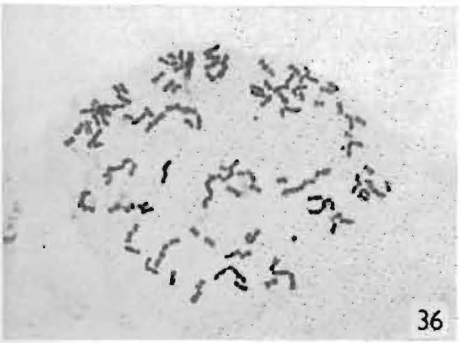
Figs. 27-32. — Cytology of the cellular endosperm in Straits Settlements Apricot. All figures ×750.

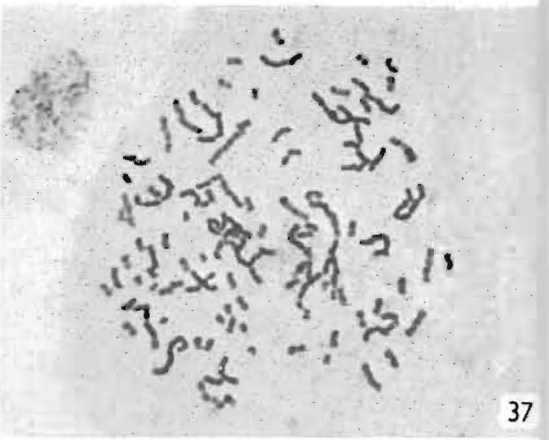
Fig. 27. Mitotic metaphase showing 48 chromosomes (3*n*). *Fig. 28.* Metaphase with 96 chromosomes (6*n*). *Fig. 29.* c-metaphase in a 6*n* cell. *Fig. 30.* Metaphase with 192 chromosomes (12*n*). *Fig. 31.* A cell showing about 30*n*. *Fig. 32.* Chromatin bridges at anaphase.

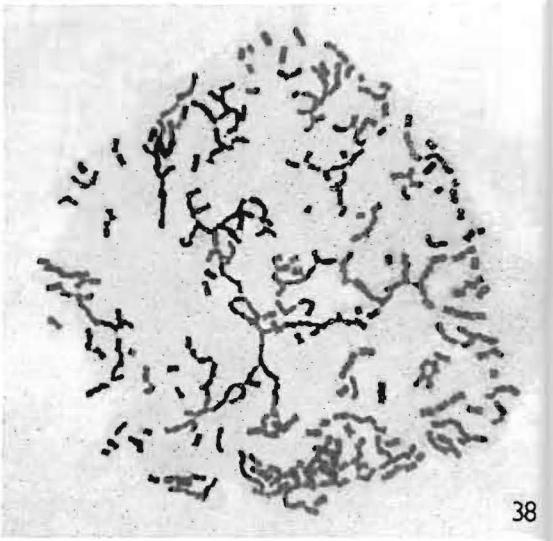


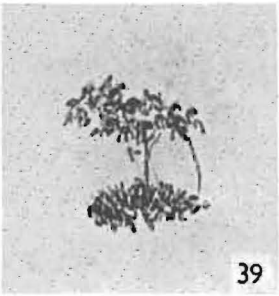


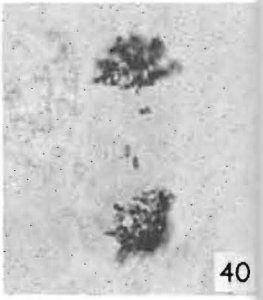












Figs. 33-40. — Cytology of the cellular endosperm of Andaman Dwarf. All figures ×750.
Fig. 33. Mitotic metaphase with 48 diploclromosomes. *Fig. 34.* Metaphase with 96 chromosomes (6*n*). *Fig. 35.* c-metaphase in a 6*n* cell. *Fig. 36.* Metaphase with 144 chromosomes (9*n*). *Fig. 37.* A cell showing ca. 12*n*. *Fig. 38.* A cell showing ca. 24*n*. Note the characteristic and to end associations of chromosomes. *Fig. 39.* Anaphase showing sticky bridges. *Fig. 40.* Late anaphase showing laggards.

that the initiation of amitosis and nuclear proliferation is accompanied by the unlimited growth of the endosperm which affords strong comparison to the situation in plant and animal tumours and neoplasms. BUCHER (1963) considers increase in cell activity and high polyploidisation as conditions which bring about amitosis, both of which characterise the initiation of amitotic activity in makapuno endosperm. KOMURO (1932) from a study of coal tar tumours in *Vicia faba* concluded that the growth of the tumour appears to be due to an amitotic multiplication of cells. LEVAN (1959) showed that there is wide variation in chromosome numbers in tumour cells which indicate genetic variability and adaptation to the changed environment of tumours. It is of considerable interest that the later stages of growth of the makapuno endosperm are accompanied by the appearance of multinucleate cells (which might result by repeated amitotic divisions without cytokinesis), giant nuclei (possibly by the fusion of amitotically divided nuclei), budding and fragmentation which increase the nuclear polymorphism characterised by lobed, cleft and notched nuclei. Besides, the above changes relating to the nuclear situation, the transition to the makapuno is also characterised by the appearance of cell inclusions. SMITH (1916) found that the nuclei of plant tumours divide both mitotically and amitotically and variously lobed, notched and cleft nuclei are common in plant and animal neoplasms. Occurrence of irregular and abortive mitoses, presence of giant nuclei, multinucleate giant cells, division by amitotic means and also by budding and fragmentation are often noted in tumours (PETROV 1962). FERNANDES MARIA and KOPROVSKA (1963) also observed that transformation of mouse cervix subjected to carcinogenic treatment was accompanied by the presence of various inclusions, and was associated with an increased number of chromosomes, and appearance of large number of nuclear blebs and multinucleate and giant cells with nuclear multilobulation. In the advanced stage of formation of the buttery endosperm, cellular and nuclear degeneration characterised by pycnosis, karyorrhexis and karyolysis in seen and such changes are also reported in advanced degenerating tumour cells and cells undergoing autolysis (CHAMBERS and WEISER 1964, CAMERON 1964).

It is thus seen that there is striking resemblance in the situation characterising the transition to the development of abnormal endosperm with the characteristic uncontrolled and high growth rate, wide variation in chromosome numbers with very high level and frequency of endopolyploidy, occurrence of aneuploidy, increased mitotic abnormalities, onset of division by amitotic means, budding and fragmentation, wide nuclear polymorphism, appearance of characteristic inclusions, cellular alterations and nuclear degeneration to that generally observed in tumour cells or tissues treated with carcinogens. It may however be pointed out that the makapuno character is an endosperm trait which is reported to be genetically controlled (TORRES 1937). KEHR (1951) found that the occur-

rence of abnormal tumourous growth without normal cell differentiation in certain interspecific combinations in *Nicotiana* is caused by genes controlling the growth regulating phytohormone mechanism. It is possible that when the growth regulating mechanism of the endosperm is thrown out of balance in certain genetic combinations as in the makapuno, the development of the endosperm may become abnormal. The makapuno endosperm thus provides an instance of genetically controlled abnormal development simulating the situation in tumour cells. It is of interest in this connection that suppression of mitotic division, pycnosis of nuclei and stickiness of chromosomes which simulate the situation in tumour cells reported by KOLLER (1943) have also been reported in the endosperm of *Lolium perenne* × *Festuca pretensis* hybrids (REUSCH 1959).

BRINK and COOPER (1947) have pointed out the importance of normally functioning endosperm for the normal development and functioning of the seed. The embryo of makapuno nut is apparently normal and cytological examination has shown that it has normal diploid chromosome constitution of $2n = 32$ and no cytological abnormalities have been observed. Thus the non-germinability of embryo of makapuno nut under *in vivo* conditions may be due to the incompatibility between normal embryo and abnormal endosperm. This is further borne out by the fact that makapuno embryos can be made to grow under *in vitro* conditions, as recent investigations in the Bureau of Plant Industries, Manila, Philippines have shown (private communication).

ABRAHAM (1963) noted an inverse relation between oil content and ploidy level in certain zones of the endosperm of the West Coast tall variety of coconuts. Results of further investigations on different dwarf and tall varieties of coconuts conducted in this laboratory show that such a relationship possibly characterises different coconut varieties as data in Table III reveals.

TABLE III

Polyploidy and oil content in some varieties of coconuts.

Variety	Percentage of polyploidy in endosperm above $3n$	Percentage of oil in the endosperm
Laccadive tall	34.89	72.2
Straits Settlements Apricot	38.35	68.6
Chowghat dwarf green	29.70	66.2
Chowghat dwarf orange	36.90	66.0
Andaman dwarf	46.00	62.0
Philippine makanuno	54.21	58.45

It is of considerable interest that the makapuno endosperm with the highest frequency of polyploid cells (54.21%) shows the lowest oil content (58.45%) while the Laccadive tall variety with the lowest percentage of polyploidy (34.89%) has the highest oil content (72.2%). This trend is also observed in the dwarf coconuts studied. It is pertinent to point out here that induced autopolyploids of other oil yielding crops like *Brassica nigra* and *B. campestris* also show lower oil content than the diploids (Olsson 1960, Anon 1961). It would be quite interesting to examine the relation between frequency of polyploidy and oil content of the endosperm in different varieties and hybrids of coconuts.

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REFERENCES

Abraham A., 1963. — *Chromosome constitution and oil content in the coconut endosperm.* Journ. Indian Bot. Soc., **42**A: 1-3.

Abraham A. and Mathew P. M., 1963. — *Cytology of coconut endosperm.* Ann. Bot., **27**: 505-512.

Abraham A., Ninan C. A. and Gopinath P., 1965. — *Cytology of the endosperm in some varieties of coconuts (Cocos nucifera L.).* Indian Journ. Genet. *(in press).*

Anonymous, 1961. — Annual progress report of the regional research centre (Oilseeds and Millets), I.C.A.R., PIRRCOM, Kanpur.

Beaudry J. R., 1951. — *Seed development following the mating in Elymus virginicus, L. × Agropyron repens (L.) Beauv.* Genetics, **36**: 109-133.

Boyes J. W. and Thompson W. P., 1937. — *The development of the embryo and endosperm in reciprocal interspecific crosses in cereals.* Journ. Genet., **34**: 203-227.

Brink R. A. and Cooper D. C., 1947. — *The endosperm in seed development.* Bot. Rev., **13**: 423-541.

Brock R. D., 1954*a*. — *Spontaneous chromosome breakage in Lilium endosperm.* Ann. Bot., **18**: 7-14.

—, 1954*b*. — *Fertility in Lilium hybrids.* Heredity, **8**: 409-420.

—, 1955. — *Chromosome balance and endosperm failure in hyacinths.* Heredity, **9**: 199-222.

Bucher O., 1963. — *Le probléme de l'ámitose.* In « Cell Grofth and Cell Division », Vol. 2, Symposia of the International Society of Cell Biology, pp. 313-321. Academic Press. Inc., New York.

Cameron R., 1934. — *Pathological changes in cells.* In « Cytology and Cell Physiology », Edited by G. H. Bourne, pp. 667-692. Academic Press, New York.

Chambers V. C. and Weiser R. S., 1964. — *An electron microscopic study of sarcoma in a homologous host. II. Changes in the fine structure of the tumor cell during the homograft reaction.* Cancer Res., **24**: 1368-1390.

Fernandes Maria A. R. and Kropowska I., 1963. — *Tissue culture studies of cells from mouse cervix subjected to carcinogenic treatment.* Acta Cytol., **7**: 215-223.

Kehr A. E., 1951. — *Genetic tumors in Nicotiana.* Am. Naturalist., **85**: 51-64.

Koller P. C., 1943. — *Origin of malignant tumour cells.* Nature (Lond.), **151**: 244-246.

Komuro H., 1932. — *Betrachtungen über die zytologischen Veränderungen in de Kohlenteelösung gestuchten Wurzelspitzen junger Pflanzen.* La Cellule, **41**: 219-242.

Levan A., 1959. — *Relation of chromosome status to the origin and progression of tumors:*

The evidence of chromosome numbers. In « Genetics and Cancer », pp. 151-182. University of Texas, Austin.

OLSSON G., 1960. — *Some relations between number of seeds per pod, seed size and oil content and the effects of selection for these characters in Brassica and Sinapis.* Hereditas, **46**: 29-70.

PETROV N. N., 1962. — *Cancer. A General Guide to Research and its Treatment.* Translated by A. P. FLETCHER, pp. 387. Pergamon Press, Oxford.

RANADIVE K. J., MOHALE S. V. and GANGAL S. G., 1933. — *Cytological studies on in vitro testing of chemical carcinogen.* Nucleus, **6**: 17-30.

REISMAN L. E., ZUELZER W. W. and THOMPSON R. I., 1964. — *Further observations on the role of aneuploidy in acute leukemia.* Cancer Res., **24**: 1448-1455.

REUSCH J. D. H., 1959. — *Embryological studies on seed development in reciprocal crosses between Lolium perenne and Festuca pratensis.* S. Afr. Journ. Agric. Sci., **2**: 429-449.

SMITH E. F., 1916. — *Studies on the crown gall of plants. Its relation to human cancer.* Journ. Cancer Res., **1**: 231-258.

TANDON S. L. and KAPOOR B. M., 1962. — *Contributions to the cytology of endosperm in some angiosperms. I. Zephyranthus ajax Sprenger.* Caryologia, **15**: 21-41.

—, 1963. — *Contributions to the cytology of endosperms. II. Northoscordum fragrans Kunt.* Caryologia, **16**: 377-395.

TORRES J. P., 1937. — *Some notes on makapuno coconut and its inheritance.* Phill. Journ. Agri., **8**: 27-29.

SUMMARY

The cytology of development of the buttery kernel (endosperm) in the Philippine makapuno coconuts has been studied. Though the first formed cellular endosperm is predominantly triploid, higher levels and grades of ploidy like 6*n*, 9*n*, 12*n*, 24*n* and 48*n* (and above) characterise the maturing endosperm. The cytological situation in early stages of the makapuno endosperm is comparable to that in other coconut varieties, particularly the dwarf coconuts with which they share the relatively higher levels of polyploidy, presence of 2*n* and 9*n* nuclei and the greater frequency of mitotic abnormalities including considerable stickiness of chromosomes.

The later stages of development of the makapuno endosperm characterised by unlimited growth and proliferation, accompanied by high polyploidy, increase in frequency of abnormalities, cessation of normal mitosis, onset of amitosis, attainment of high nuclear polymorphism, appearance of characteristic cell inclusions, etc. followed by degeneration of the nuclei are reminiscent of the situation in plant and animal tumours and neoplasms. It is possible that the buttery kernel in the makapuno coconuts which is a genetically controlled endosperm abnormality is the result of disturbances in the growth regulating mechanism. Available evidences indicate that the failure of the makapuno nuts to germinate *in vivo* might be related to the incompatibility of the normal embryo with an abnormal endosperm. The results obtained from the present study support the earlier observation that there is an inverse relation between oil content and polyploidy level in the endosperm of coconut varieties.

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INDICE

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