Cytotaxonomical Studies of South Indian Scrophulariaceae

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The Scrophulariaceae consists of about 210 genera and nearly 3000 species of cosmopolitan distribution and represents on all continents (Lawrence 1966). In South India, there are about 38 genera including 87 species of Scrophulariaceae described by Gamble (1956). Apart from these wild species, there are cultivated, medicinal and ornamental species like *Digitalis purpurea*, *Antirrhinum majus*, *Angelonia grandiflora*, *Linaria vulgaris*, *Russelia juncea* and *Torenia fournieri* found in the plains as well as hill stations like Ooty, Kodaikanal and Yercaud. 21 species coming under 19 genera have been included in the present investigation. In most of the species studied there are no detailed studies and therefore, the present investigation has been undertaken. Even where the chromosome numbers have been determined (Fedorov 1974), the knowledge concerning the details of karyotype pertaining to chromosome measurements, which are vital to the understanding of karyological affinities is still meagre.

Materials and methods

The particulars about the species studied, places of collection and wild or cultivated are furnished in Table 1. All these species were grown in 1' clay pots under identical conditions under shade in our Botanical Garden, Annamalai University.

Young and healthy root tips were collected and pretreated in 0.02% hydroxyquinoline kept

Table 1.

S. no.	Species studied	Wild or cultivated	Place of collection
1	<i>Verbascum thapsus</i> L.	Wild	Ooty
2	<i>Celsia coromandeliana</i> Vahl.	Wild	Annamalainagar
3	<i>Linaria vulgaris</i> (L.) Mill.	Cultivated	Kodaikanal
4	<i>Stemodia viscosa</i> Roxb.	Wild	Annamalainagar
5	<i>Lymnophila heterophylla</i> Benth.	Wild	Annamalainagar
6	<i>Moniera cuneifolia</i> Mich.	Wild	Annamalainagar
7	<i>Dopatrium lobelioides</i> Benth.	Wild	Annamalainagar
8	<i>Torenia fournieri</i> Linden	Cultivated	Madras, Soundarya Nurseries
9	<i>Vandellia crustacea</i> Benth.	Wild	Annamalainagar
10	<i>Ilysanthes tenuifolia</i> Urban	Wild	Kille
11	<i>I. oppositifolia</i> Urban	Wild	Virudhachalam
12	<i>Scoparia dulcis</i> L.	Wild	Annamalainagar
13	<i>Sopubia trifida</i> Ham.	Wild	Kodaikanal
14	<i>Micrargeria wightii</i> Benth.	Wild	Kodaikanal
15	<i>Calceolaria mexicana</i> Benth.	Cultivated	Kodaikanal
16	<i>Antirrhinum majus</i> L.	Cultivated	Kodaikanal
17	<i>Digitalis purpurea</i> L.	Cultivated	Kodaikanal
18	<i>Angelonia grandiflora</i> C. Morr.	Cultivated	Annamalainagar
19	<i>Russelia juncea</i> Zucc.	Cultivated	Annamalainagar
20	<i>Striga lutea</i> Lour.	Wild	Annamalainagar
21	<i>S. densiflora</i> Benth.	Wild	Annamalainagar

at 4°C for 3 hours. Then, after a thorough wash, they were fixed in 1:3 acetic ethanol for 3 hours and squashed following the schedule of iron alum haematoxylin squash technique described by Marimuthu and Subramaniam (1960). From the diagram drawn with camera lucida at stage level, the chromosome measurements pertaining to short/long arms were made with a standardized scale improvised for the purpose, the details of which are presented in Table 3. For the assessment of the morphology of the chromosomes, twelve metaphase plates in each species were studied critically for the sake of confirmation.

Figs. 1-9. 1, *Celsia coromandeliana*, metaphase, $2n=26$ chromosomes. 2, *Stemodia viscosa*, $2n=32$ chromosomes. 3, *Stemodia viscosa*, $2n=42$ chromosomes. 4, *Vandellia crustacea*, metaphase, $2n=42$ chromosomes. 5 and 6, *Scoparia dulcis*, $2n=40$ chromosomes. 7, *Digitalis purpurea*, prometaphase with 48 chromosomes. 8, *Angelonia grandiflora*, prometaphase with 20 chromosomes. 9, *Russelia juncea*, prometaphase with 20 chromosomes.

Observations

The particulars about the present reports of somatic and meiotic chromosome numbers, previous reports of somatic chromosome numbers, authors and years are furnished in Table 2.

In *Verbascum thapsus*, the somatic chromosome number is $2n=34$. The previous reports show $2n=34$ and 36 chromosomes in this species (Table 2). The present study shows the rare occurrences of 48 and 128 somatic chromosomes as well.

In *Celsia coromandeliana*, there are $2n=80$ chromosomes and this is confirmed by the earlier observation of Malik and Sobti, Singh (1961). Besides, there are rare occurrences of aneuploid cells with 26, 36 and 72 chromosomes.

Table 2. Particulars about the species studied, somatic and meiotic chromosome numbers, previous reports of chromosome numbers, authors and years

S. no.	Species studied	Somatic chromosome numbers	Meiotic chromosome numbers	Previous reports of somatic chromosome numbers, authors and years
1	<i>Verbascum thapsus</i>	34	17	34, 36 Hakanson 1926. 36 Tischler 1934, Packer 1964, Heiser, Whitaker 1948, Mulligan 1961a.
2	<i>Celsia coromandeliana</i>	80	40	80 Malik 1960b, Sobti, Singh 1961.
3	<i>Linaria vulgaris</i>	12	—	12 Heitz 1926, 1927b, Lawrence 1930; East 1933, Tischler 1934, Tandon, Bali 1958.
4	<i>Stemodia viscosa</i>	28	14	42 Raghavan, Srinivasan 1940b.
5	<i>Lymnophila heterophylla</i>	34*	17*	—
6	<i>Moniera cuneifolia</i>	80	40	—
7	<i>Dopatrium lobelioides</i>	14	7	14 Raghavan, Srinivasan 1940b (D. 1955)
8	<i>Torenia fournieri</i>	18	9	18 Simon, Lowig 1930, Sugiura 1931, 1936b, Straub 1939, Tandon, Bhutani 1964.
9	<i>Vandellia crustacea</i>	42	21	42 Raghavan, Srinivasan 1940b.
10	<i>Ilysanthes tenuifolia</i>	16*	8*	—
11	<i>I. oppositifolia</i>	18*	—	—
12	<i>Scoparia dulcis</i>	40	20	20 Lewis <i>et al.</i> 1962. 40 Raghavan and Srinivasan 1940b.
13	<i>Micrargeria wightii</i>	—	16*	—
14	<i>Sopubia trifida</i>	36*	—	—
15	<i>Calceolaria mexicana</i>	60	30	60 Sugiura 1928a, Srinath 1940 (D. 1955).
16	<i>Antirrhinum majus</i>	24	12	16 Winge 1925, Heitz 1927a, b; Straub, 1939, Stubbe 1966. 16, 17, 32 Bamford, Winkler 1941. Rajhathy 1960a.
17	<i>Digitalis purpurea</i>	48	24	48 Hassae-Bessel 1916, 1921. 56 Buxton, Newton 1928, Michaelis 1931, Regnart 1935, Sakai 1935a, Love and Love 1956b, Carpio 1957, 1963.
18	<i>Angelonia grandiflora</i>	20	10	20 Raghavan, Srinivasan 1940b.
19	<i>Russelia juncea</i>	20	10	20 Pal 1961, Takag 1938, Raghavan and Srinivasan 1940b.
20	<i>Striga lutea</i>	—	20	40 Kumar, Abraham 1941.
21	<i>S. densiflora</i>	—	20	40 Kumar, Abraham 1941.

* First record of somatic and meiotic chromosome numbers.

In *Linaria vulgaris*, there are $2n=12$ chromosomes and this is confirmed by the earlier reports of Heitz (1926), Lawrence (1930), etc. (vide, Fedorov 1974).

In *Stemodia viscosa*, there are $2n=28$ chromosomes and this count differs from the earlier report of Raghavan and Srinivasan (1940b, 1942) who reported $2n=42$ chromosomes in this species. There are also rarely aneuploid cells with $2n=32$ and 42 chromosomes in this species,

as evidenced by the present investigation.

In *Dopatrium lobelioides*, there are $2n=14$ chromosomes and this is confirmed by the previous reports of Raghavan and Srinivasan (1940b).

In *Torenia fournieri*, there are $2n=18$ chromosomes and also rarely 36 chromosomes. The

IDIODRAM

Verbascum thapsus

Celsia coromandelina

Linaria vulgaris

Stemodia viscosa

Lymnophila heterophylla

Monura cuneifolia

Dopatrium lobelioides

Torenia fournieri

Figs. 10-17. Idiograms of the various species mitotically studied.

earlier reports also show $2n=18$ chromosomes in this species (Table 2).

In *Vandellia crustacea*, there are $2n=42$ chromosomes. This number is confirmed by the earlier reports (Table 2). Besides, there are rarely cells in this species, having $2n=22$ and 28 chromosomes.

In *Scoparia dulcis*, there are $2n=40$ chromosomes. According to Lewis *et al.* (1962), there are $2n=20$ chromosomes in this species, but according to Raghavan and Srinivasan (1940b) there are $2n=40$ chromosomes. Therefore, there may be different euploid populations available in this species.

In *Calceolaria mexicana*, the present study shows $2n=60$ chromosomes and this number is

IDIОGRAM

Vandellia crustacea

Ilysanthes tenuifolia

Ilysanthes oppositifolia

Scoparia dulcis

Sopubia trifida

Calceolaria mexicana

Antirrhinum majus

Digitalis purpurea

Angelonia grandiflora

Russelia juncea

Figs. 18–27. Idiograms of the various species mitotically studied.

confirmed by the earlier reports (Table 2).

In *Antirrhinum majus*, there are $2n=24$ chromosomes and in *Digitalis purpurea* $2n=48$ chromosomes. The earlier reports show $2n=16$ and 32 chromosomes in the former species and $2n=48$ and 56 chromosomes in the latter.

In *Angelonia grandiflora* and *Russelia juncea*, there are $2n=20$ chromosomes and in *Striga lutea* and *S. densiflora*, $2n=40$ chromosomes and the counts in these 4 species have been confirmed by the earlier observations (Table 2).

In *Ilysanthes tenuifolia*, *I. oppositifolia*, *Sopulia trifida*, *Lymnophila heterophylla*, *Moniera cuneifolia* and *Micrargeria wightii* first record of chromosome numbers have been made.

Fig. 28. Histogram showing the absolute chromosome lengths of the species studied.

The chromosomes of most of the taxa of Scrophulariaceae are rather smaller. The size of them ranges from 0.6 to 2.5 μm . Based on the length, the chromosomes have been grouped into shorter, short, medium and long sized chromosomes. Under each of these groups, the following categories of chromosomes have been recognized.

Long (2.0 μm to 2.5 μm)

Type A: Chromosome with medium primary and subterminal secondary centromeres.

Type B: Chromosome with submedian primary and subterminal secondary centromeres.

Type C: Chromosome with submedian centromere.

Type D: Chromosome with median centromere.

Medium (1.5 μm to 1.9 μm)

Type E: Chromosome with submedian primary and subterminal secondary centromeres.

Type F: Chromosome with submedian centromere.

Figs. 29–104. 29 to 34=*Verbascum thapsus*; 29=prometaphase with 17 bivalents; 30=tripolar anaphase; 31 to 33=tetrads with 2 or 3 sterile pollens; 34=metaphase II; 35 to 37=*Celsia coromandeliana*; 35=metaphase with 49 bivalents; 36 to 41=combinations of univalents, trivalents, quadrivalents and multivalents along with bivalents; 42=I anaphasic bridge; 43=tripolar anaphase; 44=I anaphasic laggard; 45=metaphase II; 46=II anaphasic bridges and laggards; 47=polyads; 48 to 51=*Stemodia viscosa*; 48=metaphase with 14 bivalents; 49=prometaphase; 50 and 51=combinations of quadrivalents and multivalents with bivalents; 52 to 49=*Lymnophila heterophylla*; 52=metaphase with 17 bivalents; 53 to 56=combinations of univalents, trivalents quadrivalents and multivalents along with bivalents; 57=tripolar anaphase; 58=opposite orientation of II anaphase; 59=I anaphasic laggards; 60 to 67=*Moniera cuneifolia*; 60 and 61=metaphase and prometaphase with 40 bivalents; 62=tripolar anaphase; 63=I anaphasic laggards; 64 to 66=I anaphasic bridges; 67=multipolar anaphase; 68 to 78=*Dopatrium lobelioides*; 68=metaphase with 7 bivalents; 69 to 71=combinations of univalents, trivalents quadrivalents; 72 and 73=metaphase II; 74=I anaphasic laggard; 75=tripolar anaphase; 76=II anaphasic laggard; 77 and 78=tetrads with 1 and 2 sterile pollens respectively; 79 to 88=*Torenia fournieri*; 79 and 80=prometaphase and metaphase with 9 bivalents; 81 to 83=combinations of multivalents, quadrivalents, trivalents and univalents with bivalents; 84=tripolar anaphase; 85=I anaphasic

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bridge; 86=metaphase II; 87=opposite orientation of anaphase II; 88=unequal anaphase II; 89 to 104= *Vandellia crustacea*; 89=prometaphase with 21 bivalents; 90= combinations of quadrivalents and bivalents; 91=metaphase II with larger and smaller chromosomes; 92 and 94 to 97= tripolar anaphases; 93=opposite orientation of metaphase II; 98=precocious movements of chromosomes at metaphase I; 99 to 101=tetrads with 2 and 4 sterile pollens. 102=chromatin connections among the pollen grains of tetrads; 103=II anaphasic laggard; 104=I anaphasic bridge.

Type G: Chromosome with median centromere.

Type H: Short (1.0 μm to 1.4 μm) Chromosome with submedian centromere.

Type I: Chromosome with median centromere.

Type J: Chromosome with subterminal centromere.

Type K: Shorter (0.6 μm to 0.9 μm) Chromosome with median centromere.

Type L: Chromosome with subterminal centromere.

The total number of secondary constricted chromosomes has been found to vary from species to species. The details of chromosome measurements are given in Table 3. In this table, the particulars about the karyotype analyses of the species and the descriptions of the various columns are as follows:

1. Chromosome number (2n)
2. Size range in millimicrons
3. Number of chromosomes with secondary constrictions
4. Number of chromosomes with submedian constrictions
5. Number of chromosomes with median constrictions

Table 3. Summarised karyomorphological features of the taxa investigated here

Taxa	1	2	3	4	5	6	7	8
<i>Verbascum thapsus</i>	34	0.8 to 1.5	—	14	12	8	42.0	1.66
<i>Celsia coromandeliana</i>	80	0.9 to 1.5	—	32	32	16	94.8	1.186
<i>Linaria vulgaris</i>	12	1.2 to 2.3	—	4	6	2	17.6	1.466
<i>Stemodia viscosa</i>	28	0.9 to 1.9	2	2	20	4	34.2	1.22
<i>Limnophila heterophylla</i>	34	1.1 to 2.0	4	14	10	6	49.8	1.46
<i>Moniera cuneifolia</i>	80	0.8 to 1.8	—	34	28	18	115.6	1.45
<i>Dopatrium lobelioides</i>	14	0.9 to 2.2	—	6	4	4	22.4	1.60
<i>Torenia fournieri</i>	18	0.9 to 2.0	—	8	6	4	25.2	1.40
<i>Vandellia crustacea</i>	42	0.9 to 2.2	—	16	20	6	63.0	1.50
<i>Ilysanthes tenuifolia</i>	16	0.9 to 1.4	—	6	6	4	18.0	1.16
<i>I. oppositifolia</i>	18	1.1 to 1.8	—	6	8	4	25.2	1.40
<i>Scoparia dulcis</i>	40	1.1 to 2.5	10	22	4	4	63.4	1.59
<i>Sopubia trifida</i>	36	1.1 to 2.2	2	18	10	6	52.2	1.42
<i>Calceolaria mexicana</i>	60	0.9 to 1.8	4	22	22	12	82.6	1.38
<i>Antirrhinum majus</i>	24	0.9 to 1.6	—	8	12	3	30.2	1.26
<i>Digitalis purpurea</i>	48	0.6 to 2.0	4	10	18	16	55.8	1.16
<i>Angelonia grandiflora</i>	20	1.1 to 2.0	4	4	8	4	29.8	1.49
<i>Russelia juncea</i>	20	0.9 to 1.8	—	8	8	4	29.6	1.48

Figs. 105–178. 105=109=*Ilysanthes tenuifolia*; 105=prometaphase with 8 bivalents; 106=quadrivalents and bivalents at metaphase I; 107=metaphase II with 8 chromosomes at each pole; 108=tripolar anaphase; 109=I anaphasic bridge; 110 to 118=*Scoparia dulcis*; 110=I metaphase with 20 bivalents; 111 to 113=combinations of multivalents, quadrivalents and bivalents; 114=tripolar anaphase; 115 to 117=tetrads with 2 and 4 sterile pollens; 118=chromatin connections among the 4 pollens of the tetrads; 119 to 128=*Micrargeria wightii*; 119=metaphase I with 20 bivalents; 120 to 124=combinations of multivalents, quadrivalents, trivalents and univalents with bivalents; 125=metaphase II; 126=tripolar anaphase; 127=I anaphasic laggard; 128=polyads; 129 to 137=*Calceolaria mexicana*; 129=prometaphase with 30 bivalents; 130=prometaphase with 15 bivalents; 131=metaphasic nucleus; 132=tripolar anaphase. 133=tetrad with one sterile pollen; 134=tetrad with 4 fertile pollens; 135=precocious movements of chromosomes at metaphase I; 136 and 137=I anaphasic bridges; 138 to 145=*Antirrhinum majus*; 138 and 139=prometaphase and metaphase with 12 bivalents; 140 and 141=combinations of quadrivalents, multivalents and bivalents; 142=metaphase II; 143 and 144=polyads; 145=I anaphasic bridge; 146 to 153=*Digitalis purpurea*; 146 and 147=prometaphase and metaphase with 24 bivalents; 148 to 150=combinations of quadrivalents, multivalents, univalents and bivalents; 151=metaphasic nucleus; 152=tripolar anaphase; 153=multipolar anaphase; 154 to 146=*Angelonia grandiflora*; 154 and 155=prometaphase and metaphase with 10 bivalents; 156 and 157=combinations of multivalents, quadrivalents, trivalents, univalents and bivalents; 158=I anaphasic

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bridge; 159=II anaphasic bridge; 160=II anaphasic laggards; 161 to 167=*Russelia juncea*; 161=metaphase I with 10 bivalents; 162=prometaphase II with 10 chromosomes at each pole; 163=II anaphasic laggards; 164 and 165=I anaphasic bridges and laggards; 166=tripolar anaphase; 167=multipolar anaphase; 168 to 172=*Striga lutea*; 168 and 169=prometaphase and metaphase with 20 bivalents; 170 and 171=tetrads with 4 sterile pollens; 172=tetrads with 2 sterile pollens; 173 to 178=*Striga densiflora*; 173=metaphase with 20 bivalents; 174 to 176=combinations of quadrivalents, multivalents, univalents and bivalents; 177=II metaphase with smaller and larger chromosomes; 178=I anaphasic laggards.

6. Number of chromosomes with subterminal constrictions
7. Absolute chromosome length in millimicrons
8. Average chromosome length in millimicrons

2 to 4 and rarely 10 secondary constricted chromosomes were observed in 7 out of 18 species examined. A comparison of the total chromatin contents in different species shows a range from 17.6 μm to 115.6 μm , the lowest being in *Linaria vulgaris* and the highest being in *Moniera cuneifolia*. This indicates considerable variation in total chromatin content. However, it should be added that the possibility of a part of this variation being due to differences in the degree of condensation of the chromosomes cannot be ruled out. More emphasis, therefore, will have to be laid on the degree of asymmetry rather than on total chromatin content. The mitotic plates for some of the species studied are presented in Figs. 1 to 9 and their idiograms are presented in Figs. 10 to 27 and the histogram showing absolute chromosome lengths of the 18 species studied mitotically are presented in Fig. 28. The figures illustrate the differences in the karyotypes of different species.

Meiotic study has been made in *Verbascum thapsus*, *Celsia coromandeliana*, *Stemodia viscosa*, *Lymnophila heterophylla*, *Moniera cuneifolia*, *Dopatrium lobelioides*, *Vandelia crustacea*, *Ilysanthes tenuifolia*, *Scoparia dulcis*, *Micrargeria wightii*, *Calceolaria mexicana*, *Antirrhinum majus*, *Digitalis purpurea*, *Angelonia grandiflora*, *Russelia juncea*, *Striga lutea* and in all these species, the haploid number is in confirmation with diploid numbers.

Discussion

Cytological studies have been made in 21 taxa of South Indian Scrophulariaceae, in which first record of chromosome number has been made in *Lymnophila heterophylla*, *Ilysanthes tenuifolia*, *I. oppositifolia*, *Micrargeria wightii* and *Sopubia trifida*.

In the present study when the karyotype of 18 taxa were examined, it was obvious that karyotype asymmetry was of a high order. From the works of Löve and Löve (1942) on boreal plants, Babcock (1947) in *Crepis*, Satō (1942) in Liliaceae and Stebbins, Jenkins and Walters (1953) in Cichorieae of Asteraceae, and Sharma and Sarkar (1950) in plams, it is clear that chromosomes of uniform size with symmetrical karyotypes are likely to be found in less derived plants than those of unequal size with asymmetrical karyotypes. Besides, the 'SC' chromosomes with two constrictions have been observed in 7 out of 18 species mitotically studied. We may assume that the absence of two more constricted chromosomes in most of the taxa studied may be an indication of the advanced status of the family. The karyotype analyses of the taxa of Myrtaceae by Atchison (1947) support the same conclusion. The karyotype analyses of the various species studied show that each and every species has a distinct karyotype. Therefore, it may be assumed that karyotype alteration plays important role in speciation.

The Scrophulariaceae shows a wide range of basic numbers from 6 to 84 (Fedorov 1974). The commonest basic number in the family is $n=8$ and it is assumed to be the original basic number of the family and that $n=10, 11, 12, 13, 14$ etc. derived by polyploidy. Evolution of an aneuploid series ($n=6, 7, 8, 9, 10, 11, 12, 13, 14, 17, 18, 20, 23, 24, 28, 30, 32, 50, 60$ etc.) from the original number $n=8$, followed by polyploidy might have given rise to the wide range of basic numbers now observed in the family.

The formation of an aneuploid series prior to polyploidy is indicated by *Ilysanthes tenuifolia* ($2n=16$), *I. oppositifolia* ($2n=18$), *Torenia fournieri* ($2n=18$), *Angelonia grandiflora* ($2n=20$), *Russelia juncea* ($2n=20$), *Antirrhinum majus* ($2n=24$) and *Vandellia crustacea* ($2n=28$), as evidenced by the present investigation (Table 4). Basic numbers 17 to 30 and above might have been arisen by diphasic amphidiploidy, by combination of any two basic numbers by natural hybridizations and or by gain or loss of chromosomes following polyploidy. Examples for

this type of evolution are *Verbascum thapsus* ($2n=34$), *Lymnophila heterophylla* ($2n=34$), *Celsia coromandeliana* ($2n=36$), *Moniera cuneifolia* ($2n=36$), *Sopubia trifida* ($2n=36$), *Scoparia dulcis* ($2n=40$), *Striga lutea* ($2n=40$), *S. densiflora* ($2n=40$), *Digitalis purpurea* ($2n=48$) and *Calceolaria mexicana* ($2n=60$), as evidenced by the present investigation. It is concluded that aneuploid and diphasic amphidiploidy together with structural alterations of chromosomes play important role in speciation.

Meiotic studies have been made in 18 species of 21 taxa included in the present investigation and the haploid chromosome numbers of the species were found to be in conformity with the diploid numbers.

Anaphasic laggards and bridges have been noticed in *Celsia coromandeliana*, *Moniera cuneifolia*, *Dopatrium lobelioides*, *Torenia fournieri*, *Vandellia crustacea*, *Scoparia dulcis*, *Micrargeira wightii*, *Calceolaria mexicana*, *Antirrhinum majus*, *Angelonia grandiflora*, *Russelia juncea* and *Striga densiflora*. It is an established fact that the bridges and fragments at anaphase I and

Table 4. Chromosome types

Taxa	Long				Medium			Short			Shorter	
	A	B	C	D	E	F	G	H	I	J	K	L
<i>Verbascum thapsus</i>	—	—	—	—	—	6	—	8	12	4	—	4
<i>Celsia coromandeliana</i>	—	—	—	—	—	8	—	24	32	4	—	12
<i>Linaria vulgaris</i>	—	—	—	2	—	2	—	—	6	2	—	—
<i>Stemodia viscosa</i>	—	—	—	—	2	—	—	2	20	2	—	2
<i>Lymnophila heterophylla</i>	2	2	—	—	8	—	2	—	8	6	—	—
<i>Moniera cuneifolia</i>	—	—	—	—	—	10	6	24	22	12	—	4
<i>Dopatrium lobelioides</i>	—	—	—	2	—	6	2	—	—	2	—	2
<i>Torenia fournieri</i>	—	—	2	—	—	4	—	2	6	—	—	4
<i>Vandellia crustacea</i>	—	—	4	2	—	10	6	2	12	4	—	2
<i>Ilysanthes tenuifolia</i>	—	—	—	—	—	—	—	6	6	—	—	4
<i>I. oppositifolia</i>	—	—	—	—	—	2	4	4	4	4	—	—
<i>Scoparia dulcis</i>	6	2	2	—	2	6	—	14	4	4	—	—
<i>Sopubia trifida</i>	2	—	2	—	—	2	2	10	8	6	—	—
<i>Calceolaria mexicana</i>	—	—	—	—	2	16	8	6	14	4	—	8
<i>Antirrhinum majus</i>	—	—	—	—	—	2	2	6	10	—	—	4
<i>Digitalis purpurea</i>	2	—	—	—	2	4	4	6	14	2	—	14
<i>Angelonia grandiflora</i>	—	—	2	—	4	2	2	—	6	4	—	—
<i>Russelia juncea</i>	—	—	—	—	—	8	6	—	2	2	—	2

II are indicative of inversion heterozygosity (Upcott 1937). The frequency of bridge formation in any species depends on three factors namely, chiasma frequency, number of inversions and size of inversions. Out of 18 species meiotically studied here, bridges and laggards have been observed in 12 species. This shows that inversion heterozygosity has also played important role in speciation. The inversion heterozygosity is known to cause univalency and the univalents formed are lagged behind as anaphasic laggards. In most of the species meiotically studied, multivalents and quadrivalents occur along with bivalents during metaphase. The formations of these may be attributed to polyploidy or structural alterations in the chromosomes. The species studied are aneuploids and therefore, these multivalents and quadrivalents are due to aneuploid nature of the species. The same may be responsible of the presence of tripolar anaphases observed in *Verbascum thapsus*, *Celsia coromandeliana*, *Lymnophila heterophylla*, *Moniera cuneifolia*, *Dopatrium lobelioides*, *Torenia fournieri*, *Vandellia crustacea*, *Ilysanthes tenuifolia*, *Scoparia dulcis*, *Micrargeira wightii*, *Calceolaria mexicana*, *Digitalis purpurea* and *Russelia juncea*.

Summary

The chromosome number of 21 species belonging to 17 genera of Scrophulariaceae from South India has been studied, of which first record of chromosome has been made in *Lymnophila heterophylla*, *Moniera cuneifolia*, *Ilysanthes tenuifolia*, *I. oppositifolia*, *Micrargeria wightii* and *Sopulia trifida*. Chromosome numbers determined in the present study range from $2n=12$ to $2n=80$.

Chromosome numbers determined in the present study and those reported previously in the family (Fedorov 1974) reveal the presence of a continuous series of basic number between $n=6$ to 84. The commonest basic number in the family is $n=8$ and it is assumed to be the original basic number of the family. It appears that aneuploid changes of chromosome numbers produced the basic numbers of $n=6, 7, 8, 9, 10, 11, 12, 13$ and 14 in the early evolution of the family, after which polyploid and dibasic amphidiploid gave rise to the higher basic numbers ($n=17$ to $n=84$) now found in the family.

Karyotypes in the family also show differences in absolute chromosome size indicating changes in nuclear DNA in evolution. The meiotic chromosome number studied in 17 species is in confirmation with the mitotic chromosomes. The presence of multivalents and quadrivalents along with bivalents and the presence of anaphasic laggards and bridges and triplar anaphases show evidences in support of the aneuploid and polyploid nature of the species.

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