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Ecological indicators and altitude zones of the diploid taxa

Ecological indicators evaluate the sites in terms of moisture, pH, nitrogen content etc. (ELLENBERG 1952, 1963). The following abbreviations are used below: F - humidity of the soil; R - pH value of the soil; N - the nitrogen content of the soil; L - the light amount. The numbers range from 1 to 5; in each case higher number represents higher indicator for the given factor. The altitude zones are specified according to Hess, Landolt and Hirzel (1967).

Cardamine granulosa: colline. F 3-4, N 3, R 37, L 3
Cardamine Matthioli: colline. F 3-4(4-5), N 3-4, R 2-3, L 4
Cardamine udicola: colline, montane. F 4-5, N 2, R 2-3, L 4
Cardamine rivularis: montane, subalpine. F 4-5, N 2, R 2-3, L 4
Cardamine pratensis: colline, montane. F 3-4, N 3-4, R 4, L 3-4
Cardamine nemorosa: colline, montane. F 3-4, N 3, R 4, L 2-3

7. Cytology

7.1 Chromosome numbers

The diploid level within the *Cardamine pratensis* group is represented by $2n=16$, the primary basic number being thus $x=8$. The present results stay in agreement with previous data (GUINOCHET 1946, MATTICK cit. acc. to TISCHLER 1950, LÖVKVIST 1953, 1956, DERSCH 1969, KUZMANOV and KOZUHAROV 1969, LANDOLT and URBANSKA-WORYTKIEWICZ 1971). It should be mentioned that LÖVKVIST assumed an occurrence of another primary basic number viz. 7 as being of evolutionary importance for the *C. pratensis* group. However, no 14 chromosomic plants have been found in the course of the present investigations; deviating chromosome numbers at the diploid level were invariably hyperdiploid ($2n=17,18,19,20$) and in most of the studied cases the resp. plants apparently represented polysomic types (URBANSKA-WORYTKIEWICZ and LANDOLT 1974).

The origin of the studied material is given in Tables 1 - 6. The studied diploid populations most frequently proved to be cytologically uniform (160 populations out of 208). Cytological variation observed in 48 populations was apparently conditioned not by a single factor but represented diverse aspects. At least three phenomena contributed to the formations of mixed populations: 1) local migrations, 2) gene flow, 3) aneusomy.

Table 1. *Cardamine granulosa*: origin of material (collection numbers are those of the authors)

No of sample	Place of origin	Altitude a.s.l.	pH	2n	Number of investigated plants
	Italy				
	Piedmont:				
560 *	Avigliana	600 m	5.0	16	10
567 *	Stupinigi	240 m	5.0	16	8

* karyotype investigated

Table 2. *Cardamine Matthioli*: origin of material (Collection numbers are those of the authors)

No.of sample	Place of origin	Altitude a.s.l.	pH	2n	Number of investigated plants
	Italy				
	Lombardy:				
698	Ballabio	710 m	6.0	16	15
871	Pavia	80 m	5.0	16	14
	Piedmont:				
561 *	Pinerolo I	500 m	5.0	16	14
562	Pinerolo II	500 m	5.0	16	5
564 *	Pinerolo III	500 m	7.0	16	7
565	Villar Perosa	450 m	4.5	16	9
566	Pinerolo IV	530 m	4.0	16	9
568 *	Lago di Candia	230 m	6.5	16	11
569 *	Lago di Viverone	230 m	5.0	16	9
570 *	Arona	195 m	5.0	16	8
	Switzerland:				
	Ticino				
872	Rivera	450 m	5.5	16	12

* karyotype investigated

Table 3. *Cardamine udicola*: origin of material (collection numbers are those of the authors)

No. of sample	Place of origin	Altitude a.s.l.	pH	2n	Number of investigated plants
	Switzerland				
	Bern:				
860 *	Geistsee	660 m	-	16,32	3,22
330 861	Unterseen	559 m	5.0	16,32	23,21
579	Gwatt	558 m	-	16	8
	Ticino:				
56	Magadino I	195 m	5.0	16	10
57	Magadino II	195 m	4.5	16	27
137	Lido di Ascona	195 m	6.0	16	7

* mixed with *Cardamine pratensis* (2n=40, 2n=48)

Table 4. *Cardamine rivularis*: origin of material (collection numbers are those of the authors)

No. of sample	Place of origin	Altitude a.s.l.	pH	2n	Number of investigated plants
	Austria				
	+Tyrol:				
225	Telfs	660 m	6.5	16	6
226	Fernsteinsee	1000 m	6.0	16	7
466	Flirsch	1100 m	6.5	16	1
467 *	Haiming	660 m	4.5	16	15
468	Silz	650 m	5.5	16	15
	Switzerland				
	Graubünden:				
33 *	Valbella I	1484 m	-	16	9
34	Valbella II	1484 m	-	16	6
36 *	St. Moritz-Bad	1768 m	-	16	4
37	Lej da Staz	1790 m	-	16	6

Table 4: Continuation

No. of sample	Place of origin	Altitude a. s. l.	pH	2n	Number of investigated plants
211	Tigias	1977 m	6.0	16	7
212	Maloja I	1800 m	5.0	16	9
213	Maloja II	1800 m	4.0	16	6
214 [*]	Lej da Champfèr	1800 m	4.5	16	8
	St. Gallen:				
39 [*]	Schwendisee I	1159 m	-	16	7
40	Schwendisee II	1159 m	-	16	6
41	Schwendisee III†	1159 m	-	16	6
	Appenzell (AR):				
703	Schwägalp	1275 m	5.0	16	11
	Schwyz:				
233 [*]	Sihlsee I	1830 m	5.0	16	9
234	Sihlsee II	1830 m	4.0	16	8
236 ^{**}	Richisau	1130 m	7.0	16	2
707	Pragelpass	1545 m	-	16	6
	Uri:				
167 [*]	Urnerboden I	1310 m	-	16	2
168	Urnerboden II	1310 m	-	16	1
169 [*]	Klausenpass	1764 m	-	16	10
182	Urnerboden III	1310 m	4.3	16	7
855	Brunnital	1650 m	-	16	5
	Vaud:				
624 [*]	Col du Pillon	1685 m	6.0	16	16
625	Les Diablerets	1180 m	6.0	16,32	12,1
627	Pierre de Moëllé	1661 m	7.0	16	13

* karyotype investigated

** mixed with *Cardamine pratensis* (2n=40)

+ Taxonomical status of the Tyrolian plants is not definite (see p. 66).

Table 5. *Cardamine pratensis*: origin of material (collection numbers are those of the authors)

No. of sample	Place of origin	Altitude a.s.l.	pH	2n	Number of investigated plants
	Austria				
	Tyrol:				
401*	Vils	820 m	5.0	16,18,21	7,1,1
461	Innsbruck	570 m	6.0	16	10
472	Weer	550 m	7.0	16,40	3,4
	Vorarlberg:				
217	Nenzing	490 m	7.0	16	8
218	Braz	700 m	8.0	16	9
219	Klösterle	1050 m	5.0	16	8
231	Bregenz	600 m	5.0	16	9
359	Hard	400 m	6.5	16	12
396	Dornbirn	437 m	8.5	16	11
397	Bödele	1146 m	7.5	16	9
398	Vorder-Mellau	670 m	8.0	16,40	3,3
399	Schopfernau	840 m	5.0	16	7
463	St. Anton i.M.	650 m	6.0	16	10
464*	St. Gallenkirch	850 m	5.0	16	14
	Germany				
	Bavaria:				
229	Immenstadt	740 m	7.0	16	8
230	Ober Reute	850 m	7.5	16	9
360*	Lindau	470 m	5.0	16	11
368	Opfenbach	580 m	5.5	16	10
369	Isny	680 m	5.0	16,17,18,19	7,1,1,1
370	Wengen	750 m	5.0	16,30	2,12
373	Nesselwang	900 m	5.5	16	12
374	Pfronten	900 m	7.0	16,17,19,24	6,1,1,1,
	Baden-Württemberg:				
361	Degersee I	470 m	5.0	16	7
362	Degersee II	470 m	5.5	16	12

Table 5. Continuation

No. of sample	Place of origin	Altitude a.s.l.	pH	2n	Number of investigated plants
363	Degersee III	470 m	6.0	16	7
364	Tett nang	470 m	5.5	16	10
507	Obereschach	750 m	6.0	16,17	6,1
508	Horgen	650 m	7.0	16,30	7,4
509	Rottweil I	600 m	5.0	16,17,18,19	10,1,2,2
510	Rottweil II	600 m	6.5	16	13
511	Neufra	600 m	7.0	16	8
514	Balgheim	700 m	-	16,17,18,19	7,1,1,1
515	Engen	550 m	7.0	16,30	1,13
518*	Schiener Berg I	650 m	6.5	16	15
519	Schiener Berg II	680 m	7.0	16	9
520	Moos	400 m	6.5	16,18,38	13,2,4
521	Stetten	420 m	6.0	16	20
525*	Baindt	500 m	7.0	16	18
526	Bad Waldsee	580 m	5.0	16,18	14,1
542	Tuttlingen	650 m	7.0	16,30	2,15
591	Balsheim	570 m	5.5	16,30	4,6
592	Bohlingen	450 m	6.0	16	5
593*	Allensbach	400 m	5.5	16	13
594	Liggeringen	530 m	5.0	16	12
597	Beuren	552 m	7.0	16	9
601	Feldmoos	550 m	6.0	16,30,38,46	2,7,3,2
606	Krätermühlhöfe ca.	650 m	7.0	16,30	2,5
607	Liptingen ca.	600 m	7.0	16	9
Liechtenstein:					
216	Nendeln	450 m	6.5	16	4
462*	Balzers	470 m	7.5	16	10
Switzerland:					
Graubünden:					
75*	Pardisla	580 m	7.0	16	10
138	Andeer	985 m	7.0	16,32	6,1
141	Bonaduz	600 m	-	16	7

Table 5. Continuation

No. of sample	Place of origin	Altitude a.s.l.	pH	2n	Number of investigated plants
142*	Bad Ragaz I	500 m	-	16	5
143	Bad Ragaz II	500 m	-	16	8
210	Bad Serneus	1010 m	6.5	16	6
385	Igis	535 m	6.0	16	9
386	Untervaz	540 m	7.0	16	7
645	Chur	600 m	7.0	16	12
	St. Gallen:				
15	Ricken	805 m	-	16	7
38	Gams	510 m	-	16	6
101	Kaltbrunner Ried	300 m	5.8	16	7
103*	Berschis	440 m	5.0	16	7
104	Trübbach	470 m	6.5	16	6
105	Grabs	443 m	7.0	16	8
106	Wildhaus	970 m	6.5	16	5
107	Stein	860 m	6.0	16	9
108	Wattwil	620 m	6.0	16	8
125	Steinach	440 m	6.0	16	7
127	Oberwil I	585 m	6.0	16	3
128	Oberwil II	585 m	6.0	16,32	5,1
295	Mühlrüti	760 m	6.0	16	6
308	Sirnach	530 m	6.0	16	5
309	Wil	575 m	6.5	16	7
311	Niederwil	605 m	6.0	16	8
338	Brunnadern	660 m	7.0	16	6
347*	Altstätten	480 m	5.5	16	10
358	Rheineck	410 m	6.0	16	13
704	Mörschwil	530 m	-	16	12
708	Vättis	1000 m	6.0	16	9
720	Schänis	420 m	5.5	16	9
	Appenzell-Ausserrhoden:				
339	Urnäsch	1000 m	6.0	16	13
344	Bühler	860 m	5.0	16	10

Table 5. Continuation

No. of sample	Plant of origin	Altitude a.s.l.	pH	2n	Number of investigated plants
346 *	Landmarch	1000 m	6.0	16	10
356	Wissegg	1030 m	4.5	16	5
357	Rehetobel	950 m	5.0	16	12
	Appenzell-Innerrhoden:				
340	Gonten I	900 m	5.0	16,17,18	8,1,4
341 *	Gonten II	900 m	6.0	16	11
342	Pfannenstil	940 m	6.0	16	11
343	Brülisau	900 m	7.0	16	13
	Glarus:				
721	Bilten	440 m	6.0	16	9
	Thurgau:				
310	Sonnental	500 m	7.0	16	6
296	Fischingen	610 m	6.5	16	8
297	Bichelsee	585 m	6.5	16	6
307	Balterswil	570 m	6.0	16	9
316	Aadorf	538 m	7.0	17	1
317	Münchwilen	575 m	7.5	16	7
318	Bettwiesen	540 m	7.0	16	5
319	Mettlen	530 m	6.5	16	8
320	Sulgen	480 m	7.0	16	8
322	Hauptwil	570 m	5.0	16	3
352	Pfyn	565 m	5.5	16,30	5,7
588	Homburg I	615 m	6.5	16,30,38	1,10,1
589	Salen I	730 m	6.0	16,30,38	4,3,3
667	Matzingen I	465 m	6.5	16	9
668	Matzingen II	450 m	7.0	16,38	8,1
669 *	Matzingen III	455 m	7.0	16	12
670	Stettfurt I	470 m	6.0	16	15
671	Stettfurt II	490 m	7.5	16,19,38,54	4,1,2,1
672	Sonnenberg	590 m	7.5	16	11
673	Freudenberg	547 m	5.5	16,18	10,1
674	Thundorf I	570 m	7.0	16,30	1,10

Table 5. Continuation

No. of sample	Place of origin	Altitude a.s.l.	pH	2n	Number of investigated plants
675	Thundorf II	570 m	6.5	16,30	4,9
676	Wolfikon	625 m	5.5	16	8
677	Strohvilen	580 m	6.0	16,30,38	7,2,1
678	Burghof	555 m	7.0	16,30	9,3
680	Hüttlingen	400 m	7.5	16,30	10,2
681	Eschikofen I	410 m	7.0	16,30	7,1
682	Eschikofen II	410 m	7.0	16,30	2,12
683	Hüseren	410 m	7.5	16,30,54	6,1,3
684	Mülheim I	405 m	7.0	16,30	1,11
685	Mülheim II	450 m	7.5	16,30	1,7
686	Unter-Hörstetten	495 m	6.5	16	12
687	Hörhausen I	530 m	7.0	16,30	2,6
688	Hörhausen II	555 m	7.0	16,18,23,24,30	3,1,2,4
689	Reckenwil	575 m	7.0	16,30,38	1,6,3
691	Homburg II	600 m	7.0	16,30	6,4
692	Lören	640 m	6.0	16,30	7,1
693	Salen II	686 m	7.0	16,38	10,2
694 *	Salen III	640 m	7.0	16	8
695	Steckborn	610 m	7.5	16	6
	Zürich:				
315	Elgg	630 m	6.0	16	4

* karyotype investigated

Table 6. *Cardamine nemorosa*: origin of material (collection numbers are those of the authors)

No. of sample	Place of origin	Altitude a.s.l.	pH	2n	Number of investigated plants
	Germany				
	Baden-Württemberg:				
409	Erzingen	420 m	6.5	16	12
440*	Haagen I	380 m	5.0	16	12
441	Haagen II	320 m	7.0	16	11
445	Wehr	600 m	5.0	16	12
450*	Wutachschlucht	680 m	7.0	16	11
452	Wutachmühle	580 m	7.0	16	9
501	Achdorf	600 m	7.0	16	12
512	Balgheim I	700 m	7.0	16	9
513	Balgheim II	700 m	6.0	16	10
	Switzerland				
	Aargau:				
46	Sisseln I	305 m	-	20	1
47	Sisseln II	305 m	-	16	1
50	Sisseln III	305 m	8.0	16,30	1,6
86	Rheinfelden	295 m	-	20	3
88*	Zurzach	400 m	6.0	16	6
	Neuchâtel:				
32	Chaux-de-Fonds	830 m	-	20	4
	Vaud:				
9	Baulmes I	605 m	-	20	7
10	Baulmes II	605 m	-	20	6
63	Le Sentier	1020 m	-	20	1
	France				
	Ain:				
26	Belleydoux	800 m	-	20,32	4,1
	Doubs:				
31*	Lac de St. Point	850 m	-	16	8
65*	Frès-de-Vaire I	720 m	7.0	16	11

Table 6. Continuation

No. of sample	Place of origin	Altitude a.s.l.	pH	2n	Number of investigated plants
66	Près-de-Vaire II	720 m	-	16,30	3,4
67*	Marais de Saône I	390 m	5.5	16	11
68	Marais de Saône II	390 m	7.0	16	8
69	Marais de Saône III	390 m	6.5	16	7
70*	Besançon	450 m	5.0	16	10
	Meurthe-et-Moselle:				
764	Nancy	300 m	6.0	16	10
	Vosges:				
845*	Hohneck	1250 m	5.0	16	10

* karyotype investigated

The most frequent mixed populations were those obviously influenced by local migrations: 26 populations comprised not only diploids but also tetraploids ($2n=30$ or $2n=32$), in two other stations pentaploid plants ($2n=40$) were growing among the diploids. Still more complex was a population of *C. udicola* from Geistsee: three diploids were accompanied by numerous tetraploids of the same taxon, but pentaploids and hexaploid belonging to *C. pratensis* occurred as well in this habitat.

11 studied populations consisted not only of diploids and tetraploids, but also of some higher polyploids ($2n=38, 46, 54$), that apparently were of a hybrid origin.

In 13 populations plants with hyperdiploid chromosome numbers, representing most frequently various polysomic types, were found among the diploids.

Above mentioned cytological variation was observed mostly within *C. pratensis* (42 populations), *C. nemorosa* (3 populations) and *C. udicola* (2 populations). As to *C. rivularis*, a single tetraploid plant ($2n=32$) was once found within otherwise diploid population from Les Diablerets (Table 4). Its occurrence might be explained by a local migration from neighbouring tetraploid populations; however, a possibility of an incidental polyploidization cannot be excluded. *C. Matthioli* and *C. granulosa* proved to be cyto-

logically uniform.

It is interesting to note that there seems to occur a certain pattern of cytological variation within the diploid taxa of the *C. pratensis* group: deviating populations were most frequently found in the regions where the diploids came into contact with various polyploid types. One could assume that populations inhabiting the center of the distribution area of given taxon are subject to selection pressures which are different from those occurring within the marginal populations.

Cardamine granulosa All.

This taxon has not been cytologically studied hitherto. The authors investigated 18 plants from two stations in Piedmont (table 1); diploid chromosome number $2n=16$ has been invariably found.

Cardamine Matthioli Moretti

Previous reports of MATTICK (cit. acc. to TISCHLER 1950) and those of LÖVKVIST (1956) dealt with *C. Matthioli* from Eastern Alps and from the surroundings of Vienna. The present results obtained on the material from 11 stations dispersed in western part of the range (Table 2) are in agreement with the previous data. No cytological variation has been observed.

Cardamine udicola. Jord.

C. udicola has been studied here for the first time. Out of six stations that have been investigated four proved to be cytologically uniform and comprised solely the diploids. (Table 3). It is interesting to note that *C. udicola* from southern Ticino was invariably 16 chromosomic whereas the populations from the surroundings of the Lake of Thun were rather differentiated. The station from Weissenau was inhabited by diploids and tetraploids, the population from Geistsee comprised not only some diploids and tetraploids of *C. udicola* but also pentaploids and hexaploids of *C. pratensis* type.

Cardamine rivularis Schur

C. rivularis has been previously studied by LÖVKVIST (1956) from Engadine and from Austrian Alps. More recently, a report from the easternmost limit of the range of this taxon i.e. from the Rila Mts has been published (KUZMANOV and KOZUHAROV 1969). The present authors studied numerous plants from 29 populations within the Alpine range (Table 4). Except

for a single tetraploid plant from Les Diablerets , all the studied individuals were 16 chromosomic. Our results stay in agreement with the previous data.

It can be assumed that the tetraploid plant found within otherwise diploid population of *C. rivularis* may reflect local migrations: in the investigated area, several tetraploid populations were found in the mountains. These tetraploids remain to be investigated in detail.

Another plausible explanation for a sporadic occurrence of 32 chromosomic plants within the diploid population could be their putative autopolyploid origin. In numerous populations of the diploid *C. rivularis* unreduced pollen grains were observed in a variable frequency. The results obtained on live material corroborate with numerous pollen tests performed on herbarium specimens. The problem of karyological differentiation within *C. rivularis* requires further studies.

Cardamine pratensis L.

Diploid chromosome number for the meadow plants has been reported for the first time by the present authors in their previous publication (LANDOLT and URBANSKA-WORYTKIEWICZ 1971). Since then, numerous populations of this taxon were studied and its whole area of geographical distribution has been traced (Table 5). Out of 132 investigated stations, 90 proved to be cytologically uniform. In 42 populations various cytotypes occurred among the diploid plants: 13 populations comprised hyperdiploids ($2n=17, 18, 19, 20$), in 31 populations two or more different cytotypes were observed. It should be emphasized that nearly all mixed populations were found near the distribution limits of the diploid *C. pratensis*, where this taxon comes into contact with various polyploid types of the group (URBANSKA-WORYTKIEWICZ and LANDOLT 1974). Accordingly it can be assumed that this cytological variation might partly reflect local migrations from neighbouring populations; on the other hand, some higher polyploids were apparently of a hybrid origin and their occurrence was probably due to the gene flow between the populations.

Cardamine nemorosa Lejeune

The first cytological record for *C. nemorosa* has been presented by GUINOCHET (1946) from the French Jura. More recently, DERSCH (1969) has

published numerous chromosome counts of diploid plants growing in deciduous forests in Central Germany. It should be noted that DERSCH was the first author who reported the occurrence of aneuploids ($2n=17,18,19,20$) within *C. nemorosa*: he has found 10 stations where the hyperdiploids were growing among the diploids. However, the German author neither specified the frequency of the hyperdiploids within the given populations nor has he suggested any interpretation for an origin of supernumerary chromosomes. He has solely mentioned their similarity to other chromosomes of the diploid set of *C. nemorosa*.

In the course of the present study 28 stations of *C. nemorosa* were investigated (Table 6). Most of the studied stations proved to be cytologically uniform; however, it is interesting to note that some small and isolated populations in the Jura appeared to consist exclusively of 20 chromosomal plants.

In two populations of *C. nemorosa* the diploid plants were accompanied by hypotetraploids ($2n=30$); in a single population, sampled in French Jura, 4 individuals of *C. nemorosa* proved to be 20 chromosomal and one plant was tetraploid ($2n=32$).

7.2 Analysis of karyotype

Comparative analysis of karyotype was performed on root-tips pretreated with 0.02 mol/l aqueous solution of oxyquinolin and stained with lacto-propionic orcein. Populations used for this study are marked by asterisks in Tables 1 - 6.

Eight good metaphases with about the same degree of contraction of the chromosomes were selected from each sample. The measurements were taken from drawings made with LEITZ camera lucida under 3500 x magnification. Mean values of the length were subsequently worked out and used for calculations of the ratio short arm/ long arm (index). The results are presented in Figs. 13 to 18 and Tables 7 to 12.

On the whole, morphological differentiation of the chromosomes does not seem to be particularly distinct in the diploid taxa of the *C. pratensis* group. In most of the studied species the chromosome set consisted of rather small, submetacentric chromosomes, one pair bearing satellites.

On the other hand, some differences were found between the particular taxa both in total amount of the chromatine (TCL) as well as in structural arrangement of the chromosomes.

Cardamine granulosa. The chromosome set of *C. granulosa* consisted of the chromosomes that were only slightly differentiated (Table 7); the longest pair measured 1.57 μ of total length, the shortest one 1.12 μ . As to the position of centromere, one pair appeared to be metacentric; the others represented submetacentric types, the index varying from 0.55 to 0.98, respectively the SAT-chromosomes were the longest pair of the set (Fig. 13).

Total length of the karyotype (TCL) presented the lowest value of all the studied diploid taxa (i.e. 20,42 μ) (Fig. 18, Table 12).

Table 7. *Cardamine granulosa*: Analysis of karyotype (mean length values in μ)

Long arm	Short arm	Total length	Index Type
0.99 ⁺ 0.01	0.58 ⁺ 0.02	1.57 ⁺ 0.02	0.58 SM SAT
0.87 ⁺ 0.02	0.48 ⁺ 0.01	1.35 ⁺ 0.02	0.55 SM
0.78 ⁺ 0.02	0.56 ⁺ 0.02	1.34 ⁺ 0.03	0.72 SM
0.69 ⁺ 0.01	0.49 ⁺ 0.02	1.18 ⁺ 0.02	0.71 SM
0.65 ⁺ 0.02	0.65 ⁺ 0.02	1.30 ⁺ 0.02	1 M
0.64 ⁺ 0.03	0.54 ⁺ 0.01	1.18 ⁺ 0.04	0.84 SM
0.59 ⁺ 0.02	0.58 ⁺ 0.01	1.17 ⁺ 0.02	0.98 SM
0.58 ⁺ 0.01	0.54 ⁺ 0.01	1.12 ⁺ 0.02	0.93 SM

Cardamine Matthioli. The chromosome set of *C. Matthioli* was rather uniform and comprised solely submetacentric chromosomes. The length of the chromosomes presented rather low values, the longest pair measuring 1.69 μ , the shortest one - 1.13 μ . SAT-chromosomes were of a medium type for *C. Matthioli* (Fig. 14).

Position of centromere varied only slightly in the studied material; the respective values of the index ranged from 0.68 to 0.89 (Table 8).

C. Matthioli was next to *C. granulosa* as far as the total length of the karyotype is concerned (Fig. 18): it comported 22,52 μ (Table 12).

Table 8. *Cardamine Matthioli*: Analysis of karyotype (mean length values in μ)

Long arm	Short arm	Total length	Index Type
0.96 ⁺ -0.01	0.73 ⁺ -0.02	1.69 ⁺ -0.03	0.76 SM
0.88 ⁺ -0.02	0.60 ⁺ -0.02	1.48 ⁺ -0.02	0.68 SM
0.88 ⁺ -0.02	0.66 ⁺ -0.01	1.54 ⁺ -0.03	0.75 SM
0.83 ⁺ -0.02	0.64 ⁺ -0.03	1.47 ⁺ -0.02	0.77 SM
0.76 ⁺ -0.01	0.60 ⁺ -0.02	1.36 ⁺ -0.02	0.78 SM
0.70 ⁺ -0.02	0.62 ⁺ -0.02	1.32 ⁺ -0.02	0.89 SM SAT
0.69 ⁺ -0.01	0.58 ⁺ -0.01	1.27 ⁺ -0.02	0.84 SM
0.67 ⁺ -0.02	0.46 ⁺ -0.02	1.13 ⁺ -0.02	0.69 SM

Cardamine udicola. *C. udicola* remains to be investigated in details. However, preliminary observations permit to characterize its chromosome set as falling into nearly the same category as that of *C. Matthioli* i.e. the chromosomes are rather small, submetacentric and not very much differentiated.

Cardamine rivularis. The chromosomes of *C. rivularis* represented mostly a submetacentric type; however, the index values were rather variable, ranging from 0.45 to 0.99 (Table 9). In addition, one pair of acrocentric chromosomes was observed (Fig. 15). *C. rivularis* proved to be the taxon which showed the highest value of total karyotype length: it comported 25.26 μ , the chromosomes being rather uniform within the set (Table 12).

The present results, obtained on pre-treated material from the Alpine range, are somewhat different from the data of KUZMANOV and KOZUHAROV. Unfortunately, the Bulgarian authors gave only a general characteristics of the chromosome complement of *C. rivularis* from the Rila Mts. It would be interesting to compare detailed measurements of the chromosomes of *C. rivularis* from various parts of its wide geographical range.

Table 9. *Cardamine rivularis*: Analysis of karyotype (mean length values in μ)

Long arm	Short arm	Total length	Index Type
1.19 ⁺ -0.01	0.43 ⁺ -0.02	1.62 ⁺ -0.02	0.36 A
1.06 ⁺ -0.02	0.48 ⁺ -0.01	1.54 ⁺ -0.02	0.45 SM
0.94 ⁺ -0.02	0.49 ⁺ -0.02	1.43 ⁺ -0.02	0.52 SM
0.88 ⁺ -0.02	0.76 ⁺ -0.01	1.64 ⁺ -0.02	0.84 SM SAT
0.87 ⁺ -0.03	0.77 ⁺ -0.01	1.64 ⁺ -0.02	0.88 SM
0.83 ⁺ -0.02	0.81 ⁺ -0.02	1.64 ⁺ -0.02	0.97 SM
0.81 ⁺ -0.02	0.80 ⁺ -0.01	1.61 ⁺ -0.02	0.99 SM
0.77 ⁺ -0.02	0.74 ⁺ -0.02	1.51 ⁺ -0.03	0.96 SM

Cardamine pratensis. Diploid *C. pratensis* has the chromosome set that seems to be rather well-differentiated both as to the length of the respective chromosomes as well as to the position of centromere (Fig. 16). The longest pair of chromosomes measured 2.07 μ , the shortest one 0.88 μ . Most of the chromosomes proved to be submetacentric, their index values ranging from 0.41 to 0.98. The SAT-chromosomes were of a medium length (Fig. 18, Table 10).

Table 10. *Cardamine pratensis*: Analysis of karyotype (mean length values in μ)

Long arm	Short arm	Total length	Index Type
1.38 ⁺ -0.02	0.69 ⁺ -0.01	2.07 ⁺ -0.03	0.50 SM
1.18 ⁺ -0.01	0.38 ⁺ -0.01	1.56 ⁺ -0.02	0.32 A
1.12 ⁺ -0.02	0.46 ⁺ -0.01	1.58 ⁺ -0.02	0.41 SM
0.97 ⁺ -0.02	0.65 ⁺ -0.02	1.62 ⁺ -0.02	0.67 SM
0.78 ⁺ -0.01	0.72 ⁺ -0.02	1.50 ⁺ -0.03	0.91 SM SAT
0.76 ⁺ -0.02	0.66 ⁺ -0.02	1.42 ⁺ -0.02	0.87 SM
0.64 ⁺ -0.03	0.63 ⁺ -0.01	1.27 ⁺ -0.03	0.98 SM
0.52 ⁺ -0.01	0.36 ⁺ -0.01	0.88 ⁺ -0.01	0.69 SM

Total karyotype length of *C. pratensis* amounted to 23.80 μ . (Table 12)

Cardamine nemorosa. The chromosome complement of *C. nemorosa* is notably similar to that of *C. pratensis*. Two longer chromosomes (2.12 μ) are present; one pair of very short chromosomes (0.69 μ) was also observed. On the whole, the chromosomes of *C. nemorosa* are mostly submetacentric, their centromere position being rather variable within the set (index values range from 0.44 to 0.99 (Table 11). SAT-chromosomes are of medium length. The shortest chromosomes within the set represent acrocentric type (Fig. 17). In this respect, *C. nemorosa* differs from *C. pratensis*; the shortest pair of the chromosomes of the latter taxon is submetacentric.

Total length of the karyotype represented the second highest value within the studied material (24.74 μ , Fig. 18, Table 12).

Table 11. *Cardamine nemorosa*: Analysis of karyotype (mean length values in μ)

Long arm	Short arm	Total length	Index Type
1.31 ⁺ -0.02	0.81 ⁺ -0.01	2.12 ⁺ -0.02	0.62 SM
1.25 ⁺ -0.01	0.62 ⁺ -0.02	1.87 ⁺ -0.01	0.50 SM
1.13 ⁺ -0.01	0.50 ⁺ -0.01	1.63 ⁺ -0.02	0.44 SM
1.12 ⁺ -0.02	0.37 ⁺ -0.02	1.49 ⁺ -0.02	0.33 A
0.87 ⁺ -0.01	0.82 ⁺ -0.03	1.69 ⁺ -0.03	0.94 SM
0.76 ⁺ -0.02	0.75 ⁺ -0.01	1.51 ⁺ -0.02	0.99 SM
0.69 ⁺ -0.02	0.68 ⁺ -0.02	1.37 ⁺ -0.02	0.98 SM SAT
0.44 ⁺ -0.01	0.25 ⁺ -0.01	0.69 ⁺ -0.02	0.57 SM

Chromosome length and their structural differentiation can be employed only in a general way as criteria for classification of the diploid taxa within the *C. pratensis* group. One could distinguish two groups:

1) taxa with small, not much differentiated chromosomes (*C. granulosa*, *C. Matthioli*, *C. udicola*) and 2) taxa with more pronounced structural differentiation of the chromosomes, showing higher values of the total karyotype length (*C. rivularis*, *C. pratensis*, *C. nemorosa*).

The first group does not seem to offer any characteristic pattern of differentiation within the chromosome set. On the other hand, *C. rivularis*,

C. pratensis and *C. nemorosa* have the same general formula of the karyotype i.e. their sets consist of one pair of acrocentric chromosomes and seven pairs of submetacentric ones, a single pair being that of SAT-chromosomes. However, one can distinguish within this group rather pronounced differences in frequency of chromosomes representing the given values of the length. This means that *C. rivularis* has rather uniform chromosomes, their length varying only slightly from 1.43 to 1.64 μ . By contrast, both *C. pratensis* and *C. nemorosa* show a well-defined chromosomes differentiation: the respective values of maximal and minimal chromosome length comport 2.07 μ - 0.88 μ in the former taxon and 2.12 μ - 0.69 μ in the latter one.

Table 12. Karyotype characteristics in five diploid taxa of the *C. pratensis* group

Taxon	TCL (in μ)	Karyotype formula
<i>Cardamine granulosa</i>	20.42	$2_{M} 14_{SM} (2_{SM} SAT)$
<i>Cardamine Matthioli</i>	22.52	$16_{SM} (2_{SM} SAT)$
<i>Cardamine pratensis</i>	23.80	$14_{SM} (2_{SM} SAT) 2_A$
<i>Cardamine nemorosa</i>	24.74	$14_{SM} (2_{SM} SAT) 2_A$
<i>Cardamine rivularis</i>	25.26	$14_{SM} (2_{SM} SAT) 2_A$

The particular similarity of the chromosome sets occurring between *C. nemorosa* and *C. pratensis* points to a close relationship of the two taxa. It can be assumed that *C. pratensis* and *C. nemorosa* either represent different forms derived from the same ancient stock, or one taxon might have contributed in the formation of another one. The details of the geographical distribution and ecology of the two taxa are rather in favour of the second hypothesis: it seems probable that *C. nemorosa* was one of the parent taxa for *C. pratensis*.

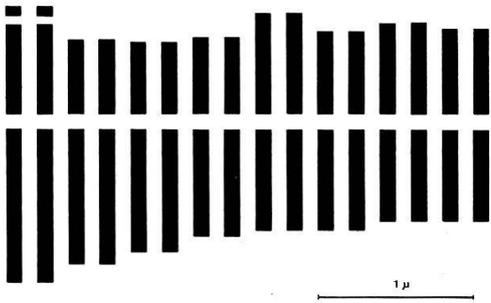


Fig. 13 Chromosome complement of *Cardamine granulosa*

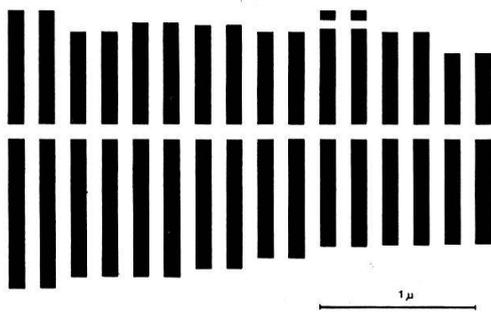


Fig. 14 Chromosome complement of *Cardamine Matthioli*

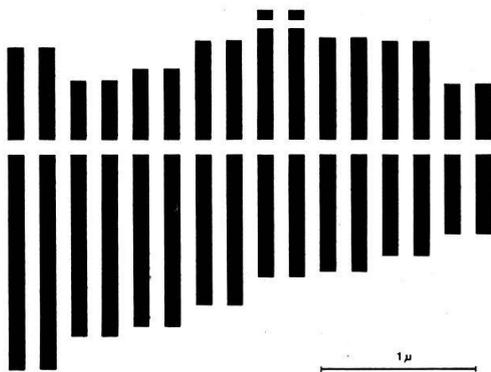


Fig. 15 Chromosome complement of *Cardamine rivularis* ^{pratensis}

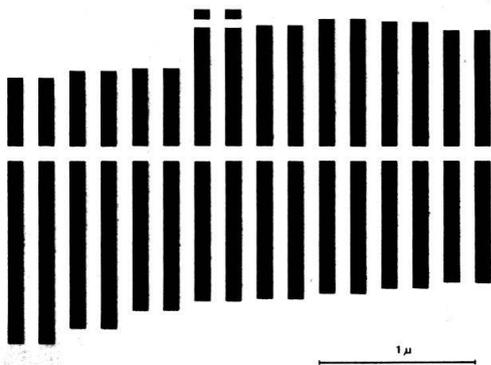


Fig. 16 Chromosome complement of *Cardamine rivularis* ~~*pratensis*~~

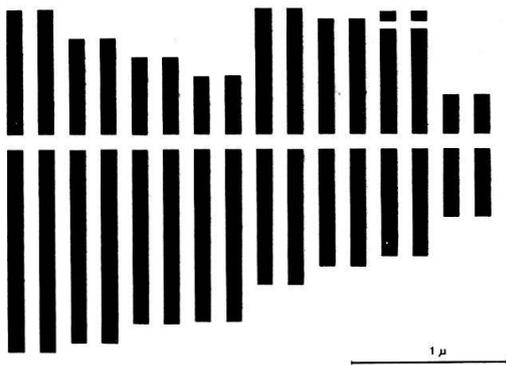


Fig. 17 Chromosome complement of *Cardamine nemorosa*

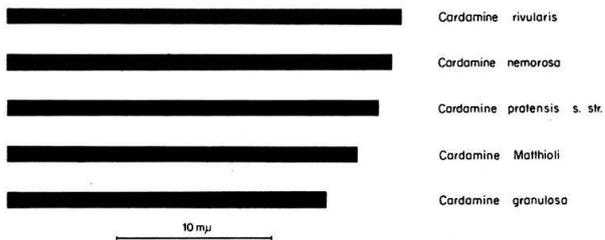


Fig. 18 Total karyotype length of five diploid taxa of the *Cardamine pratensis* group.