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 worldwide 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), Mehta and Sareen (1969) and Mehta et al. (1972). The latter three contributors have concentrated mainly on the 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 2-8 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 0.05 μm 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 constriction. The average size of the chromosomes is computed by totaling 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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1) Permanent address: Dept. of Botany, Panjab University, Chandigarh, India.
<table>
<thead>
<tr>
<th>Taxa studied</th>
<th>Voucher specimen and record</th>
<th>Chromosome Number</th>
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<th>Growth habit</th>
<th>Previous reports</th>
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<tr>
<td>Chukrasia tabularis A. Juss.</td>
<td>Nigeria (cult.), Olokomeji For. Res., Ibadan, G. A. Adesida sn</td>
<td>2n = 26</td>
<td>31.50 µ</td>
<td>1.15µ</td>
<td>Tali tree</td>
<td>n = 13; Rao, 1967; Mehra et al., 1972</td>
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<td>C. tabularis A. Juss.</td>
<td>India, Dehra Dun, New For., Ram Dayal 2</td>
<td>2n = 26</td>
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<td>Entandropitragus caudatum (Sprague)</td>
<td>Rhodesia, Matopo Hills, FHO 130481</td>
<td>2n = 72</td>
<td>125.00 µ</td>
<td>1.75µ</td>
<td>Large tree</td>
<td>2n = 72; Styles and Vosa, 1971</td>
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<td>E. cylindricum (Sprague)</td>
<td>Uganda, Budongo For., For. Dept. sn</td>
<td>2n = 72</td>
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<td></td>
<td>Very large tree</td>
<td>n = 26; S &amp; G. Mangenot, 1957</td>
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<td>Soymida jebriyuga A. Juss.</td>
<td>Hyderabad, Andhra Pradesh, Forest Dept. sn</td>
<td>2n = 56</td>
<td>65.50 µ</td>
<td>1.15µ</td>
<td>Medium-sized tree</td>
<td>2n = 56; Styles and Vosa, 1971</td>
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<tr>
<td>Cedrela fissilis Vell.</td>
<td>Brazil, Parãia, Iguatu Falls, Forest Department sn</td>
<td>2n = 56</td>
<td>34.75 µ</td>
<td>0.62µ</td>
<td>Tali tree</td>
<td>2n = 56; Styles and Vosa, 1971</td>
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<td>C. odontia L.</td>
<td>Holite, Mt. Pine Ridge, Cayo Dist. Styles 166</td>
<td>2n = 56</td>
<td>60.00 µ</td>
<td>1.05µ</td>
<td>Large tree</td>
<td>2n = 50, 56; Styles and Vosa, 1971</td>
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<td>C. tonduzi C. DC.</td>
<td>Costa Rica, Santa Cruz de Turrialba, Styles 82</td>
<td>2n = 56</td>
<td>44.50 µ</td>
<td>0.79µ</td>
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<td>Toona ciliata M. J. Roem.</td>
<td>Uganda, Entebbe Bot. Gard., FHO 129769</td>
<td>2n = 56</td>
<td>66.50 µ</td>
<td>1.15µ</td>
<td>Large tree</td>
<td>n = 26; Mehta and Saareen, 1969; Mehta et al., 1972</td>
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<td>T. ciliata var. australis (F. von Moll.) C. DC.</td>
<td>Australia, NSW, Nolam's Creek, A. L. Mitchell 943</td>
<td>2n = 56</td>
<td>65.50 µ</td>
<td>1.19µ</td>
<td>Large tree</td>
<td>2n = 56; Seng, 1951; Styles and Vosa, 1971</td>
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<td>T. serrata (Roth) M. J. Roem.</td>
<td>Uganda, Makerere Univ. Commp., Synnot sn</td>
<td>2n = 56</td>
<td>66.00 µ</td>
<td>1.12µ</td>
<td>Medium-sized tree</td>
<td>2n = 52; Mehta and Saareen, 1969; Mehta et al., 1972</td>
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<td>Carapa guianensis Aubl.</td>
<td>Malaysia, Perak (cult.), Whitmore sn</td>
<td>2n = 58</td>
<td>60.60 µ</td>
<td>1.05µ</td>
<td>Medium-sized tree</td>
<td>2n = 50; Monfray, 1963 b; Styles and Vosa, 1971</td>
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<td>Turraea? floribunda Hochst.</td>
<td>Uganda, Budongo For., Synnot 1443</td>
<td>2n = 30</td>
<td>80.50 µ</td>
<td>1.58µ</td>
<td>Shrub or a small tree</td>
<td>2n = 30; Styles and Vosa, 1971</td>
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<td>T. obtusifolia Hochst.</td>
<td>Rhodesia, 3 km W. Salisbury, Hiegel 2274</td>
<td>2n = 59</td>
<td>34.96 µ</td>
<td>0.39µ</td>
<td>Shrub</td>
<td>2n = 30; Styles and Vosa, 1971</td>
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<td>Cipadessa baccifera (Roth) Moq.</td>
<td>India, Poona, Bot. Surv. India 119, 386.</td>
<td>2n = 56</td>
<td>118.80 µ</td>
<td>2.08µ</td>
<td>Shrub</td>
<td>2n = 56; Styles and Vosa, 1971</td>
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<td>Ekebergia capensis Sparre.</td>
<td>Zambia, Ndola, Monkey Fountain Park, Fahnshawe sn</td>
<td>2n = 46</td>
<td>32.70 µ</td>
<td>0.70µ</td>
<td>Medium-sized tree</td>
<td>2n = 46; Styles and Vosa, 1971</td>
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<td>E. pterophylla (C. DC.) Hook.</td>
<td>Natal, Izotsha R. Gorge, White 19,523</td>
<td>2n = 50</td>
<td>66.50 µ</td>
<td>1.32µ</td>
<td>Shrub</td>
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<td>Trichilia conneroides (W. and A.) Bentv.</td>
<td>India, New For. Res., Dehra Dun, Dayal 4</td>
<td>2n = 28</td>
<td>52.80 µ</td>
<td>1.45µ</td>
<td>Small tree</td>
<td>2n = 14; Rao, 1967; Mehta and Saareen 1969; Mehta et al., 1972</td>
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<th>Growth habit</th>
<th>Previous reports</th>
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<tr>
<td><em>T. connaroides</em> (W. and A.) Bentv.</td>
<td>India, Dehra Dun, Sahni sn</td>
<td>2n = 28</td>
<td>33.00</td>
<td>1.86</td>
<td>Medium-sized tree</td>
<td>2n = 50; Styles and Vosa, 1971</td>
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<td><em>T. emetica</em> Vahl</td>
<td>Natal, Ndumu Game Reserve, White 1945</td>
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<td>93.30</td>
<td>1.86</td>
<td>Medium-sized tree</td>
<td>2n = 50; Styles and Vosa, 1971</td>
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<td><em>Wahlenbergia trifolia</em> (A. Juss.) Harms</td>
<td>India, Sibpur, Howrah Bot. Gard., FHO 13457</td>
<td>2n = 28</td>
<td>42.00</td>
<td>1.50</td>
<td>Small tree</td>
<td>n = 14; 2n = 28; Ghosh, 1961, 1968.</td>
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<td><em>Chioschon ton morobotetus</em> Harms</td>
<td>Papua and New Guinea, Lae, LAE 56067</td>
<td>2n = 92</td>
<td>67.70</td>
<td>0.72</td>
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<td><em>Chioschon ton</em> sp.</td>
<td>Papua and New Guinea, Lae, LAE 46746</td>
<td>2n = 46</td>
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<td>0.73</td>
<td>Tree</td>
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<td><em>Dysoxylum binectariferum</em> Hook. f.</td>
<td>India, New For. Res., Dehra Dun, Ram Dayal 3</td>
<td>2n = 80</td>
<td>75.50</td>
<td>0.90</td>
<td>Tall tree</td>
<td>n = 49; Mehta and Khosla, 1969; Mehta et al., 1972</td>
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<td><em>D. binectariferum</em> Hook. f.</td>
<td>Ceylon, Ashton sn</td>
<td>2n = 80</td>
<td>78.40</td>
<td>0.90</td>
<td>Medium-sized tree</td>
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<td><em>Synnum glandulosum</em> (Sm.) A. Juss.</td>
<td>Australia, Queensland, Little Yagba, S. W. Kenilworth, BRI 145828</td>
<td>2n = 64</td>
<td>78.40</td>
<td>0.90</td>
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<td><em>S. glandulosum</em> (Sm.) A. Juss.</td>
<td>Australia, Queensland, State For., Woondum S. E. Gympie, BRI 145828</td>
<td>2n = 64</td>
<td>78.40</td>
<td>0.90</td>
<td>Medium-sized tree</td>
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<td><em>Aphanamixis polystachya</em> (Wall.) Paker</td>
<td>India, Dehra Dun, New For. Res. (cult.), Ram Dayal 1</td>
<td>2n = c. 150</td>
<td>97.50</td>
<td>0.60</td>
<td>Tall tree</td>
<td>2n = 76; Minshew, 1963; Styles &amp; Vosa, 1971</td>
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<td><em>Aglaia</em> sp.</td>
<td>Papua and New Guinea, Lae, LAE 56067</td>
<td>2n = 92</td>
<td>75.50</td>
<td>0.83</td>
<td>Tree</td>
<td>n = 18; Mehta and Khosla, 1969; Mehta et al., 1972</td>
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<td><em>Azadirachta indica</em> A. Juss.</td>
<td>Nigeria (cult.) Zaria, Rander sn</td>
<td>2n = 28</td>
<td>22.40</td>
<td>0.80</td>
<td>Medium-sized to large tree</td>
<td>2n = 28; Patnaik and Singh, 1969</td>
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<tr>
<td><em>Melia azedarach</em> L.</td>
<td>Zambia, Katondwe Mission, Strid 2743</td>
<td>2n = 28</td>
<td>23.60</td>
<td>0.84</td>
<td>Medium-sized tree</td>
<td>2n = 28; Bowden, 1945; Patnaik and Singh, 1969; Gabella et al., 1966; Minshew 1963; Styles and Vosa, 1971.</td>
</tr>
<tr>
<td><em>M. azedarach</em> L.</td>
<td>Greece, Corinth, Dawson 44</td>
<td>2n = 28</td>
<td>33.00</td>
<td>0.84</td>
<td>Medium-sized tree</td>
<td></td>
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<tr>
<td><em>M. coposia</em> Willd.</td>
<td>India, Lucknow Bot. Gard., sin. coll.</td>
<td>2n = 28</td>
<td>19.60</td>
<td>0.70</td>
<td>Large tree</td>
<td>n = 14; Zerva, 1952; Mehta et al., 1972</td>
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<td><em>M. d. dubia</em> Cav.</td>
<td>Australia, Maroochydore, McWhirter 2</td>
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<td>17.60</td>
<td>0.62</td>
<td>Large tree</td>
<td>n = 14; Mehta and Khosla, 1969; Mehta et al., 1972</td>
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<tr>
<td><em>Sandoricum radiatum</em> King</td>
<td>Malaysia, Singapore Bot. Gard., Mahmud Awang sn</td>
<td>2n = 28</td>
<td>26.60</td>
<td>0.82</td>
<td>Small tree</td>
<td>2n = 28; Styles and Vosa, 1971</td>
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</tbody>
</table>
Figs. 1–12. — (Magnification X1500). Fig. 1: Chukrasia tubularis, 2n = 28. Large pair of chromosomes is heteromorphic (see arrow). — Fig. 2: Erontandrophora caudatum, 2n = 72. Large pair of chromosomes possess secondary constrictions (see arrow). — Fig. 3: Soymida febrifuga, 2n = 56. — Fig. 4: Turraea obtusifolia, 2n = 56. — Fig. 5: Cubedessa cinerascens, n = 14. — Fig. 6: Cubedessa cinerascens, 2n = 28. — Fig. 7: Cubedessa baccifera, 2n = 28. — Fig. 8: Ekebergia pterophylla, 2n = 56. — Fig. 9: Trichilia connaroides, 2n = 28. Arrows indicate a pair of chromosomes with secondary constrictions. — Fig. 10: Chisholceton morobeanus, 2n = 28. — Fig. 11: Trichilia harounensis, 2n = 22. — Fig. 12: Walskea trifolia, 2n = 28.
C. tabularis A. Juss., is an important timber tree. Somatic counts of 2n = 28 (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 2.55μ) + 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 endopolyploidy with 2n = 36 and 72
in *E. angolense* (*Welw.*). The remaining species are thus tetraploid.

*Soymia* 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 am (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 Cedrealeae:**

*Cedrela* P. Brown (7–9 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* Vent., 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 heterogenous as x = 25, 27 and 28 have been recorded (see *Stylos* and *Vosa*, loc. cit.). The first two series have been reported in *C. angustifolia* Sees 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 *Stylos* 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* (Rottl.) M. J. Roem., and a variety *T. ciliata* var. australis (P. von Muel). 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 31) 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 *Stylos* 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. *Stylos* and *Vosa* (loc. cit.) have also hinted at two cytotypes in *T. siensis* (A. Juss.) M. J. Roem. with 2n = 46 as against 2n = 56 published by Minnay (1963, a). Thus, the genus is heterogeneous cytologically with x = 13 and 14 (26) and 23.

**Tribe Xylocarpeae:**

*Cerpea* 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 *Stylos* and *Vosa* loc. cit., Minnay, 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 1.55 μm to 0.90 μm.

Subfamily Melioidae

Tribe Turraeeae: Turraea L. (c. 70 species, small trees and shrubs; Africa, Madagascar 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 1.65 μm - 0.30 μm. 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 3.20 μm to 1.00 μm. Constrictions are also more prominent as seen in the following types (2L sm (3.20 μm to 2.80 μm) + 2L nearly m (2.80 μm to 2.40 μm) + 10M sm to m (2.90 μm to 1.80 μm) + 6M m (1.80 μm to 1.60 μm) + 5S m to m (1.60 μm to 1.00 μm)).

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 (Ronn) Mio. (Figs. 7, 22) and n = 14 (Fig. 5) and 2n = 28 (Fig. 6) in C. cinerascens (Palmer) Hanf - 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 rod and ring 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. Tetrads formation was normal with 100% well stained pollen.

Somatic studies show 2n = 28 in this species, with moderately large chromosomes varying in length from 3.20 μm to 1.60 μm. Constrictions are median to submedian. This observation is in agreement with the results of Styles and Vosa (loc. cit.). Besides normal counts, endopolyplid 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. Tetrads formation was normal, Mitotic studies revealed the complement as 2L m (3.30 μm to 2.90 μm) + 2L sm (3.00 μm to 2.80 μm) + 12M nearly sm to m (2.55 μm to 1.80 μm) + 8M nearly m to sm (2.22 μm to 1.70 μm) + 4S m to sm (1.50 μm to 1.90 μm)).

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

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

E. capensis Sparthm. 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 0.85 μm to 0.45 μm. Primary constrictions are not very distinct.

Cytological studies of E. senegalensis A. Juss. (Styles and Vosa, unpublished) have also revealed 2n = 46. This species occurs in West Africa and the Congo River basin may not be specifically distinct from E. capensis Sparthm.

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

Triticum P. Brown. (c. 60 species in tropical America, and 18 species in Africa).

The two Indo-Malayan and Chinese species of the genus Heynea Roxb. have now been included in this genus under section Eutrichilis (Bentivign, 1961). Somitic studies of three species in this section are enumerated below.

T. cononeroides (W. and A.) Bentv. is a small tree of the Indo-Malayan region. This species was placed under Heynea Roxb. as H. trijuga Roxb. ex Sims until Bentivign (loc. cit.) combined it under the polymorphic genus Triticilin, mainly on anatomical and phytochemical grounds.

Mitotic counts of 2n = 50 (Figs. 9, 24) for two provenances obtained from India agree with observations of Mohr et al., loc. cit. Chromosomes vary in length from 2.80 μm to 1.15 μm. 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 (2.80 μm) + 1L sc (2.40 μm) + 1L m (2.30 μm) + 5M m (2.25 μm to 1.95 μm) + 2M sm (1.90 μm to 1.00 μm) + 4S m to sm (1.25 μm to 1.10 μm).

T. emetica Vahl. is a medium sized tree, widespread in Africa and often planted for shade. Mitotic counts showed 2n = 56 in accordance with earlier reports (Table 1). The chromosomes are relatively large and vary in length from 3.00 μm to 0.90 μm. 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 (3.00 μm) 3L nearly m to nearly sm (2.80 μm to 2.10 μm) + 8M m (1.90 μm to 1.80 μm) + 6M sm (1.80 μm to 1.60 μm) + 7S m to nearly sm (1.00 μm to 0.90 μm) (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. oordata Andr. in the section Mesoaxyllum Harms. (S. and G. Mann, 1957). Styles and Vosa (loc. cit.) have reported a diploid series of n = 23 in the African T. rubescens Olivi. in section Apotrichilis Harms. Chromosomes are relatively large in size and vary in length from 3.20 μm to 0.85 μm, and can be distinguished in the following types (5L m (3.20 μm to 2.40 μm) + 3L sm (2.80 μm to 2.50 μm) + 16M sm to nearly sm (2.00 μm to 1.85 μm) + 9M sm (1.85 μm to 1.35 μm) + 1M st (1.80 μm) + 12S m to sm (1.00 μm).
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. The tree often cultivated for its medicinal properties. Our mitotic count of 2n = 28 (Figs. 12, 26) agrees with Gnossi (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 Gnossi (1968). The absence of secondary constrictions in the long arm 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 trilonga_ Roxb. (_Trichilia comoroides_ (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 (Gnossi, 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 Guareae:_

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

_C. morobeanus_ Harms with 2n = 92 (Fig. 16) 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 40746) showed 2n = 46. These reports confirm an earlier report of x = 23 for _C. paniculatus_ Hieron (Menra et al., loc. cit.). _C. morobeanus_ is thus tetraploid and it is envisaged that this large genus will exhibit considerable interspecific ploidy.

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

_D. bicentenarium_ Hook.f. is an important timber tree in the Eastern Himalayas, Khali Hills and Western Peninsula of India and in Sri Lanka. The count of 2n = 80 for this species agrees with earlier observations of Mehta et al. (loc. cit.). Chromosome size varies from 1.40μ to 0.50μ. Mehta 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_ Hieron. The present species as such is therefore octoploid. However, in _D. pachypodium_ 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 (?). The genus, however, is a large one and further studies are required.

_Synonym A. Juss._ (2 species; Australia).

*S. gansulorum* 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 (1.00μ to 1.25μ).

_Apamamizis_ 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; Mehta et al., loc. cit.) and tetraploid (4n + 2; 2n = 76; Minnery, 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.

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

In the present studies the somatic count of 2n = 92 (Fig. 14) for _Agalia_ sp. differs from earlier reports of two species based on x = 20 (Mehta et al., loc. cit.). Chromosomes vary in length from 0.90μ to 0.60μ. Centromeres are not distinct. Cytologically the _Agaliaeae_ is the most neglected tribe in the family. The available chromosomal data on _Agalia_ 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 _Apamamizis_, where chromosomes have been examined only for _A. polystachya_, is euploid seen at diploid, tetraploid (4n + 2) and octoploid (8n) levels. _Lanarium_, another genus in the tribe, shows cytological affinities with _Apamamizis_ as the haploid number of n = 72 for _L. domesticum_ Coix. could have evolved at octoploid level from a diploid stock of x = 18, a number which is still preserved in _Apamamizis_.

_Tribe Meliaceae:_

_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; Pithak and Singh, 1949; Mukherjee, 1952; Deshmukh, 1959; Mehta 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) + 6M in sm to sm (0.80μ to 0.50μ).

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

_Azadirachta_ 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 0.93μ 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 Meliaceae is invariably based on x = 14 as seen in Azadirachta and Mela. 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 Sandoricaceae:
Sandoricum Cav. (3—5 rather variable species; Indo-Malayan 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 africanaus (2n = c. 280; Styles and Vosa, loc. cit.), Aphanamixis polystachya (2n = c. 150; present report) and Lansium domesticum (n = 72; Barandiro and Ramirez, 1958). Polyploid series are by no means a rare phenomenon in the group, being apparent in at least Chisocheton and Dyssozyzum. 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 polyploidal 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 contrast 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 autopoloid origin coupled with inter-racial hybridization. Our observations of endopoloid 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. 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 do 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 Kumbria (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 dytopic 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. pillistiminea 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 alloplloid 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

5) At the time of going to press we have observed 2n = c. 144 for the Brazilian Cabralea gabriellina A. Junip.

6) Recently material of Australian Ocotea rurivacea F. Von Muel.

7) Cytological studies on Swietenia form the basis of a separate report.
high base numbers can be explained either through aneuploidy or amphiploidy at X<sub>1</sub> and X<sub>2</sub> 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 maximizing the generation of recombinational variability, and favourable ecological conditions in stable forest communities have exposed woody species to selection for aneuploid increases. Darlington's (1950) 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 havanaensis 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, Minnay (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 heterochromatic. 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 Ehnathera drophragma caudatum, Trichilia connaroides, Walsura trifolia and Sandooricum 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 Sandooricum 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 Stebbins' (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. Mehera (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.

Acknowledgements

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Summary

Karyological studies on 33 taxa belonging to 19 genera in the Meliaceae were undertaken. The genus Symoum with 2n = 84 for S. glandulosum has been recorded for the first time. Cedrela todzuzii (2n = 56), Toona ciliata var. australis (2n = 56), Ekebergia pterophylla (2n = 50), Trichilia havanaensis (2n = 92), Chisocheton morobeanus (2n = 92) and Sandooricum radiatum (2n = 28) are the first chromosome counts for these species. Azadirachta indica had been established as monobasic with x = 14. The genera Aplgia, 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 polyastachya 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. Endopolyploidy 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 Turraeae, 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 Hegnea. A ditpict 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

(tetrploid, 2n = 4x = 56) bei Cipadessa cinerascens (2n = 28). Die Chromosomen sind im allgemeinen klein, etwas größer bei den mehr strauchartigen Triichtilieae und Tur-
raeae.

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Notes

40. Deutsche Pflanzenschutztagung

Vom 6. bis 10. Oktober findet in Oldenburg die 40. Deut-
schc Pflanzenschutztagung statt. Veranstalter sind die Bio-
logische Bundesanstalt für Land- und Forstwirtschaft, der Deut-
sche Phytophazinische Gesellschaft. Anfragen sind zu richten an:
Biologische Bundesanstalt für Land- und Forstwirtschaft
D-33 Braunschweig, Messweg 11/12.

Arbeitsgemeinschaft für Forstgenetik und Forstpfianzen-
züchtung

In der Zeit vom 16.–19. September 1957 tagte in Schma-
lenbeck die Arbeitsgemeinschaft für Forstgenetik und
Forstpfanzenzüchtung. Neben den Berichten über die For-
schungsarbeiten der Mitglieder fand eine offene Sitzung
der Arbeitsgruppen „Blühstimulierung“ und „Richtlinien
fürstlichen Vermehrungsgut“ statt. Einen Schwerpunkt
bildeten Vorträge zum Thema „Salz- und Immissionsresi-
denz als Ziele forstlicher Züchtung“.

Autor-Berichtigung

Erratum: FERRT, P. P. and BRYANT, R. L. 1974. Genetic Diff-
erences Between American and Chinese Ailantho-

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

- Root, **; Stem, *; Bachis, NS; Leaf, NS; Total, *; Area, NS; Height, **; Diameter, NS; Area per leaflet, **; Root Ratio, **; Stem Ratio, **; Bachis 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
regression report.

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

Peter P. FERRT

Referate

results with the following species are presented: Abies religiosa,
Cupressus lusitanica, C. macrocarpa, Pinus brutia, P. cariba var.
honordurensis, P. kesiya, P. merkusi, P. nigra, P. oocarpa, P.
pseudostrobus, and P. tenuifolia. According to the site of the
plantation Pinus cariba var. oocarpa, P. kesiya, and P. tenui-
folia seem promising species for the country. Particularly P.
oocarpa reacts favourably to soil cultivation, but only for C.
lusitanica intensive establishment with fertilizing, dicing, weed-
ing and other treatments proved more profitable than the nun-

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