Notes RBG Edinb. 41(3):541–559 (1984)

CYTOTAXONOMIC STUDIES IN THE ZINGIBERACEAE

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ABSTRACT. Chromosome numbers of 33 species of Malayan Zingiberaceae were determined in pollen mother cells. The species investigated are distributed in three tribes: *Zingibereae, Hedychieae* and *Alpineae*. These include 30 species and five genera which have not been studied cytologically before. Cytological data by previous workers are compared and reviewed with reference to current knowledge of the taxonomy of the Zingiberaceae. It is shown that in the monogeneric tribe *Zingibereae* the basic number is x = 11, with a consistent diploid condition (2n = 2x = 22). In all members of the *Alpineae* studied so far, the basic number is x = 12 (n = 24) except in *Renealmia* (x = 11). In the *Hedychieae* the haploid number lacks the constancy seen in the *Alpineae* and *Zingibereae* and n = 10, 11, 12, 14, 17, 21 and 25 are reported.

INTRODUCTION

The cytology of species of the Zingiberaceae has been studied by various authors (Chakravorti, 1948, 1952; Raghavan & Venkatasubban, 1943; Sato, 1948, 1960; Sharma & Bhattacharyya, 1959; Spearing & Mahanty, 1964; Ramachandran, 1969; Mukherjee, 1970; Mahanty, 1970; Larsen, 1972; and Lim, 1972). Most of the reports were on Indian species and the African *Kaempferia,* and except for *Zingiber spectabile, Z. zerumbet, Alpinia mutica* and *Globba* spp., none of the native species of the Malay Peninsula (22 genera and about 155 species according to Holttum, 1950) have been studied cytologically.

Chromosome numbers and morphology of Zingiberaceae have previously been most often studied in somatic cells and information on chromosome behaviour at meiosis is sparse. The present study reports the meiosis of 33 species in the Malay Peninsula.

MATERIALS AND METHODS

Most of the species investigated were collected by the authors from the wild and transplanted to the nursery at the Penang Waterfall Garden. Also included in the investigation were species already in cultivation in the Penang Waterfall Garden which had been collected from different regions of Malaya by the various directors of the Garden. Unfortunately, records of the origins of the latter collections are not available. Voucher specimens (dried material and preserved inflorescences in FAA) as well as permanent slides of the chromosomes are deposited in the Universiti Sains Malaysia herbarium.

Young flower buds for chromosome studies were collected from the wild as well as from the nursery. They were fixed in Carnoy's solution (three parts absolute ethanol, and one part each of chloroform and glacial acetic acid) for 24 hours and then washed in two changes of 70% ethanol at 30 minute intervals. The buds were then stained for at least a week in alcoholic hydrochloric acid carmine (Snow, 1963). The stained buds were

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then rinsed in 70% ethanol and the anthers dissected out and squashed in 45% acetic acid.

Results and Observations

Chromosome numbers for the 33 Malayan species counted in this study are listed in Table 1. A compilation of the chromosome numbers of all species of Zingiberoideae reported elsewhere is given in Table 2. Some original references were not available to the present authors and counts were taken from Darlington & Wylie (1955), Ornduff (1967) and Moore (1970)—such cases are indicated in the references.

Tribe Zingibereae

This tribe consists of only the one genus *Zingiber*, of which about 13 species are found in Malaya (Holttum, 1950). Nine of these and one cultivar, *Z. zerumbet* cv. Darceyi (with variegated leaves) were investigated. All show $2n=22$ and regular meiosis, forming 11 bivalents at MI with equal segregation of the chromosomes at AI and AII (Fig. 1–10).

One species (*Kam* 312) could not be identified using Holttum's key to Malayan *Zingiber* (Holttum, 1950). The labellum is mottled purple with white side-lobes as in *Z. chrysostachys*, but the shape and bracts of the inflorescence do not fit the description of that species.

Tribe Hedychieae

There are 16 genera within the tribe *Hedychieae* (Burtt & Smith, 1972), of which seven occur in Malaya. Chromosome numbers of 10 species in the four genera, *Boesenbergia, Curcuma, Hedychium* and *Scaphochlamys* are reported here.

Boesenbergia. *Boesenbergia prainiana, B. plicata* and its variety *lurida* all have $n=10$. Fig. 27 and 28 show diakinesis in *B. plicata* and MII in *B. plicata* var. *lurida*. The preparation of *B. prainiana* was too poor to be photographed, but $n=10$ was also observed in this species.

Curcuma. *Curcuma aurantiaca* is the commonest species of *Curcuma* in Java (Holttum, 1950). The plant is cultivated in the Penang Waterfall Garden but the provenance of the original collection is not known. Like most of the species of *Curcuma* reported elsewhere the haploid number is $n=21$ (Fig. 29).

Hedychium. The *Hedychium coronarium* reported here is cultivated in the Cameron Highlands as an ornamental. The species is stated to be a native of Burma (Holttum, 1950). Seventeen bivalents were observed at MI (Fig. 30).

Scaphochlamys. Holttum (1950) recognized 20 species of this genus in the Malay Peninsula. The haploid number of four species and one unidentified plant are reported here. *Scaphochlamys biloba*, an East Malayan species, has $n=13$ (Fig. 31). The collection was made at Bukit Bakar, Kelantan, and the population was polymorphic for presence or absence of white

bands on the upper surface of the leaves and for purplish versus green undersurface.

The other species, *S. kunstleri, S. oculata, S. perakensis* and *S.* sp., are West Malayan plants and all have n = 14 (Figs 32–34). Meiosis was regular in all the species of *Scaphochlamys* studied: bivalents were regularly formed at MI and segregation of the homologous chromosomes at AI was even.

The *S. perakensis* population at Selama, Perak, was also found to be morphologically variable. There was a gradation in the colour intensity of the floral bracts, some plants having pale green bracts, while others had them slightly tinted with red or intensely red at the edges. The white labellum of the flower also differed from plant to plant: in some there were markings on both sides of the midline near the base, whereas others lacked these markings. All these variants were found growing near each other, and all proved to have n = 14.

Initial study of the breeding system of *S. perakensis* showed that the species is self-incompatible. Pollen-grains did not germinate on the stigma of the parent plant whereas foreign pollen-grains germinated quickly. The pollen-tubes reached the base of the style within five to six hours after pollination. The flower is ephemeral, lasting for about a day; it opens in the early morning and begins to disintegrate by the later afternoon. Therefore, for fertilization to occur, cross-pollination must take place within a few hours after the flower opens. Possibly, for these reasons, the fruits and the seeds have never been collected for many species of *Scaphochlamys*.

Tribe Alpineae

Burtt & Smith (1972) listed 24 genera in this tribe, and 12 are known to occur in Peninsular Malaya (Holttum, 1950). The chromosome numbers of 16 species in five genera have been investigated in this study.

Achasma. The young inflorescences of *Achasma* are subterranean and it is difficult to obtain young flower buds for chromosome study. The inflorescences only emerge partially above ground when they flower, by which time they are already too old for meiotic study. The chromosome number of only one species, *Achasma triorgyale,* has been determined. Fig. 11 shows the 24 chromosomes at MII. All the chromosomes are about the same size (c. 0·7 μm) and they are amongst the smallest encountered in the family.

The flowers of *Achasma* are visited by the Spider Hunter, *Arachmothera longirostra,* a nectar-feeding bird. When the flower withers into a slimy mess, the lower part of the labellum rolls spirally inwards and towards the anther and stigma. This facilitates self-pollination. However, very few fruits have been encountered in this genus and those of *A. triorgyale* are unknown. Possibly the species are self-incompatible as in *Scaphochlamys* (see above).

Amomum. The seven species of *Amomum* (Figs 12–18) reported here all show 24 bivalents at meiosis except *A. lappaceum,* which is heterozygous for a single interchange and forms a ring of four associated chromosomes

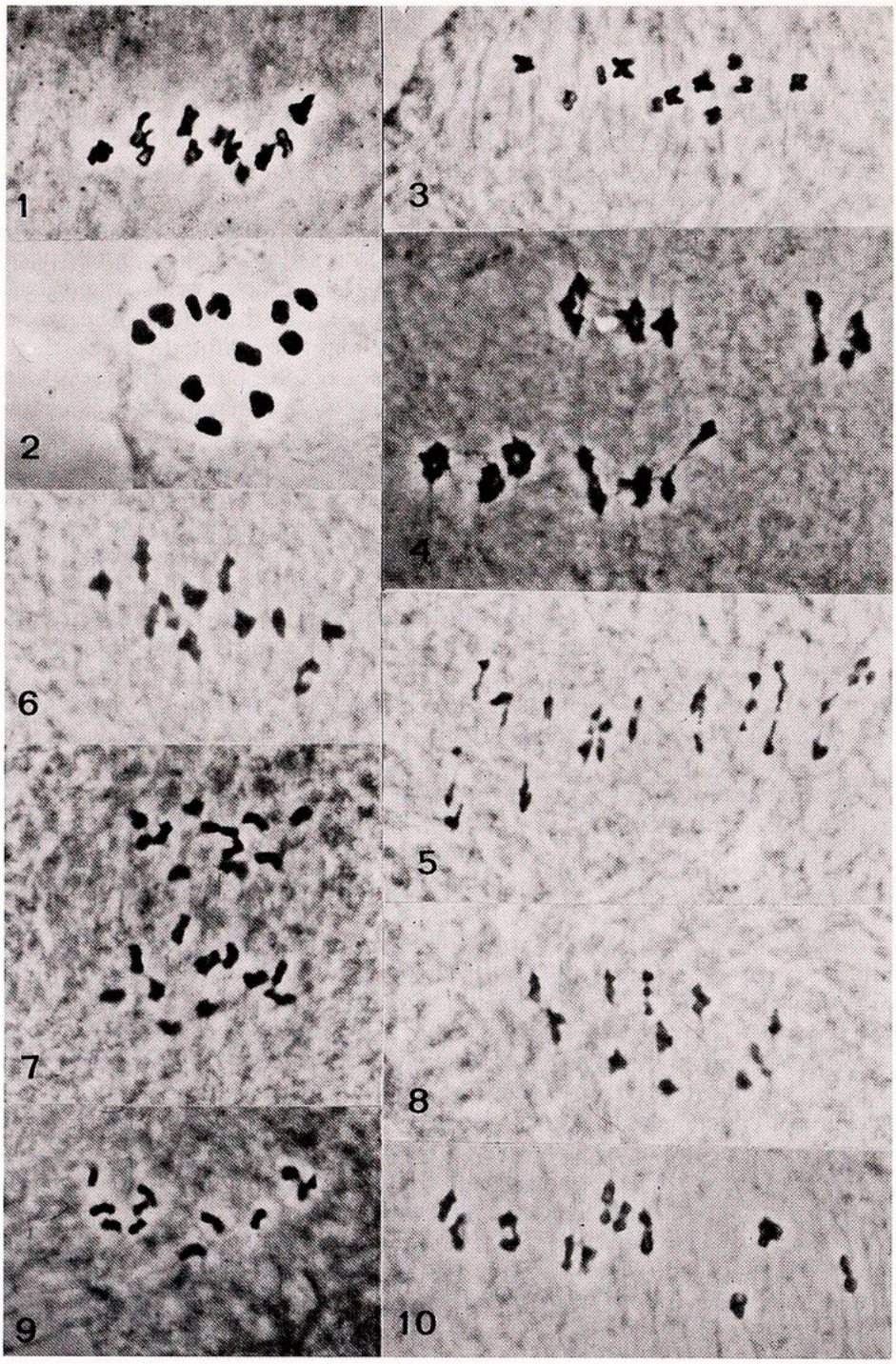

FIG. 1–10 (×1200): 1, *Zingiber purpureum*, MII, n=11; 2, *Z. chrysostachys*, MII, n=11; 3, *Z. griffithii*, MII, n=11; 4, *Z. multibracteatum*, MI, 11_{11}; 5, *Z. ottensii*, MI–AI, 11_{11} dissociating; 6, *Z. puberulum* var. *ovoideum*, MI, 11_{11}; 7, *Z. spectabile*, AII, n=11; 8, *Z. zerumbet*, MI, 11_{11}; 9, *Z. zerumbet* cv. Darceyi, AII, n=11; 10, *Z.* sp., MI, 11_{11}.

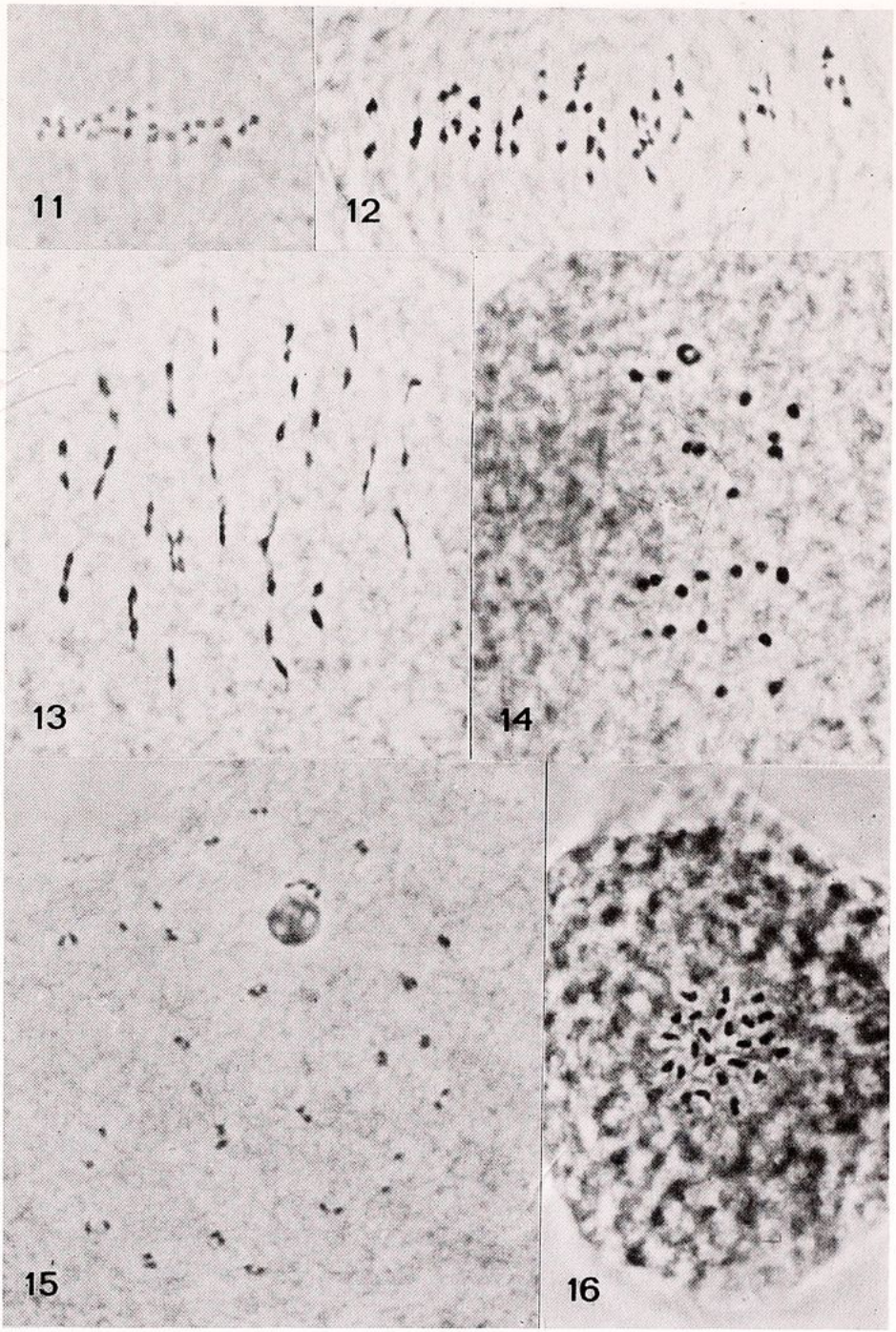

FIG. 11–16 (15 × 600, others × 1200): 11, *Achasma triorgyale,* MII, n = 24; 12, *Amomum aculeatum,* MI, 24_{II}; 13, *A. hastilabium,* MI, 24_{II}; 14, *A. lappaceum,* MI, 22_{II} + 1 ring IV; 15, *A. macrodus* diakinesis, 24_{II}; 16, *A, squarrosum,* MII, n = 24.

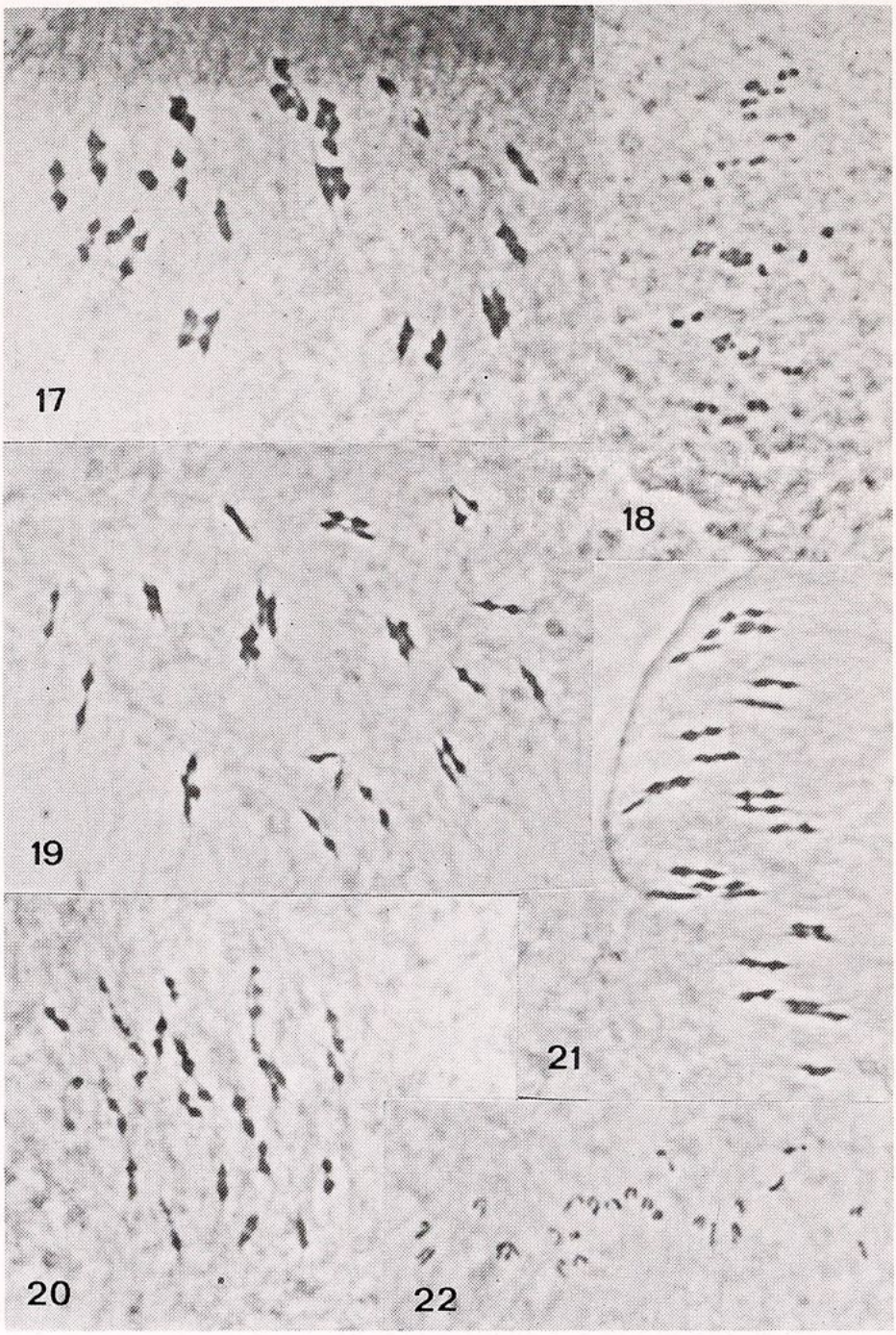

FIG. 17–22 (×1200): 17, *Amomum testaceum*, MI, 24_{11}; 18, *A. uliginosum*, MI, 24_{11}; 19, *Elettariopsis curtisii*, MI, 24_{11}; 20, *E. smithiae*, MI, 24_{11}; 21, *E. smithiae* var. *rugosa*, MI, 24_{11}; 22, *E. triloba*, AII, n=24. Note 2ndry associations in 17–21.

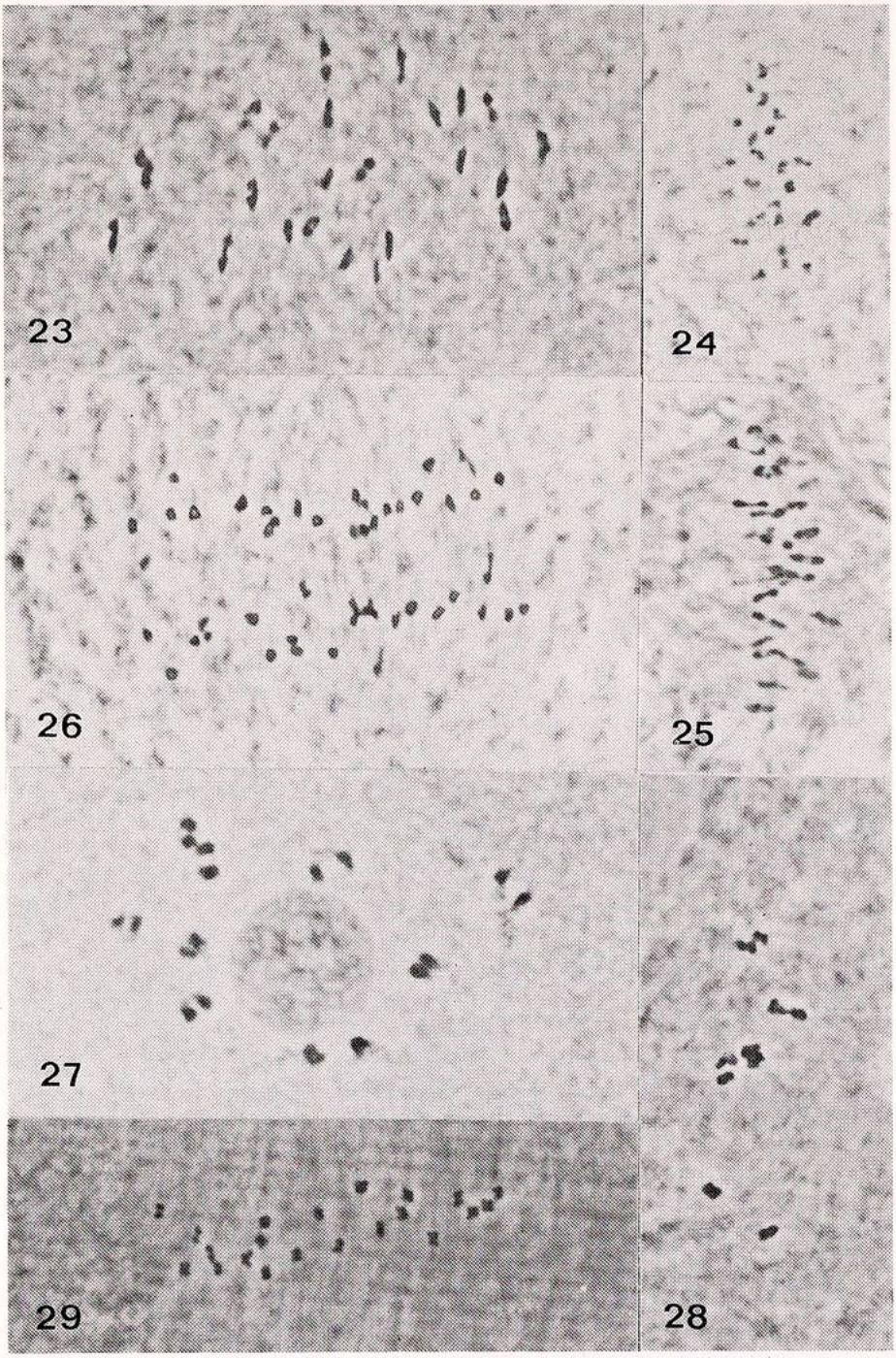

FIG. 23–29 (×1200): 23, *Hornstedtia leonurus*, MI, 24_{11}; 24, *Nicolaia elatior*, MII, n=24; 25, *N. maingayi*, MI, 24_{11}; 26, *N. venusta*, AI, n=24; 27, *Boesenbergia plicata*, diakinesis, 10_{11}; 28, *B. plicata* var. *lurida*, MII, n=10; 29, *Curcuma aurantiaca*, MII, n=21.

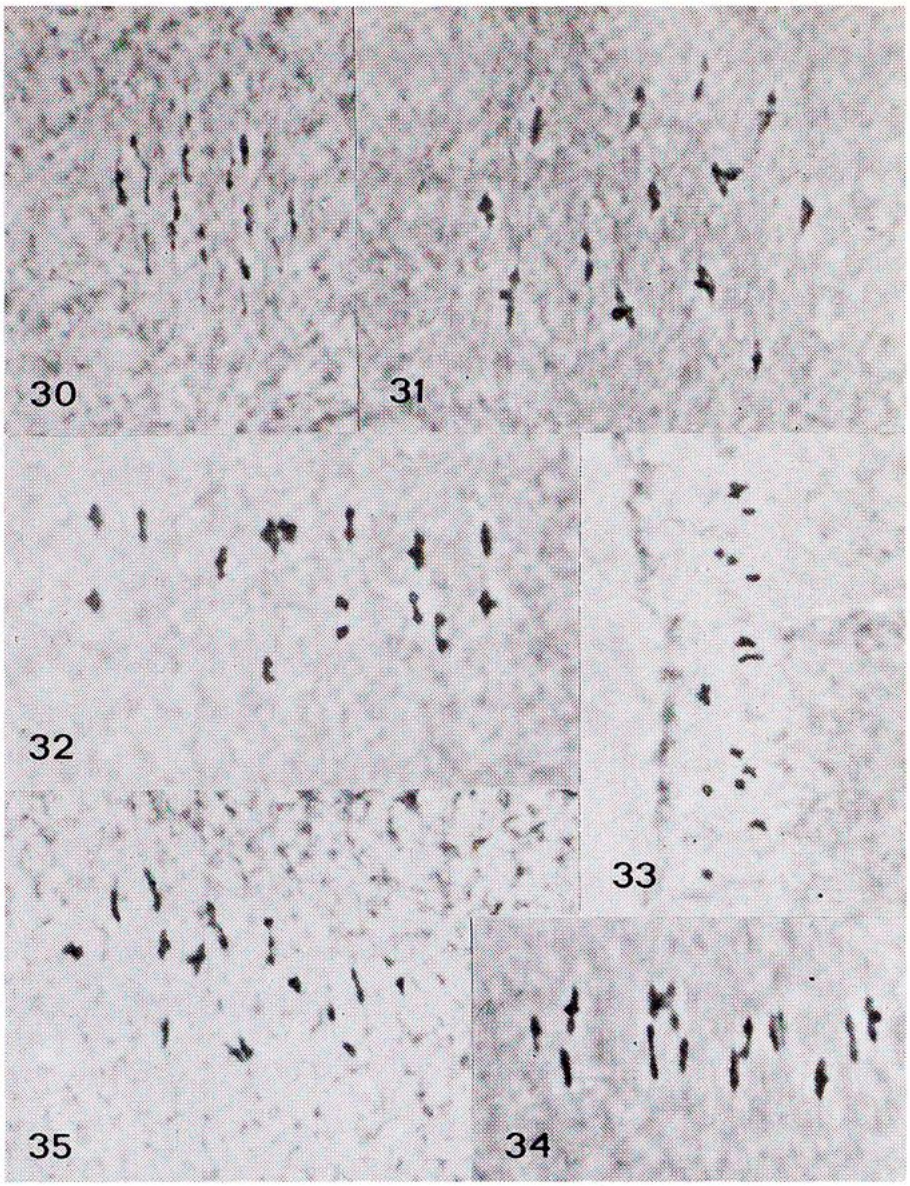

FIG. 30–34 (×1200): 30, *Hedychium coronarium*, MI, 17_{11}; 31, *Scaphochlamys biloba*, MI, 13_{11}; 32, *S. kunstleri*, yellow var., MI, 14_{11}; 33, *S. oculata*, MII, n=14; 34, *S. perakensis*, MI, 14_{11}; 35, *S.* sp. MI, 14_{11}.

plus 22 bivalents at MI (Fig. 14). In all cases n=24. The size of the chromosomes differs in different species. *A. testaceum* seems to have larger chromosomes which are comparable in size to those of *Zingiber*.

Elettariopsis. This genus, in which Kam (1982) recognized five Malayan species, has not previously been studied cytologically. Three species and a variety, *E. smithiae* var. *rugosa*, are reported here (Figs 19–22), all

showing n = 24 and regular meiosis. The length of the chromosomes of *E. triloba* varies from 1·6 μm to 4·15 μm.

Hornstedtia. There are seven known species of *Hornstedtia* in Malaya (Holttum, 1950). *H. leonurus* shows 24 bivalents at MI (Fig. 23), and this is the first chromosome number to be reported in the genus. The size of the chromosomes is similar to those of *Amomum* and *Scaphochlamys*.

Nicolaia. Out of the four species recognized by Holttum in this genus, for which he used the incorrect name *Phaeomeria* (1950, 1974), the chromosome numbers of three, *N. elatior, N. maingayi* and *N. venusta,* are reported here. All show 24 bivalents at MI and regular segregation at AI (Figs 24, 25). The small size of the chromosomes (0·7 μm) of *N. elatior* is similar to that of *Achasma triorgyale*.

Discussion

Tribe Zingibereae

Burtt & Olatunji (1972) proposed that the genus *Zingiber* be recognized as an independent tribe, the *Zingibereae*. This is based on the observation that *Zingiber* can be distinguished from the *Hedychieae* by the characteristic lateral staminodes, the anther crest wrapped around the style, and by the morphology and anatomy of the petiole. These characters are of the same order as those separating the *Hedychieae* and *Alpineae*.

Zingiber is a widely distributed genus whose species range from Indomalaysia to Southeast Asia and as far east as Japan. All the Indian and Malayan species examined are diploids (2n = 22), while the one species from Japan, *Z. mioga,* is pentaploid (2n = 55). Meiosis in most of the diploids examined was regular. However, structural hybridity for inversions has been reported in *Z. macrostachyum* and *Z. officinale* (Ramachandran, 1969). Aneuploidy (2n = 24), polyploidy (2n = 66), and β-chromosomes have also been observed in the somatic cells of the cultivated ginger, *Z. officinale* (see Table 2). Reproduction of *Z. officinale* is by vegetative means, as it is not known to set seeds. Thus, any somatic mutation in the tissue of the growing shoot can easily be propagated by cultivation, and clones of different chromosomal biotypes are formed. It has been suggested that for members of *Zingibereae* in which propagation is exclusively asexual, this may be the only way through which speciation is accomplished (Sharma & Bhattacharyya, 1959).

Tribe Hedychieae

In tribe *Hedychieae* the 12 genera that have been cytologically examined show a wide range of numbers from n = 10 to 34 (Tables 1 & 2). The lowest basic number, n = 10, is found in *Caulokaempferia* (Larsen, 1964) and *Boesenbergia. B. longifolia,* examined by Ramachandran (1969), has n = 25 and was recently assigned to a new genus *Curcumorpha* based on morphological characters (Rao & Verma, 1971). The two Malayan *Boesenbergia* species and the one variety examined have n = x = 10 and are quite different cytologically from *B. longifolia*. The transfer of *B. longifolia* to the new monotypic genus *Curcumorpha* is thus supported.

Caulokaempferia was established by Larsen (1964) for species which were formerly placed in *Kaempferia*. He suggested that the new genus is probably closer to *Camptandra* and *Boesenbergia* than to *Kaempferia*. The inflorescence of *Caulokaempferia* is variable but most of the species examined had determinate inflorescences, where the uppermost flower opens first as in *Boesenbergia* (Larsen & Smith, 1972). The somatic chromosome number of $2n=20$ reported for *C. saxicola* from Thailand indicates a basic number $x=10$ for *Caulokaempferia* (Larsen, 1964). Thus *Caulokaempferia* and *Boesenbergia* share the same basic number and a determinate inflorescence, which is not found elsewhere in the family, suggesting their close relationship.

The genus *Scaphochlamys* is largely endemic to the Malay Peninsula with outliers in Peninsular Thailand and Borneo. The genus is one of the most polymorphic of the family, and has more local species than any other (Holttum, 1950). The inflorescence with its spirally arranged floral bracts provides the main distinguishing characters in the separation of the species. Each floral bract encloses a cincinnus of several flowers except in *S. biloba* (incl. *S. longifolia*) where each floral bract has only one flower. *S. biloba* has $n=13$, the three other species counted have $n=14$.

Change in basic chromosome number and occurrence of polyploidy in association with migration has been well described by Stebbins (1971). An example of this has also been reported in the genus *Kaempferia* sens. lat. The Asiatic species of *Kaempferia* show a preponderance of diploids, $2n=22$, presumably derived from a basic $x=11$: the African species, however, have either $2n=28$ or $2n=42$ with $x=14$ as the basic number (Spearing & Mahanty, 1964). Evidence from morphology, anatomy and cytology warrants the recognition of the African species as a separate genus. This was set out in full under the name *Cienkowskiella* by Kam (1980), but unfortunately the generic name has had to be superseded by *Siphonochilus* (Burtt, 1982).

Tribe Alpineae

Ten of the 24 genera of the *Alpineae* have been studied cytologically and all, except *Renealmia*, appear to have a basic number of $x=12$. In these $x=12$ genera only a single diploid has been recorded, *Alpinia intermedia* from Taiwan (Hsu, 1967); the rest of the species that have been counted are tetraploids with $2n=48$.

All the $x=12$ genera are Asiatic in origin, except *Aframomum* which is from tropical Africa. *Renealmia* from tropical west Africa and tropical America has a basic number of $x=11$, and out of the 15 species examined only two are diploids and the rest are tetraploids (Kliphuis & Maas, 1977). Thus in the *Alpineae*, the Asiatic genera form a natural group with a basic number of $x=12$ and, judging from the species so far investigated, preponderant tetraploidy.

The tribal classification of Zingiberoideae

The classification of Zingiberoideae into four tribes (*Zingibereae, Hedychieae, Globbeae* and *Alpineae*) can now be compared with the available cytological information. *Zingibereae* (with the single genus *Zingiber*) has a consistent basic number of $x=11$ with most of the species

diploid. *Hedychieae* shows a remarkably wide range of basic numbers in its genera, x = 9, 10, 11, 12, 13, 14, 16, 17, 18, 21, 25 and 27, together with various polyploid and high aneuploid derivatives in the 12 genera that have been studied cytologically. *Kaempferia* has x = 11 and the largest chromosomes (2·4 μm–5·8 μm) in the tribe, much the same size as those of *Zingiber* (2·1 μm–4 μm) which has the same basic number. Thus chromosome number gives no evidence to support the treatment of *Zingiber* as a separate tribe, although *Kaempferia* and *Zingiber* can scarcely be close allies.

Chromosome size in the rest of *Hedychieae* is comparable with that of most of *Alpineae:* only in *Achasma triorgyale* and *Nicolaia elatior* are the chromosomes remarkably small. However, the cytological pattern of *Alpineae* is quite different from that of *Hedychieae*. In *Alpineae* the basic number x = 12 is widespread, with a great majority of species having 2n = 48. This applies to all the Asiatic genera studied and to *Aframomum* in tropical Africa. The one exception is *Renealmia,* from tropical America and tropical west Africa: here the basic number is x = 11, but again nearly all the species that have been examined are tetraploids with 2n = 44.

No species of the tribe *Globbeae* were included in this investigation as the Malayan species have been intensively studied by Lim (1972)—for completeness, however, *Globba* is included in Table 2. The situation in *Globba* is complicated and a wide range of chromosome numbers has been recorded. Lim has provided very strong evidence for a basic number of x = 8, but there may be a secondary x = 11 and other numbers. Other genera of the tribe are unknown cytologically.

It should be noted that triploids and pentaploids are not uncommon in genera which are much propagated by vegetative means (e.g. *Curcuma* and *Zingiber*). The same occurs in *Globba,* where many species produce asexual bulbils, and triploids are common.

The conclusion may be reached that the tribes of Zingiberoideae tend to show different patterns in their chromosome numbers, which confirms that they are natural groupings.

TABLE 1

Chromosome numbers in Malayan Zingiberaceae

	n	Origin	Collection No.
Tribe Zingibereae			
Zingiber chrysostachys Ridl.	11	W	*Beltran* 224
griffithii Bak.	11	Te	*Kam* 323
multibracteatum Holtt.	11	Ulu Gombak, Selangor	*Kam* 328
ottensii Valet.	11	Sungai Ara, Penang	*Beltran* 202
puberulum var. ovoideum Holtt.	11	Ta	*Kam* 189
purpureum Rosc. (syn. Z. cassumunar Roxb.)	11	Penang (cult.)	*Beltan* 209
spectabile Griff.	11	W	*Beltran* 219
	11	Ta	*Kam* 202
zerumbet (L.) Sm.	11	W	*Beltran* 157
zerumbet cv. Darceyi	11	W	*Beltran* 225
Z. sp.	11	W	*Kam* 312
Tribe Hedychieae			
Boesenbergia plicata (Ridl.) Holtt.	10	Ta	*Kam* 222
plicata var. lurida (Ridl.) Holtt.	10	W	*Beltran* 159
prainiana (Bak.) Schltr.	10	Kuala Rompin, Johore	*Beltran* 170
Curcuma aurantiaca van Zijp.	21	W	*Beltran* 164
Hedychium coronarium Koenig	17	Cameron Highlands, Pahang	*Beltran* 206
Scaphochlamys biloba (Ridl.) Holtt.	13	Bukit Bakar, Kelantan	*Beltran* s.n.
kunstleri (Bak.) Holtt.	14	Bukit Berapit, Perak	*Beltran* 187
oculata (Ridl.) Holtt.	14	Ulu Gombak, Selangor	*Kam* 326
perakensis Holtt.	14	Selama, Perak	*Kam* 272
S. sp.	14	W	*Beltran* 223
Tribe Alpineae			
Achasma triorgyale (Bak.) Holtt.	24	Te	*Beltran* 122
Amomum aculeatum Roxb.	24	W	*Beltran* 210
hastilabium Ridl.	24	Sungai Bakap, Penang	*Beltran* 140
lappaceum Ridl.	24 (incl. ring of 4)	Bukit Hijau, Perak	*Kam* 233
macrodous Scort.	24	Gunung Keledang, Perak	*Beltran* 123
squarrosum Ridl.	24	Te	*Beltran* 113
testaceum Ridl.	24	W	*Kam* 342
	24	Gunung Tempurong, Perak	*Beltran* 194
uliginosum Koenig	24	W	*Kam* 315
Elettariopsis curtisii Bak.	24	Sungai Buloh, Selangor	*Beltran* 100
	24	Ta	*Kam* 221
	24	W	*Kam* 352
smithiae Kam	24	Ulu Gombak, Selangor	*Beltran* 110
var. rugosa Kam	24	W	*Kam* 228 (holo. KLU)
	24	Te	*Kam* 332
triloba (Gagnep) Loes.	24	W	*Beltran* 204
	24	Kuala Rompin, Johore	*Beltran* 182
Hornstedtia leonurus (Koenig) Retz.	24	Te	*Kam* 321
Nicolaia elatior (Jack) Horan.	24	Sungai Dua, Penang	*Beltran* 161
(syn. N. speciosa (Bl.) Horan.)	24	Gunong Tempurong, Perak	*Beltran* 193
maingayi (Bak.) Horan.	24	W	*Kam* 114
venusta (Ridl.) Horan.	24	Ulu Berang, Trengganu	*Beltran* s.n.

W = Waterfall Garden, Penang; Ta = Taman Negara, Pahang; Te = Templar Park, Selangor.

TABLE 2

Chromosome numbers of Zingiberoideae

	Origin	n	2n	Author
Tribe Zingibereae				
Zingiber cylindricum Thwaites	Ceylon		22	Mahanty, 1970
macrostachyum Dalz.	India	11	22	Ramachandran, 1969
mioga Rosc.	Japan		55	Morinaga et al., 1929
			55	Sato, 1948
			55, 53	Suzuka & Mitsuoka, 1968
officinale Rosc.	India		22	Raghavan & V., 1943
	cult.		22	Morinaga et al., 1929
			24	Takahaski, 1930
	Malaya		22+2B	Janaki-Ammal, 1945
			22	Sharma & B., 1959
			66	Bisson et al., 1968
purpureum Rosc. (Syn. Z. cassumunar Roxb.)	India		22	Raghavan & V., 1943
		11	22	Chakravorti, 1948
roseum Rosc.	Nepal, India	11	22	Ramachandran, 1969
rubens Roxb.	India	11	22	Chakravorti, 1948
spectabile Griff.	Malaya		22	Mahanty, 1970
wightianum Thwaites	India	11	22	Ramachandran, 1969
zerumbet (L.) Sm.	India		22	Raghavan & V., 1943
		11		Chakravorti, 1948
		11	22	Ramachandran, 1969
zerumbet 'darceyi'		11		Bhattacharyya, 1968
Tribe Hedychieae				
Boesenbergia longiflora (Syn. Curcumorpha longiflora (Wall.) Rao & Verma.)	Indomal. Nepal	25		Ramachandran, 1969 See Smith, R. M., 1981
Brachychilum thyrsiforme	Java		32	Holzer, 1952
Caulokaempferia saxicola K. Larsen	Himalaya		20	Larsen, 1964
Cautleya spicata Baker			34	Sharma & B., 1959
	W Himalaya	13		Mehra & Sachdeva, 1971
	E Himalaya	13		Sachdeva, 1977
lutea Royle	E Himalaya	12, 13		Sachdeva, 1977
Curcuma amada Roxb.	India		42	Raghavan & V., 1943
			42	Chakravorti, 1948
			42	Sharma & B., 1959
			42	Ramachandran, 1969
angustifolia Roxb.	India		42	Chakravorti, 1948
			42	Sharma & B., 1959
aromatica Salisb.	India		42	Raghavan & V., 1943
			42	Chakravorti, 1948
			63	Ramachandran, 1969
decipiens Dalz.	India	21	42	Ramachandran, 1969
longa L.	India		64	Sugiura, 1931
	Malaya		62	Raghavan & V., 1943
			32	Sato, 1948
			62, 63, 64	Chakravorti, 1948
			62	Sharma & B., 1959
			63	Ramachandran, 1969
neilgherrensis Wt.	India	21	42	Ramachandran, 1969
petiolata Roxb.	Burma		64	Venkatasubban, 1946

TABLE 2 (cont.)

	Origin	n	2n	Author
zedoaria Rosc.	India		63, 64	Chakravorti, 1948
			64	Venkatasubban, 1946
			63	Ramachandran, 1969
Siphonochilus*				
(Kaempferia) brachystemon (K. Schum) B. L. Burtt	Trop. Africa		26	Mahanty, 1970
aethiopicus (Schweinf.) B. L. Burtt	Trop. Africa		26	Mahanty, 1970
kirkii (Hooker) B. L. Burtt	Trop. Africa		28	Mahanty, 1970
carsonii	Trop. Africa		28	Mahanty, 1970
rosea	Trop. Africa		28	Mahanty, 1970
'ethelae'	Trop. Africa		26	Mahanty, 1970
S. sp.	Trop. Africa		42	Mahanty, 1970
			28	Mahanty, 1970
Hedychium angustifolium Hamilt.	India		34	Mukherjee, 1970
			52	Venkatasubban, 1946
aurantiacum Hamilt.	India		34	Sharma & B., 1959
			34	Mukherjee, 1970
coccineum Ridl.	Nepal		68	Mukherjee, 1970
coccineum var. angustifolium		17		Bhattacharyya, 1968
conronarium Koenig	India	18		Bhattacharyya, 1968
			54	Raghavan & V., 1943
			54	Chakravorti, 1948
		17	34	Sharma & B., 1959
		17	34	Ramachandran, 1969
		17	51	Ramachandran, 1969
			18	Hsu, 1967
		17		Bhattacharyya, 1968
var. angustifolium	Sikkim		34	Sharma & B., 1959
var. chrysoleucum		17		Bhattacharyya, 1968
var. flavescens		25		Bhattacharyya, 1968
var. flavum		17		Bhattacharyya, 1968
var. flavum type 1		17		Bhattacharyya, 1968
var. flavum type 2		26		Bhattacharyya, 1968
var. maximum			34	Sharma & B., 1959
		17		Bhattacharyya, 1968
elwesii Baker	India		66	Gregory, 1936
ellipticum Hamilt.			34	Mukherjee, 1970
flavescens Cau.	Sikkim		34	Raghavan & V., 1943
			51	Sharma & B., 1959
flavum Roxb.	India		52	Raghavan & V., 1943
			34	Sharma & B., 1959
			34	Mukherjee, 1970
gardnerianum Rosc.	Sikkim		54	Raghavan & V., 1943
			34	Sharma & B., 1959
gracile Roxb.	India		66	Raghavan & V., 1943
greenii			36	Raghavan & V., 1943
			52	Sharma & B., 1959
spicatum Hamilt.	Himalaya		34	Sato, 1948
			34	Mukherjee, 1970

*See p. 550.

TABLE 2 (cont.)

	Origin	n	2n	Author
thyrsiforme Hamilt.	Himalaya		24	Sharma & B., 1959
		17		Mahanty, 1970
villosum Wall.	Sikkim		34	Sharma & B., 1959
Hitchenia caulina Baker	India	21		Ramachandran, 1969
Kaempferia angustifolia	India		54	Sharma & B., 1959
			22	Mahanty, 1970
		11	22	Chakravorti, 1948
atrovirens		11		Bhattacharyya, 1968
decora		14+ (1–4f)		Bhattacharyya, 1968
elegans (Wall.) Bak.	Burma	11	22	Mahanty, 1970
galanga L.	India		54	Raghavan & V., 1943
		11	22	Sharma & B., 1959
			54	Ramachandran, 1969
gilbertii Bull	India		36	Raghavan & V., 1943
			33	Chakravorti, 1948
			33	Mahanty, 1970
		17		Bhattacharyya, 1968
gibsoni			24	Raghavan & V., 1943
ovalifolia Roxb.	Sikkim	11	22	Sharma & B., 1959
pulchra Ridl.	Thailand	11	22	Mahanty, 1970
rotunda L.	India		54	Raghavan & V., 1943
			33	Chakravorti, 1948
			44	Ramachandran, 1969
			33	Mahanty, 1970
		$16+1_1$ (=17)		Bhattacharyya, 1968
speciosa Baker	Burma		22	Venkatasubban, 1946
Roscoea alpina Royle	India		24	Sharma & B., 1959
		12		Mahanty, 1970
cautleoides Gagnep.			24	Mahanty, 1970
humeana Balf. & Smith	China		24	Mahanty, 1970
purpurea Smith	Burma		24	Bisson et al., 1968
		13		Bhattacharyya, 1968
procera Smith	W Himalaya	13		Mehra & Sachdeva, 1971
	E Himalaya	13		Sachdeva, 1977
Tribe Alpineae				
Alpinia aquatica Rosc.		24	48	Chakravorti, 1948
bracteata Roxb.		24	48	Chakravorti, 1948
calcarata Rosc.	India		48	Raghavan & V., 1943
			48	Chakravorti, 1948
chinensis (Retz.) Rosc.	China		48	Sato, 1948
formosana K. Schum.	Taiwan		48	Mahanty, 1970
		24		Hsu, 1968
galanga (L.) Willd.	India		48	Raghavan & V., 1943
			48	Ramachandran, 1969
intermedia Gagnep.	Taiwan	12		Hsu, 1967
japonica Bl.	Japan		48	Sato, 1948
malaccensis Rosc.	NE India	24	48	Chakravorti, 1948
mutica Roxb.	Malaya		48	Mahanty, 1970
nigra (Gaertn.) Burtt	India			See Burtt, 1977
(syn. A. allughas Rosc.)			48	Raghavan & V., 1943
			48	Chakravorti, 1948
			48	Ramachandran, 1969
nutans Rosc.	NE India		48	Raghavan & V., 1943
		24	48	Chakravorti, 1948
		25		Bhattacharyya, 1968

TABLE 2 (cont.)

	Origin	n	2n	Author
vittata Bull	Polynesia		48	Raghavan & V., 1943
sanderae		23		Bhattacharyya, 1968
Aframomum granum paradisi (Hook.) Schum.	Africa		48	Bisson et al., 1968
latifolium Schum.	Africa		48	Mangenot & M., 1962
Amomum hypoleucum Thwaites	S India		48	Ramachandran, 1969
involucratum Benth.	S India		48	Ramachandran, 1969
microstephanum Baker	S India		48	Ramachandran, 1969
magnificum Rosc.	E Indies		48	Venkatasubban, 1946
subulatum Roxb.	Himalaya	24	48	Sharma & B., 1959
Burbidgea schizocheila hort.	Borneo		48	Bisson et al., 1968
Elettaria cardamomum Maton.	India		48	Gregory, 1936
	cult.		52	Chakravorti, 1948
	cult.		48	Sato, 1948
	India		48	Sharma & B., 1959
	S India	24	48	Ramachandran, 1969
		24		Bhattacharyya, 1968
speciosa		26		Bhattacharyya, 1968
Nicolaia (Phaeomeria) atropurpurea	Malaya	24		Boehm, 1931
Renealmia africana	Africa		44	Gadella, 1972
alpinia	Trop. Amer.		44	Kliphuis & Maas, 1977
battenbergiana Cummis.	Africa		44	Mangenot & M., 1962
breviscapa	Trop. Amer.		44	Kliphuis & Maas, 1977
caucana	Trop. Amer.		44	Kliphuis & Maas, 1977
guianenis	Trop. Amer.		44	Kliphuis & Maas, 1977
ligulata	Trop. Amer.		22, 44	Kliphuis & Maas, 1977
maculata Stant.	Africa		44	Mangenot & M., 1962
nicolaioides	Trop. Amer.		44	Kliphuis & Maas, 1977
occidentalis var. occidentalis	Trop. Amer.		44	Kliphuis & Maas, 1977
pallida	Trop. Amer.		44	Kliphuis & Maas, 1977
polypus	Africa		44	Kliphuis & Maas, 1977
puberula	Trop. Amer.		22	Kliphuis & Maas, 1977
scaposa	Trop. Amer.		44	Kliphuis & Maas, 1977
thyrsoidea subsp. thyrsoidea	Trop. Amer.		44	Kliphuis & Maas, 1977
Tribe Globbeae				
Globba albiflora Ridl.				
var. albiflora	Malaya	16	32	Lim, 1972
var. aurea Holtt.	Malaya	16	32	Lim, 1972
		16		Mahanty, 1970
aphanantha K. Larsen	Thailand		28	Larsen, 1972
atrosanguinea Teysm. & Binn.	Borneo	24		Mahanty, 1970
bulbifera Roxb.	India & Malaya		48	Raghavan & V., 1943
			48	Chakravorti, 1948
			44	Sharma & B., 1959
cernua Bak,				
subsp. cernua	Malaya	16, 24	32, 48	Lim, 1972
subsp. crocea Lim	Malaya	16, 24	32, 48	Lim, 1972
subsp. porphyria Lim	Malaya	16	32	Lim, 1972
clarkei Bak.	Thailand	12	24	Larsen, 1972
curtissi Holtt.	Malaya	24	48	Lim, 1972
fragilis Lim	Malaya	16	32	Lim, 1972
garrettii Kerr	Thailand		32, 48	Larsen, 1972

TABLE 2 (cont.)

	Origin	n	2n	Author
heterobractea K. Schum.	Phillipines	32		Mahanty, 1970
holttumii Lim				
subsp. aurea Lim	Malaya	24	48	Lim, 1972
subsp. holttumii	Malaya	24	48	Lim, 1972
hookeri C. B. Cl.	Reg. Himalayas		22	Sharma & B., 1959
×intermedia Lim	Malaya	24	48	Lim, 1972
kerri Craib	Thailand		32	Larsen, 1972
laeta K. Larsen	Thailand		32	Larsen, 1972
leucantha Miq.				
var. peninsularis Holtt.	Malaya	16	32	Lim, 1972
marantina L.	Malaya		80	Lim, 1972
nisbethiana Craib	Thailand		c. 32	Larsen, 1972
nuda K. Larsen	Thailand	17		Larsen, 1972
obscura K. Larsen	Thailand		32	Larsen, 1972
patens Miq.				
var. costulata Lim	Malaya	16	32	Lim, 1972
var. patens	Malaya	16, 24	32, 48	Lim, 1972
pendula Roxb.	cult.		32	Larsen, 1972
subsp. montana (Ridl.) Lim	Malaya	16	32	Lim, 1972
subsp. pendula	Malaya	16, 24	32, 48	Lim, 1972
subsp. pendula var. elegans (Ridl.) Holtt.	Malaya	16	32	Lim, 1972
purpurescens Craib	Thailand		32	Larsen, 1972
racemosa Smith	Reg. Himalayas		24	Sharma & B., 1959
reflexa Craib	Thailand		32	Larsen, 1972
schomburgkii Hook. f.	Thailand		c. 64	Larsen, 1972
	cult.		48	Larsen, 1972
			48	Bisson et al., 1968
unifolia Ridl.				
var. sessiliflora Holtt.	Malaya		32	Lim, 1972
variabilis Ridl.				
subsp. pusilla Lim	Malaya	16	32	Lim, 1972
subsp. variabilis	Malaya	24	48	Lim, 1972
winitii C. H. Wright	Thailand, cult.	16	32	Larsen, 1972
	Thailand, cult.		48	Bisson et al., 1968
	Thailand, cult.	16		Mahanty, 1970

ACKNOWLEDGEMENTS

We wish to thank Dr B. Stone of the University of Malaya and Miss R. M. Smith and B. L. Burtt for their helpful suggestions and comments on the preparation of the manuscript. We should also like to thank Encik Adenan Jaji Jaafar for his help in the collection of live specimens, Mr Chong Peng Keat for his technical advice on photography and Puan Fatimatol Zahrah Ismail who typed the manuscript. Permission by Mr Lye Fook Sun, the former Director of Penang Waterfall Garden, to use the cultivated species of Zingiberaceae is gratefully acknowledged.

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