PART III

DISCUSSION

DISCUSSION

Chromosome number :

Among the 20 species and a variety of the genus Indigofera studied, 16 species and a variety have 2n = 16, 2 species viz. I. hochstetteri and I. angulosa have 2n = 32 and the remaining 2 species viz. I. amblyantha and I.heterantha have 2n = 48 chromosomes in their somatic complements.

Based on the present and previous reports (Senn, 1938; Sampath and Ramanathan, 1949; Ramanathan, 1950, 1959; Darlington and Wylie, 1955; Cave, 1956-62; Frahm-leliveld, 1953, 1960a, 1960b, 1962, 1966; Turner, 1956; Miege, 1962; Bir and Sidhu, 1966, 1967; Singh and Roy, 1970 and Bhatt, 1974), it can be concluded that, 2n = 16 is the most predominant chromosome number in the genus, suggesting x = 8 as the primary base number. However, Senn (1938) and Frahm-leliveld (1966) based on their reports of 2n = 12 in I. anil and I. microcalyx respectively, have suggested x = 6 as one of the base numbers. Further Frahm-leliveld's observation of 2n = 8 in I.richardsiae made him to suggest that x = 4 as the base number, from which the tetraploid species having 2n = 16 must have originated. Singh and Roy (1970) have remarked that, the proposed base number x = 4 has to be accepted with reservation, till more critical evidences are brought forth.

In the present work, as well, x = 4 is not observed in any species nor could be arrived at by meiotic behaviour.

The diploid number 2n = 16 has been reported in the species I. hochstetteri (Frahm-leliveld, 1960; Singh and Roy, 1970), I. amblyantha (Frahm-leliveld, 1960) and I. heterantha (Bir and Sidhu, 1960). However, in the present work, 2n = 48 is observed in I. amblyantha and I. heterantha and 2n = 32 in I. hochstetteri and in I. angulosa. Occurrence of 8 groups of 16 bivalents during meiosis (Fig. 67) in I. angulosa indicates the euploid origin of the species from a parent having x = 8. Thus, the above observations further substantiates the claim of considering x = 8 as the base number, from which species with 2n = 32 and 2n = 48 must have been derived. Hence, the species with 2n = 32 and 48 represent the tetraploid and hexaploid taxa respectively. However, Frahm-leliveld (1966) considers the species with 2n = 48 as octaploids, with the base number 6.

Love and Love (1943, 1949, 1957) have observed an increase in percentage of polyploids with a corresponding increase in altitude. Frahm-leliveld (1966) has also remarked that several cases of polyploidy in the genus *Indigofera* have their original habitats in higher altitudes or in dry climate. Of the 4 polyploid species studied presently, *I. hochstetteri* and *I. angulosa* were collected from drier habitats in north Gujarat and seeds of *I. amblyantha* and *I. heterantha* were obtained from Kew Gardens (origin not known).

All the 12 species of the genus *Alysicarpus* investigated, show 8 bivalents in meiosis and 16 chromosomes in their somatic complements. The present as well as the previous reports (Bir and Sidhu, 1966, 1967; Mitra and Datta, 1967; Baquar and Warsi, 1968; Mehra and Dhawan, 1971; Bir and Kumari, 1973; Bhatt, 1974 and Sareen and Singh, 1975) indicate the total absence of polyploidy in the genus. Therefore, x = 8 should be considered as the basic number for the genus.

12 out of 13 species of the genus *Desmodium* studied, show 2n = 22 chromosomes in their somatic complements. However, 2n = 20 is recorded in *D. salicifolium*. 2n = 20 is also reported in *D. gyroides* (Pritchard and Gould, 1964), *D. motorium* and *D. painteri* (Rotar and Urata, 1967). Based on the present as well as the previous works (Young, 1940; Pantulu, 1942; Turner, 1956; Frahm-leliveld, 1957; Turner and Fearing, 1959; Miege, 1960; Mitra, 1964; Tixier, 1965; Bir and Sidhu, 1967;

Pritchard and Gould, 1967; Rotar and Urata, 1970; Larsen, 1971; Mehra and Dhawan, 1971; Bir and Kumari, 1973; Bir and Talwar, 1973; Koul and Gohil, 1973; Bhatt, 1974 and Bhaumik, 1975) it is evident that, the genus *Desmodium* is dibasic having base numbers x = 10 and 11.

In the genus *Dendrolobium* the only species (*D. triangulare*) studied shows 2n = 22 chromosomes in the somatic cells, indicating 11 as the basic chromosome number.

Wanscher (1934), Senn (1938), Atchison (1951), Darlington and Wylie (1955), Delay (1950-51), Turner (1956), Berger,*et al.* (1958), Turner and Fearing (1959), Cave (1956-62), Frahm-leliveld (1960a, 1966), Bir andSidhu (1967), Fedorov (1969), Bandel (1974) and several others have reported different basic chromosome numbers (4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 30, 32, 33, 40, 41, 42, 48, 49, 52, 63, 64, 65, 80 and 90) for the family Fabaceae. Bandel (1974) while commenting on "chromosome numbers and evolution in Leguminoceae" has remarked that, x = 8 is the most frequent number (27.75%) and the next frequent numbers are x = 11 (14.73%) and x = 7 (11.56%). So it is apparent that, the basic chromosome number for the family Fabaceae is 8. The other numbers arose as a result of aneuploid loss or gain or by chromosomal duplication from early 8 chromosome forms (Senn,1938).

In the present investigation of 45 species and one variety distributed in 4 genera, x = 8 (Indigofera and Alysicarpus) and x = 10 and 11 (Desmodium and Dendrolobium) are the base numbers observed. This supports the earlier suggestions of considering 8, 10 and 11 as basic chromosome numbers for the family.

Karyotypic considerations :

Precise determination of arm ratios of chromosomes in different species of the genera Indigofera, Desmodium, Dendrolobium and Alysicarpus reveals the presence of nearly median and nearly submedian types of chromosomes. However, two species of the genus Indigofera show the presence of a pair of chromosomes with exactly median (I. amblyantha) and submedian centromeres (I. trita). No chromosomes with terminal and subterminal centromeres are observed. The variation in TF% from 31.65 to 40.93 indicates that the karyotypes of different species investigated are of asymmetrical type. The degree of asymmetry varies with the types of the chromosomes and ratio of longest to the shortest pair (L/S) in the complement. The symmetry of the karyotype has been frequently suggested as an indication of degree of specialization of a species (Levitsky, 1931; Stebbins, 1950), so that an asymmetrical karyotype would be

Fig. 308. Comparison of idiograms of different species of the genus *Indigofera*.

1 *I. duthei*

2 *I. colutea*

3 *I. spicata*

4. *I. astragalina*

5 *I. hirsuta*

6 *I. trifoliata*

7 *I. vicioides*

Contd....

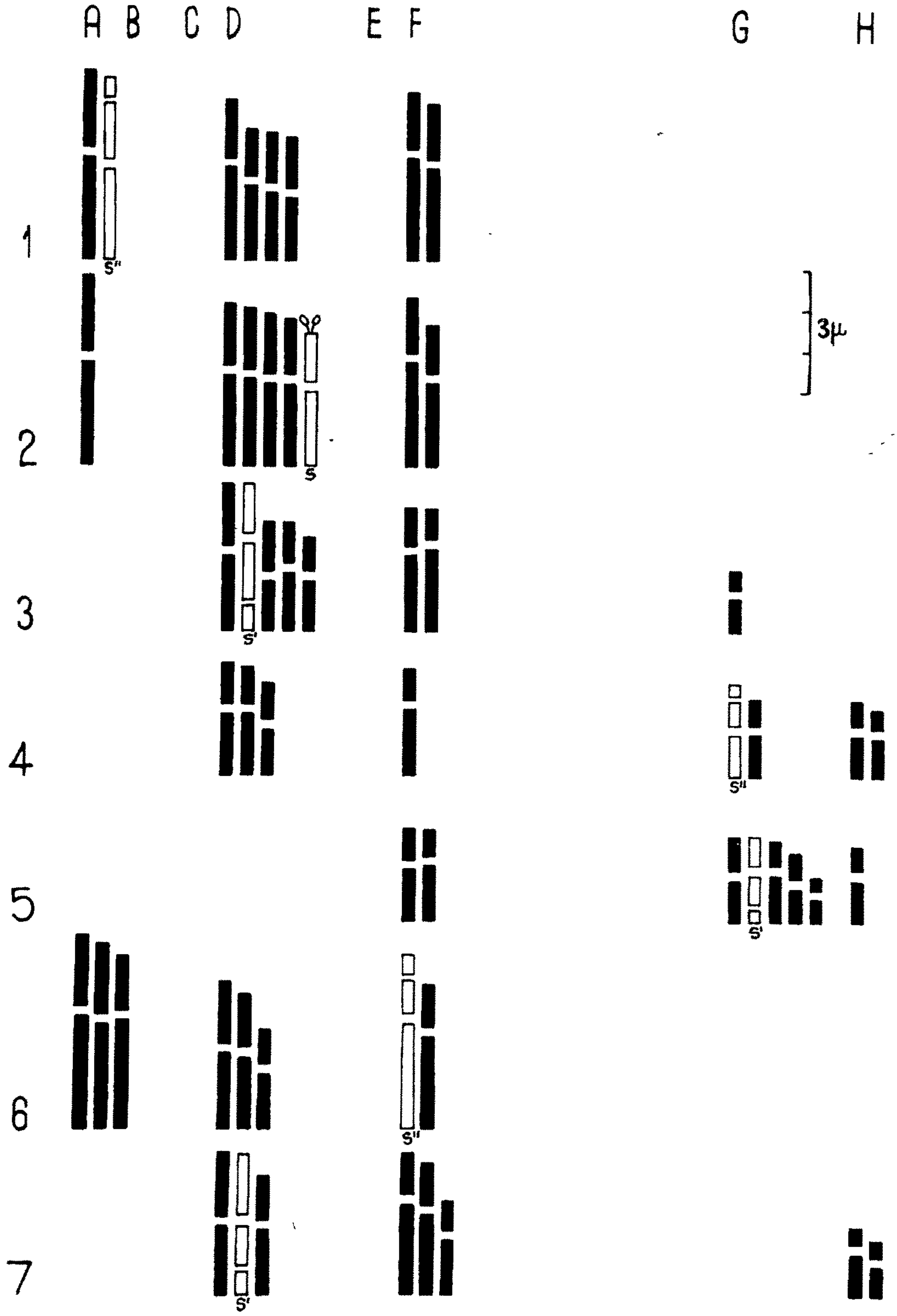

A B C D E F G H
1
2
3
4
5
6
7
S''
S
S'
3μ

Fig. 309. Comparison of idiograms of different species of the genus Indigofera

8 I. linnaei

9 I. arrecta

10 I. tinctoria

11 I. cordifolia

12 I. linifolia var. campbelli

13 I. linifolia

14 I. oblongifolia

Contd....

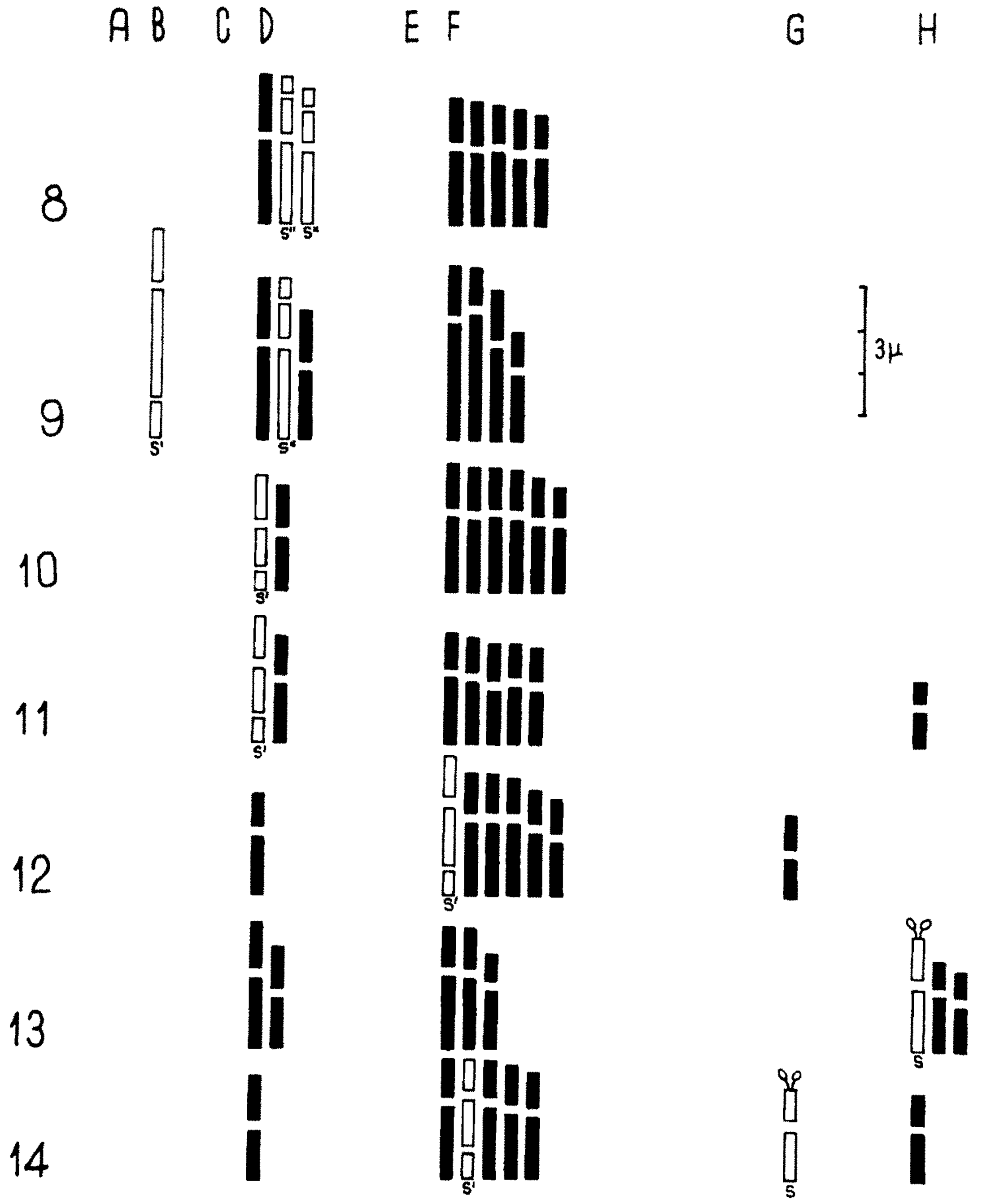

A B C D E F G H
8
9
10
11
12
13
14
S''
S*
S'
S*
S'
S'
S'
S'
S
S
3μ

Fig. 310. Comparison of idiograms of different species of the genus *Indigofera*

15 *I. glandulosa*

16 *I. trita*

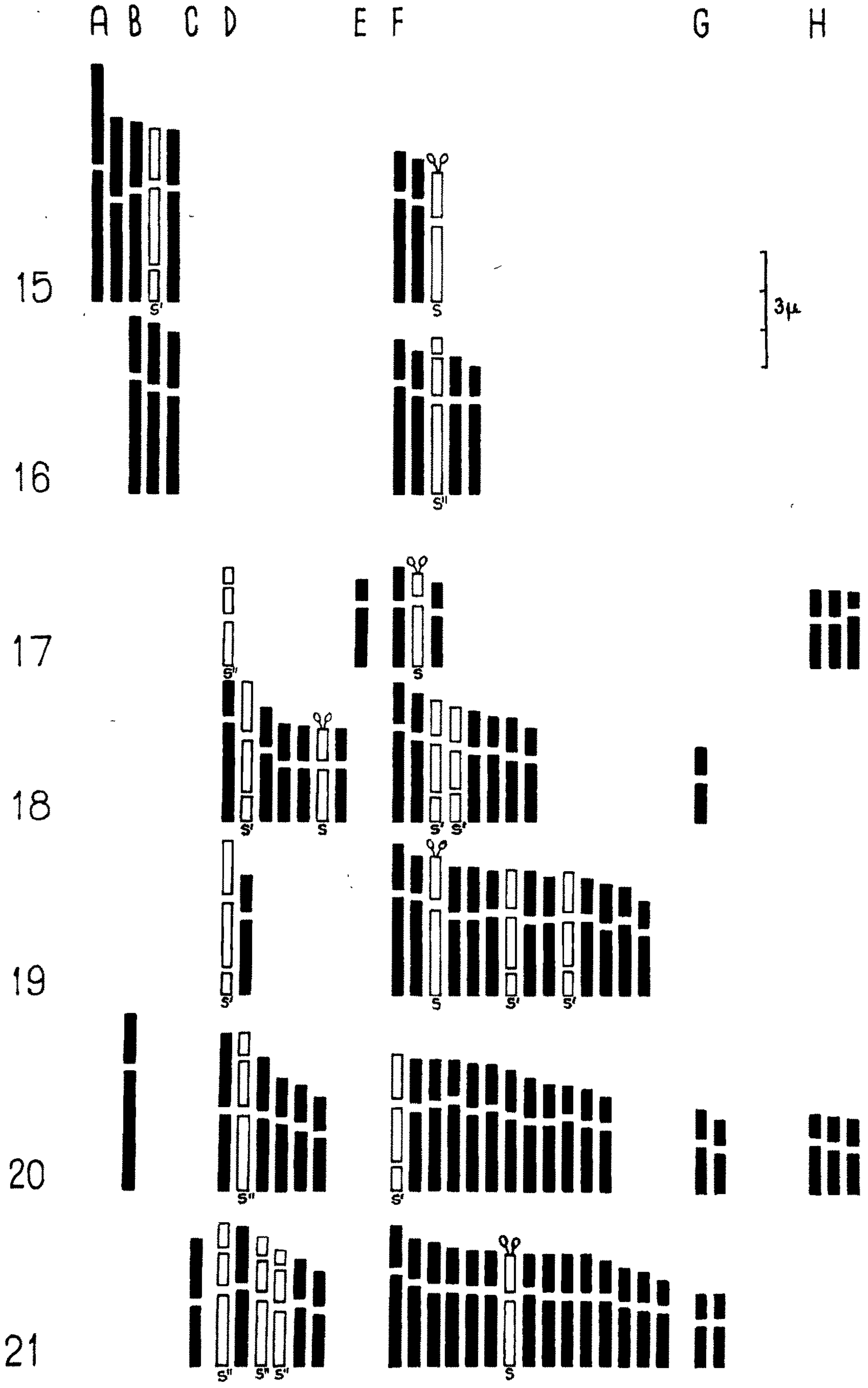
17 *I. subulata*

18 *I. hochstetteri*

19 *I. angulosa*

20 *I. amblyantha*

21 *I. heterantha*


A
B
C
D
E
F
G
H
15
16
17
18
19
20
21
3μ
S'
S
S''
S'
S
S'
S'
S
S'
S'
S
S'
S'
S''
S'
S''
S''
S''
S

characteristic of an advanced species as compared with the symmetrical karyotypes. Considering this as true representation of evolutionary trends, the species of different genera investigated are arranged accordingly.

The analysis of karyotypes of different species and a variety of *Indigofera* reveals that, there is a strong similarity in the general pattern of chromosome morphology. The chromosomes mostly have nearly median and nearly submedian centromeres, except for *I. amblyantha* and *I. trita* which have a pair of chromosomes with median and submedian centromeres respectively. The karyotypes are mostly of graded type. In majority of the species, the chromosomes are medium to short sized, while in *I. glandulosa*, *I. trifoliata*, *I. duthei*, *I. colutea*, *I. arrecta* and *I. subulata*, the chromosomes are comparatively longer (Figs. 308-310).

In the genus *Indigofera* the different species investigated can be arranged in the following evolutionary sequence based on their karyotypic data. The karyotypes of *I. duthei*, *I. colutea* and *I. spicata* with 2n = 16 resemble among themselves, in having the same number of chromosomes with nearly median and nearly submedian centromeres and closely comparable TF% (Table 91). Of the 3 species, the karyotype of *I. duthei* with

2 pairs of longer chromosomes and high TF% (40.75), appears more primitive than the other two. The karyotype of I. spicata having medium sized chromosomes and comparatively less TF% (39.06) is the most evolved one. While, I. colutea with one pair of longer chromosomes occupies an intermediate position.

The somatic complements of I. astragalina, I. hirsuta and I. trifoliata have the same number of nearly median, nearly submedian and secondarily constricted chromosomes. Among the 3 species, the resemblance is more between I. astragalina and I. hirsuta. Based on TF% (Table 91) the 3 species can be arranged in the following evolutionary sequence : I. astragalina - I. hirsuta - I. trifoliata.

The karyotypes of three species viz. I. linnaei, I. vicioides and I. arrecta resemble among themselves in having the same number of nearly median and nearly submedian types of chromosomes (Table 91). The advanced nature of I. arrecta is reflected by its karyotype in having 2 pairs of chromosomes with secondary constrictions and low TF% (32.69). While, in I. vicioides the comparatively high TF% (37.26) indicates the primitive nature of its karyotype. The karyotype of I. linnaei is intermediate between the advanced I. arrecta and primitive I. vicioides.

Five species and a variety of Indigofera viz. I. tinctoria, *I. cordifolia*, *I. linifolia* var. *campbelli*, *I. linifolia*, *I. glandulosa* and *I. oblongifolia* show 2 pairs of chromosomes with nearly median and 6 pairs with nearly submedian centromeres in their karyotypes (Table 91). Based on the number of chromosomes with secondary constrictions, TF% and L/S ratio in general, these taxa can be arranged in the following evolutionary sequence : *I. tinctoria* - *I. cordifolia* - *I. linifolia* var. *campbelli* - *I. linifolia* - *I. glandulosa* - *I. oblongifolia*. However, the karyotype of *I. arrecta* discussed above, is advanced over all the preceeding species in many respects (Table 91), except for an additional pair of chromosomes with nearly median centromeres.

The karyotype of *I. subulata*, though it has only one pair of chromosomes with secondary constrictions, it can be considered more advanced in having only nearly submedian types of chromosomes in the somatic complement.

In contrast to *I. subulata*, the karyotype of *I. trita* has a pair of chromosomes with nearly median, a pair with submedian, and 6 pairs with nearly submedian centromeres. Among them one pair of chromosomes are with secondary constrictions and an another pair with satellites. Thus, *I. trita* with comparatively shorter chromosomes and an additional pair of satellited chromosomes, together with low TF% (37.87) can be considered more advanced over *I. subulata*.

The somatic complements of *I. hochstetteri* and *I. angulosa* having 2n = 32, *I. heterantha* and *I. amblyantha* having 2n = 48 represent tetraploid and hexaploid species. The karyotypes of *I. hochstetteri* and *I. angulosa* show gross resemblance in many respects (Table 91). However, the karyotype of *I. hochstetteri* having 6 pairs of chromosomes with nearly median centromeres appears comparatively more primitive than *I. angulosa*, which has only 2 pairs of chromosomes with nearly median centromeres. The karyotypes of the two hexaploid species viz. *I. heterantha* and *I. amblyantha* also show similarity in some respects (Table 91). Of the two, the comparatively primitive karyotype of *I. heterantha* has only 2 pairs of chromosomes with secondary constrictions while, the advanced karyotype of *I. amblyantha* has 3 pairs of chromosomes with secondary constrictions and 1 pair with satellites.

The species of the genus *Desmodium* investigated presently, have only nearly median and nearly submedian types of chromosomes in their karyotypes (Figs. 311 and 312). Among the 13 species studied, the karyotype of *D. salicifolium* is primitive as it has comparatively low chromosome number (2n = 20), longer chromosomes (with equal number of nearly median and nearly submedian centromeres) and high TF% (45.93). While, the

Fig. 311. Comparison of idiograms of different species of the genus Desmodium

1 D. salicifolium

2 D. laxiflorum

3 D. uncinatum

4 D. dichotomum

5 D. triflorum

6 D. intortum

7 D. velutinum

contd....

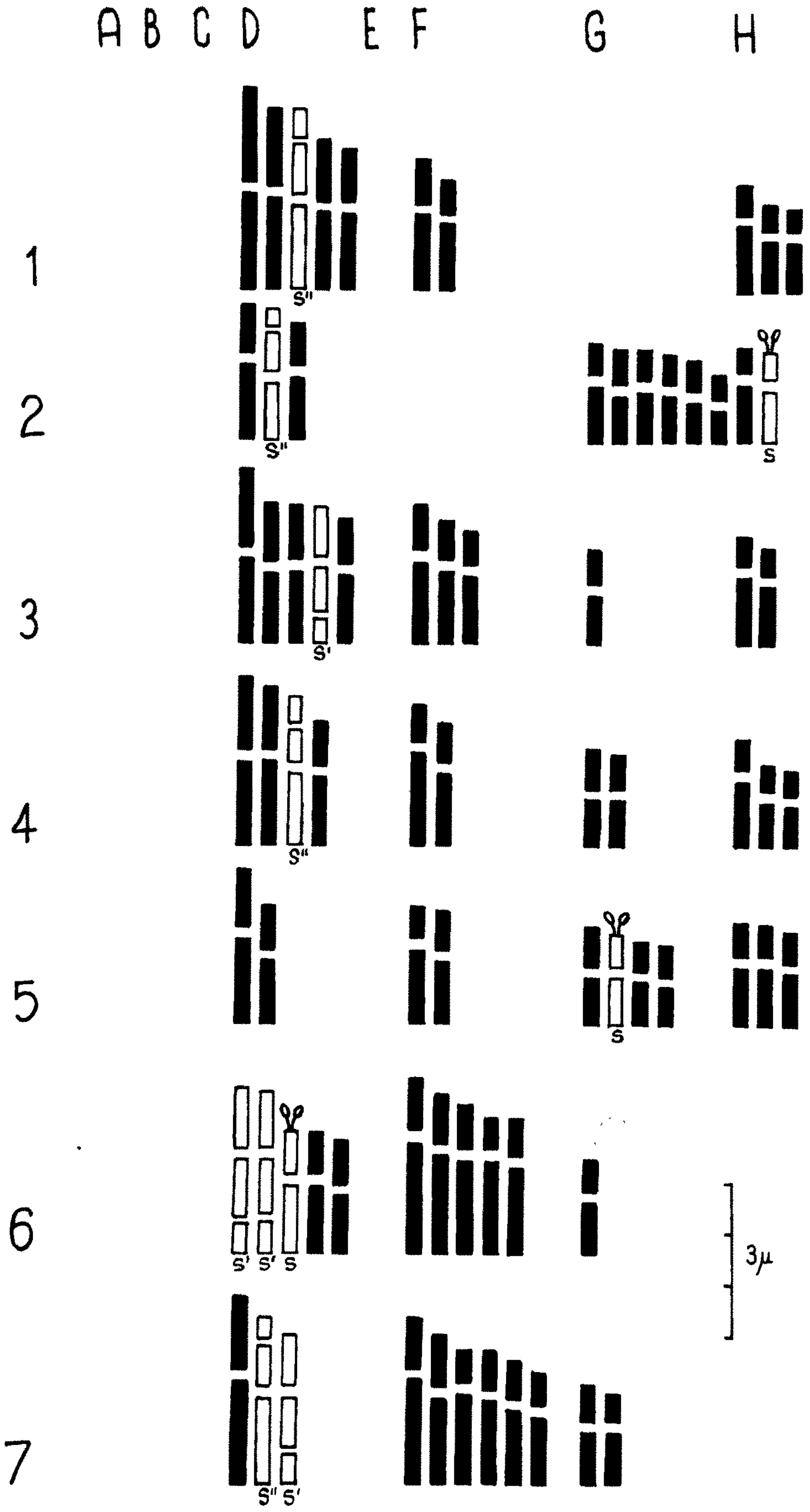

A B C D E F G H
1
S"
2
S"
S
3
S'
4
S"
5
S
6
S' S' S
3μ
7
S" S'

Fig. 312. Comparison of idiograms of different species of the genus Desmodium

8 D. heterocarpon var. strigosum

9 D. sandwicense

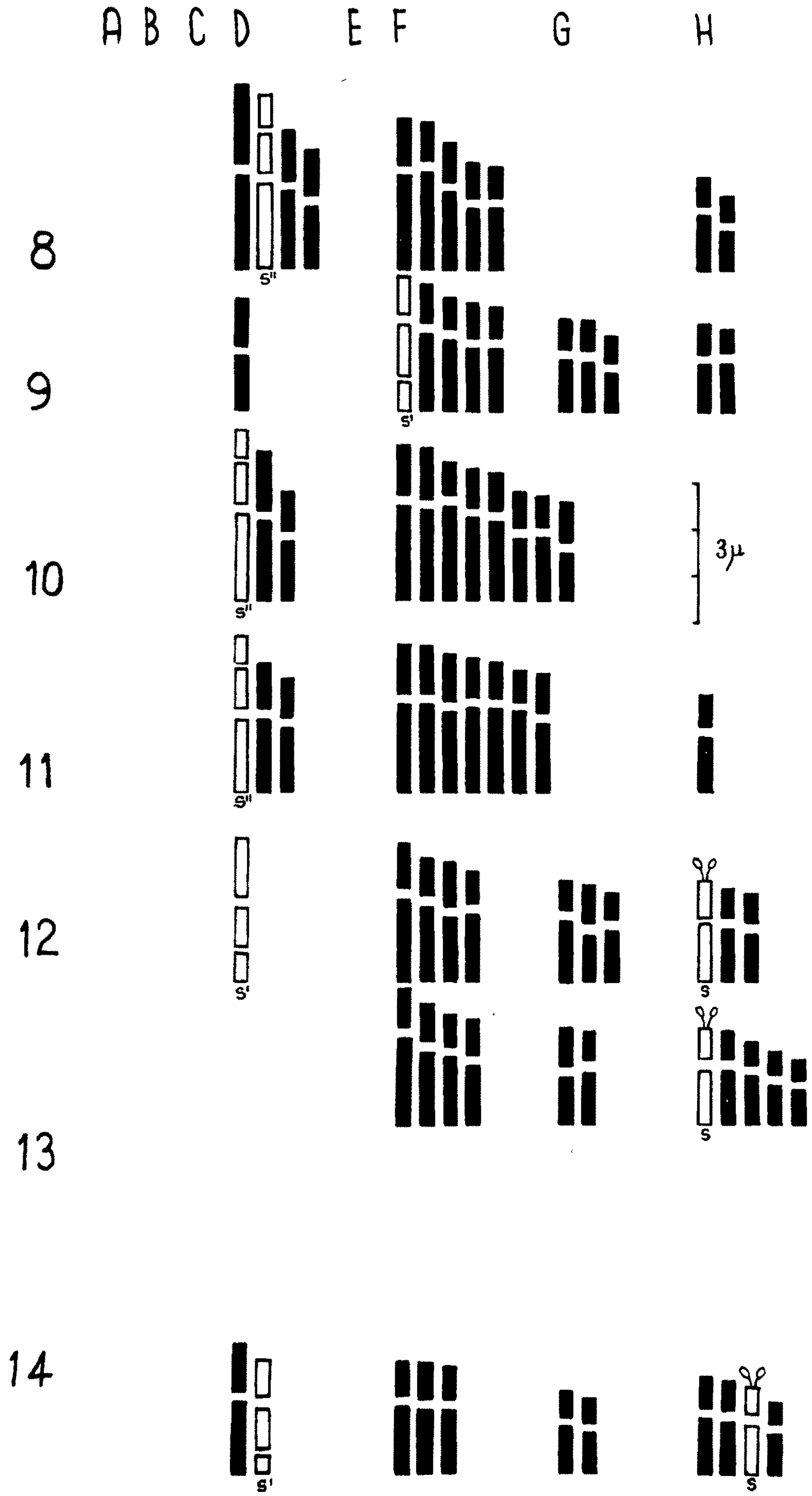
10 D. elegans

11 D. rotundifolium

12 D. distortum

13 D. gangeticum

14 Dendrolobium triangulare


A B C D E F G H
8
s"
9
s'
10
s"
3µ
11
s"
12
s'
s
s
13
14
s'
s

karyotype of *D. gangeticum* is advanced in having 2n = 22, shorter chromosomes (1 pair with nearly median and 7 pairs with nearly submedian centromeres) and low TF% (34.74).

Of the remaining species with 2n = 22, the karyotype of *D. laxiflorum* having 9 pairs of nearly median and 2 pairs of nearly submedian types of chromosomes and high TF% (40.02) point to its primitive nature.

The somatic complements of *D. uncinatum*, *D. dichotomum*, *D. triflorum* and *D. intortum* have the same number of chromosomes with nearly median (6 pairs) and nearly submedian (5 pairs) centromeres (Figs. 311 and 312). Based on the number of chromosomes with secondary constrictions or satellites and TF% the 4 species can be arranged in the following evolutionary sequence : *D. uncinatum* - *D. dichotomum* - *D. triflorum* - *D. intortum*. The advanced nature of *D. intortum* over all the preceeding species is evidenced by its karyotype, which has 2 pairs of chromosomes with secondary constrictions, a pair with satellites and less TF% (Table 92).

The karyotype of *D. velutinum* shows an overall similarity with the karyotype of *D. intortum* (Table 92), but differs from it, in having more chromosomes (5 pairs) with nearly median centromeres, comparatively high TF% (37.24) and absence of chromosomes with satellites.

Four species viz. *D. heterocarpon* var. *strigosum*, *D. sandwicense*, *D. elegans* and *D. rotundifolium* exhibit similarity in having 4 pairs of chromosomes with nearly median centromeres and 7 pairs with nearly submedian centromeres in their karyotypes. Based on the number of chromosomes with secondary constrictions and TF%, these species can be represented in the following evolutionary sequence : *D. heterocarpon* var. *strigosum* - *D. sandwicense* - *D. elegans* - *D. rotundifolium*.

The karyotype of *D. intortum* discussed above can be placed between *D. elegans* and *D. rotundifolium*, if the number of chromosomes with secondary constrictions, satellites and TF% are considered as the criteria for evolutionary sequence. Similarly the karyotype of *D. velutinum* can as well be placed between *D. heterocarpon* var. *strigosum* and *D. sandwicense*.

D. distortum is the only species, in which, the karyotype has 3 pairs of nearly median and 8 pairs of nearly submedian types of chromosomes. Thus, the karyotype of this species is advanced over all the preceeding species.

D. gangeticum is most evolved among all the presently investigated species.

The only species of the genus *Dendrolobium* investigated is *D. triangulare*. The somatic complement has 2n = 22

Fig. 313. Comparison of idiograms of different species of the genus *Alysicarpus*

1 *A. bupleurifolius*

2 *A. procumbens*

3 *A. rugosus*

4 *A. glumaceus*

5 *A. longifolius*

6 *A. ovalifolius*

contd . . . .

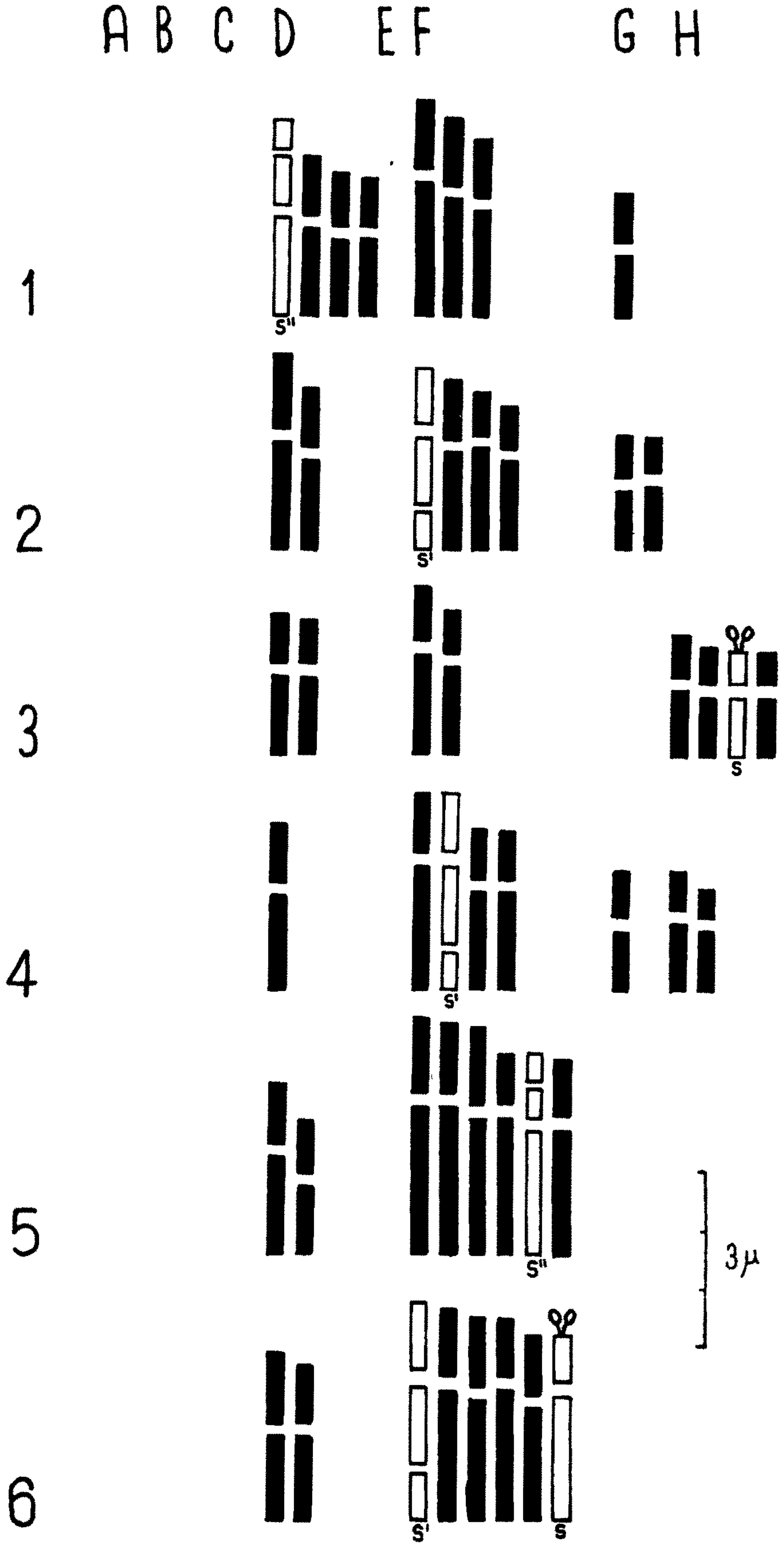

A B C D E F G H
1
S''
2
S'
3
S
4
S'
5
S''
3μ
6
S'
S

Fig. 314. Comparison of idiograms of different species of the genus *Alysicarpus*

7 *A. tetragonolobus*

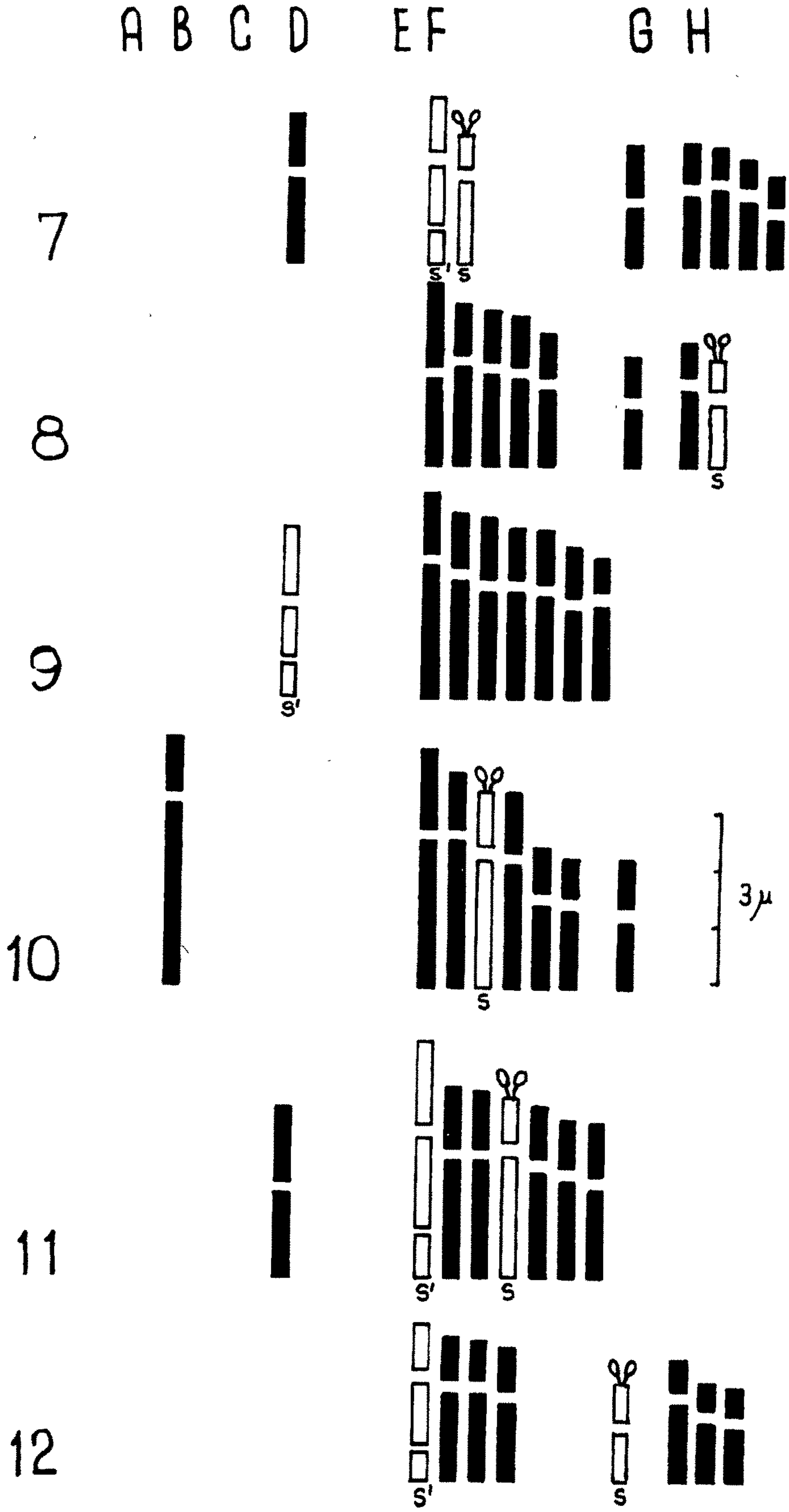
8 *A. heyneanus*

9 *A. wallichii*

10 *A. styracifolius*

11 *A. monilifer*

12 *A. vaginalis*


A B C D E F G H
7
S'
S
8
S
9
S'
10
S
3μ
11
S'
S
12
S'
S

chromosomes, distributed in 4 pairs of nearly median and 7 pairs of nearly submedian types. Chromosomes with satellites and secondary constrictions are represented by a pair each.

All the species of the genus *Alysicarpus* investigated show remarkable consistency in chromosome number ($2n = 16$) and in having only nearly median and nearly submedian types of chromosomes (Fig. 313-314). The karyotypes of majority of species have one pair of chromosomes with secondary constrictions, except *A. rugosus*, *A. wallichii* and *A. styracifolius*. However, all these three species show one pair of chromosomes with satellites in their somatic complements.

Among the 12 species studied, the karyotype of *A. bupleurifolius*, having 5 pairs of chromosomes with nearly median and 3 pairs with nearly submedian centromeres is most primitive. While, the karyotype of *A. vaginalis*, having only one pair of chromosomes with nearly median and 7 pairs with nearly submedian centromeres, appears to be the most advanced one. The advanced nature of *A. vaginalis* is further evidenced by its karyotype in having one pair of chromosomes with satellites, one pair with secondary constrictions and low TF% (34.90).

A. procumbens having comparatively shorter chromosomes, low TF% and equal number of nearly median and nearly submedian types of chromosomes (Table 93) is more evolved than *A. bupleurifolius*.

The somatic complements of *A. rugosus*, *A. glumaceus*, *A. longifolius*, *A. tetragonolobus* and *A. ovalifolius*, have 2 pairs of nearly median and 6 pairs of nearly submedian types of chromosomes (Table 93). The karyotypes of these species have secondary constrictions and/or satellites on 1 or 2 pairs of chromosomes. Thus, these species are advanced over the preceeding two species. Among the 5 species the karyotype of *A. rugosus* is primitive as it has comparatively high TF% (36.23) and only one pair of chromosomes with satellites. The somatic complements of *A. tetragonolobus* and *A. ovalifolius* are advanced in having a pair of chromosomes with satellites, a pair with secondary constrictions and low TF% (Table 93). While, *A. glumaceus* and *A. longifolius* resemble each other in their karyotypes and occupy the position between the primitive *A. rugosus* and the advanced *A. ovalifolius*.

The remaining 5 species of *Alysicarpus*, have only one pair of nearly median and 7 pairs of nearly submedian types of chromosomes. Of these 5 species, the karyotypes of three viz. *A. heyneanus*, *A. wallichii* and *A. styracifolius* have only one pair of chromosomes with satellites or secondary constrictions.

Fig. 315. Histograms showing absolute length of chromosomes of different species of :-

Genus *Indigofera*

1 *I. duthei*
2 *I. colutea*
3 *I. spicata*
4. *I. astragalina*
5 *I. hirsuta*
6 *I. trifoliata*
7 *I. vicioides*
8 *I. linnaei*
9 *I. arrecta*
10 *I. tinctoria*
11 *I. cordifolia*
12 *I. linifolia* var. *campbelli*
13 *I. linifolia*
14 *I. oblongifolia*
15 *I. glandulosa*
16. *I. trita*
17. *I. subulata*
18. *I. hochstetteri*
19 *I. angulosa*
20 *I. amblyantha*
21 *I. heterantha*

Genus *Desmodium*

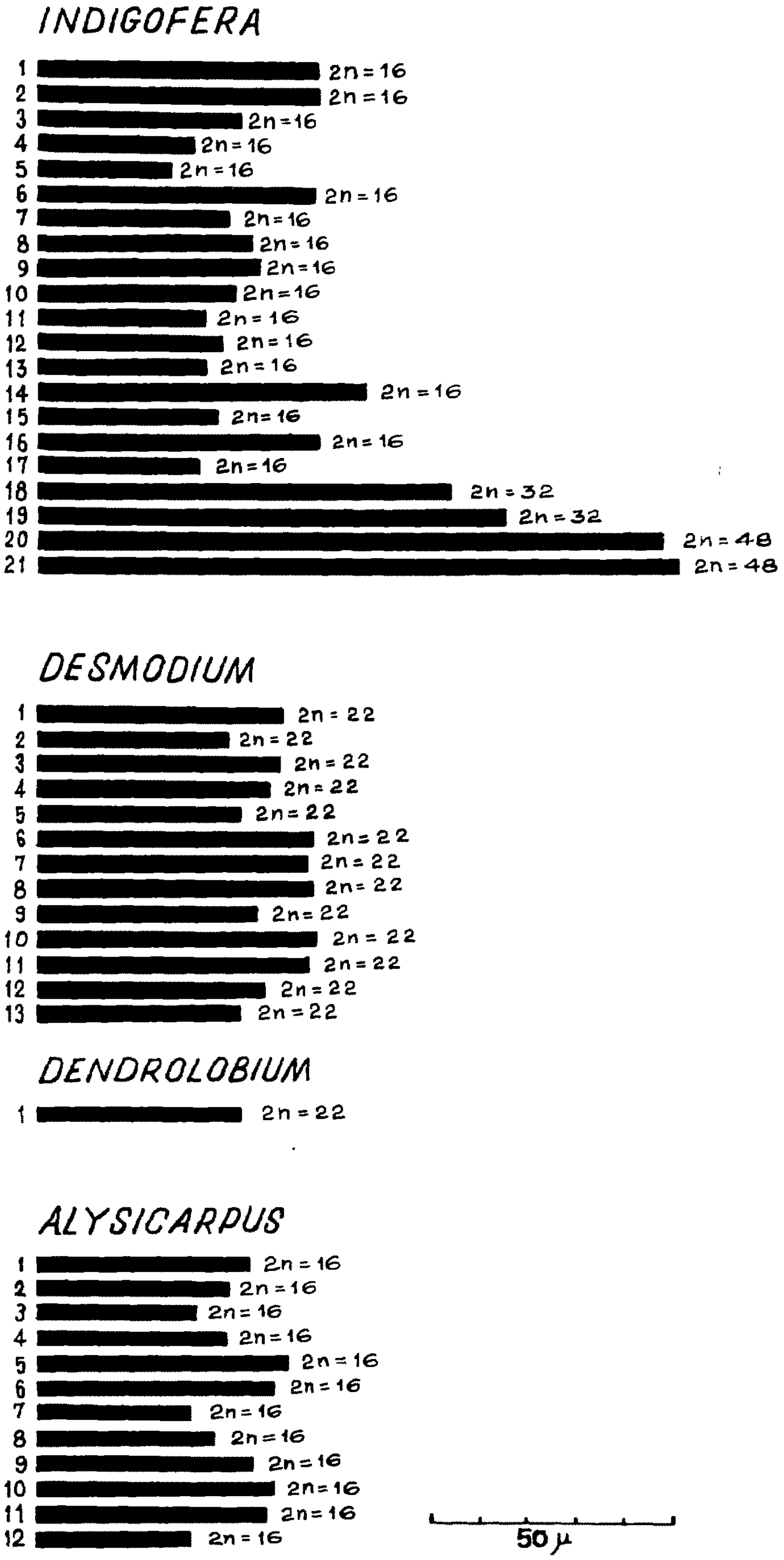
1 *D. salicifolium*
2 *D. laxiflorum*
3 *D. uncinatum*
4 *D. dichotomum*
5 *D. triflorum*
6 *D. intortum*
7 *D. velutinum*
8 *D. heterocarpon* var. *strigosum*
9 *D. sandwicense*
10 *D. elegans*
11 *D. rotundifolium*
12 *D. distortum*
13 *D. gangeticum*

Genus *Dendrolobium*

1 *D. trangulare*

Genus *Alysicarpus*

1 *A. bupleurifolius*
2 *A. procumbens*
3 *A. rugosus*
4 *A. glumaceus*
5 *A. longifolius*
6 *A. ovalifolius*
7 *A. tetragonolobus*
8 *A. heyneanus*
9 *A. wallichii*
10 *A. styracifolius*
11 *A. monilifer*
12 *A. vaginalis*


INDIGOFERA
1 2n=16
2 2n=16
3 2n=16
4 2n=16
5 2n=16
6 2n=16
7 2n=16
8 2n=16
9 2n=16
10 2n=16
11 2n=16
12 2n=16
13 2n=16
14 2n=16
15 2n=16
16 2n=16
17 2n=16
18 2n=32
19 2n=32
20 2n=48
21 2n=48
DESMODIUM
1 2n=22
2 2n=22
3 2n=22
4 2n=22
5 2n=22
6 2n=22
7 2n=22
8 2n=22
9 2n=22
10 2n=22
11 2n=22
12 2n=22
13 2n=22
DENDROLOBIUM
1 2n=22
ALYSICARPUS
1 2n=16
2 2n=16
3 2n=16
4 2n=16
5 2n=16
6 2n=16
7 2n=16
8 2n=16
9 2n=16
10 2n=16
11 2n=16
12 2n=16
50 µ

While, the other two viz. *A. monilifer* and *A. vaginalis* have a pair of chromosomes with satellites and a pair with secondary constrictions. Based on the number of chromosomes with satellites and secondary constrictions and TF% (Table 93), these species can be arranged in the following evolutionary sequence : *A. heyneanus* - *A. wallichii* - *A. styracifolius* - *A. monilifer* - *A. vaginalis*. However, if the presence of more number of chromosomes with satellites or secondary constrictions are considered as an advanced character (De Mol, 1928, Hazara and Sharma, 1971), *A. tetragonolobus* and *A. ovalifolius* discussed above can be placed between *A. styracifolius* and *A. monilifer* in the evolutionary sequence.

The total chromatin length of different species of the genera *Indigofera*, *Desmodium*, *Dendrolobium* and *Alysicarpus* are shown in the histogram (Fig. 315). There is no diminution of total chromatin length with the advancement of the species in any of the genera studied. However, the polyploid species of the genus *Indigofera* show an increase in total chromatin length, with the increase in ploidy level.

Heteromorphism in karyotypes :

Some species investigated presently showed karyotypic variations among their populations . In some cases these karyotypic variations accompanied by morphological differences are also observed. These variations point towards the existence of cytotypes or ecotypes present within a species. Such karyotypic variations at specific level are no less significant from speciation point of view. According to Stebbins (1950) and Clausen (1951), these variations are the results of chromosomal repaterning, may be at initial steps of speciation. Heteromorphism in karyotypes has been observed in some species of Indigofera viz. I. hirsuta (Table 29), I. trifoliata (Table 36), I. linnaei (Table 11), I. tinctoria (Table 23), I. linifolia (Table 6), I. oblongifolia (Table 41), I. glandulosa (Table 33), I. trita (Table 18), in Desmodium gangeticum (Table 50) and some species of Alysicarpus viz. A. procumbens (Table 66), A. longifolius (Table 79), A. wallichii (Table 89), A. monilifer (Table 63) and A. vaginalis (Table 72).

Meiosis

The meiotic behaviour of chromosomes in majority of the taxa investigated, is mostly regular showing 8 (Indigofera and Alysicarpus) and 11 (Desmodium) bivalents at diakinesis and metaphase I. However, the occurrence of univalents, association of bivalents, interbivalent connections, precocious movement, non-synchronised movement, unequal distribution, grouping of chromosomes, laggards, micronucleii and cytomixis are some of the abnormalities recorded in very low percentage of PMCs.

Interbivalent connections leading to secondary associations have been reported earlier by Thomas and Revell (1946) in Cicer and Majumdar (1953) in Monochoria. In the present investigation the same is observed in Indigofera trita, Alysicarpus vaginalis and Desmodium dichotomum. Significance of this in the presently investigated species cannot be ascertained at this juncture, as they are observed in very few PMCs. The formation of 8 groups of 16 bivalents by secondary association during metaphase I, is observed in several PMCs of Indigofera angulosa. If the theory of secondary association with maximum grouping is considered as reliable check of the phylogeny, then the ancestoral forms of this species would be supposed to contain 8 chromosomes in the haploid set.

The most commonly observed abnormalities are grouping of chromosomes at metaphase II and cytomixis. Cytomixis was first observed in Oenothera by Gates (1911). Later this was observed by West and Letchmere (1915) in Lilium, Youngmann (1931) in Thespesia populnea, Bhandari et al.,(1969) in Canavalia ensiformis and Patil (1970) in Crotolaria. In the present investigation, the cytomixis is observed in almost all the species of Alysicarpus, some species of Indigofera

(*I. cordifolia*, *I. glandulosa*) and *Desmodium* (*D. velutinum*, *D. laxiflorum*, *D. heterocarpon* var. *strigosum* and *D. distortum*). Cytomixis is observed at all stages of meiosis including the premeiotic stage.

As all these abnormalities are present in low percentage, the meiotic behaviour in general, points towards the stabilized nature of the species studied. This is further evidenced by high pollen fertility (86-95%) observed in different species.

Cytotaxonomical considerations :

The relationships of different taxa investigated are evaluated on the basis of cytological observations. These relationships are discussed in light of the known classifications of Gillett (1958) for the genus *Indigofera*, Ohashi (1973) for *Desmodium* and *Dendrolobium* and Baker (1876) for *Alysicarpus*.

Indigofera (Tribe Indigoferae)

Gillett (1958) in his revision of the genus *Indigofera* from Tropical Africa, has divided the genus into subgenera, sections and subsections. 20 species and a variety investigated presently belong to the subgenera *Amecarpus* and *Indigofera*. *I. hochstetteri* belongs to the section *Amecarpus* of the subgenus

Amecarpus. While, the remaining species belong to the section Indigofera of the subgenus *Indigofera*. The species of the section Indigofera belonging to different subsections are as follows :-

	Subsection	
1.	Alternifoliae :	*I. spicata*
		I. oblongifolia
2.	Microcarpae :	*I. glandulosa* *
		I. trifoliata *
		I. duthei *
3.	Hirsutae :	*I. hirsuta*
		I. astragalina
4.	Tinctoriae :	*I. tinctoria*
		I. arrecta
		I. subulata
		I. trita
		*I. amblyantha**
		I. heterantha *
		I. angulosa *
5.	Centrae :	*I. vicioides*

6. Viscosae : *I. colutea*
7. Brevi-erectae : *I. linifolia*
I. linifolia var. *campbelli*
I. cordifolia
I. linnaei

* The species marked with asterisk are not included in Gillett's monograph. But, they are included in the respective subsections, after personal communication with Dr. Gillett (dated 31st August, 1976).

I. hochstetteri of the section Amecarpus (subgenus *Amecarpus*) is a tetraploid species having 2n = 32 chromosomes in its complement.

I. spicata and *I. oblongifolia* belonging to the subsection Alternifoliae have distinct karyotypes, differentiating one from the other. Of the two, the karyotype of *I. spicata* is more primitive.

The karyotypes of the three species viz. *I. glandulosa*, *I. trifoliata* and *I. duthei* resemble among themselves in having the same chromosome number and longer chromosomes. This supports Gillett's contention of their inclusion in the subsection Microcarpae. However, the karyotypes of these species differ in types and number of each type of chromosomes (Table 91). The comparatively primitive karyotype of *I. duthei* resemble that of *I. spicata* of the subsection Alternifoliae.

I. hirsuta and *I. astragalina* of subsection hirsutae closely resemble with each other in number and morphology of chromosomes. This supports the taxonomic treatment of grouping them in the same subsection. Both these species show resemblance with *I. trifoliata* of the subsection Microcarpae in certain karyotypic details (Table 91).

Among the 7 species of the subsection Tinctoriae studied, four are diploids (2n = 16), one is a tetraploid (2n = 32) and two are hexaploids (2n = 48). All the diploid species viz. *I. arrecta*, *I. tinctoria*, *I. subulata* and *I. trita* show markedly distinct karyotypes. Among them *I. trita* exhibits the advanced nature of the karyotype. The tetraploid *I. angulosa* resemble *I. hochstetteri* of the subgenus *Amecarpus* in having the same chromosome number and asymmetrical karyotypes. However, *I. angulosa* shows less number (2 pairs) of chromosomes with nearly median centromeres. The two hexaploid species (i.e. *I. heterantha* and *I. amblyantha*) show resemblance in gross morphology of their karyotypes. But differ from each other in types and number of chromosomes with secondary constrictions (Table 91). Different species of the subsection Tinctoriae studied presently, show marked differences in chromosome number and morphology, supporting Gillett's view of considering it as the most diverse group (personal communications, 31st August, 1976).

The karyotype of *I. vicioides* of the subsection Centrae shows similarity with that of *I. arrecta* of the subsection Tinctoriae. While, the karyotype of *I. colutea* belonging to the subsection vicosae, resemble those of *I. duthei* of the subsection Microcarpae and *I. spicata* of the subsection Alternifoliae.

Of the three species and a variety of the subsection Brevi-erectae studied, *I. linifolia*, *I. linifolia* var. *campbelli* and *I. cordifolia* have gross resemblance among themselves in chromosome morphology. While, *I. linnaei* shows resemblance with *I. vicioides* of the subsection centrae in its karyotype.

Different levels of ploidy metwith in the different species of the genus *Indigofera* together with differences in chromosome morphology indicate its advanced nature. The karyotypic similarities between species of different subgenera, sections and subsections indicate that, interrelationships between them ~~is~~ are probably of a reticulate type. Within the genus, the subsection Tinctoriae is most advanced and diversified as the karyotypes of its species exhibit varying degree of asymmetry and different levels of ploidy. The structural differences observed in different chromosome complements suggest the role of minor structural alterations in the speciation of the genus. The presence of polyploidy in the genus also indicates its share in speciation.

Ohashi (1973) in his monograph on "The Asiatic species of *Desmodium* and its allied genera" has divided the genus *Desmodium* into 7 subgenera and each one of them is further divided into section and subsections. Species investigated presently belong to the following subgenera, sections and subsections :-

Subgenus : *Desmodium*

  Section : Desmodium ... *D. salicifolium*

  Section : Angustistipulosa .. *D. laxiflorum*

Subgenus : *Dollinera*

  Section : Dollinera

    Subsection : Tilifoliae .. *D. elegans*

Subgenus : *Sagotia*

Section : Chalarioidea .. *D. dichotomum*
D. distortum

Section : Heteroloma .. *D. gangeticum*
D. velutinum

Section : Nicolsonia ... *D. heterocarpon* var. *strigosum*
D. rotundifolium
D. intortum
D. sandwicense
D. uncinatum

Section : Sagotia *D. triflorum*

Based on morphological characters Ohashi (1973) considers the subgenus *Desmodium* as an advanced group. However, the karyotypes of the species viz. *D. salicifolium* (Sect. Desmodium) and *D. laxiflorum* (Sect. Angustistipulosa) of the subgenus investigated presently exhibit primitiveness.

Ohashi (1973) considers the subgenus *Dollinera* as a primitive group, showing some specialized morphological features. The karyotypic study of *D. elegans* belonging to the group supports its advanced nature, as the karyotype is asymmetrical showing 4 pairs of chromosomes with nearly median centromeres and 7 pairs with nearly submedian centromeres.

Majority of the species investigated presently belong to the polymorphic and advanced subgenus *Sagotia*. Among them *D. dichotomum* and *D. distortum* of the section Chalarioidea show distinct karyotypes. Between the two, the karyotype of *D. distortum* is more evolved. Two species viz. *D. velutinum* and *D. gangeticum* of the section Heteroloma also have distinct karyotypes. Of the two, the karyotype of *D. gangeticum* is comparatively more advanced.

Among the five species of the section *Nicolsonia* studied, the karyotypes of *D. uncinatum* and *D. intortum* closely resemble with each other and show great similarity with those of the section Chalarioidea (Table 92). The karyotypes of the remaining species viz. *D. heterocarpon* var. *strigosum*, *D. sandwicense* and *D. rotundifolium* resemble among themselves more closely than with the other species of the section. The karyotypes of these three species and *D. elegans* of the subgenus *Dollinera* exhibit gross similarity.

The karyotype of *D. triflorum* of the section Sagotia resembles those of *D. dichotomum* (Sect. Chalarioidea), *D. uncinatum* and *D. intortum* (Sect. Nicolsonia), in having same number of chromosomes with nearly median and nearly submedian centromeres (Table 92). The polymorphic and advanced nature of the subgenus Sagotia (Ohashi, 1973) is also justifiable on the basis of the present karyomorphological study.

12 out of 13 species of the genus Desmodium studied have the same number i.e. 2n = 22(except D. salicifolium) and the types of chromosomes in their somatic complements. This supports the inclusion of all the investigated species in one genus. However, the heterogenous nature of the genus (Ohashi, 1973) is evidenced by the presence of both primitive and advanced karyotypes in different species at the sectional as well as at subgeneric levels. The minor structural differences among the karyotypes of different species of the genus indicate that, structural alterations must have played an important role in speciation. The present and previous studies indicate that, polyploidy has not played any role in speciation of the genus.

The only species studied under the genus Dendrolobium is D. triangulare, which resembles Desmodium in morphological characters. The cytological observations also support its close relation with Desmodium in many respects.

The species of the genus *Alysicarpus* show remarkable uniformity in exomorphological characters. A similar uniformity is also observed in somatic number and types of chromosomes in all the 12 species investigated presently. Baker (1876), based on length of the calyx on pod, has divided the genus into 2 groups viz. Microcalycinae and Macrocalycinae.

Among the 4 species belonging to Microcalycinae studied, *A. procumbens* shows primitive karyotype in having equal number of chromosomes with nearly median and nearly submedian centromeres. While, the remaining species viz. *A. ovalifolius*, *A. monilifer* and *A. vaginalis* show more advanced karyotypes (Table 93). The presence of a pair chromosomes with satellites and pair with secondary constrictions in these 3 species supports Baker's view of grouping them under Microcalycinae.

Among 8 species of the group Macrocalycinae studied, *A. bupleurifolius* exhibits primitive karyotype resembling that of *A. procumbens* of the group Microcalycinae. While, the other species viz. *A. rugosus*, *A. glumaceus*, *A. longifolius*, *A. tetragonolobus*, *A. heyneanus*, *A. wallichii* and *A. styracifolius* show progressively advanced karyotypes. However, the karyotypes of *A. rugosus* and *A. glumaceus*, *A. heyneanus*, *A. wallichii* and *A. styracifolius* resemble more closely among themselves (Table 93).

The present cytotaxonomical study supports Sedgwick's contention of considering *A. heyneanus* and *A. styracifolius* as distinct species, which were earlier considered as varieties of *A. rugosus* (Baker, 1876).

The presence of primitive and advanced karyotypes in the species of both the groups indicate their parallel evolution. There is no report of interspecific hybrids in nature or produced experimentally and polyploidy in the genus. This suggests that, the minor structural changes in chromosomes must have played a major role in speciation of the genus.

Among the four genera studied, the genus *Alysicarpus* can be considered primitive, as majority of its species show uniformity in exomorphological characters and karyotypic details. The morphological diversities in the genus *Indigofera* (Gillett, 1958) accompanied by different chromosome numbers ($2n = 16$ to 48) and high ploidy levels metwith in the species studied are indicative of its advanced nature. The genera *Desmodium* and *Dendrolobium* occupy the position in between *Alysicarpus* and *Indigofera*.

The present investigation of the taxa belonging to two tribes of the family Fabaceae, shows variation in chromosome numbers i.e. 2n = 16, 32 and 48 in tribe Indigoferae and 2n = 16, 20 and 22 in tribe Desmodiae. According to Bandel (1974) the variation in chromosome number occurs at different levels of classification and among tribes, there is a typical range, distribution frequency and frequent numbers. This indicates that, the evolution of tribes must have proceeded independently within the family. The same holds good for the two tribes of the family studied presently. The occurrence of primitive as well as advanced karyotypes in both the tribes also supports their early divergence.

Based on the thesis work, the research papers published or accepted for publication are as follows :-

Bhatt, R. P. and Sanjappa, M.
1975 Karyomorphological studies in the genus Indigofera Linn. The nucleus 18(3) : 172-177.

Sanjappa, M. and Bhatt, R. P.
1976 IOPB Chromosome number reports LIII Taxon 25(4) : 494-495.

Sanjappa, M. and Bhatt, R. P.
1976 Cytology of the genus Alysicarpus Neck. ex Desv. Cytologia (in press).

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