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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 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 heartfelt 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 presaturated 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	$29^{\circ} . 22' \text{N}$	$79^{\circ} . 29' \text{E}$	1900 m
Mussoorie Hills (Mussoorie, Dehra Dun, Chakrata, Rishikesh, Gangotri, Kedarnath)	Mussoorie	$30^{\circ} . 28' \text{N}$	$78^{\circ} . 10' \text{E}$	1900 m
Kashmir (Gulmarg, Srinagar, Pahalgam, Ladakh, Gurez valley, Batot, Aporwat, Sonamarg)	Gulmarg	$34^{\circ} . 25' \text{N}$	$74^{\circ} . 40' \text{E}$	2700 m
Siwalik Hills and adjacent plains (Chandigarh, Pinjore, Kalka, Kasauli)	Chandigarh	$30^{\circ} . 44' \text{N}$	$76^{\circ} . 53' \text{E}$	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 (Siwaliks), 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 cytobotany. 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 between 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.

<i>Upper limit</i>	<i>Vegetation</i>	<i>Name of the level</i>
ca. 6000 m	Open nival vegetation	Nival
5500 m	Alpine meadows and scrub of <i>Rhododendron anthopogon</i> , <i>Juniperus spec.</i> , <i>Salix</i> , etc.	Alpine
4000 m	<i>Abies spectabilis</i> and <i>Betula utilis</i> forest, with <i>Rhododendron</i> , <i>Sorbus</i> , etc.	Level of highmountain forest
3300 m	<i>Quercus semecarpifolia</i> forest	Moist mountainous level
2700 m	<i>Picea morinda</i> - <i>Cedrus</i> forests	
2400 m	<i>Quercus dilatata</i> forest	
2100 m	<i>Cedrus deodara</i> - <i>Quercus incana</i> forest	
1800 m	Dry forest with <i>Pinus roxburghii</i>	Subtropical
1000 m	Dry deciduous forest with <i>Shorea</i>	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	n	Chromosome number 2n	Level of ploidy	Previous report
<i>Species from the Western Himalayas studied by the author (A)</i>						
Subfamily Gentianoideae						
Tribe Gentianeae						
Subtribe Erythraeinae						
<i>Centaurium pulchellum</i> * (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 <i>Gentiana</i>						
Subgenus Gentiana						
Section Chondrophylla Bg.	1900 m Nainital, India	2045	10	—	2x	
<i>G. argentea</i> Royle **						
<i>G. capitata</i> Ham. var. <i>strobiliformis</i> Clarke **	Gulmarg, 2700 m Kashmir, India	4212	10	—	2x	
<i>G. carinata</i> Griseb. **	Razhan Hill, 2900 m Kashmir, India	4278	10	—	2x	
		4213	20	—	4x	n = 20, Mehra & Gill 1968
<i>G. pedicellata</i> Wall. ** (= <i>G. quadrifaria</i> Blume)	Khathi, 2200 m Kumaon, India	2548	9	—	2x	
Subgenus Gentianella						
Section Amarella Griseb. (!)	Tajawas glacier, 2700 m Kashmir, India	4263	9	—	2x	2n = 26, Wada 1966
<i>G. moorcroftiana</i> Wall.*						
Section Crossopetalum Fröhl.	Sind Valley, 2700 m Kashmir, India	4252	13	—	2x	2n = 44, Löve 1953
<i>G. detonsa</i> Fries*						
2. <i>Jaeschkea latisepala</i> Clarke**	Khilanmarg, 3000 m Kashmir, India	4253	10	—	2x	
3. <i>Pleurogyne carinthiaca</i> Griseb. ** (= <i>Lomatogonium carinthiacum</i> Wulfen)	Sonamarg, 2700 m Kashmir, India	4264	24	—	8x	2n = 40, Fürnkranz 1965 n = 23, Favarger (unpublished)
4. Genus <i>Swertia</i>						
Section Ophelia (Don)						
Benth. and Hook.	3050 m Badrinath, India	2009	10	—	2x	n = 10, Khoshoo and Tandon 1963 n = 12, Mehra and Gill 1968
<i>S. paniculata</i> Wall.	1900 m Nainital, India	2015	8	—	2x	n = 8, Khoshoo and Tandon 1963
<i>S. cordata</i> Wall.	Chinapeak, 1900 m Nainital, India	2014	13	—	2x	2n = 13, Khoshoo and Tandon 1963 n = 13, Mehra and Gill 1968
<i>S. chirata</i> Ham.	1900 m Nainital, India	2020	13	—	2x	n = 13, Khoshoo and Tandon 1963
<i>S. angustifolia</i> Ham.	Binsor, 2100 m Almora, India	2013	13	—	2x	n = 13, Khoshoo and Tandon 1963 n = 12, Mehra and Gill 1968
<i>S. tetragona</i> Clarke	1900 m Nainital, India	2032	9	—	2x	n = 9, Khoshoo and Tandon 1963
<i>S. lurida</i> Royle **	1900 m Mussoorie, India	2067	13	—	2x	
<i>S. alata</i> Royle	1900 m Nainital, India	2008	13	—	2x	n = 13, Khoshoo and Tandon 1963 n = 12, Mehra and Gill 1968
Section <i>Swertia</i>						
<i>S. speciosa</i> Wall.	Gulmarg, 2700 m Kashmir, India	4284	13	—	2x	n = 13, Khoshoo and Tandon 1963 n = 13, Mehra and Gill 1968
<i>S. petiolata</i> Royle	Aporwat, 3900 m Kashmir, India	4241	13	—	2x	n = 13, Khoshoo and Tandon 1963
<i>S. thomsonii</i> Clarke	Sonamarg, 2700 m Kashmir, India	4254	13	—	2x	n = 13, Khoshoo and Tandon 1963
5. <i>Halenia elliptica</i> D. Don	Gangaria, 2800 m Kumaon, India	2011	11	—	2x	2n = 22, Favarger 1952b
Subfamily Menyanthoideae						
Tribe Menyantheae						
<i>Limnanthemum nymphaeoides</i> Link.	Srinagar, 165 m Kashmir, India	4226	27	—	6x	2n = 54, Scheerer 1939 and Sobti and Singh 1961
<i>Species from the Alps studied by the author (B)</i>						
Gentiana subgenus						
Gentianella						
<i>G. ramosa</i> Hegetschw.*	Mattmark, 2210 m Valais, Switzerland	—	36			
<i>G. anisodonta</i> Borbas	Klagenfurterhütte, 1050 m Karawanken, Austria	18	—		n = 18, Favarger 1965	
	Zochpass, 2250 m Lienzer, Dolomiten, Austria	18	—		n = 18, Favarger 1965	
<i>G. germanica</i> Willd. ssp. <i>rhaetica</i> A. et J. Kerner (?)	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.

(!) Nilsson (1967, p. 106) placed this species in section *Arctophila*.(?) After Fiori (1925–1929), this plant would be the *forma forojuliensis* Gortani

Table 2: CONVOLVULACEAE

Taxa	Source and altitude	Collection number	n	Chromosome number 2n	Level of ploidy	Previous report
<i>Species from the Western Himalayas studied by the author (A)</i>						
Subfamily Convolvuloideae						
Tribe Convolvuleae						
<i>Ipomoea coccinea</i> L.*	Kathgodam, 400 m Nainital, India	2034	15	—	2x	2n = 28, Sharma and Datta 1958
<i>I. quamoclit</i> L.	Karnaprayag, 1000 m Kumaon, India	2026	15	—	2x	2n = 30, Sharma and Datta 1958
<i>I. hederacea</i> Jacq.	1900 m Nainital, India	2524	15	—	2x	n = 15, Ting <i>et al.</i> 1957 2n = 30, Sharma and Datta 1958
<i>I. purpurea</i> Lamk.	1900 m Nainital, India	2540	15	—	2x	n = 20, Baqar <i>et al.</i> 1965 2n = 30, Sharma and Datta 1958 Nishiyama <i>et al.</i> 1961, Jones 1964
<i>I. cairica</i> L.	400 m Haldwani, India	2530	15	—	2x	n = 15, Jones 1964
<i>I. tricolor</i> Cav.	300 m Chandigarh, India	2062	15	—	2x	n = 15, Jones 1964
<i>Convolvulus pluricaulis</i> 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
<i>C. arvensis</i> 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
<i>Porana racemosa</i> Roxb.*	Binsor Road, 2000 m Almora, India	2041	14	—	2x	
Tribe Dicranostyleae						
<i>Evolvulus alsinoides</i> L.	Thal, 1000 m Kumaon, India	2046	13	—	2x	2n = 26, Raghavan 1959
Subfamily Cuscuoideae						
Genus <i>Cuscuta</i>						
Subgenus Grammica						
Section Euphragmica						
<i>Cuscuta chinensis</i> Lamk.*	Kargil, 2500 m Ladakh, India	4247	8	16	2x	
Subgenus Monogyna						
Section Callianche						
<i>C. reflexa</i> 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						
<i>C. planiflora</i> Tenore *	Tangmarg, 2100 m Kashmir, India	4246	7	14	2x	
<i>C. capitata</i> Roxb.*	Kargil, 2500 m Ladakh, India	4227		20	2x	
<i>C. spec.</i>	Hanuman Chatti, 2800 m Kumaon, India	2019	31	62	8x	
<i>Species from Europe studied by the author (B)</i>						
<i>Convolvulus arvensis</i> L.	Sesém Bot. G. Coimbra Portugal		—	48	4x	videte supra (Table 2A)
<i>Cuscuta</i>						
Section Monogyna						
<i>C. lupuliformis</i> Krock.	Puszczykowko Bot. G. Poznan Poland		—	28	4x	2n = 28, Reese 1961
<i>C. scandens</i> Brot.*	S. Facundo Bot. G. Coimbra Portugal		—	16	2x	
Subgenus Cuscuta						
<i>C. epithymum</i> (L.) Murray	Bot. G. Neuchâtel		7	14	2x	2n = 14, Tischler 1934, Finn 1937, Ehrenberg 1945
<i>C. europaea</i> L.	Bot. G. Neuchâtel		7	14	2x	2n = 14, Finn 1937, Reese 1952, Tischler 1934
	Col du Simplon Switzerland		7	14	2x	
<i>C. alba</i> Presl.*	Gourdon, A.M., France		—	30	4x	

* A new chromosome 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 (inkl. *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, Gunderson, 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 *Ericoila* Renéalm.

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 *Jaeschkeia 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 $2n = \text{ca. } 36$ 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 ($36 = 4 \times 9$) 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.

Jaeschkeia 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), Kanot (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 Chatterji (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 Eurasian 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 autoploidy 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 dioica* 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 $4,5 \mu$ while the shortest one measures 2μ .

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 $3,1 \mu$ while the shortest pair measured $1,1 \mu$. *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 4.8μ while the shortest pair measured 3.4μ . 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 autoploid 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: *Jaesaea 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 bivalent 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

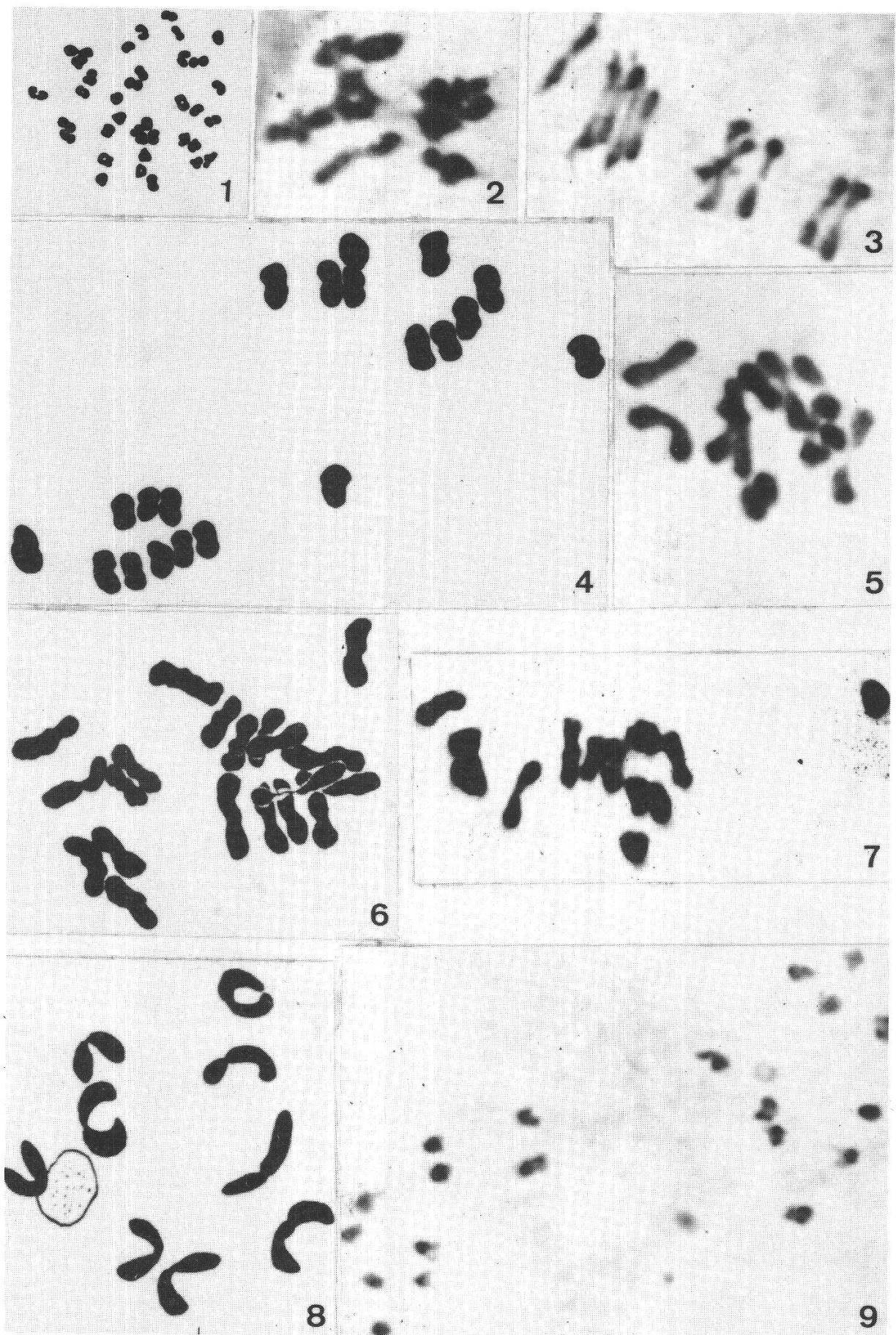
Fig. 30: *Cuscuta capitata* Roxb. 2n = 20 idiogram.

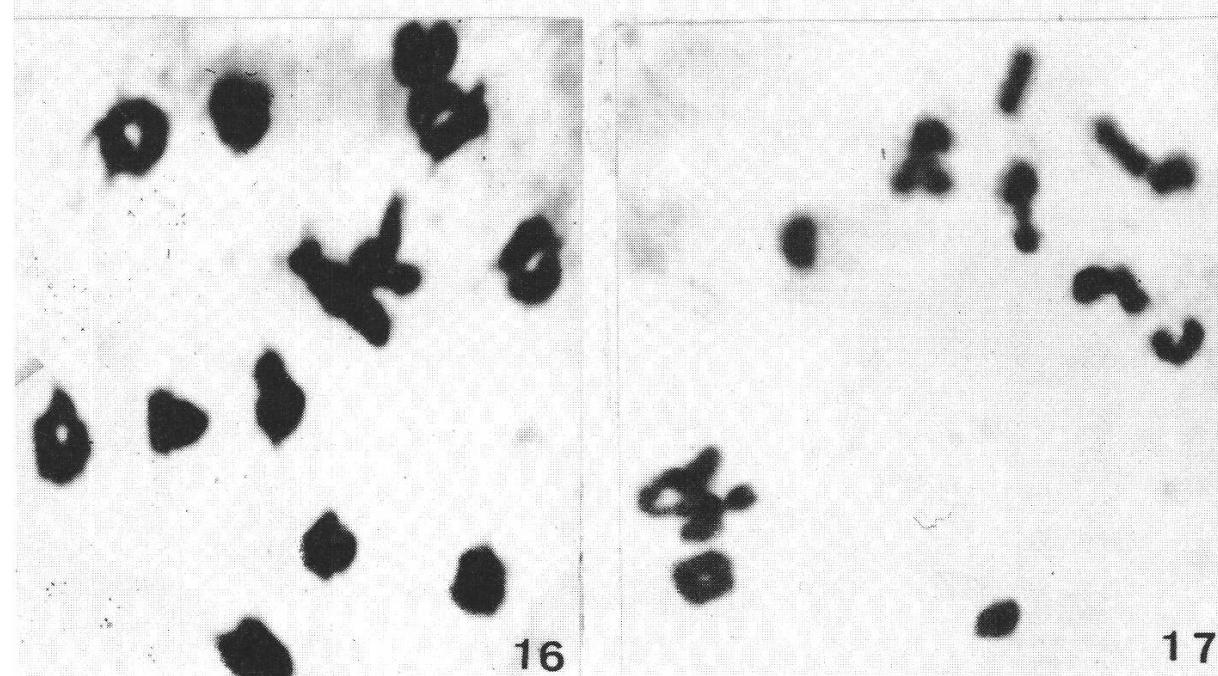
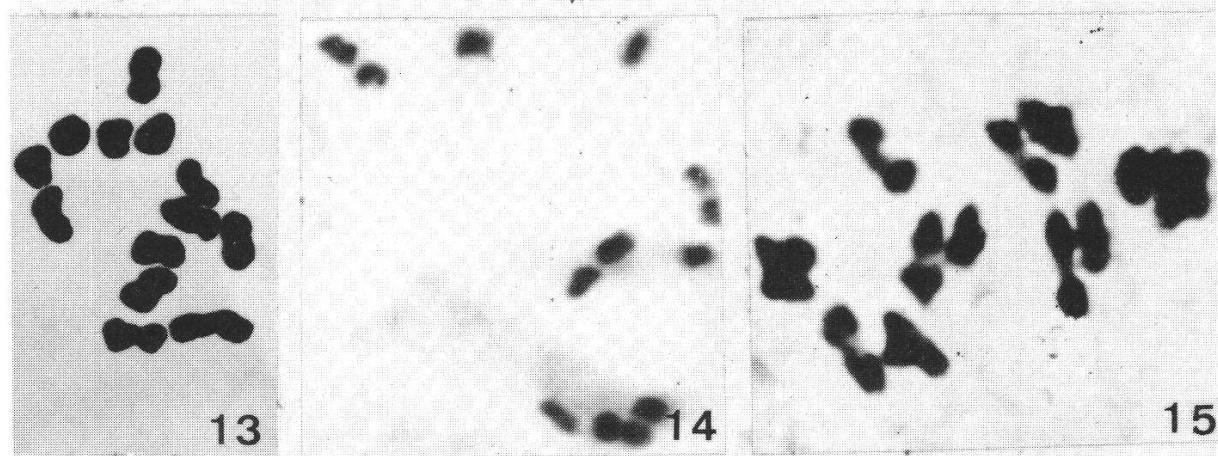
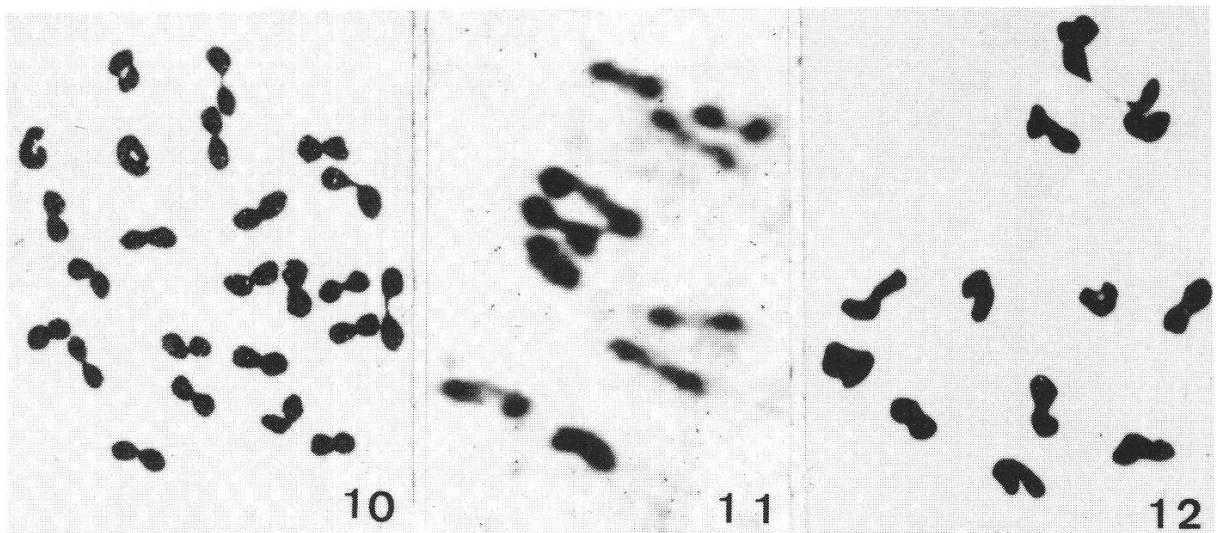
Fig. 31: *Cuscuta epithymum* (L.) Murray 2n = 14

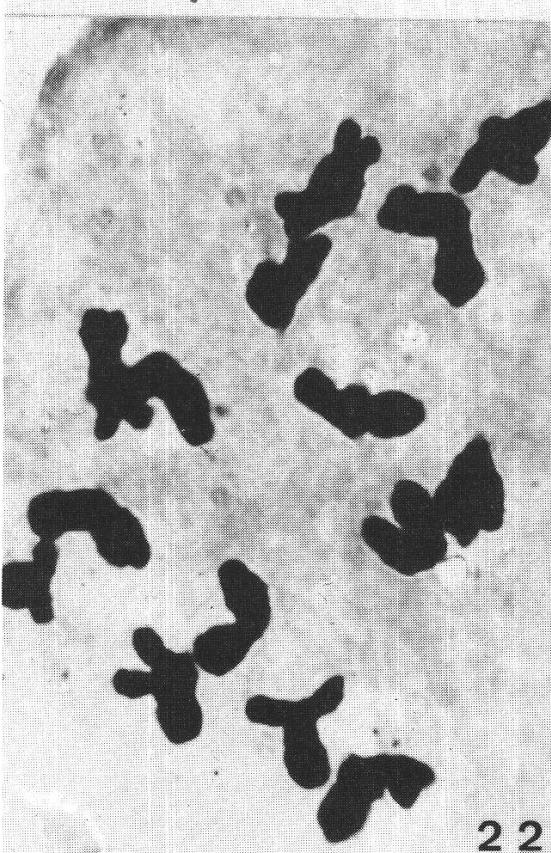
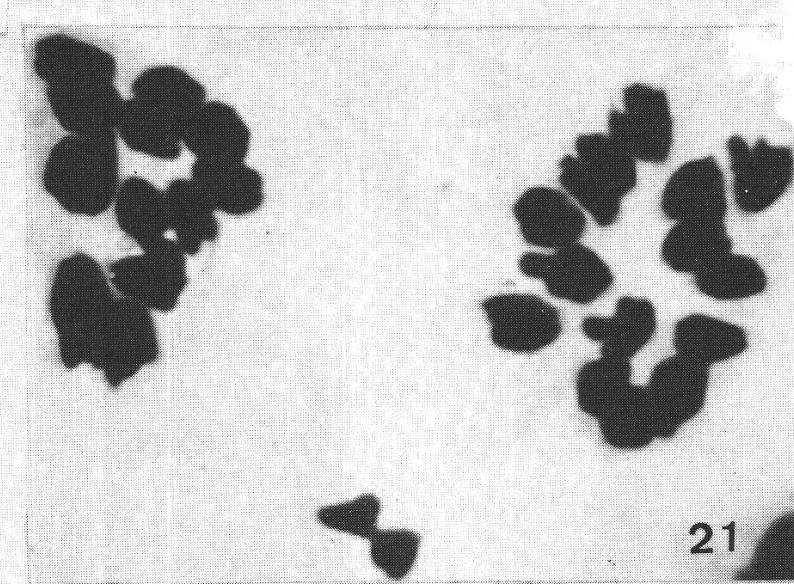
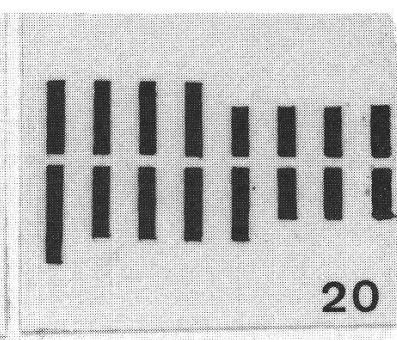
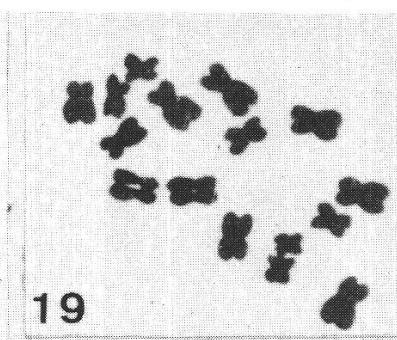
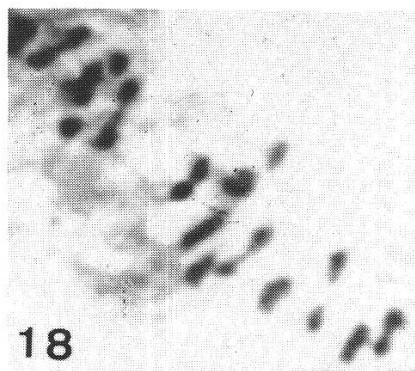
Fig. 31A: *Cuscuta epithymum* (L.) Murray 2n = 14 idiogram.

Fig. 32: *Cuscuta europaea* L. 2n = 14

Fig. 32A: *Cuscuta europaea* L. 2n = 14 idiogram.

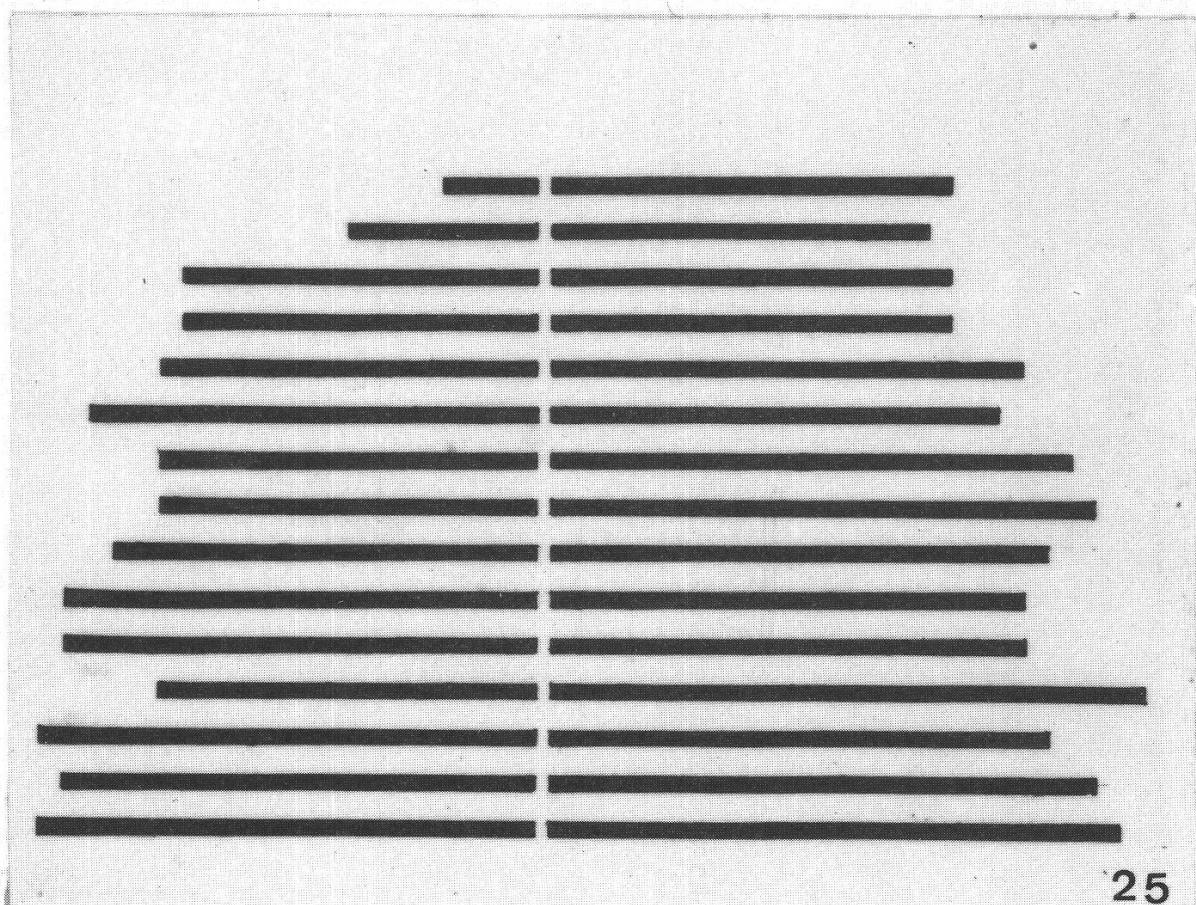








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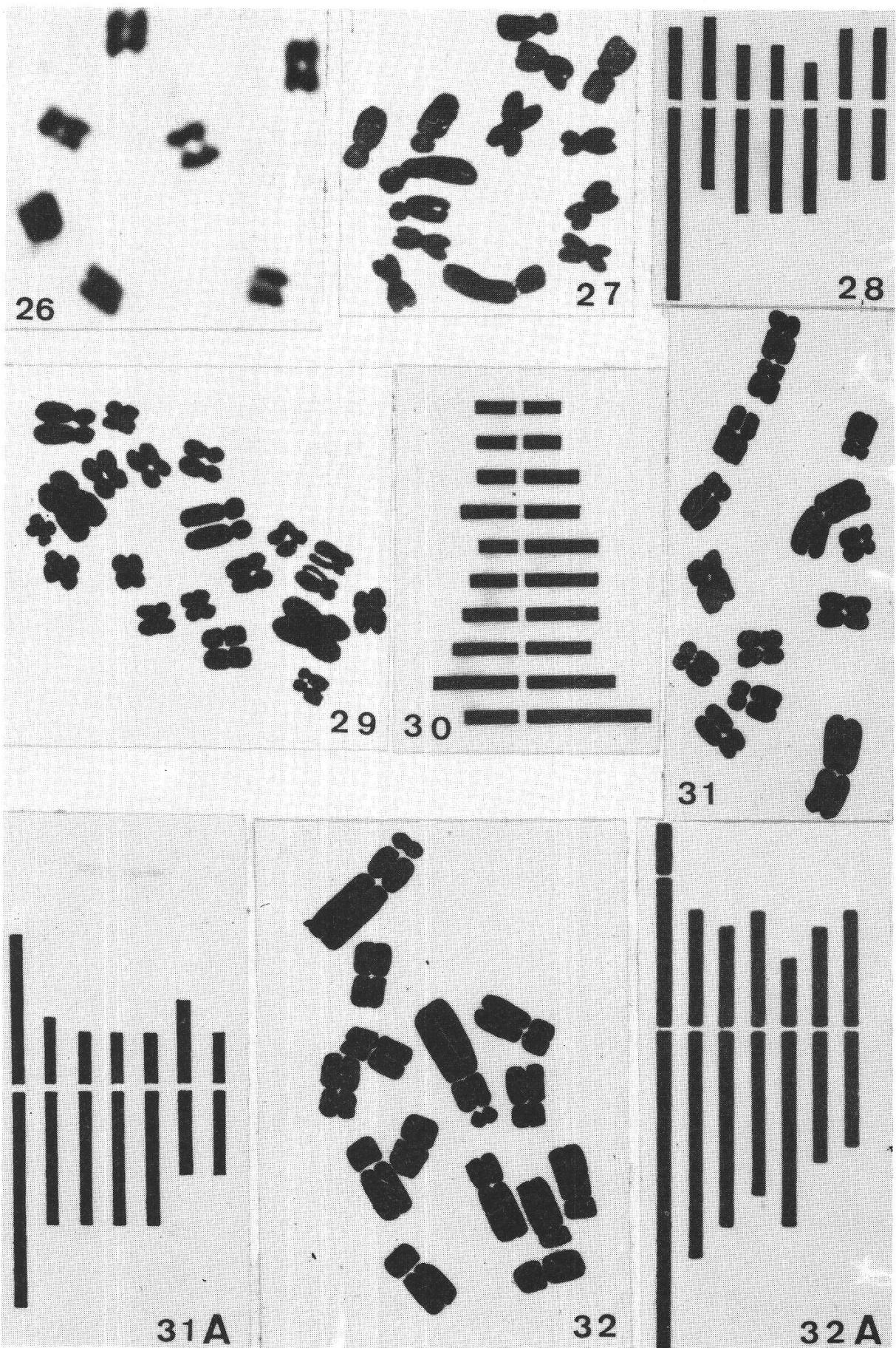


Figure 33

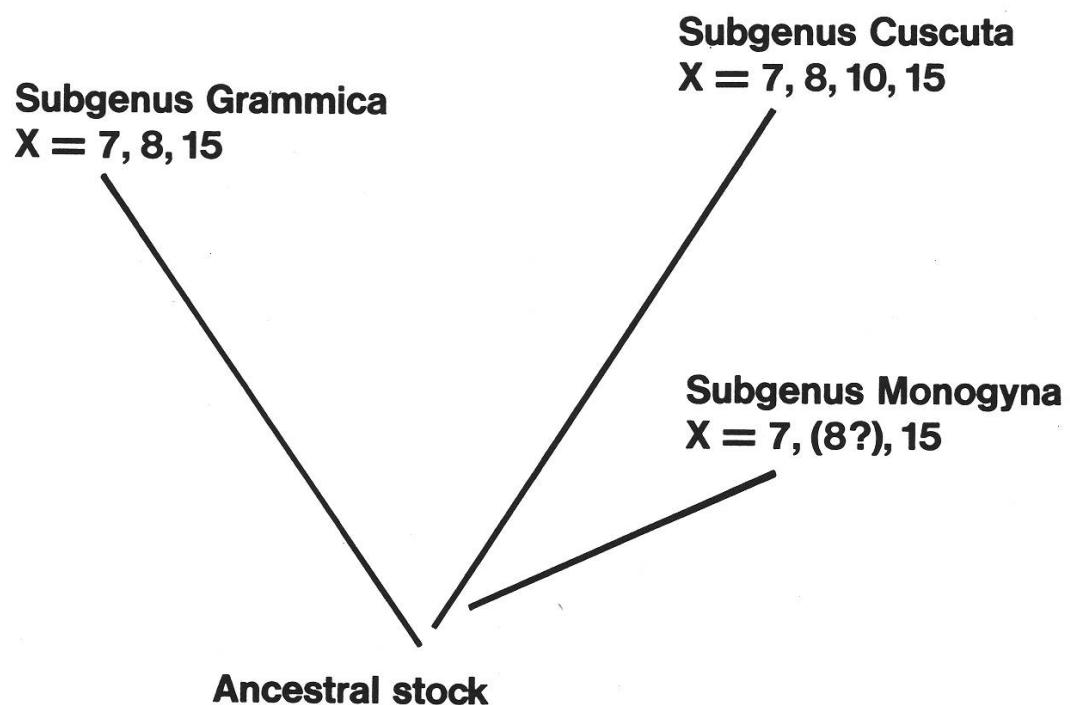


Fig. 33: Probable relationships between the three subgenera of *Cuscuta*.