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Karyological Studies and Chromosomal Evolution in Meliaceae

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Introduction

This paper embodying cytological research on 30 species of Meliaceae is a continuation of earlier studies of STYLES and VOSA (1971). This project was initiated by Dr. B. T. STYLES at the Commonwealth Forestry Institute, Oxford, in order to compile chromosome data on a world-wide basis for an arborescent group comprising some of the best tropical timbers (see STYLES and VOSA, *loc. cit.*). Other important workers on the cytology of Meliaceae include S. and G. MANGENOT (1957, 1958 and 1962), MINFRAY (1963a, b), MEHRA and KHOSLA (1969), MEHRA and SAREEN (1969) and MEHRA et al. (1972). The latter three cmtributors have concentrated mainly on Himalayan Meliaceae.

An overall picture of chromosome data on Meliaceae is portrayed in order to understand the process of speciation in the family. This is one of the most important criteria on which to base any Programme of forest tree improvement through induced ploidy changes or mutation breeding.

Material and Methods

Methods involved in these studies were the same as those cited by STYLES and VOSA (loc. cit.). Root-tip squashes for examination of mitosis were made from freshly germinated seeds in petri dishes and also from seedlings raised in a tropical greenhouse at the University Field Station, Wytham, Oxford. The root-tips were pre-treated with 0.05 per cent colchicine for four hours and fixed in 1 : 3 acetic-alcohol. The material was stained by the Feulgen method and the preparations made permanent. Meiotic counts have been made in three instances where flowering occurred in the greenhouse. Sources of material along with voucher records are given in Table 1.

In order to study the karyotype several slides were made of each taxon, the number of which varied with the availability of material. On average 2–5 plants were examined per species. Only those slides that showed well-spread chromosomes with straight or almost straight arms were used for drawing or for making measurements. Usually the best metaphase plate was selected for drawing and the chromosomes were measured with the aid of a stage micrometer. The averages of at least five drawings were calculated to the nearest 0.05μ to show the karyotypic differences in different species.

Attempts have been made to study the morphology of chromosomes but this is often difficult because of their small size. In the text the relative size of chromosomes in the complement is denoted by L = large, M = medium and S = small; the centromeric position is represented by m = median, sm = sub-median, st = sub-terminal, and sc = secondary cosntriction. The average size of the chromosomes is computed by totalling the individual lengths and then dividing the sum by the total number of chromosomes. Measurements in each case are taken from metaphases of five cells. Figures are at a uniform magnification of 1500 X. The circumscription of taxa and nomenclature follows that proposed in A Generic Monograph of the Meliaceae, PENNINGTON and STYLES (1975).

Observations

Table 1 summarizes cytological data on 33 taxa. This includes the source of the material and voucher record, chromosome number, total chromatin length, average chromosome size, habit of the plant and any previous chromosome counts.

Subfamily Swietenioideae

Tribe Swietenieae:
Chukrasia A. Juss. (1–2 species; India to S. China and W. Malesia).

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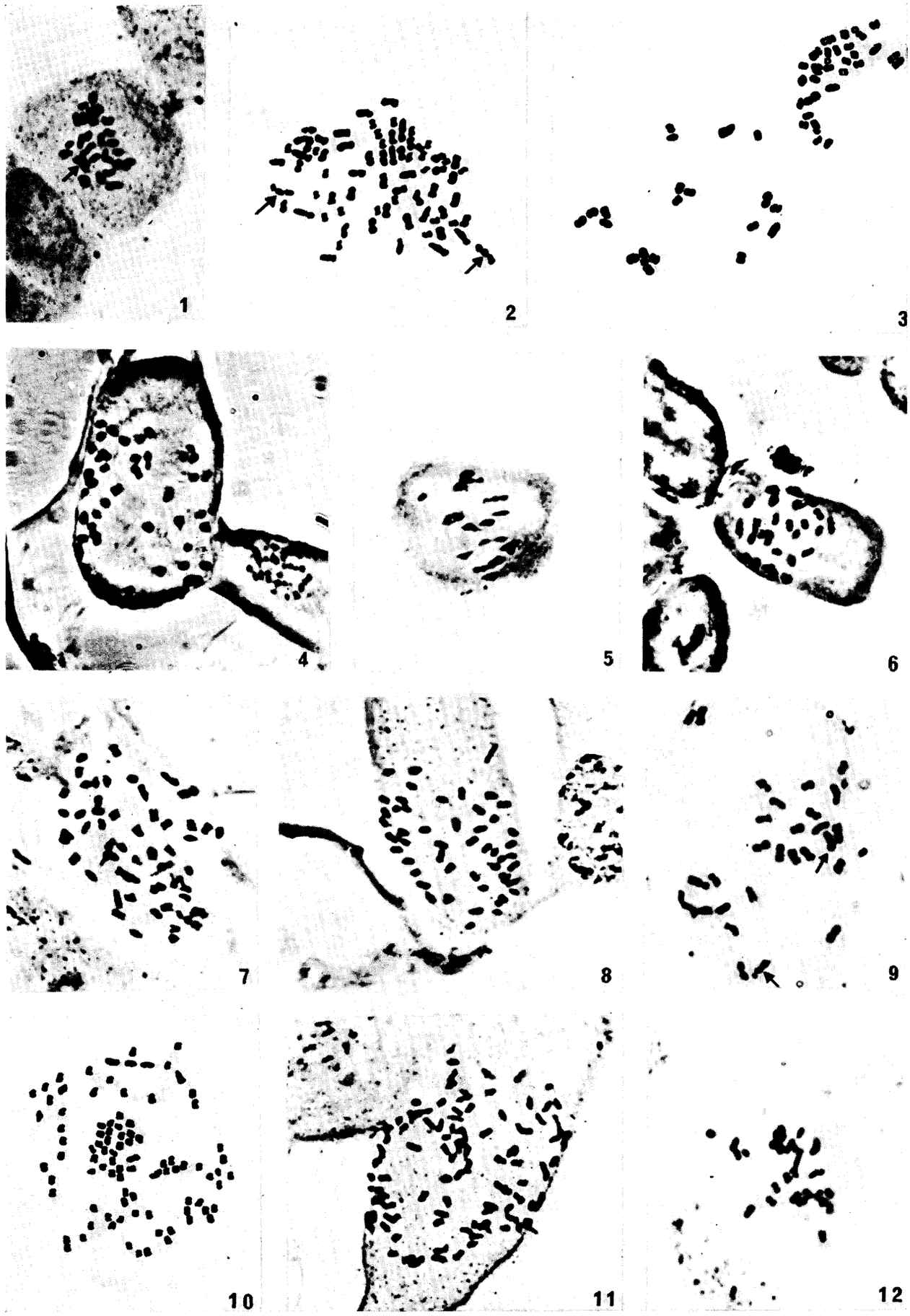
Table 1.

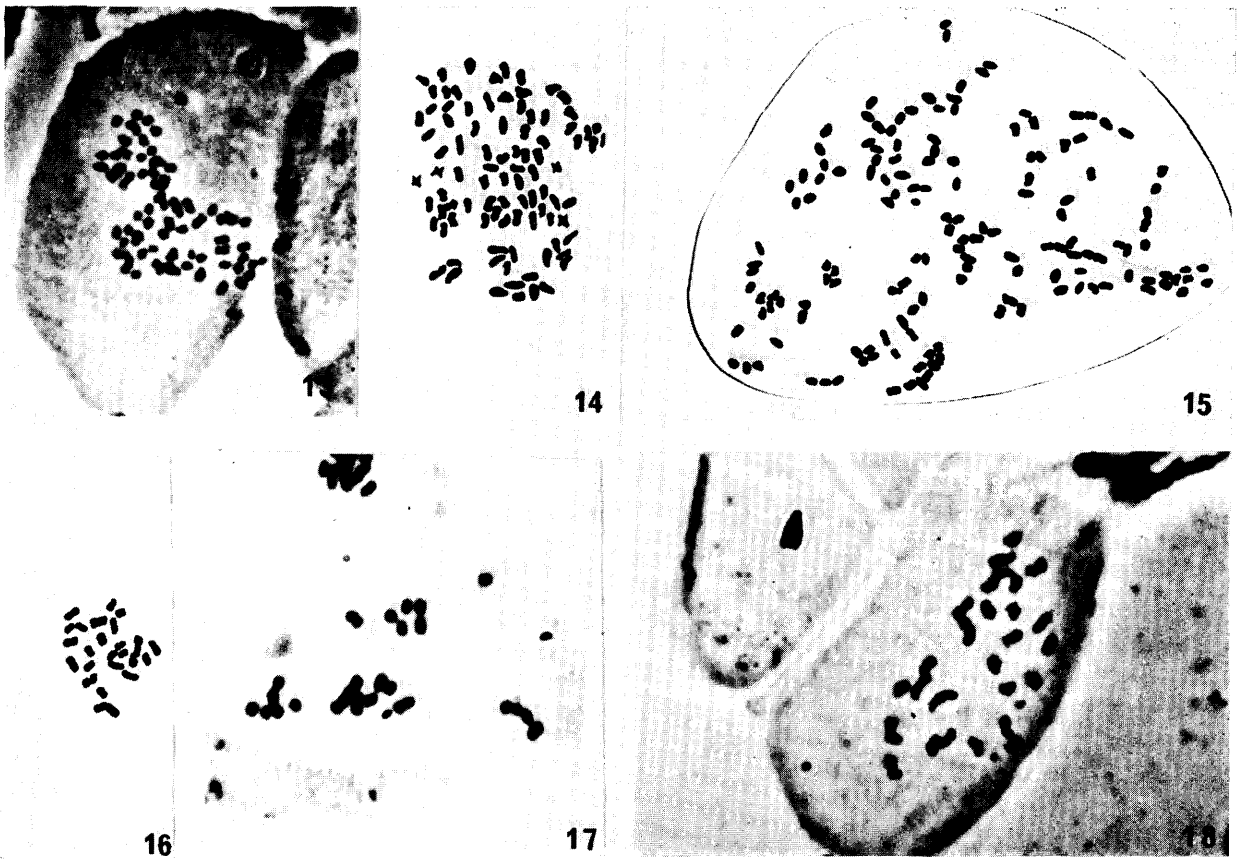
Taxa studied	Voucher specimen and record	Chromosome Number	Total chromatin length	Average size of chromosomes	Growth habit	Previous reports
Chukrasia tabularis A. Juss	Nigeria (cult.), Olokomeji For. Res., Ibadan, G. A. Adesida sn	2n = 26	31.50μ	1.15μ	Tall tree	n = 13; Rao, 1967; Mehra *et al.*, 1972.
C. tabularis A. Juss.	India, Dehra Dun, New For., Ram Dayal 2	2n = 26				
Entandrophragma caudatum (Sprague) Sprague	Rhodesia, Matopos Hills, FHO 130481	2n = 72	125.00μ	1.75μ	Large tree	2n = 72; Styles and Vosa, 1971
E. cylindricum (Sprague) Sprague	Uganda, Budongo For., For. Dept. sn	2n = 72			Very large tree	2n = 36; S & G. Mangenot, 1957
Soymida febrifuga A. Juss.	Hyderabad, Andhra Pradesh, Forest Dept. sn	2n = 56	65.50μ	1.15μ	Medium-sized tree	2n = 56; Styles and Vosa, 1971
Cedrela fissilis Vell.	Brazil, Paraná, Iguacú Falls, Forest Department sn	2n = 56	34.75μ	0.62μ	Tall tree	2n = 56; Styles and Vosa, 1971
C. odorata L.	Belize, Mt. Pine Ridge, Cayo Dist. Styles 166	2n = 56	60.00μ	1.05μ	Large tree	2n = 50, 56; Styles and Vosa, 1971
C. tonduzii C. DC.	Costa Rica, Santa Cruz de Turrialba, Styles 82	2n = 56	44.50μ	0.79μ	Tall tree	
Toona ciliata M. J. Roem.	Uganda, Entebbe Bot. Gard., FHO 129760	2n = 56	66.50μ	1.15μ	Large tree	n = 26; Mehra and Sareen, 1969; Mehra *et al.*, 1972 n = 28; Mehra and Khosla, 1969; Mehra *et al.*, 1972 2n = 56; Singh, 1951; Styles and Vosa, 1971.
T. ciliata var. australis (F. von Muell.) C. DC.	Australia, NSW, Nolam's Creek, A. L. Mitchell 643	2n = 56	65.50μ	1.10μ	Large tree	
T. serrata (Royle) M. J. Roem.	Uganda, Makerere Univ. Compd., Synnot sn	2n = 56	66.00μ	1.12μ	Medium-sized to tall tree	2n = 52; Mehra and Sareen, 1969; Mehra *et al.*, 1972
Carapa guianensis Aubl.	Malaysia, Perak (cult.), Whitmore sn	2n = 58	60.60μ	1.05μ	Medium-sized tree	2n = 58; Minfray, 1963 b; Styles and Vosa, 1971
Turraea? floribunda Hochst.	Uganda, Budongo For., Synnot 1443	2n = 50	80.50μ	1.58μ	Shrub or a small tree	2n = 50; Styles and Vosa, 1971
T. obtusifolia Hochst.	Rhodesia, 3 km W. Salisbury, Biegel 3274.	2n = 50 n = 25	34.90μ	0.30μ	Shrub	2n = 50; Styles and Vosa, 1971
Cipadessa baccifera (Roth) Miq.	India, Poona, Bot. Surv. India 119, 386.	2n = 56 n = 28	116.80μ	2.08μ	Shrub	2n = 56; Styles and Vosa, 1971
C. cinerascens (Pellegr.) Hand.-Mazz.	China, (Bot. Gard. Munich), FHO 133123	2n = 28 n = 14			Shrub	2n = 28; Styles and Vosa, 1971
Ekebergia capensis Sparrm.	Zambia, Ndola, Monkey Fountain Park, Fanshawe sn	2n = 46	32.70μ	0.70μ	Medium-sized tree	2n = 46; Styles and Vosa, 1971
E. pterophylla (C. DC.) Hofm.	Natal, Izotsha R. Gorge, White 10,523	2n = 50	66.50μ	1.32μ	Shrub	
E. senegalensis A. Juss.	Nigeria, Ibadan, Fed. Res. Inst. Compd., Uzoechina 18/71	2n = 46			Medium-sized tree	
Trichilia connaroides (W. and A.) Bentv.	India, New For. Res., Dehra Dun, Dayal 4	2n = 28	52.80μ	1.85μ	Small tree	n = 14; Rao, 1967; Mehra and Sareen 1969; Mehra *et al.*, 1972 2n = 24; Nanda, 1962

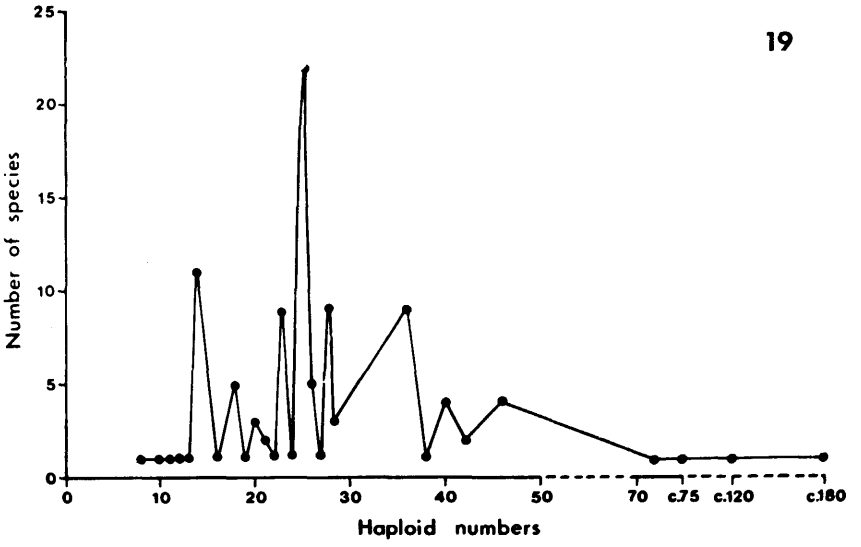
(Continued from Table 1)

Taxa studied	Voucher specimen and record	Chromosome Number	Total chromatin length	Average size of chromosomes	Growth habit	Previous reports
T. connaroides (W. and A.) Bentv.	India, Dehra Dun, Sahni sn	2n = 28				
T. emetica Vahl	Natal, Ndumu Game Reserve, White 10415	2n = 50	93.30μ	1.86μ	Medium-sized tree	2n = 50; Styles and Vosa, 1971
T. havanensis Jacq.	Caribbean, (ex Bot. Gard. Edinburgh), FHO 136027	2n = 92	196.50μ	1.75μ	Shrub	
Walsura trifolia (A. Juss.) Harms	India, Sibpur, Howrah Bot. Gard., FHO 134157	2n = 28	42.80μ	1.50μ	Small tree	n = 14; 2n = 28; Ghosh, 1961, 1968.
Chisocheton morobeanus Harms	Papua and New Guinea, Lae, LAE 58007	2n = 92	67.70μ	0.73μ	Medium-sized tree	
Chisocheton sp.	Papua and New Guinea, Lae, LAE 46746	2n = 46	39.00μ	0.75μ	Tree	
Dysoxylum binectariferum Hook. f.	India, New For. Res., Dehra Dun, Ram Dayal 3	2n = 80	75.50μ	0.93μ	Tall tree	n = 40; Mehra and Khosla, 1969; Mehra *et al.*, 1972
D. binectariferum Hook. f.	Ceylon, Ashton sn	2n = 80			Tree	
Synoum glandulosum (S_M.) A. Juss.	Australia, Queensland, Little Yagbe, S. W. Kenilworth, BRI 145628	2n = 84	78.40μ	0.98μ	Medium-sized tree	
S. glandulosum (Sm.) A. Juss.	Australia, Queensland, State For., Woondum S. E. Gympie, BRI 145628	2n = 84			Medium-sized tree	
Aphanamixis polystachya (Wall.) Parker	India, Dehra Dun, New For. Res. (cult.), Ram Dayal 1	2n = c. 150	97.50μ	0.65μ	Tall tree	2n = 76; Minfray, 1963 a; Styles & Vosa, 1971 n = 18; Mehra and Khosla, 1969; Mehra *et al.*, 1972
Aglaia sp.	Papua and New Guinea, Lae, LAE sn	2n = 92	75.50μ	0.83μ	Tree	
Azadirachta indica A. Juss.	Nigeria (cult.) Zaria, Rander sn	2n = 28	22.40μ	0.80μ	Medium-sized to large tree	2n = 28; Pathak and Singh, 1949 n = 14; Mukherjee, 1952; Deshmukh 1959, Mehra *et al.*, 1972 2n = 30; S. and G. Mangenot, 1958; Styles and Vosa, 1971.
Melia azedarach L.	Zambia, Katondwe Mission, Strid 2743	2n = 28	23.60μ	0.84μ	Medium-sized tree	2n = 28; Bowden, 1945; Pathak and Singh, 1949; Gadella *et al.*, 1966; Minfray 1963 a; Styles and Vosa, 1971. n = 14; Zerpa, 1953; Mehra *et al.*, 1972
M. azedarach L.	Greece, Corinthe, Dawson 44	2n = 28				
M. coposita Willd.	India, Lucknow Bot. Gard., sin. coll.	2n = 28	19.60μ	0.70μ	Large tree	n = 14; Mehra and Khosla, 1969; Mehra *et al.*, 1972
M. ? dubia Cav.	Australia, Maroochydore, McWhirter 2	2n = 28	17.60μ	0.62μ	Large tree	2n = 28; Styles and Vosa, 1971
Sandoricum radiatum King	Malaysia, Singapore Bot. Gard., Mahmud Awang sn	2n = 28	26.60μ	0.83μ	Small tree	



Figs. 1—12. — (Magnification X1500). *Fig. 1.* — *Chukrasia tabularis*, 2n = 26. Large pair of chromosomes is heteromorphic (see arrow). — *Fig. 2: Entandrophragma caudatum*, 2n = 72. Large pair of chromosomes possess secondary constrictions (see arrow). — *Fig. 3: Soymida febrifuga*, 2n = 56. — *Fig. 4: Turraea obtusifolia*, 2n = 50. — *Fig. 5: Cipadessa cinerascens*, n = 14. — *Fig. 6: Cipadessa cinerascens*, 2n = 28. — *Fig. 7: Cipadessa baccifera*, 2n = 56. — *Fig. 8: Ekebergia pterophylla*, 2n = 50. — *Fig. 9: Trichilia connaroides*, 2n = 28. Arrows indicate a pair of chromosomes with secondary contrictions. — *Fig. 10: Chisocheton morobeanus*, 2n = 92. — *Fig. 11: Trichilia havanensis*, 2n = 92. — *Fig. 12: Walsura trifolia*, 2n = 28.





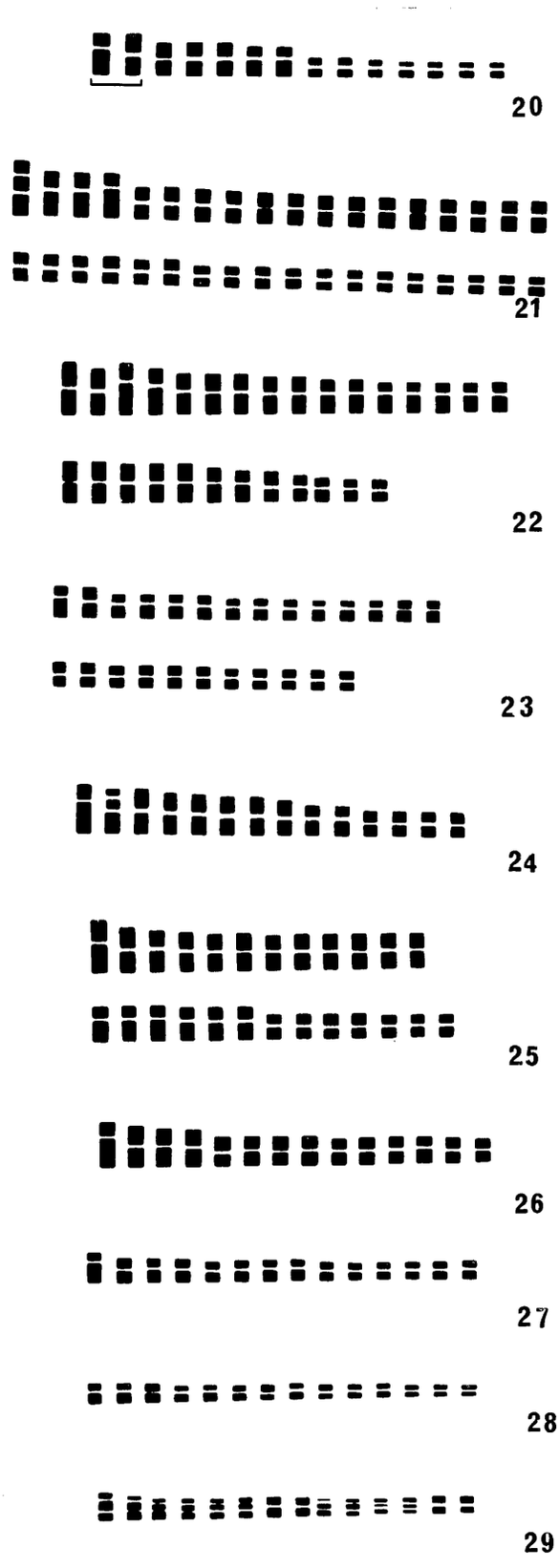
Figs. 13—18. — (Magnification X1500). *Fig. 13: Synoum glandulosum*, 2n = 84. — *Fig. 14: Aglaia* sp., 2n = 92. — *Fig. 15: Aphanamixis polystachya*, 2n = c. 150. — *Fig. 16: Azadirachta indica*, 2n = 28. — *Fig. 17: Melia azedarach*, 2n = 28. — *Fig. 18: Sandoricum radiatum*, 2n = 28. — *Fig. 19:* Frequency distribution of known haploid numbers in various taxa of Meliaceae.

C. tabularis A. Juss. is an important timber tree. Somatic counts of 2n = 26 *(Figs. 1, 20)* from two different provenances are in conformity with previous reports *(Table 1)*. The chromosome complement is classified as follows (1L heteromorphic (2.20μ) + 3M m (1.80μ) + 2M sm (1.65μ) + 7S m to sm (0.95μ to 0.65μ).

Entandrophragma C. DC. (10 or 11 important timber species; tropical Africa).

2n = 72 *(Figs. 2, 21)* for *E. caudatum* (Sprague) Sprague and *E. cylindricum* (Sprague) Sprague is in line with the observations of Styles and Vosa *(loc. cit.)*. Four morphologically distinguishable types of chromosomes are identified in the former species (1L sc (3.25μ) + 3L nearly sm (2.70μ to 2.56μ) + 20M nearly m to sm (2.50μ to 1.85μ) + 12S m to sm (0.95μ to 0.75μ).

Cytological studies of 7 species have so far been reported in the literature. On the basis of 2n = 36, also reported in *E. cylindricum* (S. and G. Mangenot, 1957), the base number of the genus can be postulated with confidence as x = 18. These authors also record endoploidy with 2n = 36 and 72



Figs. 20—29. — Idiograms. *Fig. 20: Chukrasia tabularis.* — (Heteromorphic pair indicated) *Fig. 21: Entandrophragma caudatum.* — *Fig. 22: Cipadessa baccifera.* — *Fig. 23: Ekebergia pterophylla.* — *Fig. 24: Trichilia connaroides.* — *Fig. 25: T. emetica.* — *Fig. 26: Walsura trifolia.* — *Fig. 27: Izadirachta indica.* — *Fig. 28: Melia azedarach.* — *Fig. 29: Sandoricum radiatum.*

in *E. angolense* (Welw.) C. DC. The remaining species are thus tetraploid.

Soymida A. Juss. (1 highly-prized timber species; India and Sri Lanka).

Chromosome counts of 2n = 56 *(Fig. 3)* for *S. febrifuga* A. Juss. coincide with the previous report *(Table 1)*. Three types of chromosomes are recognised in the complement (4L nearly m (1.95μ to 1.60μ) + 14M m to nearly sm (1.30μ to 0.90μ) + 10S m (1.00μ to 0.75μ). x =28 is a high base number for this monospecific genus. It seems to have evolved through a lower series such as 14.

Tribe Cedreleae:

Cedrela P. Browne (7—8 species, nearly all yielding valuable timber; American tropics).

Mitotic counts with 2n = 56 were made on three species of the genus. Chromosomes are very small in size (1.10μ to 0.35μ in *C. fissilis* Vell., 1.50μ to 0.55μ in *C. tonduzii* C. DC. and 2.00μ to 0.50μ in *C. odorata* L.). Centromeric position appears to be median to sub-median.

Cytologically the genus is heterogeneous as x = 25, 27 and 28 have been recorded (see Styles and Vosa, *loc. cit.*). The first two series have been reported in *C. angustifolia* Sesse et Moç. while *C. odorata* L. includes x = 25 and 28. In our studies of the latter species, four provenances representing its geographical range are cytologically consistent, implying thereby that the two chromosome races are not as geographically localized as earlier suggested by Styles and Vosa *(loc. cit.)*. The count for *C. fissilis* confirms the previous report whereas *C. tonduzii* is investigated cytologically here for the first time.

Toona (Endl.) M. J. Roem. (c. 6 morphologically variable timber species distributed in tropical Asia, Malesia and Australia).

Cytological studies have been undertaken for two species namely *T. ciliata* M. J. Roem. and *T. serrata* (Royle) M. J. Roem., and a variety *T. ciliata* var. *australis* (F. von Muell.) C. DC. All of these showed diploid numbers of 2n = 56. The chromosomes are small (1.85μ to 0.55μ in *T. ciliata* and 1.60μ to 0.85μ in *T. serrata)*. The former is the most widespread species of the genus and is highly variable in vegetative and floral characters. Over its distributional range De Candolle (1908) has formed as many as 20 varieties.

Mehra *et al., loc. cit.* have reported three cytotypes (n = 26, 28 and 39) in *T. ciliata*. Our present somatic count of 2n = 56 agrees with their haploid count of n = 28 from East Himalayas. This also coincides with similar reports published by Singh (1951) and Styles and Vosa *loc. cit. (Table 1)*. Our findings of 2n = 56 for *T. serrata* differ from Mehra *et al. (loc. cit.)* who have recorded 2n = 52 in this species from West Himalayas. These authors have also reported the low haploid number of n = 12 in East Himalayan *T. microcarpa* (C. DC.) Harms and postulated x = 12, 13 and 14 as the base numbers of the genus. However, on checking the voucher material cited by them we find the record of n = 12 was based on mis-identified material. Styles and Vosa *(loc. cit.)* have also hinted at two cytotypes in *T. sinensis* (A. Juss.) M. J. Roem. with 2n = 46 as against 2n = 56 published by Minfray (1963, a). Thus, the genus is heterogeneous cytologically with x = 13 and 14 (28) and 23.

Tribe Xylocarpeae:

Carapa Aubl. (c.3 species; Central and S. America and W. and C. Africa).

Somatic studies for *C. guianensis* showed 2n = 58 in agreement with previous reports for this and two other species (see Styles and Vosa *loc. cit.*, Minfray, 1963 b). This

excellent timber tree is distributed in Central and Northern S. America, from Belize to the Amazon basin. Chromosomes are small in size and vary in length from 1.55μ to 0.90μ.

Subfamiliy Melioideae

Tribe Turraeeae:

Turraea L. (c. 70 species, small trees and shrubs; Africa, Malagasy Republic and Asia).

The currently studied *T. obtusifolia* HOCHST. *(Fig. 4)* and *T. floribunda* HOCHST. each with 2n = 50 confirms previous reports *(Table 1)*. Another interesting series, 2n = 36 has also been listed by STYLES and VOSA *(loc. cit.)*.

T. obtusifolia HOCHST. is a small South African shrub. Chromosome size ranges from 1.65μ—0.30μ. Constrictions are not distinct as such but appear to be median to submedian.

Meiotic studies have also been made from flowering material raised in the greenhouse. Twenty five bivalents were clearly discernible at first metaphase (M-I). The mean number of rod and ring bivalents per pollen mother cell was 8 and 17 respectively, and the number of half chiasma per chromosome 0.96. At first anaphase (A-I) there is unequal distribution of chromosomes as some of them have the tendency to lag behind. The further course of meiosis is normal.

T. floribunda HOCHST. is a deciduous shrub or a small tree, distributed in E. and S. Africa. In strong contrast to the former species, the chromosomes are relatively large and vary in length from 3.20μ to 1.00μ. Constrictions are also more prominent as seen in the following types (2L sm (3.20μ to 2.80μ) + 2L nearly m (2.80μ to 2.40μ) + 10M sm to m (2.20μ to 1.80μ) + 6M m (1.80μ to 1.60μ) + 5S m to sm (1.40μ to 1.00μ)).

Tribe Trichilieae:

Cipadessa BL. (c. 2 species of shrubs or small trees; Indo-Malayan region).

Observations of n = 28 and 2n = 56 in *C. baccifera* (ROTH) MIQ. *(Figs. 7, 22)* and n = 14 *(Fig. 5)* and 2n = 28 *(Fig. 6)* in *C. cinerascens* (PELLEGR.) HAND.-MAZZ. have shown that speciation in the genus has taken place through euploidy. Although the latter has for some time been included as a variety of *C. fruticosa* BL. (= *C. baccifera)* there are now cytological reasons for maintaining them as two distinct species.

Meiotic studies of *C. cinerascens* showed 14 bivalents at first metaphase (M-I). Chromosome pairing was normal and both ring and rod type bivalents were observable. The mean number of rod and ring bivalents per pollen mother cell were 5 and 9 respectively and the number of half chiasma per chromosome 0.78. Tetrad formation was normal with 100% well stained pollen.

Somatic studies show 2n = 28 in this species, with moderately large chromosomes varying in length from 3.20μ to 1.60μ. Constrictions are median to sub-median. This observation is in agreement with the results of STYLES and VOSA *(loc. cit.)*. Besides normal counts, endoploidy with cells showing 2n = 56 has been observed. Of 50 cells examined 44 had 2n = 28 and 6 had 2n = 56.

The course of meiosis was also normal in *C. baccifera*. Twenty-eight bivalents were clearly visible both in polar and lateral views. The mean number of rod and ring bivalents was 8.5 and 19.5 respectively, and the number of half chiasma per chromosome was calculated as 0.85. Tetrad formation was normal, Mitotic studies revealed the complement as 2L m (3.30μ to 2.90μ) + 2L sm (3.00μ to 2.80μ) + 12M nearly sm to m (2.55μ to 1.80μ) + 8M nearly m to sm (2.22μ to 1.70μ) + 4S m to sm (1.50μ to 1.00μ)).

Ekebergia SPARRM. (4 tree and shrub species; Africa).

E. capensis SPARRM. with 2n = 46 and *E. pterophylla* (C. DC) HOFM. with 2n = 50 are studied here. The genus thus seems to be dibasic with x = 23 and 25.

E. capensis SPARRM. is a medium-sized tree of semi-evergreen and evergreen forests of E. & S. Africa. Chromosome studies from material of a single provenance showed 2n = 46 in agreement with previous counts *(Table 1)*. The chromosomes are very small in size and vary in length from 0.85μ to 0.45μ. Primary constrictions are not very distinct.

Cytological studies of *E. senegalensis* A. JUSS. (STYLES and VOSA, unpublished) have also revealed 2n = 46. This species which occurs in West Africa and the Congo River basin may not be specifically distinct from *E. capensis* SPARRM.

E. pterophylla (C. DC.) HOFM., an isolated species in the genus, has been found to posses 2n = 50 *(Figs. 8, 23)*. Chromosome size ranges from 1.60μ to 0.95μ and the complement can be identified as 1L sm (1.60μ) + 1L m (1.40μ) + 12M nearly sm to m (1.25μ to 0.95μ) +11M nearly m to sm (1.20μ to 0.90μ).

Trichilia P. BROWNE (c. 60 species in tropical America, and 18 species in Africa).

The two Indo-Malesian and Chinese species of the genus *Heynea* ROXB. have now been included in this genus under section *Eutrichilia* (BENTVELZEN, 1961). Somatic studies of three species in this section are enumerated below.

T. connaroides (W. and A.) BENTV. is a small tree of the Indo-Malesian region. This species was placed under *Heynea* ROXB. as *H. trijuga* ROXB. ex SIMS until BENTVELZEN *(loc. cit.)* combined it under the polymorphous genus *Trichilia,* mainly on anatomical and phytochemical grounds.

Mitotic counts of 2n = 28 *(Figs. 9, 24)* for two provenances obtained from India agree with observations of MEHRA *et al., loc. cit.* Chromosomes vary in length from 2.80μ to 1.15μ. Primary constrictions are mostly median to submedian. A pair of chromosomes with distinct secondary constrictions is observed. The karyotype can be distinguished as 1L sm (2.80μ) + 1L sc (2.40μ) + 1L m (2.30μ) + 5M m (2.25μ to 1.95μ) + 2M sm (1.90μ to 1.80μ) + 4S m to sm (1.25μ to 1.10μ)).

T. emetica VAHL is a medium sized tree, widespread in Africa and often planted for shade. Mitotic counts showed 2n = 50 in accordance with earlier reports *(Table 1)*. The chromosomes are relatively large and vary in length from 3.00μ to 0.90μ. Five types are recognized both on the basis of the relative length of the chromosomes and on the position of the centromere i.e., 1L sm (3.00μ) 3L nearly m to nearly sm (2.80μ to 2.10μ) + 8M nearly m (1.90μ to 1.80μ) + 6M sm (1.95μ to 1.80μ) + 7S m to nearly sm (1.00μ to 0.90μ) *(Fig. 25)*.

T. havanensis JACQ. is a shrub or a small tree from Central America and the West Indies. The species with 2n = 92 is reported cytologically here for the first time *(Fig. 11)*. A similar number is also known for caribbean *T. odorata* ANDR. in the section *Moschoxylum* HARMS (S. and G. MANGENOT, 1957). STYLES and VOSA *(loc. cit.)* have reported a diploid series of x = 23 in the African *T. rubescens* OLIV. in section *Apotrichilia* HARMS. Chromosomes are relatively large in size and vary in length from 3.20μ to 0.85μ, and can be distinguished in the following types (5L m (3.20μ to 2.40μ) + 3L sm (2.80μ to 2.50μ) + 16M to nearly sm (2.00μ to 1.85μ) + 9M sm (1.85μ to 1.35μ) + 1M st (1.80μ) + 12S m to sm (1.00μ

to 0.85μ)). (See discussion). Cytological studies of *Trichilia* so far, and on very few counts, show it to be tribasic with x = 14, 23 and 25. The first number is known only among the Asiatic species.

Walsura Roxb. (7 species; Indo-Malesian region).

This genus is taxonomically close to *Heynea* and *Trichilia* and differs mainly in the dehiscence of the fruit (indehiscent in *Walsura* and a dehiscent capsule in *Heynea* and *Trichilia).* The occurrence of wood vessels in the pith of the twigs of *Walsura* differentiates it from *Trichilia.* The genus also shares some further minor features with *Heynea* such as a papillose epidermis on the lower leaf surface.

W. trifolia (A. Juss.) Harms is a small tree often cultivated for its medicinal properties. Our mitotic count of 2n = 28 *(Figs. 12, 26)* agrees with Ghosh (1961, 1968) for *W. piscidia* Roxb., which is now treated as a synonym of *W. trifolia.* Chromosomes are classified into the following types (1L sm (2.00μ) + 3L m to nearly sm (1.75μ to 1.65μ) + 8M nearly m to sm (1.50μ to 1.25μ) + 2S m (1.00μ to 0.95μ)).

The karyotype of this species is symmetrical and our observations do not agree in all respects with those of Ghosh (1968). The absence of secondary constrictions in the long pair of chromosomes in our preparations may be attributed to chromosomal polymorphism. Due to the small size of chromosomes, classification into medium and long types is difficult.

The karyomorphology of *W. trifolia* resembles *Heynea trijuga* Roxb. *(Trichilia connaroides* (W. and A.) Bentv.) in a number of characteristics such as basic number (n = 14), centromeric position and the occurrence of a long sub-median pair of chromosomes with secondary constrictions (Ghosh, *loc. cit.).* It is deduced, therefore, that both have evolved from the same stock and structural alterations in chromosomes must have helped in the diversification of these genera. Their close cytological similarity indicates wide separation from *Trichilia* with which *Heynea* had now been merged. In our opinion *Heynea* should, on cytological grounds at least, be maintained as a genus distinct from *Trichilia.*

Tribe Guareeae:

Chisocheton Bl. (50 species of trees; Indo-Malesian region):

C. morobeanus Harms with 2n = 92 *(Fig. 10)* is a new report for the genus. The chromosomes are small in size and vary in length from 1.65μ to 0.55μ; constrictions are median to sub-median. Six pairs are relatively large (1.65μ to 0.85μ) and the remaining complement is more or less uniform (0.65μ to 0.55μ).

Mitotic studies in another *Chisocheton* sp. (LAE 46746) showed 2n = 46. These reports confirm an earlier report of x = 23 for *C. paniculatus* Hiern (Mehra *et al., loc. cit.). C. morobeanus* is thus tetraploid and it is envisaged that this large genus will exhibit considerable interspecific ploidy.

Dysoxylum Bl. (60 tree species; Indo-Malayan region extending eastwards to Australia, Papua New Guinea and Polynesia with one species in New Zealand).

D. binecteriferum Hook.f. is an important timber tree in the Eastern Himalayas, Khasi Hills and Western Peninsula of India and in Sri Lanka. The count of 2n = 80 for this species agrees with earlier observations of Mehra *et al. (loc. cit.).* Chromosome size varies from 1.40μ to 0.50μ. Mehra *et al. (loc. cit.)* have suggested x = 10 as the base number of the genus, a figure which is based on their haploid report of n = 10 for *D. pallens* Hiern. The present species as such is therefore octoploid. However, in *D. pachyphyllum* Hemsl. and *D. spectabile* (Forst.f.) Hook.f., 2n = 84 has been listed (Styles and Vosa, *loc. cit.).* Accordingly, the genus is at least dibasic with x = 10 and 42. The latter series seems to have evolved from an antique stock with a base number of 14 (7). The genus, however, is a large one and further studies are required.

Synoum A. Juss. (2 species; Australia).

S. glandulosum A. Juss. with 2n = 84 *(Fig. 13)* represents the first cytological count for this genus of small trees. Two provenances have been studied. Chromosomes vary in length from 1.60μ to 0.65μ, and primary constrictions are median to sub-median. Six pairs are relatively larger than the remainder (1.60μ to 1.25μ).

Tribe Aglaieae:

Aphanamixis Bl. (4—5 species; Indo-Malesia).

A. polystachya (Wall.) Parker; a commercial timber species of India is morphologically extremely variable. Cytologically the species is also very interesting. Both diploid (n = 18; Mehra *et al., loc. cit.)* and tetraploid (4n + 2: 2n = 76; Minfray, 1963 a; Styles and Vosa, *loc. cit.)* races are reported in the species. The present report of 2n = c. 150 *(Fig. 15)* seems to be at an octoploid level.

The chromosomes are again extremely small and do not show any appreciable variation in size in the complement (0.70μ to 0.60μ). Constrictions are mostly median; however, sub-median types are also encountered.

Aglaia Lour. (100 woody species; Indo-Malesia, Australia, Malanesia and Polynesia).

In the present studies the somatic count of 2n = 92 *(Fig. 14)* for *Aglaia* sp. differs from earlier reports of two species based on x = 20 (Mehra *et al., loc. cit.).* Chromosomes vary in length from 0.90μ to 0.60μ. Centromeres are not distinct.

Cytologically the *Aglaieae* is the most neglected tribe in the family. The available chromosomal data on *Aglaia* so far suggest it is dibasic with x = 20 and 46. Perhaps, as in other Meliaceae, 46 is a chromosome duplication of x = 23. Among species of *Aphanamixis,* where chromosomes have been examined only for *A. polystachya,* is euploidy seen at diploid, tetraploid (4n + 2) and octaploid (8n) levels. *Lansium,* another genus in the tribe, shows cytological affinities with *Aphanamixis* as the haploid number of n = 72 for *L. domesticum* Corr. could have evolved at octoploid level from a diploid stock of x = 18, a number which is still preserved in *Aphanamixis.*

Tribe Melieae:

Azadirachta A. Juss. (2 tree species; Indo-Malesian region).

The present studies in *A. indica* A. Juss. were undertaken to examine the previously reported discrepancy in chromosome numbers for this species, (n = 14 or 2n = 28; Pathak and Singh, 1949; Mukherjee, 1952; Deshmukh, 1959; Mehra *et al., loc. cit.)* and 2n = 30; S. and G. Mangenot, 1958; Styles and Vosa, *loc. cit.) (Table 1).* The material for the present study was obtained from Nigeria (where the tree is introduced) and from India. Our studies showed very clearly 28 chromosomes in metaphase plates from both provenances *(Figs. 16, 27).* However, one pair of chromosomes is larger than the remaining pairs in the complement. It is very likely that the earlier report of 2n = 30 might have arisen as a consequence of the breakage of this larger pair. Chromosome size varies in length from 1.60μ to 0.55μ. Both median and sub-median types of chromosomes are identified as 1L sm (1.60μ) + 3L m to sm (1.25μ to 1.00μ) + 4M nearly sm (0.75μ to 0.70μ) + 6S m to sm (0.60μ to 0.50μ).

Melia L. (c. 6 poorly defined, woody species; old world tropics and subtropics):

M. azedarach L. is a native of India and is widely planted.

The tree is extremely variable in its growth habit, but a diploid chromosome number of 2n = 28 *(Figs. 17, 28)* has been consistently recorded in the literature and our present studies from two provenances support this. The chromosomes have both median and sub-median constrictions and vary in length from 1.45μ to 0.50μ. The four types identified in the complement are: 2L sm (1.45μ to 1.40μ) + 3M sm (1.15μ to 0.95μ) + 3M m (0.95μ to 0.80μ) + 6S nearly m to sm 0.60μ to 0.35μ).

M. composita WILLD. is a tree of the Eastern Himalayas and our record of 2n = 28 for the species is in agreement with earlier reports *(Table 1)*. Chromosomes are small (1.00μ to 0.40μ), and the primary constrictions, which are not very distinct, seem to be median to sub-median. One pair is relatively larger (1.00μ) and the remaining pairs range from 0.80μ to 0.40μ.

The karyomorphology of *M. ? dubia* CAV. was also studied to compare it cytologically with the previous species (with which it has been merged). Constrictions are again obscure due to the small size of chromosomes, the latter varying in length from 0.95μ to 0.30μ, but size differences overlap, as in *M. composita*. Except for a large sub-median pair, the rest are small with mostly median to nearly sub-median constrictions. Thus, karyologically the two species do not exhibit any appreciable differences.

The tribe Melieae is invariably based on x = 14 as seen in *Azadirachta* and *Melia*. This is one of the low series which is also found among a few more genera which are exclusively distributed in the old world tropics.

Tribe Sandoriceae:

Sandoricum CAV. (3—5 rather variable species; Indo-Malesian region to Papua New Guinea).

Our somatic studies for *S. radiatum* KING with 2n = 28 *(Figs. 18, 29)* differ from the earlier reports of 2n = 16, 32 (TIXIER, 1958) and n = 11, 22 (RAMIREZ, 1961) for *S. indicum* CAV. and *S. koetjape* (BURM f.) MERR. respectively. However the taxonomy of this genus at the species level is very confused. The karyotype is asymmetrical as most of the chromosomes possess secondary constrictions. These are studied in the following types: 2L sc (1.40μ to 1.20μ) + 4M sc (1.10μ to 1.00μ) + 2M m (1.00μ to 0.90μ) + 4S sc (0.60μ to 0.50μ) + 2S m to sm (0.60μ to 0.45μ). (See below).

Discussion

Range of Chromosome Numbers and their Evolution

The Meliaceae is highly unusual among woody plant families because it shows extreme polymorphism of chromosome numbers. To date about one tenth of all species have been investigated cytologically, and chromosome numbers so far range from n = 8 (2n = 16), *Sandoricum indicum)* to 2n = c. 360 *(Trichilia dregeana)* (STYLES and VOSA, *loc. cit.)*. This latter count is perhaps the highest number yet met with among hardwoods. Other high counts are *Turraeanthus africanus* (2n = c. 280; STYLES and VOSA, *loc. cit.), Aphanamixis polystachya* (2n = c. 150; present report) and *Lansium domesticum* (n = 72; BERNARDO and RAMIREZ, 1959). Polyploid series are by no means a rare phenomenon in the group, being apparent in at least *Chisocheton* and *Dysoxylum*. Intra-specific chromosome races occur within *Swietenia* and *Aphanamixis*.

The frequency distribution of species with different gametic numbers is shown in the graph *(Fig. 9)*. Species with more than one number are included as separate taxa. Examination of this graph suggests polymodal chromosomal evolution in the family. The maximum peak is at 25 which is high. Other represented series also seen are x = 14, 23, 28 and 36. The remaining series are either dibasic polyploids, polyploid drops, or polyploid jumps. The average haploid number of chromosomes per species among the Meliaceae investigated has been estimated to be n = 27. This is in wide constrast to n = 16.07 and n = 15.99 in tropical dicotyledons and all angiosperms respectively as estimated by GRANT (1963).

A base number of x = 14 or its multiples such as 28, 42 or even higher ploidy levels in the family represent the vestiges of an archaic stock of x = 7, which has been considered by many workers in the field as one of the original base numbers of angiosperms (DARLINGTON, 1956; HAIR, 1966; STEBBINS, 1971). Among the Meliaceae, the gene pool of the 14 series may be of autoploid origin coupled with interracial hybridization. Our observations of endoploidy in *Cipadessa cinerascens* (2n = 28, 56) support this contention. The apparent rarity of x = 14 in the family and its occurrence among those genera which are either monospecific or which contain only a few poorly defined species with their centre of distribution restricted to the tropics of the old world further strengthens this view.[3]) Extensive hybridization accompanied by introgression may have occurred in these groups perhaps leading to the reticulate variation patterns of morphological traits and the complex interrelationships of the various taxa which are now encountered. The problems of generic delimitation in the family are already well known (PENNINGTON and STYLES *loc. cit.)*.

MEHRA *et al.* (1972) have proposed x = 7 as the basic number for Meliaceae and derived other numbers through aneuploidy at various ploidy levels. However, our observations based on the cytology of the very important timber genus *Swietenia*[4]) indicate a probable dibasic origin of the family. In *S. mahagoni* (L.) JACQ we have found a surprisingly large euploid series of numbers on x = 6 (2n = 12, 18, 24, 36, 42, 48, 54, 60 and 108) among cultivated (plantation) trees from the Fiji Islands. However, STYLES and VOSA *loc. cit.* working on material from the natural range of the genus report 2n = 48 *(S. mahagoni)*, 2n = 54 *(S. macrophylla* KING) and 2n = 56) *(S. humilis* ZUCC.). On the basis of 2n = 56 in the latter species the role of x = 7 along with x = 6, as discussed above, is understandable. Recently, SAREEN and KUMARI (1973) have reported n = 28 in *S. mahagoni*, thereby further supporting a dibasic mode of speciation in the genus. *Toona*, another timber genus, also seems to have passed through a similar ditypic basic mode. MEHRA *et al. (loc. cit.)* having reported it tribasic with x = 13 (n = 26 in *T. ciliata*, n = 39 in *T. ciliata* var. *pillistaminea* C. DC.) and x = 14 (n = 28 in *T. ciliata)*.

This implies, therefore, that in the initial stages, chromosomal evolution of the Meliaceae has taken place through the somatic doubling of 6 and 7, or through alloploid combination, perhaps accompanied by the elimination of chromosomes. Very likely, in the absence of x = 9 in any cytologically known species of the group, x = 18 orits multiples 36 and 72 have evolved as a consequence of secondary ploidy from x = 6. The probable evolution of a more or less continuous series such as x = 19 to 20, 22 to 29 with a maximum peak at 25 and another moderate peak at 23 presents an interesting situation. The emergence of such

[3]) At the time of going to press we have observed 2n = c. 144 for the Brazilian *Cabralea glaberrima* A. JUSS.

[3]) Recently material of Australian *Owenia vernicosa* F. VON MUELL. has been shown to be diploid with 2n = 28.

[4]) Cytological studies on Swietenia form the basis of a separate report.

high base numbers can be explained either through aneuploidy or amphiploidy at X_3 and X_4 levels. According to STEBBINS (1938, 1947, 1950, 1971) the moderately high base numbers (x = 11—16), as well as still higher ones (x = 19 *etc.)* in many woody families are of secondary derivation and are the results of amphiploidy in the early history of the angiosperms. GRANT (1971) suggests that ascending aneuploidy has occurred in many groups of forest trees and shrubs as high diploid number is a means of maximising the generation of recombinational variability, and favourable ecological conditions in stable forest communities have exposed woody species to selection for aneuploid increases. DARLINGTON's (1956) views are contrary to this. According to him, in long-lived shrubs and trees, genomic functioning is so delicately balanced in these species that changes in chromosome number by deletion or duplication could upset this balance and act adversely. ASHTON (1962), however, considers that tropical forests provide a diversity of habitats in which opportunities for the colonization of new forms occur. This would encourage the establishment of polyploid forms.

Although the theories produced so far to explain these high base numbers are conflicting there seems little doubt to us that the present-day high numbers of chromosomes in many tropical tree genera and some whole tribes and families are of polyploid origin derived through amphiploidy from extinct diploid ancestors. In the Meliaceae which are mostly distributed in the rain forests and various other types of forest of the old and new world tropics, chromosomal evolution of the odd numbers seems to have followed this path. Thus, x = 25, which so far forms the core of the family is represented in 22 species in 10 genera. The majority of these genera appear to have passed through two or more cycles of ploidy, a situation also observed in *Bombacaceae* (S. and G. MANGENOT, 1962).

Chromosome size and morphology

Chromosomes are generally small to very small in size in the family and appear to have median to sub-median constrictions. In certain genera this small size makes their identification difficult. However, all the species discussed in the text, appear to have a ± symmetrical karyotype which is considered to be a primitive feature. It is only in *Trichilia havanensis* that asymmetry is marked with a single sub-terminal pair of chromosomes. The species is tetraploid (2n = 92) based on x = 23 which is the number also reported for *T. odorata,* MINFRAY (1963 a). This indicates, therefore, that in the genus *Trichilia* in the series of x = 23 at tetraploid level, species delimitation has taken place through chromosomal alterations. A chromosomal aberration is met in *Chukrasia tabularis* where the large-sized pair is heterobrachial. This polymorphism in chromosome morphology could also be due to structural changes such as deletion or duplication. Both primary and secondary constrictions among the species currently studied are reported in *Entandrophragma caudatum, Trichilia connaroides, Walsura trifolia* and *Sandoricum radiatum.* The occurrence of one pair of chromosomes with both primary and secondary constrictions in *Trichilia connaroides* and *Walsura trifolia* suggests their origin from a common parental stock and which is supported by their close morphological similarity. The x = 14 series in *Sandoricum radiatum,* with secondary constrictions in as many as 10 pairs, has diversified a great deal from the similar primitive base number met within the tribe Melieae.

In view of the high chromosome numbers cited in earlier papers on the *Meliaceae* and also in numerous accounts on other tropical woody species, DARLINGTON's (1937) and STEBBIN's (1938, 1950) suggestion that small chromosomes and less frequent polyploidy among tree genera are due to the small size of cambial initials appears to be unsupported by our studies. MEHRA *(loc. cit.)* has postulated that the small size of the chromosomes and polyploidy in hardwoods may be due to chromosomal saturation in relation to the amount of cytoplasm available. We do not wish to pursue this point until we have accumulated more data on chromosome number and size, cell size, DNA content, and specific gravity of the wood.

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Summary

Karyological studies on 33 taxa belonging to 19 genera in the Meliaceae were undertaken. The genus *Synoum* with 2n = 84 for *S. glandulosum* has been recorded for the first time. *Cedrela tonduzii* (2n =56), *Toona ciliata* var. *australis* (2n = 56), *Ekebergia pterophylla* (2n = 50), *Trichilia havanensis* (2n = 92), *Chisocheton morobeanus* (2n = 92) and *Sandoricum radiatum* (2n = 28) are the first chromosome counts for these species. *Azadirachta indica* had been established as monobasic with x = 14. The genera *Aglaia,* with x = 20 and x = 46 and *Ekebergia,* x = 23 and x = 25 have been discovered to be dibasic. A new chromosome count for *Aphanamixis polystachya* with 2n = c. 150 at 8x ploidy level has been added to the already known diploid and tetraploid numbers. Interspecific ploidy based on x = 23 was seen in *Chisocheton.* Endoploidy at the tetraploid level (2n = 4x = 56) was observed in *Cipadessa cinerascens* (2n = 28). The chromosomes are generally small in size but are relatively larger in the tribes *Trichilieae* and *Turraeeae,* where shrubs rather than large trees occur. Karyotypic analysis of *Trichilia connaroides* suggests affinities with *Walsura trifolia* and supports the retention of the generic status for Asian species of the genus *Trichilia* now placed in *Heynea.* A ditypic mode of speciation from x = 6 and 7 has been postulated for the family as euploids built on these antique numbers exist in the group. Polymorphism of chromosome numbers in the family is attributed to amphiploidy and species hybridization.

Key words: Meliaceae, karyological studies, chromosome numbers of 33 taxa.

Zusammenfassung

An 33 Taxa von 19 Gattungen aus der Familie der Meliaceen wurden karyologische Untersuchungen durchgeführt. Zum ersten Mal wurde der Chromosomensatz für *Synoum glandulosum mit* 2n = 84 ermittelt, weiterhin für *Cedrela tonduzii* mit 2n = 56, *Toona ciliata var. australis* mit 2n = 56, *Ekebergia pterophylla* mit 2n = 50, *Trichilia havanensis* mit 2n = 92 und *Sandoricum radiatum* mit 2n = 28. Für *Azadirachta indica* stellte sich die Grundzahl mit x = 14 heraus. Bei den Gattungen *Aglaia* und *Ekebergia* konnten je zwei Grundzahlen mit x = 20 und x = 46 *(Aglaia*-Arten) sowie mit x = 23 und x = 25 *(Ekebergia*-Arten) gefunden werden. Eine erneute Auszählung erbrachte für *Aphanamixis polystachya* einen Chromosomensatz von 2n = c. 150 (oktoploid). Interspezifische Polyploidie auf der Basis x = 23 wurde bei *Chisocheton* beobachtet, Endopolyploidie

(tetraploid, 2n = 4x = 56) bei *Cipadassa cinerascens* (2n = 28). Die Chromosomen sind im allgemeinen klein, etwas größer bei den mehr strauchartigen *Trichilieae* und *Turraeeae*.

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Notes

40. Deutsche Pflanzenschutztagung

Vom 6. bis 10. Oktober findet in Oldenburg die 40. Deutsche Pflanzenschutztagung statt. Veranstalter sind die Biologische Bundesanstalt für Land- und Forstwirtschaft, der Pflanzenschutzdienst der Länder und die Deutsche Phytomedizinische Gesellschaft. Anfragen sind zu richten an: Biologische Bundesanstalt für Land- und Forstwirtschaft D-33 Braunschweig, Messeweg 11/12.

Arbeitsgemeinschaft für Forstgenetik und Forstpflanzenzüchtung

In der Zeit vom 16.—19. September 1975 tagte in Schmalenbeck die Arbeitsgemeinschaft für Forstgenetik und Forstpflanzenzüchtung. Neben den Berichten über die Forschungsarbeiten der Mitglieder fand eine offene Sitzung der Arbeitsgruppen „Blühstimulation" und „Richtlinien forstliches Vermehrungsgut" statt. Einen Schwerpunkt bildeten Vorträge zum Thema „Salz- und Immissionsresistenz als Ziele forstlicher Züchtung".

Autor-Berichtigung

Erratum: Feret, P. P. and Bryant, R. L. 1974. Genetic Differences Between American and Chinese *Ailanthus* Seedlings. Silvae Genetica **23** (5): 144—148.

During manuscript preparation errors were made in assigning significance levels between country means of *Table 2*. Correct significance levels are as follows:

Root, **; Stem, *; Rachis, NS; Leaf, NS; Total, *; Area, NS; Height, **; Diameter, NS; Area per leaflet, **; Root Ratio, **; Stem Ratio, **; Rachis Ratio, NS; Leaf Ration, *; Shoot/Root, **.

The errors necessitate some wording changes in the text. The authors will supply text corrections upon receipt of manuscript reprint request.

The authors regret the errors and assume full responsibility for them.

Peter P. Feret

Referate

Anonymus: **The Thai-Danish Pine Project 1969—1974.**

This report presents first results of forestry improvement research in Thailand in relation to this project of mutual interest of the Thai and Danish governments. With its clear objectives and its implementation on programming basis this project certainly will be of importance also to neighbouring countries of similar environmental conditions.

Beside of a description of the field research areas and details of nursery experiments with the species in question — preliminary results with the following species are presented: *Abies religiosa, Cupressus lusitanica, C. macrocarpa, Pinus brutia, P. caribaea var. hondurensis, P. kesiya, P. merkusii, P. nigra, P. ooccarpa, P. pseudostrobus,* and *P. tenuifolia*. According to the site of the plantation *Pinus caribaea, P. ooccarpa, P. kesiya,* and *P. tenuifolia* seem promising species for the country. — Particularly *P. ooccarpa* reacts favourably to soil cultivation, but only for *C. lusitanica* intensive establishment with fertilizing, discing, weeding and other treatments proved more profitable than the nun-