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Contribution to the Cytotaxonomy and Cytogeography of the Flora of the Western Himalayas (with an attempt to compare it with the Flora of the Alps).

Thesis

presented to the Faculty of Sciences of the University of Neuchâtel to obtain the Doctorate Degree in Sciences (Ph.D.)

by

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Rerodruck R. Rotach CH-8620 Wetzikon ZH – 1977

The Faculty of Sciences, based on reports of the Professors

C. Favarger, J. Miège and Ch. Terrier

authorizes the impression of this thesis without expressing an opinion on its contents.

Reprint from
„Berichte der Schweizerischen Botanischen Gesellschaft"
1975 (volume 85), 1976 (volume 86)

Ber. Schweiz. Bot. Ges. *85* (1), 57–84 (1975)

Contribution to the Cytotaxonomy and Cytogeography of the Flora of the Western Himalayas (with an attempt to compare it with the Flora of the Alps). Part I.

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I. Introduction

1. The object of the present work.

The occurrence of about 30'000 species of flowering plants in the Indian subcontinent (G.S. Puri, 1960), representing more than 1/8th of the estimated quarter million species of the flowering plants of the world (Davis and Heywood, 1963, p. 194) gives an idea of the richness of the flora in this subcontinent. According to Hooker (1897) „the flora of the Indian continent is perhaps the richest and is certainly the most varied botanical area on the surface of the globe, and one which, in a greater degree than any other, contains a representation of the flora of both the Eastern and Western Hemispheres".

Cytological characters are often regarded as of predominant importance in the taxonomy since chromosomes are closely connected with the mechanisms of heredity (Darlington, 1956; Stebbins, 1959; Löve, 1960). They may give the direction of evolutionary changes, indicating which groups are derived from others. The study of chromosome numbers suggests an improved rearrangement of tribes and genera. Even generic status is being shifted by chromosome information as in the example of *Cicendia* (*Gentianaceae;* Favarger, 1960).

Whereas about 70% of the flora of Central Europe has been cytologically studied (Tischler, 1950), for 25% of the higher plants growing in the Himalayas chromosome numbers are known today. These facts made us initiate the present project with the following main points:

(1) Discovery of chromosome numbers of many plant species and genera hitherto unknown.
(2) Estimation of implications of cytological findings in the taxonomical status of different groups.
(3) Utilization of cytological data to obtain some information on the age of the alpine flora of the region surveyed.
(4) Attempt to compare the alpine flora of the W.Himalayas and the flora of the Alps in Europe.

2. Acknowledgements.

I have a great pleasure to express my whole gratitude to Professor Claude Favarger, Director of the Institute of Botany, University of Neuchâtel, under whose direction I prepared this thesis. Since 1971, when I started working on European plants under the guidance of Professor Favarger, I have been thoroughly introduced to the various critical problems of cytotaxonomy and cytogeography and their offspring biosystematics by his constant and inspiring discussions at every stage and on every aspect of the concerned study.

I am deeply thankful to the State of Neuchâtel for granting me a fellowship in November 1971, which enabled me to pursue my studies in this University. I express my heartful thanks to Professors Ch.Terrier and J. Miège (Geneva) who have been kind enough to read the present work.

The first part of the studies concerning the flora of Western Himalayas was supported by the financial assistance of PL 480 Scheme of United States in India. I extend my profound thanks to their authorities. I am also happy to thank Professor P.N. Mehra, Head of the Department of Botany, Panjab University, Chandigarh, India, for providing me facilities to work in the PL 480 Scheme operated through his department.

Everybody at the Institute of Botany of Neuchâtel was very helpful to me through my studies there: I am greatly indebted to all of them. I wish to thank particularly: Mrs S. Favarger, Mrs M.-M. Duckert, Miss F. Prieur, Mrs B. Emery, MM.K.-L. Huynh, Ph. Küpfer, E. Beuret, G. Boss and P. Correvon.

3. Material and Methods

Material for research was collected from wild populations of Western Himalayas and at the foothills of Siwalik Hills near Chandigarh. To collect the maximum number of alpine plants in their habitat, a special procedure was adapted to W. Himalayas. Temporary laboratories were set up in higher hill stations of W. Himalayas (Nainital, Mussoorie, Simla and Gulmarg, see Table A) during the flowering period of mountain plants. From these stations, continuous plant exploration trips were made to all accessible regions of W. Himalayas from 1968 to October 1971. Every year, for about six to nine months, flower buds were fixed for cytological preparations, and slides and herbarium material were prepared in the laboratories.

The plants from Europe were collected from many places in Switzerland, especially in the Simplon region of the Alps. In a few cases, seeds were received from many places (collected in the fields by botanical gardens). Plants raised from seeds were cultivated in the botanical garden at Neuchâtel for identification. The specific localities and the altitude of the collections are mentioned in a Table for each family.

Meiotic behaviour was studied from the pollen mother cells. Young flower buds were fixed in Carnoy's fluid (1:3:6 acetic acid, chloroform and absolute alcohol). The acetic acid component was prasaturated with iron acetate. The flower buds were usually transferred to 95% alcohol after one or two days. The anthers were squashed in 1% aceto-carmine as early as possible because delayed squashing results in poor staining. After passing through 1:1, 1:3 and 1:9 acetic butanol, and finally through pure butanol, the slides were mounted in euparal and dried at 40°C.

For karyotypic studies, mature seeds were germinated on moist blotting paper in Petri dishes. Root tips were squashed by the oxyquinoline technique of Tjio and Levan (1950). The material was subsequently macerated in a 9:1 mixture of aceto-lacmoid and N/1 HCl and then squashed in 1% aceto-lacmoid. Slides were made permanent in euparal. Somatic chromosomes of the genus *Cuscuta* were studied from the tapetal cells which undergo division in the early stages of meiosis of PMC's. Since the genus is highly responsive to aceto-carmine stain, somatic chromosomes of the tapetal cells get nicely stained during normal squashing of anthers.

Photomicrographs and camera-lucida drawings are at a uniform magnification of x = 2270 with few exceptions (mentioned in explanation to figures) on account of the large size of their cytoplasm in PMC's.

Pollen fertility refers to morphologically normal pollen grains stained with aceto-carmine.

Stomatal studies are made by peel method. The dried leaves from voucher specimens were heated in 5% KOH solution at 60°C for 2 hours. This facilitated the subsequent removal of peels from both the surfaces of the leaves with the aid of a pair of forceps. The peels were made transparent by gently heating them with a chlorohydrate solution. After proper washing, the peels were stained in 1% safranin solution and double-mounted in 20% glycerine and Canada balsam for observation. Stomatal size is measured in microns (μ) with the help of an Ocular Micrometer and Stage Micrometer.

Voucher specimens from W. Himalayas have been deposited in the herbarium of the Botany Department, Panjab University, Chandigarh-14, India, and those from Europe in the Institute of Botany, University of Neuchâtel, 2000 NEUCHATEL, Switzerland. Families have been arranged according to Engler and Prantl (1897).

Table A

	Base station			
Region of collections with areas covered in W. Himalayas	Station	Latitude	Longitude	Average altitude
Kumaon Hills (Almora, Nainital, Ranikhet, Pindari glacier, Badrinath, Valley of flowers)	Nainital	29°. 22'N	79°. 29'E	1900 m
Mussoorie Hills (Mussoorie, Dehra Dun, Chakrata, Rishikesh, Gangotri, Kedarnath)	Mussoorie	30°. 28'N	78°. 10'E	1900 m
Kashmir (Gulmarg, Srinagar, Pahalgam, Ladakh, Gurez valley, Batot, Aporwat, Sonamarg)	Gulmarg	34°. 25'N	74°. 40'E	2700 m
Siwalik Hills and adjacent plains (Chandigarh, Pinjore, Kalka, Kasauli)	Chandigarh	30°. 44'N	76°. 53'E	300 m

4. Brief survey of the flora and vegetation of the Western Himalayas

a) Area of survey

The area of the present investigation in Himalayas extends from Kashmir in the west to Nainital in the central Himalayas. In the north, the limits are the Tibet and Nepal borders (National boundaries) and in the south, the outer hills of Himalayas touching the northern plain of India.

The region of Western Himalayas lies between 29°N. 35°N latitude and 74°W. 80°E longitude. The author used the main and the only routes leading to higher altitude localities in the interior Himalayas to observe the alpine vegetation of *Pindari glacier, Badrinath, Narkanda, Kedarnath* etc., in Kumaon; *Aporwat, Pahalgam* and *Ladakh* via *Sonamarg* in Kashmir. These routes are connected with different „hill stations" where temporary laboratories were set up for the present investigation. Most of the regions surveyed are situated in the temperate Himalayas (see p. 13), while a part of the foothills comes under the subtropical Himalayas. The following table shows the geographical position of the main territories explored.

b) The flora

The Western Himalayas are situated at the crossroad of three important floristic empires which, according to Gaussen (in Legris, 1963) constitute the Indo-African empire (1), the Mediterranean empire and the Holarctic empire. Species from Indo-African tropical origin are abundant on the first slopes (Siwalikhs), in the forest of *Shorea robusta* and in the bushes of *Acacia* and *Carissa*. They still represent approximately half of the species in the forest of *Pinus roxburghii* (Meusel *et al.*, 1971, p. 391) of the submountainous level which is considered as subtropical by Legris (1963, p. 295). They disappear completely from the upper mountainous level or „altomontane" level of Meusel *et al.* (forests of *Abies spectabilis* and *Picea smithiana*). Species of Mediterranean origin (*sens. lat.*) may be found mainly at the mountainous level in the forests of *Pinus griffithii* and *Cedrus deodara*, especially stretched in the western part of the surveyed area. They also constitute an important part of the vegetation in the woods of *Olea ferruginea* and *Quercus baloot* in the longitudinal valleys of Kashmir (Chenab) and in the „bush" of the Kashmir Basin (Meusel *et al.*, 1971, p. 424).

Almost all the species of the upper mountainous level, of the subalpine level and of the alpine level belong to the Holarctic contingent which is already present at the mountainous level, chiefly in the forests of *Quercus incana* in the eastern part of the area.

The distinction of three large floristical empires is not sufficient to allow a more detailed analysis of the flora. As endemism is very important in the Himalayan flora (28.8% of the Dicotyledon species (after Chatterjee, in Puri, 1971), many authors have considered the Western Himalayas as one of the floristic region in India (10 regions are distinguished by Chatterjee, loc. cit.). Amongst the 24 elements

(1) For other authors, especially Emberger (1968), the flora of the Indian Peninsula belongs to the Asiatico-Pacific empire.

represented in the Flora of India, Legris (op. cit.) reports 7 Himalayan elements: three being the „chief elements" and the remaining four called „joining elements". One of the main elements is the *Western Himalayan element*.

On the other hand, Meusel *et al.* (1971) have made a detailed analysis of the chorology of many species belonging to the different levels of vegetation in the Western Himalayas. Unfortunately, their study does not include the orophilous flora, i.e. the flora of the subalpine and alpine levels.

However, these authors reached very interesting inferences particularly on the relationship between the extratropical elements of the Himalayas and old Mediterranean taxa and taxa from the Sino-Japanese flora. Therefore, they conclude that „from the genetical point of view the whole of the Himalayas is considered to be part of the Sino-Japanese region".

Gupta (1972) has recently published a paper on the boreal and arcto-alpine elements in the flora of the Western Himalayas. In fact, he mainly develops the classical conception of the floral exchanges between the arctic region and the high mountains of the northern hemisphere during the glacial period (cf. p. 170) and that of „nunatakkers". According to the same author, the glaciations have noticeably depressed the snout of the glaciers and the permanent snowline in the Western Himalayas. For example, the snout of the Kedarnath glacier, which reaches nowadays 4500 m above sea level, was at an altitude of 1950 m during the greatest glacial maximum (1). Regarding the perpetual snowline, it would have been depressed of 800 m on the northern slope and of 160 m on the southern slope.

In spite of these facts, all the authors (for ex.: Antevs, 1929, Charlesworth 1957, Gupta, op. cit., and Legris, op. cit.) agree to affirm that the glaciations were smaller in Asia compared to those in Europe and America, and that the range of „nunatakkers" was wider in the Himalayas than in Europe.

Gupta (p. 171) thinks that a detailed study of the endemics would allow an explanation of many problems regarding the history of the flora. After Favarger & Contandriopoulos (1961), such studies must be based, for the main part, on cytotaxonomy. This branch of science also allows to obtain important informations about the relative age of a flora and its history (Favarger, 1961).

c) The vegetation (2)

The vegetation of the Western Himalayas is very complicated and it is difficult to give a synthesis of it. As it is the case in most mountainous regions, the climax vegetation occupies a relatively small place on account of the steepness of the slopes and of the human influence in the valleys. Moreover, there are rather great

(1) According to Legris (op. cit.) the Himalayas having risen during the Pleistocene, it can be estimated that the real altitude of the snout of the glaciers during the maximum glacial period varies between 600 m and 1300 m.

(2) Pictures of vegetation are shown in Figs 175 to 185.

climatic differences between the western part (Kashmir) which is dryer, and the more humid eastern part (Kumaon), just as betweeen the exterior chains which are under the influence of the monsoon rainfall and the interior much dryer valleys. According to Legris (op. cit.) and to Meusel *et al.* (op. cit., p. 141), the Kashmir Basin's climate is like the Mediterranean climate; the climate which prevails from Punjab to Nepal is a bixeric one with rainfalls both in the summer and in the winter (Legris, op. cit., p. 287).

The authors who have described the series of vegetation in the Western Himalayas, for ex. Legris (op. cit.), Puri (op. cit.), Meusel *et al.* (op. cit.), and Aymonin and Gupta (1965), do not agree together and do not use the same terminology.

As Aymonin and Gupta (op. cit.) pointed out: „in going from West to East (i.e., from the high mountains of Western Europe to those of Central Asia), one can observe very great changes which make difficult to employ the terms classically used for the Alps".

In the following scheme, we adopt the levels of vegetation proposed by Legris (1963) for the western and central Himalayas.

Upper limit	*Vegetation*	*Name of the level*
ca. 6000 m	Open nival vegetation	Nival
5500 m	Alpine meadows and scrub of *Rhododendron anthopogon, Juniperus spec., Salix*, etc.	Alpine
4000 m	*Abies spectabilis* and *Betula utilis* forest, with *Rhododendron, Sorbus*, etc.	Level of highmountain forest
3300 m	*Quercus semecarpifolia* forest	Moist mountainous level
2700 m	*Picea morinda-Cedrus* forests	
2400 m	*Quercus dilatata* forest	
2100 m	*Cedrus deodara-Quercus incana* forest	
1800 m	Dry forest with *Pinus roxburghii*	Subtropical
1000 m	Dry deciduous forest with *Shorea*	Tropical

In the western part of the surveyed region (Kashmir), the series of vegetation are rather different from those of Kumaon. The *Shorea* forest is replaced by a dorny scrub of *Acacia* and *Carissa* with *Olea cuspidata*. At the mountainous level, the *Cedrus deodara* forest replaces *Quercus dilatata* and *incana* in the north of the valley of Jhelum.

The series of vegetation reported by Meusel *et al.* (op. cit.) tallies more or less with those of Legris, except for the names given to the different levels. The tropical level is designed with the term „Kollin" (hill level), the subtropical one with „submontan" and the level of *Betula utilis* with „subalpin". On the other hand, the forest of *Quercus semecarpifolia* is transferred to the level of high mountain

Table 1: *GENTIANACEAE*

Taxa	Source and altitude	Collection number	Chromosome number n	2n	Level of ploidy	Previous report
	Species from the Western Himalayas studied by the author (A)					
Subfamily Gentianoideae						
Tribe Gentianeae						
Subtribe Erythraeinae						
Centaurium pulchellum * (Sw.) Druce	Almora, 1800 m Kumaon, India	2600	36	–	8x	2n = 36, Zeltner 1962, 1970 2n = 36, 54, 56, Khoshoo & Khushu, 1966
Subtribe Gentianinae						
1. Genus Gentiana						
Subgenus Gentiana						
Section Chondrophylla Bg. *Gentiana argentea* Royle **	1900 m Nainital, India	2045	10	–	2x	
G. capitata Ham. var. *strobiliformis* Clarke **	Gulmarg, 2700 m Kashmir, India	4212	10	–	2x	
G. carinata Griseb. **	Razhan Hill, 2900 m Kashmir, India	4278	10	–	2x	
	Gulmarg, 2700 m Kashmir, India	4213	20	–	4x	n = 20, Mehra & Gill 1968
G. pedicellata Wall. ** (= *G. quadrifaria* Blume)	Khathi, 2200 m Kumaon, India	2548	9	–	2x	
Subgenus Gentianella						
Section Amarella Griseb.(1) *G. moorcroftiana* Wall.*	Tajawas glacier, 2700 m Kashmir, India	4263	9	–	2x	2n = 26, Wada 1966
Section Crossopetalum Fröl. *G. detonsa* Fries*	Sind Valley, 2700 m Kashmir, India	4252	13	–	2x	2n = 44, Löve 1953
2. *Jaeschkea latisepala* Clarke**	Khilanmarg, 3000 m Kashmir, India	4253	10	–	2x	
3. *Pleurogyne carinthiaca* Griseb.** (= *Lomatogonium carinthiacum* Wulfen)	Sonamarg, 2700 m Kashmir, India	4264	24	–	8x	2n = 40, Fürnkranz 1965 n = 23, Favarger (unpublished)
4. Genus Swertia						
Section Ophelia (Don) Benth. and Hook. *Swertia purpurascens* Wall.	3050 m Badrinath, India	2009	10	–	2x	n = 10, Khoshoo and Tandon 1963 n = 12, Mehra and Gill 1968
S. paniculata Wall.	1900 m Nainital, India	2015	8	–	2x	n = 8, Khoshoo and Tandon 1963
S. cordata Wall.	Chinapeak, 1900 m Nainital, India	2014	13	–	2x	2n = 13, Khoshoo and Tandon 1963 n = 13, Mehra and Gill 1968
S. chirata Ham.	1900 m Nainital, India	2020	13	–	2x	n = 13, Khoshoo and Tandon 1963
S. angustifolia Ham.	Binsor, 2100 m Almora, India	2013	13	–	2x	n = 13, Khoshoo and Tandon 1963 n = 12, Mehra and Gill 1968
S. tetragona Clarke	1900 m Nainital, India	2032	9	–	2x	n = 9, Khoshoo and Tandon 1963
S. lurida Royle **	1900 m Mussoorie, India	2067	13	–	2x	
S. alata Royle	1900 m Nainital, India	2008	13	–	2x	n = 13, Khoshoo and Tandon 1963 n = 12, Mehra and Gill 1968
Section Swertia						
S. speciosa Wall.	Gulmarg, 2700 m Kashmir, India	4284	13	–	2x	n = 13, Khoshoo and Tandon 1963 n = 13, Mehra and Gill 1968
S. petiolata Royle	Aporwat, 3900 m Kashmir, India	4241	13	–	2x	n = 13, Khoshoo and Tandon 1963
S. thomsoni Clarke	Sonamarg, 2700 m Kashmir, India	4254	13	–	2x	n = 13, Khoshoo and Tandon 1963
5. *Halenia elliptica* D. Don	Gangaria, 2800 m Kumaon, India	2011	11	–	2x	2n = 22, Favarger 1952b
Subfamily Menyanthoideae						
Tribe Menyantheae						
Limnanthemum nymphaeoides Link.	Srinagar, 165 m Kashmir, India	4226	27	–	6x	2n = 54, Scheerer 1939 and Sobti and Singh 1961
	Species from the Alps studied by the author (B)					
Gentiana subgenus Gentianella						
G. ramosa Hegetschw.*	Mattmark, 2210 m Valais, Switzerland	–	36			
G. anisodonta Borbas	Klagenfurterhütte, 1050 m Karawanken, Austria	18	–			n = 18, Favarger 1965
	Zochpass, 2250 m Lienzer, Dolomiten, Austria	18	–			n = 18, Favarger 1965
G. germanica Willd. ssp. *rhaetica* A. et J. Kerner (2)	Canale di Cimolais, 1000 m Italy	18	–			2n = 36, Favarger 1965

* A new chromosome report for the species.
** Chromosome number of the species reported for the first time.
(1) Nilsson (1967, p. 106) placed this species in section *Arctophila*.
(2) After Fiori (1925–1929), this plant would be the *forma forojuliensis* Gortani

Table 2: *CONVOLVULACEAE*

Taxa	Source and altitude	Collection number	Chromosome number n	2n	Level of ploidy	Previous report
	Species from the Western Himalayas studied by the author (A)					
Subfamily Convolvuloideae						
Tribe Convolvuleae						
Ipomoea coccinea L.*	Kathgodam, 400 m Nainital, India	2034	15	–	2x	2n = 28, Sharma and Datta 1958
I. quamoclit L.	Karnaprayag, 1000 m Kumaon, India	2026	15	–	2x	2n = 30, Sharma and Datta 1958
I. hederacea Jacq.	1900 m Nainital, India	2524	15	–	2x	n = 15, Ting *et al.* 1957 2n = 30, Sharma and Datta 1958
I. purpurea Lamk.	1900 m Nainital, India	2540	15	–	2x	n = 20, Baquar et al. 1965 2n = 30, Sharma and Datta 1958 Nishiyama *et al.* 1961, Jones 1964
I. calrica L.	400 m Haldwani, India	2530	15	–	2x	n = 15, Jonas 1964
I. tricolor Cav.	300 m Chandigarh, India	2062	15	–	2x	n = 15, Jones 1964
Convolvulus pluricaulis Chois.	300 m Chandigarh, India	2071	18	–	4x	2n = 20, Singh 1951 2n = 18, 36, Malik and Tandon 1959 n = 18, Malik and Grover 1968 2n = 36
C. arvensis L.	Chamoli, 700 m Kumaon, India	2030	24	–	4x	2n = 50, Wolcott 1957 2n = 48, Khoshoo and Sachdeva 1961 2n = 50, Heiser and Whitaker 1948
Porana racemosa Roxb.*	Binsor Road, 2000 m Almora, India	2041	14	–	2x	
Tribe Dicranostyleae						
Evolvulus alsinoides L.	Thal, 1000 m Kumaon, India	2046	13	–	2x	2n = 26, Raghavan 1959
Subfamily Cuscutoideae						
Genus Cuscuta						
Subgenus Grammica						
Section Eugrammica	Kargil, 2500 m	4247	8	16	2x	
Cuscuta chinensis Lamk.*	Ladakh, India					
Subgenus Monogyna						
Section Callianche						
C. reflexa Roxb.	Dehra Dun, India	2085	14	–	4x	n = 16, Raghavan 1957 2n = 28, Finn 1937 2n = 42, Sharma and Chatterji 1957
	2100 m Govindghat, India	2029	15	30	4x	
	500 m Kalka, India	2061	16	–	4x	
Subgenus Cuscuta						
Section Cuscuta						
C. planiflora Tenore *	Tangmarg, 2100 m Kashmir, India	4246	7	14	2x	
C. capitata Roxb.*	Kargil, 2500 m Ladakh, India	4227		20	2x	
C. spec.	Hanuman Chatti, 2800 m Kumaon, India	2019	31	62	8x	
	Species from Europe studied by the author (B)					
Convolvulus arvensis L.	Sesém Bot. G. Coïmbra Portugal		–	48	4x	videte supra (Table 2A)
Cuscuta Section Monogyna *C. lupuliformis* Krock.	Puszczykowko Bot. G. Poznan Poland		–	28	4x	2n = 28, Reese 1961
C. scandens Brot.*	S. Facundo Bot. G. Coïmbra Portugal		–	16	2x	
Subgenus Cuscuta						
C. epithymum (L.) Murray	Bot. G. Neuchâtel		7	14	2x	2n = 14, Tischler 1934, Finn 1937, Ehrenberg 1945
C. europaea L.	Bot. G. Neuchâtel		7	14	2x	2n = 14, Finn 1937, Raesa 1952, Tischler 1934
	Col du Simplon Switzerland		7	14	2x	
C. alba Presl.*	Gourdon, A.M., France		–	30	4x	

* A new chromosoma report for the species.

forest („altomontan" level) and the upper limit of the latter is not as high as in Legris' scheme (3000 m instead of 4000 m). The scrub of *Betula utilis* (3000 m to 3600 m) is considered by Meusel as a subalpine level.

Evidently, the terms used by Meusel *et al.* should be considered as having a pure descriptive meaning and not as having a similarity with the series of vegetation in Europe to which the same names were given. The only term which is not too misplaced here is perhaps the „subalpin level"(1) for the vegetation of *Betula utilis* and *Rhododendron* above the timber line, but it is not sure that the climate at this level is similar to that of the „horizon of transition" of Favarger (1972) in the Alps.

Puri (op. cit.) includes the scrub of *Betula utilis* and *Rhododendron* in the alpine vegetation, as did many botanists in Europe for the heath of *Ericaceae* (*Rhododendron, Vaccinium*, etc.) which grows in the Alps between timber line and the upper limit of isolated trees. Certainly, as in the Alps, there are some difficulties in tracing a border between true alpine vegetation (meadows, pastures, etc.) and the „subalpin" scrub in Western Himalayas.

In Legris' scheme (op. cit., Fig. 22), the scrub of *Betula utilis* is incorporated to the high montane forests, which makes useless the establishment of a subalpine level. Up to what point may these forests be compared with the true subalpine forest of Coniferous in the Alps is questionable.

After the author's observations, the dominating herbaceous and shrubby plants of the so-called „temperate zone" (1800–2700 m) which more or less corresponds to the mountainous level, are species of the genera *Swertia, Cynoglossum, Scrophularia, Veronica, Pedicularis, Salix, Rosa, Rubus, Lonicera, Viburnum, Berberis, Indigofera* and others. In W. Himalayas, the maximum height recorded for a Phanerogam is 6400 m (*Christolea himalayensis*, a member of *Cruciferae* was collected by Gurdial Singh on Mt. Kamet, 1955).

In Eastern Himalayas, the vegetation is of a quite different type. The tropical influence is much more felt in this region's vegetation, as it is more southwardly situated and exposed to monsoon rainfalls. The tropical level here again comprises forests of *Shorea*, while the subtropical level consists of the *Castanopsis* forest and the mountainous level of *Lauraceae* and evergreen oaks forests. However, at the „subalpin" and alpine levels, the flora seems to be mainly constituted of Holarctic species.

Flowering begins in early spring. In April, the weather is bright with occasional showers. The species of *Fragaria, Geranium, Viola, Veronica, Valeriana* and *Taraxacum* start to flower. From April onwards, the temperature increases until the end of June when the rainy season commences. Extensive flowering throughout W. Himalayas takes place in July and August. A little delay in flowering is observed at higher altitudes in every region. The early spring plants are succeeded by many others of European families common to Himalayas. They are mainly *Scrophulariaceae, Gentianaceae, Ranunculaceae, Rosaceae, Labiatae, Polygonaceae, Oenotheraceae, Primulaceae* and *Plantaginaceae*. During the rainy season, the luxuriant vegetation of the temperate and alpine regions is in full bloom. At this season, in many regions of W. Himalayas, there is a festival of flowers in the plant community, like for example in the Simplon Alps in Europe. (The „Valley of

(1) also used by Aymonin and Gupta (1965)

Flowers" looks like a carpet of multicoloured flowers at the end of August). Many species of *Impatiens*, *Orchidaceae*, *Labiatae*, *Ranunculaceae*, several gentians, *Compositae*, many species of *Cyperaceae*, *Drosera*, *Pedicularis*, *Roscoea*, *Thalictrum* and *Swertia* come up with flowers. By the end of September, the plants' holiday is over with the commencement of winter, and by the end of November, the seeds are covered with snow.

The flora of the Alps was more accurately studied than the flora of the Western Himalayas. The first studies date back to about two hundred years ago, and probably very few species have not been seen by the botanists. The reader will find the essential data in the classical work of Schröter (1926) and in the contributions of Merxmüller (1952) and Favarger (1972). Concerning some important aspects of the history of the flora, see Favarger (1972).

The vegetation of the Alps, which has been the focus of many important monographies, was recently summarized by Ozenda (1966) and, in a more popular fashion, by Favarger (1972).

II. Cytological study of ten families of the Sympetalae

Gentianaceae (incl. *Menyanthaceae*)

The family *Gentianaceae* comprises about 80 genera and 900 species (Willis, 1966), and has a world-wide distribution. They are found from Arctic regions to Tropics as well as from highest mountains to lowlands and seashores. Many species, especially in the genera *Gentiana* and *Swertia*, belong to montane floras.

The family is less represented in Europe than in India. The flora of Hermann (1956) noticed 61 species in North and Middle Europe, out of which 45 species were recorded from the Alps. From British India, Hooker (1885) has reported not less than 132 species. Out of these, nearly 87 are mentioned from Western Himalayas. About 78% of the Gentianaceae found in India are endemic to this subcontinent (Chatterji, 1939).

Many classical and modern taxonomists (cf. Gilg, 1895, Gundersen, 1950, Fernald, 1950 and Lawrence, 1951) have treated *Gentianaceae* in a broad sense, including *Menyanthes* and *Nymphoides* and related genera while others (cf. Lindsey, 1938 etc.) regarded it excluding the family *Menyanthaceae* on the basis of its morphology and anatomy, whereas others (Wettstein, 1935, Jones, 1950) took other characters of taxonomical importance for its separation.

Other important taxonomic problems concerning the subtribe *Gentianinae* Kusnezov (= tribe *Swertieae* Clarke) are as follows. In fact, many contemporary botanists namely, Smith (1936), D. Löve (1953), Gillett (1957), Toyokuni (1961, 1962, 1963, 1965), Iltis (1965), partially following opinions of ancient authors, proposed to dismember the genus *Gentiana* into a number of smaller genera, viz. *Gentianella* Moench, *Comastoma* (Wettst.) Toyokuni, *Gentianopsis* Ma. These three genera resulted from splitting the ancient subgenus *Gentianella* Kusnezov, since the latter is rather heterogeneous. Löve and Löve (1956 and 1961a), as well as Toyokuni (1965) went even further: they preconized a splitting of the subgenus *Eugentiana* Kusnezov as well, and the restoration of the ancient genera *Hippion* F.W. Schmidt and *Ericolla* Renealm.

Recently, H. Smith (in Nilsson, 1967) proposed rather large modifications in Kusnezov's sections. With regard to the Himalayan flora, he recommended the suppression of the section

Isomeria, (the species of which were hence allotted by him in sections *Pneumonanthe* and *Frigida*) and the fusion of sections *Stylophora* and *Megacodon* in a new genus, the genus *Megacodon* (Hemsl.) H. Sm.

Since cytological data may support or disfavour such proposed taxonomic modifications, it is important to study from this point of view the largest number of *Gentianaceae* species, especially in the subtribe *Gentianinae*.

The pioneers in gentian cytology are Stolt (1921), Woycicki (1932, 1933, 1937), Scheerer (1939), Sakai (1934), Sokolovskaja and Strelkova (1938). However, it was only through the contribution of Rork (1946, 1949), that the family was properly known cytologically. At about the same time, Favarger (1949, 1952) and Skalinska (1950, 1952) commenced to investigate the Gentians of the Alps and the Tatra mountains, respectively. Knaben (1950) reported the chromosome number of two species from Norway. In 1953, Löve studied the chromosome numbers of seven species of Gentians found in Iceland. By that time, the cytology of only 56 species were known. Later, Wada (1966) contributed to the cytology of Gentians. Though Himalayas are rich of Gentians, the cytology of the *Gentianaceae* of that region was not known until Khoshoo and Tandon (1963) studied the cytology of *Swertia* species of Himalayas. In 1968, Mehra and Gill made chromosome counts for some Himalayan species.

The results of the present cytological investigations are reported in Table 1.

Discussion

Cytological investigations were made on 26 taxa belonging to seven genera of the family *Gentianaceae*. The chromosome numbers are documented for the first time in 11 taxa (cf. Table 1). In all the cases except *G. ramosa*, meiosis has been studied, which uniformly revealed a normal reduction division. Chromosome size is medium in all the species with the exception of *Limnanthemum nymphaeoides* (n = 27) and *Jaeschkea latisepala* (n = 10) which possess comparatively small chromosomes. *Centaurium pulchellum* is a very interesting species from the point of view of cytogeography. It is the only species of the genus which grows in Himalayas. (Four species of *Centaurium* were described by Hooker from India.) The current observation of n = 36 for *C. pulchellum* (Fig. 1) from Kumaon of W. Himalayas is a new chromosome report and a new level of polyploidy for the species. The intensive study of Zeltner (1961–1970) revealed another chromosome number (n = 18) in this species, which has a distribution in many countries of Europe (England, Spain, Belgium, Austria, France, Greece, Holland, Hungary, Morocco, Switzerland and Yugoslavia) and Africa. It is of interest to note that Khoshoo and Khushu (1966) studied three taxa of this species from Himalayas, which have shown gametic chromosome numbers n = 18, 27 and 28, respectively. This shows that the chromosome race n = 18 is present even in Himalayas. In 1961, Zeltner observed two chromosome races with n = 10 and n = 20 of *C. pulchellum* from Tunisia and Portugal, respectively. These findings incited Khoshoo (1966) to assess the species as a complex of many cytotypes. But, later on, Zeltner (1970) found sufficient morphological differences of taxonomical value, in both the races with x = 10 to separate them from *C. pulchellum* as a distinct species: *C. tenuiflorum*. This is closely allied to *C. pulchellum*. Contrarily

Table 1C:

Summary of distinctive characters of the cytological types of *Gentiana carinata*.

Characters	Diploid (n = 10)	Tetraploid (n = 20)
Locality and altitude	(Razhan Hill, 2900 m), Kashmir	(Gulmarg, 2700 m), Kashmir
Habitat	Meadows of high altitude	Meadows of high altitude
Habit	Small, tufted, rarely branched	Slightly larger, tufted, profusely branched
Height	3–4 cm	5–7 cm
Length of leaf	2–2.6 cm	1–2 cm
Breadth of leaf	0.6–0.9 cm	0.3–0.5 cm
Leaf margin	Entire	Partially wavy
Inflorescence	Cyme	Cyme
Colour of flower	Blue	Light blue
Length of flower	1.5–2.0 cm	2.0–2.5 cm
Length of corolla	Short	Long
Size of stomata	8 x 6 μ	8 x 7 μ

to the observations of Zeltner (1962), neither Khoshoo nor the present author could observe a pair of chromosomes considerably large in size in the complement of *C. pulchellum*.

The results obtained by Khoshoo and Khushu, especially the fact that the Himalayan *C. pulchellum* with n = 27 had a normal meiosis, permit to suppose the existence of a base number x = 9 in the genus *Centaurium*. But this is in contradiction with the conclusions of Zeltner (1962, 1970), who thinks that the number 2n = 36 derived from the number 2n = 40 through fragmentations and fusions. One is therefore facing the following alternatives:

1. A base number x = 9, proper to the Himalayan populations, would effectively exist in the group of *C. pulchellum*. Subsequently, the complex formed by the very close taxa found in India would have had an independent origin from the European *C. pulchellum* with n = 18, and could then be considered as a different species.

2. On the other hand, Zeltner's hypothesis (op. cit.) that the number 2n = 36 derived from 2n = 40 could be applied to the Himalayan populations. Accordingly, the plants with n = 27 of Khoshoo and Khushu would be hypohexaploids, and their meiosis would be rather normal, disregarding the possible existence of two trivalents. In connection with these, it will be noted that observation of multivalents in small chromosomes plants such as *Centaurium* species, is often difficult.

Further investigations are necessary to elucidate this problem.

Suppose the Himalayan *Centaurium* species belong to the complex of the European *C. pulchellum*, which has undoubtedly a Mediterranean origin, then the n = 36 plants studied by the present author indicate that the highest polyploids were recorded till now only in the margins of the area of this species.

([1]) Fig. 167 shows the cytological races of *G. carinata*.

The genus *Gentiana* is well known for the variability of the base numbers recorded (cf. Rork op. cit., Skalinska, 1952, Favarger, 1949, 1952, 1965). The present data showed that the section Chondrophylla, well represented in Himalayas, is a polybasic section, since the base number x = 9 has been noted (Fig. 8) by the present author in *G. pedicellata*, in addition to the two other numbers x = 10 and x = 13 already recorded in the section. *G. prostrata* perhaps belongs also to the group of species with x = 9. In fact, Favarger (1952) and Johnson and Packer (1968) have counted in this species 2n = ca. 36 and 2n = 32–36, respectively. The presence of many Himalayan species with n = 10 in this section fills to some extent the immense geographic gap between New Guinea, where exist three species with n = 10, and Spanish Sierra Nevada where grows *G. boryi* (n = 10) (Küpfer, 1968). (See Figs 3 & 4, for *G. argentea* and *G. capitata.)*

In *G. carinata* Griseb, the author has encountered two chromosome races. This small tufted species is restricted to Kashmir meadows in the Western Himalayas where it is abundant between 2700–3000 m. A diploid with n = 10 (Fig. 5) and a tetraploid with n = 20 (Fig. 6) were studied. Meiosis was normal in both the cases as evidenced by regular segregation at Anaphase I and normal pollen formation. The bivalents in both the taxa were comparable in size. Table 1C summarizes their morphological features and distribution. Apparently, one is here in the presence of two distinct taxa, each of which deserves a subspecific rank. But, before doing so, it would be necessary to see the type specimen of this species.

In the subgenus *Gentianella*, the present results in (Fig. 2) *Gentiana moorcroftiana* are of particular interest. The chromosome numbers of all the species studied till now in sections *Arctophila*, *Amarella*, and *Andicola* were almost steadily 2n = 36. This was confirmed by our observations in some alpine species. Favarger (1949) assumed that the number 2n = 36 was a tetraploid number, and derived from x = 9. At that time, no *Gentiana* with n = 9 was known. Later on, Quézel (1957) found n = 9 in *G. tornezyana* from the Atlas. It is true that this species is quite an unusual one because of its winged seeds-which has induced De Litardière and Maire (1924) to make it the type of a new section, the section *Pseudentotricha*-whereas, *G. moorcroftiana* is a member of either section *Amarella* or section *Arctophila*. Present data thus corroborated Favarger's opinion and permitted to assume that the number 2n = 36, widely represented in the subgenus *Gentianella*, is in reality a tetraploid number (36 = 4 x 9) and not a hexaploid one (base x = 6).

As to the number 2n = 26 recorded by Wada (1966) in *G. moorcroftiana*, it is hardly thinkable that the same species could have two so widely different numbers. Consequently, we wonder whether this number was due to a misleading identification.

In the section *Crossopetalum*, the current counting in (Fig. 7) *Gentiana detonsa*, 2n = 26, differed from that of D. Löve (1953), 2n = 44. No valid explanation could be given to elucidate this disagreement. D.Löve (op. cit.) preconized a splitting of the section into two subgroups according to chromosome numbers with which Iltis (1965) disagreed. If *G. detonsa* had two different basic numbers (x = 11 and x = 13), it would corroborate Iltis' opinion.

Jaeschkea latisepala with n = 10, is the first chromosome (Fig. 9) report in this genus. *Pleurogyne carinthiaca*, (2n = 48), is (Fig. 10) a new chromosome report for the species. This result differs from the number 2n = 40, recorded by Fürnkranz (1965) on a material from the Austrian Alps. It is to be noted here, that Favarger (unpublished) has counted n = 23 in a pollen mitosis of a plant of the same species he had collected in Val d'Avers (Switzerland, Graubünden). He thought that the gametic number of this plant was probably 24, but a meiotic anomaly (non-disjunction) had given n = 23 in some pollen grains. Therefore, it appears rather strange that the same species could have two different base numbers in Austria and Switzerland. Since Favarger's counting approaches the number we recorded on a Himalayan plant, we think the data of Fürnkranz need to be confirmed.

For the time being, I think that *Lomatogonium carinthiacum* is an octoploid. Furthermore the normal formation of bivalents and the normal meiosis observed in this species suggest an allopolyploid nature. This is one of the few *Gentianaceae* species common to both the Alps and the Himalayas.

Since D. Löve (1953) counted 2n = 10 in *L. rotatum*, it appears that *Lomatogonium* is also a polybasic genus (x = 5 and x = 6). Nilsson (1967) noted three pollen types in the genus. However, he ranged *L. rotatum* (n = 5) and *L. carinthiacum* (n = 24) in the same pollen type.

The genus *Swertia* has been investigated with its 11 species from Western Himalayas. With the exception of *S. purpurascens* (Fig. 11) (n = 10), *S. paniculata* (n = 8) and *S. tetragona* (n = 9), all the other species were uniform in having a gametic set of 13 (Figs. 12–16) chromosomes. The chromosome numbers in all the species fall in line with the earlier reports of Khoshoo and Tandon (1963). However, the counts of Mehra and Gill (1968) are at variance with some of the present observations for the genus (Table 1). A perusal of literature, together with present studies, reveal that though 13 is the most common haploid chromosome number for the genus *Swertia*, other known chromosome numbers for the genus form an aneuploid series ranging from 8 to 14 with the exception of 11 (cf. Rork, 1949, Löve, 1953, Khoshoo and Tandon, 1963 and Mehra and Gill, 1968).

The number 13, which is the most common haploid chromosome number in the genus, is considered by most of the authors cited above as the base number of the genus *Swertia* which has arisen secondarily, and different chromosome numbers (n = 12, 9 and 8) have resulted from it after reduction in the chromosome number. However, as regards to the mode of origin of this secondary base number x = 13, different views are expressed. According to Favarger (1949) the number 13 has arisen from n = 7 by polyploidy followed by fusion of two chromosomes. The interpretations leveled by Skalinska (1952) and Löve (1953) differ from that of Favarger. They believed that it has been compounded from 7 and 6 and the line of thought was agreed upon by Khoshoo and Tandon (1963).

Whatever may be the mode of origin of base number x = 13, this number seems to have been established in most of the species of *Swertia*, and the other known chromosome numbers in the genus seem to have arisen through aneuploidy. Further support to this conclusion seems to be imminent from the perennial habit and relatively generalized morphological features noticed in *S. speciosa*, *S. petiolata*, *S. thomsoni* and *S. chirata*, all of which possess gametic number 13,

while the rest which are annuals have n = 13 and less. These facts indicated that secondarily derived and established base number 13 gave rise to annuals with gametic number 13 and less in course of evolution.

Large populations of *Swertia* in Himalayas, in contrast to only two species of the same in Europe (*S. perennis* L and *S. punctata* Baumg) show the probability of Himalayas to be one center of origin of the genus *Swertia*. The geographical, ethological and ecological isolation mechanisms found in *Swertia*, allow the species to grow sympatrically even when they have the same chromosome number. Out of the 30 species of *Swertia* recorded in India, 24 are endemic to Himalayas. Evolution of species might have taken place through abrupt speciation, or has been favoured by different isolation mechanisms.

Halenia elliptica is the only member of the genus in the Himalayas, and the genus is not represented in Europe. The gametic number 11 observed currently is in line with the earlier findings of Favarger (1952b) and confirms the base number x = 11 for the genus.

Limnanthemum nymphaeoides with n = 27 is a hexaploid on base number x = 9. The current observation of chromosome number agrees with the earlier observations of 2n = 54 for the species. Since the basic number x = 9 of the genus tallies with many other genera of the *Gentianaceae*, it seems that the number of chromosomes do not support the treatment of *Menyanthaceae* as a separate family.

Convolvulaceae

The family *Convolvulaceae* consists of 50 genera and 1000 species (Willis, 1966) distributed abundantly in the tropical regions and less so in the temperate and cold regions of the world.

Hooker (1885) has described 152 species from British India, of which nearly 30 species extend their distribution to the Himalayan regions. Hermann (1956) described 17 species of *Convolvulaceae* for North and Middle Europe and Hegi (1927), 16 species.

Peter (1891) has classified the members of the family into two subfamilies: *Convolvuloideae* and *Cuscutoideae* on the basis of leafy and cotyledonous characters of the former and non-leafy and parasitic nature of the latter. Choisy (1841) was the first to treat *Cuscuta* monographically. Recent monographs of Yuncker (1932) on *Cuscuta* gave a new systematic classification of *Cuscuta* on the basis of phylogeny.

Chromosome studies on *Convolvulaceae* have been initiated since 1900 by Hause (1909), Yasui (1928), Kanoi (1929), Un (1930), King and Bamford (1937), Nagao (1928), Rao (1947), Sharma and Datta (1957), Jones (1964), Nakajima (1963), Nishiyama *et al.* (1961), Ting *et al.* (1957), Sharma and Charterji (1957) and Vijaya Bai *et al.* (1969), who have studied mainly *Ipomoea* species, while Wolcott (1937), Khoshoo *et al.* (1961) and Malik and Grover (1968) studied the chromosome behavior of the genus *Convolvulus*. Our results are shown in Table 2.

Discussion

Out of the 20 species of *Convolvulaceae* studied cytologically here, chromosome numbers of 6 species are new reports. Regular meiosis is observed in all the cases. The chromosome size of *Cuscuta reflexa* and *C. lupuliformis* is considerably larger than in other members of the family.

Chromosome number of 6 species of *Ipomoea* worked out currently agrees with the previous reports (Table 2A), with the exception of *I. coccinea* (n = 15) which differs from the report of 2n = 28 by Sharma and Datta (1958). *I. coccinea* and *I. tricolor* are cultivated in India, but they can also be found growing „quasi wild" (Hooker, 1885). The other species studied here are spontaneous in our region (sometimes cultivated). *I. hederacea* grows up to 1900 m in Western Himalayas and *I. purpurea* ascends to 2000 m in Kumaon Hills. A perusal of the literature on *Ipomoea* reveals considerable variation in chromosome number in other species of the genus. Ting *et al.* (1957) observed n = 30 both in *I. gracilis* and *I. tiliacea* which are tetraploids, if 15 is considered as the basic chromosome number of the genus. Sharma and Datta (1958) brought forth the existence of species with 24, 28, 48 and 78 as somatic chromosome numbers. Later, chromosome counts made by Jones (1964) on 33 species of *Ipomoea* indicated the haploid number 15 as a common phenomenon for *Ipomoea*. Hence, the present investigation in the light of earlier observations is clearly an indication that x = 15 is the base number of the genus *Ipomoea* because the largely worked out species revealed gametic number 15. Darlington and Wylie (1955) had recorded x = 15 for the genus while Löve and Löve (1961) suggested x = 5 for *Ipomoea*. The fact that euploidy is common in this genus is understandable as a source of polyploid evolution of the genus. The natural tetraploid species, *I. tiliacea* (Ting *et al.*, 1957), *I. biloba* (Vijaya Bai *et al.*, 1969) and hexaploid species as *I. batatas* have arisen as direct multiples of the basic chromosome number x = 15, of which *I. biloba* and *I. tiliacea* show intraspecific polyploidy. Therefore, it seems that speciation in genus *Ipomoea* might have taken place through structural alteration of chromosomes and polyploidy.

The gametic number 24 and 2n = 48 of *Convolvulus arvensis*, a species with Eurasiatic distribution, differ from the report 2n = 50 by Wolcott (1937) but tallies with the report of Khoshoo *et al.* (1961). In Himalayas, this plant grows as a weed up to a height of 2100 m from Kashmir in the West to Nainital in the East; it shows the same chromosome number in W. Himalayas and in Europe. Our observations about *C. pluricaulis* with gametic number 18 and multivalent formation of chromosomes indicating autopolyploidy are in agreement with those of Malik and Grover (1968) (Fig. 17). In the present work, an average of two quadrivalents in a PMC may be demonstrating a tendency of gradual shift towards bivalent association accompanying natural selection for fertility. We have also observed 2 univalents in some PMC's. Pollen fertility was found to be 70%. The tetraploid might have arisen as a result of direct duplication of diploid form through the chance fusion of unreduced gametes. As a matter of fact, Malik and Tandon (1959) have recorded plants with n = 9.

It is worth mentioning that in the same species, Singh (1951) has observed plants with 2n = 20, and Baquar *et al.* (1965) a population in the Indus delta with

n = 20. Therefore, it seems likely that basic chromosome number 9 may also be considered as one of the basic numbers of the genus *Convolvulus* in addition to x = 10 and 11 recorded by Darlington and Wylie (1955). On the base number 12, *C. arvensis* is a tetraploid. Hence, it is clear that evolution of species in this genus took place through polyploidy and dysploidy.

Evolvulus alsinoides with n = 13 agrees with the count of Raghavan (1959). This genus seems to have two basic numbers, n = 13 and n = 12 (Sharma and Chatterji, 1957). *Porana racemosa* with n = 14 is cytologically a (Fig. 18) new report. Another species, *Porana paniculata* has 2n = 26 after Sharma and Chatterji (op. cit.).

It is interesting to note that the maximum number of species of *Cuscuta*, which are predominantly members of subgenus *Grammica*, are distributed in United States and Mexico (Yuncker, 1921). Out of the ten species noted in India, 4 belong to *Grammica*, 2 to *Monogyna* and 4 to the subgenus *Cuscuta*. In North and Central Europa, after Hermann, there are 11 species, 1 belonging to *Grammica*, 5 to *Monogyna* and 5 to *Cuscuta*.

In India, *Cuscuta* species inhabit from plains to mountainous level, about 2800 m in Himalayas. Cytological information on *Cuscuta* is sought by Fedortschuk (1931) onwards. The major cytological contributions are from Finn and Safijovska (1934), Fogelberg (1938), Raghavan (1957) and Sharma and Chatterji (1957).

C. reflexa Roxb. is met throughout the W. Himalayas, from plain level up to an altitude of 2300 m. This common parasitic species is accepted by a variety of hosts ranging from herbs to big trees. *Lantana indica* is a common host. The flowering period of *C. reflexa* is from August to October.

Cytological studies were made from material collected from different localities (Table 2A). Meiotic observations of the species from Kalka, Kasauli Road, showed 16 bivalents at MI (Fig. 23). The plants from Gobindghat showed 15 bivalents at MI (Fig. 22), while another individual from Dehra Dun revealed a chromosome number of 14 distributed equally at AI. One bivalent was found to be lagging (Fig. 21). In all the other cases, meiosis was found to be perfectly normal. Critical studies on the individuals showing aneuploid chromosomal races did not reveal any morphological variation among them. Because of the observation of aneuploid series in this species, from different localities of W. Himalayas including Kashmir, many individuals have been cytologically investigated. In all the other cases, meiosis was found to be normal with 15 bivalents at MI.

Somatic chromosomes were studied from mitosis of tapetal cells. The size of the chromosomes was large in this species (Fig. 24). Somatic complement was divided into three groups on the basis of centromeric position (Fig. 25). Four pairs of chromosomes possessed a median centromere, 10 pairs a submedian centromere and the last pair a subterminal one.

C. chinensis Lamk. was found in exposed dry places of Kargil in Ladakh at a height nearing 2400 m, but the species was not seen in Kumaon. The host is usually a member of *Labiatae*. Flowering takes place in July. Meiosis revealed 8 bivalents at MI. The course of meiosis was normal. Somatic chromosomes (2n = 16) were studied from the mitosis of tapetal cells (Fig. 19). The chromosome size was smaller than in *C. reflexa*. Six pairs of chromosomes possessed a median centromere while two pairs had a submedian centromere (Fig. 20).

The distribution of *C. capitata* Roxb. is confined to temperate W. Himalayas between 2000–3500 m. In Kashmir, it is found in abundance in Ladakh, whereas the author did not observe it in Kumaon. Normally, the host is a member of *Labiatae*.

Flowering takes place in July. Somatic chromosome number was counted as 20 from the mitotic stages of the tapetal cells of the immature anthers (Fig. 29). Chromosome size was medium. Five pairs possessed a median centromere and the other five pairs, a submedian centromere. (Fig. 30).

C. planiflora Tenore is spread out commonly in subtropical W. Himalayas between plain level to 2000 m, from Punjab to Kashmir Hills. Flowering takes place in July. Gametic chromosome number was determined as n = 7 at MI of meiosis (Fig. 26). Somatic chromosomes were studied from the dividing nuclei of (fig. 27) tapetal tissue. Chromosome size was medium. Three pairs of the complement possessed a median centromere, 3 pairs a submedian centromere and one pair a subterminal centromere (Fig. 28).

For comparison, we have also studied some samples of *Cuscuta* species from Europe.

Cuscuta europaea L. is largely distributed in Europe and Asia, but very uncommon in Himalayas. One plant cultivated at the Neuchâtel Botanical Garden on *Urtica dioeca* revealed somatic chromosome number 14 (Fig. 32) and gametic number 7. Chromosomes are medium-sized. Somatic complement always consists of one pair of chromosomes with median centromere, five pairs with submedian centromere, and one pair with subterminal centromere, the last pair with one satellite. One pair of the complement is comparatively larger in size (Fig. 32A). The largest chromosome is 4,5 μ while the shortest one measures 2 μ.

One specimen has been found at 2800 m in W. Himalayas showing an extreme gigantism in morphology. This plant was not unlike *Cuscuta europaea* but the picture of chromosomes was very different; at diakinesis, there were 31 bivalents and the chromosomes were very large. After an examination of the plants of *Cuscuta europaea* from Europe, we have some doubts upon the identity of the Himalayan plant and we think that it might belong to another species. Therefore, we have temporarily designed this plant as *Cuscuta spec.*

C. epithymum (L.) Murray is growing in the Neuchâtel Botanical Garden on *Silene ciliata*. It has chromosome numbers n = 7 and 2n = 14 (Fig. 31). The chromosomes are medium-sized. As observed in *C. europaea*, one pair of chromosomes was large. Somatic complement consisted of one pair of chromosomes (Fig. 31A) with median centromere and five pairs of chromosomes with submedian centromere. The largest pair measured 3,1 μ while the shortest pair measured 1,1 μ. *C. epithymum*, unlike other species of the genus, exhibited extensive morphological variation, leading to a number of taxonomical varieties.

The specimen of *C. alba* Presl. collected at Gourdon, in the Maritime Alps in France possessed somatic chromosome number 30. The chromosome size was comparatively large. Like *C. europaea* and *C. epithymum*, one pair of the complement was comparatively large. *Thymus vulgaris* was the host of this species.

The seed collection of *C. lupuliformis* Krock. from Poznan revealed, on germination, 28 chromosomes in the dividing cells of the root tips. The size of the chromosomes was large. Five pairs of the chromosomes had a median centromere and the remaining

nine pairs a submedian centromere. The longest pair was 4,8 μ while the shortest pair measured 3,4 μ. Thus, the size of the chromosomes in the complement was more or less equal.

The present chromosome counts of *Cuscuta chinensis* (n = 8), *C. capitata* (2n = 20), *C. planiflora* (n = 7) from W. Himalayas, and *C. alba* (2n = 30) from Europe are new reports. The chromosome numbers of *C. epithymum* (2n = 14), *C. europaea* (2n = 14) and *C. lupuliformis* (2n = 18) agree with the earlier observations (Bolkhovskikh, *et al.*, 1969). The plant from Himalayas related to *C. europaea* and designed as *C. spec.* is perhaps an intraspecific chromosome race of *C. europaea* with n = 31 and 2n = 62. The meiosis with normal bivalents and 100% pollen fertility indicates allopolyploid features of the chromosome race. This chromosome race might have evolved as a multiple of the base number x = 7, and undergone an aneuploid alteration of a few chromosomes at higher ploidy level, or might have been produced by amphidiploidy between a taxon with n = 15 and another with n = 16.

The most interesting cytological observation is that of *C. reflexa* from Himalayas. Three populations collected from three different localities possessed gametic chromosome numbers of n = 14, 15 and 16, respectively, without distinct differences in the morphology of the plants. The past reports of somatic chromosome numbers 42 and 28 in *C. reflexa* by Sharma and Chatterji (1957) and Finn (1937) add further proof to the fact that *C. reflexa* is in the active state of evolution, revealing extensive intraspecific chromosomal variation. But, curiously enough, the observation of normal meiosis with regular bivalent formation in all the cases differs from the observation of irregular meiosis by Sharma *et al.* who, on that basis, assigned an autopolyploid type of evolution to *C. reflexa* because of the presence of multivalents in the polyploid taxon.

Since the lowest gametic chromosome number found in the genus is 7 in many species, it seems certain that x = 7 is one of the basic chromosome numbers of the genus. But the current observation of gametic numbers 8 and 10 probably gives an indication of the existence of a series of basic chromosome numbers in *Cuscuta*. As for the gametic numbers 15 and 30, they are probably coming up through amphidiploidy from ancestors with n = 7 and n = 8, respectively. The basic numbers 7 and 8 do exist in both the subgenera *Grammica* and *Monogyna*. In the subgenus *Cuscuta*, the gametic number n = 15 in *C. alba* proves that the number x = 8 is also existing beside x = 7 and x = 10. Thus, the three mentioned subgenera seem to have undergone a separate evolution starting from a common stock of species (Fig. 33).

The karyotypic analysis of seven species of *Cuscuta (C. reflexa, C. europaea, C. lupuliformis, C. epithymum, C. capitata, C. planiflora* and *C. chinensis)* supplies other informations about the evolutionary process at work and the trends which evolution has taken in this genus.

Somatic complements of *C. capitata, C. chinensis, C. epithymum* and *C. lupuliformis* possess only chromosomes with median and submedian centromeres and hence, the caryotype is symmetrical in nature, while *C. europaea* and *C. reflexa* possess chromosomes with median, submedian and subterminal centromeres showing a tendency towards gradual asymmetry and subsequent higher status of evolution. But the presence of only one subterminal chromosome pair out of 15 pairs of *C. reflexa*, five pairs of subterminal chromosomes out of 31 pairs of

C. species indicates a dominant nature of symmetry in the karyotype in spite of the asymmetry of the whole complement.

Maximum disparity in length between the longest and the shortest chromosome of the complement is demonstrated in *C. epithymum* and *C. europaea* and to a lesser extent in *C. capitata* and *C. chinensis* (see idiograms), in all of which, one chromosome pair is found to be exceptionally large.

With regards to the size of the chromosomes, *C. reflexa*, *C. spec.* and *C. lupuliformis* stand apart from the rest of the species by virtue of their large chromosome size. The former two are closer from a karyological point of view, because of the little difference in length between the longest and the shortest chromosomes of the complement. The large chromosome size of members of the subgenus *Monogyna*(1) offers some evidence for its separation (Engelmann, 1859 and Yuncker, 1921) from the subgenus *Cuscuta*. The members of the latter are characterized by relatively small chromosomes.

Summing up the morphological characters of the chromosomes, we can assert again that in each subgenus studied here, there are primitive types with relatively symmetrical karyotype and in both the subgenera *Monogyna* and *Cuscuta*, more advanced types with more asymmetrical karyotype. (It would probably be the same in the third subgenus, but very few species were studied). From a morphological point of view (cf. Yuncker, 1932), the evolution in the genus *Cuscuta* was going from *Grammica* to *Cuscuta* and *Monogyna*. The only karyological proof of the fitness of this assumption is the great disparity in the length of the chromosomes in the karyotypes of *C. europaea* and *C. epithymum*.

Sharma and Chatterji (1957) have written: „The genus *Cuscuta* with its unusually large size chromosomes and symmetrical karyotype has been considered as representing perhaps the oldest group in the family". In fact, as we have seen above, the size of chromosomes in *Cuscuta* is not always large and some species *(C. campestris* and *C. pentagona)* „have extremely small chromosomes" (Fogelberg, 1938). As we have seen, the karyotype in some taxa is rather asymmetrical. Moreover, it would be strange that a parasitical genus should be the oldest one of the family *Convolvulaceae*.

Our observations are reported on Table 2A & B.

(1) The species *C. monogyna* has also rather large chromosomes after Finn and Safijovska (in Fogelberg, op. cit.)

Summary

The present study consists in a cytological investigation of numerous species of the families *Gentianaceae* and *Convolvulaceae* from the Western Himalayas and from Europe. Some chromosome numbers were determined for the first time; others differed from earlier determinations. Intraspecific polyploidy was observed in *Gentiana carinata* (n = 10, 20) in Himalayan populations. The intrageneric cytological evolution of all genera studied was tentatively explained (see discussion of the families). An analysis of the karyotype in *Cuscuta* (with comparatively large chromosomes) was made and the cytological basis of species evolution was discussed. New basic numbers (x) have been suggested for several genera. The studies will be continued in other families and the bibliography will be given at the end of the series.

Zusammenfassung

Cytotaxonomische und cytogeographische Untersuchungen an Pflanzen aus dem Himalaya im Vergleich zu verwandten Pflanzen aus den Alpen. Teil I.

Aus den Familien *Gentianaceae* und *Convolvulaceae* werden zahlreiche Arten aus dem westlichen Himalaya und aus den Alpen cytologisch untersucht. Manche Chromosomenzahlen wurden erstmals bestimmt; andere waren von früheren Bestimmungen verschieden. Intraspezifische Polyploidie wurde bei *Gentiana carinata* aus dem Himalaya beobachtet (n = 10, 20). Die intragenerische cytologische Entwicklung wurde für alle Gattungen diskutiert (siehe Diskussion der Familien). In der Gattung *Cuscuta* (mit relativ grossen Chromosomen) wurde der Karyotyp analysiert und die cytologischen Grundlagen der Artentwicklung diskutiert. Für mehrere Gattungen wurden neue Grundzahlen (x) vorgeschlagen. Die Untersuchungen werden in anderen Familien weitergeführt; die Literatur wird am Ende der Serie zusammengestellt werden.

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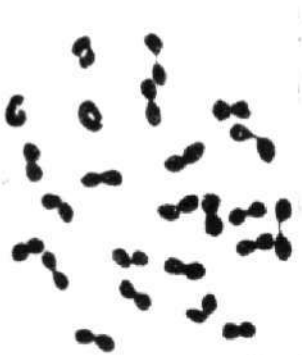
Fig. 1: Centaurium pulchellum (Sw.) Druce n = 36 Late Diakinesis. (1600 x)
Fig. 2: Gentiana moorcroftiana Wall. n = 9 MI.
Fig. 3: Gentiana argentea Royle n = 10 MI.
Fig. 4: Gentiana capitata Ham. var. strobiliformis Clarke n = 10 AI.
Fig. 5: Gentiana carinata Griseb. n = 10 MI.
Fig. 6: Gentiana carinata Griseb. n = 20 MI.
Fig. 7: Gentiana detonsa Fries n = 13 MI.
Fig. 8: Gentiana pedicellata Wall. n = 9 Diakinesis.
Fig. 9: Jaeskea latisepala Clarke n = 10 AI.
Fig. 10: Pleurogyne carinthiaca Griseb. n = 24 MI.
Fig. 11: Swertia purpurascens Wall. n = 10 MI.
Fig. 12: Swertia chirata Ham. n = 13 MI.
Fig. 13: Swertia lurida Royle n = 13 MI
Fig. 14: Swertia alata Royle n = 13 MI.
Fig. 15: Swertia petiolata Royle n = 13 MI.
Fig. 16: Swertia thomsoni Clarke n = 13 MI.
Fig. 17: Convolvulus pluricaulis Chois. N = 18 MI. Note the presence of two quadrivalents.
Fig. 18: Porana racemosa Roxb. n = 14 MI.
Fig. 19: Cuscuta chinensis Lamk. 2n = 16
Fig. 20: Cuscuta chinensis Lamk. 2n = 16 idiogram.
Fig. 21: Cuscuta reflexa Roxb. n = 14 AI. One bivalant is lagging. (1600 x).
Fig. 22: Cuscuta reflexa Roxb. n = 15 MI. (1600 x).
Fig. 23: Cuscuta reflexa Roxb. n = 16 MI. (1600 x).
Fig. 24: Somatic chromosomes of C. reflexa 2n = 30
Fig. 25: Cuscuta reflexa Roxb. 2n = 30 idiogram.
Fig. 26: Cuscuta planiflora Tenore n = 7 MI.
Fig. 27: Cuscuta planiflora Tenore 2n = 14
Fig. 28: Cuscuta planiflora Tenore 2n = 14 idiogram.
Fig. 29: Cuscuta capitata Roxb. 2n = 20
Fig. 30: Cuscuta capitata Roxb. 2n = 20 idiogram.
Fig. 31: Cuscuta epithymum (L.) Murrey 2n = 14
Fig. 31A: Cuscuta epithymum (L.) Murrey 2n = 14 idiogram.
Fig. 32: Cuscuta europaea L. 2n = 14
Fig. 32A: Cuscuta europaea L. 2n = 14 idiogram.



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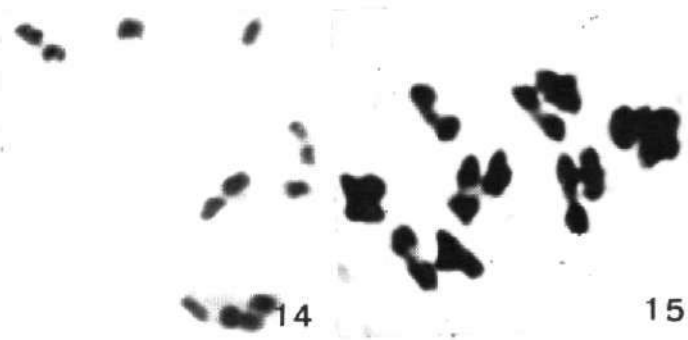

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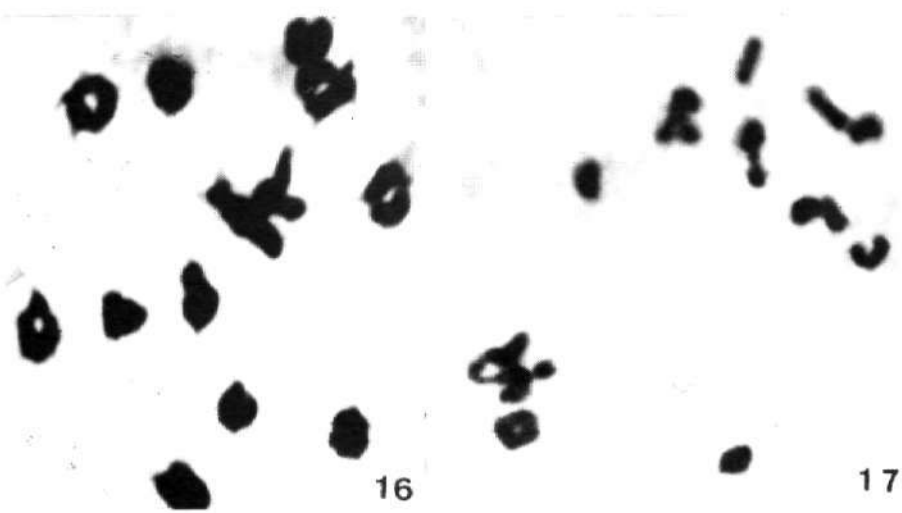

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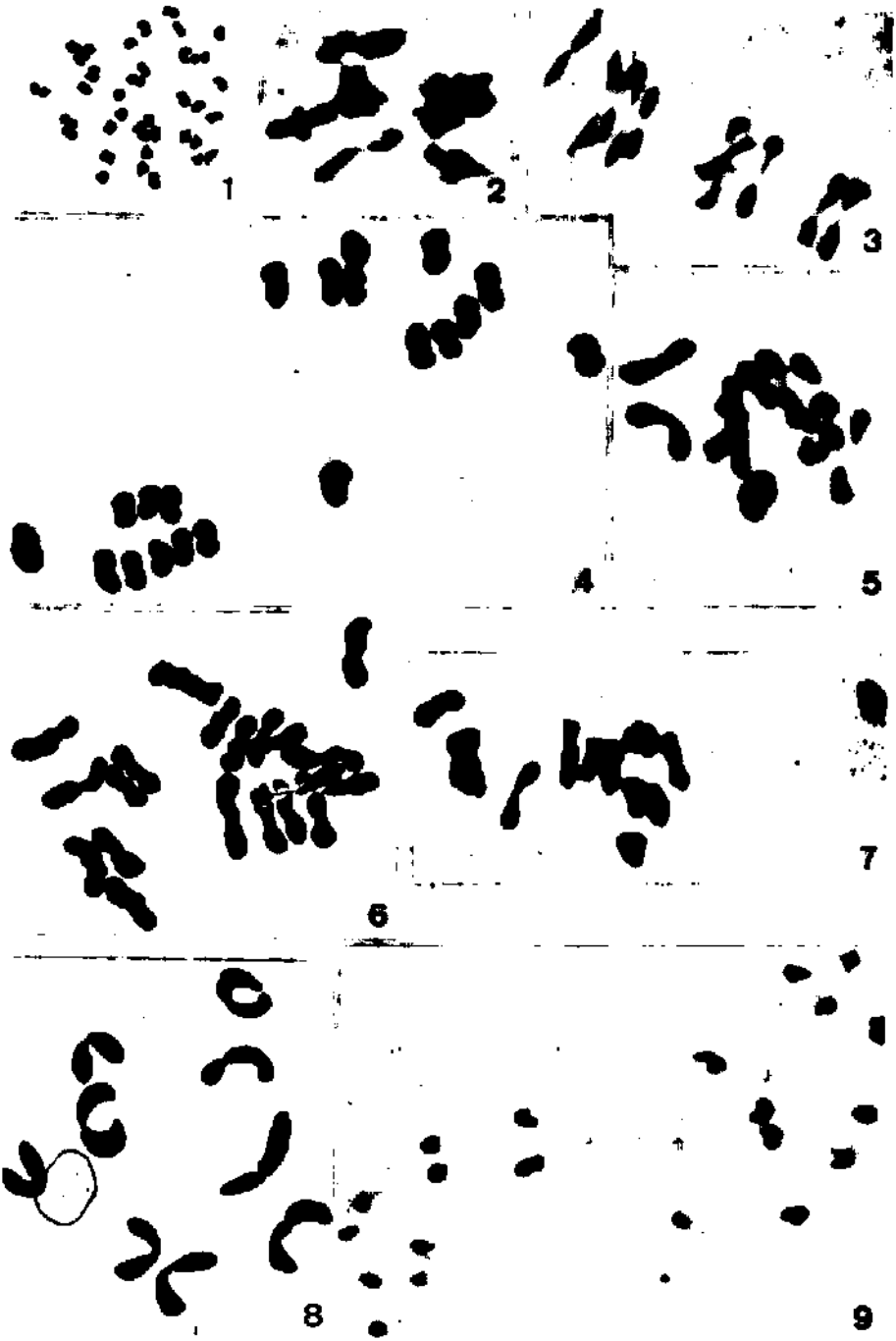
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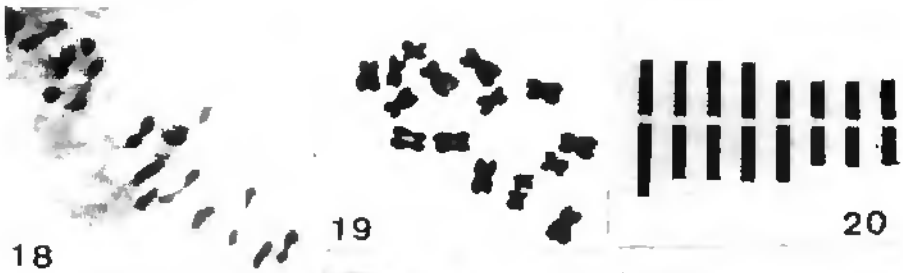

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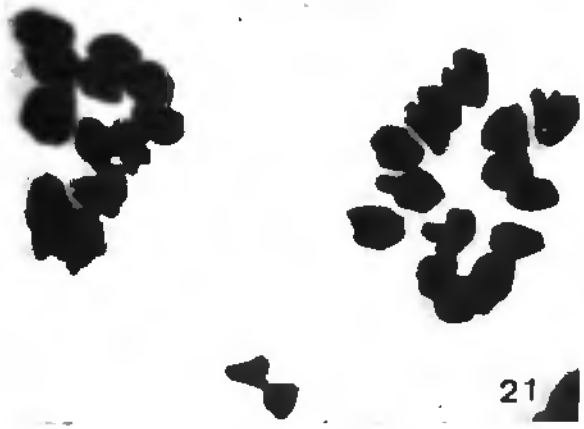

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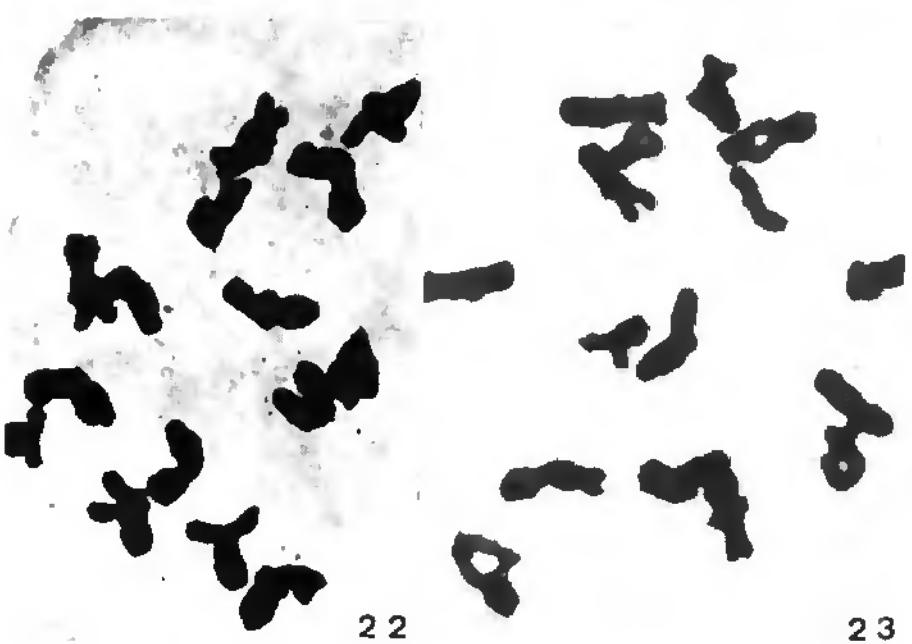

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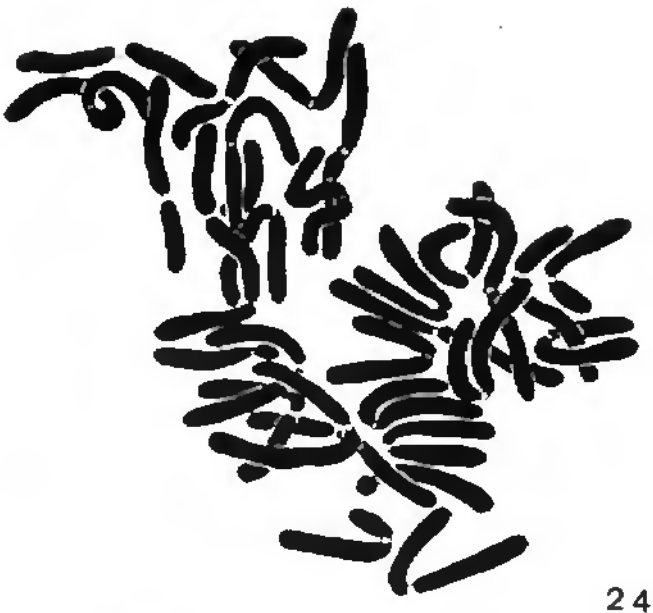

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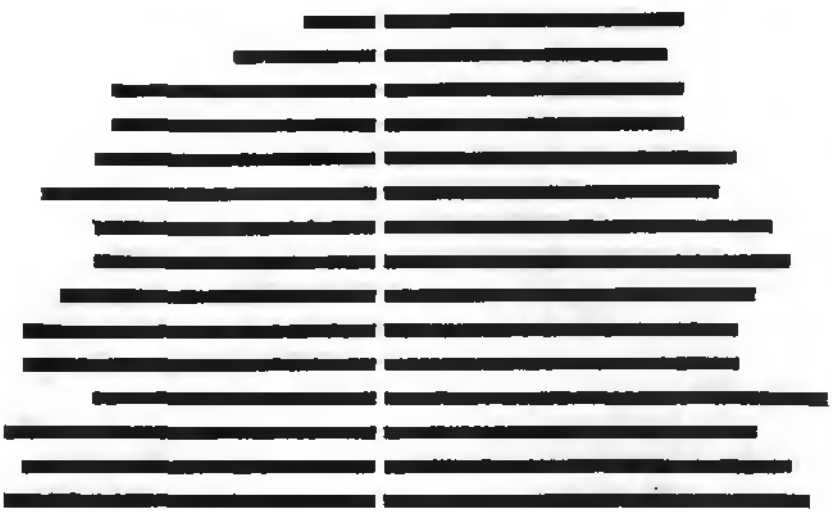

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Figure 33

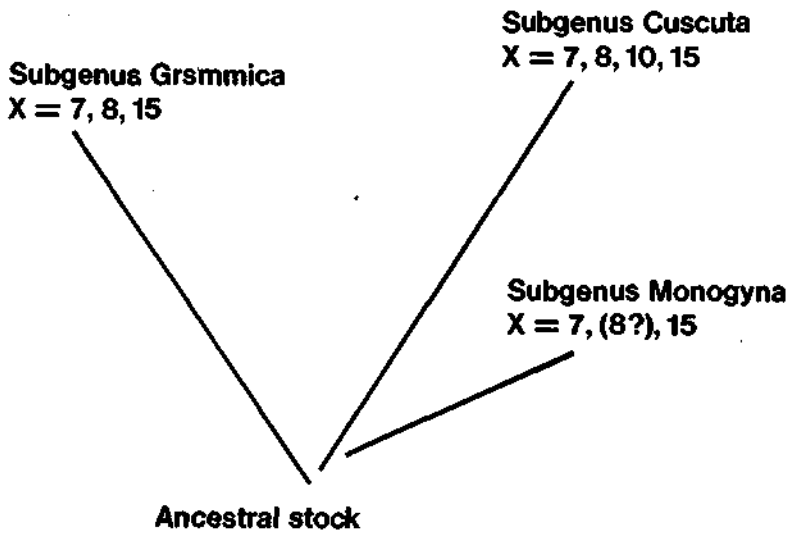

Fig. 33: Probable relationships between the three subgenera of Cuscuta.

Contribution to the Cytotaxonomy and Cytogeography of the Flora of the Western Himalayas (with an attempt to compare it with the Flora of the Alps). Part II.

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Ber. Schweiz. Bot. Ges. *85* (3), 210–252 (1975)

Contribution to the Cytotaxonomy and Cytogeography of the Flora of the Western Himalayas (with an attempt to compare it with the Flora of the Alps). Part II.

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In the first part of this series, cytological studies on species of the families *Gentianaceae* and *Convolvulaceae* were reported. The present paper continues these studies in other families of the Sympetalae.

Boraginaceae

According to Willis (1966), this family consists of 100 genera and 2000 species. The members are distributed in tropical as well as temperate regions of the world. Hooker (1885) has described 185 species from British India, of which a large percentage inhabits the Himalayas. Hegi (1927) has counted 41 species for Central Europe, and Hermann (1956) 79 species for North and Central Europe. Gürke (1897) divided the family into four subfamilies on the basis of flower morphology. They are: *Cordioideae, Ehretioideae, Heliotropioideae* and *Boraginoideae*. He further divided the *Boraginoideae* into seven tribes. Johnston (1924b) rearranged these tribes and genera.

Though *Boraginaceae* is a large family, the chromosome numbers of only about 300 species are known hitherto (Bolkhovskikh, *et al.*, 1969). Among the workers who studied the cytology, the contributions of Strey (1931), Smith (1932), Sugiura (1936), Mulay and Jaisingani (1945), Britton (1951), Pal (1957), Faruqui (1961b), Merxmüller and Grau (1963, 1969), Grau (1964a, b, 1965, 1966, 1967a, b, 1968a, b, 1970, 1971), Chaudhuri (1967) and Blaise (1970, 1972) are particularly significant.

Our cytological results are reported in Table 3.

Discussion

The chromosome number of *Heliotropium eichwaldi* (n = 32) tallies with the earlier finding of Ahuja (1955). *H. strigosum,* with n = 11, falls in line with the identical report of Pal (1964) but differs from the finding of Faruqi (1961) who reported 2n = 32 for this species. The present observation of 2n = 48 in *H. europaeum* (seeds collected in France) is a new chromosome report for the species. Darlington and Wylie (1955) suggested the genus to be polybasic with x = 7–13, while Löve and Löve (1961) attributed x = 8, 9, 10 to this same genus. The current observation indicates that *H. europaeum* from France is a chromosome race at the hexaploid level on the base number x = 8. Of all the genera studied in this family, the genus *Heliotropium* had the greatest variation in chromosome numbers, excepted for the genus *Myosotis.* The different zygotic numbers in the genus (14, 16, 18, 22, 24, 26, 28, 32 and 64) are suggestive of its speciation through aneuploidy or dysploidy accompanied by euploidy. According to Britton (1951), the variation in chromosome number is due to the study of types which are morphologically very diverse. Intraspecific polyploidy does exist in *H. europaeum,* but the exact distribution of the cytotypes or races is unknown.

Trichodesma indicum with n = 22 confirms the observations of Pal (1964) who also reported a diploid cytotype (n = 11) in this species, thereby indicating the presence of chromosome races in *T. indicum.*

The genus *Cynoglossum* consists of sixty species (Willis, op. cit.) spread over subtropical and temperate regions and sometimes found in mountainous regions. During the flowering season, those plants dominate the vegetation in W. Himalayas by virtue of their luxuriant flowering. *C. petiolatum* is confined to alpine W. Himalayas. The author could observe this species only in the Gulmarg region of Kashmir, generally under *Abies* trees.

Of the 8 species of *Cynoglossum,* 3 are reported cytologically for the first time, whereas the chromosome number in the remaining 5 agrees with the report of Britton (1951) (Table 3A). All the 21 species of *Cynoglossum* cytologically known so far (Strey, 1931; Sugiura, 1940b; Britton, 1951; Baksay, 1958; Chaudhuri, 1967 and author) have haploid chromosome number 12 or its multiples. All these data are against Britton's assumption of x = 8 as the basic number for the genus *Cynoglossum.* Darlington and Wylie (l.c.) have proposed x = 12 (6) for this genus, while Löve and Löve (1961) admitted x = 6. The uniformity of 12 as the haploid chromosome number in the genus, except for *C. aequinoctiale* (2n = 48, Britton, 1951), suggests that speciation in the genus is primarily due to structural alterations or gene mutations.

In *C. lanceolatum,* one bivalent is partially attached to the nucleolus at meiosis; in *C. nervosum,* clustering of bivalents and lagging of one bivalent away from metaphase plate were commonly observed. However, the later course of meiosis was found to be normal with regular tetrad formation and well filled pollen grains.

The genus *Lindelofia* Lehm. consists of 10 species (Willis) distributed in the Alpine regions of Central Asia, Afghanistan and Himalayas. *L. spectabilis* occurs in Ladakh of Kashmir and the Garhwal region of Kumaon, between 2700–3000 m. *L. longiflora* ascends to 2700 m in Kashmir. *L. longiflora* with n = 12 agrees with the finding of Strey (1931). *L. angustifolia* with n = 12 is a new report. Basic numbers

10 and 12 are proposed for *Lindelofia*. More cytological data is needed to comment upon the evolutionary pattern of this genus.

Paracaryum glochidiatum (n = 12) is documented cytologically for the first time. This number falls in line with the only other species in which the chromosome number is known (*P. coelestinum*, n = ca. 12, Strey, 1931), on which basis the genus seems to be built. Two populations were observed in the valley of flowers (3600 m) and Gurez (2700 m) in Kashmir. They showed differences in flower colour, the former having pink petals and the latter, white petals. The chromosomes of both varieties were similar (Fig. 44). The differences in flower colour are probably due to either genetic or environmental factors.

The species *Lappula deflexa* from Norway with 2n = 48 is cytologically a new report. *L. echinata* (2n = 48) from three different regions of Europe tallies with the chromosome counts of Löve and Löve (1956) and of Mulligan (1957). *L. microcarpa* (n = 11) from Himalayas is also a new chromosome count. The present findings seem to support the assumption of x = 12, (Darlington and Wylie, 1955) as the basic chromosome number for the genus. The gametic chromosome number 11 of *L. microcarpa* may be an aneuploid derivative of x = 12. In this plant, one bivalent is attached to the nucleolus at meiosis. The present finding of low chromosome number in Himalayas and the count from Tchouksanova (unpublished) in *Lappula barbata* (M.B.) Gürke, support the assumption that the centre of distribution of *Lappula* is Asia.

Eritrichium nanum with n = 23 and 2n = 46 collected from two different places in the Alps agrees with the earlier count of Favarger (1965). But *E. strictum* of W. Himalayas is cytologically a new report. This plant is common in Kashmir at a range of 2000–3000 m, in dry cold regions of Ladakh. The genus *Eritrichium* seems to be polybasic, with x = 12 and x = 11 (Grau, 1968). This fact can explain the gametic number n = 23 for *E. nanum* as coming through amphidiploidy from a taxon with n = 11 and another with n = 12. The polyploid *E. nanum* seems to have a remote Asiatic origin. After Favarger (unpublished), the variety *terglouense* from the Eastern Alps is also polyploid.

The gametic chromosome number 12 found in the material collected from W. Himalayas is a new report for *Asperugo procumbens*. But the higher ploidy (2n = 48) observed in the material collected from Briançon in the French Alps agrees with the earlier findings of Reese (1953) and Löve and Löve (1956). The chromosomes are small. The two reports stand for the intraspecific polyploidy in this species. The higher degree of polyploidy in European material is an interesting fact and seems to prove that in this case also, the plants from Europe have migrated from an Asiatic centre.

Lycopsis orientalis L. with gametic number 8, from Himalayas, agrees with the finding of Strey (1931). This taxon was included by some authors as subspecies in *Lycopsis arvensis* L. European material of the latter is characterized by a polyploid chromosome number. Our observations on plants from Belgium allows to determine more precisely the approximate number ca. 48, counted by Löve and Löve (1956). In all the cases, the size of the chromosomes is very large. Thus, the Asiatic and East European taxon *L. orientalis* seems to be an ancestor of the largely distributed *L. arvensis* from Central and Western Europe.

Nonnea caspica G. Don. was met in the valley of Kashmir on the exposed slopes near water channels. It was absent in the Kumaon regions of W. Himalayas. The chromosome number n = 8 is a new report. The genus seems to be polybasic with n = 7, 8, 10 (Grau, 1971). The majority of species of *Mertensia* reported from India are montane plants representative of Himalayas. *M. elongata* Benth.(1) was sometimes observed in open hill tops at an altitude of 3500 m in Kashmir, but could not be observed in other parts of W. Himalayas surveyed by the author. The chromosome count of n = 12 for this species agrees with the finding of 2n = 24 by Britton (1951). But n = 11, in *M. exserta* (2) (a plant distributed in small patches, in *Abies* forests in Gulmarg but not seen in Kumaon) is documented for the first time for the species. Incidentally, this is the only report of a gametic number differing from 12 or its multiples hitherto recorded for *Mertensia*.

Riedl (1967) had separated, from a morphological point of view, the Central Asiatic species of *Mertensia* from the American and Siberian species and proposed to include the former in a new genus: *Pseudomertensia* H. Riedl. Thus, the genus *P.* seems to be polybasic with n = 12 and n = 11.

Myosotis caespitosa Schultz was met at a range of 1800–2000 m in Kashmir valley, growing in marshy or small water channels and ditches on roadsides. The chromosome number n = 44 (Fig. 50) indicated an octoploid level on basic number x = 11. After Merxmüller and Grau (1963) there are diploid, tetraploid, hexaploid and octoploid taxa in the *palustris* group in Europe. The octoploid taxa are forms from Scandinavia probably belonging to *M. baltica* Sam. and a taxon from the Eastern Pyrénées. Our plants from Kashmir probably represent another octoploid taxon in this group. In a plant from Germany belonging to *M. palustris* (L.) Nath., we have found 2n = 64. This count tallies with those of Strey, Löve and Löve etc. but disagrees with those of Merxmüller and Grau (2n = 66). *M. stricta* Link., grows luxuriantly between 1800–2000 m in the valley of Kashmir in exposed places, in common with grasses. Its distribution is restricted to Kashmir in W. Himalayas. The gametic number n = 18 counted in this species agrees with the oldest counts (for example, Löve and Löve, 1956, on Icelandic material) but not with those of Grau (1968a) who has found 2n = 48 in material from various countries (among which a plant came from Iran). Therefore, Merxmüller (1970) thought that the somatic numbers 36–40 for this species rested on wrong counts! Meanwhile, the present author is sure of both identification of the plant and meiotic chromosome count.

Onosma emodi Wall. was observed in Kedarnath hills, in the midst of bushy shrubs up to 3000 m. The gametic number 9 in *O. emodi* Wall. is the first chromosome report for this species. Another species from Himalayas, *Onosma hookeri* Clarke, has the same basic number (Chaudhuri, 1967). *O. „echioides"* was described by Clarke in Hooker's Flora and it was considered by Riedl (op. cit.) as identical to *O. hispidum* Wall. Grau (1968) had counted 2n = 12 in two plants of this species: one coming from W. Pakistan, and the other from E. Afghanistan. It is difficult to understand the reason of this discrepancy. The chromosomes of *O. „echioides"* are very large compared to those of *O. emodi*.

(1) = *Pseudomertensia elongata* (Decne) H. Riedl.
(2) = *Pseudomertensia parviflora* (Decne) H. Riedl.

The number n = 18 for *Lithospermum arvense* from Himalayas is a new chromosome count for the species. The number 2n = 42 for the same species from Europe, is also a new chromosome report.

In this plant, Grau (1968) had counted 2n = 28 (material from Southern France). The German worker thinks that the older chromosome counts (2n = 24 and 2n = 16) should be considered cautiously. It seems that in this group, European material is built on the chromosome basic number 7 and the W. Himalayan one, on basic number 9.

The cytological conditions in the *Boraginaceae* are extremely complicated. Many genera seem to have more than one basic number, (for example, x = 11 and x = 12 in *Pseudomertensia, Eritrichium, Lappula, Myosotis*, etc.). In was interpreted by Merxmüller and Grau (1969) as dysploidy (aneuploidy with structural changes). This phenomenon can even arise in the same species. The present work brings some new examples of this intraspecific dysploidy such as in *Lithospermum arvense, Myosotis stricta*, and perhaps also in *Onosma hispidum*.

Another interisting feature is the difference observed in some cases between the level of ploidy of certain Himalayan species and the same species in Central Europe, as in *Asperugo procumbens* and *Lycopsis arvensis*, the Himalayan populations having the lowest chromosome number.

Verbenaceae

The family *Verbenaceae* consists of 75 genera and 3000 species (Willis, 1966) distributed in tropical and subtropical regions. Hooker (1885) had reported 129 species from British India. Since most of them are tropical and subtropical, their representation in W. Himalayas is poor. In Central Europe (after Hegi, op. cit. and Hermann, op. cit.), a singla wild species is growing.

Clarke (1885) divided the family into six tribes on the basis of joined characters of inflorescence, ovary, fruit and seeds. Briquet (1894) classified the entira family into 7 subfamilies but treated the ganus *Phryma* as belonging to a separate family, the *Phrymaceae*.

In this family, the main cytological studies were made by Sugiura (1936b) on the genera *Verbena* and *Callicarpa*, Patermann (1935), Nishiyama and Kondo (1942) and Bowden (1945) on the genus *Clerodendron*, Schnack and Covas (1947), Tjio (1948), and Natarajan and Ahuja (1957) on the genus *Lantana*, Cooper (1941) on the genus *Phryma*, and Sharma (1956) and Sharma and Mukhopadhyay (1963) on other genera of the family. Our cytological results are reported in Table 4.

Discussion

Phryma L. (1) is a small genus consisting of only one species, reported from Himalayas by Hooker (1885). *P. leptostachya* L. is frequent in W. Himalayas from Kashmir to Kumaon between 700 and 2000 m. The gametic chromosome number counted at meiosis from PMC's is n = 7.

(1) Triba Phrymeae in the acception of Clarke (1885). For some authors, this genus belongs to a separate family: *Phrymaceae*.

Lantana camara L. is widly distributed in India. It is very common in plains and outer hills of Himalayas. Various morphological types are noticed with respect to the flower colour. 16 bivalents are clearly discernible at MI of meiosis.

Verbena bonariensis L. is a native of Brazil but was introduced in Himalayas. It is seen, but rarely, in Mussoorie and Sathal regions of Kumaon, with conspicuous absence in Kashmir. 14 bivalents are counted at MI of meiosis. *V. officinalis* L. occurs in Nainital and Mussoorie regions of W. Himalayas at a range between 300 and 2000 m. It is sometimes seen in Kashmir also. This species is common in many parts of Europe. PMC's indicated 7 bivalents at MI of meiosis. *V. bipinnatifida* Nutt. is an exotic species native of California and Mexico. It is cultivated in gardens in Chandigarh. A chromosome count at meiosis shows n = 5 with normal meiosis. Bivalents were comparatively large.

Callicarpa longifolia Lamk. is observed in Almora of Kumaon, but is not very common in W.Himalayas. A chromosome count at MI of meiosis showed 18 bivalents with normal sequence of later stages (fig. 57).

Caryopteris grata Benth. is common in Kumaon in bushy jungles up to 2000 m. The meiotic chromosome number is n = 30 at AI.

Of the seven species of *Verbenaceae* investigated presently, the chromosome number of one species is a new report. The lowest gametic number was found in *Verbena bipinnatifida* (n = 5), whereas the highest one was observed in *Caryopteris grata* (n = 30).

According to the literature, there are two chromosome races in *Phryma leptostachya*, a diploid one studied by Sugiura and by the author, and a tetraploid one with 2n = 28 (Sugiura, Cooper and Sokolovskaja). The plant examined by Sokolovskaja was coming from Siberia (region of Primorye) and the plant examined by Cooper, from the U.S.A. Since Sugiura has studied spontaneous plants from Japan, it is possible to conclude that the monotypical genus *Phryma* was born in Asia, perhaps in Himalayas, and that the tetraploids have migrated to Atlantic North America and to East Siberia. Recently, Hara (1972) has ascertained that in *Phryma*, „The Himalayan, Japanese and Eastern North American plants agree well with each other . . . and have the same chromosome number (2n = 28)." He does not report any of Sugiura's results, and the current finding does not agree with the assertion of Hara.

Lantana camara, a species highly variable in flower colour, showed various chromosome numbers. The present result tallies with the number recorded by Schnack and Covas (1947). It would be interesting to establish a correlation between chromosome numbers and flower colours in *L. camara*. If such a correlation did exist, one would be facing a morphological splitting within the species. Hence intraspecific variation in chromosome numbers may be considered as the main evolutionary trend in this species.

The three different chromosome numbers (n = 5; n = 7; n = 14) found in the presently studied species of *Verbena* refer to two distinct basic numbers, x = 5 and x = 7. These two basic numbers have been recorded in many other species of the genus. From another point of view, it could be mentioned here that karyotypical studies made by Sharma and Mukhopadhyay (1963) enabled them to conclude that *Verbena* is the most primitive genus in the family: a hypothesis based on the long chromosomes and „fairly symmetrical karyotype" observed in this genus.

Callicarpa longifolia (n = 18) has the same chromosome number as *C. japonica* (Patermann, 1935). Hence, it seems that x = 9 is one of the basic numbers of this genus; a secondary gametic number is n = 17. Unpublished data of Bawa (personal communication) indicated that both intraspecific and interspecific polyploidy were prevalent in the genus.

Caryopteris grata, with n = 30 agrees with Mehra and Gill's results (1968). It is difficult, in the present state of knowledge to assign a basic number to this genus.

Although, the author has not made an exact count of the chromosomes of *Stachytarpheta indica*, he could observe in this species a very high number of small chromosomes. Therefore the author agrees with Sharma *et al.* (1963) who have proposed to place this genus in a separate tribe other than *Verbeneae*.

A critical examination of the chromosome numbers of cytologically studied species of *Verbenaceae* clearly reveals a considerable intra- and interspecific variation in chromosome numbers.

The vegetative mode of reproduction of some members of the family perhaps favours speciation through polysomaty (Sharma, 1956).

Solanaceae

The family *Solanaceae* comprises about 90 genera covering about 2000 species (Willis, 1966); it has a wide spread distribution in tropical and temperate regions. Of the 51 species from India recorded by Clarke (in Hooker, 1885), some were found at the montane and subalpine levels of Western Himalayas. The family is poorly represented in Europe: 16 species after Hegi (op. cit.) and 11 after Hermann (op. cit.) of which many are cultivated plants. Some species are common to both Europe and India.

Wettstein (1895) divided the family *Solanaceae* into five tribes on the basis of both flower and embryo characters: *Nicandreae*, *Solaneae*, *Datureae*, *Cestreae*, and *Salpiglossideae*. The most important cytological contributions on non-tuberous members were made by Belling and Blakeslee (1923), Kojima (1925), Lesley (1926), Vilmorin and Simonet (1927), Jörgensen (1928, 1929), Janaki Ammal (1932, 1934), Tokunaga (1934), Nakamura (1937), Nisimura (1939), Ellison (1936a and b), Goodspeed and Avery (1939), Paddock (1942 and 1943), Westergaard (1948), Bhaduri (1933, 1945, 1951) Oinuma (1949), Stebbins and Paddock (1949), Hardas and Joshi (1954), Sinha (1950), Ramprakash and Biswanath Chatterjee (1953), Mehra *et al.* (1954), Swaminathan *et al.* (1953), Sharma and Sharma (1957), Rai (1959, 1960), Soria and Heiser (1961), Magoon *et al.* (1962), Bezbaruah and Bezbaruah (1963), Venkateswarlu and Rao (1963), Rao (1962), Tandon and Rao (1964, 1966), Chennaveeraiah and Krishnappa (1965, 1966), Venkateshwaralu and Bhiravamurthy (1962) and Philomena Madhavadian (1968).

Our cytological results are reported in Table 5.

Discussion

Twenty-nine taxa of *Solanaceae* from W. Himalayas, pertaining to 27 species, are studied in the present work, revealed some interesting cytological features, so far not recorded in the family. Four taxa from Europe were also examined for comparison.

Table 6: *SCROPHULARIACEAE*

Taxa	Source and altitude	Collection number	Chromosome number n	2n	Level of ploidy	Previous report
	Species from the Western Himalayas studied by the author (A)					
Subfamily Pseudosolaneae						
Tribe Verbasceae						
Verbascum thapsus L.	Nainital, 1900 m	2518	18	–	?	2n = 34, 36, Håkansson 1926 2n = 36, Mulligan 1961 2n = 36, Packer 1964
Subfamily Antirrhinoideae						
Tribe Antirrhineae						
Linaria ramosissima Wall.	Ranikhet, 1900 m	2598	9	–	2x	n = 9, Verma & Dhillon 1967
L. cymbalaria Mill.	Nainital, 1900 m	2506	7	–	2x	n = 7, Verma & Dhillon 1967
L. bipartita Willd.	Nainital, 1900 m	2513	6	–	2x	n = 6, Verma & Dhillon 1967
L. dalmatica L.	Sankaracharya Hill, 2100 m, Kashmir	4215	6	–	2x	2n = 12, Heitz 1927 Tjebbes 1928 Matsura & Suto 1935
L. subsessilis Pennell *	Anandnag, 1500 m Kashmir	4271	18	–	4x	
Antirrhinum majus L.	Nainital, 1900 m	2508	8	–	2x	2n = 16, Baur 1924, 1932 Propach 1934 et 1935 n = 8, Rieger 1957 2n = 32, Morrison & Rajhathy 1960 n = 8, Verma & Dhillon 1967
A. orontium L.	Pinjore, 400 m	2080	8	–	2x	2n = 14, Sobti & Singh 1961 n = 8, Verma & Dhillon 1967
Tribe Cheloneae						
Scrophularia obtusa Edgew.*	Almora, 1900 m	2570	24	–	4x	
S. scopolii Hoppe +	Gulmarg, 2700 m Kashmir	4225	24	–	4x	2n = 26, Varama & Hiirsalmi 1967
S. edgeworthii Benth.*	Manna valley, 3600 m Kumaon		24 + 1B	–	4x	
S. himalensis Royle *	Nainital, 1900 m	2574	24	–	4x	
	Shervan, 2000 m Kashmir	4234	12	–	2x	n = 10, Mehra & Gill 1968
S. lucida L.	Tangmarg, 2100 m Kashmir	4214	13	–	2x	n = 13, Shaw 1962
S. variegata Bieb.+	Tangmarg, 2100 m Kashmir	4216	24	–	4x	n = 12, Shaw 1962 Vaarama and Hiirsalmi 1967
S. dentata Royle *	Kargil, 2500 m Ladakh	4257	12	–	2x	
Tribe Gratioleae						
Mazus rugosus Lour.	Kuchiathal, 1200 m Nainital	2594	20	–	4x	n = 20, Verma & Dhillon 1967
M. surculosus D.Don *	Nainital, 1900 m	2532	10	–	2x	
Lindenbergia grandiflora Benth.*	Didihat, 1400 m Kumaon	2038	14	–	4x	
L. macrostachya Benth.*	Haridwar, 400 m	2093	16	–	4x	
L. urticaefolia Lehm.*	Lohorkhet, 2100 m Kumaon	2549	25	–	?	
Adenosma capitatum Benth.*	Thal, 1400 m Almora	2042	36	–	?	
Limnophila roxburghii G.Don *	Bageswar, 1400 m Almora	2047	18	–	?	
Bacopa monniera (L.) Wettst. (= *Herpestis monniera* H.B. & K.)	Surajpur, 350 m	2084	32	–	?	n = 24, Srinath 1934 2n = 64, Raghavan 1959b Lewis *et al.* 1962
Bacopa chamaedryoides (H.B.K.) Wettst. (= *Herpestis chamaedryoides* H.B.K.)*	Uttarkashi, 1200 m	2606	10	–	2x	
Torenia cordifolia Roxb.*	Nandaprayag, 1000 m Kumaon	2013	16	–	4x	
Vandellia nummularifolia D.Don *	Almora, 1900 m	2571	12	–	2x	
Bonnaya brachiata Link & Otto *	Sathal, 1200 m Nainital	2568	9	–	2x	
B. veronicaefolia Spreng.*	Sathal, 1200 m Nainital	2566	18	–	4x	
Subfamily Rhinanthoideae						
Tribe Digitaleae						
Wulfenia amherstiana Benth.	Lariakanta, 2000 m Nainital	2538	8	–	2x	n = 8, Verma & Dhillon 1967 n = 8, Mehra & Gill 1968
Veronica ciliata Fisch.*	Lianmarg, 3600 m Kashmir	4262	8	–	2x	
Veronica anagallis L.+	Surajpur, 350 m	2068	27	–	6x	2n = 36, Ehrenberg 1945 n = 27, Verma & Dhillon 1968
	Tangmarg, 2100 m Kashmir	4208	18	–	4x	n = 18, 27, Khoshoo & Khushu 1964 2n = 36, Löve & Löve 1956
Veronica beccabunga L.+	Tangmarg, 2100 m Kashmir	4205	9	–	2x	2n = 18, Schlenker 1936 Gadella & Kliphuis 1963 2n = 18, 36, Sokolowska-Kulczycka *in* Skalinska 1964
V. hederifolia L.+	Tangmarg, 2100 m Kashmir	4222	9	–	2x	2n = 28, Gadella & Kliphuis 1966 2n = 56, Hofelich 1935 Sorsa 1963 Rohweder 1937 Lehmann *et al.* 1954 2n = 18, 36, 54, Fischer 1967
V. polita Fries	Chandigarh, 350 m	2076	7	–	2x	n = 7, Huber 1927 Yamashita 1937
V. persica Poir.	Kasauli, 1500 m	2092	14	–	4x	2n = 28, Borgmann 1964
V. biloba L.	Srinagar, 1650 m Kashmir	4204	14	–	4x	2n = 28, Zündorf 1939
V. laxa Benth.	Pindari glacier, 3500 m, Kumaon	2543	23	–	?	n = 23, Mehra & Gill 1968 Yamasaki 1936
V. verna L.	Sankaracharya Hill, 2100 m, Kashmir	4217	8	–	2x	2n = 16, Hofelich 1935
V. cana Wall.*	Dwali, 3000 m Almora	2544	26	–	?	
V. serpyllifolia L.	Tangmarg, 2100 m Kashmir	4201	7	–	2x	2n = 14, Löve & Löve 1956b Sokolovskaya 1963 Hara 1956 Gadella & Kliphuis 1966
Lagotis glauca Gaertn.	Aporwat, 3900 m Kashmir	4243	11	–	2x	2n = 22, Sakai 1934 Sokolovskaja 1963, 1965
Tribe Gerardieae						
Buchnera hispida Ham.*	Nainital, 1900 m	2021	14	–	2x	
Leptorhabdos benthamiana Walp.**	Nainital, 1900 m	2037	7	–	2x	
Tribe Rhinantheae						
Euphrasia officinalis L.*	Basudhara, 3800 m Kumaon	2004	22	–	4x	
E. platyphylla Pennell *	Khilanmarg, 3000 m Kashmir	4270	22	–	4x	
Pedicularis pectinata Wall.	China peak, 2600 m Nainital	2016	8	16	2x	n = 8, Verma & Dhillon 1967 Mehra & Gill 1968
P. tenuirostris Benth.*	Banihal, 2550 m Kashmir	4265	8	–	2x	

Table 5C: Summary of distinctive characters of the races of *Solanum nigrum*

Characters	Diploid (n = 12)	Tetraploid (n = 24)	Hexaploid (n = 36)
Locality	Nainital	Nainital	Almora
Habitat	Shady and humid places	Shady and open places	Shady and open places
Habit	Erect and quite branched	Erect and profusely branched, sometimes semi-prostrate	Erect and profusely branched giving bushy appearance
Height	65–98 cm	75–95 cm	50–210 cm with intermediate forms
Stem	Green, non-prominent ribs	Thick dull green with purplish tint, prominent ribs	Green with or without ribs
Leaves	Thin, ovate, serrate	Thick, ovate, serrate margin	Thick, ovate, lanceolate, bigger and fewer serrations, petiole prominently marginate
Length of petiole	1,1–2,3 cm	1,5–4,2 cm	3,0–6,0 cm
Length of lamina	3,0–7,5 cm	5,6–9,8 cm	9,0–13,1 cm
Flowers per inflorescence	4–6	5–6	7–9
Diameter of corolla	4–6 mm	7–8 mm	8–11 mm
Fruit colour	Shiny blue black	Orange red	Purplish black
Fruit size	Small	Small	Large
Seeds per fruit	25	23	45
Size of stomata	20 x 18 μ	24 x 20 μ	32 x 28 μ

Table 5: *SOLANACEAE*

Taxa	Source and altitude	Collection number	Chromosome number n	2n	Level of ploidy	Previous report
	Species from the Western Himalayas studied by the author (A)					
Tribe Nicandreae						
Nicandra physaloides (L.) Gaertn.	Nainital, 1900 m	2519	10	–	2x	2n = 20, Venkateswarlu & Rao 1962, 1963
						2n = 19, 20, Darlington & Janaki Ammal 1945
						2n = 20, Vilmorin & Simonet 1928
						Delay 1947
						Gottschalk 1954
						2n = 21, Sinha 1951
Tribe Solaneae						
Subtribe Lyciinae						
Atropa belladonna L.	Gulmarg, 2700 m Kashmir	4223	36	–	6x	2n = 72, Marchal 1920
						Vilmorin & Simonet 1928
						Delay 1947
						Gottschalk 1954
						Mehra & Sobti 1954
						2n = 50, Homedes Ranquini 1943
Tribe Solaneae						
Subtribe Hyoscyaminae						
Physochlaina praealta Miers	Kargil, 2500 m Ladakh	4249	41	–	?	2n = 82, Mehra & Sobti 1954
Hyoscyamus niger L.	Gulmarg, 2700 m Kashmir	4224	17	–		2n = 34, Griesinger 1937
						2n = 34, Vaarama 1950
						Vilmorin & Simonet 1928
						Tischler 1934, 1937
						Delay 1947
						Löve & Löve 1948
						Gottschalk 1954
						Garajova 1959
						n = 17, Mehra & Sobti 1954
H. pusillus L.	Dras, 2700 m Ladakh	4250	34	–	4x	n = 34, Mehra & Sobti 1954
Tribe Solaneae						
Subtribe Solaninae						
Solanum nigrum L.	Ranibag, 600 m Nainital	2537	12	–	2x	2n = 24, 48, 72, Bhaduri 1933
						n = 12, 24, 36, Tandon & Rao 1964
						2n = 36, 72, 96, 144, Jörgensen 1928
	Nainital, 1900 m	2507	24	–	4x	2n = 24, 36, 48, Winkler 1921
						2n = 72, Vilmorin & Simonet 1928
	Almora, 2100 m	2001	36		6x	Masubuchi 1961
	Lalkuan, 350 m	2553	24	–	4x	Mulligan 1961 etc. (cf. Bolkhovskikh *et al.*, 1969)
S. verbascifolium L.	Almora, 1900 m	2585	12	–	2x	2n = 24, Bhaduri 1933
						Ratera, 1943
						Bezbaruah & Bezbaruah 1963
						Mehra & Gill 1968
						Chandola *et al.* 1966
S. khasianum Clarke	Pantnagar, 300 m	2066	12	–	2x	2n = 24, Haiser 1963a
						Mehra & Gill 1968
						Bezbaruah & Bezbaruah 1963
S. torvum Swartz.	Lalkuan, 350 m	2554	12	–	2x	2n = 24, Haiser 1963
						Bhaduri 1933
						Bezbaruah & Bezbaruah 1963
S. indicum L.	Haldwani, 400 m	2033	12	–	2x	2n = 24, Bhaduri 1933, 1935
						Miège 1962
						Bezbaruah & Bezbaruah 1963
S. xanthocarpum Schrad. Wendl.	Lalkuan, 350 m	2552	12	–	2x	2n = 24, Jörgensen 1928
						Baquar *et al.* 1965
						Bhaduri 1933
						Mehra & Gill 1968
S. hispidum Pers.	Dehra Dun, 400 m	2077	12	–	2x	n = 12, Haiser 1963
S. incanum L.	Pantnagar, 300 m	2560	12	–	2x	2n = 24, Miège 1962
S. jasminoides Paxt.	Nainital, 1900 m	2562	12	–	2x	2n = 24, Vilmorin & Simonet 1927a, 1968
S. macranthum Dun.	F.R.I., 400 m Dehra Dun	2091	12	–	2x	2n = 24, Nanda 1962
S. pseudocapsicum L.	Someswar, 800 m Kumaon	2547	12	–	2x	2n = 24, Vilmorin & Simonet 1927a, 1928
						Bezbaruah & Bezbaruah 1963
						Kawano 1965
Lycopersicum pimpinellifolium Dun.	Almora, 1900 m	2036	12	–	2x	2n = 24, Luckwill 1943
						Rick 1956
						Humphrey 1932, 1937
						Upadhya & Majid 1964
						2n = 24, 48, Lindstrom 1932
Physalis minima L.	Garampani, 1000 m Nainital	2564	24	–	4x	2n = 48, Bhaduri 1933
						Gottschalk 1954
						Baquar et al. 1965
P. peruviana L.	Almora, 1900 m	2584	24	–	4x	2n = 24, Yamamoto & Saksi 1932
						2n = 48, Menzel 1951 etc. (cf. Bolkhovskikh *et al.*, 1969)
Capsicum frutescens L.	Rajhati, 800 m Nainital	2590	12	–	2x	2n = 24, Sinha 1950
						Kapoor & Tandon 1964 etc. (cf. Bolkhovskikh *et al.*, 1969)
Withania somnifera Dunal.	Lalkuan, 350 m	2551	24	–	2x	2n = 24, Mohan Ram & Kamini 1964
						2n = 48, Miège 1960
						Baquar *et al.* 1965
						Bhaduri 1933
						Gottschalk 1954
Tribe Datureae						
Datura stramonium L	Nainital, 1900 m	2521	12	–	2x	2n = 24 (12, 25), Satina *et al.* 1941
						2n = 48, Belling & Blakeslee 1922
						2n = 24, Bönicke 1911 etc. (cf. Bolkhovskikh *et al.* 1969)
D. fastuosa L.	Almora, 1900 m	2586	12	–	2x	2n = 24, Vilmorin & Simonet 1927, 1928
						Bhaduri 1933
						Bhaduri & Sharma 1946
D. innoxia Mill.	Haldwani, 400 m	2527	12 + 1	–	2x	2n = 24, Sobti & Singh 1961
						Blakeslee *et al.* 1935
						Buchholz *et al.* 1935
D. suaveolens Humb. & Bonpl.	Bowali, 1700 m	2523	12	–	2x	n = 12, Gottschalk 1954
Tribe Cestreae						
Subtribe Nicotianinae						
Nicotiana rustica L.	Haldwani, 400 m	2545	24	–	4x	2n = 48, Goodspeed 1923 etc. (cf. Bolkhovskikh *et al.* 1969)
N. plumbaginifolia Viv.	Haldwani, 400 m	2579	10 + 1B	–	2x	2n = 20, Goodspeed 1945
						Gottschalk 1954 etc. (cf. Bolkhovskikh *et al.* 1969)
	Species from Europe studied by the author (B)					
Tribe Solaneae						
Subtribe Solaninae						
Solanum nigrum L.	Neuchâtel, Switzerland	–	36		6x	see Table 5A, under the same species
Physalis alkekengi L.	Locality unknown Hungary (Bot. Gard., Gödöllö)	–	–	24	2x	2n = 24, Vilmorin & Simonet 1927, 1928
						Yamamoto & Sakai 1932
						Nakajima 1933
						Tokunaga 1934
						Menzel 1951
						Gottschalk 1954
						Murin & Vachova 1967
Subtribe Lyciinae						
Atropa belladona L.	Timisul de Sas, Beasov, Rumania (Bot. Gard., Bucarest)	–	–	72	6x	see Table 5A, under the same species
Subtribe Hyoscyaminae						
Hyoscyamus niger L.	Vallée d'Eyne, East Pyrénées, France (Bot. Gard., Liège)	–	–	34	4x	see Table 5A, under the same species

Table 3: *BORAGINACEAE*

Table 4: *VERBENACEAE*

Taxa	Source and altitude	Collection number	Chromosome number n	2n	Level of ploidy	Previous report
Phryma leptostachya L.	Nainital, 1900 m	2588	7	–	2x	2n = 14, Sugiura 1936b 2n = 28, Sugiura 1936a Cooper 1941 Sokolovskaja 1966
Subfamily Verbenoideae Tribe Lantaneae *Lantana camara* L.	Jeolikot, 1400 m Nainital	2504	16	–	4x	2n = 32, 44, Schnack & Covas 1947 2n = 44, Tjio 1948 2n = 22, 33, 44, 66, Nataraian & Ahuja 1957 2n = 44, Raghavan & Arora 1960 Singh 1951 2n = 22, 33, 44, Sen & Sahni 1958
Subfamily Verbenoideae Tribe Verbeneae *Verbena officinalis* L.	Bandipur, 1800 m Kashmir	4260	7	–	2x	2n = 12, Schnarf 1923 Paterman 1935 2n = 14, Junell 1934 Tischler 1934 Dermen 1936 Noack 1937 Schnack & Covas 1944
Verbena bipinnatifida Nutt.	Chandigarh, 300 m	2060	5	–	2x	n = 15, Lewis & Oliver 1961
Verbena bonariensis L.	Bhimthal, 1400 m Kumaon	2572	14	–	4x	2n = 28, Derman 1936 Noack 1937 Schnack *et al.* 1959 Covas & Schnack 1947
Subfamily Viticoideae Tribe Callicarpeae *Callicarpa longifolia* Lamk.*	Almora, 1900 m	2583	18	–	2x	
Subfamily Caryopteridoideae *Caryopteris grata* Benth.	Nainital, 1900 m	2502	30	–	?	n = 30, Mehra & Gill 1968

* Chromosome number of the species reported for the first time

Table 3: *BORAGINACEAE*

Taxa	Source and altitude	Collection number	Chromosome number n	2n	Level of ploidy	Previous report
	Species from the Western Himalayas studied by the author (A)					
Subfamily Heliotropioideae						
Heliotropium eichwaldi Steud.	Lalkuan, 350 m Kumaon	2558	32	–	8x	n = 32, Ahuja 1955 Malik *et al.* 1959
H. strigosum Willd.	Ranikhet, 1900 m	2597	11	–	2x	n = 11, Pal 1964 2n = 32, Faruqi 1961 2n = 26, Malik *et al.* 1959
Subfamily Boraginoideae						
Tribe Cynoglosseae						
Trichodesma indicum Br.	Ranikhet, 1900 m	2599	22	–	4x	n = 11, 22, Pal 1964 2n = 22, Malik *et al. 1959* Baquar *et al.* 1965 n = 22, Chaudhuri 1967
Cynoglossum furcatum Wall.*	Nainital, 1900 m	2555	12	–	2x	
C. lanceolatum Forsk.	Banihal, 2550 m Kashmir	4276	12	–	2x	n = 12, Chaudhuri 1967 2n = 24, Chaudhuri 1967
C. wallichi G. Don	Nainital, 1900 m	2546	12	–	2x	n = 12, Chaudhuri 1967 2n = 24, Chaudhuri 1967
C. microglochin Benth.*	Nainital, 1900 m	2577	12	–	2x	
C. nervosum Benth.	Almora, 2000 m	2095	12	–	2x	2n = 24, Britton 1951
C. petiolatum A. DC*	Gulmarg, 2700 m Kashmir	4240	12	–	2x	
C. zeylanicum Thunb.	Qurez valley, 2700 m Kashmir	4259	12	–	2x	2n = 24, Britton 1951
C. amabile Stapf. and Drumm.	Govindghat, 2100 m Almora	2086	12	–	2x	2n = 24, Britton 1951
Lindelofia angustifolia Brand.*	Sonamarg, 2700 m Kashmir	4231	12	–	2x	
L. longiflora Baillon	Gulmarg, 2700 m Kashmir	4242	12	–	2x	2n = ca. 24, Strey 1931
Paracaryum glochidiatum Benth.	Valley of flowers, 3600 m, Kumaon	2002	12	–	2x	
Tribe Eritrichieae						
Lappula microcarpa (Ledeb.) Gürke *	Dras, 2700 m Ladakh	4269	11	–	2x	
Eritrichium strictum Done.*	Zoji La, 3300 m Kashmir	4251	12	–	2x	
Asperugo procumbens L.+	Dras, 2700 m Ladakh	4258	12	–	2x	2n = 48, Reese 1953 Löve & Löve 1956
Tribe Anchuseae						
Lycopsis orientalis L.	Mahagam, 1650 m Kashmir	4227	8	–	2x	2n = 16, Strey 1931
Nonnea caspica G. Don.*	Tangmarg, 2100 m Kashmir	4206	8	–	2x	
Tribe Lithospermeae						
Mertensia elongata Benth.	Lianmarg, 3900 m Kashmir	4261	12	–	2x	2n = 24, Britton 1951
M. exserta I.M. Johnston*	Gulmarg, 2700 m Kashmir	4203	11	–	2x	
Myosotis stricta Link	Pahalgam, 2100 m Kashmir	4218	18	–	?	2n = ca. 36, Löve & Löve 1956 2n = 48, Grau 1968
M. caespitosa Schultz	Pahalgam, 2100 m Kashmir	4228	44	–	?	2n = 22, 44, Merxmuller & Grau 1963 2n = ca. 80, Strey 1931 Tischler 1934 Rohweder 1937
Lithospermum arvense L.+	Sankaracharya Hill, 2100 m, Kashmir	4219	18	–	?	2n = 28, Löve & Löve 1944 Britton 1951 Haneli & Schultze-Motel 1962 Grau 1968
Onosma „echioides" L.+	Zoji La, 3300 m Kashmir	4248	7	–	2x	
O. emodi Wall.*	Kedarnath Hill, 3600 m Kumaon	2603	9	–	2x	
	Species from Europe studied by the author (B)					
Subfamily Heliotropioideae						
Heliotropium europaeum L.+	Sète-Hérault, France (Bot. Gard. Liège)	–	–	48	6x	2n = 24, Svensson 1925 2n = 32, Britton 1951
Subfamily Boraginoideae						
Tribe Eritrichieae						
Lappula echinata Gilib.	Locality unknown Hungary (Bot. Gard., Gödöllö)	–	–	48	4x	2n = 48, Mulligan 1957 Löve et Löve 1956
	Ceillac, 1670 m France (Prof. C. Favarger)	–	–	48	4x	
	Charrat, 600 m Valais, Switzerland	–	–	48	4x	
L. deflexa Garcke*	Oppland, Lom-Lom Norway (Bot. Gard., Oslo)	–	–	48	4x	
Eritrichium nanum (All.) Schrader	Oberrothorn, 3000 m Valais, Switzerland	–	–	46	?	2n = 44–46, Favarger 1942 2n = 46, Favarger & Huyhn 1964 Favarger 1965
Asperugo procumbens L.	Briançon, 1700 m Hautes-Alpes, France (Bot. Gard., Dijon)	–	–	48	4x	see Table 3A, under the same species
Tribe Anchuseae						
Lycopsis arvensis L.	La Panne, Flandre-occidentale, Belgium (Bot. Gard., Liège)	–	–	48	6x	2n = ca. 48, Löve & Löve 1956 2n = ca. 54, Svensson 1925 Tischler 1934 Rohweder 1937
	Pisse-vache, 470 m Valais, Switzerland (Bot. Gard., Geneva)	–	–	48	6x	
	Quarri-les-Tombes, 390 m Yonne, France (Bot. Gard., Dijon)	–	–	48	6x	
Tribe Lithospermeae						
Myosotis palustris (L.) Nath	Cottbus, Germany (Bot. Gard., Jena)	–	–	64	?	2n = 22, 66, Merxmüller & Grau 1963 2n = 64, Strey 1931 Tischler 1934 Rohweder 1937 Löve & Löve 1942, 1956
Lithospermum purpureocaeruleum L.	Neuchâtel, 700 m Jura, Switzerland	–	8	–	2x	2n = 16, Reese 1952 Grau 1966
L. officinale L.	Lossy, 530 m Haute-Savoie, France (Bot. Gard., Geneva)	–	–	28	4x	2n = 28, Strey 1931 Tischler 1934 Britton 1951 Mulligan 1957 Gadella & Kliphuis 1966
L. arvense L.	Charral, 650 m Valais, Switzerland (Prof. C. Favarger)	–	–	42	6x	see Table 3A, under the same species

* Chromosome number of the species reported for the first time
\+ A new chromosome report for the species

Taxa	Source and altitude	Collection number	Chromosome number n	2n	Level of ploidy	Previous report
P. gracilis Wall.	Badrinath, 3050 m	4265	8	–	2x	n = 8, Mehra & Gill 1968
	Simla Hills, 2600 m Narkunda	–	–	16	2x	n = 8, Mehra & Gill 1968
Pedicularis porrecta Wall.*	Kedarnath, 3600 m	2604	8	–	2x	
P. brevifolia D. Don *	Aporwat, 3900 m Kashmir	4275	–	16	2x	
P. pycnantha Boiss.*	Dras, 2700 m Ladakh	4244	8	16	2x	
P. macrantha Klotzsch *	Kedarnath, 3600 m	2602	7–8	–	2x	
P. megalantha Don *	Valley of flowers, 3600 m, Kumaon	2005	8	–	2x	
P. bicornuta Klotzsch *	Aporwat, 3900 m Kashmir	4245	7	–	2x	
P. siphonantha D. Don	Tangmarg, 2100 m Kashmir	4236	–	16	2x	n = 8, Verma & Dhillon 1967 Mehra & Gill 1968
P. carnosa Wall.	Lariakanta, 2400 m Nainital	2595	6	12	2x	n = 6, Verma & Dhillon 1967
P. rhinanthoides Schrenk *	Aporwat, 3900 m Kashmir	4285	8	–	2x	
P. pyramidata Royte *	Tangmarg, 2100 m Kashmir	4238	8	16	2x	
P. oederi Vahl +	Aporwat, 3900 m Kashmir	4290	–	30	4x	2n = 16, Knaben in Löve & Löve 1948
	Species from Europe studied by the author (B)					
Subfamily Antirrhinoideae						
Tribe Antirrhineae						
Antirrhinum orontium L. var. *nanum* Gaut.	Roussillon, East Pyrénées, France (Bot. Gard., Versailles)	–	–	16	2x	2n = 16, Heitz 1926, 1927b Tischler 1934 Larsen 1960b 2n = 14, Sobti & Singh 1961 n = 8, Verma & Dhillon 1967
Tribe Cheloneae						
Scrophularia scopolii Hoppe	Gran Sasso, 2250 m Italy (Prof. C. Favarger)	–	13	–	2x	2n = 26, Varaama & Hiirsalmi 1967
Scrophularia scopolii Hoppe	Monkovadolina, 1250 m Belanske, Tatry, Czechoslovakia (Bot. Gard., Komenskeho)	–	–	26	2x	see Table 6A, under the same species
S. nodosa L.	Bottelare, Palus, Belgium (Bot. Gard., Genl)	–	–	36	4x	2n = 36, Scheerer 1939 Löve & Löve 1944b Polya 1949 Löve A. 1954b Shaw 1962 Gadella & Kliphuis 1963
	Simplon Pass, 1400 m Alps, Switzerland	–	18	–	4x	Vide supra
S. umbrosa Dumort.	Angermund, Germany (Bot. Gard., Düsseldorf)	–	–	52	6x	2n = 26, Murin & Vachova 1967 2n = 52, Scheerer 1940
S. canina L.+	Gondo, Simplon Pass, 1300 m Alps, Switzerland	–	12	–	2x	2n = 22, 45, 51, 52, 54–58, ca. 112 Rodrigues 1956 2n = 26, Rodrigues 1953
Subfamily Rhinanthoideae						
Tribe Digitaleae						
Wulfenia carinthiaca Jack.	Karnische Alpen, Austria (Bot. Gard., Klagenfurt)	–	–	18	2x	2n = 18, Favarger & Huynh 1964
Veronica hederifolia L.	Degeberga, Skane, Sweden (Bot. Gard., Lund)	–	–	54	6x	2n = 54, 36, Nordenstam & Nilsson 1969 Fischer 1967
	Neuchâtel, Switzerland	–	18	–	4x	see Table 6A, under the same species
V. persica Poir.	Landskrona, Skane, Sweden (Bot. Gard., Lund)	–	–	28	4x	see Table 6A, under the same species
V. verna L.	Chaudes Aigues, 800 m Cantal, France (Bot. Gard., Versailles)	–	–	16	2x	see Table 6A, under the same species
V. serpyllifolia L.	Sur-les-Toules, 2000 m Valais, Switzerland (Bot. Gard., Geneva)	–	–	14	2x	see Table 6A, under the same species
	Jura de Neuchâtel, 750 m Switzerland	–	7	–	2x	
V. scutellata L.	Cuisery, Saône-et-Loire, France (Bot. Gard., Dijon)	–	–	18	2x	2n = 18, Scheerer 1939 Hagerup (Löve & Löve 1942b) 1944 Löve & Löve 1956b Gadella & Kliphuis 1963, 1966
V. chamaedrys L.	Neuchâtel, 750 m Jura, Switzerland	–	16	–	4x	2n = 16, Mattick in Tischler 1950 2n = 32, Simonet 1934d Löve & Löve 1944b, 1956b Sorsa 1962 Gadella & Kliphuis 1963, 1966
V. anagallis-aquatica L.	Saby, Skane, Sweden (Bot. Gard., Lund)	–	–	36	4x	2n = 36, Ehrenberg 1945 Löve & Löve 1956b
V. anagalloides Guss.	Salonta, Jud Behor Rumania (Bot. Gard., Cluj)	–	–	36	4x	2n = 36, Schlenker 1936
V. beccabunga L.	Bg-St-Pierre, 1700 m Valais, Switzerland	–	–	18	2x	see Table 6A, under the same species
Tribe Rhinantheae						
Tozzia alpina L.	Laggintlial, 1400 m Simplon Pass, Alps Switzerland	–	10	–	2x	2n = 20, Witsch 1932 Mattick in Tischler 1950
Euphrasia alpina Lam.	Schallberg, 1400 m Simplon Pass, Alps Switzerland	–	11	–	2x	2n = 22, Favarger 1969 n = 11, Yeo 1970
Euphrasia alpina Lam.	Furggstalden, 1900 m Alps, Switzerland (Prof. C. Favarger)	–	11	–	2x	
E. rostkoviana Hayne	Schallberg, 1400 m Simplon Pass, Alps Switzerland	–	11	–	2x	2n = 22, Witsch 1932 Yeo 1956 Holmen in Löve & Löve 1961
Pedicularis oederi Vahl	Gantrisch, 1690–1760 m Bern, Switzerland	–	–	16	2x	2n = 16, Knaben 1950 Hara 1956
P. rostrato-spicata Crantz *	Clausis-de-St-Véran, Hautes Alpes, France (Prof. C. Favarger)	–	–	16	2x	
P. rostrato-capitata Crantz	Schneeberg, 2070 m Östliche Kalkalpen, Austria (Bot. Gard., Vienna)	–	–	16	2x	2n = 16, Mattik in Tischler 1950
P. pyrenaica J. Gay	Massif du Puigmale, East Pyrénées, France (Bot. Gard., Liège)	–	–	16	2x	2n = 16, Küpfer & Favarger 1967
P. recutita L.	Turracher Berge, 2000–2400 m, Nockgebiet, Austria (Alpengarten in Belvedere, Vienna)	–	–	16	2x	2n = 16, Mattik in Tischler 1950
P. kerneri D.T.	Alpjr, 2300 m Simplon Pass, Switzerland	–	–	16	2x	2n = 16, Favarger 1959a

+ A new chromosome report for the species
* Chromosome number of the species reported for the first time
** Genus worked out for the first time

In the genus *Solanum*, thirteen taxa including the cytological races of *Solanum nigrum* showed a gametic number 12 or its multiple. In the light of the large number of *Solanum* species studied chromosomally (see Bolkhovskikh *et al.*, 1969), predominance of the gametic number 12 undoubtedly indicates this number as the basic number of this genus. This agrees with Ellison (1936), but disproves Wancher (1934) who deduced the number 4 as the true basic number of the genus. Müntzing (1932–33) basing his opinion on the secondary associations in diploid species of *Solanum*, thought that the original basic number was 6 instead of 12, and he was followed by Löve and Löve (1961). If it was the case, the taxa with 2n = 36 would be hexaploids and not triploids. Meanwhile, von Olah (1938) showed that *Solanum commersonii* Dun. (2n = 36) has an irregular meiosis with trivalents and univalents. In the bybrid between the races of *Solanum nigrum* with 2n = 24 and 2n = 48, respectively, Tandon and Rao (1966) noticed meiotic irregularities such as in triploids with three different genomes. Therefore, it seems more likely that 12 would be the basic number for *Solanum*.

We noticed intraspecific polyploidy only in *S. nigrum* (n = 12, 24 and 36). This species has an eurasiatic distribution and is widespread in India. It occurs in plains and ascends up to 2700 m in mountains (Gulmarg). Three cytological races were collected from different places of W. Himalayas. The diploids (n = 12) (Fig. 60) are common in Nainital and Mussoorie; tetraploids (n = 24) (Fig. 61) from Kumaon and hexaploids (n = 36) (Fig. 62) from Gulmarg, Kashmir and Almora Kumaon, were observed. This intraspecific polyploidy is accompanied by morphological distinctiveness with regard to certain characters. The morphological features of these races(1) are summarized in Table 5C. A hexaploid population noticed in Almora shows extraordinary gigantism. It grows up to about 7 feet and spreads around giving it a big bushy appearance. This form seems to be genetically fixed. The rest of the hexaploids are found to be small in size, comparatively.

The cytological races have been studied in detail by many authors. The main contributors are Jörgensen (1928), Bhaduri (1933, 1945, 1951), Nakamura (1937), Stebbins and Paddock (1949), Swaminathan (1949), Stebbins (1950), Gunther (1959), Magoon *et al.* (1962) and Tandon and Rao (1964 and 1966) (see taxonomic status of cytotypes in general discussion).

Even a genome analysis has been made (Tandon and Rao, 1966). As a result, the hexaploid race has a wider geographical distribution than the other races. The material from Europe investigated in the present work, also revealed the existence of the hexaploid race on this continent.

Another noticeable cytological aspect so far not described in *S. nigrum* is the presence of desynapsis in a tetraploid form of this species. At MI instead of pairing, most of the chromosomes remained as univalents (Fig. 63). Chromosomes were found to be scattered throughout the cytoplasm of PMC's at this stage. An average of 2 or 3 bivalents only were noticed in a large number of cells observed (Fig. 63). Separation of chromosomes at AI is unequal. Some chromosomes were found to be lagging. Non-congression and non-orientation of bivalents were frequent.

(1) Fig. 168 shows the cytological races of *Solanum nigrum*.

At MII, no polarization of chromosomes was seen. At AII, lagging chromosomes were common (Fig. 64). At Telophase II, micronuclei numbering up to 7 were observed (Fig. 65). Monads, diads, triads and pentads were common as the end product of meiosis, instead of tetrads. Pollen grains varied in size and 97% were sterile. No seed set was observed on the plant. In fact, only 2 to 4 bivalents were observed at the stage of diakinesis and at MI, whereas the other chromosomes remained unpaired. This type of desynapsis may be assigned to the „medium strong" category of Prakken's classification (1943). A more or less similar phenomenon was observed in *Withania somnifera* Dun. (n = 24), a frequent plant in Punjab plains and outer Himalayas. Chromosome number counts at MI give n = 24 (Fig. 66). About 6 to 8 univalents are observed in every PMC's. Lagging chromosomes is noticed at AI and non-orientation of chromosomes is found in MII. Micronuclei, numbering up to 7 are found at Telophase II (Fig. 67). About 15% of pollen sterility is noticed. Thus, the chromosome pairing at MI is comparatively better than in *Solanum nigrum*. This may be attributed to the weak desynapsis suggested by Prakken (1943). Desynapsis has perhaps a genetical basis.

In *Datura innoxia* Mill., chromosomes at MI were found in the form of 2 or 3 chains, each having 4 to 6 bivalents (Fig. 69). Later stages of meiosis were also abnormal with the formation of laggards at AI and AII. In some PMC's, one additional chromosome was noticed (Fig. 68).

Physochlaina praealta (n = 41) is an alpine species met in Ladakh, Kashmir, in open places as small communities. It is not seen in other places of W. Himalayas. In this species, (Fig. 59) three tetravalents were noticed at MI in some PMC's. The rest of the meiosis was normal. The presence of tetravalents seems to indicate a remote autopolyploid origin.

Nicandra physaloides Gaertn. is native from Perou and is found in abundance as cultivated and quasi wild in subtropical Himalayas at a range between 900—1800 m. It is highly variable in its growth habit. Some individuals showed very small size of about half a foot of height, whereas, others are noticed with gigantic growth of about 6 feet of height and profused branching. Cytological studies revealed 10 bivalents (Fig. 58) at MI of meiosis. Plants with various growth habit are found to have the same chromosome number.

Though aneuploid series have not been encountered in *Solanaceae*, accessory chromosomes were reported in many species by different authors: Lesley and Lesley (1930) in *Lycopersicum esculentum*, Blakeslee (1931) in *Datura stramonium*, Rai (1949) in *Solanum melongena*, and Chennaveeraiah and Krishnappa (1965) in 6 species of *Solanum*. In the present investigation, one small accessory chromosome was noticed at AI in *Nicotiana plumbaginifolia* Viv. (Fig. 70), a genus in which this phenomenon was unknown. At the same stage in this plant, there are lagging bivalents. Partial sterility of pollen grains was observed. With the exception of four species, *Solanum nigrum*, *Withania somnifera*, *Nicotiana plumbaginifolia* and *Datura innoxia*, with aberrant meiosis, the others revealed normal meiosis.

Another significant finding is the lack of meiotic abnormalities noticed in the present work in diploid species of *Solanum*, contrarily to the findings of Krishnappa (1968). The species with meiotic aberrations mentioned by Krishnappa were found to have normal meiosis in the present material from W. Himalayas.

Under the few species of *Solanaceae* common to W. Himalayas and Europe, *Atropa belladonna* and *Hyoscyamus niger* have the same chromosome number in both regions. *Solanum nigrum* is represented in Europe as tetraploid (= *S. luteum)* and as hexaploid *(S. nigrum).*

After Tandon and Rao (1966a and b), the hexaploid was produced through amphidiploidy between diploid *S. nigrum* and a geographical race of *S. luteum.* Therefore, the origin of hexaploid *S. nigrum* seems to be found in regions where diploid *S. nigrum* grows, for example in W. Himalayas.

Scrophulariaceae

Scrophulariaceae is a large family consisting of 220 genera with 3000 species (Willis, 1966), distributed in all parts of the world. Hooker (1885) has described about 54 genera from the Indian subcontinent, comprising nearly 216 species out of which about 125 species are harboured in Himalayas alone. Hermann (1956) has reported 210 species of *Scrophulariaceae* in his Flora von Nord und Mitteleuropa, and Hegi (1914), 153 species from Central Europe.

In India, they grow from plain level to high alpine level of the Himalayan mountains. Some genera like *Striga, Pedicularis, Euphrasia, Melampyrum* and *Castilleja* are semiparasites growing on grass lands. The genus *Veronica* has got some members with xerophytic as well as aquatic habitat. Some species of *Scrophularia* also adapt well to dry xerophytic conditions. In addition to the intergeneric morphological specialization, intraspecific polymorphism is also a feature in some members of this family (*Veronica anagallis, Scrophularia himalensis,* etc.).

Wettstein (1895) classified this family into 3 subfamilies: *Pseudosolaneae, Antirrhinoideae* and *Rhinanthoideae.*

The most important contributions to the family *Scrophulariaceae* are from Bentham (1846) and Pennell (1943). Many genera of the family are treated separately by different workers. The taxonomic contributions of Stiefelhagen (1910) on *Scrophularia,* Bonati (1918), Prain (1890) and Hui Lin Li (1948) as well as Limpricht (1924) and Tsoong (1956) on *Pedicularis,* Yeo (1968) on *Euphrasia,* Römpp (1931), Lehmann (1941) and Fischer (1920) on *Veronica,* Soo (1927) on *Melampyrum,* Murbeck (1925) on *Celsia* and *Verbascum* (1933), Grant (1924) on *Mimulus* and Keck (1932–1945) on *Penstemon* are some of the praiseworthy contributions besides many other published works on this family.

Though a luxuriant population of *Scrophulariaceae* is present in India especially in the Himalayas, very little cytological work has been done on these plants. After the preliminary study of Raghavan and Srinivasan (1940b and 1941), Srinath (1934), Kumar and Abraham (1941), Iyengar (1937) and Simon and Lowing (1930), there was practically no attempt towards the cytology of Indian *Scrophulariaceae* until Pal (1961) and Khoshoo & Khushu (1966) studied the cytology of *Russelia* species and *Veronica anagallis,* respectively. Chromosome counts were made for some species by Sobti and Singh (1961), Verma and Dhillon (1967), Mehra and Gill (1968). A considerable amount of work on the cytology of *Scrophulariaceae* has been done in different parts of the world (vide Darlington & Wylie, 1955, and Bolkhovskikh *et al.,* 1969). Still the data are insufficient to draw definit conclusions regarding the cytological evolution of this family because of the considerable number of species involved.

The cytological results of the present author are recorded in Table 6.

Discussion

A total of 73 species are cytologically investigated in the family *Scrophulariaceae;* chromosome numbers of 36 species are reported for the first time. The genera *Lindenbergia* and *Leptorhabdos* were not cytologically studied till now. The lowest gametic number of the family recorded currently is n = 6 *(Pedicularis carnosa, Linaria bipartita)* and the highest number noticed is n = 36 for *Adenosma capitatum.* Chromosome size of the genera *Linaria, Leptorhabdos* and *Pedicularis* is comparatively larger in this family.

Pseudosolaneae

Verbascum thapsus L. is extensively populated in W. Himalayas from Kashmir to Kumaon between 1800 and 3200 m. It grows on exposed grassy slopes. The present chromosome count for this species (n = 18) is in line with the zygotic number 36 observed by Håkansson (1926), Mulligan (1961) and Packer (1964) but differs from another chromosome report by Håkansson: 2n = 34. Somatic chromosome numbers in this genus range from 30 to 66. Lawrence (1930) observed a regular polyploid series in the genus and considered 8 as the probable basic number. Both Darlington & Wylie (x = 15, 16 and 18) and Löve and Löve (x = 8, 9, 11, 15 and 17) suggested that *Verbascum* is polybasic. *V. thapsus* with n = 18 can be regarded as a diploid, but the basic number x' = 18 is probably a secondary one and suggests an old phenomenon of polyploidization.

Antirrhinoideae

The chromosome counts made on *Linaria bipartita* (n = 6), *L. dalmatica* (n = 6), *L. supina* (from Europe: 2n = 12) and *L. cymbalaria* (n = 7) agree with the findings of earlier authors. The present observation of n = 9 for *L. ramosissima* which confirms that of Verma and Dhillon (1967), gives an additional proof to the assumption of Valdés (1969) and of Viano (1971) that basic number 9 characterizes the section *Elatinoides.* The new chromosome report n = 18 for *L. subsessilis* indicates its polyploid condition at tetraploid or hexaploid level on a base number 9 or 6 (Fig. 71).

The gametic chromosome numbers of 2 species of *Antirrhinum* (*A. majus* (n = 8) and *A. orontium* (n = 8) studied here, are in line with the earlier reports except 2n = 14 reported by Sobti & Singh (1961) for *A. orontium.* The extensive phenotypic variability of common Snapdragon *(A. majus)* may be due to genic mutations.

The genus *Scrophularia* L. has three hundred species (Willis, 1966) of herbaceous habit distributed in the mountains of northern and temperate regions. Thirteen species are reported from India by Hooker, all being inhabitants of Himalayas. They ascend up to alpine level. Hermann has reported 11 species of *Scrophularia* from North and Central Europe. The wide distribution of *Scrophularia* species in America, Europe and Asia indicates beyond doubt the oldness of the genus.

S. obtusa Edgew. is very common in the Almora region of Western Himalayas but absent in Kashmir. It grows on open places, on roadsides. *S. scopolii* Hoppe was observed in Gulmarg forests near small streams and water channels. This species

was not found in the other parts of Western Himalayas surveyed by the author. It grows also in Central and Eastern Europe and in the Pyrénées. *S. edgeworthii* Benth. grows in abundance between 2500–2900 m in the mountains of Kumaon but was not observed in Kashmir. *S. himalensis* Royle is very widely distributed in the surveyed area from Kashmir to Kumaon at a range between 1700–2300 m. The taxon collected from Nainital reveals 24 bivalents at meiosis, (Fig. 76) whereas the plant from Kashmir has 12 bivalents. In both cases, meiosis is perfectly normal with normal bivalent (Fig. 77) formation. Pollen grains are well filled in both cases. Morphologically both taxa show a lot of differences. A table (6D) showing the salient phenotypic variation of both cytotypes (1) is given. *S. lucida* Linn. was commonly found at about 2000 m in Kashmir while it was very rare in the Kumaon region. *S. variegata* Bieb. is very common at alpine level of Kashmir but rare in the Eastern parts of Western Himalayas. It grows between 2500–3300 m of altitude. *S. dentata* Royle is met in Kargil (Kashmir). It grows on walls of open dry places. Leaves are considerably reduced to fit with xerophytic condition of Ladakh.

Chromosome numbers of *Scrophularia dentata* (n = 12), *S. edgeworthii* (n = 24 + 1B) (2), *S. obtusa* (n = 24) and *S. himalensis* (n = 24) are new reports in this genus. The gametic numbers n = 12 for *S. himalensis* and n = 24 for *S. variegata* are new reports for these species since they differ, respectively, from n = 10 (Mehra and Gill, 1968) and n = 12 (Shaw, 1962, and Vaarama and Hiirsalmi, 1967). The haploid chromosome number 13 of *S. lucida* agrees with that found by Shaw (1962) while *S. scopolii* with n = 24 differs from 2n = 26 reported for this species by Vaarama & Hiirsalmi (1967), and Murin and Vachova (1967). (Figs. 73, 74 for present count).

Small sized chromosomes and relatively high chromosome numbers of many species are general features of the genus *Scrophularia*.

Darlington & Wilie (l.c.) and Löve and Löve (l.c.) recorded the basic chromosome numbers x = 9, 10 and 13 for the genus *Scrophularia*. Vaarama and Hiirsalmi (1967) suggested two additional base numbers, x = 12 and x = 7. The latter number was already mentioned by Larsen (1960).

A confirmation of the existence of a basic chromosome number (x = 12) was given by observing gametic number 12 in *S. himalensis* and *S. dentata* collected from Kashmir. Further proof is brought by the finding in Kumaon, of a tetraploid taxon of *S. himalensis* (n = 24) on the basic number x = 12.

On the basis of x = 12 for the genus *Scrophularia*, only 5 out of 9 taxa studied from Western Himalayas are tetraploids. In this genus, after Carlbom (1969), the polyploidy seems to be directly responsible for migrational stimulus towards more inclement regions in the Northern hemisphere. It is worth mentioning that Stiefelhagen (1910) believed that the major centre of diversity and evolution of the genus was the Himalayan region. He classified the genus into two sections, *Tomiophyllum* and *Anastomosantes*, on the basis of leaf venation, and observed that the former section must be younger on account of its more restricted distribution. The species of the older section *Anastomosantes* have had time to expand and migrate to East

(1) Fig. 169 shows the cytological races of *S. himalensis*.

(2) One small accessory chromosome was observed in few PMC's, which may be a B chromosome. Further course of meiosis is regular.

Asia, Europe and North America; and these migrations were favoured by polyploidy (Carlbom op. cit., p. 300). The species currently studied from Western Himalayas and falling under *Anastomosantes*, group more polyploids than the *Tomiophyllum* section.

Section *Tomiophyllum*		Section *Anastomosantes*	
S. dentata	n = 12	*S. edgeworthii*	n = 24 + 1
S. lucida	n = 13	*S. himalensis*	n = 12, 24
S. variegata	n = 24	*S. obtusa*	n = 24
		S. scopolii	n = 24

If the assumption of Stiefelhagen is correct, the polyploid species from the section *Anastomosantes* actually growing in Eurasia and North America are *rather old polyploids*. But it seems likely too that the section *Tomiophyllum* could be the oldest. This latter hypothesis also gives a good explanation for the presence in Himalayas of several diploid taxa of *Scrophularia* sect. *Tomiophyllum*.

The evolution of the genus *Scrophularia* has been pursued till now by the formation of several neopolyploids, chiefly in the section *Anastomosantes*.

As a matter of fact, intraspecific polyploidy seems to be a rather frequent feature in *Scrophularia*. Vaarama and Hiirsalmi (1967) have reported two races (2n = 26 and 52) in *S. alata* (Gilib.) (= *S. umbrosa* Dum.). The gametic number 12 for *S. variegata* reported by Shaw (1962) and by Vaarama and Hiirsalmi (op. cit.) is not in line with the present author's count from plants of Western Himalayas (n = 24). Unfortunately, the exact origin of Vaarama's material is unknown (Bot. Garden of Copenhagen). Also, the authors's observations of a diploid (n = 12) and a tetraploid (n = 24) taxa in *S. himalensis* give further support to the role of intraspecific polyploidy. As regards the case of *S. scopolii*, the existence of two chromosome races (the diploid with 2n = 26 in Europe, and the hypotetraploid with n = 24 in Himalayas) is not entirely proved and it seems necessary to compare the voucher specimen from the Himalayan plants with samples from Europe. Gametic number 12 (Fig. 80) is a new report for *S. canina*.

Out of the two species of the genus *Mazus* studied here (Figs. 81, 82) chromosome number of *M. surculosus* (n = 10) is a new report, while *M. rugosus* (n = 20) agrees with the finding of Verma and Dhillon (1967). Since n = 10 is the lowest haploid number observed in this genus, x = 10 is considered as the basic number. The chromosome numbers present in *M. radicans* (n = 52) and *M. pumilio* with 2n = 38 (Hair & Beuzenberg, 1960) are an indication that chromosome evolution in genus *Mazus* has taken place through aneuploidy. However, after Index Kewensis, *Mazus radicans* was transferred in *Mimulus*.

The genus *Lindenbergia* has not been cytologically studied hitherto. The chromosome number of 3 species is, hence, reported here for the first time. Two basic numbers: x = 7 and x = 8 can be tentatively proposed for this genus, but the gametic number 25 speaks for an aneuploid alteration of the chromosome set. The two

species *L. grandiflora* and *L. macrostachya* are probably paleopolyploids, and *L. urticaefolia* a mesopolyploid. Again the perennial growth habit of *L. grandiflora* and *L. macrostachya* and the annual habit of *L. urticaefolia* point out the possibility of a recent origin for the latter. (See Figs. 83, 84, 85 for chromosome numbers).

Chromosome numbers of the marshy species *Limnophila roxburghii* (n = 18) and *Adenosma capitatum* (n = 36) are reported for the first time. The relatively high chromosome numbers of these species (Figs. 87, 86) probably point out again their polyploid nature (paleopolyploids). It is interesting to mention that in tropical or subtropical genera of *Scrophulariaceae*, such as *Limnophila*, *Adenosma* and *Lindenbergia*, one can observe only high secondary basic numbers, exactly as in the *Acanthaceae*.

In *Bacopa monniera* (L.) Wettst. (= *Herpestis monniera* H.B. and K.), the gametic chromosome number observed (n = 32) is perfectly in agreement with the report of Lewis *et al.* (1962), but it differs from the finding of n = 24 for this species, by Srinath (1934). In the Himalayan plants, 6–8 univalents were observed at MI (Fig. 88). Few laggards were noticed at AI. The fertility of pollen reached about 85%. In *Bacopa chamaedryoides* (H.B. & K.) Wettst. not yet cytologically studied, the gametic number is n = 10. (Fig. 89). This species was probably introduced from America, but grows as quasi wild in open grassy grounds at low altitudes. It is a diploid one with basic number 10, whereas *B. monniera* is probably a paleopolyploid belonging to another section of the genus *Bacopa*.

The chromosome number n = 16 of *Torenia cordifolia* is a new report (Fig. 90). Darlington and Wylie have recorded x = 8,9 as basic numbers and in this case, the taxon is at the tetraploid level.

The genus *Vandellia* is represented here by only one species: *V. nummularifolia* with n = 12 is a new report (Fig. 91). The documentation of 2n = 42 for *V. crustacea* (Raghavan, 1940) is a pointer to show the polyploid evolution in this genus. The present findings may suggest the possible occurrence of another basic number, x = 6, in this genus, besides x = 7 already recorded by Darlington and Wylie.

The chromosome number of two species of the genus *Bonnaya* namely, *B. brachiata* (n = 9) and *B. veronicaefolia* (n = 18), is reported for the first time. The basic number of this genus seems to be x = 9 and, on this basis, *B. veronicaefolia* is a tetraploid. The report of a large number of morphotypes (Hooker, l.c.) in *B. veronicaefolia* again emphasizes the active state of evolution of the species. (See Figs 92 and 93).

The small genus *Wulfenia* consists of 4 species, one in W. Himalayas and Afghanistan *(W. amherstiana)*, one in Syria *(W. orientalis)*, another in Albania *(W. baldaccii)* and the last one in the South-Eastern Alps and in Montenegro *(W. carinthiaca)*. This extremely wide and disrupted distribution gives a proof of the genus' old age. According to Merxmüller (1962), *W. carinthiaca* is a relict species from the Tertiary. *W. amherstiana* is distributed from Kashmir to Kumaon at an altitude range of 2000–3000 m, especially in Nainital and Mussoorie regions. It grows on walls on roadsides. At AII of the meiosis, eight chromosomes are distributed on each pole. This number is in agreement with the previous workers' counts. Though *W. carinthiaca* was already studied by Favarger (1965) and by Fischer (1969), its cytological features were explored anew by the present author. The number is 2n = 18; two chromosomes of the somatic complement were found to be larger than the others. It is astonishing that the Himalayan and the Alpic species, which seem to be true

vicarious species, do not have the same chromosome number. However, both are diploids. Perhaps these species, geographically separated for a very long time, have endured a divergent chromosomal evolution through such events as translocations with loss or gain of 1 chromosome. It does not hinder to consider both as schizo-endemic taxa (Favarger and Contandriopoulos, 1961).

Out of the 15 species of *Veronica* studied both from Himalayas and Europe in the course of this investigation, chromosome number of *V. cana* (n = 26), and *V. ciliata* (n = 8) are documented for the first time. In this genus, the lowest chromosome number observed in the region surveyed by the author is n = 7 *(V. polita, V. serpyllifolia)* and the highest number, n = 27 *(V. anagallis)*. In every case, regular bivalent formation and normal meiosis were noticed. Chromosome size is comparatively small in all the species.

Veronica is a polybasic genus, showing an even more complicated cytological evolution than the genus *Scrophularia*. Darlington & Wylie (l.c.) have recorded $x = 7, 8, 9, x_2 = 15, 17$ and $x_3 = 26$ as basic numbers, while Löve and Löve (1961) suggested x = 7, 8, 9, 13(?) and 17. Wanscher (1934) opined that in this genus, a 8 series exist from which the other numbers evolved through aneuploidy. He believed that in *Veronica*, there was a descending series 8–7, in basic chromosome numbers.

In Western Himalayas, species representing the three primary basic numbers, x = 7, 8 and 9 have been found, besides species with n = 23 and n = 26, which seem to be secondary polyploids.

The counts of chromosomes in *Veronica polita* Fr. and *V. biloba* L. are in agreement with those of the earlier authors on material from Europe and Japan *(V. polita)* and from India (*V. biloba*, cf. Lehmann, 1940).

Veronica ciliata Fisch. is an annual plant growing at high altitudes; it was found in isolated groups, in exposed alpine mountain peaks of Kashmir between 3300–3800 m. At AI of meiosis, 8 chromosomes can be seen at each pole (Fig. 94). Römpp (1931) has placed this species in the *Beccabunga* section, but he said that it had been set by Ledebour in the *Pentasepalae*. The present author believes that the chromosome number n = 8, which does not exist in the section *Beccabunga*, but is very frequent in the *Pentasepalae*, allows to transfer *V. ciliata* to the section *Pentasepalae*. Moreover, the plant seems to have 5 sepals!

Veronica laxa is a conspicuous species with blue coloured flowers found in Kashmir and Phurkia in Kumaon. The gametic number n = 23 already counted by Yamazaki (1936) is surprising in the *Multiflorae* group, to which belong for example, *V. chamaedrys* (n = 16(1) and n = 8, see Fischer, 1970) and *V. melissifolia* n = 21 (Afanisiyeva and Meschkowa, 1961). The number n = 23 can proceed from n = 24 through aneuploidy; the gametic number of *V. melissifolia* needs to be confirmed. On the other hand, a possible evolution of a species with n = 23 from ancestors with n = 16 and n = 7 is conceivable. *V. cana* was met near the Pindari glaciers as well as in the Kedarnath mountains in Kumaon. It was totally absent from Kashmir. The gametic number n = 26 is unusual in the genus *Veronica*.

(1) The number n = 16 was confirmed by the author on plants growing in the Jura mountains, near Neuchâtel.

As *V. montana* and *V. scutellata*, from the same group, both have x = 9, it is likely that *V. cana* is a hypohexaploid. (Fig. 100).

The chromosome number of *V. serpyllifolia*, *V. persica*, *V. verna* and *V. beccabunga* from different localities in Europe, is in agreement with the chromosome counts of the same species from Himalayas.

Like many other species of *Veronica*, *V. hederifolia* also forms a polyploid complex with an Eurasiatic distribution. The present observations of chromosome number on plants from Europe, agree with the finding by Nordenstam and Nilsson (1969) of a (Fig. 99) hexaploid (2n = 54) besides a tetraploid race of *V. hederifolia* (2n = 36) in Scandinavia. The tetraploid race is found in (Fig. 98) Switzerland too. The current observations of a diploid race (n = 9) in Western Himalayas are in line with Fischer's count (1967) in a population from Pakistan. As Nordenstam and Nilsson (1969) could not establish a good correlation between morphological characters and ploidy level, they treated the two main taxa from Scandinavia as subspecies: ssp. *hederifolia* (2n = 54) and ssp. *lucorum* (2n = 36). Fischer (1967) proceeded to search for morphological characters distinguishing the cytotypes. His findings led him to determine five taxa, to which he gave the rank of species. In Western Himalayas, *V. hederifolia* occurs in exposed places in Kasauli, in outer Himalayas and in the Kashmir valley under the shade of coniferous trees. The plants of Kashmir are bigger than the samples from Kasauli, but these populations are diploid with n = 9 (Fig. 97). Fischer's separation of a Himalayan taxon (2n = 18) as a new species, *V. hederoides*, seems to be more realistic on account of the morphological features and the different chromosome number, which hold the Himalayan populations apart from the tetraploid and hexaploid taxa. A map of the distribution of the taxa from this group was given by Fischer (op. cit.). It can be supposed that the whole complex has an Asiatic (perhaps Himalayan) origin. But now, some diploid populations *(V. triloba)* are found in Europa too.

V. anagallis Linn. sensu lato is one of the most common species in the genus *Veronica*. It occurs frequently in Punjab plains, Kumaon and Kashmir in India, where it ascends to 2700 m. The populations found in Kashmir differ from other populations of the species in several morphological characters. The meiotic study shows that plants growing in the Kashmir valley are tetraploids (n = 18) (Fig. 96), while the plants in the Punjab plains as well as Nainital are hexaploids (n = 27) (Fig. 95). Among the tetraploids, morphological variants could be observed. A chart (Table 6C) comprising morphological features of cytological races(1) and morphotypes among them, is given.

The current observations are in complete agreement with those of Khoshoo and Khushu (1966) who have detected for the first time in India, two cytotypes of *V. anagallis:* a tetraploid one, in Kashmir, and a hexaploid one in the Punjab plains. Moreover, striking morphological differences were found by the present author between the various populations of the tetraploid in Kashmir. Some of these variants grow in the same habitat side by side with the normal tetraploids, which rules out the possibility of their ecological specialization. Since the differences seem to be genetically fixed, they can be due to structural changes or to genic

(1) Figs 170 and 171 show the cytological races and varieties among tetraploids of *V. anagallis*.

mutations. One of these variants, with long narrow leaves, could belong to *V. anagalloides*. This last taxon was found to be diploid by Schlenker (1936) and by Afanisiyeva and Meschkowa (1961) (see Bolkhovskikh *et al.*), but Meschkova (1965) reported a tetraploid too, likewise a plant from Rumania studied by the present author (see Table 6B). As shown by Khoshoo and Khushu, all the cytotypes of the *V. anagallis* complex in Western Himalayas seem to be allopolyploid on account of their regular meiosis without multivalents, which was confirmed by the present author. Khoshoo and Khushu supposed that one ancestor of the hexaploid race should be a plant „with more or less lanceolate type of blad". It is likely that the tetraploid narrow leaved population from Kashmir which perhaps belongs to *V. anagallóides*, is one ancestor of the hexaploid race from Punjab. More work is needed before one can obtain a clear picture of the whole complex in W. Himalayas and of its relation with European populations. Until now, the distribution of the hexaploid race of *Veronica anagallis* is limited to North-Western India.

The process of reduction in floral parts of *Veronica* is still in progress today, with the result that many species must be in an unstable state. The frequency of intraspecific polyploidy, the great number of species complexes with incomplete separation of the taxa, all this points out the active state of evolution in which the genus *Veronica* is involved.

The genus *Leptorhabdos* is cytologically investigated for the first time. *L. benthamiana* (n = 7) is the only species (Fig. 103) observed in the area of the present investigation. The basic number x = 7 can be assigned to the genus. *Buchnera hispida* (Fig. 102) with n = 14 is also a new report. This species is a tetraploid on basic number x = 7, whereas *B. americana* (2n = ca. 42) is a hexaploid.

Lagotis glauca Gaertn. is an Arctic Alpine species distributed in mountains from Central and North Asia, and Arctic Asia and America, but not in Europe. This small herb is noticed on the mountains of Kashmir above 3300 m from sea level, on exposed slopes. Haploid chromosome number is determined as n = 11 at AI with equal distribution of chromosomes on either pole (Fig. 101). Chromosome size is small. The same number has been counted by earlier authors on Japanese and Siberian material (see Bolkhovskikh *et al.*).

The genus *Euphrasia* L. was intensively studied in Europe and splitted into many microspecies with narrow ranges of distribution. Hooker has reported one species from temperate Himalayas. Another one was described more recently by Pennell.

E. officinalis occurs in temperate Himalayas from Kashmir to Kumaon between an altitudinal range of 2100–3600 m. Fig. 104 shows 22 bivalents at MI of meiosis. The chromosome size is small. This species is tetraploid on basic number x = 11. In comparison with *Euphrasia rostkoviana* from the Alps (n = 11), the plants from W. Himalayas are taller (20–40 cm high).

E. platyphylla Pennell is a small herb of hardly 5–8 cm, growing in abundance in the alpine meadows of Khilenmarg and nearby Lianmarg regions of Kashmir, at an altitude of about 3300 m. Chromosome number has been ascertained as n = 22 at AI. (In the Fig. 105 the two plates of anaphase were brought in the same plane by squashing). This tetraploid species seems to be endemic to W. Himalayas. According to Yeo (1956), the evolution of the genus *Euphrasia* proceeded in part through polyploidy, in part through hybridization, between diploids and tetraploids too, which allows some degree of introgression. Some recombinants of the very

variable progeny can grow in new habitats to which they become narrowly adapted. Such a phenomenon was not studied until now in Himalayas. Fig. 106 shows n = 11 for *E. alpina* from the Alps.

The genus *Pedicularis* L. is one of the largest genus of the family *Scrophulariaceae* with beautiful flowers of pink, pale violet, white or yellow colours. It belongs to the Arctic-Alpine flora and consists of about 600 species (Sprague, 1962), both annuals and perennials. Almost half of the species (282) are confined to China (Hui Lin Li, 1948). Hooker (1885) has reported 37 species of *Pedicularis* from India, of which 35 are distributed in the Himalayas and 2 species on the Nilgherry Hills, in the south of India. This genus with a wide geographical distribution is characterized by a high amount of endemism. Prain (1890) reported for example, 52.5% of endemic *Pedicularis* in the circumpolar „province", 89% in the Himalayan province and 85% in Europe. In the Alps, about 20 species are growing as orophytes, of which 42% are endemic. (Favarger, oral communication).

This semiparasitic genus „exhibits a variety of corolla forms that may be unparalleled in any other genus" (Sprague, 1962). The flowers, like those of all members of the tribe *Euphrasiae*, are among those most highly specialized for insect pollination.

As pointed out by Sprague (1962), the species of „Bombus" are principal pollinators. Corollas are of various size to suit the size of different pollinators as *Lepidoptera* and humming birds. Prain (1890) in his monograph on *Pedicularis* has considered the yellow colour and the absence of a beak on corolla as more archaic characters. Hui Lin Li (op. cit.) believed that the alternate leaves are more advanced than the opposite or verticillate arrangement.

Fourteen species from W. Himalayas and five species from Europe were cytologically studied in the course of this investigation. In eleven cases, an idiogram could be established based on pollen mitosis or on dividing cells of root tips made available by germinating seeds in the laboratory.

The cytological data are reported on Table 6A & B and Table 6E. Course of meiosis is regular in all the cases, with the exception of *P. megalantha*. In this species, transfer of chromatin material from one pollen mother cell to the neighbouring one was observed (Fig. 118, 119). As a result of this cytomixis, some PMC's are observed with less chromosomes while the others possess more than the normal haploid set. Subsequent stages of meiosis showed irregular behaviour such as laggards at AI and micronuclei at telophase, culminating in polyads and sterility of pollen as the end product of meiosis. Perhaps the plant investigated was a hybrid. In *P. rhinanthoides*, an anaphase bridge is clearly seen in a PMC, but the meiotic course is found to be undisturbed. (Figs. 126, 127).

The chromosome number of 9 species from the Himalayas and 1 from Europe are new reports. The other counts are in agreement with those of earlier authors with the exception of *P. oederi* (Himalayan material). In the last species, the number 2n = 16 was ascertained by several workers and was confirmed by the present author on plants from the Swiss Alps. The plant from Kashmir (Fig. 131) revealed the somatic number 2n = 30 which could have arisen through aneuploidy (32→30). However, in looking at the idiogram, one can observe rather striking differences between the Alpic plant and the Himalayan one, the latter having eleven pairs of chromosomes with a subterminal centromere while the former had only one pair. This case needs further investigations to know if the plant from Kashmir had perhaps

arisen through hybridization between the normal cytotype (n = 8) and another very different cytotype of *P. oederi* with n = 7.

The great majority of Pedicularis species cytologically investigated till now possess the basic number n = 8. Favarger (1953) discovered the basic number n = 6 in *Pedicularis verticillata*. This number is represented in *P. carnosa* from the Himalayas too. Moreover a gametic number n = 7 became evident according to the present investigations. It characterized *P. bicornuta* and *P. macrantha* (1). Therefore, it seems logical to attribute to the genus *Pedicularis* the basic numbers x = 6, 7 and 8. Polyploidy is very unfrequent in *Pedicularis:* three cases were reported in Bolkhovskikh *et al.*, to which the report of *P. oederi* from Kashmir can be added. See Figs 109, 112, 137 for new chromosome reports.

The relatively large size of the chromosomes was already mentioned: this gives the opportunity to study the karyotype.

Each species seems to be characterized by a special karyotype but in such cases as *P. pectinata*, *P. brevifolia* and *P. siphonantha*, the idiograms are rather similar. The karyotype of *P. carnosa*, having only chromosomes with median or submedian centromere, is more symmetrical and perhaps gives the proof of the archaic character of the species belonging to the *Rhyncholophae* (2). On the contrary, *P. pyramidata* seems to be more advanced on account of its karyotype showing a majority of subtelocentric and acrocentric chromosomes. It belongs to the more advanced section *Orthorrhynchae*.

As regards *P. oederi*, the karyotype of the plants from Kashmir is very asymmetrical but this feature can proceed from a recent event, and the karyogram of the Swiss plant is more like those of other species with chromosomes more or less symmetrical. If *Pedicularis carnosa* (n = 6) and *P. verticillata* (n = 6; *Anodontae*) are relatively archaic species, it is not unlikely to suppose that the basic number 6 is the oldest in the genus.

As to the origin of the genus, the opinion of the authors are greatly divergent. Prain (op. cit.) and more recently Tsoong (1956) thought it originated from the Arctic region, and migrated along some meridians, at the end of the Tertiary and showed a striking, mostly divergent, evolution in the mountains of the southern parts of the Northern Hemisphere. On the other hand, Limpricht (1924) believed that the mountains of Central Asia (Altaï and Sayan) are the center of origin, and Hin-Lin-Li (op. cit.) was of the same opinion.

The presence of a large amount of species in the Himalayan and Chinese provinces, the existence of species with x = 6, 7 and 8 in the Himalayas and of some types bearing a primitive karyotype perhaps bring some support to the hypothesis of a Central Asiatic origin.

(1) In the latter species, the presence of seven bivalents at meiosis is not entirely proved. (Fig. 117).
(2) Size of chromosomes is larger in *P. carnosa* than in the other species (3,3 μ for the shortest and 5,8 μ for the longest).

Summary

Cytological studies on species of *Boraginaceae, Verbenaceae, Solanaceae,* and *Scrophulariaceae* from the Western Himalayas and from Europe are presented. Some chromosome numbers were determined for the first time; others differed from earlier determinations. Intraspecific polyploidy was observed in *Solanum nigrum* (n = 12, 24, 36), *Scrophularia himalensis* (n = 12, 24) and *Veronica anagallis* (n = 18, 27) in populations from W. Himalayas. Our own observations joined to those of various authors showed the existence of chromosome races in other species from the Himalayas or from India.

In several species growing in the Himalayas as well as in Europe (especially in the Alps) the chromosome number is the same in both regions (e.g. *Atropa belladonna, Veronica serpyllifolia, V. persica*). In some other cases the Himalayan taxon is diploid whereas the corresponding taxon (or the same species) in the Alps is polyploid (*Asperugo procumbens, Lycopsis arvensis, Veronica* grex *hederifolia*); in a few other groups the opposite situation was found *(Pedicularis oederi, Scrophularia scopolii)*. In *Phryma leptostachya,* the Himalayan population is diploid whereas those from North America and Japan are (in part) polyploid.

The intrageneric cytological evolution of all genera studied was tentatively explained (see discussion of the families). An analysis of the karyotype in *Pedicularis* (with comparatively large chromosomes) was made and the cytological basis of species evolution discussed. New basic numbers (x) were suggested for many genera. The bibliography will be given at the end of the series.

Zusammenfassung

Cytotaxonomische und cytogeographische Untersuchungen an Pflanzen aus dem Himalaya im Vergleich zu verwandten Pflanzen aus den Alpen. Teil II.

Aus den Familien der *Boraginaceae, Verbenaceae, Solanaceae* und *Scrophulariaceae* wurden zahlreiche Arten aus dem westlichen Himalaya und aus den Alpen cytologisch untersucht. Manche Chromosomenzahlen wurden erstmals bestimmt; andere waren von früheren Bestimmungen verschieden. Intraspezifische Polyploidie wurde bei *Solanum nigrum* (n = 12, 24, 36), *Scrophularia himalensis* (n = 12, 24) und *Veronica anagallis* (n = 18, 27) aus dem Himalaya beobachtet. Eigene Beobachtungen und solche anderer Autoren zeigten das Vorkommen von Chromosomenrassen bei anderen Arten aus dem Himalaya und Indien.

Bei verschiedenen Arten, die im Himalaya und in Europa (v.a. in den Alpen) vorkommen, ist die Chromosomenzahl in beiden Regionen gleich (z.B. *Atropa belladonna, Veronica serpyllifolia, V. persica*). In anderen Fällen ist die Art aus dem Himalaya diploid und die gleiche oder entsprechende Art aus den Alpen polyploid (*Asperugo procumbens, Lycopsis arvensis, Veronica* grex *hederifolia*); andere Arten verhalten sich

umgekehrt *(Pedicularis oederi, Scrophularia scopolii). Phryma leptostachya* aus dem Himalaya ist diploid; die Populationen aus Nordamerika und Japan sind teilweise polyploid.

Die intragenerische cytologische Entwicklung wird diskutiert (siehe Diskussion der Familien). In der Gattung *Pedicularis* (mit relativ grossen Chromosomen) wird der Karyotyp analysiert und die cytologischen Grundlagen der Artbildung diskutiert. Für mehrere Gattungen werden neue Grundzahlen (x) vorgeschlagen. Die Literatur wird am Ende der Reihe zusammengestellt werden.

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Fig. 34: Cuscuta lupuliformis Krock. 2n = 28 MI.
Fig. 34A: Cuscuta lupuliformis Krock. 2n = 28 idiogram.
Fig. 35: Cuscuta alba Presl. n = 15 Diakinesis.
Fig. 36: Cynoglossum furcatum Wall. n = 12 MI.
Fig. 37: Cynoglossum lanceolatum Forsk. n = 12 Late Diakinesis.
Fig. 38: Cynoglossum wallichi G.Don n = 12 MI.
Fig. 39: Cynoglossum microglochin Benth. n = 12 MI.
Fig. 40: Cynoglossum nervosum Benth. n = 12 MI.
Fig. 41: Cynoglossum nervosum, showing one bivalent lying away from metaphase plate.
Fig. 42: Cynoglossum petiolatum A. DC n = 12 Late Diakinesis.

Fig. 43: Lindelofia angustifolia Brand. n = 12 MI.
Fig. 44: Paracaryum glochidiatum Benth. n = 12 MI.
Fig. 45: Lappula microcarpa (Ledeb.) Gürke n = 11 Diakinesis.
Fig. 46: Lappula reflexa Garcke 2n = 48 MI.
Fig. 47: Eritrichium strictum Dcne. n = 12 MI.
Fig. 48: Asperugo procumbens L. 2n = 48 MI.
Fig. 49: Mertensia exserta I.M.Johnston n = 11 MI.
Fig. 50: Myosotis caespitosa Schultz n = 44 MI.
Fig. 51: Lithospermum arvense L. 2n = 42 MI.
Fig. 52: Lithospermum arvense L. (W.Himalayas) n = 18 Late Diakinesis.
Fig. 53: Onosma echioides L. n = 7 MI.
Fig. 54: Onosma emodi Wall. n = 9 Late Diakinesis.

Fig. 55: Lycopsis orientalis L. n = 8 MI.
Fig. 56: Nonnea caspica G.Don. n = 8 Diakinesis.
Fig. 57: Callicarpa longifolia Lamk. n = 18 MI.
Fig. 58: Nicandra physaloides Gaertn. n = 10 MI.
Fig. 59: Physochlaina praealta Miers n = 41 MI. See the quadrivalents.
Fig. 60: Solanum nigrum L. n = 12 MI.
Fig. 61: Solanum nigrum L. n = 24 MI.
Fig. 62: Solanum nigrum L. n = 36 MI.

Fig. 63: Solanum nigrum L. n = 24 revealing univalents at MI.
Fig. 64: Solanum nigrum L. n = 24 showing lagging chromosomes at Anaphase II.
Fig. 65: Solanum nigrum L. n = 24 showing 8 micronuclei (1600x).
Fig. 66: Withania somnifera Dunal. n = 24, many univalents are seen at MI.

Fig. 67: Withania somnifera Dunal. n = 24 show 9 chromatin groups at telophase II.
Fig. 68: Datura innoxia Mill. A mixed telophase II shows 24 + 1 Chromosomes.
Fig. 69: Datura innoxia Mill. n = 12, shows 2 ring bivalents of 3 each and one ring of three chromosomes.
Fig. 70: Nicotiana plumbaginifolia Viv. n = 10, shows one additional chromosome at AI.
Fig. 71: Linaria subsessilis Pennell n = 18 Diakinesis.
Fig. 72: Scrophularia obtusa Edgew. n = 24 AI.

Fig. 73: Scrophularia scopolii Hoppe (W.Himalayas) n = 24 MI.
Fig. 74: Scrophularia scopolii Hoppe n = 13 Diakinesis.
Fig. 75: Scrophularia edgeworthii Benth. n = 24 + 1 MI.
Fig. 76: Scrophularia himalensis Royle n = 24 MI.
Fig. 77: Scrophularia himalensis Royle n = 12 MI.
Fig. 78: Scrophularia variegata Bieb. n = 24, some bivalents are secondarily associated.
Fig. 79: Scrophularia dentata Royle n = 12 MI.

Fig. 80: Scrophularia canina L. n = 12 AI.
Fig. 81: Mazus rugosus Lour. n = 20 MI.
Fig. 82: Mazus surculosus D.Don. n = 10 MI.
Fig. 83: Lindenbergia grandiflora Benth. n = 14 Diakinesis.
Fig. 84: Lindenbergia macrostachya Benth. n = 16 MI.
Fig. 85: Lindenbergia urticaefolia Lehm. n = 25 MI.
Fig. 86: Adenosma capitata Benth. n = 36 MI.
Fig. 87: Limnophila roxburghii G.Don n = 18 Diakinesis.
Fig. 88: Herpestis monniera HB and K. n = 32 MI, four to six univalents are observed.
Fig. 89: Herpestis chamaedryoides HB and K. n = 10 MI.

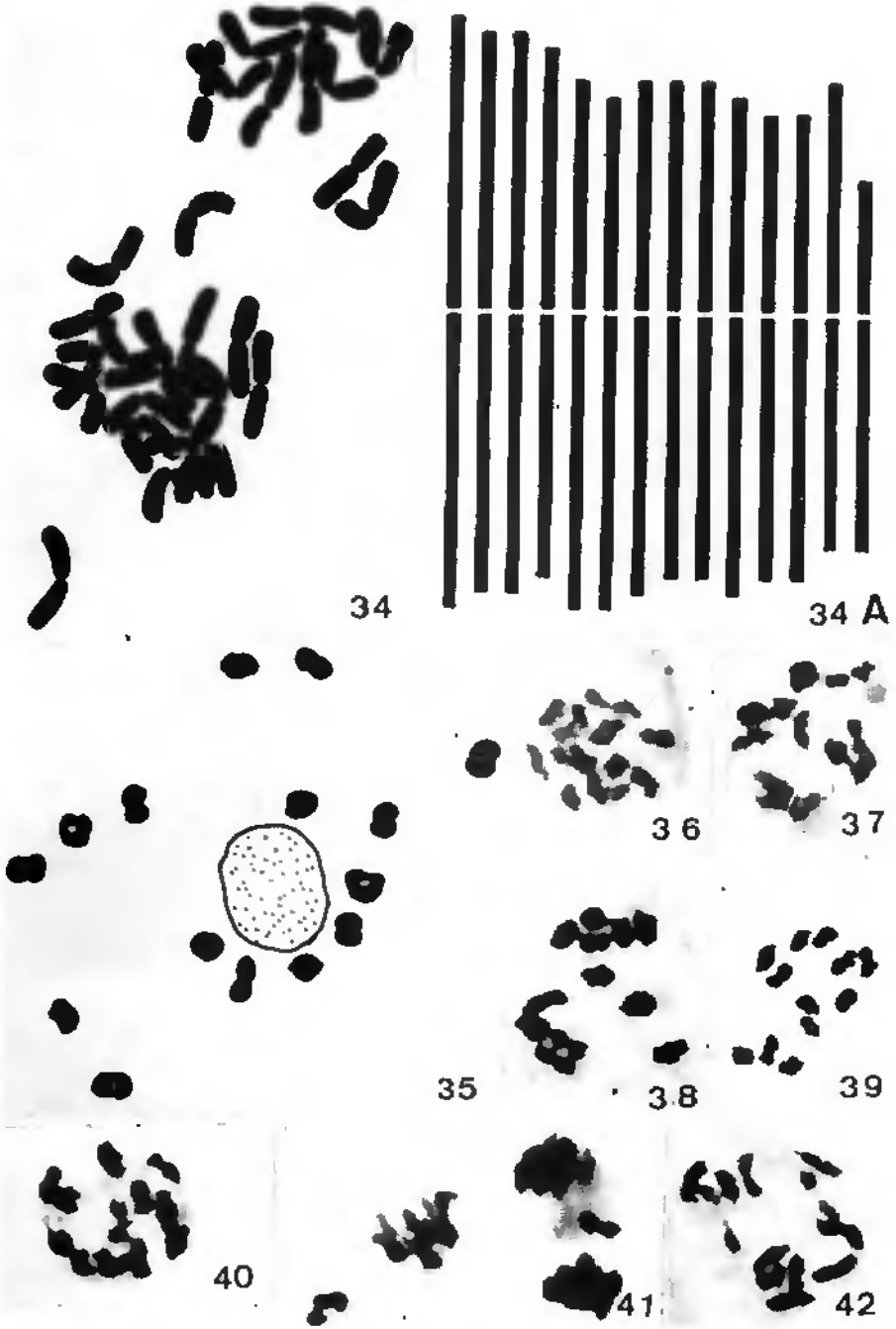
Fig. 90: Torenia cordifolia Roxb. n = 16 MI.
Fig. 91: Vandellia nummularifolia D.Don n = 12 MI.
Fig. 92: Bonnaya brachiata Link and Otto n = 9 MI.
Fig. 93: Bonnaya veronicaefolia Spreng. n = 18 MII.
Fig. 94: Veronica ciliata Fisch. n = 8 AI.
Fig. 95: Veronica anagallis L. n = 27 MI.
Fig. 96: Veronica anagallis L. n = 18 MI.
Fig. 97: Veronica hederifolia L. n = 9 AI (one pole only).
Fig. 98: Veronica hederifolia L. (Europe) n = 18 AI.
Fig. 99: Veronica hederifolia L. (Europe) 2n = 54 MI.

Fig. 100: Veronica cana Wall. n = 26 Diakinesis.
Fig. 101: Lagotis glauca Gaertn. n = 11 AI (one pole only).
Fig. 102: Buchnera hispida Ham. n = 14 MI.
Fig. 103: Leptorhabdos benthamiana Walp. n = 7 MI.
Fig. 104: Euphrasia officinalis L. n = 22 MI.
Fig. 105: Euphrasia platyphylla Pennell n = 22 Mixed anaphase I.
Fig. 106: Euphrasia alpina Lam. n = 11 AI.
Fig. 107, A: Pedicularis pectinata Wall. 2n = 16 MI.
Fig. 108: Pedicularis pectinata Wall. 2n = 16 MI (idiogram).
Fig. 109: Pedicularis tenuirostris Benth. n = 8 MI.

Fig. 110: Pedicularis gracilis Wall. 2n = 16 MI.
Fig. 111: Pedicularis gracilis Wall. 2n = 16 idiogram.
Fig. 112: Pedicularis porrecta Wall. n = 8 MI.
Fig. 113: Pedicularis brevifolia D.Don. 2n = 16 MI.
Fig. 114: Pedicularis brevifolia D.Don. 2n = 16 idiogram.
Fig. 115: Pedicularis pycnantha Boiss. n = 8 (pollen mitosis)
Fig. 116: Pedicularis pycnantha Boiss. n = 8 idiogram.
Fig. 117: Pedicularis macrantha Klotzsch n = 7 (?) MI.
Fig. 118: Pedicularis megalantha Don. n = 8 MI.
Fig. 119: Pedicularis megalantha Don. n = 8 showing cytomixis.

Fig. 120: Pedicularis bicornuta Klotzsch n = 7 MI.
Fig. 121: Pedicularis siphonantha D.Don. 2n = 16 MI.
Fig. 122: Pedicularis siphonantha D.Don 2n = 16 idiogram.
Fig. 123: Pedicularis carnosa Wall. n = 6 Diakinesis.
Fig. 124: Pedicularis carnosa Wall. 2n = 12 MI.
Fig. 125: Pedicularis carnosa Wall. 2n = 12 idiogram.
Fig. 126: Pedicularis rhinanthoides Schrenk n = 8 MI.
Fig. 127: Pedicularis rhinanthoides Schrenk n = 8 showing bridge formation at AI.
Fig. 128: Pedicularis pyramidata Royle 2n = 8 MI.
Fig. 129: Pedicularis pyramidata Royle 2n = 16 MI.
Fig. 130: Pedicularis pyramidata Royle 2n = 16 idiogram.
Fig. 131, 131A: Pedicularis oederi Vahl (W.Himalayas) 2n = 30 MI.

Fig. 132: Pedicularis oederi Vahl 2n = 30 idiogram.
Fig. 133: Pedicularis oederi Vahl (Europe) 2n = 16 MI.
Fig. 134: Pedicularis oederi Vahl (Europe) 2n = 16 idiogram.
Fig. 135: Pedicularis rostrato-capitata Crantz 2n = 16 (3000 x).
Fig. 136: Pedicularis rostrato-capitata Crantz 2n = 16 idiogram.
Fig. 137: Pedicularis rostrato-spicata Crantz 2n = 8 (3000 x).
Fig. 138: Pedicularis pyrenaica J.Gay 2n = 16 (3000 x).
Fig. 139: Pedicularis pyrenaica J.Gay 2n = 16 idiogram.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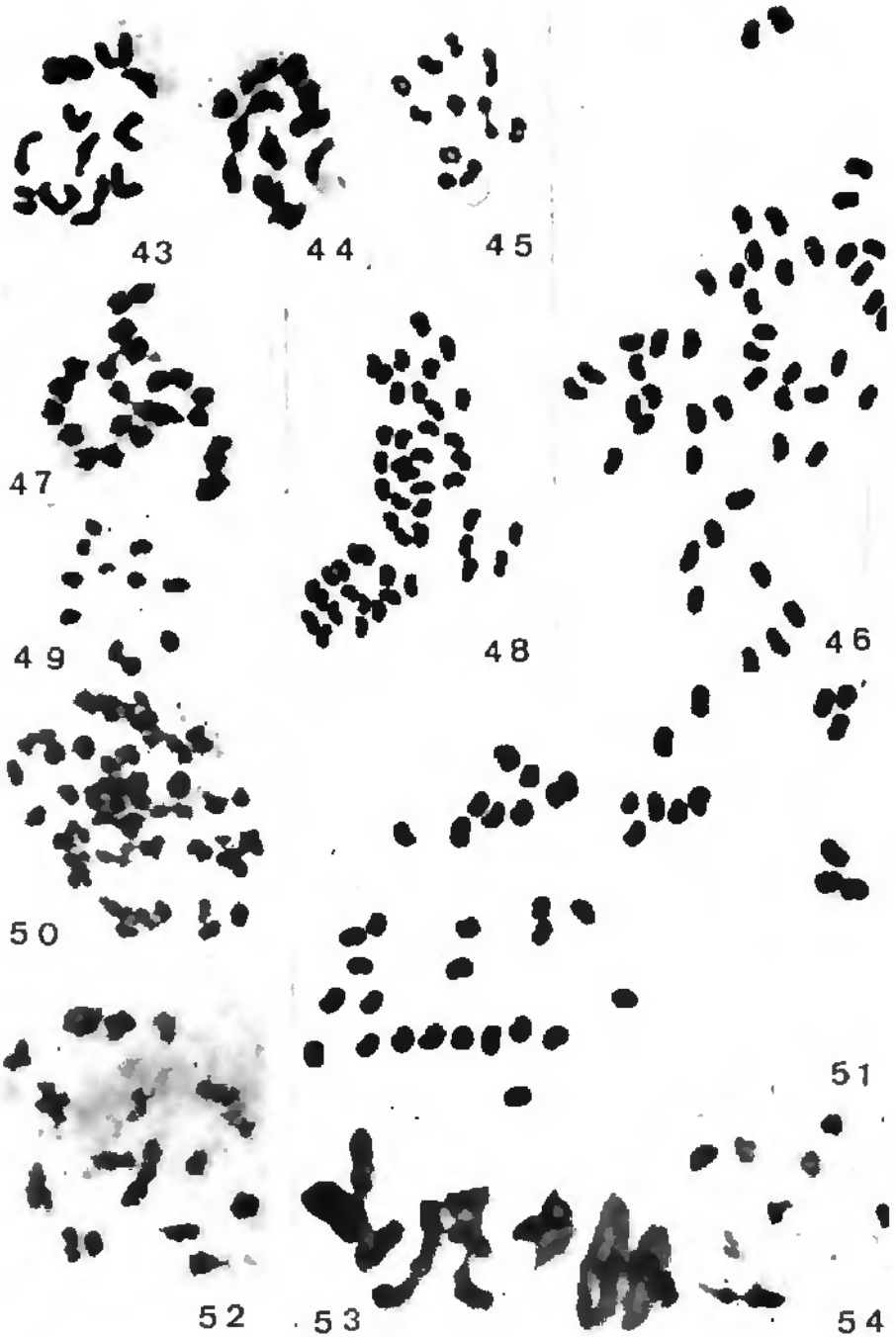
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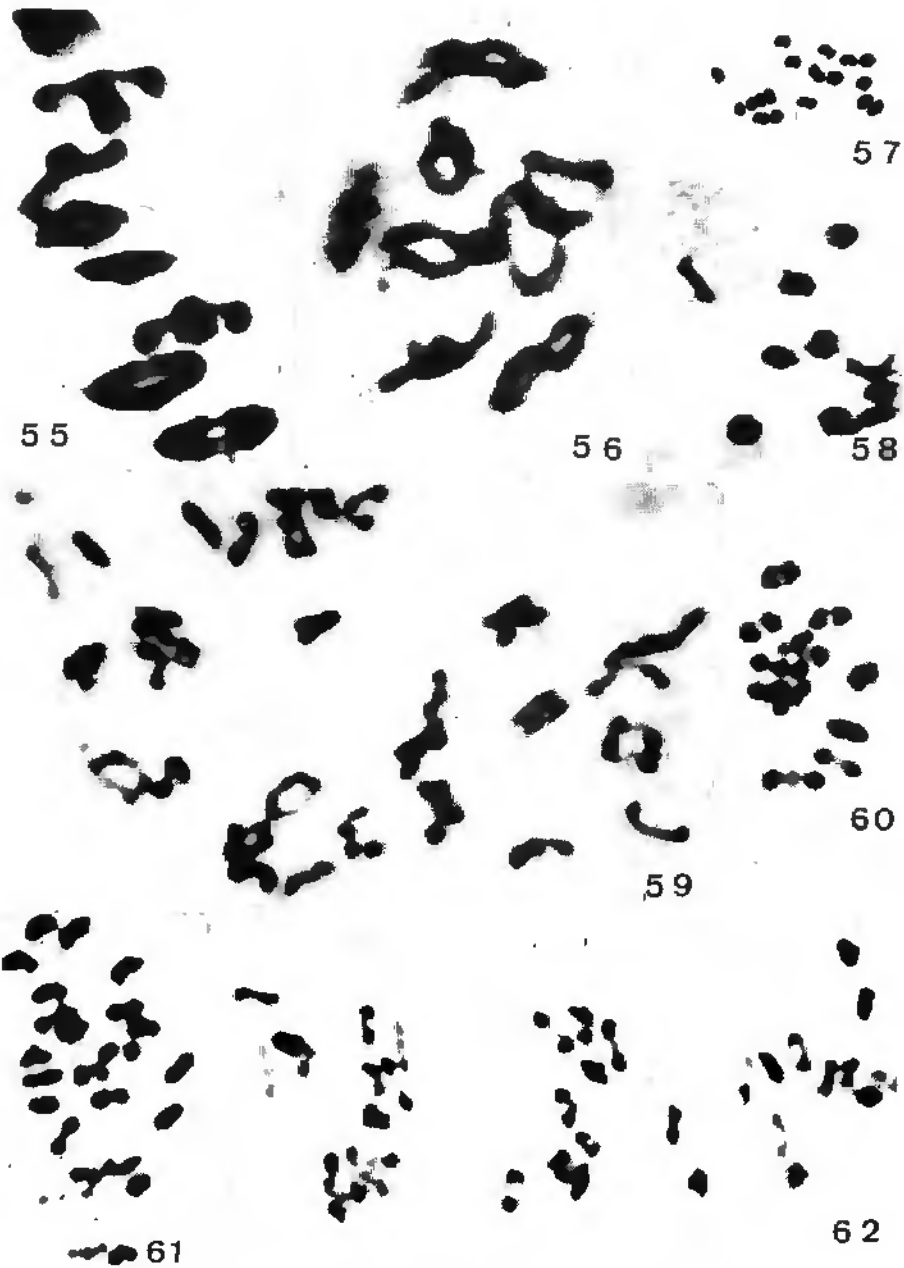
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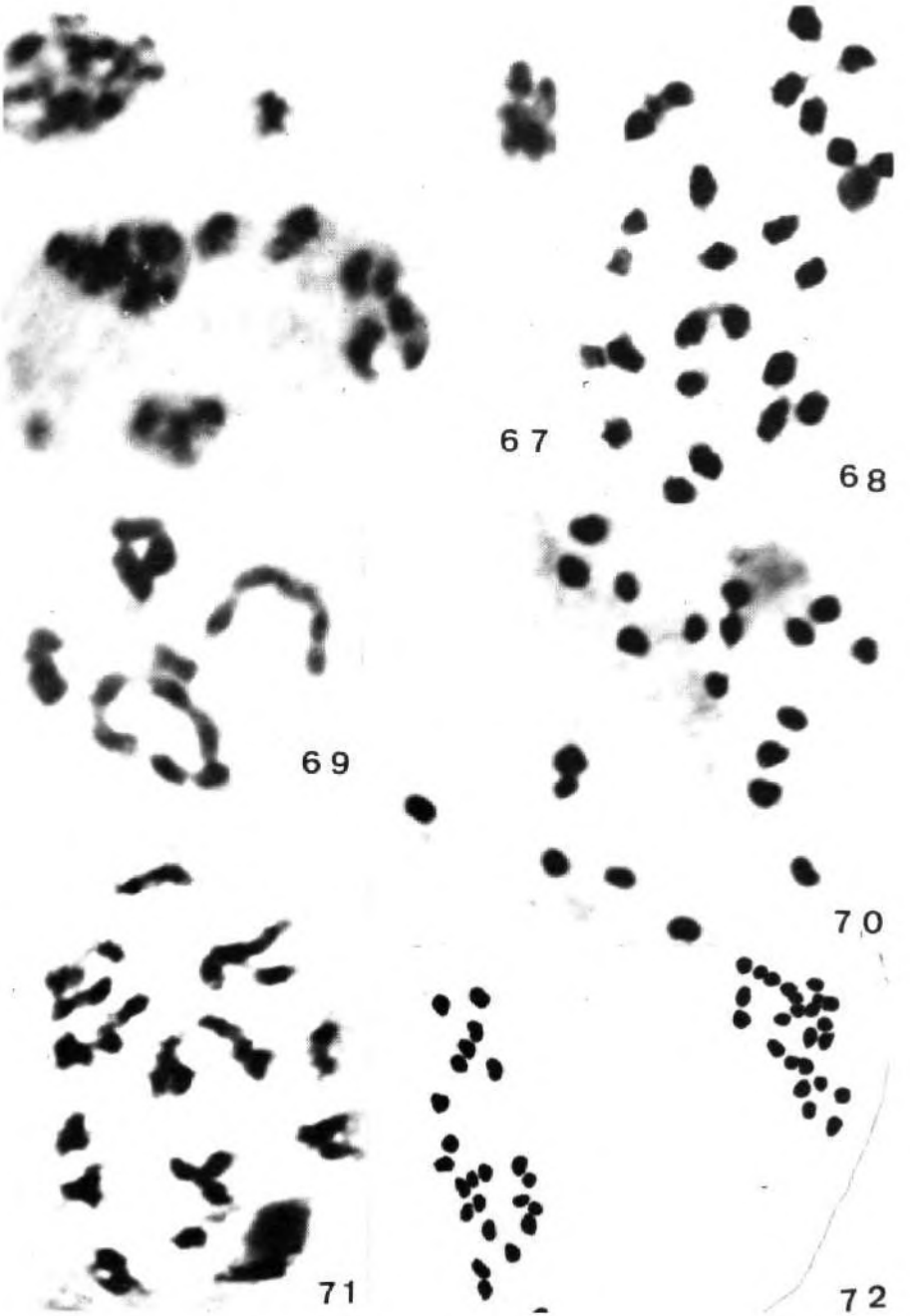
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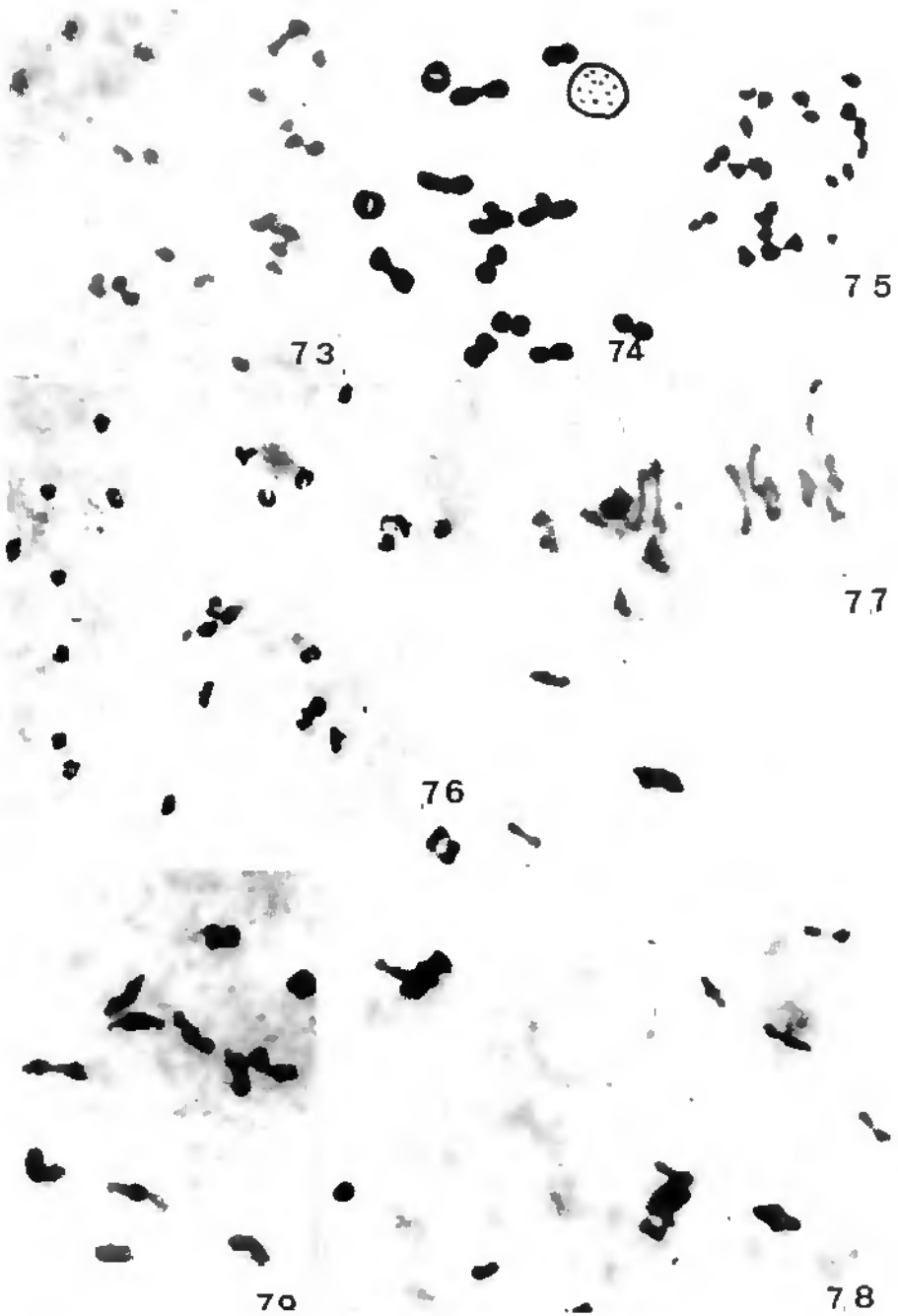
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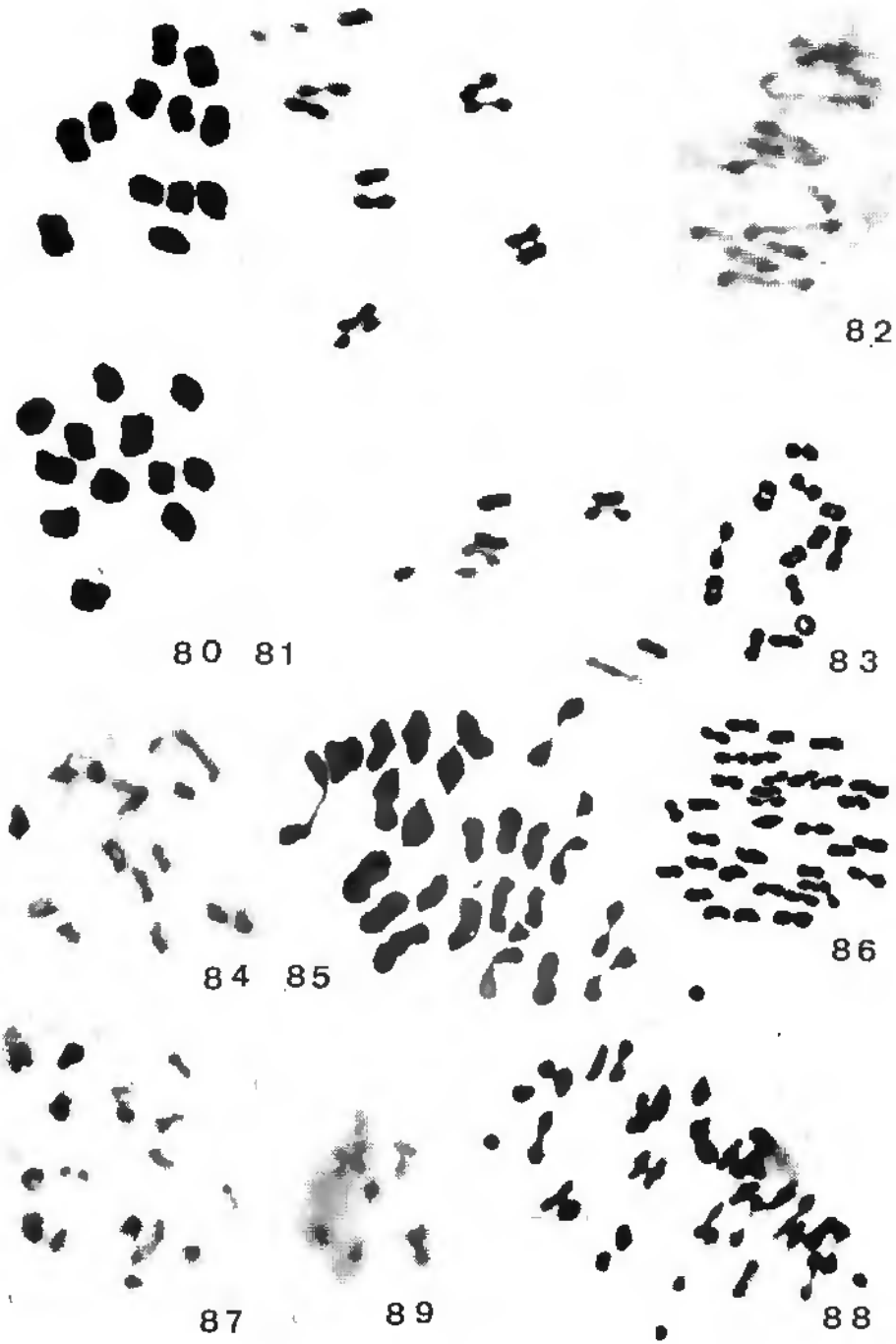
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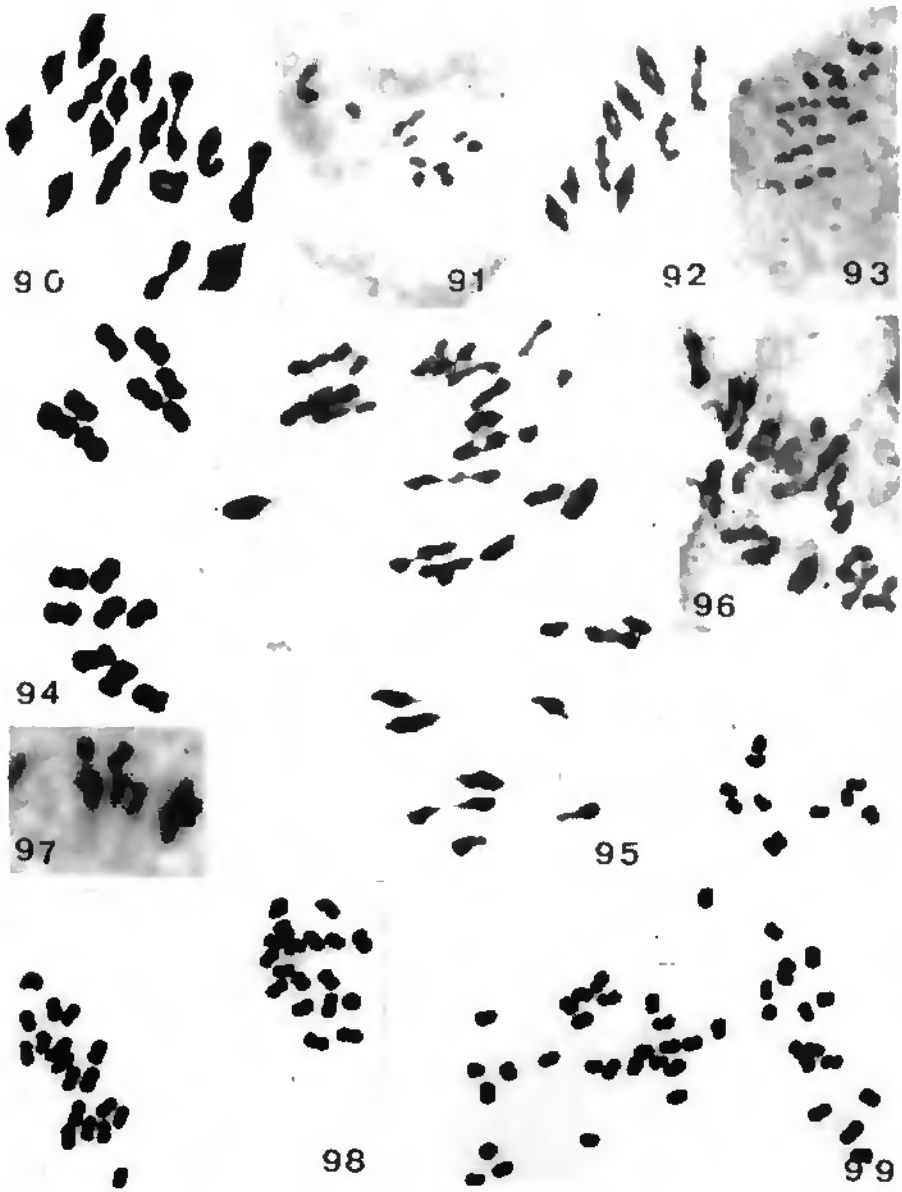
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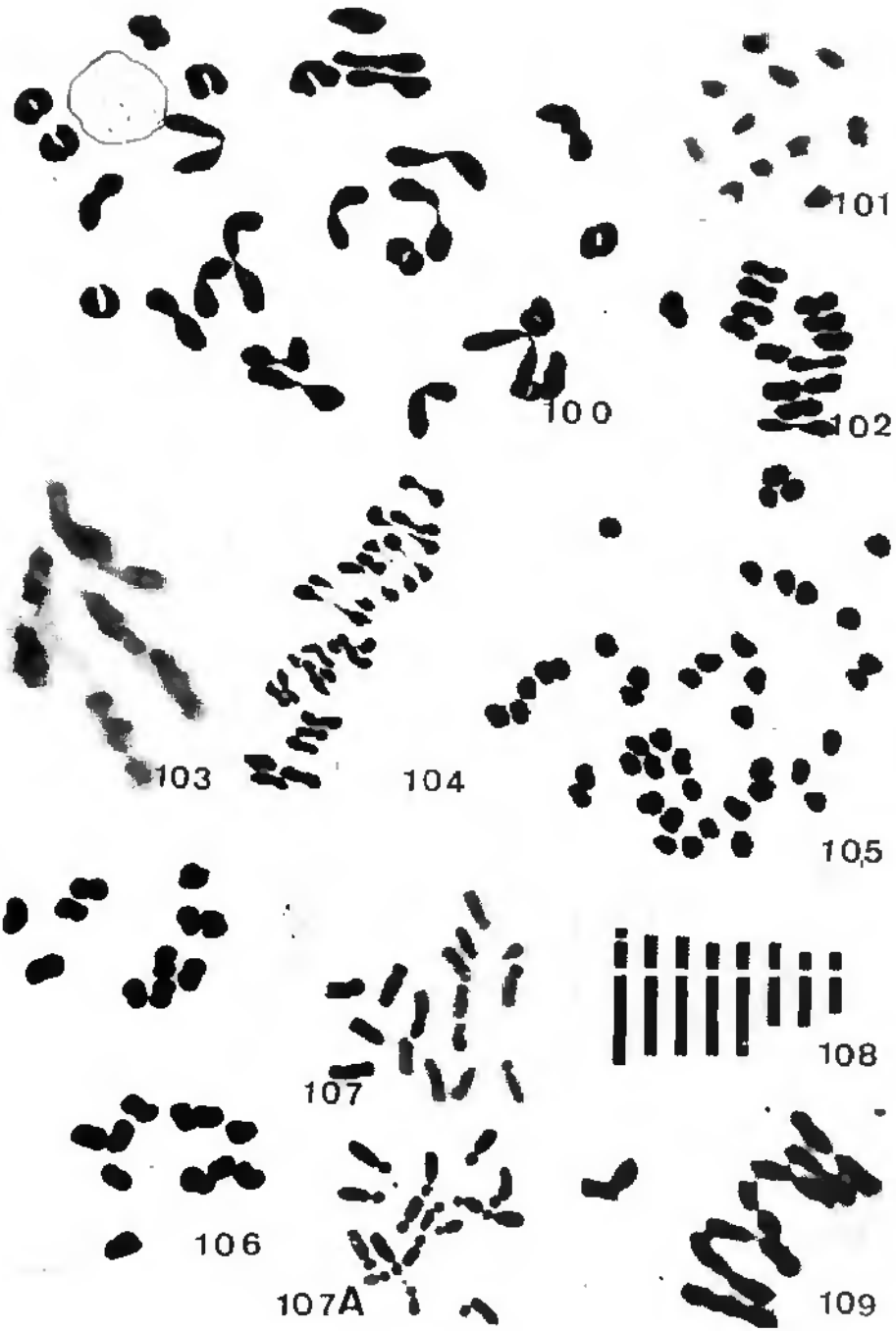
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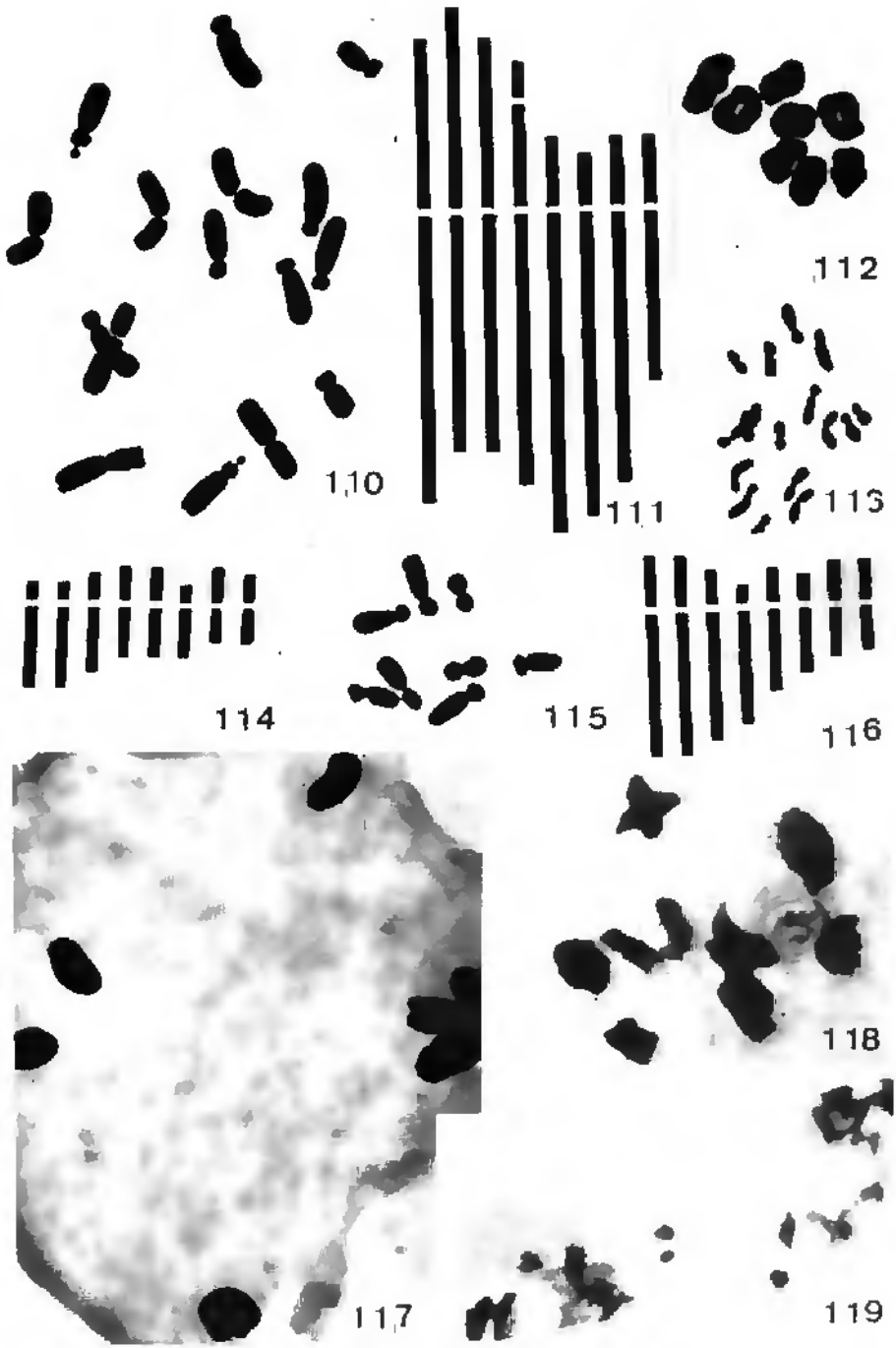
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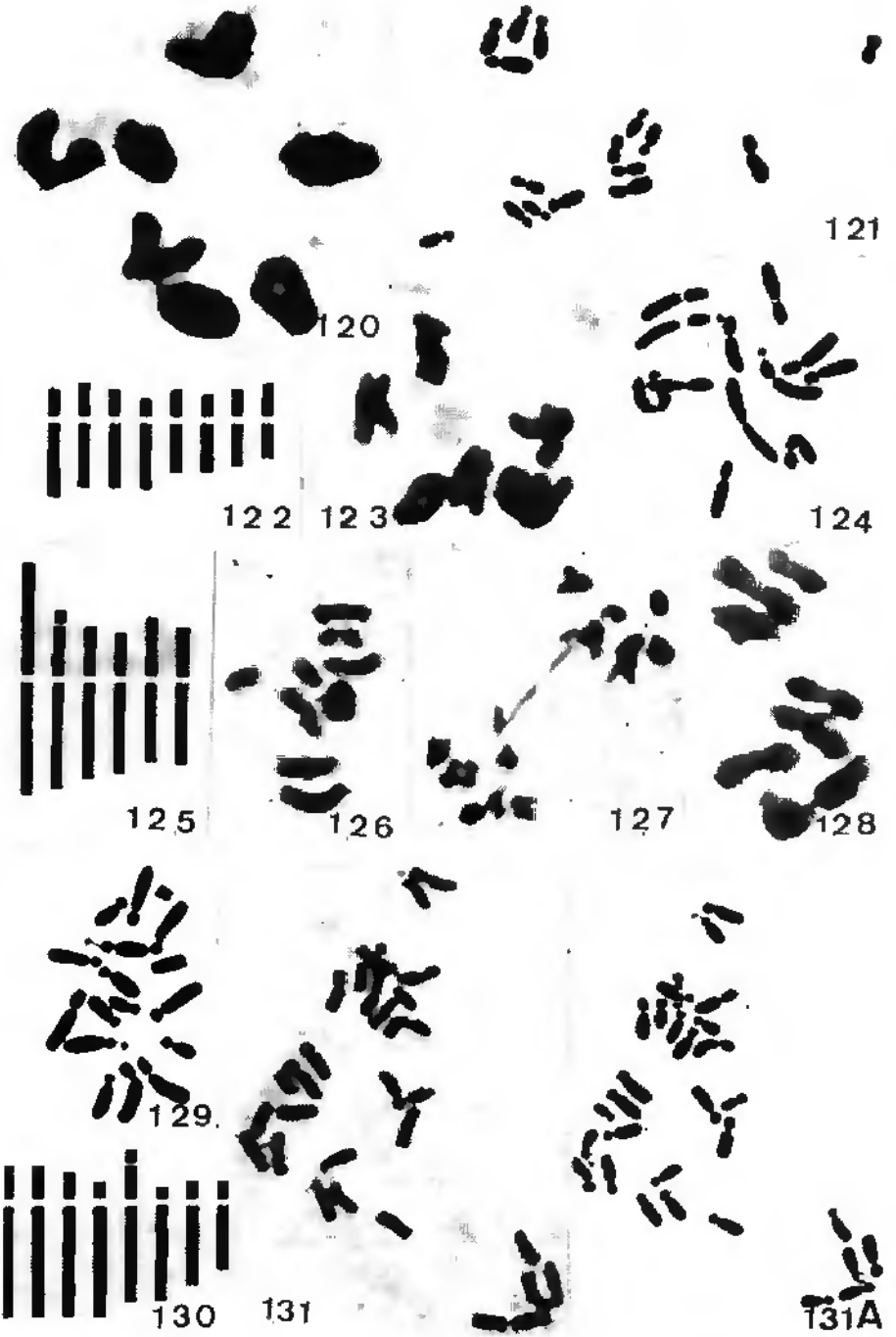
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Contribution to the Cytotaxonomy and Cytogeography of the Flora of the Western Himalayas (with an attempt to compare it with the Flora of the Alps). Part III.

by *K.N. Vasudevan*

(Department of Botany,
University of Neuchâtel, Switzerland)

Ber. Schweiz. Bot. Ges. *86* (3/4), 152–203 (1976)

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In the last part of this series the cytological studies on several families of the Sympetalae are concluded. [1])

Gesneriaceae

The family *Gesneriaceae* comprises 85 genera and 1100 species (Willis, 1966), and is distributed in tropical and subtropical regions of both the hemispheres.

Fourteen genera, some of which are monotypic, are restricted to China. Few species of the genus *Streptocarpus* have their habitat in South Africa and Madagascar. The monotypic genus *Rhabdothamnus* is endemic to New Zealand. Some genera are found growing in the New World also. Three species of the genus *Klugia* grow in Southern India and one species in Mexico.

The family is represented in India (after Hooker, op. cit.) by 129 species, some of which grow at low and medium altitudes in Himalayas (subtropical and temperate Himalayas). The number of species of *Gesneriaceae* is smaller in Western Himalayas than in Eastern Himalayas. Six species belonging to three different genera are endemic to some mountains of Europe (Balkan Peninsula, and Pyrénées).

Clarke (in Hooker, 1885) classified the family, on the basis of capsule characters, into five tribes: *Trichosporeae, Didymocarpeae, Leptoboeae, Epithemeae* and *Eucyrtandreae*. Later Fritsch (1895) made a revision of the classification with some alterations. He divided the family into two subfamilies, *Cyrtandroideae* and *Gesnerioideae* on the basis of flower

[1]) The publication of this series was made possible by a generous contribution of the State of Neuchâtel (Switzerland).

Table 7: *OROBANCHACEAE*

Taxa	Source and altitude	Collection number	Chromosome number n	2n	Level of ploidy	Previous report
	Species from the Western Himalayas studied by the author (A)					
Subfamily Orobanchaceae bicarpellatae Genus Orobanche (Tournef) G. Beck Section Osproleon Wallroth						
Orobanche epithymum D.C.*	Basudhara, 3800 m Kumaon	2012	19	–	4x	
O. kashmirica Clarke*	Balthal, 2900 m Kashmir	4279	19	–	4x	
	Species from Europe studied by the author (B)					
O. alba Stephan. (= *O. epithymum* D.C.)	Jura Hills, Neuchâtel Switzerland	–	19	–	4x	
Section Trionychon Wallroth						
O. purpurea Jacq.	Plateau de Ceillac, 1600 m, French Alps (Prof. C. Favarger)	–	12	24	2x	

* Chromosome number of the species reported for the first time

characters: the flower is hypogynous in the first subfamily, whereas it is more or less epigynous in the second. These two taxa represent two lines of parallel evolution from nearly actinomorphic flowers to zygomorphic flowers. Each subfamily is again divided into several tribes. The subfamily *Cyrtandroideae* is predominantly distributed in the Indomalayan region.

Cytological investigations undertaken up to now were mostly confined to chromosome counts. Main contributors are Sugiura (1939), Thathachar (1942), Rogers (1954), Eberle (1956), Fussell (1958), Ratter (1963), Ratter and Prentice (1964), Lee (1962a, 1966a, b) and Contandriopoulos (1966). Most of the earlier chromosome studies have been on material from different botanical gardens.

Our cytological investigations are reported on Table 8.

Discussion

Didymocarpus Wall. (syn. *Roettlera* Vahl.) of the subfamily *Cyrtandroideae*, tribe *Didymocarpiae*, is a genus consisting of 120 species (Willis, 1966), distributed in India, Malaya, South China and Madagascar, Australia and tropical Africa. Hooker (1885) has described 40 species from India.

D. pedicellata Br. occurs in subtropical W. Himalayas between an altitude of 800 to 1400 m in damp places. Distribution is confined to Kumaon only. Chromosome number at MI is counted as 18 bivalents (Fig. 143).

Didissandra Clarke. comprises some 33 species, 30 of which are distributed in India and China, while 3 species are reported from India alone.

D. lanuginosa Clarke. is met in temperate Himalayas at an altitude of 1200 m in damp places. No species is met in Kashmir. Fig. 144 shows 10 bivalents at MI of meiosis.

Chirita Hamm. is a large genus of *Gesneraceae* comprising 80 species distributed in Indomalayan regions (Willis, op. cit.). Three species are described from India by Hooker (op. cit.).

C. bifolia Don. Prodr. is collected from Bowali (1600 m). It is common at this altitude in Kumaon. Chromosome counts clearly show 12 bivalents and 4 univalents at diakinesis of meiosis (Fig. 145).

C. pumila Don. Prodr. occurs in subropical Himalayas at an altitudinal range of 500–1800 m in rare localities, as small groups. Four bivalents were counted at MI of meiosis (Fig. 146).

Platystemma Wall. of the tribe *Championieae* is a monotypic genus represented only in the Himalayas. It is a small herb with violet flowers.

P. violoides Wall. is found in Mussoorie and Nainital regions of Kumaon in abundance on the walls along roadsides. Counting of chromosomes reveals 20 bivalents at MI of meiosis. Secondary association of bivalents seems to be a feature at this stage (Fig. 147). Later course of meiosis is normal.

Six species of *Rhynchoglossum* Blume. of the tribe *Klugieae*, are reported from Indomalaya and Formosa (Willis, 1966).

R. obliquum Blume. is common up to 1500 m in the W. Himalayas. Chromosome number is 18 bivalents at MI (Fig. 148).

Table 8: *GESNERIACEAE*

Taxa	Source and altitude	Collection number	Chromosome number n	2n	Level of ploidy	Previous report
Subfamily Cyrtandroideae						
Tribe Didymocarpeae						
Didymocarpus pedicellata Br.*	Ranibag, 1400 m Nainital	2575	18	–	4x	
Didissandra lanuginosa Clarke*	Ranikhet, 1900 m	2557	10	–	2x	
Chirita bifolia D. Don*	Bowali, 1850 m	2582	14	–	4x	
C. pumila D. Don	Nainital, 1900 m	2581	4	–	2x	n = 4, Ratter 1963
Tribe Championieae						
Platystemma violoides Wall.*	Nainital, 1900 m	2559	20	–	4x	
Tribe Klugieae						
Rhynchoglossum obliquum Blume*	Garampani, 1400 m	2030	18	–	4x	

* Chromosome number of the species reported for the first time

Six species belonging to five genera of *Gesneriaceae* have been studied in the present work. The chromosome numbers of five of them were reported for the first time.

The cytological data of Sugiura (1940) and Thathachar (1942) enabled them tho assess x = 9 as the basic number of the genus *Didymocarpus*. On this basis, *D. pedicellata* (n = 18) is on a tetraploid level. The basic number of the genus *Didissandra* seems to be x = 10 *(D. lanuginosa)*.

Chirita pumila, with n = 4, provided the lowest base number of the genus (cf. Ratter, 1963). *C. bifolia* (n = 14) might have arisen from x = 4, or from another base number probably x = 7 which is one of the basic numbers suggested for the family by Sugiura (1940). In the light of the present work, a review of the chromosome counts in the genus *Chirita* clearly indicates that the genus possesses several basic numbers (x = 4, (7), 9) probably starting from the lowest number x = 4. The gametic number 14 does not necessarily come from x = 7, but perhaps through amphidiploidy between 4 and 10.

The high chromosome number n = 20 of *Platystemma violoides* showed a polyploid origin. The secondary pairing of bivalents at MI in this species may provide another support to this conclusion.

Rhynchoglossum obliquum with n = 18 also seems to be polyploid on a basic number 9.

From the literature and from the current data, it may be concluded that polyploidy played an important role in chromosomal evolution of the 5 genera of *Gesneriaceae* currently studied.

The inclusion of the genera *Chirita* and *Didymocarpus* as sections of a large genus, *Roettlera, in Fritsch's* classification seems to be well supported by the similarity of their basic chromosome numbers (x = 4 and x = 9). Besides, in *Chirita*, we have species with n = 14 and n = 17. The few representatives of the family in Europe are comparatively high polyploids, and *Ramonda serbien* (Contandriopoulos, op. cit.) has the highest somatic number (2n = 96) counted hitherto in *Gesneriaceae*, after *Aeschynanthus ellipticus* (Ratter and Prentice, 1969).

Ramonda, Haberlea and *Jankaea* are paleopolyploid genera. A migration from Himalayas or China is not likely for the European *Gesneriaceae*. It seems more probable that they would derive from a stock of *Gesneriaceae* already present in South Europe at the middle Tertiary.

Acanthaceae

The family *Acanthaceae* including 250 genera and 2500 species (Willis, 1966) is the ninth largest family of dicotyledonous plants. According to fossil records of *Strobilanthes* obtained by Velenovsky and Viniklar (1931), it is believed that the *Acanthaceae* date back to the Cretaceous period. This pantropical family has four centers of distribution: Indomalaya *(Strobilanthes* and *Andrographideae)*, Brazil *(Ruellia)*, Central America *(Aphelandreae* and *Odontonema)* and Africa *(Barleria)*. In Europe, it is represented by only a few species of the genus *Acanthus*, which grow in the Mediterranean region. No species of this family has reached

Central Europe. About twelve genera are found throughout the Tropics. These include the two largest genera of the family: *Justicia* and *Ruellia* with 325 and 225 species, respectively (Grant, 1955). Subtropical species are found in Australia, South Africa, China, Japan and the United States. Nineteen genera have species both in Africa and Asia (Willis, 1949). Nearly 120 genera are monotypic and restricted in range.

Acanthaceae are considered by many botanists to have been derived from the *Scrophulariaceae* or stocks ancestral to them. Bessey (1915) placed the family in the *Scrophulariales;* Wettstein (1924), Engler and Diels (1936) and Emberger (1960) placed it in the order *Tubiflorae* and Bentham and Hooker (1876) and Hutchinson (1948) in the order *Personales.*

Hooker (1885) reported 49 genera and 250 species under *Acanthaceae* from British India. They grow at altitudes which range from plain level to about 2100 m. The members are predominantly represented at lower altitudes between plain level and 1800 m beyond which only a few species ascend.

Clarke (in Hooker op. cit.) has divided the family into 5 tribes: *Thunbergieae, Nelsonieae, Ruellieae, Acantheae* and *Justicieae.* Lindau (1895) also using pollen characters in his classification, distinguished four subfamilies: *Nelsonioideae, Mendoncioideae, Thunbergioideae* and *Acanthoideae,* the last one comprising numerous tribes. Van Tieghem (1908) proposed to group the first three taxa of Lindau in a separate family: *Thunbergiaceae,* whereas the last one constitutes the *Acanthaceae, sensu stricto.* Bremekamp (1938, 1948, 1953) using chiefly characters of the sporoderm has proposed many changes in the internal taxonomy of the family but he was not followed by Melchior (1964). An interesting discussion upon these taxonomical problems was made by Long (1970).

Important contributions with respect to the cytology of this family have been made by Sugiura (1936a, b, 1939, 1940), Bowden (1940), Narayanan (1951a-d), Rangaswamy (1941), Mukherjee (1952), Grant (1955), Joseph (1961), Ellis (1962), Miège (1962), Mangenot and Mangenot (1962), Kaur (1965, 1966), De (1963, 1966), Bhat and Tandon (1967), Verma and Dhillon (1967), Mehra and Gill (1968), Kaur and Nizam (1970).

Our cytological results are reported on Table 9.

Discussion

Chromosome numbers of 12 species are new reports out of the 31 species of *Acanthaceae* belonging to 15 genera presently studied. The lowest chromosome number observed is n = 9 in *Strobilanthes dalhousianus* and *Justicia quinque-angularis* while the highest number is n = 42 in *Lepidagathis purpuricaulis.* Most of the species investigated so far have rather high chromosome numbers which makes the assessment of polyploidy difficult. In general, the chromosome size is small, except in the species of *Barleria.*

Thunbergia shows 3 basic numbers, x = 7, 8 and 9 (Darlington & Wylie, op. cit.). The present finding of n = 14 for *T. erecta* (a perennial species cultivated in Northern India) places the taxon from Haldwani at a tetraploid level on x = 7. This report differs from the previous counts of 2n = 52 (Narayanan, 1951), 2n = 56 (Grant, 1955) and 2n = 64 (Mangenot and Mangenot, 1962), thereby indicating intraspecific polyploid and perhaps aneuploid races in the species. The chromosome numbers of *Thunbergia* known so far (Bolkhovskikh, op. cit.) suggest that variation in chromosome number has been important in speciation in this genus.

Hygrophila spinosa and *H. polysperma* with n = 16 agree with the results of earlier authors (Table 9A) except for Sugiura's report (1940) of 2n = 24 for the former species. Darlington & Wylie (l.c.) suggested x = 12, 16 as base numbers

for *Hygrophila* while Grant (1955) considered 8 as the probable basic number of the genus. Grant (1955) states that „*Hygrophila* appears to be a natural group since these chromosome number determinations were representative of both the Old and New World species". The subsequent observations of De (1966) and of Miège (1962) have confirmed the somatic number 2n = 32. Therefore, it seems that this genus is a paleopolyploid one with basic number x = 8.

Ruellia tuberosa shows intraspecific aneuploidy with 2n = 32 (Sugiura, 1936b; Narayanan, 1951a) and 2n = 34 or n = 17 (Narayanan, 1951a; Grant, 1955; Ellis, 1962; De, 1963; and author). Darlington & Wylie (l.c.) suggested x = 16, 17, 18 as base numbers for *Ruellia*. De (1966) regarded 16 as the basic number of the genus and suggested that numbers 2n = 34 and 36 could have arisen through aneuploid addition of one or two chromosomes, respectively. As all of the 25 species of *Ruellia* studied by Grant (1955) have 2n = 34, we are inclined to think that 17 is the basic (secondary) number of this genus and that 2n = 32 or 36 represents exceptional cases of aneuploidy. *Ruellia* also would be a paleopolyploid genus.

Aechmanthera tomentosa with n = 15 confirms the previous finding of Verma & Dhillon (1967). Since *Aechmanthera* is a small genus of three species, x = 15 may be the basic chromosome number. This genus is again a paleopolyploid one.

Hemigraphis latebrosa with n = 14 is cytologically studied for the first time. Grant (l.c.) recorded n = 14 and 2n = 28 for *H. drymophila* and considered 7 as the probable basic number of the genus. However, Kaur (1965) has counted 2n = 26 in *Hemigraphis rupestris*. (See Fig. 149 for the present count).

Strobilanthes is a large genus with 250 species (Willis, op. cit.) growing in tropical Asia and Madagascar. Hooker described about 150 species from India. Most of the species are shrubs or subshrubs with perennial habit. Many occur gregariously, forming almost the sole undergrowth in forests. This is one of the rare genera of *Acanthaceae* growing up to the alpine regions. For example, *S. wallichii* Nees grows up to 3200 m. *S. atropurpureus* Nees is confined to the Western Himalayas from Kashmir to Nepal between 1800 and 2300 m.

S. dalhousianus Clarke is a suberect shrub, restricted to the Western Himalayas, frequent between 1800–2400 m. This species exhibits morphological variation. (1) The comparison between the normal type and a variant is made in Table 9B. Both the type and his variant have the same gametic number n = 9. This genus is interesting from a cytomorphological angle. Seven, presently studied species show gametic chromosome numbers 9, 11, 13, 14, 16 and 20, respectively, indicating the probable role of dysploidy in the evolution of species. Four species (*S. atropurpureus* n = 16, *S. glutinosus* n = 14, (Figs. 150–153), *S. quadrangularis* n = 11 and *S. wallichii* n = 20) are chromosomally known for the first time. *S. alatus* with n = 16 agrees with Mehra and Gill's report (1968); *S. dalhousianus* and *S. anisophyllus* showing gametic chromosome numbers 9 and 13, respectively, agree with the counts of Verma and Dhillon (1967). According to Grant (l.c.) 7 and 10 (5) are probably the basic numbers from which the polyploid series arose. In the light of the present results, it seems likely to ascertain the following basic numbers for this genus: x = 6, 7, 8, 9, 10, 11.

(1) Picture 6 shows the morphotypes of *Strobilanthes dalhousianus*.

Blepharis boerhaaviaefolia with n = 14 differs from the chromosome count of n = 13 by Kaur (1966). The genus seems to be polybasic with x = 6, 7, 8, 9 (cf. Miège, 1962). (See Fig. 155).

Barleria gibsoni (n = 20) is chromosomally studied for (Fig. 154) the first time. *B. prionitis* with n = 20 supports the chromosome count of this species by De (1966) but disagrees with the earlier finding of 2n = 30 by Narayanan (1951a). Narayanan (1951a) reported 2n = 34, 36, 38 and 40, for varieties of *Barleria cristata* with withe, pink, striped and blue flowers, respectively. Reports by other workers on the same species are n = 20 or 2n = 40 (Ellis, 1962; De, 1963; Verma & Dhillon, 1967; the present study) and 2n = 38 (Grant, l.c.). The chromosome numbers known in the genus are 2n = 30, 34, 36, 38, 40, 42 (cf. De, 1966). This evidently points out the significant role of aneuploidy in evolution at intra- and interspecific level within the genus. According to De (1966), 15 could be taken as the basic number of the genus since 30 is the lowest zygotic number in *Barleria*. In the present state of knowledge, it is very difficult to know if the genus *Barleria* is polybasic (x = 7, 8, 9, 10) or if the numbers differing from 2n = 40 are brought about by fragmentations and fusions.

Three cytotypes are known in *Crossandra undulaefolia* Salish. (= *infundibuliformis* Nees.) with n = 19 or 2n = 38 (Grant. 1955; Ellis, 1962; Verma & Dhillon, 1967; and present study), 2n = 20 (Narayanan, 1951a), and 2n = 60 (De, 1966). De (l.c.) took x = 10 as the basic number for the genus and thought that the origin of the 2n = 38 complement came through the loss of one chromosome from the gametic set at tetraploid level. As Mangenot and Mangenot (1962) have found 2n = 42 in *Crossandra flava*, the same alternative as in the genus *Barleria* (x = 7, 9, 10 or an aneuploidy from 2n = 40) seems to be applicable to *Crossandra*.

Lepidagathis purpuricaulis showing n = 42 is reported (Fig. 156) for the first time. *L. cuspidata* with n = 11 agrees with the report of Verma & Dhillon (1967). Miège (1962) attributed the basic number x = 10 to this genus, because *L. anobrya* from Africa possesses 2n = 20. Therefore, it seems likely that *Lepidagathis* would be polybasic with x = (7), 10 and 11, but the somatic number 42 (see Bolkhovskikh *et al.*) may also proceed from 2n = 40 through aneuploidy.

Out of the five species of the genus *Justicia*, studied (Figs. 159, 157) cytologically, the chromosome number of *J. diffusa* (n = 9) and (Fig. 158). *J. pubigera* (n = 14) are recorded for the first time. For their chromosome numbers, the species *J. simplex* (n = 18) (*), *J. quinqueangularis* (n = 9) are in line with earlier authors (See Table 9A). The chromosome number of *J. gendarussa* differs from that found by other authors (2n = 32, Narayanan, 1951a; 2n = 30, Joseph, 1961) but agrees with the count of Basak (1959). Darlington & Wylie (l.c.) have suggested x = 14 as the basic chromosome number of the genus *Justicia*, and De (op. cit.) x = 12. Grant (1955) and Long (1970) believed 7, 8, 6 or 9 to be probable basic numbers for this genus.

The discovery of species with 2n = 18 allows us to conclude that 9 is one of the basic numbers of the genus *Justicia*, the other ones being 6, 7, 8. With regards to the gametic numbers 13 and 15, they probably originated through amphidiploidy (6 + 7 and 6 + 9) and this fact stresses the role of polyploidy in the evolution of this genus.

(*) *J. simplex* has also a diploid race with n = 9 (Pal, 1964 in Bolkhovskikh *et al.*).

The chromosome number of *Adhatoda vasica* was found to be n = 17 by many workers (see Table 9A) including the author, but intraspecific polyploidy in this species was established by Grant (l.c.) who reported 2n = 56. According to Grant (l.c.) x = 7 is the basic number of the genus, and *A. vasica* would be a „tetraploid in comparison to *Justicias* with 28 chromosomes". In the view of the author, x = 17 is also a basic number for the genus but a secondary one which perhaps came from 9 + 8 through amphidiploidy. This opinion would imply that in a single species, *Adhatoda vasica*, the three basic numbers 7, 8 and 9 existing in *Justicia* are represented.

Haploid chromosome number 26 for *Rungia parviflora* is (Fig. 160) reported for the first time. The two species cytologically studied earlier show a great difference in their diploid chromosome numbers: *R. repens* with 2n = 20 (Narayanan, 1951a; Ellis, 1962) and *R. pectinata* with 2n = 50 (De, 1966). De (1966) has suggested x = 10 as the basic number of the genus. In the light of the results on *Dicliptera (videte infra)*, a genus from the same tribe, it appears that one basic number of *Rungia* is x = 13, besides x = 10. As regards the somatic number 2n = 50 considered by De as pentaploid, it could also proceed from 2n = 26 through aneuploidy.

Two species of *Dicliptera* were currently investigated. *D. bupleuroides* (n = 13) and *D. roxburghiana* (n = 13) show the lowest chromosome number in the genus so far recorded. In contrast, *D. assurgens* and *D. brachiata* having somatic number 2n = ca. 80 (Grant, 1955) are representatives of higher polyploids of the genus. These two species are perhaps hexaploids with 2n = 78 (= 6 x 13). Besides x = 13, this genus seems to possess x = 10 and x = 12 (Bolkhovskikh *et al.*, op. cit.).

Chromosome number of *Peristrophe speciosa* (n = 15) is the first chromosome report for the species. The gametic chromosome number 15 observed for *P. bicalyculata* agrees with Ahuja (1955) and Verma & Dhillon (1967) but differs from 2n = 20 reported by Narayanan (1951a). It is suggested that x = 15 may be considered as one of the basic numbers of the genus *Peristrophe*, the other ones being x = 10 and perhaps x = 7.

Three facts are striking in the karyology of the *Acanthaceae* studied here.

1. Out of fifteen genera, twelve are polybasic; besides, the two genera in which the basic number is x = 15 or x = 17, are probably polybasic too, because these numbers could have arisen secondarily from x = 7, 8 and 9 through amphidiploidy. Grant (1955) has determined the following basic numbers (5), 6, 7, 8, 9, 10 and 11 in the same family. The present observations are entirely in agreement with Grant's assertion and no gametic chromosome number was discovered which could not be explaned with such a basis. Most of the genera are built upon 7, 8 and 9 which are considered by Grant as predominant. Such a situation makes the use of chromosome numbers in the taxonomy and phylogeny of the *Acanthaceae* somewhat problematical. Grant thinks that „the frequency of basic chromosome numbers of 7, 8 and 9, and the extensive range of chromosome morphology suggest the reticulate nature of the genera and species". It may also be explained as a case of parallel evolution of the caryotype (Favarger, 1962).

2. The gametic numbers of most of the species hitherto studied in the *Acanthaceae are relatively high.* No gametic number lower than x = 9 was reported, and many

species possess such gametic numbers as 13, 14, 15, 16, 17 suggesting an old phenomenon of polyploidization. Therefore, some genera, as *Ruellia* and *Aechmanthera*, were regarded by the author as paleopolyploids (Favarger 1961). This fact is in line with the finding of a high percentage of polyploidy in the tropical African flora by Mangenot & Mangenot (1962). Moreover, from these high (secondary) basic numbers, more recent polyploids have arisen which would be classified by Favarger (op. cit.) as meso- and neo-polyploids. The family *Acanthaceae* seems to have already undergone a very long evolution during which *ancestral species with low basic chromosome numbers* have disappeared. However, this evolution is not completed and has been pursued by recent phenomena of polyploidization (see under 3.).

3. As a survey of the literature points out, intraspecific polyploidy and aneuploidy are very frequent in the family *Acanthaceae*. The multiplicity of chromosome numbers can be partly explained by a misidentification of the species or by wrong counts, but an important part of this variation is certainly not an artificial one. Unfortunately, nothing is known about geographical distribution or ecology of these „chromosome races". It would be very important in the future to give more attention to these aspects. The presence of such neopolyploids in a tropical flora is somewhat astonishing. Perhaps it was favoured by the herbaceous habit of numerous *Acanthaceae*, by recent or subrecent events such as changes of climate and migrations, or also by the influence of man.

Plantaginaceae

This small family of *Bicarpellatae* consists of 3 genera with 270 species (Willis, 1966). Hooker has described 10 species from India. Hegi (1914) recorded 15 species of *Plantaginaceae* from Central Europe. The members are annual or perennial herbs. Many of them have a vast distribution.

Systematic treatment of the family was first made by Barnéoud (1845). Decaisne (1852) split the genus *Plantago* into 17 sections. Harms and Reiche (1895) classified the family into 3 genera: *Litorella, Plantago* and *Bougueria*. The genus *Plantago* was split again into 2 subgenera: *Euplantago* and *Psyllium*. The subgenus *Euplantago* was divided into 11 sections. Pilger (1937) made a detailed systematic study of the family on the basis of the system adopted by Harms and Reiche.

Even though cytological investigations have been made by many authors (McCullagh, 1934; Böcher, 1943; Böcher *et al.*, 1953, 1955; Rahn, 1957; Ono, 1954 and Cartier, 1970), the great phenotypic variability, a characteristic feature of the members of the family, especially of the genus *Plantago*, still remains as an interesting aspect to study. Hence, a detailed cytomorphological study was undertaken now on two species: *Plantago major* and *P. lanceolata* (1), both growing in abundance in Himalayas and in Europe.

The cytological results of the present investigations are recorded on Table 10.

(1) Böcher (1943) has accurately studied the variation and biology of *P. lanceolata* from Europe. Hence, detailed study of this species from Europe is not attempted here.

Table 9: *ACANTHACEAE (A)*

Taxa	Source and altitude	Collection number	Chromosome number n	2n	Level of ploidy	Previous report
Subfamily Thunbergioideae						
Thunbergia erecta T. Anders.+	Haldwani, 400 m	2028	14	–	4x	2n = 52, Narayanan 1951 2n = ca. 56, Grant 1955 2n = 60, Mangenot & Mangenot 1957 2n = 64, Mangenot & Mangenot 1962
Subfamily Acanthoideae						
A. Contortae						
Tribe Hygrophileae						
Hygrophila polysperma T. Anders.	Haridwar, 300 m	2097	16	–	4x	2n = 32, Grant 1955
H. spinosa T. Anders.	Pinjore, 400 m	2070	16	–	4x	2n = 32, Rangaswamy 1941 Miège 1962 Grant 1955 2n = 24, Sugiura 1937, 1940 n = 16, Verma & Dhillon 1967 Mehra & Gill 1968
Tribe Strobilantheae						
Hemigraphis latebrosa Nees *	Kasauli Road, 800 m Kalka	2058	14	–	4x	
Aechmanthera tomentosa Nees	Thogave, 1000 m Kumaon	2048	15	–	?	n = 15, Verma & Dhillon 1967
Strobilanthes glutinosus Nees *	Bowali, 1850 m	2051	14	–	4x	
S. quandrangularis Clarke *	Didihut, 1500 m Kumaon	2044	11	–	2x	
S. dalhousianus Clarke	Nainital, 1900 m	2580	9	–	2x	n = 9, Verma & Dhillon 1967
S. antsophyllus T. Anders.	Chandigarh, 300 m	2065	13	–	nx	n = 13, Verma & Dhillon 1967
S. alatus Nees	Nainital, 1900 m	2573	16	–	4x	n = 16, Mehra & Gill 1968
S. wallichii Nees *	Nainital, 1900 m	2022	20	–	4x	
S. atropurpureus Nees *	Tangmarg, 2100 m Kashmir	4320	16	–	4x	
Tribe Ruellieae						
Ruellia tuberosa L.	Dehra Dun, 450 m	2605	17	–	?	2n = 32, Sugiura 1936 2n = 34, Bowden 1940, 1945 2n = 32, 34, Narayanan 1951 Grant 1955 Ellis 1962 De 1963
Tribe Barlerieae						
Barleria prionitis L.	Pinjore, 400 m	2098	20	–	4x	2n = 30, Narayanan 1951 2n = 40, Raman & Kesavan 1964, 1965 n = 20, De 1963
Barleria cristata L.	Chamoli, 700 m Kumaon	2027	20	–	4x	2n = 34, 36, 38, 40, Narayanan 1951 2n = 38, Grant 1955 2n = 40, De 1963 n = 20, Ellis 1962 Verma & Dhillon 1967
B. gibsoni Dalz.*	Chandigarh, 300 m	2064	20	–	4x	
B. Imbricateae						
Tribe Acantheae						
Blepharis boerhaaviaefolia Pers.+	Pinjore, 400 m	2073	14	–	4x	n = 13, Kaur 1966
Crossandra infundibuliformis Nees	Chandigarh, 300 m	2054	19	–	4x	2n = 20, Narayanan 1951 2n = 38, Grant 1955 2n = 60, De 1963 n = 30, De 1963 n = 19, Ellis 1962 Verma & Dhillon 1967
Lepidagathis cuspidata Nees	Nainital, 1900 m	2515	11	–	2x	n = 11, Verma & Dhillon 1967
L. purpuricaulis Nees*	Jeolikot, 1400 m Nainital	2517	42	–	12x	
Tribe Justicieae						
Justicia gendarussa L.	Dehra Dun, 450 m	2078	14	–	4x	2n = 28, Basak 1959 2n = 30, Joseph 1964 2n = 32, Narayanan 1951a
Justicia pubigera Wall.*	Chamoli, 700 m Kumaon	2018	14	–	4x	
J. quinqueangularis Koen.	Surajpur, 350 m	2069	9	–	2x	2n = 18, Ahuja & Natarajan 1957 n = 9, Verma & Dhillon 1967
J. diffusa Willd.*	Garampani, 1000 m	2563	9	–	2x	
J. simplex D. Don	Garampani, 1000 m	2565	18	–	4x	2n = 36, Grant 1955 Ellis 1962 n = 9, Pal 1964 n = 18, Verma & Dhillon 1967 n = 14, Mehra & Gill 1968
Adhatoda vasica Nees	Kathgodam, 500 m	2529	17	–	nx	2n = 34, Hardas & Joshi 1954 Mukherjee 1952 2n = 56, Grant 1955 n = 17, Verma & Dhillon 1967 Mehra & Gill 1968
Tribe Odontonemeae						
Subtribe Diclipterinae						
Peristrophe bicalyculata (Vahl) Nees	Bageswar, 1400 m	2043	15	–	?	2n = 20, Narayanan 1951 2n = 30, Verma & Dhillon 1967 n = 15, Ahuja 1955
P. speciosa Nees*	Kalka, 600 m	2056	15	–	?	
Rungia parviflora Nees *	Hanumanmandir, 1600 m	2025	26	–	?	
Dicliptera roxburghiana Nees	Nainital 1900 m	2511	13	–	2x	n = 13, Verma & Dhillon 1967
D. bupleuroides Nees	Govindghat, 2100 m Nainital	2539	13	–	2x	n = 13, Verma & Dhillon 1967

* Chromosome number of the species reported for the first time
\+ A new chromosome report for the species

Table 10: *PLANTAGINACEAE*

Taxa	Source and altitude	Collection number	Chromosome number n	2n	Level of ploidy	Previous report
	Species from the Western Himalayas studied by the author (A)					
Plantago major L.	Ranikhet, 1900 m	2596	18	–	6x	2n = 12, Löve & Löve 1965a, etc. (cf. Bolkhovskikh *et al.* 1969)
	Pahalgam, 2100 m Kashmir	4221	6	–	2x	
P. lanceolata L.	Tangmarg, 2100 m Kashmir	4220	6	–	2x	2n = 12, 24, 96, McCullagh 1934 2n = 12, Mulligan 1961b (for others, cf. Bolkhovskikh *et al.* 1969)
	Species from Europe and Asia studied by the author (B)					
P. major L.	Neuchâtel, Switzerland	–	–	12	2x	
P. lanceolata L.	Neuchâtel, Switzerland	–	–	12	2x	
P. asiatica L.	East Siberia (Moscow) U.S.S.R.	–	–	36	6x	2n = 12, McCullagh 1934 2n = 24, Fujiwara 1956a Subramanyan & Kamble 1966 2n = 36, Rahn 1966
P. intermedia Gilib.*	S. de Peney, Chauée, N. Grand Bois, Switzerland	–	–	12	2x	
P. media L.	Jura Mountains, Neuchâtel Switzerland	–	12	–	4x	2n = 12, 24, Raba 1954, 1957, 1966 2n = 24, McCullagh 1934 etc. (cf. Bolkhovskikh *et al.* 1969)

* Chromosome number of the species reported for the first time

Table 9B: Salient morphological features of the morphotypes of *Strobilanthes dalhousianus*

Characters	Normal	Variant
Locality and altitude	Nainital, 1900 m	Nandaprayag, 1400 m
Habitat	Shady places	Open dry places
Habit	Erect, branched	Semi-erect, profusely branched
Stem	Four-angled, thick, hairy	Cylindrical, thin, non-hairy
Leaves	Opposite, arrangement with one large and small leaf on either side	Opposite, arrangement with one large and small leaf on either side
Length of lamina	18–25 cm	6–10 cm
Breadth of lamina	4–6 cm	1.5–2.0 cm
Inflorescence axis	Short	Long

Table 9C: *Hypothetical basic numbers of different genera of acanthaceae (in brackets)*

	Probable basic numbers x =	Gametic numbers observed (the lowest is underlined)
Thunbergia	7, 8, 9	*9*, 14, 16, 24, 28, 32
Hygrophila	8	*16* (Sugiura: 12)
Ruellia	17 (= 8 + 9)	*17* (16?, 18?)
Aechmanthera	15 (= 7 + 8)	*15*
Hemigraphis	(6?), 7, 13 (= 6 + 7)	*13*, 14
Strobilanthes	6, 7, 8, 9, 10, 11	*9*, 10, 11, 15, 16, 20
Blepharis	6, 7, 8, 9	*12*, 13, 15, 17
Barleria	(7), (8), 9, 10 (15 = 7 + 8)	*15*, 19, 20
Crossandra	7, 9, 10	*10*, 19, 21, 30
Lepidagathis	6, 7, 10, 11	*10*, 11, 12, 21, 42
Rungia	(6?), (7?), 10, 13 (= 6 + 7)	*10*, 26
Dicliptera	6, 7, 10, 13 (= 6 + 7)	*13*, 20, 24
Peristrophe	7, (8), 10, 15 (= 7 + 8)	*10*, 15, 21
Justicia	6, 7, 8, 9	*9*, 12, 13, 14, 15, 16, 17, 18
Adhatoda	7, (8), (9), 17 (= 8 + 9)	*17*, 28

Table 10C: Analysis of cytomorphological characters of *P. major* L. from W. Himalayas and Europe

Characters	Nainital 1900 m	Lahorkhet 2100 m	Dehra Dun 450 m	Kedarnath 3600 m	Srinagar 1650 m	Gulmarg 2700 m	Khilanmarg 3000 m	Neuchâtel Switzerland	Simplon/Valais Switzerland
Habitat	Marshy clay soil in shady places	Wet sandy soil, exposed place	Wet sandy soil	Open, grassy ground	Wet clay soil, near roads	Open grassy ground with large population	On grassy meadows, widespread population	Open ground with clay and sandy soil	Roadsid open places
Growth habit	Semi-erect	Erect	Erect	Upper leaves erect with prostrate lower leaves	Ascendent	Prostrate	Prostrate	Semi-erect	Semi-erect
Plant height cm	60	50	60	6	40	6	3.5	45	35
Aver. no. of leaves	18	14	16	9	8	10	5	12	15
Length of petiole cm	30–35	16–20	15–25	2–3	4–7	4–5	0.7–2.0	10–13	9–14
Shape of leaves	Radial,	Radial,	Light	Light	Bright	Creen, Green,		Light	
Shape of leaves	Radial, lanceolate, dark green	Radial, green, lanceolate	Light green, lanceolate	Light green, non-hairy leaf surface	Bright green, oval shape with wavy margin	Green, ovate, hairy surface	Green, ovate, with wavy margin	Light green, ovate, undulate margin	Light green, ovate, undulate margin
Length of leaves cm	10–15	11–14.5	20–25	3–4.5	10–12	3–5	1.3–3	12–14	8–11
Breadth of leaves cm	2.5–3.5	2.2–4.8	3–7	2–2.8	4–6	2.3–2.5	0.7–2	8–10	7–8
Length of the scape cm	7–8	3–4.5	10–14	2–4	15–30	3–4.5	1–4.8	20–22	14–16
Nature of the spike	Laxed	Laxed	Laxed	Cylindrical	Cylindrical	Cylindrical, compact	Short compact with laxed flowers	Semi-compact	Compact
Length of spike cm	8–10	3–4.6	13–18	1.6–3	14–40	1.6–3.5	0.7–2	12–15	9–11
No. of seeds per capsule	7–10	5–10	8–10	7–8	5–7	8–10	7–9	7–9	8–9
Stomatal size μ	34 μ x 24 μ	32 μ x 22 μ	32 μ x 22 μ	29 μ x 18 μ	28 μ x 18 μ	31 μ x 20 μ	30 μ x 20 μ		
Chromosome (n)	18	18	6	6	6	6	6	6	6

Plantago major is a highly polymorphous species distributed from circumpolar arctic regions to Alaska, U.S.A., Europe, Africa, Asia minor, Central Asia, Himalayas, Siberia, Tibet, Mongolia, China, Manchuria, Korea, Saghal, Kuril, Formosa and Malaysia.

Cytological investigations were made on young roots of *P. major*, from seeds collected in W. Himalayas, at various altitudes and latitudes. Meiosis was studied from the flower buds fixed at Neuchâtel and at the Simplon in Switzerland. Chromosome counts were made too on the seed samples received from 50 different places in Europe. It could be observed that in the whole of Europe (see Table 10C), *P. major* grows as diploid (2n = 12). In Himalayas, the populations studied are diploid in Kashmir and in Mussoorie regions (Fig. 161), but those from Kumaon region uniformily revealed a hexaploid chromosome number (Fig. 162). Since, both the chromosomal types possess morphological variation, a comparison was made for different characters between the two cytotypes collected from different places (Table 10C). In a previous paper (Favarger et Vasudevan, 1972), it was supposed that the hexaploid plants from Kumaon belong to *P. asiatica*.

A karyotypical study of the somatic complement of a (Fig. 166) hexaploid *P. asiatica* obtained from the Botanical Garden of Moscow and collected in East Asia revealed 11 chromosome pairs with median centromere, 6 chromosome pairs with submedian centromere and the remaining 1 pair with subterminal centromere. One pair of the chromosomes with subterminal centromere also possessed a pair of satellites, and one pair of median chromosomes possessed a secondary constriction. The chromosome size in general resembled the size of chromosomes in diploid (2n = 12) *P. major* (Favarger and Vasudevan, 1972). As to the morphology of this Asiatic plant, it was similar to that of the plant collected in Kumaon (see under).

A clear example of cytomixis was observed in an individual (n = 6) from Mussoorie. At MI of the meiosis, cytoplasmic connections with chromatin contents were observed between the PMC's (Fig. 163). Some PMC's showed as many as 8 bivalents instead of the normal number of six, while few others showed one, two or five bivalents in a cell (Fig. 163). At AII, lagging chromosomes were not uncommon. About 15% pollen sterility was observed after staining the pollen with acetocarmine. The plant with cytomixis also showed a partial failure in seed setting.

P. lanceolata Linn. is a perennial species which occurs in the W. Himalayas from Kashmir to Kumaon at an altitude between 1500–3400 m. It normally grows on open grassy ground. It is very common in Europe.

Chromosome number of plants both from Europe and the Himalayas, as determined from meiosis, is n = 6 at MI. Morphological variation is found to be prevalent in this species as in *P. major*. A Table (10C) summarizing the variability of morphological types observed in different parts including different altitudes in W. Himalayas, is given.

P. intermedia Gilib. collected in Switzerland revealed (Fig. 164) a somatic number of 2n = 12. Somatic complement consists of 5 pairs of chromosomes with median centromere, and one pair with submedian centromere. Two pairs of the chromosome set possess satellites. The chromosome count of this species is made for the first time. (Fig. 165).

Discussion

It is interesting to note that in *Plantago major sens. lat.*, all the populations from Europe, so far examined, are diploids; the nearest allied species, *P. intermedia* Gilib. (one population studied) is diploid too. In so far as it may be possible to adopt a definite position in a very confused situation, the Asiatic polyploids belong to the following taxa:

P. major var. *asiatica* Decne. = *P. asiatica* L.

Tetraploids and hexaploids in Japan
(besides diploids after McCullagh, 1934)

Hexaploids from East Siberia
(the present author)

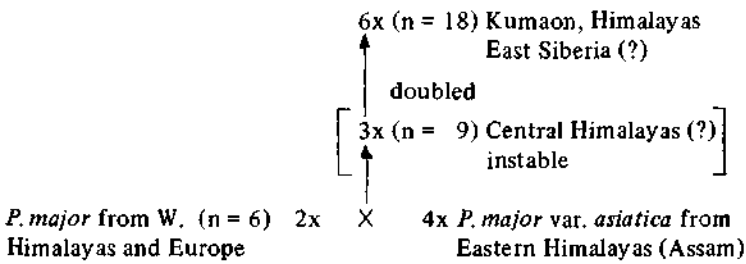
Tetraploids from Assam (Eastern Himalayas)
(Subramanyam and Kamble, 1966)

Hexaploids from Kumaon (Western Himalayas)
(the present author)

P. major var. *japonica* (Fr. et Sav.) O. Ktze = *P. japonica* Franch. et Savat.

Hexaploids in Japan (McCullagh, 1934,
besides diploids, Sinotô, 1925 etc.)

All these polyploids are localized on the borders of the area of *P. major sens. lat.* In the present state of knowledge, it is difficult to know if the Western Himalayan area of the hexaploids is, or is not, connected with that of the East Siberian one, through Tibet and Mongolia. In a previous paper (Favarger and Vasudevan, 1972), it was supposed that the hexaploids from Kumaon originated through amphidiploidy between the diploid *P. major* from Kashmir and the tetraploid plants from Assam. This suggestion may be depicted as follows:



One does not know up to what point the East Siberian populations depend on the Himalayan hexaploids. In Japan, where diploids are found besides tetraploids and hexaploids, a similar evolution of the whole complex could have taken place, perhaps at an earlier time, since the taxa *P. japonica* and *P. asiatica* seem to be more differentiated in this country.

Regular bivalent formation with normal meiosis and 100% pollen fertility noticed in the hexaploid *P. major* from Kumaon gives enough evidence to believe that the „race" is an allohexaploid. Occurrrence of both intraspecific and interspecific polyploidy in many species of *Plantago* has already been noticed by many authors (McCullagh, 1934; Böcher *et al.*, 1953, 1955; Ono, 1953;

Gorenflet, 1960 and Cartier, 1970). Extensive geographical distribution covering a vast area with various ecological nitches may be one of the causes of the successful establishment of polyploids in the genus. The evolutionary significance of the cytomixis found in an individual from Mussoorie (Himalayas) is worth considering here. Viable pollen grains developed from the aberrant FMC of the plant showing cytomixis, may probably lead to the polyploid or aneuploid race of the species. This assumption is further supported by the presence of partial seed setting in the taxon with cytomixis. This individual may be perhaps a hybrid between a diploid *P. major* and a diploid *P. asiatica* (?) which would be existing in Central Himalayas but has not been reported yet.

In the collective species *P. coronopus* L., Gorenflot (1960) believed that the tetraploid populations, in which meiosis is regular without multivalents, arose from the doubling of the chromosome sets of hybrids between different microspecies from the complex. In her excellent paper on the biosystematics of some *Plantago* species, Cartier (1970) showed that all the tetraploid populations of *P. alpina* and *P. serpentina* are allopolyploids, some coming from interspecific hybrids, the others from intraspecific hybrids. In the *Oreades* section too, the polyploids observed in West Asia are supposed to have arisen through hybridization between several diploid *subspecies* differing in karyotype, followed by doubling of the chromosome sets. For example, the ssp. *saxatilis* possesses a satellitiferous chromosome from ssp. *atrata*, and another one from the ssp. *spadicea*.

In *Plantago major sens. lat.*, the karyotype of the ssp. *intermedia* so far observed, is not exactly the same as that of *P. major* ssp. *major*, and some differences were observed too in hexaploid *P. asiatica* from the Far East. Therefore, it is likely that the polyploids from Japan, East Siberia and the Kumaon Himalayas are segmental allopolyploids (Stebbins, 1947) although no multivalents were noticed, or genomic allopolyploids though the apparent differenciation of the two chromosome sets from the parents is very slight.

A last problem is the taxonomy. The morphological differences on which Pilger (op. cit.) based his specific separation of *P. asiatica* from *P. major*, seem to be rather unimportant. Neither in the hexaploids from Kumaon, nor in the plant from Russian Far East, the bract was really separated from the calix and the latter stalked. As to the number of seeds per fruit, it varies largely in both diploids and hexaploids from W. Himalayas; moreover, the average value is a little higher in the hexaploids (see Table 10C). On the contrary, the East Siberian plants have 4–5 seeds per fruit, as indicated by Hara (1956) and by Ohwi (1965) for *Plantago asiatica* from Japan. Therefore, it seems more likely that the hexaploids from the Russian Far East are linked with the Japanese plants.

In the present author's opinion, it would be more convenient to treat *P. asiatica* as a *subspecies* from *P. major* instead of treating it as an independent species.

The extensive morphological variability present in both diploid as well as hexaploid *P. major* (1) from W. Himalayas and their subsequent overlapping make it difficult to distinguish whether the variation is a genetically controlled or environmentally adapted phenomenon. This aspect requires an experimental study of large populations under the same environment.

(1) Pictures 7 and 8 show morphological variants in the diploid and hexaploid races of *P. major*.

Intraspecific morphological variability is a common phenomenon among the members of the genus *Plantago* (*P. coronopus*, Böcher *et al.*, 1953, 1955, Gorenflot, 1959; *P. maritima*, Gregor, 1938; *P. media*, Rahn, 1957). In the present investigation, the extent of morphological variation appeared clearly when individuals of *P. major* with 3.5 cm and 90 cm height are recorded with a lot of intermediates in between (see Table 10C). In *P. lanceolata*, the variation in plant height is noticed from 11 cm to 50 cm. The other characters mentioned in the Table (10C) show the range of variation to which each trait is subjected.

The worldwide distribution of some species of *Plantago* is one of the reasons for such a great amount of morphological specialization of the genus in the process of their adaptation to the various climatical, ecological and edaphic conditions. Table 10C points out that the morphological variation in both *P. major* and *P. lanceolata* takes place even under the same ecological or geographical conditions. Reduced size of the species at higher altitudes is apparently due to low temperature, a greater amount of light and probably the constant subjugation to wind at higher elevation. Though the variation is influenced by environment to a certain extent, the occurrence of more than one morphotype under similar ecogeographical conditions evidently suggests a genetical basis for this phenomenon.

The report of an aneuploid race with 2n = 13 in *P. coronopus* by Böcher *et al.* (1953) adds sufficient proof to establish that cytological evolution in *Plantaginaceae* has arisen through interspecific and intraspecific euploidy coupled with aneuploidy.

III. General Discussion

The present cytological investigation concerns 197 plant species from the Western Himalayas and 52 species from Europe, especially from the Alps, belonging to ten families of the *Sympetalae (Tubiflorae + Gentianaceae)*. The chromosome number of 69 Himalayan species are new reports while 16 numbers differ from those of the literature. Out of the alpic plants, 5 species were cytologically investigated for the first time while in *Scrophularia canina*, a new chromosome number was discovered (n = 12).

The main results were already discussed under each family. The author will summarize here some data of general interest in two fields i.e., that of cytotaxonomy and that of cytogeography and history of the flora.

Part 1. Cytotaxonimical aspects

a) Cytotypes and their taxonomic status

Ever since an intensive cytological examination of Linnean species has been undertaken, cytologists have detected many species with more than one chromosome number. This phenomenon is more frequent in the so-called „collective species", having a wide geographical distribution and morphological variability. About 7% of the flora of Central Europe consists of such intraspecific „chromosome races" (cf. Tischler, 1950); in the last twenty years, this number has greatly increased. Until now, chromosome counts of Western Himalayan plant species show about 4.6% of „polyplotypes" out of the total number of 570 species for which the chromosome number is known.

In the present investigation, the author could notice cytotypes in *Gentiana carinata* Griseb (n = 10, 20), *Solanum nigrum* L. (n = 12, 24, 36), *Scrophularia himalensis* Royle (n = 12, 24), *Veronica anagallis* L. (n = 18, 27) and *Plantago major* L. (n = 6, 18) growing in W. Himalayas. A comparative account of the morphological features of these chromosome races was given in various Tables in the text.

Other species in which several chromosome races were observed by various authors in Himalayas or in India as a whole, are for example, *Centaurium pulchellum* (Sw.) Druce (n = 18, 27, 36), *Trichodesma indicum* (L.) RBr (n = 11, 22 in India), *Convolvulus pluricaulis* Choisy (n = 18, 2n = 36, n = 10), *Cuscuta reflexa* Roxb. (n = 14, 15, 16, 21), *Scrophularia variegata* Bieb. (n = 12, 24), *Veronica beccabunga* L. (n = 9, 2n = 36), *Veronica hederifolia* L. (n = 9, 18 and 2n = 54), *Thunbergia erecta* T. Anders. (n = 14, 2n = 56), *Crossandra infundibuliformis* Nees. (n = 19, 2n = 20, 60), *Justicia simplex* D. Don (n = 9, 18) and *Adhatoda vasica* Nees. (n = 17, 2n = 56) (1).

Interesting enough is the fact that in many species growing in Western Himalayas and having a large geographical distribution (Europe, Central Asia, and/or America), the chromosome number found in the Himalayas is not the same as that found by the present author or other workers in other parts of their area. It is the case for exemple in: *Centaurium pulchellum, Asperugo procumbens, Lycopsis arvensis, Lithospermum arvense, Scrophularia scopolii, Pedicularis oederi, Phryma leptostachya.*

The taxonomic position of intraspecific chromosome races is a much disputed actual problem. We look into this situation through a simple definition of species brought forth by Mayr (1940) who considers species as „groups of actually or potentially interbreeding natural populations which are reproductively isolated from other such groups". The Swedish taxonomist Nannfeldt (1938) was the pioneer taxonomist to advocate for specific rank of the chromosome races; he says: „As soon as chromosome races (polyplotypes) are morphologically distinct and thus, recognizable to the taxonomist, they had better to be recognized as species, even if the morphological characters are small". Later on, following Nannfeldt, Löve (1951, 1954), Löve and Raymond (1957), Valentine and Löve (1958) advocated a specific rank for all the taxa differing in chromosome number. Löve (1952) believes that morphologically indistinguishable polyploids are not in existence either in North Europe or in other areas as well (cf. Valentine, 1950), a point on which many disagreed. However, Smith (1933), Smithwhite (1954),

(1) But there is a possibility that the polyploid plant studied by Grant comes from Malaysia.

Böcher (1961), De Litardière (1939) and Guinochet (1942–1943) are among those who stand against the absolute reliance on the chromosome numbers for taxonomic divisions. Favarger (1956) expressed the opinion that taxonomic treatment of chromosome races should not be governed by the single criterion of chromosome number, but by other morphological characters too. According to him, races differing in chromosome number may be elevated to the rank of subspecies or varieties depending on the cases. Davis and Heywood (1963) have also disapproved the idea of ranking diploids and polyploids belonging to a single collective species, as distinct species, no matter what the degree of morphological differenciation is.

The intraspecific chromosome races recorded in *Gentiana carinata* Griseb., though revealing morphological differences (see Table 10) are not significant as both races are found in Kashmir Himalayas. Only after studying the type material and after comparing it with the morphology of the races, may any speculation on the taxonomic status of these races be possible. Also, it would be prudent to assess the reproductive isolation the races possess.

The polyploid complex of *Solanum nigrum* L. demonstrates definite morphological characteristics (differences in growth habit, size of the plant, fruit colour, number of seeds per fruit, pollen size, stomatal size) which can be used for assessing the taxonomic status of different cytotypes. The correlation of morphological characteristics with chromosome number of different races observed in the present investigation seems to be a sufficient reason to give specific rank to each cytotype. The hybridization studies between different races by Tandon and Rau (1966) provided additional evidences for the reproductive isolation existing among the races.

The diploid taxon of *Scrophularia himalensis* found only in the Kashmir region of W. Himalayas is geographically isolated from the tetraploid race growing in the Kumaon Himalayas. The morphological features noticed in the diploid taxon, especially the non-branching, tall habit of growth, differ considerably from those of the tetraploid one with branching nature. A critical comparison of the type specimen with races studied here, may tell us whether the latter may or may not be placed in a different taxonomic unit.

The tetraploid *Veronica anagallis* L. is found only in Kashmir while the hexaploid race is found in Punjab and Kumaon. The tetraploid is characterized by more or less ovate leaves, while the hexaploid possesses ovate-lanceolate leaves.

In addition to this, many other characters of taxonomic value (see Table 6C) show distinct differences between the races. On the basis of these differences, Khoshoo and Khushu (1966) proposed a subspecific rank for the races. But a hybridization study between the races and a thorough comparison with the type material of the species *V. anagallis* L. and various closely resembling varieties of the same, may indicate the exact taxonomic status to be given; it seems to the present author that a specific rank for the races should be given here as in the various chromosome races of *V. hederifolia* by Fischer (1967).

The diploid race of *Plantago major* has a wide Eurasiatic distribution, but the hexaploid race is restricted to Central Himalayas and Eastern Asia. The variability of morphological characters noticed in the diploid taxon is more or less shared by the hexaploid also. Hence, a sharp distinction on mophological grounds is difficult to make between diploid and hexaploid chromosome races of *P. major*.

The hexaploid *P. asiatica* L. resembles the diploid *P. major* in all morphological features. The present author failed to observe a morphological distinction between *P. major* and the material of *P. asiatica* growing in extreme Siberia. Hence, the hexaploid taxon may be placed at the subspecific level.

A number of other species listed above, showing two or more chromosome numbers require a thorough morphological study with the aid of the type specimen before drawing any conclusion about their taxonomic status.

b) Aneuploidy

Aneuploid chromosome number variation is one of the cytological mechanisms for the origin of new species, and probably also of many genera. The most extensive aneuploid series in the plant kingdom is to be found in the genus *Carex* in which haploid numbers ranging from n = 6 to n = 56 have been reported and in which every number from 12 to 43 is represented by one or more species (Stebbins, 1950). Aneuploid chromosome number variation was observed in a large number of the genera studied currently. Intraspecific aneuploid races were noticed in *Cuscuta reflexa* (n = 14, 15, 16). In the light of the present work, previous records indicate the presence of aneuploid race in *Ipomaea coccinea* (2n = 28, 30), *Convovulus arvensis* (2n = 48, 50), *Barleria cristata* (2n = 34, 36, 38, 40), *Blepharis boerhaaviaefolia* (2n = 26, 28) and *Justicia gendarusa* (2n = 28, 30, 32). If different aneuploid numbers were noticed by different authors, it is not unlikely to suppose that in some cases, the discrepancy lies in wrong counts or in mistakes in identification of the material. However, in a number of well studied species of the European flora, an aneuploid process of intraspecific differentiation was observed without any doubt for example in *Cardamine pratensis* (Lövquist, 1956, Landolt and Urbanska, 1971), *Erysimum grex. grandiflorum* (Favarger, 1964, 1972) and *Carduus defloratus* (Favarger and Küpfer, 1970).

Intrageneric aneuploidy is found to be very prevalent in many genera of the *Scrophulariaceae, Acanthaceae* and *Verbenaceae*, whereas their role is confined to few genera only in *Gentianaceae, Boraginaceae* and *Solanaceae*. In the *Scrophulariaceae*, the genus *Veronica* possesses an extensive aneuploid series (n = 7, 8, 9, 14, 18, 20, 21, 23, 26, 27); *Scrophularia* has n = 8, 9, 10, 11, 12, 13, 15, 17, 24, 25; *Pedicularis* has n = 6, 7, 8; and *Verbascum* has n = 15, 16 and 18. In the *Acanthaceae*, an aneuploid series prevails in the genera *Ruellia* and *Barleria;* the evolution of the species is attributed to this phenomenon (De, 1966). The present work, revealing a series of haploid numbers in *Strobilanthes* (n = 9, 11, 13, 14, 16, 20) is again a clear indication of intrageneric aneuploidy operating as a mechanism in the speciation. In the *Verbenaceae*, the species evolution in the genus *Callicarpa* is attributed to aneuploidy by Sharma and Chatterjee (1963). In the genus *Myosotis*, gametic numbers vary from n = 12, 18, 24, 25, 26, 27, whereas in *Heliotropium*, the series shows n = 11, 12, 32. In the *Gentianaceae*, the genera *Gentiana* and *Swertia* make use of aneuploidy for the evolution of new species, since the Himalayan species studied here and belonging to the former genus has shown gametic number n = 9, 10, 13, whereas the latter demonstrates n = 8, 9, 10 and 13. Intrageneric aneuploidy is responsible for species origin in *Plantago* also, where the gametic number varies from n = 4–6.

The missing numbers in the aneuploid series might have been non-investigated ones. The variable nature of genera in their response to aneuploidy may be attributed to genetic factors, but this variability indicates the active stage of evolution to which these genera are comparatively subjected.

The current investigations have brought about new proofs to the fact that many genera are polybasic. To what extent is it possible to affirm that one of these basic numbers is more primitive than the others remains a question. It is likely too that at the birth of one genus, there is a time of variability for the chromosome number and that after it, the more favourable and stable chromosome number, and often several of them are fixed. In neighbouring genera, it seems that a parallel evolution of the karyotype has taken place (Favarger, 1962).

Various causes have been put forth by many workers for the incidence of aneuploidy. Weijer (1952) expressed that aneuploidy results from partial return to the basic number by the progeny of a triploid, whereas Tuschnjakova (1929) attributed the phenomenon to non-disjunction. MacMahon (1936) and Richardson (1933) suggested aneuploidy to be due to fragmentation while Duncan (1945) stood against this view, suggesting „B" chromosome as the cause of aneuploidy.

c) Meiotic abnormalities

The majority of the taxa currently investigatet show normal pairing of chromosomes at diakinesis. They undergo regular meiotic segregation and normal pollen grain formation. The disturbed meiotic instances are treated below:

1. Desynapsis:

Several types of deviations from regular pairing of chromosomes have been reported in the literature and one of the most interesting is desynapsis. The term desynapsis has often been used when chromosomes pair normally at pachytene but begin to fall apart at diplotene and commonly remain unpaired at diakinesis and metaphase I.

Depending on the degree of failure in pairing, Prakken (op. cit.) classified desynapsis into three groups: weak, medium strong and complete, on the basis of percentage of chromosome pairing. Although there are several cases of desynapsis reported in various plants and animal species, only a few of them are known to be completely desynaptic (*Datura*, Bergner *et al.*, 1934; *Hevea*, Ramaer, 1935; *Allium*, Levan, 1940; *Alopecurus*, Johnson, 1944). Desynapsis noticed in *Solanum nigrum* (n = 24) in the current work, falls in Prakken's medium strong category. But desynapsis noticed in *Withania somnifera* (n = 24) is weak.

As stated above, the frequency of bivalent formation was very low at both diakinesis and MI. Lack of chromosome homology cannot be used to explain the failure of chromosome pairing since the normal plant showed regular pairing of chromosomes. Differences in environmental conditions cannot be responsible for the deviation from the normal pairing since both types of plants were grown under similar conditions. It is possible that desynapsis has a genetic basis; the fact that one desynaptic plant occurred leads one to suspect the possibility of spontaneous gene mutation.

2. Secondary association:

The phenomenon of secondary association was first observed by Kuwada (1910) in *Oryza sativa*. It is believed that the post-synaptic association results from residual affinity between different chromosomes. The real significance as an expression of ancestral homology of associated bivalents was first realized by Lawrence (1931). Secondary pairing of bivalents is generally noticed from late diakinesis to MII. According to Lawrence (op. cit.), it indicates allopolyploidy, and he considers that the degree of such an association is a measure of the phylogenetic age of the form concerned.

Secondary pairing of chromosomes was reported in many plants: *Calceolaria clibrani* (Srinath, 1940), *Digitalis purpurea* (Buxton and Newton, 1928), *Verbascum phoeniceum* (Lawrence, 1931), *Angelonia grandiflora* (Rghavan and Srinivasan, 1940), *Striga* (Kumar and Abraham, 1941) and *Russelia* (Pal, 1961), a *Scrophulariaceae* in which chromosome size is comparatively small which is, according to Srinath (1940), one of the attributes of a secondary association. In all these cases, secondary pairing has been taken as a criterion of homology of associated bivalents and has been used to determine the basic chromosome number of the species studied. The pioneer work in this line was that of Nandi (1936) in rice, in which the basic number is ascertained as 5 on the basis of secondary pairing though the haploid number is 12.

In the present work, secondary association of bivalents was noticed in *Russelia sarmentosa* and in *R. juncea* (1) in the *Scrophulariaceae* and in *Platystema violoides* in the *Gesneraceae*. The number of chromosomes and the extent of their associations, however, have been found to vary from cell to cell in the same anther. These associations do not cause any irregularities in the subsequent stages of meiosis.

The concept of secondary association and the interpretations based on it have been frequently criticized. Sax (1931, 1932) could not recognize the secondary association described by Darlington *et al.* (1930) in *Pyrus*, since it was not realized in other genera. Clausen (1931b) expressed the need for caution in interpreting the origin of basic chromosome numbers from the secondary association. On the contrary, Catcheside (1937) concluded that it is a real phenomenon and suggested that *Brassica oleracea* n = 9 is a hyperploid derived from an ancestor with the haploid number x = 6.

Various causes have been ascribed for secondary association. Unfavourable temperature and habitats are reported to be two of the causes (cf. Kobayashi, 1952). Thomas and Revell (1946) have demonstrated that heterochromatic regions have a tendency to associate at meiosis in *Cicer arietinum* and that this phenomenon is related to the activity of ribonucleic acid.

According to Stebbins (1950, p. 362), „secondary association can be considered as an actual phenomenon which, in many instances, suggests the polyploid nature of a species or a genus but which may be considerably modified by segmental interchange, duplication of chromosome segments and other phenomena not at

(1) **The present author has studied these species cytologically but has not included them in the Table.**

all related to polyploidy. It is, therefore, not a reliable index of the exact basic haploid number possessed by the original ancestors of a group". Since the cytological findings of a large number of species of *Scrophulariaceae* were not in line with the basic number x = 5 suggested by Raghavan and Srinivasan (l.c.) the writer is of the opinion that secondary association should not be relied upon for the assessment of basic number in the absence of evidences from other sources.

3. Cytomixis:

In the course of the present investigation, cytomixis was noticed in *Pedicularis megalantha* (n = 8) and *Limnophila roxburghii* (n = 18) in the *Scrophulariaceae* and in *Plantago major* (n = 6) in the *Plantaginaceae*.

Gates (1911), working with *Oenothera gigas*, named the phenomenon of extrasion or passage of chromatin material from the nucleus of one pollen mother cell into the cytoplasm of adjoining pollen mother cells as „cytomixis". This process was described as early as 1901, in the pollen mother cells of *Crocus vernus* (Kornicke), and the epidermal layers of several other monocotyledons plants (Miche, 1901).

The extrusion of chromatin material may affect a series of cells. Gates (1911) reported that cytomixis takes place at the same time in all the pollen mother cells of a given anther in *Oenothera gigas* and always in the same direction. However, Kattermann (1933) found that movement was not uniform in direction and the contents of one cell could often be seen in two or three neighbouring cells. The phenomenon in *Pedicularis megalantha* and *Plantago major* was found to take place between two neighbouring cells with the transfer of a varying amount of chromatin material. It was noted that the nucleus of the cell undergoing cytomixis may often remain behind (Gates, 1911) or pass *piecemeal* into the cytoplasm of the neighbouring cell (Youngman, 1931). Though commonly cytomixis was found to occur from leptotene to metaphase-I (Kihara and Lilienfeld, 1934), cases are also known where cytomixis occurred at a stage as late as second telophase (Stebbins, 1932). But the phenomenon observed in the present material is almost restricted at MI.

In many cases, the diminution of chromosome number has been attributed to cytomixis. Yamashita (1937) considered nuclear migration to be the cause of a group of cells with reduced chromosome numbers in *Triticum*. Kihara and Lilienfeld (1934) believed that pollen mother cells with reduced chromosome number might have arisen as a result of cytomixis. They also suggested the probable role of cytomixis in polyploidy. The observation of few PMC's with less chromosome number or little chromatin material in the present material, especially in *Plantago major*, agrees with the previous observations.

In *Pedicularis megalantha* and *Plantago major*, the cell wall may be defective and may possess narrow connections through which chromosome material passes.

Since cytomixis can bring about variation in chromosome numbers in the gametes, the possibility that cytomixis might have played a role in the production of aneuploid plants cannot be ruled out. The intraspecific polyploidy (n = 18) noticed in *Plantago major* has probably evolved through the help of cytomixis in the remote past.

Part 2. Cytogeographical aspects

An attempt to compare the alpine flora of the Western Himalayas with the orophilous flora of the Alps.

Since the works of Hagerup (1931) and Tischler (1935), statistics of polyploids have been carried out on the flora of rather numerous parts of the world, especially in Europe and North America (Löve, 1949; Reese, 1958) and in tropical Africa (Mangenot and Mangenot, 1962). It seemed interesting to us to establish the percentage of polyploid taxa in the samples of the flora of the Western Himalayas that we have been studying (Table 11). The percentage of polyploids obtained is low (37.1%). However, this result is unreliable for the following reasons: first of all, the statistics concern only the ten families of gamopetalous. Sokolovskaya and Strelkova (1938) have insisted on the necessity of working especially on the *Graminaceae* because of the importance of their sociological characteristics. On the other hand, and though we have mainly prospected the upper levels of vegetation, our collections have also included plants of the tropical, subtropical and montane (or mediterranean) levels. That is the reason why we have presented another set of statistics which seems to us more representative, that is, based on the whole lot of species with ecological optimum above 3300 m of altitude (alpine and subalpine levels including the level of the high mountains forests) which are the genuine orophilous plants after Favarger (1972). We have listed all

Table 11

	W. Himalayas			
	No. of species cytologically studied	Diploids	Polyploids	% of polyploidy
Gentianaceae	22	18	4	18.2
Convolvulaceae	15	11	4	26.7
Boraginaceae	26	21	5	19.2
Verbenaceae	7	4	3	42.9
Solanaceae	27	19	8	29.6
Scrophulariaceae	59	37	22	37.3
Orobanchaceae	2	–	2	100.0
Gesneriaceae	6	2	4	66.7
Acanthaceae	31	11	20	64.5
Plantaginaceae	2	1	1	50.0
Total	197	124	73	37.1

the orophilous species growing in the Western Himalayas whose chromosome numbers have been determined, most often by Mehra and his students and by other Indian workers (including our own results). This represents an amount of 191 taxa distributed in 31 families.

Among the orophilous plants of the Western Himalayas, there are 44% of polyploids and 56% of diploids.

Other statistics dealing with the 570 species of the flora of the W. Himalayas (known chromosome number), growing above 1800 m, that is, in what is called the temperate and alpine Himalayas (Hooker, op. cit.), have given us the same relative proportions of diploids and polyploids.

The difference between the first statistics and the following ones seems to show that in the ten gamopetalous families studied by the author, the percentage of polyploids is lower than in the whole flora. However, in the two families of *Acanthaceae* and *Gesneriaceae*, the percentage of polyploidy is relatively high (see p. 187).

So the orophilous flora of the Western Himalayas and probably all the extropical flora of this chain is characterized by a percentage of polyploids rather low, of about 44%.

However, it must be added that only about 1/3 of these floras was hitherto cytologically studied.

The orophilous flora from several other mountainous ranges in Asia was investigated by Sokolovskaya and Strelkova (1938) with the following results:

	Pamir	Altaï	Caucasus
Number of species studied	150	200	164
% of polyploids	85%	65%	50.5%

Our own results on the W. Himalayan flora mostly differ from those obtained from the Pamir range which lies not very far north, and also from those of the Altaï mountains; however, they come near the results from the Caucasus range, though they are still lower than the latter.

To explain the relatively low percentage of polyploids in the Western Himalayas, some authors will perhaps put forward the rather low latitude of this chain ($30^0 - 35^0$N.). As a matter of fact, Sokolovskaya ([1]) has shown in East Asia a south-north gradient of increasing polyploidy rather similar to that observed in Europe by Tischler, Löve and Reese (op. cit.).

	Primorye Territory	Sakhaline	Kamchatka	Koriakian Land
Number of species studied	218	156	160	119
% of polyploidy	44.1%	51.5%	58.7%	58.3%

([1]) 1960, 1963, 1966.

However, as far as mountainous ranges are concerned, the influence of the latitude will be corrected by altitude and many other factors, so that the relation of polyploidy with latitude will be defeated.

The „climatic" explanation will be partly correct because the ecological conditions to which the orophilous plants are submitted in Pamir are very severe, much more than in the Western Himalayas.

As early as 1954, Miège, discussing the distribution of the polyploid species from the genus *Dioscorea* in tropical Africa and in south Europe, and Favarger (1954) about the nival flora of the Alps, have pointed out that the Hagerup-Tischler's explanation did not apply either to the tropical regions or to the high mountains floras.

In this connection, an important proof has been given by Mangenot and Mangenot (1962) who showed that the flora of the high forests of Western Africa numbered 85–90% of polyploids.

To explain the low percentage of polyploids in the orophilous flora of Caucasus, Sokolovskaya and Strelkova (1940) have put forward a historical geobotanical explanation. Thus, when the question of polyploidy deals with historical geobotany, it is necessary to change the method of percentage of polyploids, for, as Favarger showed it (1961), polyploids considered with a historical outlook do not all have the same value. Therefore, the above author has proposed the method which he has called: „spectrum of relative oldness of a flora" in which he perceives old elements: palcopolyploids + diploids; elements of a middle age: mesopolyploids, and young elements: neopolyploids + taxa having differentiated „chromosome races" on the same territory.

Thanks to this method, Favarger has compared the nival flora of the Alps to that of S.W. Groënland. Johnson and Packer (1967) used it to analyze the flora of a particular region of Alaska.

The next table allows us to compare the spectrum of relative oldness of the orophilous flora between the W. Himalayas and the Swiss Alps (Table 12). Though, the proportion of species cytologically studied is still low in the Himalayas (27% to 29%), we think that we are able to conclude from the comparison that *the orophilous flora of W. Himalayas is richer in old elements than the flora of the Alps, and is at the same time poorer in elements (M) of a middle age and in recent elements (N + R).*

After its present composition, the orophilous flora of the W. Himalays does not show any genetical affinities with the tropical or subtropical flora of the lower levels.

After the geologists, at the time of the upheavel of the Himalayas, the Indian peninsula has separated from the chains in process of upheavel by the whole extent of the Téthys. The contact between the peninsular tropical flora and the true Himalayan flora took place only at the Pliocene, even at the Pleistocene (Legris, p. 420) and, at that time, the orophilous plants had already differentiated. However, it is most probable that at the time of the orogenic movements, the flora of low Himalayan countries, in the North as well as on the beaches of the Téthys, was a subtropical flora. Still, at the Pleistocene, the flora of the Valley of Kashmir studied by Puri (op. cit.) was partly composed of tropical genera. As Scharfetter (1929) has shown, some genera of this arcto-tertiary flora have been able to adapt

Table 12

	Orophilous flora of the Western Himalayas (above 3300 m)		Flora of the nival level of the east part of the Swiss Alps (after Favarger 1961)	
Number of species (after Hooker's flora for the Himalayas)	651		220	
Number of species cytologically known	184 (1)		204	
Paleopolyploids (P)	12%	66.3%	3.9%	56.9%
Diploids (D)	54.3%		53.0%	
Mesopolyploids (M)	24.4%		30.9%	
Neopolyploids (N)	4.4%	9.3%	6.8%	12.2%
„Chromosome races" (R)	4.9%		5.4%	

(1) The difference between this number and the number 191 reported (p. 000) and included in the statistics of the rough percentage of polyploids is due to the fact that in the last calculation, we have added to the diploid species, the diploid races of the species presenting such a differentiation

N.B. The results obtained on all the species (570) growing above 1800 m (temperate and alpine Himalayas) are very similar:

P + D = 68.9%
M = 22.5%
N + R = 8.6%

to the conditions of high mountains, for ex.: *Wulfenia amherstiana* (Himalayas) and *W. carinthiaca* (Alps) and the Rhododendrons. Others have gone through more important genetical modifications and have produced the numerous species of *Primula, Saxifraga, Androsace, Gentiana* which are found in the Alps as well as in the Himalayas. The southern branch of the arctotertiary flora related to the Mediterranean flora and even to the African flora which produced numerous orophytes in the Alps does not seem to have produced many Himalayan orophytes. The only ones which might be quoted are: *Rubia tibetica, Jurinea spec., Nepeta spec.* It is possible that the establishment of the Mediterranean group in the Kashmir valley is not very ancient. Puri (op.cit.) thinks that in the valley of Kashmir, climatic changes happened, in the direction of more xeric conditions, as the beginning of the Pleistocene which involved the destruction of the tropical flora of Liddarmarg.

In conclusion, the author believes that the orophilous flora of the Western Himalayas was differentiated at the Tertiary, from elements of the arcto-tertiary flora (mainly from the boreal and asiatic branch) which produced psychrophilous species, and that this phenomenon took place through gradual speciation (without polyploidization). The same has happened in the Alps too, but from

other stocks and in a different manner, so that there are nowadays, few similarities between the orophilous floras of the Alps and of the Western Himalayas, *at the specific level.*

After a first provisional estimation, the orophilous flora of the W. Himalayas includes about 650 species. It is likely that about 200 species were described since the publication of Hooker's flora, which gives a total of ca. 850 species, a number which can be compared with that published by Favarger (1972) for the Alps, i.e. 1049 species, though it is smaller. From these 650 species, only 88 (i.e., 13.5%) are also growing in the Alps. As Engler (1879) has already noted, all the orophilous species common to the Alps and to the Himalayas, are met in Siberia too, or in the Arctic region.

The family *Gentianaceae* gives a good example of the independent differentiation of orophytes in the Alps and in the W. Himalayas (Table 13).

It can be seen that in the W. Himalayas, there are many species of *Swertia* (a single species in the Alps). No representative of the genera *Jaeschkea* nor *Halenia* is known in Europe. The distribution of the *Gentiana spec.* into the different tribes is very different too in the Alps and in our country. A single species, *Pleurogyne carinthiaca* is common to both chains (1).

In the genus *Pedicularis*, the sections *Siphonanthae* and *Ortorrynchae* including about 15 species in the W. Himalayas are not represented in the Alps where ten species of *Rhyncholophae* are growing, whereas only two are met in the W. Himalayas.

From the previous considerations, it would be likely to conclude that the orophilous flora of the W. Himalayas is of the same date as the flora of the Alps. Now, how can this greater richness in old forms be explained?

Two main reasons can be put forward:

1. The Himalayan flora was certainly much less disturbed by the Quaternary glaciations than the flora of the Alps.

2. Besides the orophytes, differentiated on the spot from arctotertiary ancestors, the Western Himalayas received several orophytes from the neighbouring ranges of mountains, i.e. those of Central Asia and chiefly from the Western Chinese mountains (through the Eastern Himalayas). The importance of this chain as link will never be too estimated. It is well known that in the Chinese and Japanese regions, the arcto-tertiary flora was much better preserved. These exchanges took place without long migrations, because the W. Himalayas were not far from the centers of origin of these taxa.

On the contrary, it seems likely that some genera of the alpic flora such as *Primula* section *Auricula, Androsace* section *Aretia,* many species of *Gentiana* have originated in Central Asia and have undergone, at the end of the Tertiary, very long migrations from their centers to Europe during which they became polyploids (Kress, 1963).

This explanation agrees entirely with that proposed by Sokolovskaya and Strelkova for the Caucasian orophilous flora. Interesting enough, the present work

(1) *Gentiana tenella* of the Alps seems to be replaced in the W. Himalayas by *G. duthiei.*

Table 13

	Number of species in each genus	
	W. Himalayas	Alps
Genus *Gentiana* (incl. *Gentianella*)	36	38
Swertia	15	1
Pleurogyne	4	1
Halenia	1	–
Jaeschkea	2	–

	Number of species of each section of the genus *Gentiana*	
	W. Himalayas	Alps
Subgenus *Gentiana*		
Section *Coelanthe*	–	5
Pneumonanthe	–	2
Frigida	5	2
Aptera	3	1
Isomeria	2	0
Chondrophylla	17	1
Thylacites	–	4
Cyclostigma	–	9
Subgenus *Gentianella*		
Section *Crossopetalum*	2	1
Amarella	5	11
Arctophila	1	–
Comastoma	1	2

gives some examples suggesting a rather recent migration of taxa from Central Asia to Europe: *Lycopsis arvensis, Asperugo procumbens, Solanum nigrum, Veronica grex hederifolia*, in which the Himalayan taxa are diploids, whereas the corresponding taxa from Central Europe (including alpic region) are higher polyploids. However, we must say that in three other cases: *Plantago asiatica-major, Pedicularis oederi, Scrophularia scopolii* (1), the Himalayan populations, or parts

(1) The case of *Scrophularia scopolii* must be verified.

of them, are polyploid, but it does not imply that these plants were coming from Europe (for the case of *Plantago*, see Favarger and Vasudevan, 1972).

To conclude, the author cannot agree with Legris' assertion (op. cit., p. 444), when he says about the orophilous flora from W. Himalayas: „le froid et l'intensité des radiations ultraviolettes sont les causes de nombreuses mutations et d'un pourcentage élevé de polyploïdes et d'hybrides. Ces caractéristiques d'une flore jeune expliquent que l'Himalaya ait pu jouer le rôle d'un centre de dispersion vers les régions tempérées". The flora of the W. Himalayas is poorer in polyploids than the Alps and it has preserved a greater number of ancient taxa.

Summary

In the present paper, a series of cytological studies on numerous species from Western Himalayas and Europe belonging to several families of *Sympetalae* is concluded. Some chromosome numbers were determined for the first time; others differed from earlier determinations. Intraspecific polyploidy was observed in *Plantago major* (n = 6, 18) in populations from W. Himalayas. The intrageneric cytological evolution of all genera studied was tentatively explained and new basic numbers (x) have been suggested for many genera (see discussion of the families).

A special note is made on the role played by aneuploidy in evolution. Various meiotic abnormalities like desynapsis, secondary association and cytomixis are discussed.

An analysis of the extent of polyploidy in the ten families of the current investigation showed 37% polyploidy in Western Himalayas. It is significant to note that the tropical families *Gesneriaceae* and *Acanthaceae* possessed a higher percentage of polyploidy. Separate statistics of orophilous plants of Western Himalayas showed 44% polyploids and 56% diploids. A comparison of polyploidy in the flora of the alpine level of the eastern part of the Swiss Alps and in the orophilous flora of the Western Himalayas, on the basis of „polyploid spectrum" of Favarger, proved that the orophilous flora of Western Himalayas is richer in old elements and poorer in elements of middle age (M) and in recent elements (N+R). This difference is attributed by the author to the weaker influence of quarternary glaciations in the Himalayas and to exchanges, without long migrations, with the flora of Western Chinese mountains through the Eastern Himalayas.

Zusammenfassung

Cytotaxonomische und cytogeographische Untersuchungen an Pflanzen aus dem Himalaya im Vergleich zu verwandten Pflanzen aus den Alpen. Teil III.

Diese Arbeit bildet den Schluss einer Serie cytologischer Untersuchungen an zahlreichen Arten sympetaler Familien aus dem westlichen Himalaya und aus den Alpen. Manche Chromosomenzahlen wurden erstmals bestimmt; andere waren von früheren Bestimmungen verschieden. Intraspezifische Polyploidie wurde bei Plantago major (n = 6, 18) aus dem westlichen Himalaya beobachtet. Die intragenerische cytologische Entwicklung der untersuchten Gattungen wird diskutiert und für mehrere Gattungen werden neue Grundzahlen (x) vorgeschlagen (siehe Diskussion der Familien). Die Bedeutung der Aneuploidie für die Entwicklung wird untersucht; verschiedene Abnormitäten der Meiose (Desynapsis, sekundäre Assoziation, Cytomixis) werden diskutiert.

Die untersuchten Arten aus zehn Familien ergaben einen Polyploidiegrad von 37% für den westlichen Himalaya. In den tropischen Familien der *Gesneriaceae* und *Acanthaceae* war der Polyploidiegrad besonders hoch. Unter den orophilen Arten des westlichen Himalayas fanden sich 44% polyploide und 56% diploide. Ein Vergleich der Polyploidie in der Flora der alpinen Stufe der östlichen Schweizer Alpen und in der orophilen Flora des westlichen Himalayas auf der Grundlage des „polyploiden Spektrums" von Favarger zeigt, dass der westliche Himalaya reicher an alten Florenelementen und ärmer an jüngeren Florenelementen ist. Dieser Unterschied zu den Verhältnissen in den Alpen wird dem geringeren Einfluss der quartenären Vergletscherungen im Himalaya und den Beziehungen zu den Bergen Westchinas zugeschrieben.

Fig. 140: Orobanche epithymum D.C. n = 19 MI.
Fig. 141: Orobanche alba stephan n = 19 MI.
Fig. 142: Orobanche kashmirica Clarke n = 19 MI.
Fig. 143: Didymocarpus pedicellata Br. n = 18 MI (1600 x).
Fig. 144: Didissandra lanuginosa Clarke n = 10 MI.
Fig. 145: Chirita bifolia D. Don n = 14 Diakinesis.
Fig. 146: Chirita pumila D. Don n = 4 Late Diakinesis.
Fig. 147: Platystemma violoides Wall. n = 20 MI, secondary association of bivalents are noticed.
Fig. 148: Rhynchoglossum obliquum Blume n = 18 MI.
Fig. 149: Hemigraphis latebrosa Nees n = 14 (1600 x).

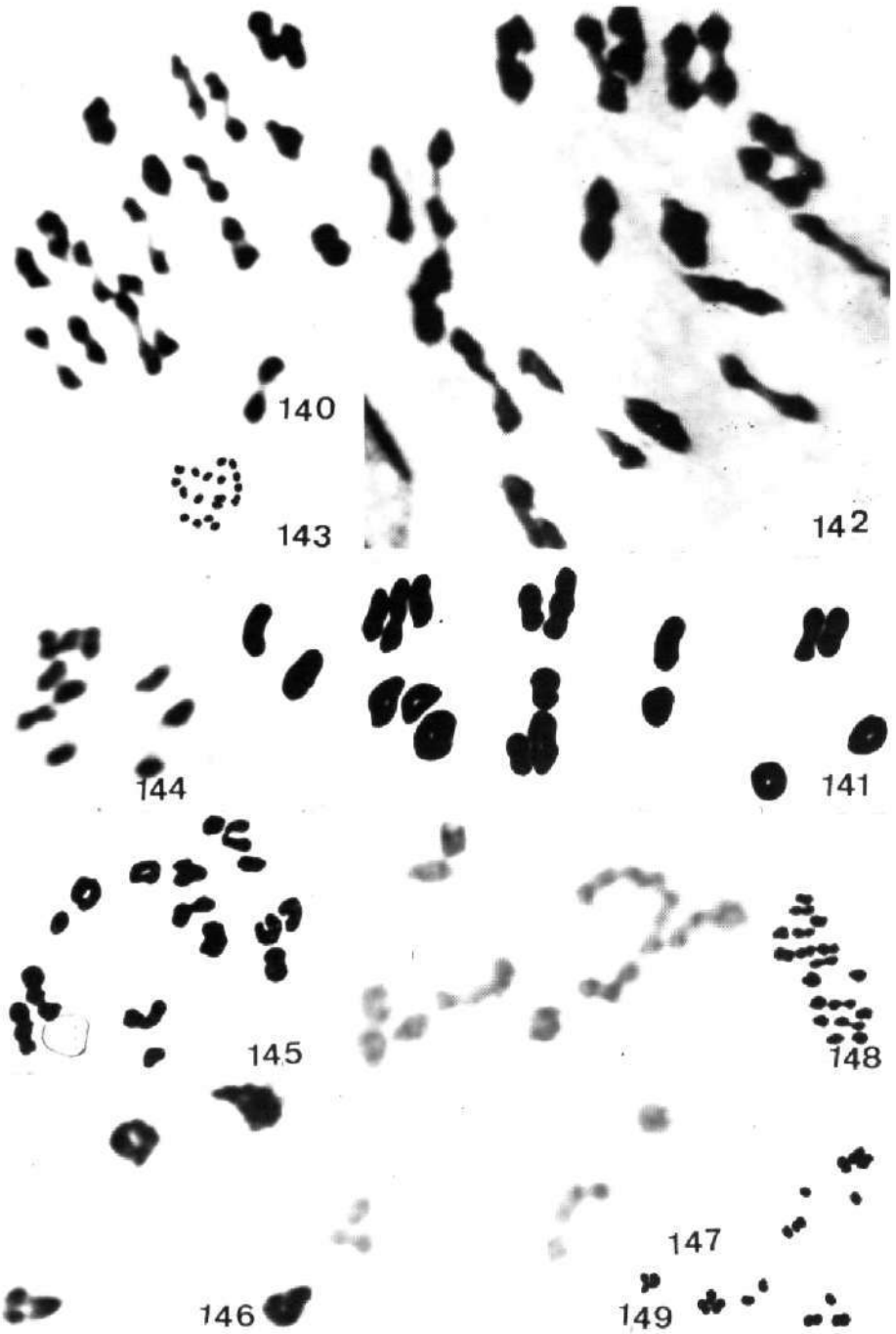
Fig. 150: Strobilanthes glutinosus Nees n = 14 MI.
Fig. 151: Strobilanthes quandrangularis Clarke n = 11 AI.
Fig. 152: Strobilanthes wallichi Nees n = 20 MI.
Fig. 153: Strobilanthes atropurpureus Nees n = 16 MI.
Fig. 154: Barlaria gibsoni Dalz. n = 20 AI.
Fig. 155: Blepharis boerhaaviaefolia Pers n = 14 AII (1600 x).

Fig. 156: Lepidagathis purpuricaulis Nees n = 42 MI.
Fig. 157: Justicia gendarussa L. n = 14 AI.
Fig. 158: Justicia pubigera Wall. n = 14 MI.
Fig. 159: Justicia diffusa Willd. n = 9 Late Diakinesis.
Fig. 160: Rungia parviflora Nees n = 26 AI.
Fig. 161: Plantago major L. n = 6 MI.
Fig. 162: Plantago major L. n = 18 MI.
Fig. 163: Plantago major L. n = 6, showing cytomixis. Note a PMC with one bivalent.
Fig. 164: Plantago intermedia Gilib. 2n = 12 showing two pairs of satellites.
Fig. 165: Plantago intermedia Gilib. 2n = 12 idiogram.
Fig. 166: Plantago asiatica L. 2n = 36 idiogram.

Fig. 167: Cytological races of *Gentiana carinata* Griseb. (n = 10, 20).
Fig. 168: Cytological races of *Solanum nigrum* L. (n = 12, 24, 36).
Fig. 169: Cytological races of *Scrophularia himalensis* Royle (n = 12, 24).
Fig. 170: Cytological races of *Veronica anagallis* L. (n = 18, 27).
Fig. 171: Varieties among the tetraploid race of *Veronica anagallis* L.
Fig. 172: Morphotypes of *Strobilanthes dalhousianus* Clarke.
Fig. 173: Morphological races among the diploid race of *Plantago major* L. (n = 6).
Fig. 174: Morphological races among the hexaploid race of *Plantago major* L. (n = 18).

Fig. 175: *Cactus* vegetation in subtropical Western Himalayas (Rampur in Siwalik) 1000 m.
Fig. 176: *Quercus incana* forest in Mussoorie Hills (1900 m).
Fig. 177: *Betula utilis* and *Abies spectabilis* growing in the subalpine zone of W. Himalayas. (In Garhwal 2700–3000 m).
Fig. 178: *Pinus gerardiana* growing in the inner dry zone of W. Himalayas at 2000 m (Sutlej valley behind Simla).
Fig. 179: *Picea exelsa* in Kashmir (3000 m).
Fig. 180: *Cedrus deodara* in Kumaon region of W. Himalayas.

Fig. 181: *Abies spectabilis* and *Acer* species in Kashmir.
Fig. 182: *Abies pindrow* forest in Gulmarg (2700–3000 m) in Kashmir.
Fig. 183: Timberline in Kumaon (3600 m).
Fig. 184: Alpine Juniperous meadows in Kashmir (3500 m).
Fig. 185: Awvalley in Ladakh, the dry cold desert of W. Himalayas. Upperslopes of mountains are nearly barren and herbaceous vegetation is found along the river banks.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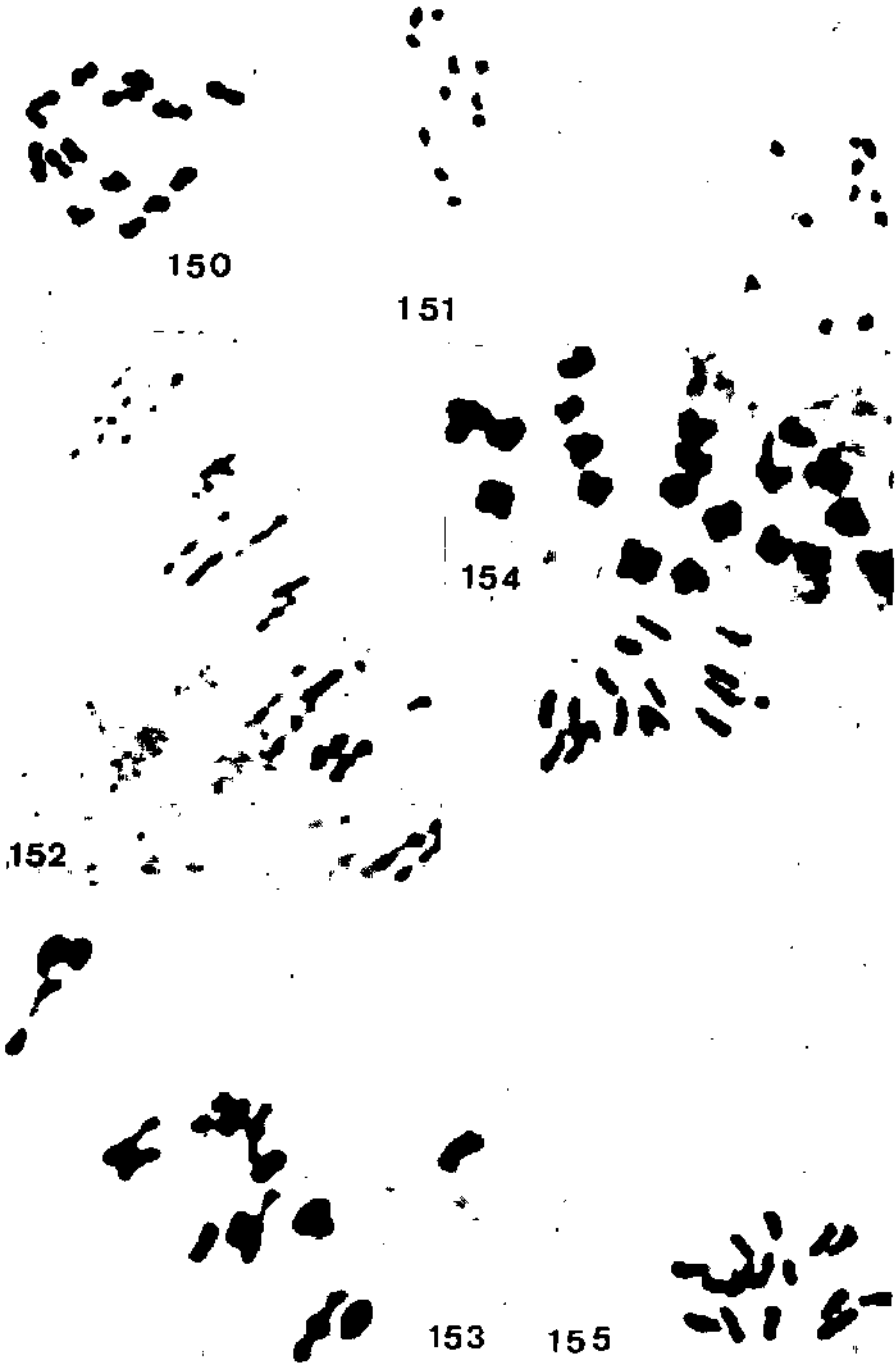
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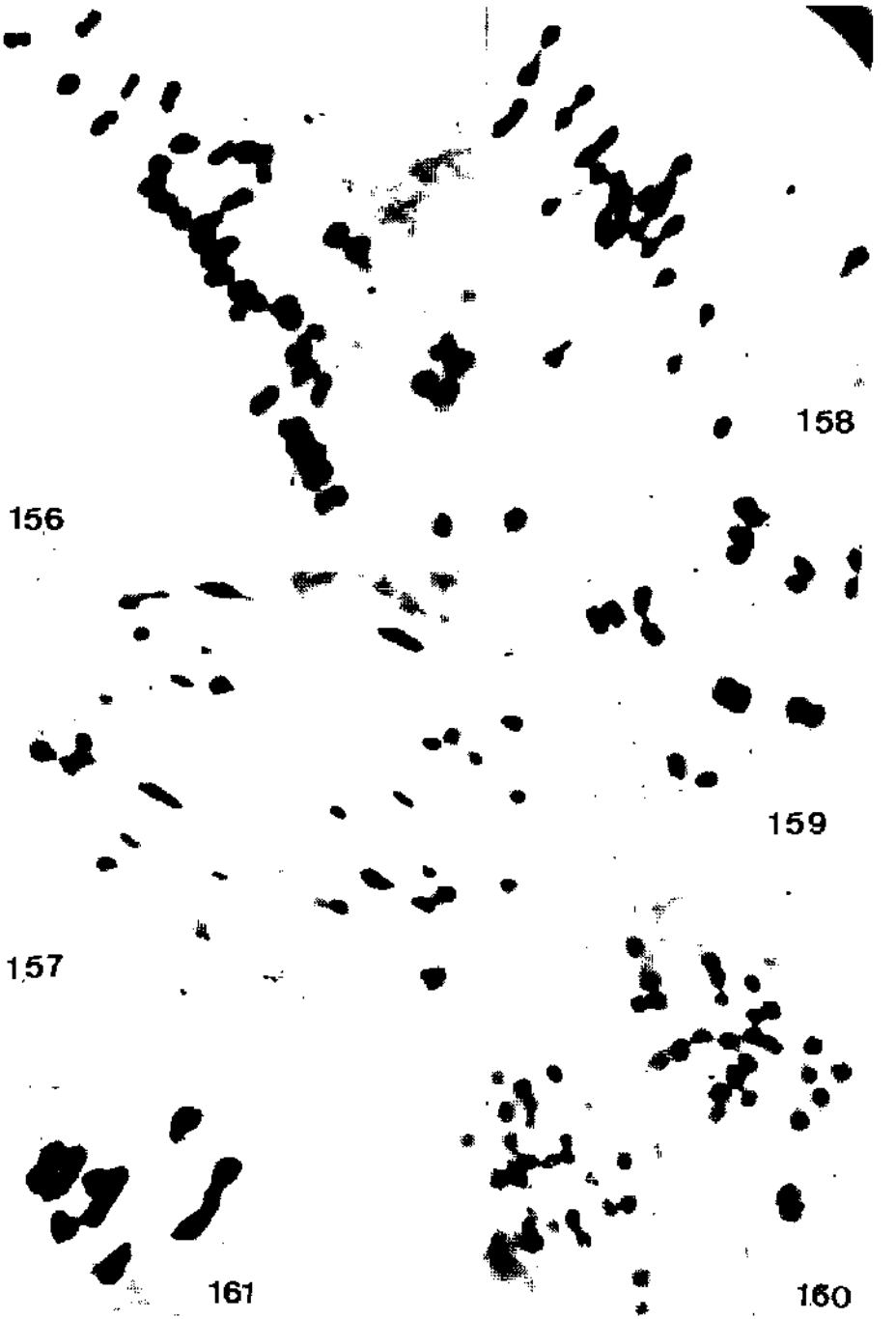
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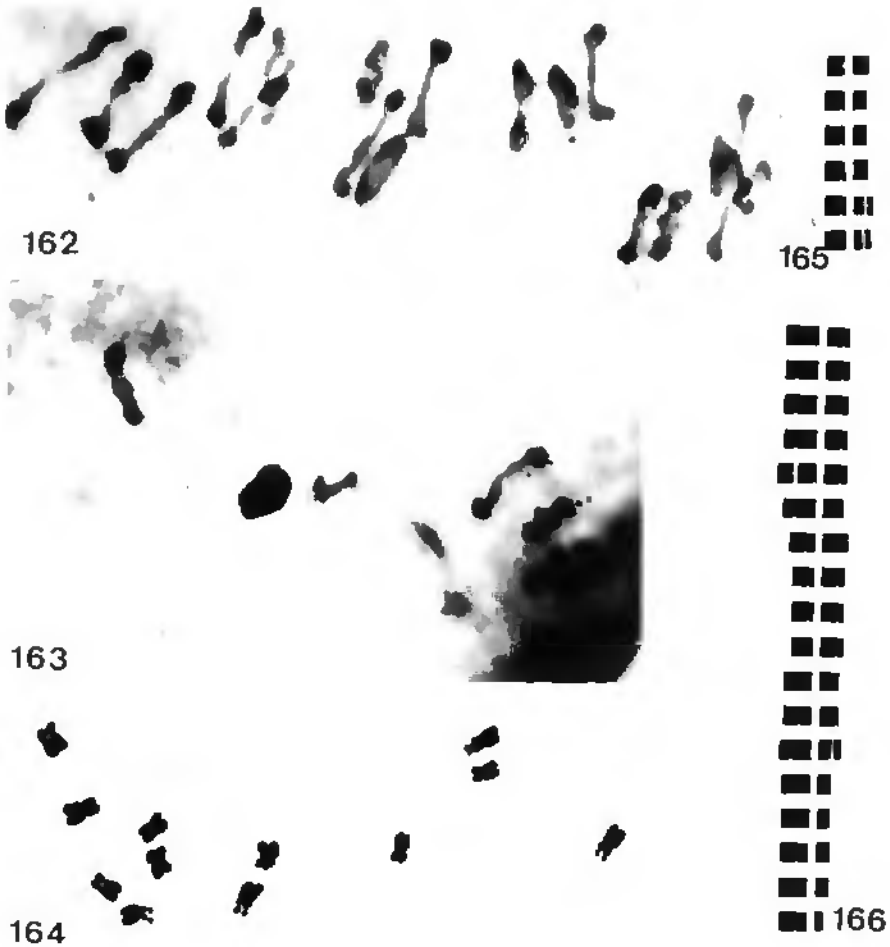
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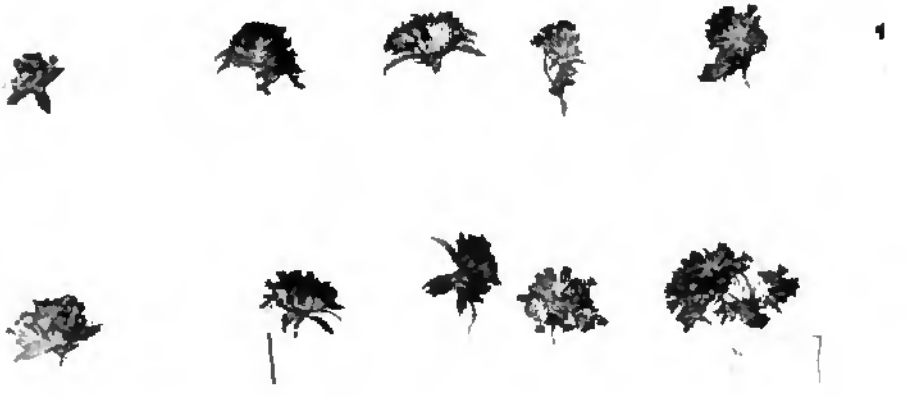

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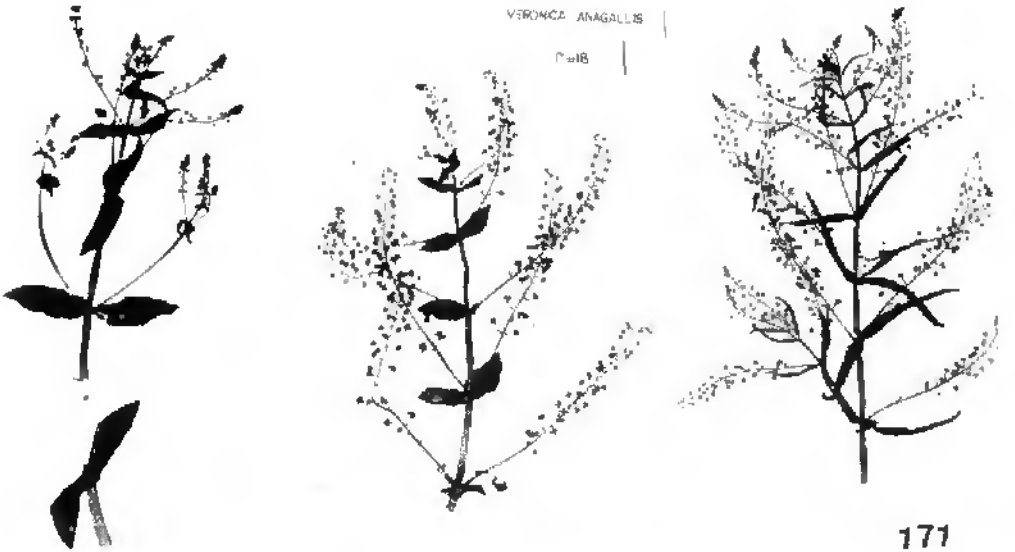
0-24 0-30 168


SCROPHULARIA HIMALENSIS
n=24
169


VERONICA ANAGALLIS
n=27
170



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