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DOI: https://doi.org/10.5169/seals-73287

Bot. Helv. 109 (1999): 67–84
0253-1453/99/010067-18 $ 1.50+0.20/0

Botanica Helvetica

Taxonomic evaluation of the tetraploid populations of *Cardamine amara* (Brassicaceae) from the Eastern Alps and adjacent areas

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Manuscript accepted January 5, 1999

Abstract

Marhold K. 1999. Taxonomic evaluation of the tetraploid populations of *Cardamine amara* (Brassicaceae) from the Eastern Alps and adjacent areas. Bot. Helv. 109: 67–84.

Tetraploid populations of *C. amara* occupying the area of the Eastern Alps and neighbouring areas are described as a new subspecies, *C. amara* subsp. *austriaca* Marhold. The distribution area of these populations largely coincides with the area heavily affected by Pleistocene glaciation and it is suggested that the polyploidization event or events occurred during interglacial or early postglacial periods. Morphometric analysis of diploid and tetraploid populations of *C. amara* revealed that the new subspecies is morphologically close to diploid *C. amara* subsp. *amara*, but it can be separated from this taxon by the combination of several morphological characters from among of which the size of pollen grains is the most important.

Key words: Cardamine amara, Cruciferae, karyology, chromosome numbers, distribution, new subspecies.

Introduction

Cardamine amara L., widespread for most of Europe and extending to Asia to the Altai, is a variable species in respect of morphology and chromosomes. On the diploid level three subspecies are recognised, namely *C. amara* subsp. *amara* (widespread for most of the area of species, especially in the lower and middle altitudes), *C. amara* subsp. *opicii* (J. Presl & C. Presl) Čelak. (confined to the higher altitudes of the Sudety Mts. and Carpathians) (Hrouda & Marhold 1993, Marhold 1995), and *C. amara* subsp. *balcanica* Marhold et al. (occurring in the mountains of SW Bulgaria and NE Greece) (Marhold et al. 1996). Diploid populations from the Pyrenees, previously treated as *C. amara* subsp. *amara*, seem to represent another taxon, for which two long forgotten names, *C. amara* subsp. *pyrenaea* Sennen and *C. amara* subsp. *siifolia* Sennen are available (Marhold, in prep.). Tetraploids are represented by *C. amara* subsp. *olotensis* O. Bolòs, local Catalonian endemic, well characterised by

the yellow colour of anthers, and by the populations occupying the area of the Eastern Alps and the neighbouring areas. The latter populations were not previously recognised as separate from *C. amara* subsp. *amara* although in certain areas they were misidentified as *C. amara* subsp. *opicii* or *C. opicii* (e.g. by Hayek 1908–1911: 483, or more recently by Markgraf 1960: 202, Löve & Löve 1974: 344, Pignatti 1982: 405, Adler et al. 1994: 593, or Maurer 1996: 105). Habeler (1963), who studied tetraploid and diploid populations mostly in Styria, concluded that *C. amara* is a variable species without any possibility of infraspecific classification. Her results influenced the authors of the corresponding accounts in the last edition of Hegi's Illustrierte Flora von Mitteleuropa (Schultze-Motel 1986) as well as the Flora of Switzerland (Hess et al. 1970).

The aim of the present paper is to summarise the results of the morphometrical and karyological studies of *Cardamine amara* in the Eastern Alps and neighbouring areas and to suggest a new taxonomic classification of the tetraploid populations occupying this area.

Materials and methods

Present study is based on chromosome counts of 153 diploid and tetraploid populations of *Cardamine amara* from the area of Austria, Germany, Czech Republic, Slovenia and Italy carried by the present author, unpublished data kindly supplied by Elias Landolt, Krystyna Urbanska, Marion Huthmann, and Věra Jarolímová, and on the data from literature. Out of them 17 population samples of tetraploids of mostly 30–40 plants (605 plants altogether) were selected for detailed morphometric study (see Appendix 2, marked as * or **), together with 38 population samples of diploid *C. amara* subsp. *amara* (2n=16) (1457 plants), 20 population samples of *C. amara* subsp. *opicii* (2n=16) (753 plants), and 11 population samples of *C. amara* subsp. *balcanica* (2n=16) (338 plants). For details about the localities of the diploid populations see Marhold (1992, 1998). For the more detailed comparison of the diploid *C. amara* subsp. *amara* and tetraploid populations from the Eastern Alps, which included the character PG (average diameter of pollen grains), 266 plants of the diploid populations of *C. amara* subsp. *amara* (populations no. 6, 33, 42, 43, 45, 54, 55, cited in Marhold 1992 and those marked by ** in the Appendix 2 of the present paper, from Austria, Czech Republic, Slovak Republic, Ukraine and Romania) and 399 plants of tetraploids (marked by ** in the Appendix 2) were used.

Chromosome numbers were counted on the mitotic figures from the root-tips of the plants taken from the localities and cultivated at the Institute of Botany in Bratislava. The root tips were pretreated with 0.002 M aqueous solution of hydroxyquinoline for 3 hrs, then fixed for 10 min. to 24 hrs in a freshly prepared mixture of ethanol and acetic acid (3 : 1), hydrolysed for 5 min. in a mixture of hydrochloric acid and ethanol (1 : 1), washed in water, and then stained with acetic or propionic orcein. Temporary slides were made by the squash method. Unless otherwise stated voucher specimens are deposited in herbarium SAV. Localities of chromosome numbers in the Appendix are arranged according to the Central European mapping scheme (Niklfeld 1971). This scheme was used also for the preparation of the distribution map.

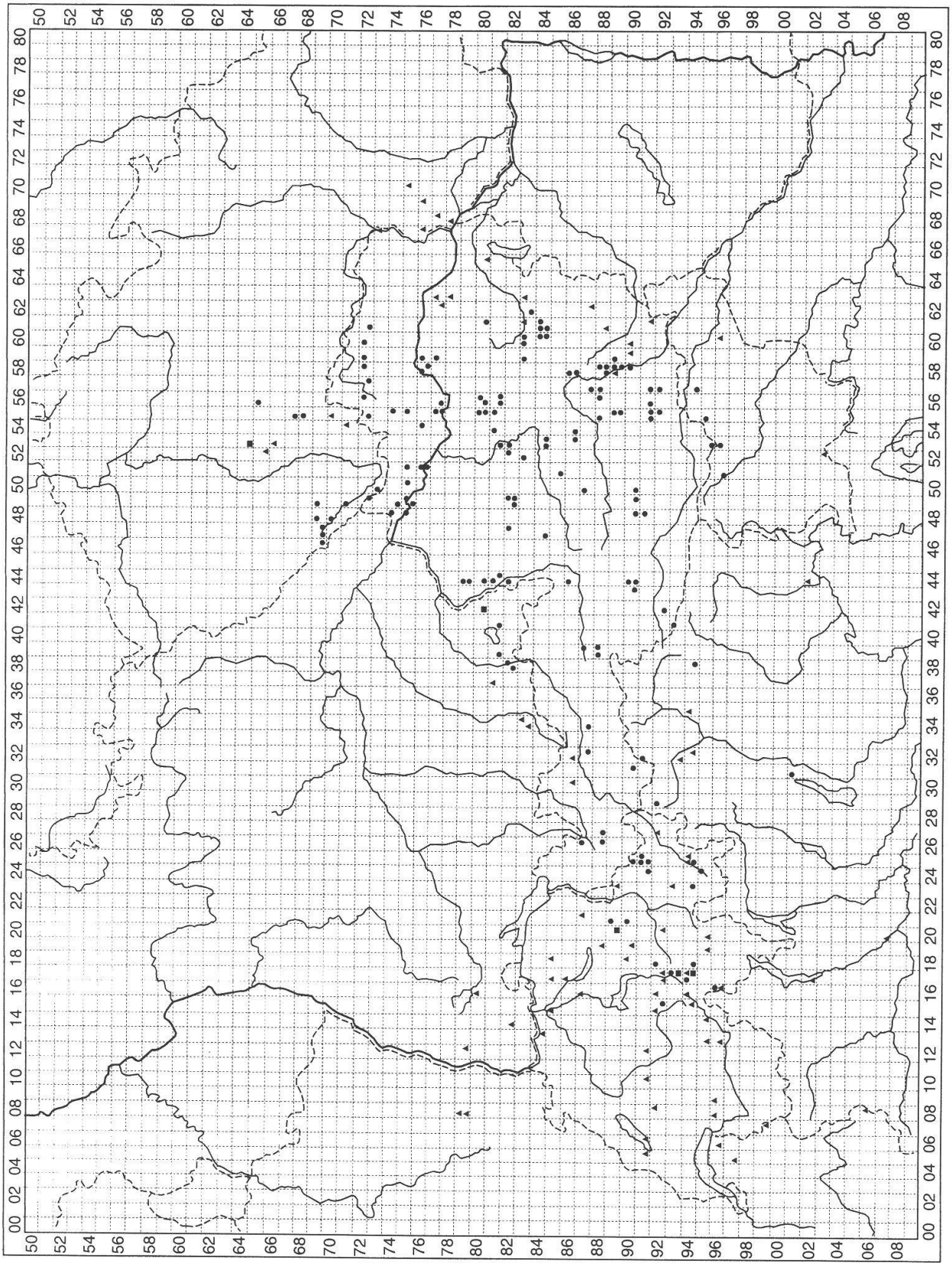
For the multivariate morphometric study the following characters were measured or scored for each plant (except of character PG measured on reduced sample): width of stem (WS), mm; branching of the stem (BS): branched (1), not branched (0); number of stem leaves (NL); maximum number of leaflets of the leaves in the upper 4/5 of stem (NLL); degree of congestion of leaves beneath the inflorescence, expressed by the number of leaves reaching the base of the uppermost stem leaf (NLR); number of flowers (including buds) in the main inflorescence (NF); length of petals (LP), mm; width of petals (WP), mm; length of sepals (LS), mm; length of filaments of the longer stamens (LF), mm; average diameter of 30 pollen grains from flowers in the main inflorescence (the shorter diameter was measured in a glycerol jelly after 48 hours) (PG), μm. The sizes of the petals, sepals and filaments were measured on fresh floral parts attached on adhesive tape and dried, so as to preserve their original size as much as possible. The characters included these traditionally used for the identification of taxa within *Cardamine amara* (or the *C. amara* group) (e.g., by Jones 1964, Markgraf 1960, Adler et al. 1994) and those which proved to be useful in previous studies of *C. amara* (Marhold 1992, 1998). Morphometric study was performed

on the population samples, characterised by the average values of characters as well as on the individual plants. Pearsson and Spearmann correlation coefficients were computed in order to reveal highly correlated groups of characters, and basic statistical parameters as the mean, minimum and maximum values, coefficient of variation, standard deviation and the Shapiro-Wilk statistic with associated probability for the test of normality, were computed for each character. In order to reveal characters useful for the identification of the tetraploid populations from the already recognised diploid taxa canonical discriminant analyses (Klecka 1980, Krzanowski 1990) were used. Classificatory discriminant analyses (Klecka 1980, Krzanowski 1990) were performed in order to test the reliability of the classification criteria. In these analyses, discriminant function was determined by the cross-validation. Because the distribution of characters within the groups was not multivariate normal, a non-parametric k-nearest-neighbour method was used together with parametric one (SAS Institute 1990b). However, although the discriminant analysis is based on the assumption of the multivariate normality of data, considerable robustness of the method in this respect was shown by several authors (cf. Klecka 1980). Multivariate analyses were carried out using the SAS statistical package on the mainframe computer of the University of Vienna (SAS Institute 1990a, b).

Results

Results of the analyses of chromosome numbers, together with the data from literature are given in the Appendix and are shown on the map (Fig. 1). Taking into account also unpublished data by Urbanska, Landolt, Huthmann and Jarolímová (Appendix 2), in the area to the south of the SE Germany, S Bohemia, to the west of the city of Vienna, to the N of Graz in Styria, middle part of Slovenia and NE Italy, and to the east of the Bernese Oberland in Switzerland, *C. amara* is represented mostly by tetraploid populations, which are formally described here as *C. amara* subsp. *austriaca* (see Appendix 1). The lowermost analysed locality is on the level of the Danube River, in the town of Spitz a.d. Donau at the altitude of 230 m, the uppermost one is in the Goldberggruppe of the Hohe Tauern, SE of Sadnigscharte at the altitude of 2440 m. In all cases only euploids were found without any variation in a chromosome number as known from the related *Cardamine pratensis* group (Marhold 1994).

Morphometric analysis shows general similarity of the tetraploid populations and the possibility of their morphological recognition from the diploid taxa. As the absolute value of correlation coefficients among the characters within three diploid taxa and within tetraploid populations, as well as in the pooled matrix of the whole material did not exceed value 0.80877 (correlation of the number and congestion of leaves in the pooled matrix), all above mentioned characters were used in the analyses. The ordination diagram of the canonical discriminant analysis of populations of three diploid taxa and tetraploids (Fig. 2) shows that although the tetraploid populations are morphologically close to *C. amara* subsp. *amara*, they can be separated from this taxon as well. The first axis expresses 64.4 % of the variation among the groups of populations, the second one 25.8 %, and the third one 9.8 %. The corresponding values of the canonical correlation are 0.95, 0.89 and 0.77 respectively. Tetraploid populations occupy somewhat intermediate position along the first canonical axis between *C. amara* subsp. *opicii* and *C. amara* subsp. *balcanica* on one side and *C. amara* subsp. *amara* on the other. From among the characters NL, NLR, WS and BS that have the highest values of correlation with the first canonical axis, tetraploids are morphologically intermediate especially in respect of the width of stem base (WS) and the branching of stem (BS), having wider and less often branched stem in comparison with *C. amara* subsp. *amara*. In respect of the second axis several tetraploid populations are positioned more close to *C. amara* subsp. *opicii*, which is connected mainly with the number of leaflets (NLL), character with the highest correlation with the second axis. Among these populations with higher number of leaflets



◀ Fig. 1. Distribution map of karyologically evaluated populations of *Cardamine amara* in the Eastern Alps and neighbouring areas according to the Central European mapping scheme (Niklfeld 1971). ● *C. amara* subsp. *austriaca* (2n=32); ▲ *C. amara* subsp. *amara* (2n=16); ■ both *C. amara* subsp. *amara* and *C. amara* subsp. *austriaca* in the same subsquare.

are those from the lower altitudes (e.g. 230 m, Spitz a. d. Donau) as well as from the higher ones (e.g. 2150 m, Schoberbach). This variation is not correlated with the distribution pattern and it seems that the position of these populations is not a result of direct influence of *C. amara* subsp. *opicii*. The third axis, which is mostly correlated with the size of the flower parts (LF, LS, LP), separates the tetraploid populations from the rest of the material studied. Canonical discriminant analysis of the individual plants of tetraploid populations and those of *C. amara* subsp. *amara* with the additional character, the diameter of the pollen grains (Fig. 3) shows quite good separation. It should be stressed, however, that according to the character correlations with the canonical axis this is mainly due to the size of pollen grains and to a lesser extent due to the characters LS, BS, NL and LF. Classificatory discriminant analysis, performed on the plant individuals without using the size of pollen grains (Tab. 1)

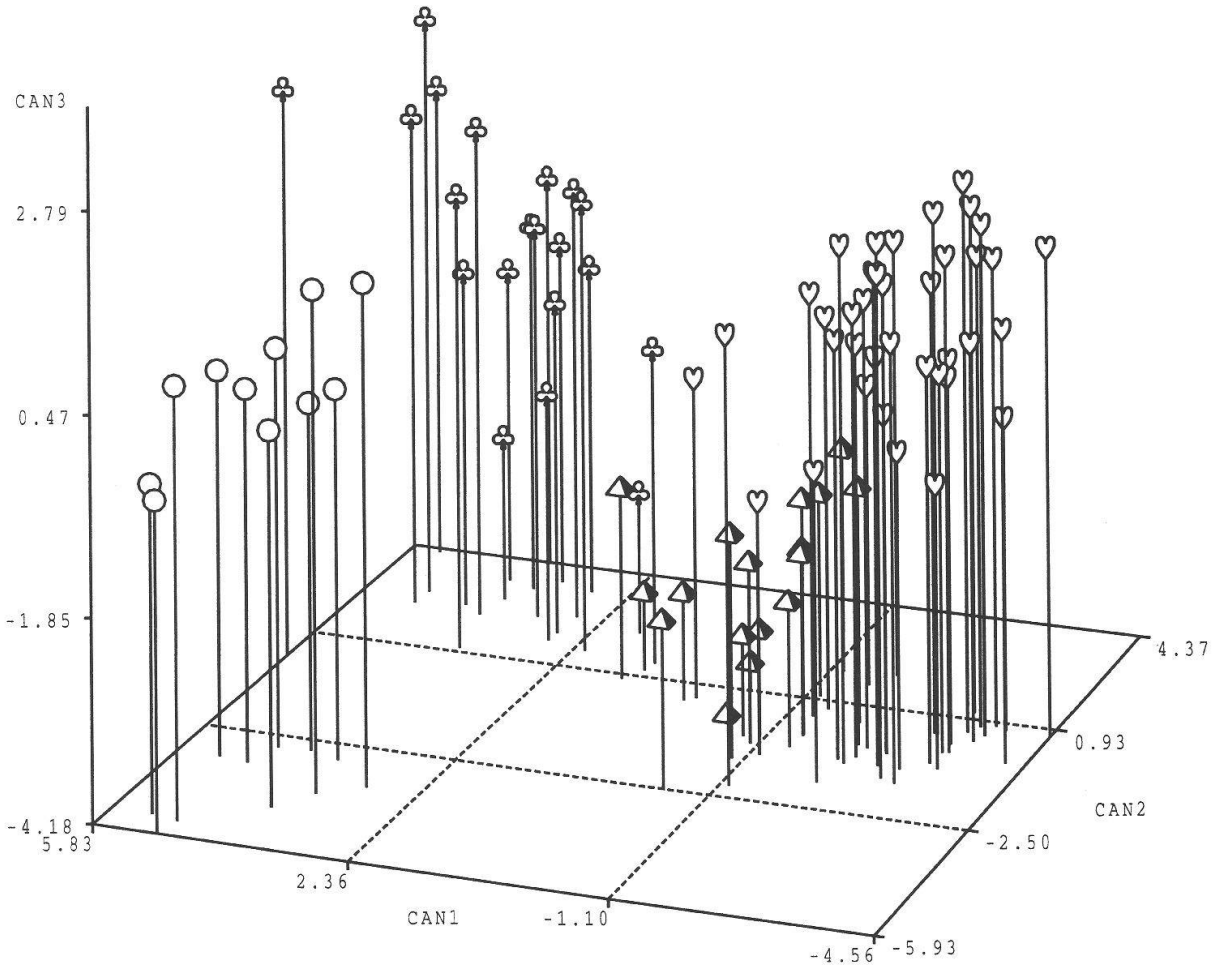


Fig. 2. Ordination diagram of the canonical discriminant analysis of populations of three diploid taxa and tetraploids (without character PG, diameter of pollen grains). Ball – *C. amara* subsp. *balcanica*, club – *C. amara* subsp. *opicii*, heart – *C. amara* subsp. *amara*, pyramid – *C. amara* subsp. *austriaca*.

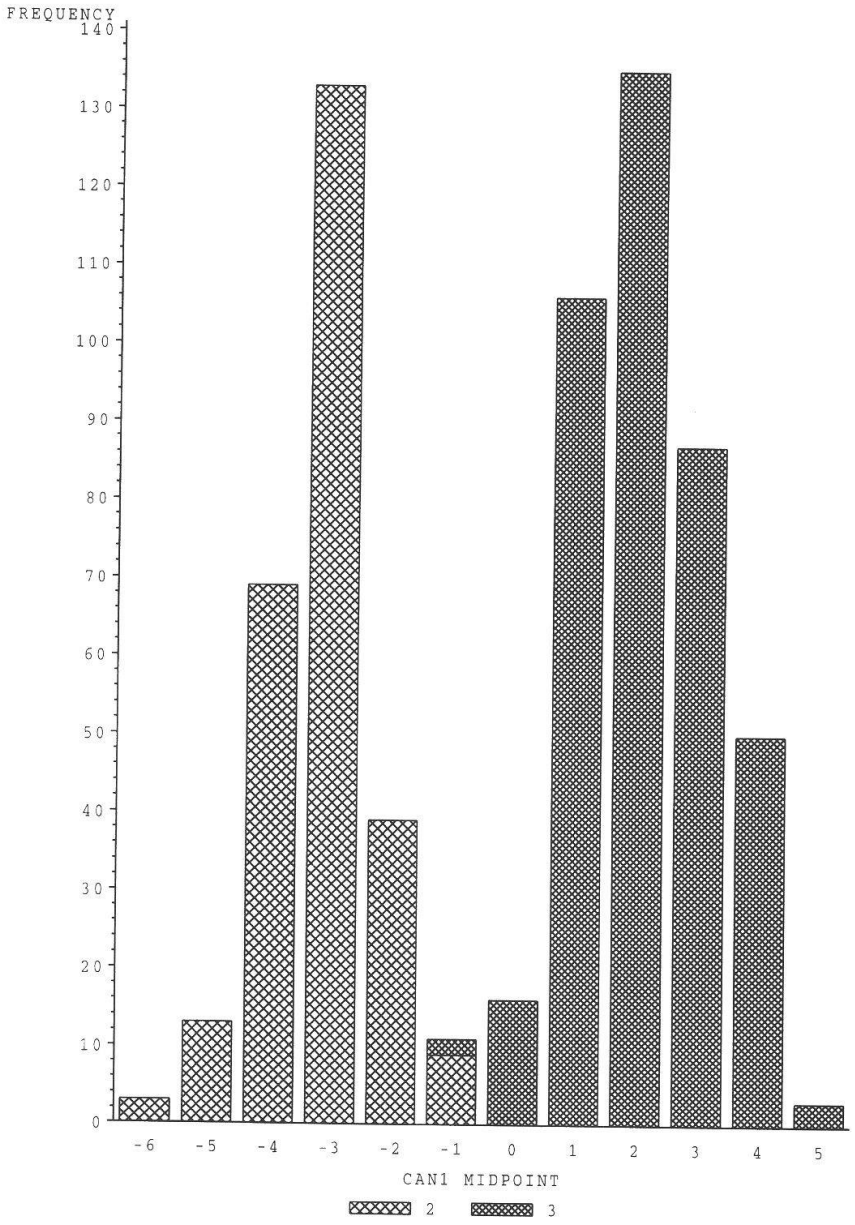


Fig. 3. Histogram of the canonical discriminant analysis of individual plants of *C. amara* subsp. *amara* (2) and *C. amara* subsp. *austriaca* (3) (character PG, diameter of pollen grains included in the analysis).

shows good level of separation of tetraploid plants from *C. amara* subsp. *opicii* and *C. amara* subsp. *balcanica*. The correctness of identification of tetraploid *C. amara* subsp. *austriaca* from the diploid *C. amara* subsp. *amara* is lower, which indicates the need for taking into account also the size of pollen grains. More deep sight onto the misclassified plants in the non-parametric discriminant analysis does not reveal any clear pattern of their distribution, although they are not equally spread within the populations studied. The following populations have more than 15% of plants wrongly classified either into or from *C. amara* subsp. *austriaca*: *C. amara* subsp. *opicii* into *C. amara* subsp. *austriaca*: Slovakia, Nízke Tatry, Ďurková (27.5%); *C. amara* subsp. *amara* into *C. amara* subsp. *austriaca*: Slovakia, Vel'ká Fatra, Gaderská dolina, Dedošová (27.5%); Poland, Gorce, Kamienica (17.5%), Huba, Ko-

Table 1. Results of the parametric (P) and non-parametric (N) discriminant analysis of *Cardamine amara* subsp. *amara* (AM), *C. amara* subsp. *opicii* (OP), *C. amara* subsp. *balcanica* (BA), and *C. amara* subsp. *austriaca* (AU).

Actual group		Predicted membership (number of observations and percent classified into groups)			
		AM	**OP**	**BA**	**AU**
AM	**P**	**1314 (90.19)**	27 (1.85)	0 (0.0)	116 (7.96)
	N	**1363 (93.55)**	4 (0.27)	0 (0.0)	90 (6.18)
OP	**P**	17 (2.26)	**696 (92.43)**	4 (0.53)	36 (4.78)
	N	15 (1.99)	**696 (92.43)**	12 (1.59)	30 (3.98)
BA	**P**	1 (0.3)	4 (1.18)	**333 (98.52)**	0 (0.0)
	N	0 (0.0)	0 (0.0)	**338 (100.0)**	0 (0.0)
AU	**P**	91 (15.04)	26 (4.3)	0 (0.0)	**488 (80.66)**
	N	57 (9.42)	8 (1.32)	0 (0.0)	**540 (89.26)**

telnica (17.5%); Romania, Sibiu (16.7%), Tălmaciu (27.8%); Austria, Gablitz (16.7%); *C. amara* subsp. *austriaca* into *C. amara* subsp. *amara*: Austria, Oberst Klinke Hütte (22.5%), Raxalpe (18.2%); Czechia, Dobrá (28.6%), Lštění (22.5%). Few of them are from the contact zones of two taxa concerned, but other are from the areas where any influence of other taxon can not be expected.

Median and 10 and 90 percentiles of measured characters are shown in Tab. 2, portion of the branched and not branched plants in Tab. 3. Overlap of the values of most characters between *C. amara* subsp. *amara* and *C. amara* subsp. *austriaca*, clearly indicates that it is not possible to identify these plants using the single character except the size of pollen grains. The data about the value of the latter character for the identification of diploids and tetraploids contradict the results of Habeler (1963), the correctness of her conclusions in this respect was, however, already put in doubt by Urbanska-Worytkiewicz and Landolt (1972).

Discussion

Tetraploid populations of *Cardamine amara* (except Catalonian endemic *C. amara* subsp. *olotensis*) are restricted in their distribution area to the Eastern Alps and the closely neighbouring areas. From the other parts of the area of *C. amara* only diploids are known (Manton 1932, Lövkvist 1957, for other references see Marhold 1994). The single report from the Carpathians by Hindáková (1974), noted also by Teppner (1980), was not confirmed and should be considered as erroneous (cf. Marhold 1994: 30–31). It is remarkable that the distribution area of tetraploid populations, especially its eastern part only marginally overlaps with the area of diploid populations of *C. amara* subsp. *amara* (Fig. 1). In the western part of the area (in Switzerland) the distribution of diploids and tetraploids are overlapping to the bigger extent, but there is a remarkable tendency for tetraploids to occupy localities in higher altitudes, while diploids tend to occur in the lower altitudes. Similar tendency is visible also in S Bohemia. Further analyses might reveal more overlaps on the margins of the distribution area, but it is clear that the main part of the Eastern Alps and the closely neighbouring areas are occupied entirely by tetraploids. As the distribution area of tetraploids large-

Table 2. Comparison of morphological characters of four subspecies of *Cardamine amara*: *C. amara* subsp. *austriaca* (AU), *C. amara* subsp. *amara* (AM), *C. amara* subsp. *opicii* (OP), and *C. amara* subsp. *balcanica* (BA).

	Median	10 percentile (1 percentile)	90 percentile (99 percentile)
width of stem (WS), mm			
AU	2.5	1.5 (1.0)	4.0 (6.5)
AM	2.0	1.5 (1.0)	3.5 (4.5)
OP	4.0	2.5 (2.0)	6.5 (11.0)
BA	4.0	2.5 (2.0)	6.0 (7.5)
number of stem leaves (NL)			
AU	9	6 (4)	14 (18)
AM	8	5 (3)	12 (17)
OP	24	15 (9)	34 (49)
BA	26	19 (15)	33 (38)
maximum number of leaflets of the leaves in the upper 4/5 of stem (NLL)			
AU	11	7 (6)	13 (15)
AM	8	7 (5)	11 (13)
OP	15	11 (9)	17 (19)
BA	9	7 (5)	9 (11)
degree of congestion of leaves beneath the inflorescence, expressed by the number of leaves reaching the base of the uppermost stem leaf (NLR)			
AU	1	0 (0)	3 (5)
AM	1	0 (0)	2 (4)
OP	6	3 (1)	9 (13)
BA	3	2 (1)	5 (6)
number of flowers (including buds) in the main inflorescence (NF)			
AU	15	7 (4)	26 (35)
AM	14	7 (3)	22 (28)
OP	17	10 (5)	25 (33)
BA	22	12 (6)	35 (42)
length of petals (LP), mm			
AU	8.8	7.6 (6.4)	9.9 (10.8)
AM	8.2	7.1 (6.1)	9.5 (10.2)
OP	8.2	6.9 (5.7)	9.4 (10.2)
BA	7.5	6.4 (5.9)	8.5 (9.2)
width of petals (WP), mm			
AU	4.5	3.6 (2.8)	5.4 (6.4)
AM	4.5	3.6 (2.9)	5.4 (6.2)
OP	3.6	2.9 (2.6)	4.7 (5.4)
BA	3.1	2.6 (2.3)	3.6 (4.2)
length of sepals (LS), mm			
AU	4.2	3.6 (3.1)	4.7 (5.2)
AM	3.6	3.1 (2.8)	4.0 (4.5)
OP	4.2	3.6 (3.1)	4.9 (5.2)
BA	3.8	3.1 (2.9)	4.3 (4.7)
length of filaments of the longer stamens (LF), mm			
AU	6.6	5.7 (4.9)	7.3 (7.8)
AM	5.6	4.9 (3.8)	6.6 (7.3)
OP	5.7	4.9 (3.3)	6.6 (7.3)
BA	6.2	5.2 (3.5)	7.1 (7.8)
average diameter of 30 pollen grains from flowers in the main inflorescence (PG), µm			
AU	24.28	23.53 (22.99)	25.07 (25.72)
AM	21.59	21.10 (20.32)	22.24 (22.97)

Table 3. Portion of branched plants in the subspecies of *Cardamine amara*: *C. amara* subsp. *austriaca* (AU), *C. amara* subsp. *amara* (AM), *C. amara* subsp. *opicii* (OP), and *C. amara* subsp. *balcanica* (BA).

	Branched	Not branched	Branched/Not branched (ratio)
AU	171	434	0.39
AM	949	508	1.87
OP	43	710	0.06
BA	49	289	0.17

ly coincides with the area heavily affected by Pleistocene glaciation, it seems probable that the polyploidisation event or events occurred during interglacial or early postglacial periods taking the advantage of the possibility of occupation of the area covered or affected by glaciation. Such theory is well supported by the general correlation between percentages of polyploidy and degree of glaciation during the Pleistocene epoch (Stebbins 1984). The first results of the isozyme studies (Marhold et al., in prep.) favour the idea of autotetraploid origin of these populations arising directly from *C. amara* subsp. *amara*. A slight shift of the morphological variation towards *C. amara* subsp. *opicii* thus seems to be a result of the parallel evolution rather than hybridisation or allopolyploid origin of tetraploids. A possibility of the participation of two or more interfertile races that had different adaptive norms, and belonged to *C. amara* subsp. *amara* should be taken into consideration as well (cf. Stebbins 1984: 3). Compact area occupied by the tetraploids suggests their monophyletic origin or at least does not support the idea of several completely independent polyploidisation events. The results of isozyme studies suggest also that tetraploid *C. amara* subsp. *olotensis* arose by the independent event. This is supported also by its different morphology.

In spite of the fact that the differences between *C. amara* subsp. *amara* and the tetraploid populations are not so pronounced as among the diploid subspecies, because of the precisely defined area of tetraploids it seems appropriate to treat them as a separate taxon. Question might arise if the treatment on the subspecific level, on which it is described here, is the most appropriate one. The difference in the ploidy level, its own area and absence (or at least rarity) of hybrids would favour the treatment at the level of species, but the less pronounced morphological differences, in the opinion of the present author prevent such solution.

The morphological and karyological variation in *C. amara* represent an example of the geographical diversification on the diploid level (the Carpathian and Sudetic *C. amara* subsp. *opicii*, Balkan *C. amara* subsp. *balcanica*, and possibly also separate subspecies in the Pyrenees) with two most probably independent polyplodisation events with tetraploids occupying small area south of the Pyrenees and much larger area in the Eastern Alps.

Similar distribution pattern of tetraploid vs. diploid populations in the area of the Alps can be found in the *Campanula patula* group (Hauser 1975). While tetraploid plants of this group (classified as *C. jahorinae* (K. Maly) Landolt, cf. Landolt 1975) are distributed nearly throughout the area of the whole Austria and also occur in Slovenia (Ljubljana), northern regions of Italy, and most probably also in Bosnia, they do not occur in Switzerland, where they are replaced by "northern" diploid *C. patula* L. and "southern" diploid *C. costae* Willk. ex Willk. et Lange. In Austria diploid *C. patula* occupies similar regions as the diploid of *C. amara*, although it is more widespread here occurring in the area to the north of the river Danube and having also localities in Carinthia and Salzburg where diploid *C. amara* is not to be found.

I would like to express my thanks to all colleagues, mentioned in the Appendix 2, who kindly helped me to collect plant material for chromosome counts, from among them especially to Ernst Vitek, as well as to Krystyna Urbanska, Elias Landolt, Marion Huthmann and Věra Jarolímová for their unpublished chromosome number data. Thanks go also to Harald Niklfeld for the help with the ascertaining localities to the Central European mapping scheme, to Elvira Hörandl for the help with the distribution map, and Katarína Cigánová for the illustration. The study was kindly supported by the Austrian Ministry for Science and Research, Vienna through the East-West Programme of the Austrian Academy of Sciences (Project no. OWP-58), by the Grant Agency VEGA, Bratislava (Project no. 6029), and by the Fellowship of the Alexander von Humboldt Foundation at the Universities in Osnabrück, Germany and Vienna, Austria, which is gratefully acknowledged.

Zusammenfassung

Tetraploide Populationen von *Cardamine amara*, die in den östlichen Alpen und angrenzenden Gebieten vorkommen, werden als neue Unterart *C. amara* subsp. *austriaca* Marhold beschrieben. Das Verbreitungsareal dieser Populationen wurde stark durch pleistozäne Vergletscherung geprägt, und es wird vermutet, daß die Polyploidisierung(en) während des letzten Interglazials oder im frühen Postglazial erfolgte(n). Morphometrische Analysen von diploiden und tetraploiden Populationen von *C. amara* erbrachten, daß die neue Unterart morphologisch *C. amara* subsp. *amara* (diploid) nahesteht, aber durch eine Kombination von mehreren morphologischen Merkmalen von diesem Taxon abgetrennt werden kann. Von besonderer Bedeutung ist dabei die Pollengröße.

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Appendix 1

***Cardamine amara* subsp. *austriaca* Marhold, *subspecies nova* (Fig. 4)**

Rhizoma (1.0–) 1.5–5.0 (–6.5) mm latum. Caulis erectus simplex aut in parte superiore ramosus, glabratus vel subglabratus. Folia caulina numero (4–) 5–15 (–18); folia cum 3–6 (–7) jugis, modo congesta sub inflorescentia. Inflorescentia racemosa, simplex vel composita, floribus (4–) 6–30 (–35); sepala (3.1–) 3.5–4.9 (–5.2) mm longa, petala alba, rarius violacea, obovata vel oblanceolata (6.4–) 7.3–10.2 (–10.8) mm longa, (2.8–) 3.3–5.7 (–6.4) mm lata, filamenta staminum longiorum (4.9–) 5.4–7.3 (–7.8) mm longa. Grana pollinis unius individui (22.99–) 23.33–25.39 (–25.72) µm. Chromosomatum numerus 2n=32.

Type: Hohe Tauern, [Goldberggruppe], Grossfragant region, Schobertal, near the rivulet Schoberbach, 2050 m, 7. 7. 1992 *K. Marhold* (holotype SAV, isotypes W, WU).

Perennial herb, 10–60 cm tall. Rhizome long, prostrate, (1.0–) 1.5–5.0 (–6.5) µm wide. Stem erect, sometimes flexuous, simple or branched above, slightly sulcate, glabrous or sparsely hairy. Leaves not in a rosette; cauline leaves (4–) 5–15 (–18), slightly congested below the inflorescence, with 3–6 (–7) pairs of lateral leaflets; leaflets sessile or shortly petiolulate, oblong to suborbiculate, almost entire, or lobate, crenate, or sharply crenate, sometimes ciliate, glabrous or with appressed hairs on upper surface. Inflorescence racemose, simple or compound, with (4–) 6–30 (–35) flowers in the main inflorescence; sepals ovate, (3.1–) 3.5–4.9 (–5.2) mm long, glabrous, margin membranous; petals white (rarely, especially in buds, reddish-violet), obovate to oblanceolate, (6.4–) 7.3–10.2 (–10.8) × (2.8–) 3.3–5.7 (–6.4) mm, with short claw, apex truncate to emarginate; stamens 6, indistinctly tetradynamous, filaments of longer stamens (4.9–) 5.4–7.3 (–7.8) mm, anthers reddish-violet to blackish-violet before anthesis; stigma not conspicuous. Average size of diameter of pollen grains (22.99–) 23.33–25.39 (–25.72) µm. 2n=32.

Flowering: April–July.

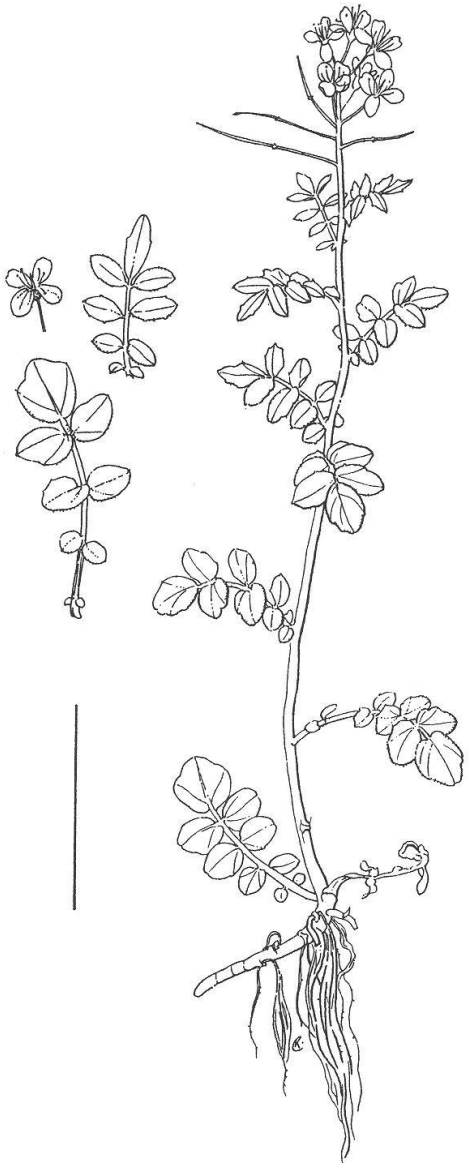

Fig. 4. *Cardamine amara* subsp. *austriaca* (del. K. Cigánová). Scale bar=5 cm.

Appendix 2

List of populations of *Cardamine amara* karyologically studied by the present author, unpublished chromosome counts kindly supplied by K. Urbanska & E. Landolt, M. Huthmann and V. Jarolímová, and the data from literature for the Eastern Alps and neighbouring areas. Unless otherwise stated material is collected by the author; populations included in the morphometric study are marked by asterisk (*), those used for comparison including the character PG (average diameter of pollen grains) are marked by two asterisks (**). L. stands for E. Landolt, U. for K. Urbanska, and K. M. for K. Marhold.

Cardamine amara subsp. *austriaca* (2n=32)

AUSTRIA. Lower Austria: 7255/3 Waldviertel, road between Altweitra and Unserfrau, at bridge over side stream of river Lainsitz, 505 m, 27. 6. 1993, leg. K. M. & E. Vitek; **7256/2** Waldviertel, at the

N end of Grossrupprechts (ca. 3 km W of Vitis), mouth of the rivulet Edelseegraben, 525 m, 27. 6. 1993, leg. K. M. & E. Vitek; **7257/4** Waldviertel, valley of river Thaua, ca. 2.5 km N of Thaua, 505 m, 27. 6. 1993, leg. K. M. & E. Vitek; **7258/2** Waldviertel, between Ellends and Blumau an der Wild, ca. 1 km NNW of Blumau at the rivulet Seebsbach, 520 m, 27. 6. 1993, leg. K. M. & E. Vitek; **7259/1** Waldviertel, ca. 1.5 km E of Japons at the rivulet Thumeritzbach, 475 m, 27. 6. 1993, leg. K. M. & E. Vitek; **7260/1** Waldviertel, ca. 3 km ESE of Geras at the rivulet Goggitschbach at the northern side of Fugnitzberg, 455 m, 27. 6. 1993, leg. K. M. & E. Vitek; **7261/3** Waldviertel, E end of Pulkau, at the bridge of the road to Röschitz across river Pulkau, 27. 6. 1993, 250 m, leg. K. M. & E. Vitek; **7455/4** Waldviertel, between Arbesbach and Griesbach, at the locality called "Rotes Kreuz", 805 m, 27. 6. 1993, leg. K. M. & E. Vitek; **7555/2** Waldviertel, between Kleinpertenschlag and Altmelon, where the road is crossing the rivulet Fichtenbach, 860 m, 27. 6. 1993, leg. K. M. & E. Vitek; **7658/1** **Spitz a. d. Donau, 230 m, 8. 4. 1992; **7658/4** Dunkelsteiner Wald, Gansbach, SE of the village, 450 m, 8. 7. 1993; **7659/1** Dunkelsteiner Wald, Oberbergen (SW of Mautern a.d. Donau), 1 km SW of the village, 380 m, 8. 7. 1993; **7755/2** Waldviertel, valley of the river Sarmingbach, 1 km N of Schlossberg (near Waldhausen i. Strudengau), 470 m, 27. 6. 1993, leg. K. M. & E. Vitek; **7755/4** Waldviertel, valley of the river Kleine Ysper, turn-off of road to Fünfling, 435 m, 27. 6. 1993, leg. K. M. & E. Vitek; **7756/3** Waldviertel, valley of the river Ysper, ca. 1.5 km from the mouth of Ysper into Danube, 230–240 m, 27. 6. 1993, leg. K. M. & E. Vitek; **7759/1** Dunkelsteiner Wald, Weyersdorf (NW of St. Pölten), in the village, 450-480 m, 8. 7. 1993; **8055/2** 4.4 km NE of Ybbsitz, Haselgraben valley, below elevation point 530 m, ca. 500 m, 12. 4. 1998, leg. K. M., E. Hörandl & F. Hadaček; **8055/4** S of Rechen (5 km SE of Ybbsitz), Wülfachgraben (side valley of Schwarze Ois), ca. 540 m, 12. 4. 1998, leg. K. M., E. Hörandl & F. Hadaček; **8056/2** Neustift (S of Scheibbs), near the river Erlauf, 350 m, 4. 11. 1993, leg. E. Vitek; **8056/3** 2 km NE of Gresten, Weyhof, ca. 430 m, 12. 4. 1998, leg. K. M., E. Hörandl & F. Hadaček; **8061/4** Kalkalpen, SW end of Steinwandgraben, at the beginning of Steinwandklamm (S of Furth an der Triesting), 540 m, 26. 6. 1994, leg. E. Vitek; **8155/2** S of Rechen (5 km SE of Ybbsitz), valley Schwarze Ois, Meyerhofeben, ca. 600 m, 12. 4. 1998, leg. K. M., E. Hörandl & F. Hadaček; **8156/3** ** Dürrenstein, Ybbstaler Hütte, E of the chalet, 1360 m, 15. 7. 1992; **8156/3** **Dürrenstein, Ybbstaler Hütte, SW of the chalet, 1330 m, 14. 7. 1992; Dürrenstein, Rotmoos, 1125 m, 16. 7. 1992; Kasten (S of Lunz am See), Lehen, 590 m, 14. 7. 1992; Kasten (S of Lunz am See), Lechnergraben, 950 m, 14. 7. 1992; **8360/2** Semmering, Breitenstein, in the village, ca. 800 m, 12. 6. 1992; **8362/3** Wechsel, Au (ca 2 km E of Kirchberg a. Wechsel), 520 m, 25. 7. 1993, leg. E. Vitek; **8461/1** **Wechsel, below the Feistritzsattel saddle, ca. 1200 m, 12. 6. 1992; **8461/2** Wechsel, between St. Corona and Kampsteiner Schwaig, ca. 1300 m, 25. 7. 1993, leg. E. Vitek. **Upper Austria: 7249/4** Hochficht (N of Ulrichsberg, on the Austrian-Czech border), 1000 m, 15. 7. 1992, leg. S. Kučera & F. Speta; **7350/1** Mühlviertel, ca. 6 km ENE of the village of Aigen im Mühlkreis, Bayerische Au, ca. 1 km ESE of Zollhaus, 740 m, 7. 6. 1996, leg. E. Vitek; **7448/2** S of Oberkappel, 500 m, 17. 5. 1994, leg. K. M. & G. Brandstätter; **7449/3** near the road from Putzleinsdorf to Oberkappel, 660 m, 17. 5. 1994, leg. K. M. & G. Brandstätter; **7548/2** near the road from Hofkirchen i. Mühlkreis to Niederranna, NW of Niederranna, 370 m, 17. 5. 1994, leg. K. M. & G. Brandstätter; **7549/2** W of Altenfelden, near the road from Hörhag to Bruckwirt, 410 m, 17. 5. 1994, leg. K. M. & G. Brandstätter; **7549/3** Schlögen, ca. 13 km NW of Aschach a.d. Donau, 280 m, 17. 5. 1994, leg. K. M. & G. Brandstätter; **7550/2** St. Veit i. Mühlkreis, 660 m, 17. 5. 1994, leg. K. M. & G. Brandstätter; near the road between St. Johann a. Wimberg and St. Peter a. Wimberg, 650 m, 17. 5. 1994, leg. K. M. & G. Brandstätter; **7551/2** ca. 2 km S of Zwettl a. d. Rodl, 630 m, 17. 5. 1994, leg. K. M. & G. Brandstätter; **7651/2** Linz N, Altenbergstrasse (road to Altenberg b. Linz), junction to Oberbairing, 560 m, 17. 5. 1994, leg. K. M. & G. Brandstätter; **7651/4** Linz, Dornach, 270 m, 18. 5. 1994; **7654/2** near the road from Mönchdorf to Königswiesen, near the bridge, near the junction to Schreineredt, 620 m, 17. 7. 1992, leg. G. Brandstätter; **7944/1** SE of Feldkirchen b. Mattighofen, between Renzlhausen and Gietzing, 490 m, 19. 4. 1998, leg. K. M., E. Hörandl & F. Hadaček; **7944/3** between Oichten and Michaelbeuern, 440 m, 19. 4. 1998, leg. K. M., E. Hörandl & F. Hadaček; **8144/4** N of Palting, ca. 500 m, 19. 4. 1998, leg. K. M., E. Hörandl & F. Hadaček; **8153/3** Reichraminger Hintergebirge, Kleinreifling, Klaus, near the rivulet Arzbach, on the path to Gr. Almkogel, 980 m, 19. 7. 1992; Reichraminger Hintergebirge, Kleinreifling, Klaus, near the rivulet Arzbach, on the path to Gr. Almkogel, 870 m, 19. 7. 1992; Reichraminger Hintergebirge, Grossraming, [area NW of Gr. Almkogel], Stallburgalm, 1070 m, 19. 7. 1992; **8154/1** Weyer Markt, Breitenau (S of Gaflenz) Breitenaubach,

N of Breitenau, 510 m, 18. 7. 1992; **8247/2** Salzkammergut, E of Attersee, side valley N of Weissenbachtal valley, ca. 580 m, 20. 8. 1996, leg. E. Vitek; **8249/2** Totes Gebirge, Almsee, N of the lake, 580 m, 20. 7. 1992; **8249/3** Totes Gebirge, Weisshorn [saddle], 1550–1600 m, 20. 7. 1992; **8249/4** Totes Gebirge, Almsee, S of the lake, 589 m, 20. 7. 1992; **8252/2** Reichraminger Hintergebirge, W of Hochkogel, S of Hochkogelhütte (in the direction to Annerlsteg), Keixengraben, 740 m, 23. 7. 1992; Reichraminger Hintergebirge, Grossraming, on the path to Anlaufalm along the rivulet Hochschlachtbach, 620 m, 23. 7. 1992; **8253/1** Reichraminger Hintergebirge, Menaueralm, near the spring of a rivulet (W of Altenmarkt b. St. Gallen, NNE of Unterlaussa), 1092 m, 22. 7. 1992; **8352/1** Spital am Pyhrn, rivulet ca. 250 m S of Vorleiten, 820 m, 13. 5. 1994, leg. E. Vitek (LI, SAV); **8447/3** Dachstein, between Vorderer Gosausee and Hinterer Gosausee, ca. 1000 m, 24. 5. 1990, leg. L. Hrouda; Dachstein, Hinterer Gosausee, 1165 m, 24. 5. 1990, leg. L. Hrouda. **Styria: 8359/1** Neuberg a.d. Mürz, 780 m, 29. 6. 1992; **8360/1** *Raxalpe, above Preiner Gscheid, near the path to Karl Ludwig Haus, ca. 1150 m, 30. 6. 1991; **Raxalpe, above Preiner Gscheid, near the path to Karl Ludwig Haus, ca. 1400 m, 30. 6. 1991; **8453/3** **Ennstaler Alpen, Oberst Klinke Hütte, 1480 m, 21. 7. 1992; **8453/4** Ennstaler Alpen, Gesäuseberge, Johnsbachtal, below Untere Koderalm, ca. 1160 m, 4. 6. 1990, leg. F. Starlinger; Ennstaler Alpen, Johnsbach, Wirthaus Kölbl, Wasserfallgraben, 1060 m, 20. 7. 1992; **8460/2** **Fischbacher Alpen, Stuhleck, between Pfaffensattel and junction to Fröschnitzsattel, 1196 m, 12. 6. 1992; Fischbacher Alpen, Stuhleck, above Pfaffensattel, ca. 1500 m, 28. 6. 1992; **8460/4** Fischbacher Alpen, Rettenegg, NE of the village, ca. 900 m, 12. 6. 1992; **8461/3** Wechsel, Feistritzwald, NE of the village, ca. 1000 m, 12. 6. 1992; **8653/4** Seckauer Alpen, Ingeringsee, 1221 m, 2. 7. 1993, leg. K. M. & W. Rehak; **8654/3** Seckauer Alpen, Gotstalbach (N of Seckauer Zinken), Gotstalkessel, above the lake, 1865 m, 3. 7. 1993, leg. K. M. & W. Rehak; **8658/3** Mixnitz, Bärenloch below Bärenschutzklamm, 450 m, 6. 7. 1993, leg. K. M. & W. Rehak; **8750/1** Schladminger Tauern, Sölkerpass, above Unterer Kaltenbachsee, 1820 m, 4. 7. 1993, leg. K. M. & W. Rehak; **8855/1** Stubalpe, N of Kleinlobming, rivulet ca. 250 m of Ebnerhütte, 880 m, 9. 6. 1994, leg. E. Vitek; **8955/2** Stubalpe, 0.8 km SE of the Altes Almhaus chalet, 1650 m, 2. 7. 1993, leg. K. M. & W. Rehak; **9255/2** *Koralpe, Grosser Speikkogel, above the Speiksee lake, 1940 m, 29. 7. 1991. **Salzburg: 8044/3** E of Obertrum a. See, Au, 640 m, 18. 4. 1998, leg. K. M., E. Hörandl & F. Hadaček; **8144/1** NE of Lengfelden, Viehhausen, ca. 450 m, 18. 4. 1998, leg. K. M., E. Hörandl & F. Hadaček; **8644/1** Mt. Hochkönig nearby the village of Dienten, track from Erichhütte to Stegmoosalm, 1590 m, 9. 7. 1997, leg. E. Vitek; **8739/2** Neukirchen am Grossvenediger, 940 m, 13. 6. 1993, leg. G. Fischer; **8839/1** Hohe Tauern, Venedigergruppe, Seebachalm (E of Obersulzbachtal, S of Neukirchen am Grossvenediger), 2040 m, 13. 6. 1993; **8839/2** Hohe Tauern, Venedigergruppe, Seebachtal (tributary of Obersulzbach, S of Neukirchen am Grossvenediger), 1200 m, 13. 6. 1993; Hohe Tauern, Venedigergruppe, Seebachtal (tributary of Obersulzbach, S of Neukirchen am Grossvenediger), 1250 m, 13. 6. 1993. **Carinthia: 9043/4** Hohe Tauern, [Goldberggruppe], Grossfragant region, SE of Sadnigscharte, near the rivulet just below the lake, 2440 m, 12. 7. 1992; **9044/1** **Hohe Tauern, [Goldberggruppe], Grossfragant region, Schobertal, near the rivulet Schoberbach, 2050 m, 7. 7. 1992; Hohe Tauern, [Goldberggruppe], Innerfragant, above the village, 1130 m, 4. 7. 1992; **Hohe Tauern, [Goldberggruppe], Grossfragant region, Fraganter Hütte, near the chalet, 1780 m, 5. 7. 1992; **9044/3** **Hohe Tauern, [Goldberggruppe], Grossfragant region, near the rivulet Sadnigbach, below the bridge on the tourist path, 1930 m, 6. 7. 1992; Hohe Tauern, [Goldberggruppe], east end of Rollbahn, W of Ausserfragant, 1740 m, 11. 7. 1992; **Hohe Tauern, [Goldberggruppe], Grossfragant region, Sadnigbach, 2130–2150 m, 6. 7. 1992; Hohe Tauern, [Goldberggruppe], Grossfragant region, Melen Boden, 2010 m, 6. 7. 1992; **9048/4** Gurktaler Alpen, Nockberge, SE of the Schneegrubensattel, 1650 m, 6. 7. 1993, leg. K. M. & W. Rehak; **9049/4** Gurktaler Alpen, Flattnitz, below the Zelinsee lake, 1840 m, 5. 7. 1993, leg. K. M. & W. Rehak; **9050/3** Gurktaler Alpen, Flattnitz, Heidnerhöhe, 1800 m, 5. 7. 1993, leg. K. M. & W. Rehak; Kärnten, Gurktaler Alpen, Flattnitz, 1390 m, 5. 7. 1993, leg. K. M. & W. Rehak; **9148/2** Gurktaler Alpen, Nockberge, SW of the Falkertsee, 1940 m, 6. 7. 1993, leg. K. M. & W. Rehak; **9155/4** Koralpe, near the Forsthaus in the valley of Rassinggraben, 1280 m, 28. 7. 1991; **9242/3** Lesachtal, Tal des Tuffbaches NNE von Maria Luggau, am kleinen Bach NE der Wiesner Alm, 1350 m, 7. 8. 1994, leg. E. Vitek; **9553/3** Karawanken, Vellach valley above Eisenkappel, 800 m, 22. 5. 1996, leg. K. M. & N. Jogan. **North Tyrol: 8827/3** Sankt Anton am Arlberg, Steissbachtal, ca. 1800 m, 7. 8. 1997, leg. G. Brandstätter, J. Chrtek, jun. & P. Mráz; **9031/4** Ötztaler Alpen, Venter Tal, ca. 100 m SW of Heiligenkreuz, 1720 m, 12. 7. 1993, leg. E. Vitek, A. Blab & G. Dietrich; **9132/1** Ötztaler Alpen, Obergurgl, near

Lobbach, 1910 m, 13. 7. 1993, leg. E. Vitek, A. Blab & G. Dietrich; Ötztaler Alpen, Obergurgl, Ferwalltal, ca. 150 m NNW of the junction to Aperes Ferwalljoch on the way to the old Zollhütte, 2380 m, 9. 7. 1993, leg. E. Vitek & A. Blab; Ötztaler Alpen, Obergurgl, near the Bundessportheim, 1940 m, 14. 7. 1993, leg. E. Vitek, A. Blab & G. Dietrich. **East Tyrol: 9341/1** Lesachtal, Obertilliacher Tal, SW of Obertilliach, 1700 m, 9. 8. 1994, leg. E. Vitek. **Vorarlberg: 8826/4** Klösterle, Nenzigasttal, 1300 m, 8. 8. 1997, leg. G. Brandstätter, J. Chrtek, jun. & P. Mráz.

SLOVENIA. Gorenjska: 9651/3 Radovljica, in an ox-bow-lake of the river Sava, ca. 410 m, 15. 4. 1994, leg. K. M. & N. Jogan; **9653/1** Karavanke, Gornje Jezersko, 880 m, 22. 5. 1996, leg. K. M. & N. Jogan. **Koroška: 9555/1** Črna, in the Bistra Valley, 630 m, 27. 4. 1994, leg. N. Jogan. **Štajerska: 9457/3** Pohorje, between Vuhred and Ribnica na Pohorju, 530 m, 22. 5. 1996, leg. K. M. & N. Jogan.

CZECH REPUBLIC. Volyňské Předšumaví: 6948/1 Stachy – Zdíkovec, Stašský potok, 700 m, 25. 5. 1989, leg. K. M. & L. Hrouda; **6949/1** *Šumavské Hoštice, Lštění, S of the settlement, 880 m, 24. 5. 1989, leg. K. M. & L. Hrouda. **Třeboňská pánev: 6855/1** Mnich (Kardašova Řečice, SE), 470 m, 3. 7. 1988; **6755/3** Červená Lhota, nearby the castle, 490 m, 4. 7. 1988. **Votická vrchovina: 6453/3** Čertovo břemeno, Nové Libenice, nearby the fishpond Libenický rybník, 620 m, 7. 7. 1988. **Českomoravská vrchovina: 6556/1** Pacov, 30. 5. 1988, ca. 500 m, leg. K. M. & L. Hrouda; Pacov, Hrádek, 530 m, 30. 5. 1988, leg. K. M. & L. Hrouda. **Šumavské pláně: 6946/4** Modrava, 980 m, 26. 5. 1989, leg. K. M. & L. Hrouda; **6947/3** **Kvilda, 1040 m, 25. 5. 1989, leg. K. M. & L. Hrouda; **6947/4** Nové Hutě, stream near blue marked touristic path on the SSW slope of Mt. Přilba, ca. 2.5 km WSW of the village, 1190 m, 18. 6. 1998, leg. M. Štech. **Boubínsko-stožecká hornatina: 7048/1** **Horní Vltavice, Slatina, 840 m, 25. 5. 1989, leg. K. M. & L. Hrouda. **Hornovltavská kotlina: 7149/1** **Dobrá na Šumavě, 740 m, 25. 5. 1989, leg. K. M. & L. Hrouda.

GERMANY. Bavaria: 8042/3 Waging am See, Dobelbach Valley, Dobelgraben, ca. 500 m, 18. 4. 1998, leg. K. M., E. Hörandl & F. Hadaček; **8139/3** S of Rosenheim, Rohdorf, ca. 500 N of exit of motorway, 460 m, 18. 4. 1998, leg. K. M., E. Hörandl & F. Hadaček; **8141/3** SW of Grabenstätt (SE of Übersee), Osterbuchberg, 525 m, 18. 4. 1998, leg. K. M., E. Hörandl & F. Hadaček; **8238/2** Nußdorf a. Inn, Breiten, 460 m, 18. 4. 1998, leg. K. M., E. Hörandl & F. Hadaček; **8238/3** nearby the road Degerndorf-Bayerischzell, above the tunnel and the junction of the path to Riesenstein, 660 m, 18. 4. 1998, leg. K. M., E. Hörandl & F. Hadaček.

ITALY. Prov. Belluno: 9438/4 Cortina d'Ampezzo, below Mt. Tre Cime di Lavaredo, 1800 m, 6. 1993, leg. L. Hrouda; **Prov. Trento: 0131/1** Lago di Garda, Riva, 200 m, leg. L. Hrouda.

Unpublished chromosome counts by K. Urbanska & E. Landolt

SWITZERLAND. Kt. Bern: 9215/4 Gental, Engstlenalp, 669.000/181.100, 1830 m, leg. L. & W. Engetschwiler, no. 204 (ZT!). **Kt. Graubünden: 9025/3** Klosters, Gretsch, 789.000/198.150, 1690 m, leg. M. Meyer, no. 928; **9124/4** Davos, Parsenn (Dorftäli), 781.600/188.000, 2250 m, leg. L. & A. Gigon, no. 957; **9125/1** Klosters, Schlappintobel, 786.700/196.750, 1450 m, leg. M. Meyer, no. 927; **9125/2** Klosters, E of Montbiel, 791/192, 1340 m, leg. M. Meyer, no. 921; **9125/3** Flüela, Flüelaberg, 788/187, 2150 m, leg. L. & U., no. 964; **9423/4** Alp Flix near Mulegus, Tigias, 770.050/154.450, 1977 m, leg. L. & U., no. 211; **9425/3** Stazerwald, God da Congiroulas, 786/152, 1840 m, leg. L. & U., no. 662; **9524/2** Silvaplana, Lej da Champfèr, 781.259/148.529, 1791 m, L. & U., no. 35. **Kt. Glarus: 8920/4** Engi, above Engistein, 731.000/208.800, 1630 m, leg. F. Grossmann, no. 963; **9021/1** Matt, Gnappetrieb, 735.650/206.100, 1520 m, leg. L. & U., no. 709, F. Grossmann, no. 955. **Kt. Uri: 9218/1** Maderanertal, Bristen, 695/180, 840 m, leg. L. & U., no. 787; **9317/2** Oberalppass, Zu den Staflen, 691.700/167.500, 1950 m, leg. L. & U., no. 647; **9317/4** above Schöllenen, 687.430/166.900, 1680 m, leg. L. & U., no. 649; Uri, Andermatt, March, 687.500/164500, 1500 m, leg. L. & U., no. 648. **Kt. Ticino: 9417/1** Gotthard-Hospiz, 686.720/156.700, ca. 2085 m, leg. F. Klötzli, no. 666 (ZT!); **9417/4** Nante, Alpe Pesciüm, 689.700/152.000, 1700 m, leg. L., no. 659; **9418/3** Val Piora, Cadagno di Fuori, 697.000/155.900, 1917 m, leg. L., no. 661. **Kt. St. Gallen: 8921/1** Grossee above Quarten, 737/215, 1618 m, leg. L., no. 962.

AUSTRIA. Vorarlberg: 8726/2 Hochtannbergpass, 1600 m, leg. L. & U., no. 400; **8826/4** Stuben am Arlberg, 1400 m, leg. U. & L., no. 465 (ZT!). **North Tyrol: 8734/3** Natters bei Innsbruck, 780 m, leg. L. & U., no. 223. **Salzburg:** 8244/1 Hellbrunn, Schlossgarten, 430 m, leg. L. & U., no. 777.

ITALY. Prov. Bozen/Bolzano: 9229/1 St. Valentin auf der Haide/S. Valentino alla Muta, Reschenpass/Pso. di Résia, ca. 1450 m, leg. L. & U., no. 484 (ZT!). **Prov. Verbano-Cusio-Ossola: 9616/2** Val Formazza, Valdo, 676.100/136.000, 1280 m, leg. L. & U., no. 652.

Unpublished chromosome count by V. Jarolímová

CZECH REPUBLIC. Českomoravská vrchovina: 6556/1 Pacov, Hrádek, bank of the rivulet Trnava, ca. 1.5 km E of Hrádek, 19. 5. 1976, leg. B. Slavík & V. Javůrková.

Data from literature:

Gadella et al. 1970: 190:

AUSTRIA. Styria: 9156/3 Glashütten, 14 km W of Deutschlandsberg, (1200 m, leg. P. Smit, U 6930(67-533)!).

Lövkvist 1957: 425:

AUSTRIA. Styria: 9156/3, Koralpe, Glashütten, 1400 m. **North Tyrol: 8732/4** St. Sigmund, 1500 m; **uncertain location** (not in the map): Perlsteinbach, 1600 m, 1750 m.

Teppner 1980: 81:

AUSTRIA. Styria: 8551/3 Planneralm, ca. 1600 m, leg. Teppner (GZU!), n=16.

Habeler 1963: 184–185:

AUSTRIA. Styria: 8658/1 Pernegg, near Gabraunbach, ca. 500 m; **8757/3** Gleinalpe, Neuhof, near Übelbach, ca. 720 m; **8856/2** Kleinalpe, NW of Geisttal, ca. 1200 m; **8857/1** Grossstübing, near Stübingbach, ca. 530 m; **8858/2** Schöckl E, near Giessbach, ca. 900 m; **8858/3** Dult bei Graz, ca. 410 m, leg. Habeler (GZU 049404!); **8858/4** Graz-Andritz, Stattegg, ca. 430 m, leg. Habeler (GZU 049403!); **8955/2** Stubalpe, near Altes Almhaus, ca. 1600 m, leg. Habeler (GZU 049434!); **8955/4** Hirschegg, near Teigitschbach, ca. 900 m, leg. Habeler (GZU 049430!); between Hirschegg and Salzstiegelhaus, ca. 1150 m, leg. Habeler (GZU 049428!); **8958/2** Graz-Stifting, ca. 410 m, leg. Habeler (GZU 049383!); **8958/4** Rudersdorf (S of Graz), nearby the river Mur, ca. 340 m, leg. Habeler (GZU 049363!); **8959/1** Hart bei St. Peter (E of Graz), ca. 480 m, leg. Habeler (GZU 049364!); **9058/2** S of Graz, ca. 2 km N of Kalsdorf (nearby the river Mur), ca. 320 m; Kalsdorf (S of Graz), nearby the river Mur, ca. 320 m; **9155/4** Koralpe, Bärentalkar, below Grillitschsattel, ca. 1710 m, leg. Habeler (GZU 049343!); **9156/3** Koralpe E, Glashütten, near Stullneggbach, ca. 1150 m; ca. 1500 m, leg. Habeler (GZU 049339!); Koralpe, between Glashütten and Schwarze Sulm, ca. 1250 m; Koralpe, between Glashütten and Gösleralm, ca. 1450 m; Koralpe, Bärental, ca. 1510 m, leg. Habeler (GZU 049341!); ca. 1320 m, leg. Habeler (GZU 049342!); Koralpe, Weinebene, Brandhöhe E, ca. 1750, leg. Habeler (GZU 049352!); **9157/3** Deutschlandsberg, end of Lassnitzklause, ca. 380 m, leg. Michel (GZU 049348!); **9257/1** Koralpe E, Mainsdorf N of Schwanberg, ca. 440 m, leg. Habeler (GZU 049330!). **Carinthia: 9155/3** Koralpe W, opposite Wolfsberg, ca. 700 m, leg. Widder (GZU 049329!); **9155/4** Koralpe, Grosses Kar, ca. 1800 m, leg. Habeler (GZU 049345!).

Urbanska-Worytkiewicz & Landolt 1972: 88:

SWITZERLAND. Kt. Graubünden: 9524/2 Oberengadin, near Lej da Champfér, 148.520/781.250, 1791 m.

***Cardamine amara* subsp. *amara* (2n=16)**

AUSTRIA. Lower Austria: 7762/4 **Gablitz, NW of the village, near the rivulet Gablitzbach, 290 m, 14. 5. 1992; **7763/1** Flysch-Wienerwald, N slope of Mt. Exelberg, close to the NW border of Vienna, 0.5 km N of the restaurant "Sofienalpe", 440 m, 11. 4. 1998, leg. G. & M. A. Fischer; **7863/1** *Purkersdorf, Baunzen, 300 m, 14. 5. 1992; 8065/4 Leithagebirge, Hof a. Leithagebirge, just below the saddle on the border with Burgenland, ca. 370 m, 26. 4. 1994; **8361/2** between the castle of Wartenstein and the town of Gloggnitz, 500 m, 14. 5. 1992; **8363/1** Wechselgebiet, S of Erlach, at crossing of road from Erlach to Bromberg with road to Breitenbuch, 370 m, 8. 5. 1994, leg. E. Vitek; Wechselgebiet, E of Leiding, S of village of Erlach, along the rivulet Leidingbach, 360 m, 11. 5. 1997, leg. E. Vitek (LI,

SAV, W, Z, etc.). **Styria: 9059/2** Heiligenkreuz am Waasen, in the village, 329 m, 2. 5. 1994, leg. K. M., W. Gutermann & E. Hörandl; **9060/1** Maxendorf (NE of Kirchbach i. Steiermark), 0.5 km NE of church, 360 m, 1. 5. 1994, leg. K. M., W. Gutermann & E. Hörandl; **9161/4** 1.6 km NE of St. Anna am Aigen, 0.2 km WSW of the Three-countries-edge (Burgenland-Styria-Slovenia), 315 m, 15. 4. 1998, leg. G. & M. A. Fischer. **Burgenland: 8065/4** Leithagebirge, Donnerskirchen, ca 1.5 km NW of the village, ca. 250 m, 26. 4. 1994; **8762/4** Wolfau (SW of Oberwart), Stögersbach, 320 m, 30. 4. 1994, leg. K. M., W. Gutermann & E. Hörandl.

SLOVENIA. Štajerska: 9660/2 Haloze, Podložje pod Ptujsko Goro, 240 m, 13. 4. 1994, leg. K. M. & N. Jogan. **Notranjsko: 0352/2** Loška dolina, river banks of Veliki Obrh, W of the village of Pudob, 570 m, 21. 5. 1996, leg. K. M. & N. Jogan.

CZECH REPUBLIC. Střední Povltaví: 6653/1 **Bečice, NW of the village, valley of the River Lužnice, 390 m, 24. 5. 1989, leg. K. M. & L. Hrouda. **Táborsko-Vlašimská pahorkatina: 6552/4** Sepekov – Podboří, ESE of Chlum Hill, 490 m, 7. 7. 1988, leg. V. Grulich. **Votická vrchovina**: **6453/3** Čertovo břemeno, Sedlec – Prčice, Vrchotice, E of the settlement, near the fishpond, 500 m, 7. 7. 1988. **Třeboňská pánev: 7055/1** Chlum u Třeboně, nearby fishpond Podsedek, 430 m, 20. 8. 1997; **7154/2** Červené blato, 475 m, 20. 8. 1997.

GERMANY. Bavaria: 8042/3 Weibhausen (between Waging am See and Traunstein), 580 m, 18. 4. 1998, leg. K. M., E. Hörandl & F. Hadaček.

ITALY. Prov. Bozen/Bolzano: 9432/4 Tisens/Tésimo, Prissianer Tal, 2 km WSW of the ruin of Zwingenburg, 940 m, 2. 6. 1998, leg. H. & E. Niklfeld. **Prov. Udine: 0244/1** Latisana, nearby the rivulet Stella, SE of Titiano, ca. 10 m, 17. 4. 1996, leg. J. Štěpánek, J. Štěpánková & Z. Kaplan.

Unpublished chromosome counts by K. Urbanska & E. Landolt

SWITZERLAND. Kt. Bern: 9110/4 Rüeggisberg, 599.450/184.900, 765 m, leg. L. & U., no. 250; **9112/4** Schallenberg, S of Sattle, 627.350/186.100, 1180 m, leg. L. & W. Engetschwiler, no. 583 (ZT!); **9216/1** Gental, Engstlen, 669.000/181.100, 1830 m, leg. L. & W. Engetschwiler, no. 203. **Kt. Uri: 9019/4** Urnerboden, 714.300/195.750, 1310 m, leg. L. & U., no. 167; **9217/3** Meiental, Meiendörfli, 685.600/175.250, 1270 m, leg. L. & W. Engetschwiler, no. 201; **9217/4** Gurtnellen, Miseli, 690.625/176.550, 1270 m, leg. F. Grossmann, no. 887; Gurtnellen, Grueben, 689.020/176.450, 1330 m, leg. F. Grossmann, no. 920; **9317/4** Andermattt, Schieni, 691.000/166.820, 1890 m, leg. F. Grossmann, no. 930. **Kt. Graubünden: 8923/4** Sieben Brunnen, 765.250/210.550, 1860 m, leg. J. Burnand, no. 705; **9220/4** Lumbrein, Alpe Nova, 726.750/173.700, 2070 m, leg. L. & U., no. 646; **9227/1** Unterengadin, Ftan, 813.990/185.850, 1600 m, leg. L. & U., no. 215; **9323/2** Albulatal, Surava, 765.800/170.400, 900 m, leg. L. & U., no. 387; **9425/1** Kt. Graubünden, La Punt, God Drosa, 789/161, 1900 m, leg. L., no. 664; **9425/2** Zuoz, Ova d'Arpiglia, 793/163, 1800 m, leg. L., no. 663. **Kt. Valais/Wallis: 9415/4** Obergesteln, towards Ulrichen, 667/157, 1360 m, leg. L., no. 968; **9416/1** Gletsch, 670/157, 1750 m, leg. U. & O. Wildi, no. 952; **9513/3** Lötschental, Fafleralp, 632/142, 1800 m, leg. J. Burnand, no. 950; **9514/4** Bellwald, 655/143, 2000 m, leg. J. Burnand, no. 956; **9613/3** Ausserberg, 631.500/129.200, ca. 1000 m, leg. J. Burnand, no. 499. **Kt. Zürich: 8517/1** Klotener Ried, Goldenes Tor, 684/257, 430 m, leg. L., no. 967; **8518/2** Erztal near Kollbrunn, 702.200/258.200, 525 m, leg. L., no. 575; **8617/1** Allmend Brunau, Sihlkanal, 681.600/244.800, 420 m, leg. L., no. 876. **Kt. Vaud: 9105/4** Fiez, Cloz du Pont, 535.000/186.150, 470 m, leg. J. Burnand, no. 857; **9608/1** Pierre de Moëllé, 569/137, 1665 m, leg. L. & U., no. 627; **9609/1** Col du Pillon, Sattle, 582/133, 1685 m, leg. L. & U., no. 624. **Kt. Ticino: 9417/2** Airolo, Piano di Pontino, 691/156, 2030 m, leg. F. Grossmann, no. 958; **9417/4** Nante, Roncascio, 691.100/152.400, 1425 m, leg. L. & U., no. 649; Airolo, Lago di Prato, 693/155, 2010 m, leg. F. Grossmann, no. 959; **9519/3** Anzonico, between Anzonico and Cavagno, 709.800/142.800, 990 m, leg. L. & U., no. 650; **9520/3** Val Malvaglia, nearby Sciarcé, 720.500/141.875, ca. 800 m, leg. F. Grossmann, no. 849; Val Malvaglia, Madra, 723.750/145.650, 1400 m, leg. F. Grossmann, no. 655. **Kt. Aargau: 8413/ 4** Sisseln, between Eiken and Kaisten, 641.600/265.550, 310 m, leg. A. Gigon, no. 854; **8515/1** Brugg, confluent of Reuss-Aare, 660/260, 329 m, leg. L., no. 657; **8716/1** Jonen, SE of Jonental, 673.650/239.200, 430 m, leg. F. Grossmann, no. 973. **Kt. Appenzell-Ausserrhoden: 8721/2** Schwägalp, 741/235, 1275 m, leg. L., no. 703. **Kt. Glarus: 8819/4** Näfels, Schwändi, 716.800/218.650, 1350 m, leg. L., no. 665; **8920/4** Ennenda, Äugsten, 726.800/209.850, 1500 m, leg. F. Grossmann, no. 951. **Kt. Schwyz: 9018/2** Muotatal, Bisistal, Seeberg, 705/201, 780 m, leg. L., no. 713. **Kt. Obwalden:**

9215/1 Sachseln, Älggialp, 660.350/183.150, 1630 m, leg. F. Grossmann, no. 853. **Kt. Fribourg: 9106/4** Cheyres, Lac de Neuchâtel, 550.150/185.750, 430 m, leg. Ch. Roth & J. Burnand, no. 939; **9208/2** Marly, Gérine, 576.800/180.550, 600 m, leg. Ch. Roth & J. Burnand, no. 922.

AUSTRIA. North Tyrol: 8630/4 Fernsteinsee, 1000 m, leg. L. & U., no. 226; **8632/3** Telfs, 660 m, leg. L. & U., no. 225.

GERMANY. Baden-Württemberg: 7912/4 Umkirch, NW of Freiburg im Breisgau, leg. L. & U., no. 736; **8016/1** 0.5 km S of Hubertshofen, 800 m, leg. L. & U., no. 505; **8214/3** ca. 3 km W of Ibach, Ibacher Kreuz, 1061 m, leg. L. & U., no. 447.

ITALY. Prov. Bozen/Bolzano: 9435/1 200 m from Kastelruth/Castelrotto, leg. U. & L., no. 481 (ZT!), **9332/3** Vinschgau, Naturns/Naturno, 550 m, leg. L. & U., no. 483. **Prov. Novara: 0217/3** Arona, Dormelletto, 230 m, leg. L. & U., no. 570. **Prov. Verbano-Cusio-Ossola: 9616/4** Val Formazza, N of Fracchie, 676.000/133.350, 1220 m, leg. L. & U., no. 651. **Prov. Pavia: 0720/3** Pavia, 5 km NW of the town, 80 m, leg. L. & U., no. 871.

FRANCE. Haute-Savoie: 9606/3 Chalet d'Oche, 545.300/133.000, 1700 m, leg. L. & U., no. 820; **9705/3** Bellevaux, La Douai, 530.200/121.700, 990 m, leg. L. & U., no. 821. **Vosges/Haut-Rhin: 7908/1** Col de la Schlucht, 1150 m, leg. L. & W. Engetschwiller, no. 844. **Haut-Rhin: 7908/3** Mt. Hohneck, E slope, 1250 m, leg. L. & W. Engetschwiller, no. 845.

Unpublished chromosome counts by M. Huthmann

GERMANY. Bavaria: 8137/1 W of Bad Aibling, Vagen, ca. 200–300 m, leg. M. Huthmann (OSBU!); **8334/2** Bayerische Alpen, S of Benediktbeuern, E of the settlement Pfisterberg, ca. 850 m, leg. R. Kohrt (OSBU!); **8334/3** Bayerische Alpen, S of Benediktbeuern, Kochler Oberalpe, NE of Kochleralm, ca. 1350 m, leg. R. Kohrt (OSBU!).

Data from literature:

Gadella & Kliphuis 1970: 490, 495:

FRANCE. Savoie: 0608/2 near l' Ecot [E of Bonneval-sur-Arc], near the fall, 1900 m, leg. Gadella (U, no. G5300!, G5301!, G5302!, G5303!).

Favarger 1965: 57:

SWITZERLAND. Kt. Valais/Wallis: 9907/4 alpage sous Col de Balme [SW of Martigny], 1900 m (n=8).

Habeler 1963: 185:

AUSTRIA. Styria: 8861/3 between Grosssteinbach and Ilz, near the castle Feistritz, ca. 330 m; **8958/1** Graz-Wetzelsdorf, near Feliferhof, ca. 440 m, leg. Habeler (GZU 049407!).

Urbanska-Worytkiewicz & Landolt 1972: 88:

SWITZERLAND. Kt. Uri: 9019/4 Klausenpass, Urnerboden, 195.750/714.300, ca. 1310 m.

Manton 1932: 542:

GERMANY. Bavaria: Starnberger See near Munich (wide locality, not in the map).

Marhold 1994a: 27–28:

CZECH REPUBLIC. Dolnomoravský úval: 7367/2 Lanžhot (SAV!).

SLOVAK REPUBLIC. Záhorská nížina: 7667/2 Bezedné (SAV!). **Malé Karpaty Mts: 7570/2** Horné Orešany (SAV!); **7669/2** Modra, Piesok (SAV!); **7768/2** Bratislava, Mt. Javorník (SAV!); **7868/1** Bratislava, Železná Studnička (SAV!).