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Cardamine pancicii (Brassicaceae), a neglected species of the Balkan Peninsula

Abstract

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Cardamine pancicii is shown to be an independent species, endemic of Mt Kopaonik in Serbia. A lectotype is selected, its morphological and molecular variation and its differentiation from related species on the Balkan and the Apennine peninsula are discussed on the basis of multivariate morphometrics and amplified fragment length polymorphism (AFLP) studies.

Key words: *Cruciferae,* Serbia, Mt Kopaonik, taxonomy, nomenclature, AFLP.

Introduction

Cardamine pancicii was collected for the first time in 1851 by Josif Pančić on a botanical journey to Mt Kopaonik. He described it as *Pteroneurum carnosum* var. *polyphylla* Pančić, with the remark: "Scheint zwischen *carnosum* und *croaticum* (*Cardam.*) Schott. die Mitte einzunehmen." (Pančić 1856: 508). Later, he introduced the name *Cardamine kopaonikensis* in a name list of the species occurring on Suvo rudište on Kopaonik (Pančić 1867: 173, 206) without any description. From the locality it is apparent that he referred to the same taxon that he originally described as *Pteroneurum carnosum* var. *polyphylla,* although there is no direct or indirect reference to this previous name. In "Flora Principatus Serbiae" Pančić reported *C. glauca* from Sucho [sic!] rudište without any reference to the above-mentioned names (Pančić 1874: 140). Finally, in "Additamenta ad Floram Principatus Serbiae" Pančić stated (translated): "*C. glauca* Spreng. (see Flora pr. Serbiae, p. 140) grows in various habitats in our country in two forms: the one from Suho Rudište and Bećirovac is a long-lived plant and it fully corresponds to the original plants from Aspromonte in Italy; the other one that grows in Derventa and around Mokra Gora seems to be short-lived, living for one or two years, and is quite similar to the plant that I received from the late Tommasini under the name *C. croatica* Schott. I cannot tell at the moment whether these plants belong to different species; late Grisebach wrote me that they are in fact the same" (Pančić 1884: 112).

After Pančić (1867) no one used the name *Cardamine kopaonikensis* until Pantocsek (1874) published the description of the variety *Cardamine glauca* var. *kopaunicensis* ascribing the name to Pančić. However, as there is no indication that Pančić provided the description, it should be attributed solely to Pantocsek. The description of this variety was based on specimens from the surroundings of Mostar (Herzegovina): "Eandem formam pr. Mostar lectam in herbario Kewensi vidi. – In saxosis montis Kom (M.)" (Pantocsek 1874: 91). Schulz in his monograph of the genus *Cardamine* (Schulz 1903: 572), accepted the name *C. glauca* var. *kopaunicensis* [as *"kopaonikensis"*], but including in its distribution besides Serbia and Albania also Calabria in Italy (Schulz 1903: 572). We were unable to find any original material of *C. glauca* var. *kopaunicensis* in Kew (K) or in any other relevant herbaria. Later Pančić's *C. kopaonikensis* is cited as nomen nudum in the synonymy of *C. pancicii* Hayek (Jovanović-Dunjić 1972: 254, Trinajstić 1976b: 230), while Pantocsek's *C. glauca* var. *kopaunicensis* is referred to as *C. glauca* f. *kopaunicensis* (Pant.) Beck (Jovanović-Dunjić 1972: 254).

Fritsch (1895: 323), apparently referring to the same populations, introduced the name *Cardamine glauca* var. *microphylla,* listing it as a synonym of *C. glauca* without providing any description. He cited a specimen collected by Pančić and deposited in Kerner's herbarium in Vienna (WU). In the herbarium of the Natural History Museum in Vienna (W) there is another original specimen collected by Pančić on Kopaonik, named by him "*Cardamine sylvatica* L. β) *microphylla* m.". This specimen was most probably collected by Pančić during his visit of Mt Kopaonik in 1851. It is interesting that Pančić himself has never used the epithet *"microphylla"* for this taxon. In recent floristic literature the epithet *"microphylla"* sensu Pančić has been used only as a synonym of *C. glauca* var. *glauca* f. *kopaunicensis* (Pant.) Beck (Jovanović-Dunjić 1972: 254).

Fourteen years after Schulz, Hayek (1918) described the species *Cardamine pancicii*. This was based on a herbarium specimen collected by Josif Pančić on Mt Kopaonik (Serbia) in 1874. (" Habitat in glareosis montis Kopaonik Serbić, ubi legit Pančić anno 1874" – Hayek 1918: 149). The protologue was accompanied by a photograph of the type specimen (Fig. 2), deposited in Kerner's herbarium in Vienna (WU). In Prodromus Florae Peninsulae Balcanicae (Hayek 1925: 394) he recombined it as *C. glauca* var. *pancicii* (Hayek) Hayek. Trinajstić (1976a: 8) introduced the new combination *C. glauca* subsp. *pancicii* (Hayek) Trinajstić, with information about its distribution in the mountain regions of Bosnia and Serbia. In recent years (Greuter & al. 1986, Jones & Akeroyd 1993, Jalas & Suominen 1994, Tan 2002) the name *C. pancicii* has been used as a synonym of *C. glauca* DC., with annotations that *C. pancicii* may represent either a subspecies of *C. glauca* (Jones & Akeroyd 1993, Jalas & Suominen 1994) or a well-established species (Greuter & al. 1986).

Cardamine pancicii is usually treated in *Cardamine* sect. *Pteroneurum* subsect. *Cryptopterum* Griseb. together with the Balkan-Apennine *C. glauca* DC., the Balkan *C. carnosa* Waldst. & Kit. and the S European *C. plumierii* Vill. (Fig. 8). However, the monophyly of some sections of the genus *Cardamine* introduced by Schulz (1903) is not supported by molecular data (Franzke & al. 1998, Sweeney & Price 2000, Bleeker & al. 2002) and the whole classification system of sections and subsections needs revision.

Cardamine pancicii is very close to *C. glauca,* which was originally described from Mt Aspromonte in the region of Calabria in S Italy ("In aspero monte prope Reggio in Calabria"; Candolle 1821). The lectotype of *C. glauca,* selected by Marhold (1995), is deposited in the herbarium G-De Candolle and was collected in 1819 by Sprengel in Calabria. This herbarium holds three other specimens cited in the original publication, collected in 1818 and 1820 in Calabria (one of them explicitly at Aspromonte), by Thomas and Andrzeiowski. Apart from S Italy, this species occurs also in the Balkan Peninsula.

The aim of the present study was to examine the morphological and macromolecular (AFLP) variation and differentiation of *Cardamine pancicii* and its closest relatives on the Balkan and the Apennine peninsula. Based on several years of field research and morphometric studies of herbarium material, we conclude that *C. pancicii* from Mt Kopaonik and *C. glauca* from the Balkans and the Apennines are morphologically distinct and represent two separate species.

Material and methods

The study was carried out with herbarium specimens from the public herbaria BEOU, BEO, SAV, SARA, W, WU, B, G, K, APP, RO, CAT and CLU (Holmgren & Holmgren 1998-), and own collections. Morphometric analyses were carried out on 390 specimens including *C. pancicii* (180 specimens), *C. plumieri* (56 specimens) and *C. glauca* from the Balkan Peninsula (114 specimens) and the Apennines (40 specimens), see Appendix. Flowers were fixed in ethanol/glycerol (1 : 1) or rehydrated by boiling in water for few minutes before measuring. The material used for the AFLP analysis included 28 individuals from 8 localities of *C. glauca,* one locality of *C. pancicii* and one locality of *C. maritima,* which was used to root the tree (for localities see Appendix).

Morphometric analysis. – The variability of the analyzed morphological characters was described by calculation of the standard statistic parameters (mean, minimum, maximum, standard deviation). Analysis of variance (ANOVA) and canonical discriminant analysis (DCA) were used in order to find statistically significant differences among the taxa studied. In addition, cluster analysis based on Mahalanobis distance and population average values of the measured characters was performed with the aim to see relationships among the populations and taxa. The data were processed with the statistical package Statistica 4.5 for Windows. The characters used in the morphometric analysis are listed in Table 1 (see electronic supplement).

AFLP analysis. – The AFLP analysis followed the protocol of Lihová & al. (2004). Total genomic DNA was extracted from silica gel-dried leaves following the CTAB extraction method (Doyle & Doyle 1987) with minor modifications. The AFLP procedure (Vos & al. 1995) was applied according to the general protocol by Applied Biosystems (PE Applied Biosystems 1996), again with a few modifications. Three primer combinations were used for selective amplification (Lihová & al. 2004). Presence or absence of resulting AFLP fragments ranging from 70 to 500 bp were scored for each sample (only well scorable fragments were analyzed) and transferred into a binary matrix using GenoGrapher (Benham 2001). For both *C. glauca* and *C. pancicii* the total number of AFLP fragments, average number of fragments per individual (± standard deviation), number of exclusive (present in a given taxon only, but not necessarily in all its samples) and diagnostic fragments (present in all samples of a given taxon and absent from all other taxa) were calculated. A neighbour-joining tree based on the Nei & Li (1979) genetic distance was computed using the PAUP (Swofford 2003), with the following settings: Unweighted Least Squares was chosen as Objective Function; constraint branch lengths were set to be non-negative and branches of effectively zero length when searching were set to collapse. Group support was assessed by a bootstrap analysis with 5000 replications. Principal coordinate analysis (PCoA; Krzanowski 1990) using Jaccard's coefficient was computed as well (SYN-TAX 2000; Podani 2001).

Results

Morphometric analysis. – The morphological differences among the three analyzed taxa, *Cardamine pancicii, C. plumieri* and *C. glauca,* are summarized in Table 1 and 2 (see electronic supplement), showing the standard statistical parameters of the measured characters. The most pronounced differences between *C. pancicii* and *C. glauca* are in the following characters: length and width of the basal leaf, length and width of its basal and terminal leaflets, length of the middle stem leaf, length and width of its basal leaflets and length of its terminal leaflet, length of the basal and terminal leaflets of the largest leaf, length of peduncle, length and width of siliquae, and length of beak (Table 2). *C. pancicii* differs from *C. plumieri* in the characters: depth of the petal indentation, length of shorter anther, length of beak, as well as in all characters in leaf morphology, especially in length of the basal and middle-stem leaf and dimension of teminal leaflets of all leaves (Table 2). This differentiation was confirmed also by the results of the analysis of

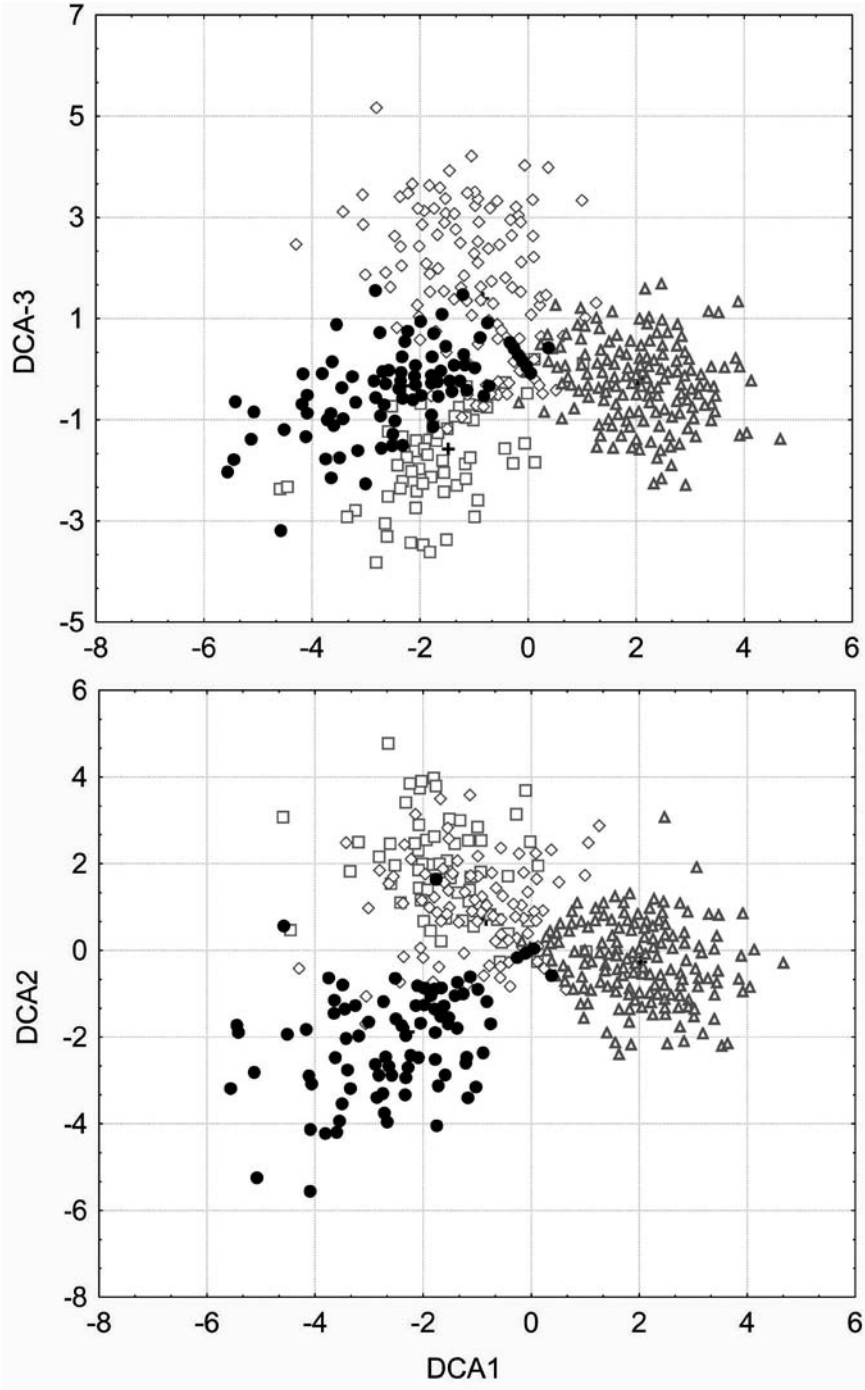

Fig. 1. Discriminant component analysis of *Cardamine pancicii* (△), *C. plumieri* (●) and Balkan (◊) and Apennine (□) populations of *C. glauca.*

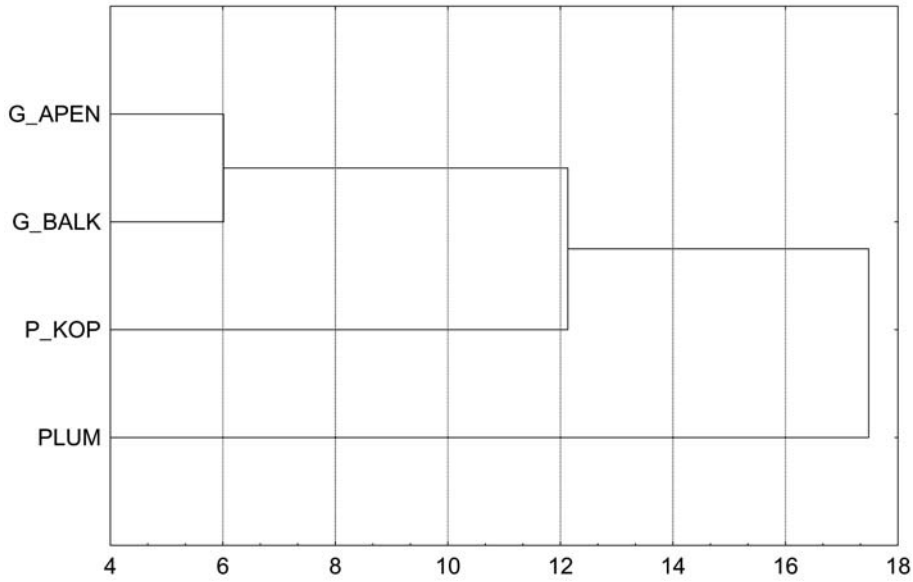

Fig. 2. Dendrogram of cluster analysis (UPGMA, Mahalanobis distance) of *Cardamine pancicii* (P_KOP)*, C. plumieri* (PLUM) and the Balkan (G_BALK) and Apennine (G_APEN) populations of *C. glauca*.

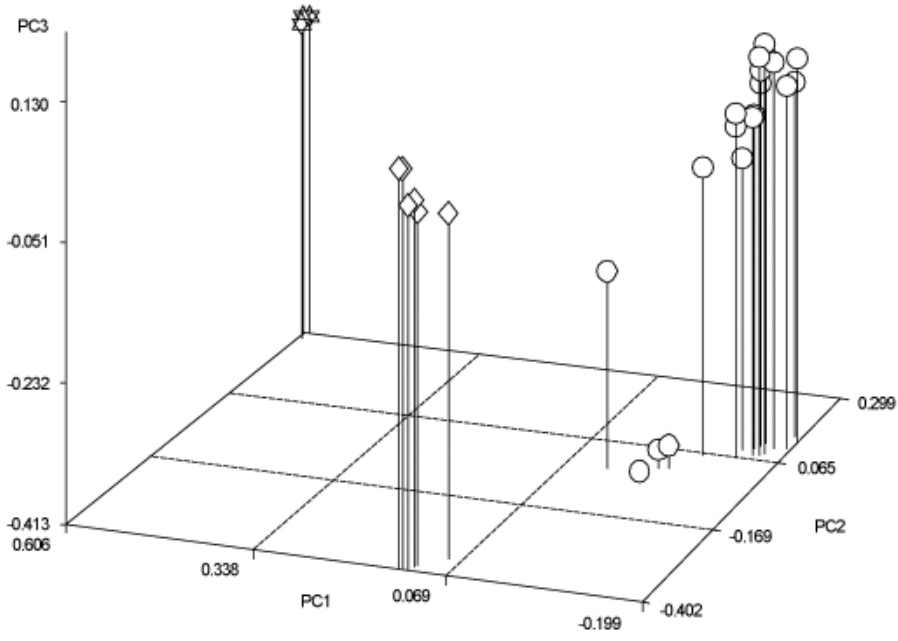

Fig. 3. Principal coordinates analysis of AFLP data of *Cardamine glauca* (●), *C. pancicii* (◊) and *C. maritima* (☆).

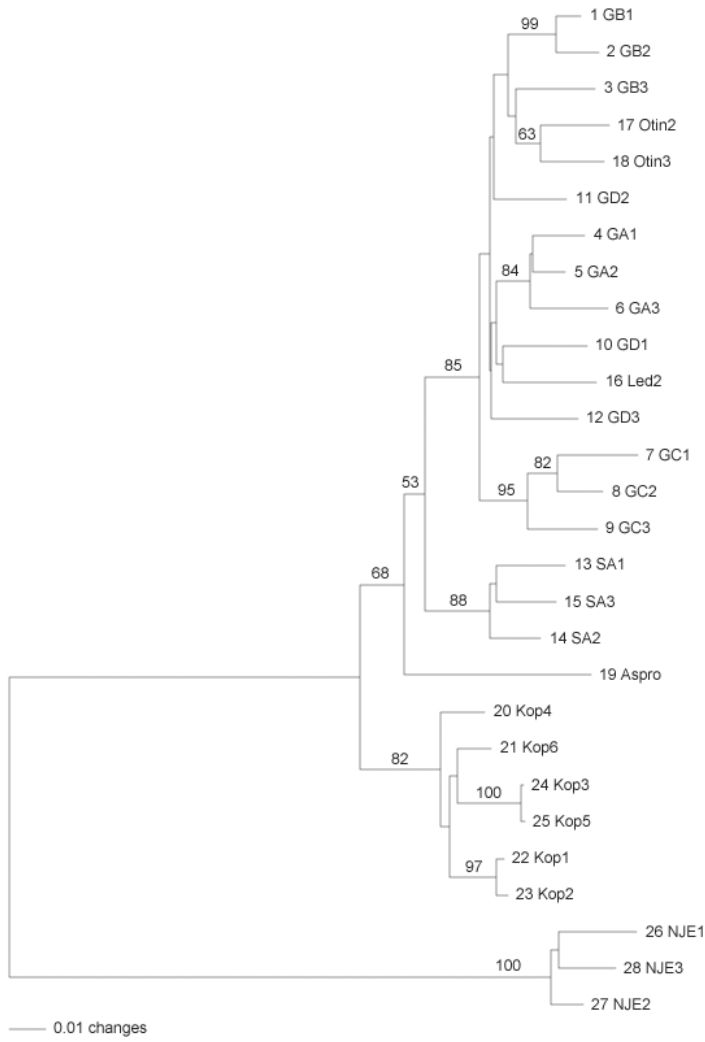

Fig. 4. Neighbour-joining distance analysis of AFLP data. Only bootstrap values higher than 50 % are shown.

variance (ANOVA), which showed statistically significant differences among the three taxa, *C. pancicii, C. plumieri and C. glauca,* in most of the analyzed characters (Table 3, see electronic supplement).

Canonical discriminant analysis based on individual plants has shown that *Cardamine pancicii, C. plumieri* and *C. glauca* are almost completely differentiated (Fig. 1). The plants of *C. pancicii* are clearly separated along the first axis, while those of *C. plumieri* and *C. glauca* get separated along the second axis. Differentiation is apparent also within *C. glauca;* specimens from the Apennine Peninsula are separated from Balkan populations along the third axis.

Mahalanobis distance (UPGMA cluster method) confirmed that *Cardamine pancicii* is well differentiated from *C. glauca* and *C. plumieri* (Fig. 2). Unexpectedly, cluster analysis indicated that *C. pancicii* and *C. plumieri* are morphologically much more similar than *C. glauca* and *C. pancicii.*

AFLP analysis. – In 28 individuals analyzed for AFLPs, altogether 243 fragments were amplified by the three primer pairs. Among them, 238 fragments were polymorphic. In *Cardamine glauca* (19 individuals), 172 fragments were resolved, with the average number of 67.3 fragments amplified per individual (s.d. = 6.63). In *C. pancicii* (6 individuals), 87 fragments were scored, with the average of 65.8 fragments per individual (s.d. = 2.57). The number of exclusive and diagnostic fragments (for definition see Material and Methods) characterizing *C. glauca* was 102 and 1, respectively. In *C. pancicii,* 12 exclusive and 7 diagnostic fragments were found.

Both the principal coordinate analysis and the neighbour-joining tree showed clear distinction between the two taxa. In the diagram of the principal coordinate analysis (Fig. 3), *Cardamine glauca* and *C. pancicii* were placed in two groups, well separated along the first and second axes. The first three axes represented 19.41 %, 16.27 % and 7.49 % of the total variation, respectively. In the neighbour-joining tree rooted by *C. maritima* (Fig. 4), *C. glauca* and *C. pancicii* formed two clusters with the bootstrap support 68 % and 82 %, respectively.

Taxonomy

In the traditional classification *Cardamine pancicii* is considered as closely related to *C. glauca*, *C. carnosa* and *C. plumierii*, included in *C. sect. Pteroneurum* subsect. *Cryptopterum. C. glauca* and *C. plumieri* have 2*n* = 16 (Tan 2000), while the chromosome numbers of *C. pancicii* and *C. carnosa* are still unknown. These taxa have rather similar ecological preferences, they grow predominantly in the mountains on screes and stony soil and in crevices, but also in open alpine vegetation above the timberline.

Despite previous taxonomic confusions, the populations from Mt Kopaonik form a well differentiated group, which should be treated as a separate species *Cardamine pancicii*. It is easily

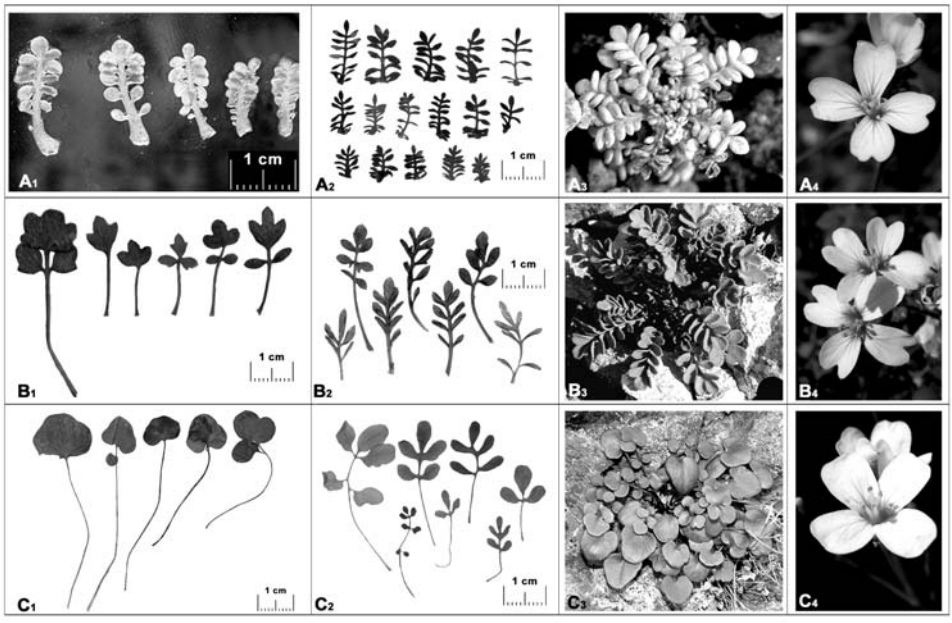

Fig 5. Differences between A: *Cardamine pancicii* (Suvo Rudište, Mt Kopaonik, Serbia), B: *C. glauca* (Aspromonte, Italy) and C: *C. plumieri* (Nebeske Stolice, Mt Kopaonik, Serbia) – A1: basal leaf of *C. pancicii;* A2: cauline leaf of *C. pancicii;* A3: leaf rosette of *C. pancicii;* A4: flower of *C. pancicii;* B1: basal leaf of *C. glauca;* B2: cauline leaf of *C. glauca;* B3: leaf rosette of *C. glauca;* B4: flower of *C. glauca;* C1: basal leaf of of *C. plumieri;* C2: cauline leaf of *C. plumieri;* C3: leaf rosette of *C. plumieri;* C4: flower of *C. plumieri*.

distinguished from *C. carnosa* by its glabrous ovarium, non-creeping, short rhizome and by its pinnate basal leaves with (3-)5-9(-11) very small lateral and terminal leaflets. The morphometric study shows that it is also distinct from *C. plumieri* and *C. glauca*, from the former by its deeply emarginate petals and its pinnate basal leaves with (3-)5-9(-11) very small lateral and terminal leaflets (Fig. 5), from the latter primarily by its perennial habit, the formation of relatively compact snow-resistant cushions with leaves in evergreen rosettes, and its basal leaves with (3-)5-9(-11) very small lateral and terminal leaflets (Fig. 5). Further differences in quantitative characters are shown in Table 2. This morphological pattern was confirmed by AFLP data, which showed genetic differentiation of *C. pancicii* from the related species and provided support for its independent status (Fig. 3, 4).

Our morphometric results indicate that there are also differences between the populations of *Cardamine glauca* in Italy and those in the Balkans, and this is confirmed by the AFLP data. Apparently the geographical disjunction has restricted gene flow. More detailed studies with more plant material from both parts of the distribution range are needed to evaluate the extent of the differentiation and to draw taxonomic conclusions.

Key to the species of for *Cardamine* sect. *Pteroneurum* subsect. *Cryptopterum* in the Balkans

1. Ovary and young siliqua densely grey-puberulent; plant with distinct, creeping rhizome . . . . . *C. carnosa*
– Ovary and siliqua glabrous; plant without distinct, creeping rhizome 2
2. Outermost and inner rosette leaves different, almost all outermost leaves entire or shallowly 3-lobed; petals rounded or slightly emarginate; infructescence not secund . . *C. plumieri*
– Outermost and inner rosette leaves very similar, all pinnate with (1-)2-9(-11) lateral leaflets; petals distinctly emarginate; infructescence secund 3
3. Annual to biennial plant; pinnate rosette leaves with (1-)2-5(-7) small lateral and relatively large, usually shallowly 3-lobed terminal leaflets . . . . . *C. glauca*
– Annual to perennial plant forming compact snow-resistant cushions with leaves in evergreen rosettes; pinnate rosette leaves with (3-)5-9(-11) very small lateral and non-lobed terminal leaflets . . . . . *C. pancicii*

Cardamine pancicii Hayek in Akad. Wiss. Wien, Math.-Naturwiss. Kl., Denkschr. 94: 149, t. II, fig. 2. 1918
≡ *Cardamine glauca* var. *pancicii* (Hayek) Hayek in Repert. Spec. Nov. Regni Veg. Beih. 30: 395. 1925 ≡ *Cardamine glauca* subsp. *pancicii* (Hayek) Trinajstić, Suppl. Fl. Anal. Jugosl. 4: 8 1976. – Holotypus: In glareosis m. Kopaonik, Serb. merid., 8.1874, *J. Pančić* (WU - herb. Kerner 000057) – Fig. 6.
= *Pteroneurum carnosum* var. *polyphylla* Pančić in Verh. Zool.-Bot. Ges. Wien 6: 508. 1856. – Type: unknown; ind. loc.: “Am Suvo rudište unter der Spitze des M. Kopaonik im Kruševacer Kr.”
= *Cardamine glauca* var. *kopaunicensis* Pant. in Verh. Vereins Natur- Heilk. Presburg, ser. 2, 2: 91, 1874. – Type: unknown. Ind. loc.: “prope Mostar, ... in saxosis montis Kom”.
– *Cardamine kopaonikensis* Pančić in Österr. Bot. Z. 17: 173. 1867, nom. nudum.
– *Cardamine glauca* var. *microphylla* Pančić ex Fritsch in Verh. k. k. Zool.-Bot. Ges. Wien 44: 323. 1895, nom. nudum, pro syn.

Perennial, entirely glabrous, not or rarely glaucous. Short vertical rhizome present. Mature plant with 10-20(-30) stems forming cushions with evergreen leaf rosettes. Stems 5-16(-32) cm, decumbent to ascending, weakly flexuose especially in infrutescence, with several to many stem branches at base. All petioles without auricles. Outermost and inner rosette leaves very similar, imparipinnate with 2-4(-5) pairs of entire, obovate to suborbicular lateral leaflets (0.5-)0.7-1.6(-2.3) × (0.1-)0.2-0.8(-1.4) mm, and an entire or shallowly 3-lobed, larger, elliptic to obovate terminal

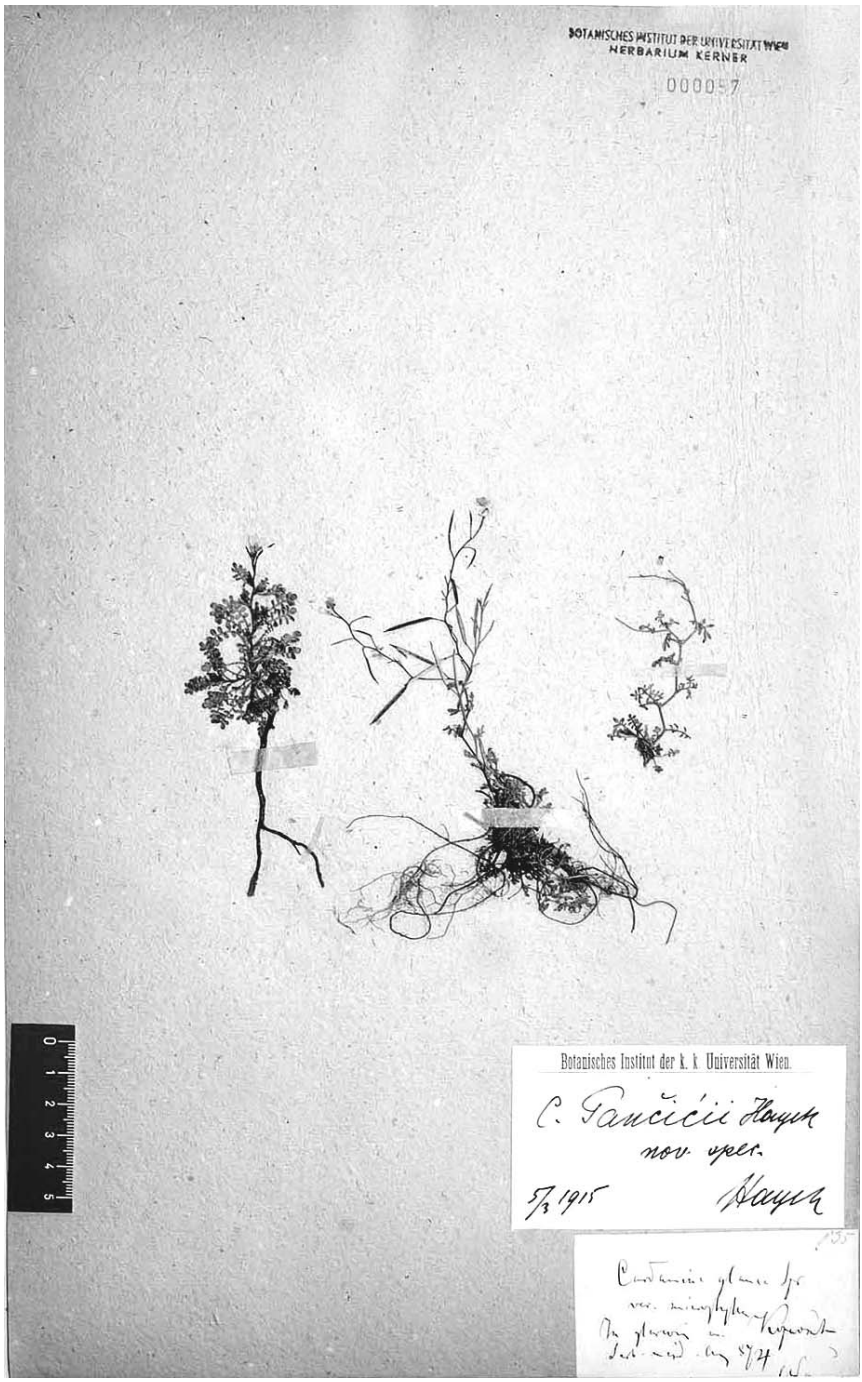

Fig. 6. Holotype of *Cardamine pancicii* Hayek – label text: *Cardamine glauca* Sprl. / var. microphyla / In glareosis m. Kopaonik / Serb. merid. Aug 874 / J. Pančić (Pančićs handwriting) // Botanisches Institut der k.k. Universität Wien / *C. Pančićii* Hayek nov. spec. / 5.4.1915 Hayek (Hayek's handwriting). – WU-herb. Kerner 000057.

Fig 7. *Cardamine pancicii* Hayek – plant from locus classicus, Suvo Rudište (43°16,271'N, 20° 48.581'E), Mt Kopaonik, Serbia.

leaflet (1-)1.5-3.2(-4.5) ×(0.2-)1.4-3.5(-5.1) mm, often green beneath; middle cauline leaves lyrate-pinnate with 3-5(-7) pairs of elliptic to obovate, sessile lateral leaflets (0.3-)0.8-2.2(-4.1) × (0.1-)0.2-0.7(-1.2) mm and an entire or shallowly 3-lobed, larger, elliptic to obovate terminal leaflet (0.9-)1.4-3.8(-7.5) × (0.3-)1.3-4.8(-9.1) mm. Sepals (1.7-)2.2-2.9(-3.6) × (0.6-)0.9-1.4(-2) mm, oblong-elliptic, reddish or green with narrow scarious margins. Petals (4.1-)4.9-6.5(-8.7) × (1.6-)2.8-4.1(-5.9) mm, white, deeply emarginate, depth of the petal indentation (0.2-)0.5-1(-1.6) mm. Stamens to ½ as long as petals, longer ones (1.4-)2-2.7(-3.2) mm, shorter ones (0.9-)1.2-1.8(-2.7) mm; anthers yellowish, (0.3-)0.6-0.9(-1.3) mm. Stylus (0.5-)0.7-1.1(-1.7) mm long, stigma (0.1-)0.2-0.4(-0.6) mm wide. Infructescence secund, mature siliquae vertically or ± horizontally spread. Mature siliquae (1.2-)6-15.4(-24) × 0.5-1.1(-1.8) mm, with beak (0.1-)0.6-1.4(-3.1) × (0.1-)0.2-0.4(-0.6) mm; peduncle (1-)3.5-6.6(-10.2) mm long. Seeds (0.9-)1-1.3(-1.8) × (0.4-)0.7-1(-1.3) mm, oblong elliptic, pale brown to reddish brown. – Fig. 7.

Distribution and ecology. – *Cardamine pancicii* is an endemic species of Mt Kopaonik in Serbia [UTM DN98]. Records from the Prokletije (Jovanovič-Dunjič 1972: 254, Jalas & Suominen 1994: 167) and Šar-planina Mts (Jalas & Suominen 1994: 167) from Balkan Peninsula and S Italian mountains (Schulz 1903: 572) remain unconfirmed (Fig. 8). This taxon primarily inhabits the alpine and subalpine zone at altitudes between 1300 and 2018 m, where it is found on rocky ground and in pastures (Juncetea trifidi Hadač 1944), peatbog ribs (Scheuchzerio-Caricetea fuscae (Nordhagen 1936) R. Tx. 1937) and stream banks (Montio-Cardaminetea Br.-Bl. & Tx. 1943). Rarely, it inhabits ribs of alpine heaths (Vaccinion uliginosi Lakušić 1974) and subalpine shrub vegetation (Juniperion sibiricae Br.-Bl. 1939). It has been noticed exclusively on iron-rich soils over acidic siliceous rock (granodiorite and cornite).

The relatives of *Cardamine pancicii* also inhabit rocky sites, but their habitat preferences are clearly different, at least in the Balkans (W Serbia, Epirus). Here *C. plumieri* mainly grows in serpentine habitats, *C. carnosa* is obligately calcicolous, while *C. glauca* preferably inhabits limestone, but also occurs on serpentine and siliceous screes and rocky habitats.

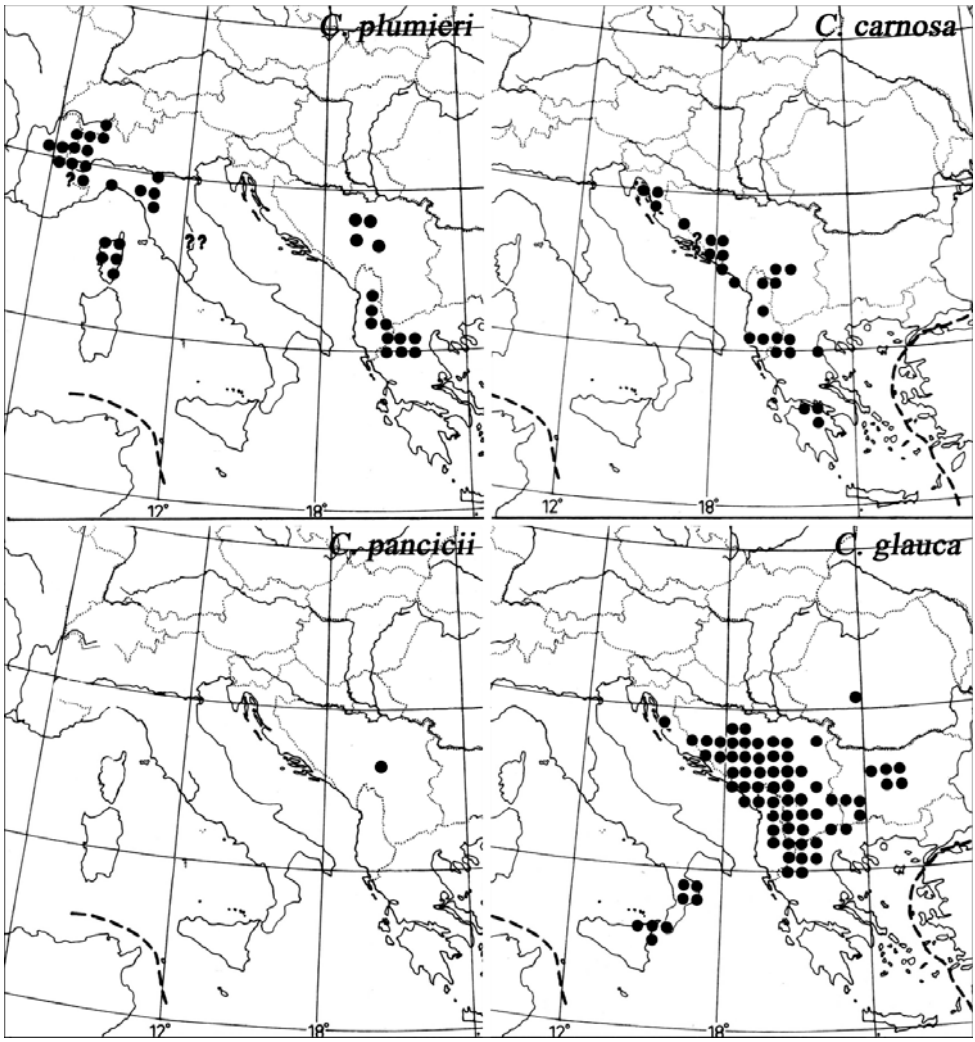

Fig 8. Distribution of *Cardamine pancicii* and related taxa (after Jalas and Suominen 1994 with minor modifications).

Further investigated specimen collected by J. Pančić

Cardamine kopaonikensis m. / In saxosis magnetitici Ko- / paonik Serb. merid. Aug / *Pteroneurum microphyllum* var. Panč) / [?] Proximae *C. glauca* Spr. / J. Pančić [Pančić's handwriting] // Botanisches Institut der k.k. Universität Wien / *C. Pančicii* Hayek n. sp. / 5.3.1915 A. Hayek [Hayek's handwriting] (WU - Herb. Kerner 000056)

Cardamine kopaonikensis m. / In glareosis magnetitici Ko- / paonik S. merid. Aug / J. Pančić [Pančić's handwriting] // Ma *Cardamine kopaonikensis* (*Pteroneurum carnosum* / var *microphyllum* Panc ?) [?] identique [?] *C. glau-* / *ca* Schrd. et ma *glauca* de Mokra Gora [?] / se qua *C. thalictroides*. Dr Pančić 1873 [Pančić's handwriting] // Conservatoire botanique, Genéve / Herbier BOISSIER, séries n'ayant pas / servi à la rédaction du / *Flora Orientalis* (typed label) // *Card. glauca* / var. *kopaonikensis* [unknown handwriting] (G-BOIS)

Cardamine kopaonikensis / Kop 864 [Pančić's handwriting] // *Cardamine glauca* (Pančić's handwriting) / Kopaonik Jul / 864 (BEOU - Herb. Panc. No. 2693)

Cardamine kopaonicensis Panč / Flora Serbica. Kopaonik: Suho / Rudište / 31.7.1886/ leg. Pančić [Unknown handwriting] (BEOU - Herb. Panc. No. 2694)

Cardamine sylvatica L. / β) *microphylla* m. / Mt Kopaonik / forma [singularis?] forma nova / JP [Pančić's handwriting] // *Cardamine glauca* Sprg. / var. *kopaonikensis* Pančić / det. O. E. Schultz [O. E. Schulz's handwriting] (W)

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Appendix

(1) Origin of the material used for the morphometric analysis

Cardamine pancici Hayek

Serbia, Kopaonik (180 specimens) – 1 km ispod hotela Bačište, 1500 m, oko potoka, silikat, 27.5.2001, *Lakušić, Sabovljević & Mitrović 15156* (BEOU); Krst, pored puta za Suvo Rudište, 1750 m, kamenjari, silikat, 20.8.2000, *Lakušić, Sabovljević & Mitrović 15157* (BEOU); Krst, 1700 m, *S*clerantho-Cardaminetum pancicii, vlažna tresetna podloga, 25.6.2003, *Lakušić* 17158 (BEOU); Pojilo Greben - Treska (lok. 5.1.), 1700 m, vlažna tresetna podloga, 25.6.2003, *Lakušić 17159* (BEOU); Pajino Preslo, 1700 m, Hygronardion, silikat, 27.6.2003, *Lakušić 17160* (BEOU); Suvo Rudište, 1950 m, Minuartietum recurvae, kornit - jalovinište, 25.6.2003, *Lakušić 17161* (BEOU); Krst, 1800 m, Sclerantho-Cardaminetum pancicii, vlažna šljunkovita podloga, 25.6.2003, *Lakušić 17162* (BEOU); Krst, 1700 m, Sclerantho-Cardaminetum pancicii, vlažna tresetna podloga, 25.6.2003, *Lakušić* 17163 (BEOU); Suvo Rudište, 1900 m, osuline sa dominacijom *Anthemis carpatica,* kornit - jalovinište, 26.6.2003, *Lakušić* 17164 (BEOU).

Cardamine glauca DC.

Italy, Aspromonte (40 specimens) – Between Gambarie and Torrente Menta, siliceous rocky grounds near the road, 27.6.2003, *Uzunov & Uzunova* (BEOU); Torrente Menta-Tre Limiti, 38°07.710'N, 15°05.565'E, 1630 m, siliceous rocky grounds, 11.7.2003, *Lakušić, Conti & Uzunov* (BEOU).

Montenegro, Durmitor (24 specimens) – Lojanik (Boban), 5.7.1989, *Stevanović & Jovanović 758/89* (BEOU); Lojanik, 2000 m, Salicion retusać, krečnjak, 29.7.1989, *Lakušić & Đorđević 631/89* (BEOU); Crvena Greda, stene, sipari, 16.7.1990, *Jovanović & Mitrović 2076/90* (BEOU); Sedlena greda, 2000 m, rudine, stene, pašnjaci, 11.7.1991, *Jovanović & al. 840/91* (BEOU); Prutaš, 12.7.1991, *Lakušić & Niketić 883/91* (BEOU); Planinica (pod - nožje), 1800 m, sipari, 18.7.1992, *Lakušić 221/92* (BEOU); Škrčka jezera - Grude (pod- nožje), 2000 m, 18.7.1992, *Stevanović 491/92* (BEOU); Šareni pasovi (podnožje), 19.7.1992, *Lakušić 269/92* (BEOU); Velika Kalica, 2000 m, 12.8.1992, *Lakušić 576/92* (BEOU); Kotao - Šljeme, 2200 m, 13.8.1992, *Lakušić 630/92* (BEOU); Velika Kalica - Velika Previja - Međed, W exp., strane, 13.8.1993, *Stevanović & al. 818/93* (BEOU); Velika Kalica (put), 13.8.1993, *Stevanović & al. 829/93* (BEOU).

Serbia, Šar planina (30 specimens) - Jezerska Čuka (podnožje), stene i rudine, 28.6.1990, *Jovanović, Lakušić & Benić 1320/90* (BEOU); Jezerska Čuka (cirk ispod), 2150 m, 28.6.1990, *Jovanović, Lakušić & Benić 1349/90* (BEOU); Jezerska Čuka (ispod), snežanici u glacijalnom cirku, 28.6.1990, *Jovanović, Lakušić & Benić 1406/90 (*BEOU); Jažinačko jezero, rudine, snežanici, kamenjar, 28.6.1990, *Jovanović, Lakušić & Benić 1492/90* (BEOU); Prevalac - lovačka kuać ispred Jažinačkog jezera, 29.9.1991, *Stevanović, Lakušić & Niketić 2390/91* (BEOU).

Montenegro, Rumija (30 specimens) – izmedju Muriać i Virpazara, krečnjak, kamenjari, 28.5. 2004, *Lakušić* (BEOU).

Serbia, Derventa (30 specimens) – kanjon, 29.5.1994, *Stevanović, Jovanović & Pavić 1944/94* (BEOU); kanjon, krečnjak, 23.5.2001, *Stevanović & Jovanović "ENDEMIT" 13826* (BEOU); kanjon, krečnjak, stene i sipari, 22.5.2004, *Lakušić & Lakušić* (BEOU).

Cardamine plumieri Vill.

Serbia, Kopaonik (56 specimens) – Treska, 1700 m, stene Silenetum serbicae, serpentinit, 26.6.2003, *Lakušić 17153* (BEOU); Nebeske Stolice, 1800 m, stene u senci Silenetum serbi- cae, serpentinit, 26.6.2003, *Lakušić 17154* (BEOU); Nebeske Stolice, 1800 m, stene na osun - čanom - i Silenetum serbicae, serpentinit, 26.6.2003, *Lakušić 17155* (BEOU); Kukavica, 1650 m, stene u senci, serpentinit, 27.6.2003, *Lakušić 17156* (BEOU); Kukavica, 1650 m, kamenjari osunčani, serpentinit, 27.6.2003, *Lakušić 17157* (BEOU).

(2) Origin of the material used for the AFLP analysis

Cardamine pancicii Hayek

Kop – Serbia, Kopaonik, Suvo Rudište, 43°16.271'N, 20°48.581'E, 25.6.2003, *Lakušić 17161* (BEOU, SAV).

Cardamine glauca DC.

Otin. – Montenegro, Cetinje, 22.4.2003, *Kučera (SAV).*
Led. – Montenegro, Ledeniče, 42°32.693'N, 18°42.749'E, 695 m, 22.4.2003, *Kučera (SAV).*
GA – Montenegro, Risan, 42°31.949'N, 18°42.032'E, 504 m, 4.5.2004, *Kučera* (SAV).
GB – Montenegro, Lovćen, 42°26.219'N, 18°51.177'E, 1058 m, 4.5.2004, *Kučera* (SAV).
GC – Montenegro, Mt Maglič, Mratinje, 43°16.112'N, 18°50.090'E, 708 m, 5.5.2004, *Kučera* (SAV).
GD – Montenegro, Spila, 42°44.678'N, 18°41.713'E, 841 m, 5.5.2004, *Kučera* (SAV).
SA – Serbia, Tara Mts, Peručac, 43°57.637'N, 19°22.875'E, 285 m, 22.5.2004, *Kučera* (SAV).
Aspro – Italy, Aspromonte, Torrente Menta-Tre Limiti, 38°07.710'N, 15°05.565'E, 1630 m, 11.7.2003, *Lakušić* (BEOU, SAV).

Cardamine maritima DC. (used for the rooting of the tree)
NJE – Montenegro, Lovćen, Njeguši, 42°24.625'N, 18°47.377'E, 919 m, 4.5.2004, *Kučera* (SAV).