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Authors: Conti, Fabio, Bracchetti, Luca, Uzunov, Dimitar, and Bartolucci, Fabrizio

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FABIO CONTI[1*], LUCA BRACCHETTI[2], DIMITAR UZUNOV[3] & FABRIZIO BARTOLUCCI[1]

A new subspecies of *Corydalis densiflora* (*Papaveraceae*) from the Apennines (Italy)

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Abstract: A morphometric study of populations from the central-southern Apennines and Sicily of the Italian endemic *Corydalis densiflora* has been undertaken, based on herbarium specimens and field research. A new subspecies, *C. densiflora* subsp. *apennina*, is described from the central Apennines. It differs from *C. densiflora* s.str. by its more divided leaves and bracts, basal leaf with more numerous and narrower leaflets, longer middle and lateral lobes of middle and upper bracts, narrower lower petal wing, shorter inner petals and shorter upper stamen.

Key words: Apennines, *Corydalis*, endemic, Italy, new taxon, *Papaveraceae*, taxonomy

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Introduction

The genus *Corydalis* DC. (*Papaveraceae*) consists of about 440 species distributed in Eurasia, North America and Africa (Lidén & Zetterlund 1997). *Corydalis densiflora* C. Presl was described from Sicily "in nemorosis Nebrodum" (Presl & Presl 1822). The name was recently typified based on a specimen housed in PRC (Conti & al. 2015). This taxon was misunderstood by Italian botanists and consequently the understanding of its distribution range was usually incomplete. Fiori (1924) recorded it as *C. solida* var. *densiflora* (C. Presl) Boiss. for Trentino-Alto Adige, southern Apennines and Sicily. Pignatti (1982) treated this taxon in a note to the name *C. solida*, as *C. solida* var. *densiflora*, recorded for Calabria and Sicily and not confirmed in Abruzzo. More recently, Pignatti (2017) recognized two taxa at subspecies level: *C. solida* (L.) Clairv. subsp. *solida* and *C. solida* subsp. *densiflora* (C. Presl) Hayek, but indicating erroneous distributions. *Corydalis densiflora* is currently recognized at species level (Lidén & Zetterlund 1997; Conti & al. 2014, 2015; Peruzzi & al. 2015; Bartolucci & al. 2018), distinguished from *C. solida* by several morphological characters (Lidén & Zetterlund 1997; and pers. obs.). It differs by compact racemes (vs loose racemes), bracts as long as wide (vs usually longer than wide), floral pedicels 3–8(–10) mm long (vs 5–15 mm long), outer petals narrowly winged (vs broadly winged), corolla apex obtuse to slightly emarginate (vs usually emarginate), lower petal usually without or with a small pouch at base (vs usually with a prominent pouch at base).

1 Scuola di Bioscienze e Medicina Veterinaria, Università di Camerino – Centro Ricerche Floristiche dell'Appennino, Parco Nazionale del Gran Sasso e Monti della Laga, San Colombo, 67021 Barisciano (L'Aquila), Italy; *e-mail: fabio.conti@unicam.it (author for correspondence).
2 Scuola di Bioscienze e Medicina Veterinaria, Università di Camerino, URDIS, Lungomare Scipioni 6, 63074 San Benedetto del Tronto (Ascoli Piceno), Italy.
3 Museo di Storia Naturale della Calabria ed Orto Botanico. Università della Calabria, 87036 Arcavacata di Rende (Cosenza), Italy.

Corydalis densiflora is endemic to central-southern Italy and Sicily (Peruzzi & al. 2014, 2015; Bartolucci & al. 2018), occurring in Umbria, Marche, Lazio, Abruzzo, Basilicata, Calabria, Sicily and not confirmed in Molise (Conti & al. 2005, 2015; Del Vico & al. 2014; Bartolucci & al. 2018). However, our preliminary observations on fresh material and the study of herbarium specimens evidenced a certain degree of morphological variability within *C. densiflora*, seemingly linked to geographical distribution (Conti & al. 2014, 2015).

Material and methods

Plant material

This study is based mainly on field surveys and an extensive analysis of relevant literature, careful examination of herbarium specimens (including the original material) in APP, BC, CAT, CLU, L, LD, MA, MPU, NAP, P, PAL, PRC and UTV (herbarium codes follow Thiers 2018+) and the personal collection of D. Uzunov (Cosenza).

In order to investigate the variability and to clarify the systematics of *Corydalis densiflora*, about of 15 plants from each of five localities (two from the C Apennines, two from the S Apennines and one from Sicily) were studied.

C Apennines:

L Gran Sasso, Piano Locce (Barisciano), pascoli, 1236 m, 23 Apr 2012, *F. Conti* & *F. Bartolucci*

V Velino, Monte Fratta (Lucoli), radure e margini di faggeta, 1600 m, 15 May 2012, *F. Conti* & *F. Bartolucci*

S Apennines:

C Catena Costiera, Passo della Crocetta, 1100 m, 31 Mar 2012, *D. Uzunov*; ibidem, 17 Apr 2012, *D. Uzunov*

P Pollino, Mormanno, 950 m, 6 May 2012, *D. Uzunov*

Sicily:

M Madonie, Piano Battaglia, 1580 m, 25 Apr 2012, *D. Uzunov*

Data acquisition

All plants were scanned before drying, using a flat scanner with a resolution of 600 dpi. Firstly, images were acquired from all plants; secondly, the different organs were separated and scanned again with highest resolution in order to capture needed details. All measurements were made by ImageJ software (Rasband 1997–2016). This procedure is time saving and allows the acquisition of a large number of characters from fresh plant material, without the preliminary need of choosing some of them. A total of 72 individuals, scanned before drying, were studied measuring the following quantitative characters:

1. number of flowers; 2. number of leaves; 3. length of scale leaf; 4. length of basal leaf; 5. width of basal leaf; 6. number of leaflets of basal leaf; 7. length of petiole of basal leaf; 8. length of middle rachis of basal leaf; 9. length of terminal rachis of basal leaf; 10. length of central leaflet of basal leaf; 11. width of central leaflet of basal leaf; 12. length of basal bract; 13. width of basal bract; 14. number of teeth of basal bract; 15. number of lobes of basal bract; 16. length of middle bract; 17. width of middle bract; 18. length of central lobe of middle bract; 19. width of central lobe of middle bract; 20. length of lateral lobe of middle bract; 21. number of teeth of middle bract; 22. number of lobes of middle bract; 23. length of upper bract; 24. width of upper bract; 25. length of central lobe of upper bract; 26. width of central lobe of upper bract; 27. length of lateral lobe of upper bract; 28. width of lateral lobe of upper bract; 29. sinus depth of lateral lobe of upper bract; 30. number of teeth of upper bract; 31. number of lobes of upper bract; 32. length of pedicel of basal flower; 33. length of pedicel of middle flower; 34. length of pedicel of upper flower; 35. length of flower; 36. maximum width of corolla tube; 37. length of spur; 38. length of upper petal; 39. length of wing of upper petal; 40. length of wing of lower petal; 41. length of lower petal; 42. width of lower petal; 43. length of inner petal; 44. length of ovary; 45. length of upper stamen; 46. width of wing of lower petal.

Statistical analyses

First, descriptive statistics (mean, median and quartiles) and graphs (box plots) were carried out. Then, our data were found to depart from normality, through the Shapiro-Wilk test (Shapiro & Wilk 1965). To understand the similarities (and differences) between the studied populations, univariate analysis of variance (one-way ANOVA) and multivariate analysis (Principal Component Analysis [PCA] and Discriminant Analysis [DA]) for the studied groups were carried out. Furthermore, in order to detect significant differences between their averages, the *a posteriori* comparison of each pair of means was performed in ANOVA; this by Tukey's honestly significant differences (HSD) test. The PCA (Sneath & Sokal 1973; Krzanowski 1990) is an exploratory analysis and in this work was performed to look for the existence of potential patterns. Subsequently, to verify the *a priori* explicit hypothesis of populations membership, defined on the geographical (central Apennines and southern Apennines [L, V, P] vs southern Apennines and Sicily [C, M]) and morphological basis, the DA (Fisher 1936; Klecka 1980) was used. These analyses were performed using SPSS version 24.0 (IBM 2016) and XLSTAT version 2017.3 (Addinsoft 2017).

Results

Descriptive statistics and one-way ANOVA

Tables 1 and 2 show the descriptive statistics and ANOVA

Table 1. Descriptive statistics of variables that differentiate the two groups (L-V-P vs M-C) in ANOVA (var/pop: variable/population; var: variable; *n*: number of observations; 1°q: first quartile; 3°q: third quartile; stand var: standard variation).

var/pop	*n*	1°q	median	3°q	mean	var	stand var
6 | C	12	14.55	19.88	26.03	20.23	61.08	7.82
6 | L	15	18.82	28.16	31.76	27.05	96.17	9.81
6 | M	16	25.04	33.40	46.28	36.52	202.12	14.22
6 | P	15	25.22	29.33	34.96	29.79	61.66	7.85
6 | V	14	21.33	23.68	35.55	28.72	206.76	14.38
11 | C	12	4.84	7.82	11.07	8.48	12.67	3.56
11 | L	15	2.45	2.61	3.69	3.36	2.22	1.49
11 | M	16	8.02	9.84	14.47	11.29	27.35	5.23
11 | P	15	3.40	3.59	4.76	3.84	1.93	1.39
11 | V	14	1.89	2.58	3.05	2.65	1.11	1.05
18 | C	12	5.61	6.76	7.36	6.38	2.17	1.47
18 | L	15	6.72	7.72	8.52	7.81	2.24	1.50
18 | M	16	5.19	5.90	6.45	5.84	1.42	1.19
18 | P	15	6.31	7.50	9.13	7.54	2.78	1.67
18 | V	14	7.51	7.90	9.61	8.26	3.90	1.97
20 | C	12	4.60	5.48	5.91	5.36	1.38	1.17
20 | L	15	5.84	6.69	7.26	6.68	1.04	1.02
20 | M	16	4.48	5.13	6.23	5.30	1.41	1.19
20 | P	15	5.66	6.99	7.67	6.63	2.31	1.52
20 | V	14	6.30	6.45	7.94	6.79	2.76	1.66
25 | C	12	4.99	5.69	6.31	5.43	1.86	1.36
25 | L	15	6.14	7.12	8.44	7.18	2.20	1.48
25 | M	16	4.37	4.98	5.84	5.05	1.64	1.28
25 | P	15	6.14	7.03	7.80	6.76	1.88	1.37
25 | V	14	5.99	6.42	7.15	6.75	2.06	1.43
27 | C	12	4.35	4.60	4.95	4.51	1.14	1.07
27 | L	15	5.10	6.04	6.73	5.85	1.36	1.17
27 | M	16	3.86	4.38	4.77	4.20	1.00	1.00
27 | P	15	5.00	5.70	6.47	5.73	0.86	0.93
27 | V	14	5.05	5.37	6.14	5.63	1.33	1.15
43 | C	12	9.15	9.42	9.71	9.39	0.23	0.48
43 | L	15	8.35	8.50	9.25	8.83	0.42	0.65
43 | M	16	10.15	10.58	10.85	10.46	0.59	0.77
43 | P	15	8.64	8.80	9.10	8.84	0.21	0.46
43 | V	14	7.47	7.80	9.00	8.21	1.00	1.00
45 | C	12	7.76	7.91	8.36	7.94	0.28	0.53
45 | L	15	6.70	7.20	7.60	7.02	0.51	0.71
45 | M	16	7.98	8.60	8.79	8.45	0.31	0.56
45 | P	15	7.43	7.71	7.81	7.59	0.22	0.47
45 | V	14	6.00	6.32	7.08	6.56	0.48	0.69
46 | C	12	1.63	1.77	1.85	1.75	0.04	0.20
46 | L	15	1.26	1.34	1.44	1.35	0.02	0.16
46 | M	16	1.58	1.94	2.12	1.87	0.12	0.34
46 | P	15	1.27	1.39	1.50	1.40	0.04	0.19
46 | V	14	0.97	1.12	1.47	1.18	0.11	0.34

results respectively. Table 2 also shows the groupings based on the similarity of the means (Tukey's test, HSD) for the studied populations. Of the 46 variables analysed, 30 showed significant differences among the populations ($P > 0.05$). By the *a posteriori* test, the differentiation between the L-V-P and M-C groups, is defined by nine variables (Table 2). Fig. 1 displays the box plot of these variables (number of leaflets of basal leaf; width of central leaflet of basal leaf; length of central lobe of middle bract; length of lateral lobe of middle bract; length of central lobe of upper bract; length of lateral lobe of upper bract; length of inner petal; length of upper stamen; width of wing of lower petal).

Factorial analysis

The diversity resulting from PCA analysis is based on the arrangement of the first two principal components, which explain 36.91% of the total variability (F1 = 20.20%, F2 = 16.71%). Scores of each specimen on the two principal components was plotted in PCA bi-plot (Fig. 2), allowing visualization of the positions of the specimens. Mainly on F2, a separation between two groups is observed; for positive values the Madonie and Catena Costiera group is defined, while for negative values the Gran Sasso, Velino and Pollino group is defined. By squared cosines (PCA), the variables that contribute most to define the F1 component are: 16 (0.576), 23 (0.567), 4 (0.541), 13 (0.538), 20 (0.496), 8 (0.450), 5 (0.417) and 27 (0.411). For F2 the variables are: 11 (0.625), 45 (0.569), 43 (0.508), 44 (0.508), 6 (0.388) and 46 (0.337). DA was used in order to verify if the variables allow definition of the studied groups and show as well as possible how separated they are. The first two axes of DA (Fig. 3) describe 82.68% and 7.06%, respectively, and the two box tests (Chi-square and

Fischer F) and Kullback's test confirm that the need to reject the hypothesis that the covariance matrices are equal among the five populations (p-value <0.0001). The correlation indices between variables and factors (Table 3) show that the variability of the first factor is more correlated with the following variables: 11. width of central leaflet of basal leaf (0.72); 43. length of inner petal (0.7); 45. length of upper stamen (0.72); 46. width of wing of lower petal (0.7). Instead, for the second factor, the most important variables are: 4. length of scale leaf (0.609); 7. length of petiole of basal leaf (0.391). The two-dimensional chart in Fig. 3 represents the observations on the factor axes 1 and 2, extracted from the original explanatory variables by DA. It shows that, in the five studied populations, the group L-V-P (central and southern Apennines) is well defined from the group M-C (southern Apennines and Sicily). The observations of the first group (L-V-P) are in fact concentrated on the left of the graph, while the second group (M-C) is on the right; essentially, the factor (F1) contributes to this differentiation. The confusion matrices of validation are displayed in Table 4.

Table 2. Results of ANOVA and populations meberschip based on Tukey's test (HSD). In **bold** the variabilities that differentiate the groups M-C vs L-V-P.

variables	**populations**					**ANOVA**		
	M	***C***	***P***	***V***	***L***	***R²***	***F***	***P***
1	AB	B	AB	B	A	0.191	3.959	0.006
2	A	A	A	A	A	0.162	3.229	0.017
3	A	B	A	A	A	0.365	9.608	< 0.0001
4	A	A	A	A	A	0.103	1.929	0.116
5	A	A	A	A	A	0.107	1.999	0.105
6	C	C	A	A	A	0.410	11.634	**< 0.0001**
7	A	B	AB	AB	AB	0.180	3.687	0.009
8	A	A	A	A	A	0.126	2.415	0.057
9	AB	B	AB	A	AB	0.152	3.000	0.024
10	A	B	AB	B	AB	0.166	3.326	0.015
11	A	A	B	B	B	0.578	22.952	**< 0.0001**
12	A	A	A	A	A	0.099	1.839	0.132
13	A	A	A	A	A	0.006	0.106	0.980
16	AB	AB	B	AB	A	0.175	3.548	0.011
15	B	AB	B	AB	A	0.163	3.254	0.017
16	A	A	A	A	A	0.057	1.005	0.411
17	A	A	A	A	A	0.040	0.702	0.593
18	C	BC	AB	A	A	0.266	6.085	**0.000**
19	A	A	A	A	A	0.130	2.493	0.051
20	B	B	AB	A	A	0.215	4.575	**0.003**
21	A	A	A	A	A	0.141	2.761	0.035
22	A	A	A	A	A	0.132	2.556	0.047
23	B	AB	AB	AB	A	0.137	2.663	0.040
24	A	A	A	A	A	0.035	0.606	0.660
25	C	C	AB	AB	A	0.285	6.684	**0.000**
26	A	A	A	A	A	0.129	2.489	0.051
27	C	BC	A	AB	A	0.314	7.671	**< 0.0001**
28	A	A	A	A	A	0.109	2.051	0.097
29	C	C	BC	AB	A	0.347	8.890	< 0.0001
30	A	A	A	A	A	0.035	0.606	0.660
31	A	A	A	A	A	0.073	1.328	0.269
32	A	B	B	B	B	0.235	5.150	0.001
33	A	A	A	A	A	0.056	0.996	0.416
34	A	A	A	A	A	0.088	1.615	0.181
35	A	A	A	A	A	0.066	1.190	0.323
36	A	A	A	A	A	0.101	1.892	0.122
37	B	A	AB	A	A	0.207	4.364	0.003
38	A	AB	B	AB	AB	0.167	3.361	0.014
39	A	A	A	A	A	0.043	0.752	0.560
40	A	AB	AB	B	AB	0.193	4.007	0.006
41	A	A	A	A	A	0.089	1.630	0.177
42	A	AB	B	AB	B	0.237	5.208	0.001
43	A	B	BC	C	BC	0.566	21.849	**< 0.0001**
44	A	A	A	B	B	0.474	15.093	< 0.0001
45	A	AB	BC	C	C	0.577	22.847	**< 0.0001**
46	A	A	B	B	B	0.519	18.038	**< 0.0001**

Discussion

The univariate and multivariate analyses carried out with different techniques (ANOVA, and PCA and DA, respectively) enabled the identification of the existing differentiation model between the populations of central and southern Apennines (L-V-P) and southern Apennines and Sicily (M-C) and to define the variables that characterize it. From a graphical visual approach (PCA and DA graph and box plot), it is easy to observe two well-distinguished systematic groups. The greatest contribution to this diversity

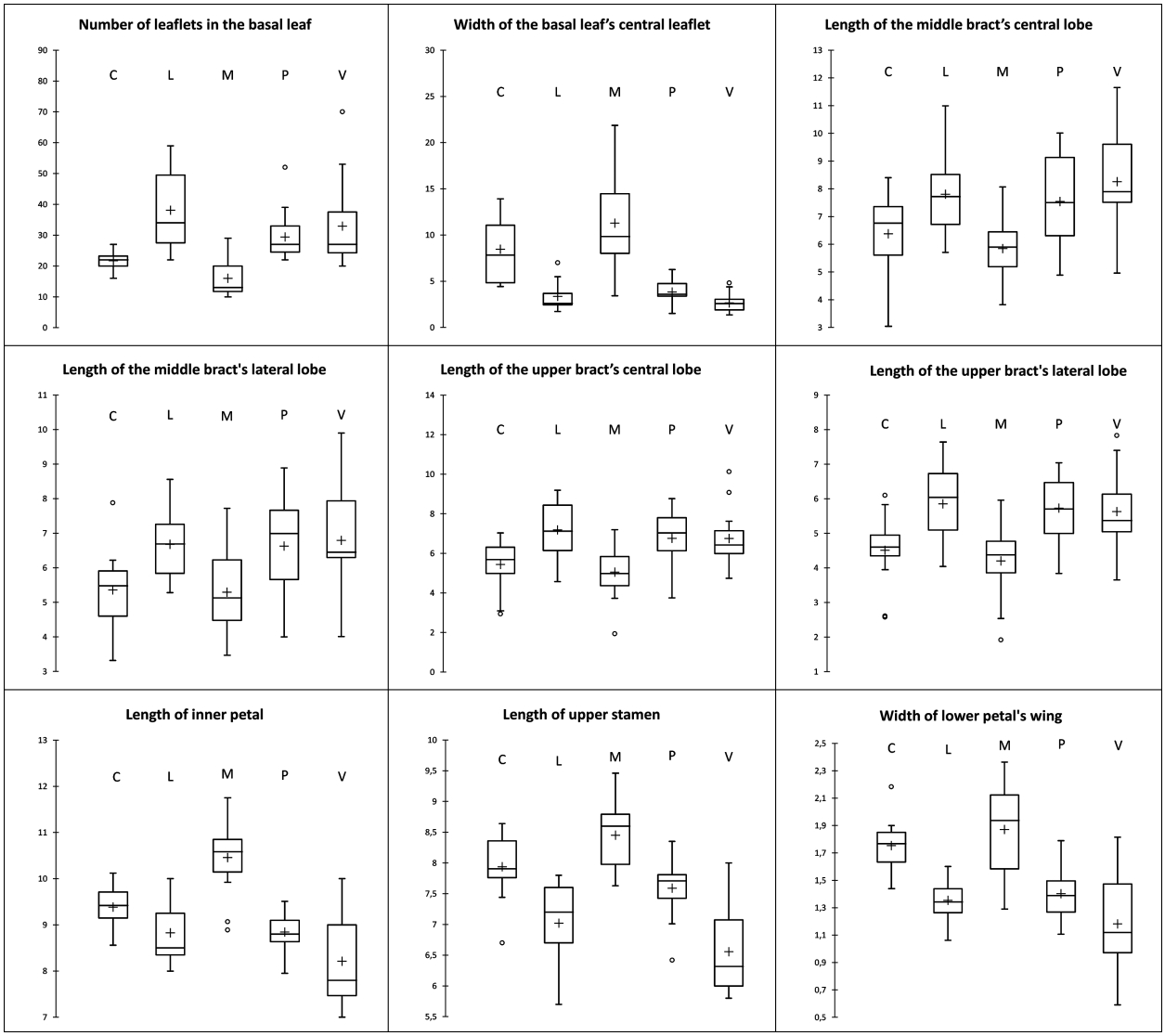

Fig. 1. Box plots for diagnostic variables selected by ANOVA and *post hoc* test. Circle anomalous values; grey cross: mean.

comes from shape of leaves and bracts and from few flower features such as length of inner petals and upper stamen and width of wing of lower petal. Noteworthy is the poor overlapping of the M and C observations, which however are far from the L-V-P group from which they differ; this aspect could be a starting point for a future investigation.

Taxonomic treatment

Corydalis densiflora subsp. ***apennina*** F. Conti, Bartolucci & Uzunov, **subsp. nov.** – Fig. 4, 5, 6.

Holotype: Italy, Abruzzo, Barisciano (L'Aquila), Gran Sasso, in località Piano Locce, pascoli, 1236 m, 23 Apr 2012, *Conti & Bartolucci* (APP no. 50943 [Fig. 5]; isotypes: APP nos. 50938, 50939, 50940, 50941, 50942, 50944, 50945, 50946, 50947, 50948, 51578, 51579, 51580, 51581).

Diagnosis — *Corydalis densiflora* subsp. *apennina* differs from subsp. *densiflora* by its more divided leaves and bracts (Fig. 6), basal leaf with more numerous leaflets (20–)33.5(–70) vs (10–)18.43(–29), narrower central leaflet of the basal leaf (1.4–)3.3(–7) mm wide vs (3.4–)10.1(–21.9) mm wide, longer middle and lateral lobes of the bracts, shorter inner petals (7–)8.6(–10) mm long vs (8.6–)10(–11.7) mm long, shorter upper stamen, and narrower wing of the lower petal (0.6–)1.3(–1.8) mm wide vs (1.3–)1.8(–2.4) mm wide.

Description — Stem (4–)16(–26) cm tall. Scale leaf (11.2–)19.2(–32.4) mm long. Leaves (2–)2.5(–4), alternate, usually triternate; leaflets narrowly obovate. Basal leaf (29.5–)76.4(–149) mm long × (14–)54.4(–91.3) mm wide, with (20–)33.5(–70) leaflets; central leaflet (9–)17.7(–26.7) mm long × (1.4–)3.3(–7) mm wide; petiole (12.1–)28.5(–59.2) mm long. Raceme (Fig. 4) usually dense, with (2–)8.9(–20) flowers. Bracts slightly wider than long, divided into usually dentate segments. Basal bract (6.9–)12.3(–19.1) mm long × (8.9–)15.9(–21.5) mm

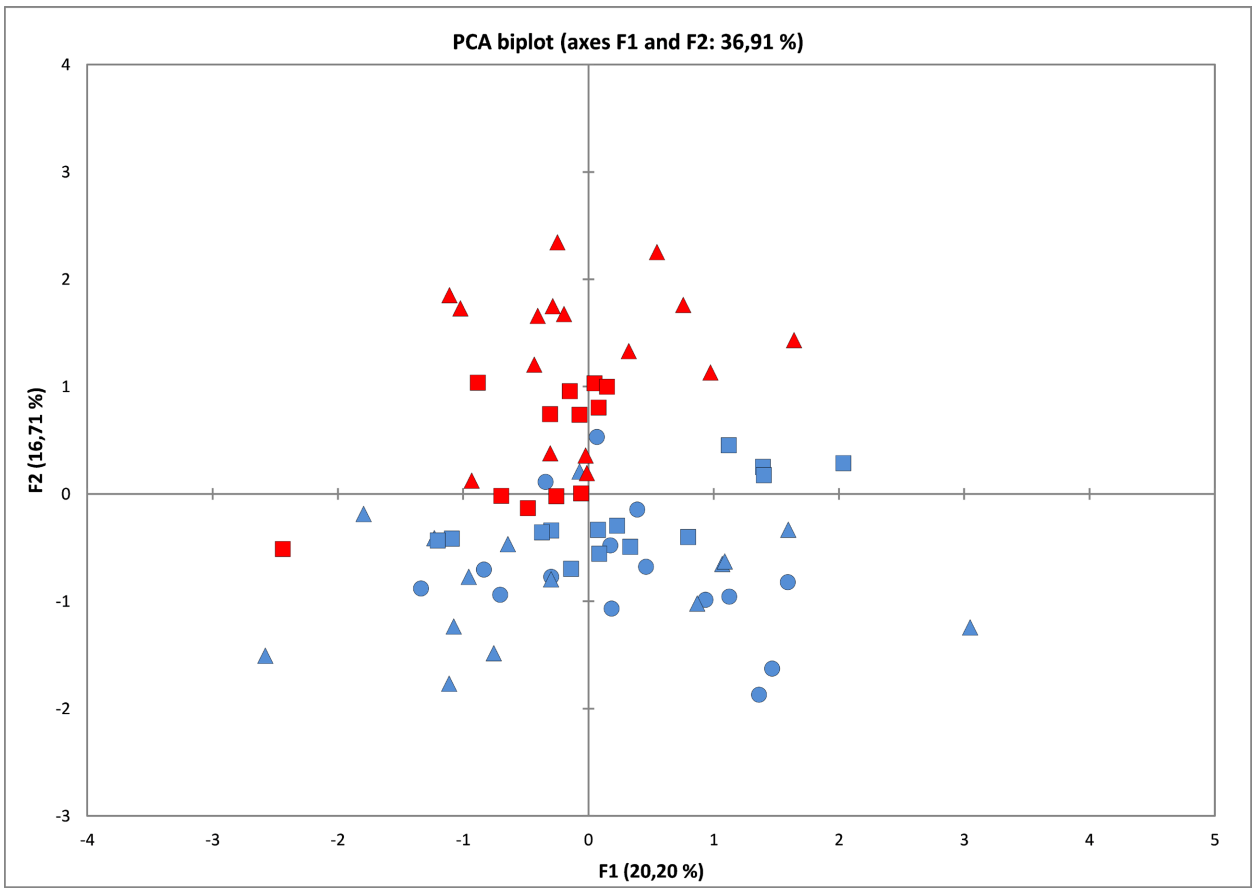

Fig. 2. Principal Component Analysis (PCA) of all variables. Blue square: P (Pollino); blue triangle: V (Monte Fratta, Velino); blue circle: L (Piano Locce, Gran Sasso); red square: C (Catena Costiera); red triangle: M (Madonie).

wide. Middle bract: central lobe (4.9–)7.9(–11.6) mm long × (0.5–)1.5(–2.6) mm wide; lateral lobe (4–)6.7(–9.9) mm long. Flowers (13.1–)18.3(–22.3) mm long; pedicel 1–10 mm long. Corolla whitish to pale pink with red margin; maximum width of corolla tube (3.1–)4.1(–5.6) mm. Spur (6.9–)10.4(–13.5) mm long. Upper petal (7.2–)8.5(–9.8) mm long; wing (2.5–)3.7(–5.2) mm long. Lower petal (8.2–)10(–11.8) mm long × (2.8–)4.1(–5.1) mm wide; wing (2.6–)4.3(–5.8) mm long × (0.6–)1.3(–1.8) mm wide. Inner petals (7–)8.6(–10) mm long. Ovary (6.5–)8.1(–11) mm long. Upper stamen (5.7–)7.1(–8.3) mm long. Fruiting pedicels (1.9–)3.4(–6) mm long. Fruits (7.5–)12.5(–17.4) mm long × (1.5–)4.1(–6.1) mm wide.

Phenology — Flowering from the second half of April to June, fruiting from May to June.

Distribution — *Corydalis densiflora* subsp. *apennina* is endemic to the central and southern Apennines, widespread in Umbria, Marche, Lazio, Abruzzo, Campania, Calabria and not confirmed in Molise. The record of *C. solida* subsp. *solida* for Campania (Bartolucci & al. 2018) has to be referred to *C. densiflora* subsp. *apennina*. *Corydalis densiflora* subsp. *densiflora* is endemic to Calabria and Sicily (Fig. 7).

Table 3. Variables (Var) / factors (F1, F2) correlations.

Var	F1	F2	Var	F1	F2
1	-0.076	0.289	24	-0.028	-0.166
2	0.080	0.285	25	-0.527	0.024
3	-0.227	0.609	26	0.195	-0.257
4	-0.036	0.288	27	-0.546	0.003
5	0.137	0.243	28	-0.537	0.230
6	-0.637	0.020	29	0.276	-0.203
7	0.139	0.391	30	0.120	0.140
8	0.042	0.189	31	-0.007	0.018
9	-0.340	0.154	32	0.349	0.335
10	0.189	0.340	33	0.151	0.196
11	0.752	0.103	34	-0.089	0.064
12	0.250	0.158	35	-0.103	-0.041
13	0.074	-0.029	36	0.092	0.270
14	-0.135	0.016	37	-0.297	-0.348
15	-0.294	0.068	38	0.292	0.263
16	-0.216	-0.069	39	0.160	0.013
17	-0.130	-0.050	40	0.292	0.013
18	-0.511	-0.028	41	0.279	0.284
19	0.218	-0.208	42	0.395	0.083
20	-0.450	0.042	43	0.701	0.270
21	0.104	0.066	44	0.639	0.051
22	-0.282	-0.042	45	0.726	0.047
23	-0.361	-0.009	46	0.703	0.021

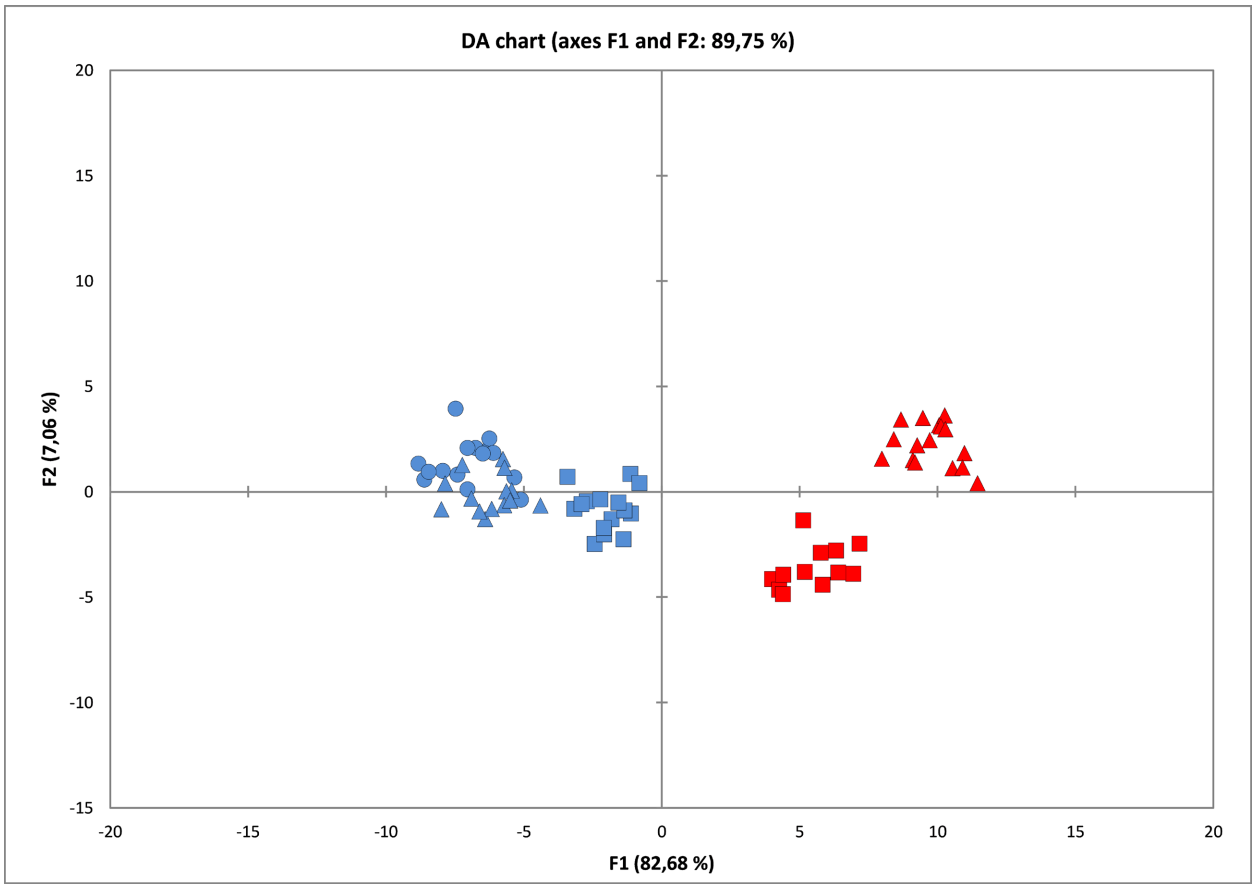

Fig. 3. Discriminant Analysis (DA) of all variables. Blue square: P (Pollino); blue triangle: V (Monte Fratta, Velino); blue circle: L (Piano Locce, Gran Sasso); red square: C (Catena Costiera); red triangle: M (Madonie).

Habitat — Meadows, edge and clearings of *Fagus sylvatica* forest.

Conservation status — According to IUCN criteria (IUCN Standards and Petitions Subcommittee 2017), we propose to include *Corydalis densiflora* subsp. *apennina* in the following category: Least Concern (LC). Recently, Orsenigo & al. (2018) proposed to include *C. densiflora* at species level in the category LC.

Etymology — The subspecific epithet *apennina* is an adjective derived from the Apennines.

Identification key to the subspecies of *Corydalis densiflora*

1. Basal leaf with (10–)18.43(–29) leaflets, central leaflet (3.4–)10.1(–21.9) mm wide; inner petals (8.6–)10(–11.7) mm long; wing of lower petal (1.3–)1.8(–2.4) mm wide . . . . . .
. . . . . .***C. densiflora*** subsp. ***densiflora***
– Basal leaf with (20–)33.5(–70) leaflets, central leaflet (1.4–)3.3(–7) mm wide; inner petals (7–)8.6(–10) mm long; wing of lower petal (0.6–)1.3(–1.8) mm wide
. . . . . .***C. densiflora*** subsp. ***apennina***

Additional specimens studied

Corydalis densiflora subsp. ***densiflora*** — Sicilia [Sicily]: Madonie, Pizzo Carbonara (Palermo), 413836E, 4194461N, UTM-ED50, margine faggeta, 1850 m, 4 Jun 2010, *F. Conti, F. Bartolucci & N. Ranalli* (APP no. 51529); Madonie, Pizzo Carbonara, 3 May 1992, *Brullo & al.* (CAT no. 30332 [digital photo]); ibidem, 9 Jun 1983, *S. Brullo* (CAT no. 46763 [digital photo]); ibidem, 5 Jun 1990, *Brullo & al.* (CAT no. 46764 [digital photo]); Madonie, Quacella, 3 May 1987, *S. Brullo & al.* (CAT no. 46761 [digital photo]); Madonie, Piano Battaglia, 27 Apr 1983, *S. Brullo* (CAT no. 46762 [digital photo]); Madonie: faggeta di Battaglia, 37°52'N, 14°02'E, organic moist soil, 1500–1600 m, 5 Jun 1990, 1240 Optima Iter Mediterraneum III in Sicily, *Raimondo & al.* (PAL); Madonie, Portella Colle, Madonie, 25 Apr 1991, *S. Brullo & G. Spampinato* (CAT no. 46765 [digital photo]); Monte Soro, 26 Apr 1981, *S. Brullo* (CAT no. 46766 [digital photo]); ibidem, 28 May 1982, *S. Brullo* (CAT no. 46767 [digital photo]); Nebrodi, da Piano Menta a Piano Daini, 19 Apr 1988, *S. Brullo & P. Minissale* (CAT no. 46768 [digital photo]); Madonie, Piano Battaglia, 1580 m, 25 Apr 2012, *D. Uzunov* (herb. Uzunov); Busambra, s.d., *Todaro* (PAL); Ficuzza alle Neviere, 8 Apr 1904, *A. Terracciano* (PAL). — Calabria: Aspromonte, loc. umbrosis in jugo, Mon-

talto, sol. granit., 1950–1956 m, 30 May 1877, *324* ex itinere italico III, *Huter, Porta & Rigo* (P); Catena Costiera, Passo della Crocetta, ad un'altitudine di 1100 m, 31 Mar 2012, *D. Uzunov* (herb. Uzunov); ibidem, 17 Apr 2012, *D. Uzunov* (herb. Uzunov).

Corydalis densiflora subsp. ***apennina*** — Marche: Monte Sibilla, presso il Rifugio Sibilla (Montemonaco, Ascoli Piceno), prati, 1600 m, 4 May 2012, *F. Conti* (APP no. 52556, 52557, 52558, 52559, 52560, 52561, 52562, 52563, 52564, 52565, 52566); M. Macchialta versante NO (Arquata del Tronto), pascolo, suolo calcareo, 1575 m, 4 May 2012, *F. Falcinelli* (APP no. 57152). — Umbria: La Montagnola versante O (Cascia, Perugia), orlo di faggeta, suolo calcareo, 1295 m, 18 Apr 2012, *F. Falcinelli* (APP no. 57178); M. la Pelosa versante O-NO (Polino, Terni), orlo di faggeta, suolo calcareo, 1490 m, 23 Apr 2012, *F. Falcinelli* (APP no. 57158); M.ti Sibillini, M. Calarelle versante N-NE (Norcia, Perugia), pascolo, suolo calcareo, 1530 m, 29 Apr 2012, *F. Falcinelli* (APP no. 57183); M.ti Sibillini, M. Serra versante SE (Norcia, Perugia), pascolo, suolo calcareo, 1670–1685 m, 17 May 2012, *F. Falcinelli* (APP no. 57184); M. Maggio, versante E (Cascia, Perugia), orlo di faggeta, suolo calcareo, 1410 m, 21 Apr 2016, *F. Falcinelli* (APP); M. Maggio, versante NO (Gualdo Tadino, Perugia), orlo di faggeta, suolo calcareo, 1400 m, 21 Apr 2016, *F. Falcinelli* (APP); Colle del Segretario, versante NO (Monteleone Di Spoleto, Perugia), 1305 m, 19 Apr 2016, *F. Falcinelli* (APP); M. Carpenale, versante N (Poggiodomo, Perugia), pascolo, 1365 m, 15 Apr 2016, *F. Falcinelli* (APP); M. Carpenale, versante NO-N (Poggiodomo, Perugia), pascolo, 1335 m, 15 Apr 2016, *F. Falcinelli* (APP). — Lazio: M. Corno versante E-SE (Leonessa, Rieti), pascolo, suolo calcareo, 1680 m, 9 May 2014, *F. Falcinelli* (APP no. 57156); M. la Pelosa versante SE (Leonessa, Rieti), orlo di faggeta, suolo calcareo, 1625 m, 23 Apr 2012, *F. Falcinelli* (APP no. 57153); ibidem, pascolo ricco, suolo calcareo, 1440 m, 23 Apr 2012, *F. Falcinelli* (APP no. 57155); M. la Pelosa versante SE (Leonessa, Rieti), pascolo, suolo calcareo, 1570 m, 23 Apr 2012, *F. Falcinelli* (APP no. 57154); M. Terminillo versante SE (Micigliano), prato comune, 1640–1680 m, 12 Jun 2014, *F. Falcinelli* (APP no. 57157); M. Boragine, Forca di Fao, sentiero 472, M. Arcione–M. Boragine (Cittareale, Rieti), 4718498N, 345676E, WGS84 33T, pascoli secondari, 1619–1809 m, 15 Apr 2016, *F. Conti* (APP no. 57369, 57374, 57375); Monti Simbruini al Campo della Pietra e sul M. Autore (Roma), faggete e radure, 1400 m, 2 May 1990, *D. Arcioni* (FI); Montagne della Duchessa (Rieti), al M. Nuria, 1600 m, in faggeta, 14 May 1989, *D. Arcioni* (FI); Monti Reatini al M. Terminillo (Rieti), in località Pian de' Valli, c. 1500 m, in faggete e radure, 28 Apr 1989, *D. Arcioni* (FI); M. Pozzoni, Cittareale (Rieti), faggeta, radura, c. 1700 m, 1 May 2010, *E. Lattanzi* (UTV no. 32032); salendo da Selvarotonda verso Forca di Fao, Cittareale (Rieti), Staz. 7, su cotico erboso al margine di faggeta, 15 Apr 2016, *A. Scoppola* (UTV no. 36088).

Fig. 4. Flowering raceme of *Corydalis densiflora* subsp. *apennina* at the type locality, 23 Apr 2012, photographed by F. Conti.

Table 4. Confusion matrices for estimation (above) and for cross-validation results (below) (DA).

from / to	C	L	M	P	V	total	% correct
C	12	0	0	0	0	12	100.00%
L	0	15	0	0	0	15	100.00%
M	0	0	16	0	0	16	100.00%
P	0	0	0	15	0	15	100.00%
V	0	0	0	0	14	14	100.00%
total	12	15	16	15	14	72	100.00%

from / to	C	L	M	P	V	total	% correct
C	11	0	1	0	0	12	91.67%
L	0	7	0	1	7	15	46.67%
M	6	4	3	3	0	16	18.75%
P	0	2	0	8	5	15	53.33%
V	0	1	0	1	12	14	85.71%
total	17	14	4	13	24	72	56.94%

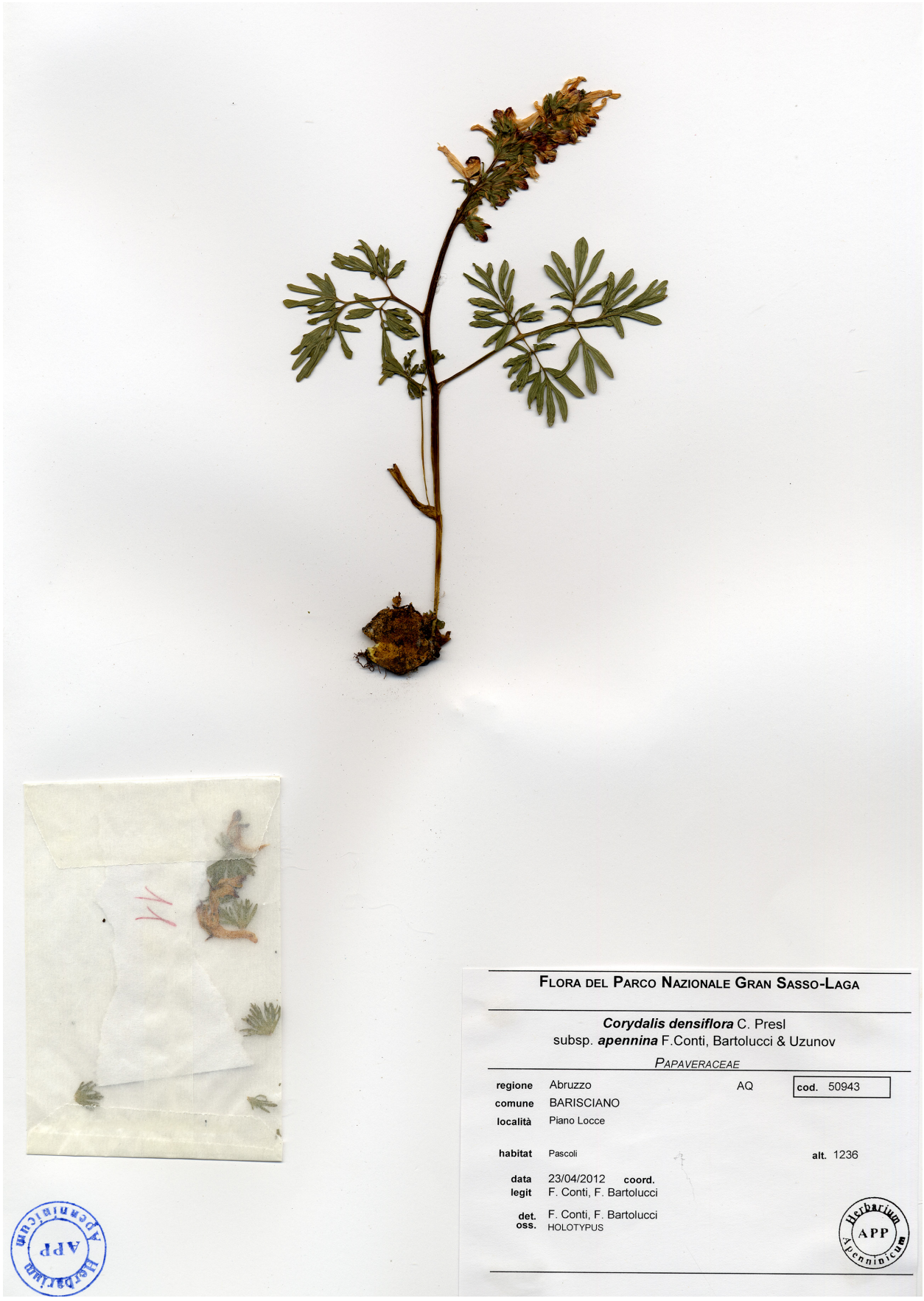

Fig. 5. Holotype of *Corydalis densiflora* subsp. *apennina* (APP no. 50943).

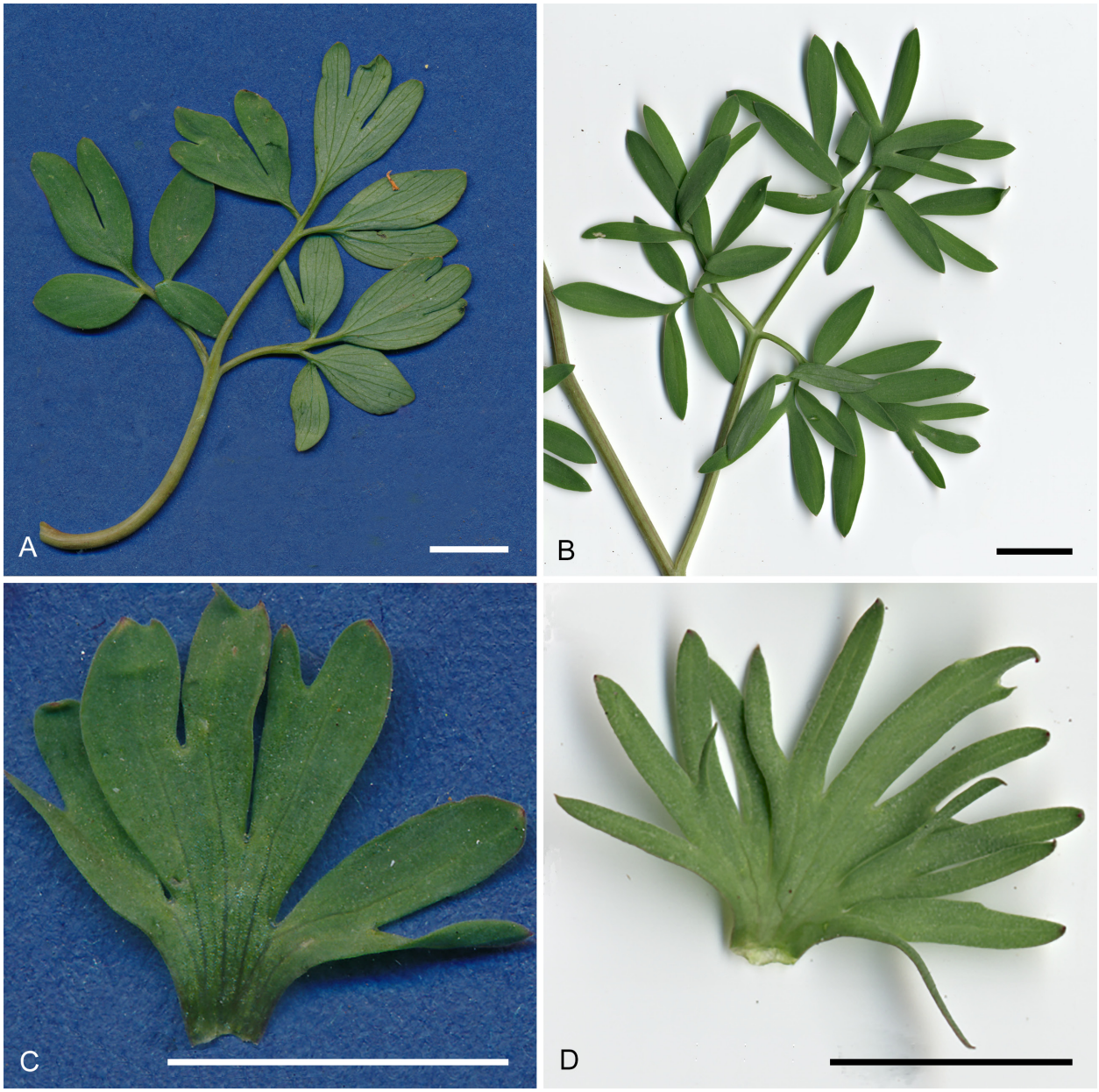

Fig. 6. A, C: *Corydalis densiflora* subsp. *densiflora* from Piano Battaglia (Madonie); B, D: *Corydalis densiflora* subsp. *apennina* from Monte Fratta (Velino); A, B: basal leaves; C, D: basal bracts. Scale bars: A–D = 1 cm.

— Abruzzo: Campo Imperatore tra Fonte Cupa e lo Scoppaturo (Castel del Monte, L'Aquila), 42°24.357'N, 13°44.589'E, UTM-ED50, pascoli, 1498 m, 1 May 2003, *F. Conti & D. Tinti* (APP no. 9640); Lago Racollo (S. Stefano di Sessanio, L'Aquila), pascoli, 1550 m, 13 May 2004, *D. Tinti* (APP no. 10591); Lago di Passaneta (Barisciano, L'Aquila), pascoli secondari, 1561 m, 18 May 2004, *A. Bernardini & L. Morelli* (APP no. 14873); base brecciaio del M Puzzillo (Lucoli, L'Aquila), pascoli, 1682 m, 17 Jun 2006, *F. Conti & R. Soldati* (APP no. 30101); M. Puzzillo-Valle Leona (Lucoli, L'Aquila), pascoli, 1500–1700 m, 13 Jun 1999, *F. Conti* (APP no. 30103); Lago S. Pietro (Calascio, L'Aquila), 20 May 2011, *F. Bartolucci* (APP no. 46539); sopra Civita d'Antino verso Collelongo (Civita D'antino, L'Aquila), 1540 m, 28 Apr 2010, *F. Conti & N. Ranalli* (APP no. 49098); Lago di Barisciano (Barisciano, L'Aquila), pascoli, 1600 m, 5 May 2012, *F. Conti* (APP no. 50932); Monte Fratta (Lucoli), radure e margine faggeta, 1600 m, 15 May 2012, *F. Conti & F. Bartolucci* (APP no. 52567, 52568, 52569, 52570, 52571, 52572, 52573, 52574, 52575, 52576, 52577, 52578, 52579, 52580, 52581, 52582); Pescasseroli (L'Aquila), Val Cervara, Fondovalle umido, al margine di faggeta, 12 May 2012, *A. Scoppola* (UTV no. 30730); Monte Rapina, Caramanico Terme (Pescara), prateria montana, 1457 m, 29 Apr 2018, *S. Nelli* (UTV no. 36596); Monte dei Fiori, pascoli, 1550 m, 29 Apr 2018, *F. Bartolucci & V. Impiccini* (APP). — Campania: Cervati, versante S, 21 May 1987, *M. Buonanno, R. Cerri & A. Santangelo* (NAP); Cervati, versante S, 1800 m, 2 Jun 1987, *M. Buonanno, R. Cerri*

& A. Santangelo (NAP); Cervati, altopiano di vetta, 6 May 1993, *A. Santangelo* (NAP). — Calabria: Pollino, Mormanno, 950 m, 6 May 2012, *D. Uzunov* (herb. Uzunov).

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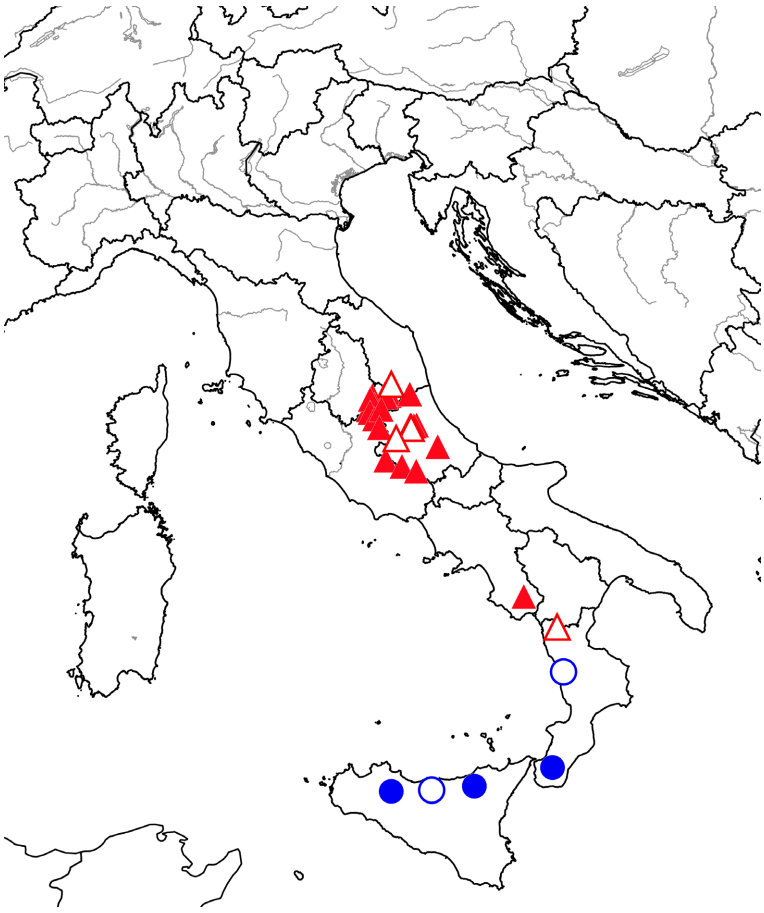

Fig. 7. Distribution map of *Corydalis densiflora* subsp. *densiflora* (blue circles) and *C. densiflora* subsp. *apennina* (red triangles) according to the material studied: hollow symbols indicate the populations included in the morphometric study; solid symbols refer to the specimens seen but not used for statistical analyses.

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