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Cardamine amara L. in the Slovakian and Polish Carpathians

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1. INTRODUCTION

The Large Bittercress, *Cardamine amara* L. s.l. (*Brassicaceae*) in the Carpathians includes populations mainly classified as *Cardamine amara* L. ssp. *amara* and *Cardamine amara* L. ssp. *opizii* (J. et C. Presl) Celak. (*Cardamine amara* L. and *Cardamine opizii* J. et C. Presl at species level, respectively). Different characters are used for the separation of these two subspecies in the interpretation of different authors. Some authors express doubts about the possibility of an infraspecific classification of this species (cf. HABELER 1963). As part of the overall study of the genus *Cardamine* L. in the Carpathians and Pannonia, populations of the Large Bittercress in the Slovakian and Polish Carpathians were examined karyologically and morphologically. The aim of the study was to ascertain the chromosome numbers of plants in individual populations and morphological characters by which these two subspecies could be determined. The present paper includes preliminary results of this study.

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2. MATERIALS AND METHODS

44 populations of *Cardamine amara* ssp. *amara* and 27 populations of *Cardamine amara* ssp. *opizii* from the Slovakian and Polish Carpathians were analysed karyologically. Chromosome numbers were examined in root tips of cultivated plants by the squash method. For a detailed morphological study 35 populations from the Slovakian Carpathians (Nos. 1-27) and Polish Carpathians (Nos. 28-35) were selected in order to represent the widest morphological variability, the greatest difference in altitude as well as geological substrata. In the course of the morphological study the following characters were measured and recorded:

- width of the stem base (WS)
- number of stem leaves (NL)
- maximum number of leaflets of the leaves in the upper 4/5 of the stem (NLL)
- number of leaves reaching the base of the uppermost stem leaf (DI)
- branching of the stem (BS)
- number of flowers in the main inflorescence (NF)
- length of petals (LP)
- width of petals (WP)
- length of sepals (LS)
- length of filaments (LF)
- LS/LP (LSP)
- LP/WP (LWP)

Two multivariate techniques were used to evaluate phenetic relationships among populations: an R-type principal component analysis (cf. SNEATH and SOKAL 1973) and sum of squares agglomerate clustering (Ward's method) (cf. ORLOCI 1978). Measurements were made on 30-40 plants from each population. Each cell in the data matrix represents the average value of one of the measured characters for one population. Principal component analysis and cluster analysis were performed using the programs PRINCOMP and NCLAS from the SYN-TAX package (PODANI 1980, 1984).

3. RESULTS

Chromosome numbers. The analysis of the plants from the populations of *Cardamine amara* from the Slovakian and Polish Carpathians showed the same, diploid chromosome number of 2n=16 in all populations of both subspecies.

Phenetic relationships among populations. The results of the principal component analysis are presented in Fig. 1. The first three components extracted from the correlation matrix cover a total of 86% of the variance. The first component (PC1) accounts for 56%, which is an unusually high percentage. The second (PC2) and third (PC3) components cover 19% and 11%, respectively. The following characters had a strong influence on the components: on PC1: NL, NLL, DI and WS, on PC2: LP, LF, LS and WP, on PC3: NF. Scores for principal component 1 make the distinction between the two groups relatively clear. These two groups correspond well to two subspecies - *Cardamine amara* ssp. *amara* and *Cardamine amara* ssp. *opizii*. Scores for principal component 2, which is mostly a function of characters connected with the size of flowers, as well as for principal component 3, which is mostly a function of the number of flowers, do not divide the populations into distinct groups. As can be seen in Fig.1, the division into two groups (two subspecies)

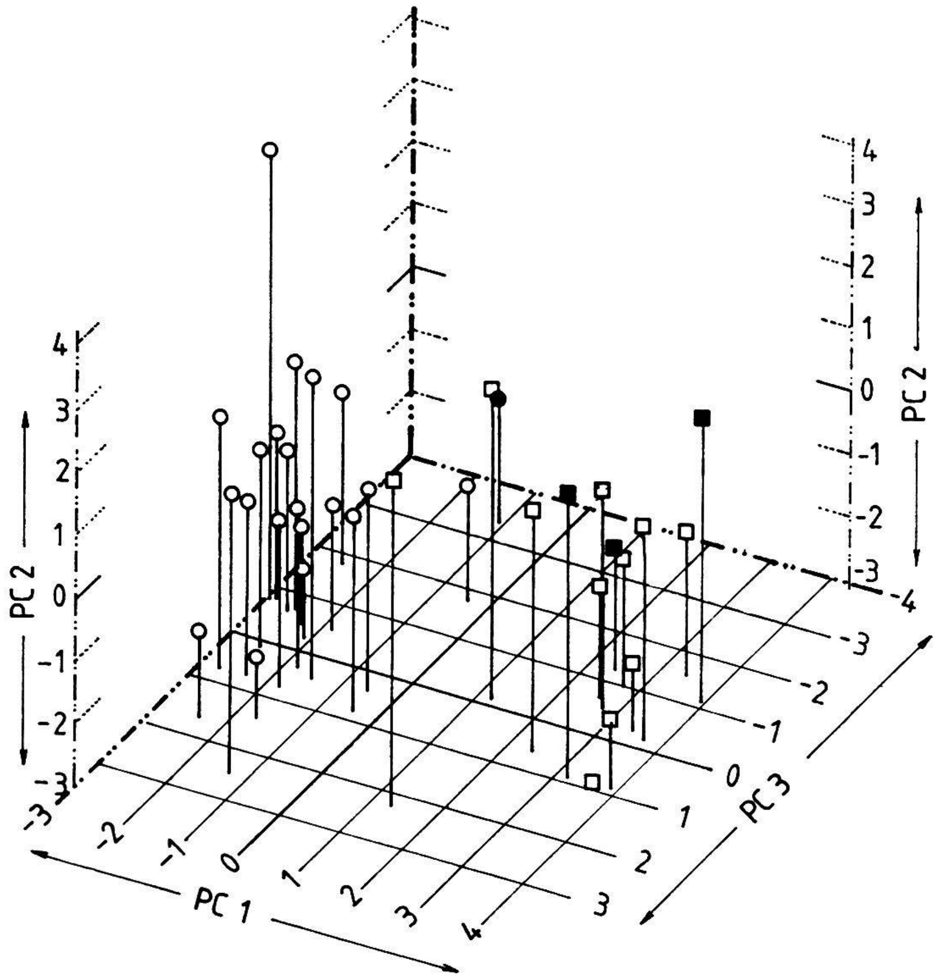

Fig. 1. Principal component analysis of populations of the *Cardamine amara*.
○ *C. amara* ssp. *amara* up to 800 m a.s.l. ■ *C. amara* ssp. *opizii* 800-1100 m a.s.l.
● *C. amara* ssp. *amara* 800-1100 m a.s.l. □ *C. amara* ssp. *opizii* above 1100 m a.s.l.

Fig. 2. Cluster analysis of populations of the *Cardamine amara*
○ *C. amara* ssp. *amara* up to 800 m a.s.l. ■ *C. amara* ssp. *opizii* 800-1100 m a.s.l.
● *C. amara* ssp. *amara* 800-1100 m a.s.l. □ *C. amara* ssp. *opizii* above 1100 m a.s.l.

is also correlated with the altitude. *Cardamine amara* ssp. *amara* has its centre of distribution in lower altitudes, while *Cardamine amara* ssp. *opizii* is characteristic of higher ones. The same two groups of populations, which conform to two subspecies, are also indicated by the results of the cluster analysis (Fig. 2).

4. DISCUSSION

Karyological analyses in the Slovakian and Polish Carpathians showed the same, diploid chromosome numbers for both subspecies. These were confirmed by hitherto published data on chromosome numbers of *Cardamine amara* from this area (BANACH 1950, BANACH-POGAN 1955, MAJOVSKY et al. 1978). BANACH-POGAN (1955) published, in addition to several diploid counts, one tetraploid count (2n=32), but she considered it to be a somatic polyploid mutation. The data of MAJOVSKY et al. (1974) for *Cardamine amara* ssp. *amara* 2n=32 could also reflect such a polyploid mutation. In the locality from which this tetraploid number was published (Velka Fatra Mts., Gaderska dolina Valley) only diploid plants were confirmed during the present study. The exclusive presence of diploids in this area in both subspecies of *Cardamine amara* are also indicated by the results of plant analyses from the Eastern and Southern Carpathians as well as from the Sudetic mountains, including both type localities of *Cardamine opizii* (Krkonose Mts., Mt. Studnicni hora and Kralicky Sneznik Mt.) (SPASSKAYA 1979, PASHUK 1987, MARHOLD unpubl.). Hence it follows that it is not possible to accept the classification of LÖVE and LÖVE (1974) who put all diploid counts together under the name of *Cardamine amara* and tetraploid ones under *Cardamine opizii*.

The morphological characters mostly used in floras and keys for discrimination of *Cardamine amara* ssp. *opizii* from the typical subspecies of *Cardamine amara* include the number of leaflets of the stem leaves, the number of flowers and the length of the petals. The number of leaflets of the stem leaves for *Cardamine amara* ssp. *amara* is given as 5-9 (some authors give a maximum of 11) and for *Cardamine amara* ssp. *opizii* as 11-19. The present study indicates that the extent of the variability of this character is 5-13(-15) for *Cardamine amara* ssp. *amara* and (9-)11-19(-23) for *Cardamine amara* ssp. *opizii*. Characters found to be of no help in discriminating between these two subspecies appeared to be the number of flowers and the length of the petals. The extent of the variability of these characters is practically the same in both subspecies (number of flowers: *Cardamine amara* ssp. *amara* 2-32, *Cardamine amara* ssp. *opizii* 3-39, length of petals: *Cardamine amara* ssp. *amara* 5.2-11.1 mm, *Cardamine amara* ssp. *opizii* 5.0-10.8 mm). However, useful discriminative characters are the number of stem leaves, being (2-)3-14 at *Cardamine amara* ssp. *amara* and (11-)13-46(-53) at *Cardamine amara* ssp. *opizii* and the number of leaves reaching the base of the uppermost stem leaf being 0-4(-6) at *Cardamine amara* ssp. *amara* and 1-13(-21) at *Cardamine amara* ssp. *opizii*, which quantifies the congestion of the leaves below the main inflorescence. In some cases also the branching of the stem could be a useful character for discriminating between the subspecies, being branched or unbranched in *Cardamine amara* ssp. *amara* and always unbranched in *Cardamine amara* ssp. *opizii*. As can be seen in the values of the discriminating characters, no single character has an unambiguous discriminative power. During the determination all characters must be taken into consideration and several plants from the same locality are needed. (Figs. 3 and 4 show the typical habitat of *Cardamine amara* ssp. *amara* and ssp. *opizii*). This variability together with an equal chromosome number were the main reason for classifying these two taxa at subspecific level. In her work based on mate-

Fig. 3. *Cardamine amara* ssp. *amara*.

Fig. 4. *Cardamine amara* ssp. *opizii*.

rial from the Eastern Alps HABELER (1963) came to the conclusion that *Cardamine amara* is a species with great variability without any possibility of infraspecific classification. She rejected a separate taxon corresponding to *Cardamine amara* ssp. *opizii* but in some respects her interpretation of this taxon was clearly wrong. Among voucher specimens of her study, which are deposited in the herbarium of Graz University (GZU), there are only plants corresponding morphologically to *Cardamine amara* ssp. *amara*. Also the plant from Koralpe that she specified as looking like *Cardamine opizii* (No. 56, according to HABELER 1963) is in my opinion morphologically identical with the typical subspecies. It will be necessary to return to an evaluation of populations of the Large Bittercress in the Alps because of the presence of diploid as well as tetraploid populations in this area.

SUMMARY

The populations of *Cardamine amara* L. ssp. *amara* and *Cardamine amara* L. ssp. *opizii* (J. et C. Presl) Celak. from the Slovakian and Polish Carpathians were studied karyologically and morphologically. Karyological analyses showed the chromosome number of 2n=16 in all populations of both subspecies. Phenetic relationships among populations were revealed with the help of ordination and clustering methods and the results of both methods coincide well. On the basis of a combination of several characters the great majority of plants are classifiable into either the first or the second subspecies.

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