



## On the true identity of the plants recently referred to *Sedum nevadense* (Crassulaceae) in Abruzzo (Italy)

LORENZO GALLO<sup>1\*</sup> & FABIO CONTI<sup>2</sup>

<sup>1</sup>Strada Val San Martino sup. 194, 10131, Torino, Italy; e-mail: [lorenzogallo1959@hotmail.it](mailto:lorenzogallo1959@hotmail.it)

<sup>2</sup>Scuola di Bioscienze e Medicina Veterinaria, Università di Camerino - Centro Ricerche Floristiche dell'Appennino, Parco Nazionale del Gran Sasso e Monti della Laga, S. Colombo, 67021 Barisciano (L'Aquila), Italy.

\*author for correspondence

### Abstract

*Sedum nevadense* was always believed to be an Iberian-Moroccan endemic with a segregated population in France, but it was recently reported for Abruzzo (Italy). To enhance our knowledge of this population that appears particularly isolated from the main distribution, specific studies were carried out that allowed its recognition as significantly different from the Iberian and north African populations from the morphological and ecological points of view. We here describe this population as a new narrow endemic species, namely *Sedum aquilanum* belonging to *Sedum* series *Subrosea*. This population is at high extinction risk due to both the small number of plants and its close proximity to areas that are affected by anthropogenic activities having a very high environmental impact.

**Keywords:** central Italy, endemic, *Sedum aquilanum*, *Sedum* series *Subrosea*, taxonomy

### Introduction

The Euro-Mediterranean species of the genus *Sedum* Linnaeus (1753: 430) were grouped into series, whereby each one represented a putatively monophyletic, biologically isolated group ('t Hart 1991). Among these, *Sedum* series *Subrosea* 't Hart (1991: 59) is characterised by the unusual nature of its ecological requirements, needing of moist soil at least during the vegetative period.

*Sedum* series *Subrosea* originally included *S. lagascae* Pau (1895: 53), *S. nevadense* Cosson (1852: 163) and *S. villosum* Linnaeus (1753: 432), which are characterised as “Densely glandular-pubescent annual” and “Petals free [...]. Stamens 10, with red anthers” ('t Hart, 1991). However, some of these characters are not always noticed, as the known taxa can be glabrous (*S. nevadense*), others are biennales or perennials (*S. villosum*), others only have five stamens [*S. pentandrum* (DC. in Lamarck & Candolle 1815: 6) Boreau (1849: n. 779)] or have yellow anthers as *S. nevadense*, *S. villosum* subsp. *glandulosum* (Moris 1827: 20) Fournier (1936: 459). Subsequently, *S. maireanum* Sennen in Sennen & Mauricio (1933: 43) was also included (Castroviejo & Velayos 1997, Jalas *et al.* 1999). Among other authors, Maire (1976) recognized four subspecies and varieties under *S. villosum*, while more recently, *S. pentandrum* has been re-evaluated (Tison & de Foucault 2014). Today, there are four to five taxa usually accepted within *Sedum* series *Subrosea* (see e.g. Pignatti 1982, 't Hart & Bleij, 2003), depending on the systematic value attributed to *S. glandulosum*. These taxa are distributed in northern Africa, between Morocco (Maire 1976) and Algeria (Quézel & Santa 1962), in Europe, from the Iberian peninsula up to Russia (Borisova 1939, Webb *et al.* 1993, Jalas *et al.* 1999, Marhold 2006 onwards), and also in Greenland and North America (Clausen 1975).

The main centre of diversity is generically reported as “western” by 't Hart (1991), and this probably stands for the Iberian peninsula, where there are many taxa of the series, albeit Italy is also an important diversity centre with very localised endemics. *Sedum* series *Subrosea* has been the subject of some taxonomic and nomenclatural studies over the years, but these have been limited to one or a few taxa, or to specific areas (Amich Garcia *et al.* 1981, Fernandes 1984, Lániz 1985, Castroviejo & Velayos 1995, 1997, Gallo 2001, Arrigoni 2006, Vargas & García 2008) However, only the name *S. villosum* has been typified ('t Hart & Jarvis 1993). Finally this series has peculiar character-states that are identifiable as apomorphic ('t Hart 1991) for the genus *Sedum*, such as sepals fused at the base, seeds costate with crowned apex, and the presence of a glandular indumentum, at least in majority of the taxa.

*Sedum nevadense* Cosson (1852: 163) was described from plants collected by E. Bourgeau in Sierra Nevada (Spain) in 4 July 1851, and it was distinguished on the basis of some flower features and because of the complete absence of glandular hairs in every phase of its development. In the protologue (Cosson 1852), the author did not mention the morphology of the leaves, while the petals were referred to as “[...] *acute, albida dorsal nerve virescenti vel rosy* [...]”. *Sedum nevadense* is known for the Iberian peninsula, where it can be considered as a rare species (Castroviejo & Velayos 1997) but treated as a Least Concerning (LC) species (Banares Baudet *et al.* 2008). It has also been mentioned for Morocco and Algeria (Quézel & Santa 1962, Maire 1976, Fennane & Tattou 2005). Its presence in France was reported by Hamet (1952), who traced some specimens (ex Herb. M. Gandoger) collected by Albert in 1880 from Department of Var in the locality of Ampus (Provence Alpes, Cote d’Azur). *Sedum nevadense* was then confirmed again (Bouchard 1956, Hamet 1957), and has been reported by some French floras (Guinochet & Vilmorin de 1984, Jovet & Vilmorin 1987). The French population was more recently considered to be extinct (Olivier *et al.* 1995), but it has been observed again very recently, as it survived in a restricted military area (Tison & de Foucault 2014, Tison *et al.* 2014, J.-M. Tison pers. comm.). *Sedum nevadense* is included in the “Red List of species under threat in France”, as a VU (vulnerable) species (Moncorps & Siblet 2012).

Recently, Minutillo *et al.* (2009) published the discovery of a tiny population of an annual *Sedum* at Campo Felice (Abruzzo, Italy) that was attributed to *S. nevadense*. This discovery was of outstanding interest from the biogeographical point of view, because of the considerable distance of this population from its main distribution centre, and because of the quite different habitat. This species was immediately included into the CR (Critically Endangered) IUCN extinction risk (Rossi *et al.* 2013).

However, an exhaustive study of the *Sedum* population from Abruzzo revealed that this is different, by a morphological and ecological point of view, from *S. nevadense* populations. As a result, this population is described here as a new species.

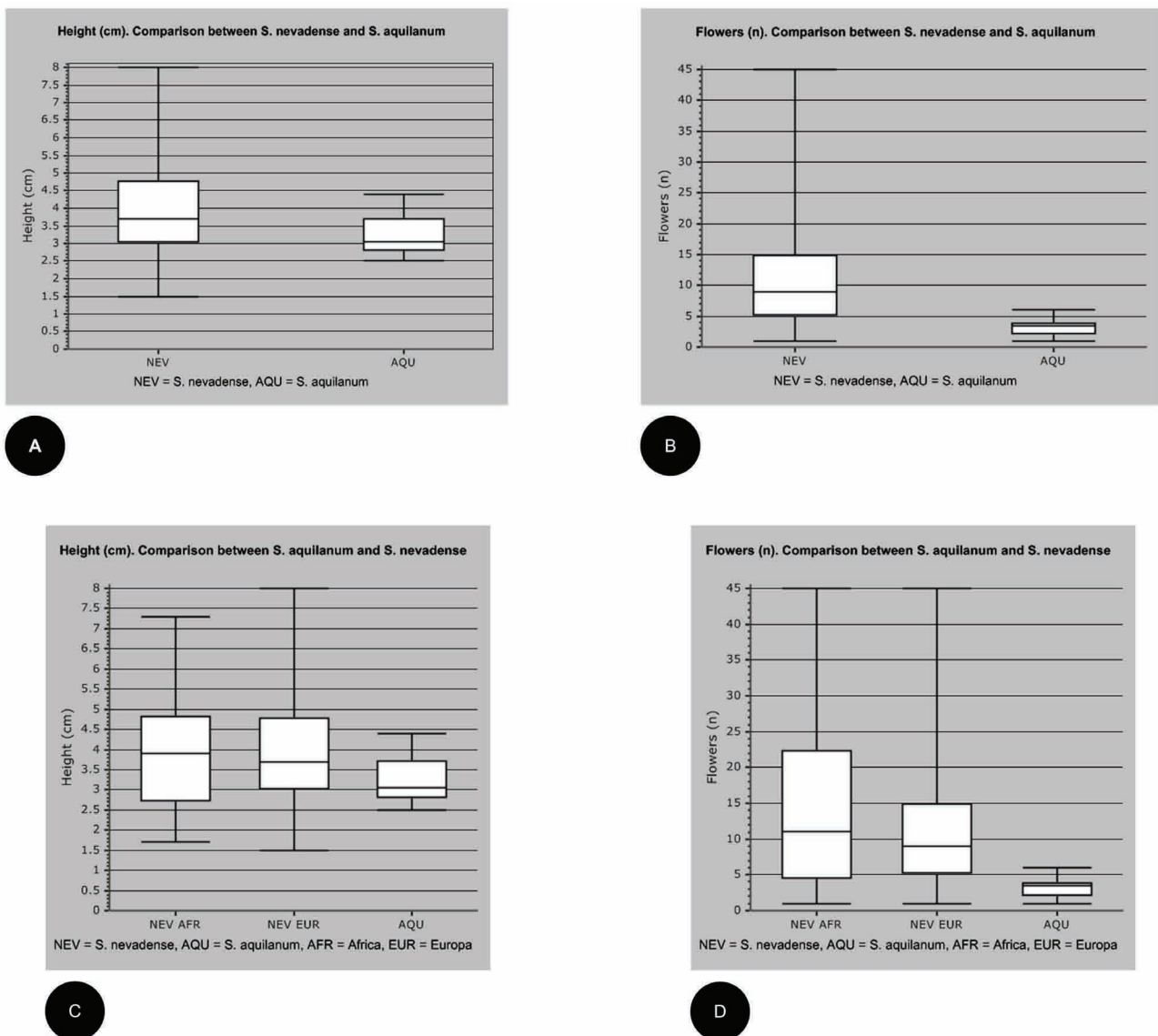
## Material and Methods

A field survey was carried out by the authors at Campo Felice (Abruzzo, Italy) on 30 June, 2011, during which a small populations of an annual glabrous fruiting plants was found. Some seeds were collected and sown in the collection of one of the authors (LG). The sowing in a glasshouse that was carried out in July 2011 had already provided about 40 seedlings by the autumn of 2011, of which approximately half were flowering and fruiting in the spring of 2012. An abundant production of seeds was obtained through spontaneous autogamy. From 2012 to 2015 a study of the biology and the morphology of the plants was carried out based on seed-raised plants in cultivation and in a survey of the vegetation in the field. Furthermore, the specimens kept in APP were reviewed, as well as the photographs of the flowering plants taken in the field. Also the specimens belonging to *S. nevadense* kept in the following herbaria (acronyms according to Thiers 2015) were studied: BUT, FI, G, LY, P, PAL, TLON, and TO (cfr. Appendix 1). On these herbarium materials, a comparative morphological study was carried out using the two most promising quantitative characters, selected after a preliminary screening: the height of the plants, and the number of flowers per plant. To test the differences between the populations examined, and any possible correlation between the characters examined, the populations, and the area of origin, Mann-Whitney test and Pearson correlation were used, by means of MaxStat<sup>®</sup> and Analyze-it<sup>®</sup> for Excel<sup>®</sup> softwares. Extensive research of the relevant literature on the western Mediterranean area was also carried out (Fröderstrom 1932, Borisova 1939, Hamet 1952, 1957, Quézel & Santa 1962, Clausen 1975, Maire 1976, Pignatti 1982, Webb *et al.* 1993, Castroviejo & Velayos 1997, Jalas *et al.* 1999, Gallo 2001, ‘t Hart & Bleij 2003, Fennane & Tattou 2005, Marhold 2006 onwards, Tison & de Foucault 2014), to acquire information about the distribution and morphobiological variability of the populations of *S. nevadense*.

## Results

The studies performed in the field and with the cultivated material, and the data analysis, have allowed the recognition of the *Sedum* population from Abruzzo (Italy) as being significantly different from typical populations of *S. nevadense* from Benalcaza (Spain). This was achieved through a series of qualitative and quantitative morphological characteristics, and as related to some ecological adaptations. The presence of the retuse shape of the base of the leaf stem, the petals entirely free at the base, and the presence (although occasional) of tetramerous flowers, are the main characteristics

that indicated the distinctiveness of the *Sedum* population from Abruzzo versus the *S. nevadense* populations from other territories. The data analysis was performed with the Mann-Whitney test, a non-parametric test. The analysis on the height and the number of flowers of 23 exsiccata (263 plants) show statistically significant differences to be highlighted (Fig. 1). Figures 1A and 1C show the results of the analyses performed on the heights of the *S. nevadense* and *S. aquilanum* plants in anthesis. The difference between the medians (AQU = 3.05, NEV = 3.7,  $p = 0,0119$ ), not significant at 99% level ( $= p < 0.01$ ) is statistically significant at 95% level; this might be due to the limited number of plants of *S. aquilanum* available for this study. For *S. nevadense*, there were no statistically significant differences between the Iberian and north African populations. The comparison between the numbers of flowers (AQU = 3.5, NEV = 9,  $p < 0.0001$ ) was instead highly significant at 99% level ( $= p < 0.01$ ) (Fig. 1B and D). On the contrary we noted that the north African plants had a greater number of flowers than the Iberian plants, although this was not statistically significant. Pearson test to determine possible correlations between height and number of flowers of *S. aquilanum* and *S. nevadense* was positive ( $r = 0.456$ ,  $df = 271$ ,  $p < 0.00001$ ). The height of plant and the number of flowers appeared to be positively correlated in *S. nevadense* ( $r = 0.423$ ,  $df = 239$ ,  $p < 0.00001$ ) but not in *S. aquilanum* ( $r = 0.198$ ,  $df = 20$ ,  $p = 0.402706$ ), perhaps because of the very small  $df$  obtained.



**FIGURE 1.** (A–D) Boxplots illustrating the variability between *S. aquilanum* (AQU) and *S. nevadense* (NEV): height of plant (A), flowers number (B). Same comparison but with data from Europe and Africa distinct (C, D).

## Taxonomy

### *Sedum aquilanum* Gallo & Conti, *sp. nov.* (Figs. 3, 5, 6)

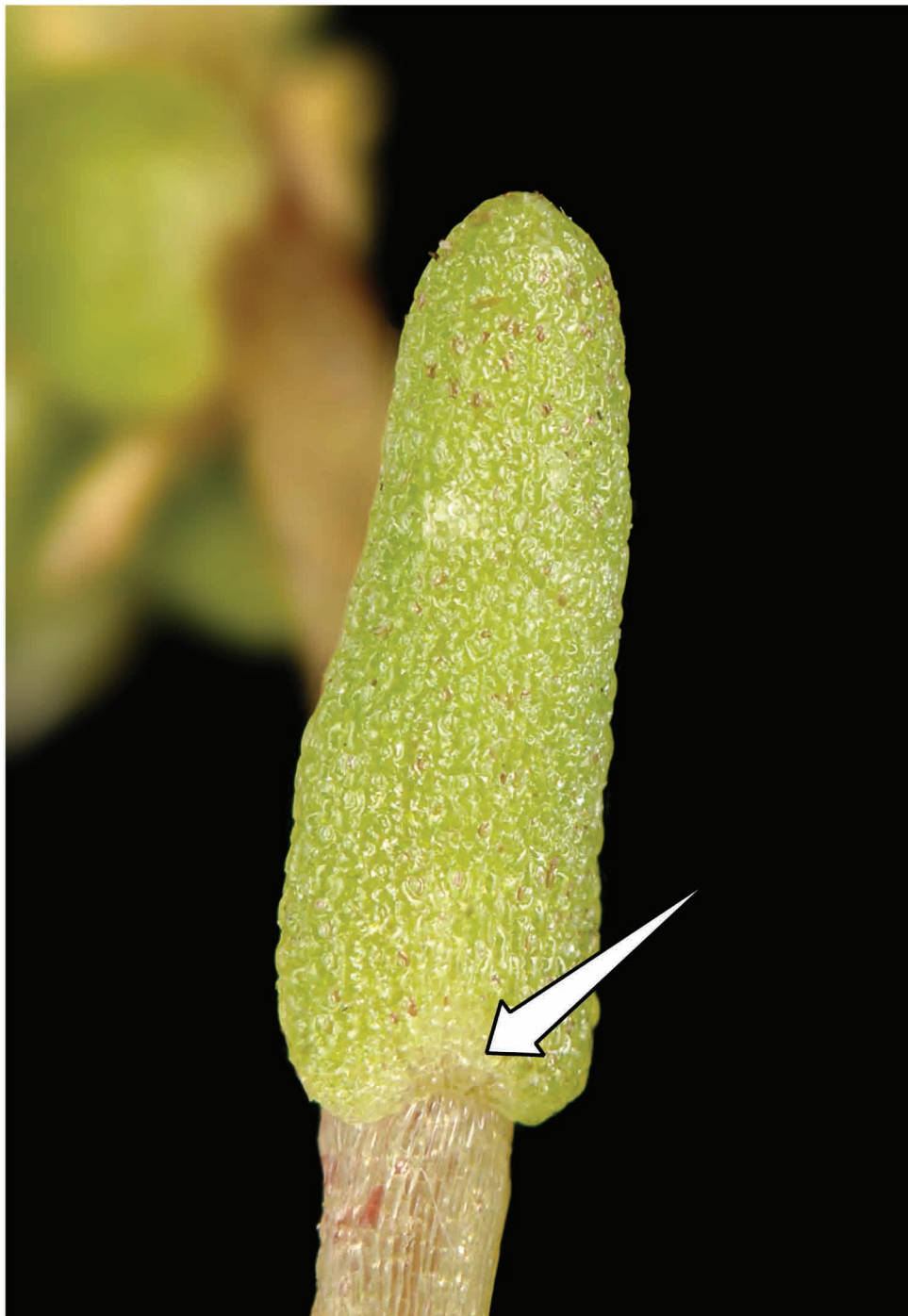
*S. aquilanum* differs from *S. nevadense* Cosson due to the cauline leaves that are retuse at the base and not truncate and spurred (Fig. 4), and the petals are free at the basis and not fused, for approximately 1 mm, linear and not lanceolate, “ovate or lanceolate” or even “triangular-ovate”, and through which it was possible to verify directly on the exsiccata examined. The anthers are yellow in bud, but under growing conditions they assume a beige colour to the anthesis. The plants are also smaller and with a reduced number of flowers.

**Type:**—ITALY. Abruzzo: Rocca di Cambio (L’Aquila). Campo Felice presso il laghetto, piccole depressioni tra i cespi di *Sesleria uliginosa*, 1525 m, WGS84 42°13’26”N 13°26’50”E, 12 June 2009, *Conti s.n.* (holotype APP no.38348!, isotype APP no. 38349!). (Fig. 2).



FIGURE 2. Holotype of *S. aquilanum* Gallo & Conti (APP no. 38348).

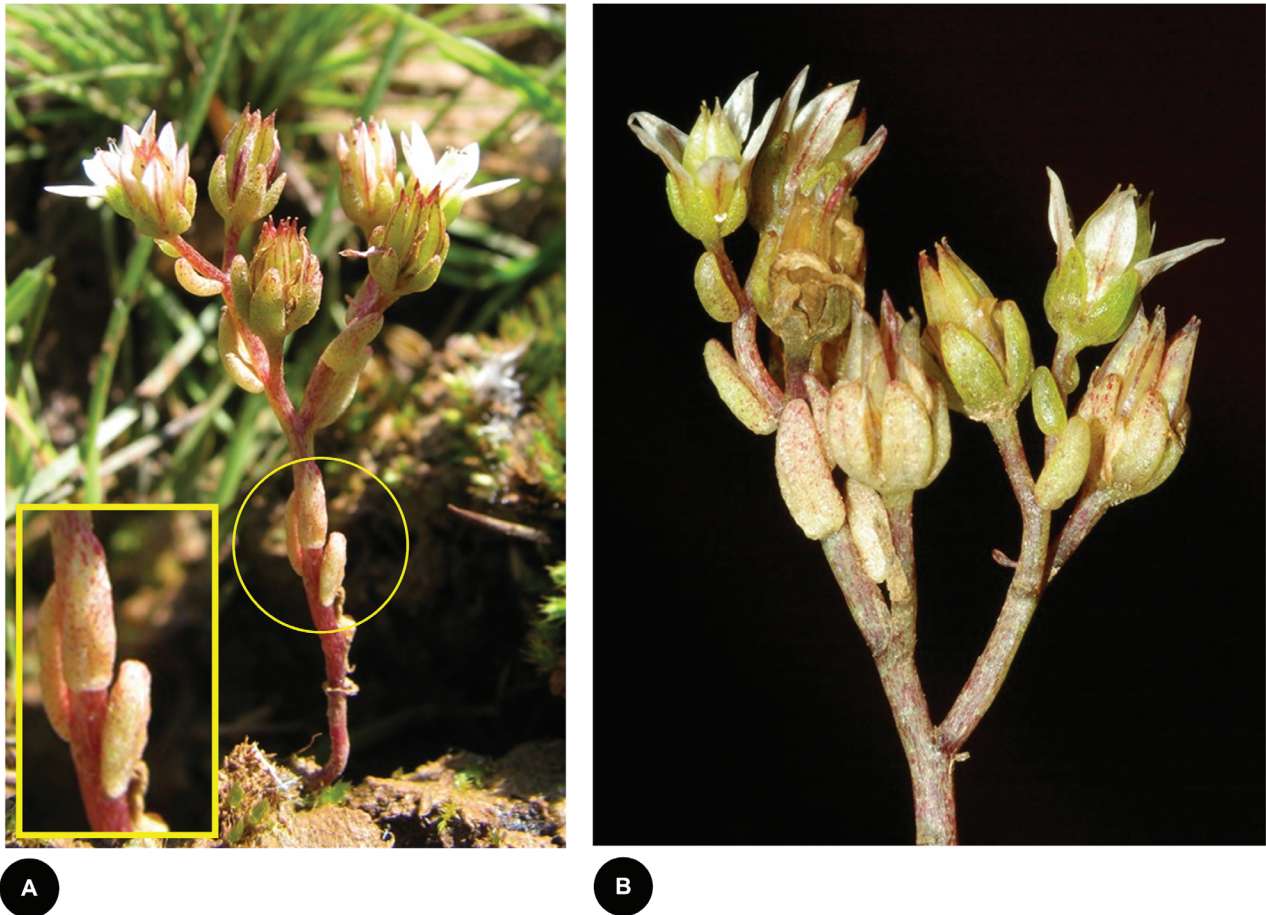
Annual plants, glabrous, with slender and short roots, tall (2.5–)3.2(–4.4) cm, branched at the inflorescence; all green but with areas of the stem more or less reddish. Linear leaves semiterete/terete, without a spur, but with the base clearly retuse, as is well visible for live plants, but less evident in exsiccata; leaves obtuse at the apex of max 5 × 2 mm alternate on the stem, half-erect and precociously drying, especially the basal leaves. Inflorescence reflexed and scorpioid before the anthesis, bracteate with bracts very similar to the leaves; at the anthesis, the inflorescence is upright, with (1–)3(–6) flowers, pedicels of 2–3(–5) mm, and roundish buds; green sepals, fused together at the base, with obtuse tip of 2 × 1 mm. Flowers of (3–)4–5(–6) × 2–3 mm tetramerous or pentamerous with (4–)5 petals free at the base. Petals linear erect or half-erect to the anthesis, with a sharp tip, white with central line green/red. Stamens, (four) five with white or white-green filaments, smooth at the base, with anthers ovoid/roundish opening already in the bud (flowers proterandrous), yellowish in the bud, and later pale brown. Carpels five, erect green smooth, usually with some gland on the ventral suture, 4 mm in length, with style erect and very short, of 0.2–0.3(–0.5) mm; style are longer than petals at anthesis. Seeds of 0.8 × 0.3 mm, light brown, pear-shaped and ribbed (description based on both living specimens and exsiccata).



**FIGURE 3.** Close-up of a *S. aquilanum* leaf, with emphasis on the retuse base (arrow) (photo by D. Vallotto).



**Phenology and reproductive biology:**—Annual plant with anthesis between mid-May and mid-June at about 1500 m a.s.l.; the plants have a short life cycle, drying in the summer. Species autogamous and proterandrous with seeds that in cultivation arise already in the winter period.



**FIGURE 4.** (A–B) *S. nevadense* at Canjuers (France) (Photo by Y. Morvant) (A). Inflorescence of *S. nevadense* collected in the same locality (Photo by J.-M.Tison (B).

**Etymology:**—The specific epithet originates from the name of the Province of the Abruzzo region where this species was found (L’Aquila).

**Distribution:**—Endemic to a periodically moist pasture at about 1500 m a.s.l. in the districts of Lucoli and Rocca di Cambio, on the Velino-Sirente massif (Abruzzo, Italy) (Fig. 7).

**Habitat and Phytosociology:**—*S. aquilanum* grows on chalky soil in small wet depressions in a grass formation dominated by *Sesleria uliginosa* Opiz in Berchtold (1836: 492) in *Cirsio acaulis-Seslerietum uliginosae* included in the class *Festuco-Brometea*, order *Brometalia erecti*, alliance *Phleo ambigu-Bromion erecti* (Ciaschetti *et al.* 2006). These depressions are wet only in early summer.

**Conservation status:**—*S. aquilanum* is found over a few tens of square metres of the pasture of Campo Felice, in a Site of Community Importance (SIC) in the Velino-Sirente Regional Park. The species is in serious danger due to a tunnel that connects Campo Felice with the Altopiano delle Rocche. At the exit of the tunnel, a large roundabout was constructed that is bounded by an escarpment that blocks the water and thus changes the natural water flow. After its discovery, this population was immediately inserted into the IUCN categories as CR [B1ab (iii, v) + B2ab (iii, v)] (Rossi *et al.* 2013 as *S. nevadense*).

**Additional specimens examined (paratype):**—ITALY. Abruzzo: Rocca di Cambio, laghetto di Campo Felice, 26 June 2009, *Soldati s.n.* (APP no. 40593!).

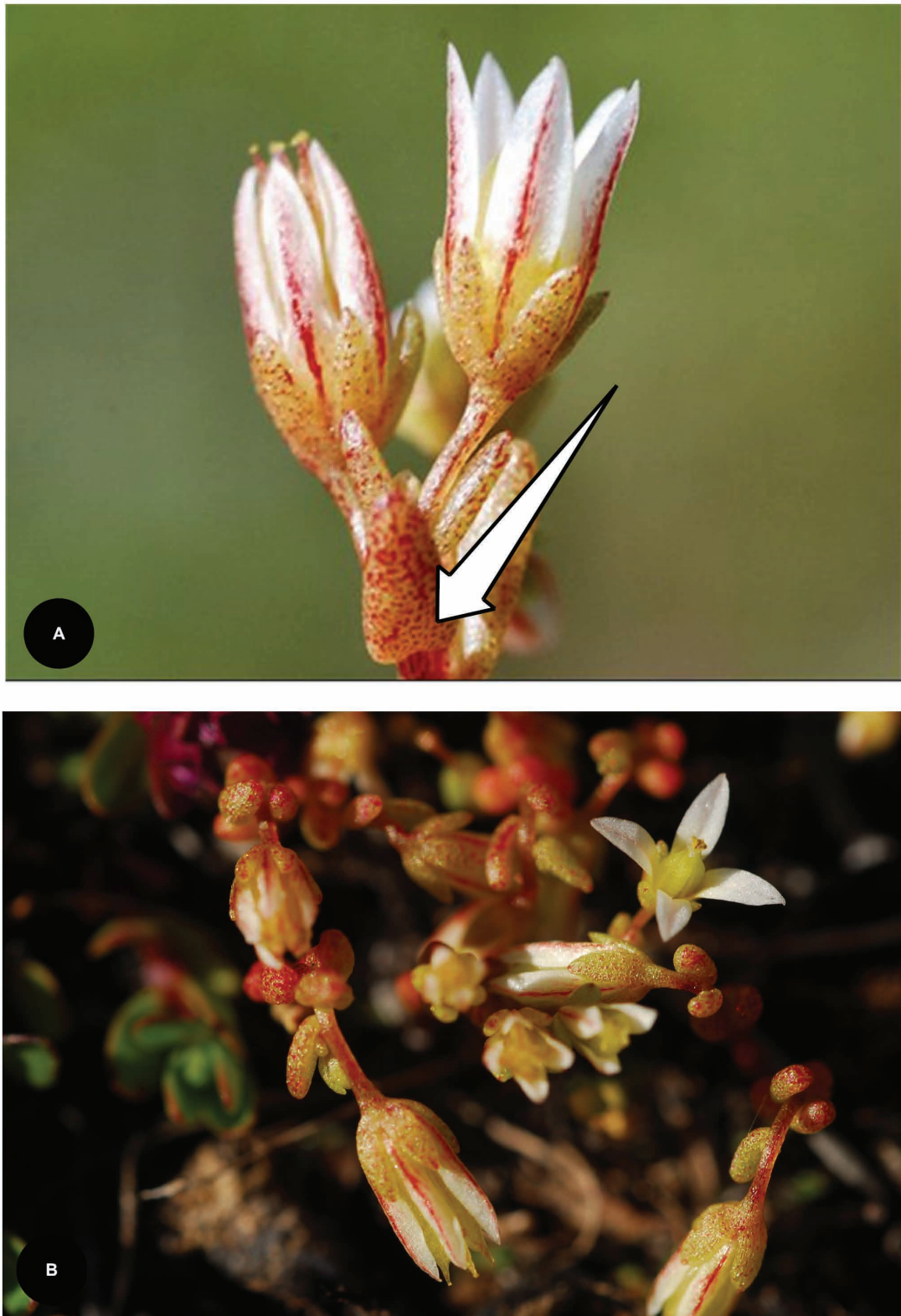
**Taxonomic relationship and Discussion:**—The discovery of a taxon belonging to *Sedum* series *Subrosea* in the Apennines, where this series was unknown until a few years ago, is to be considered relatively surprising from the biogeographical point of view. The field investigation carried out by Minutillo *et al.* (2009) allowed the discovery of this narrowly localized endemic with unquestionable morphological similarity with *S. nevadense*, but with strong ecological and morphological characteristics that make it a distinct taxon of considerable interest from the taxonomic

and phylogenetic points of view. Also from the phytosociological point of view there are noteworthy differences. In Spain *S. nevadense* grows on calcareous substrates, and often siliceous ones (Jahandiez & Maire 1932; Maire 1976; Alejandro Saenz *et al.* 2009, 2011). It has been included in ephemeral vegetation characterized mainly by therophytes (class *Isoeto-Nanojuncetea*, order *Isoetalia*, alliance *Cicendion*) with *Juncus bufonius* L., *Centaurium tenuiflorum* (Hoffmanns. & Link) Fritsch and *Juncus tenageia* L.f. as characteristic taxa (Gomez Mercado 2011).



**FIGURE 5.** Spent flower of *S. aquilanum*, with the formation of the follicles (photo by D. Vallotto).





**FIGURE 6.** (A–B) Close-up of the inflorescence of *S. aquilanum*, with emphasis on the pointing out of the retuse leaf (arrow) (photo by F. Conti) (A). Close-up of the unusual tetramerous flowers of *S. aquilanum* (photo by F. Conti) (B).

The presence of flowers that are often tetramerous in the bud—some of which remain also at anthesis—has been observed up to now only sporadically in some populations of *S. villosum* in North America (Clausen 1975). The particular shape of the base of the leaf and the presence of petals free at the base and not fused (see Castroviejo & Velayos 1997, 't Hart & Bleij 2003) makes *S. aquilanum* clearly distinguishable from the other Iberian-north African taxa, especially *S. nevadense*, and poses interesting questions about its origin. Supposing the presence of flower



tetramerous as apomorphic character (cfr. 't Hart, 1992), a hypothesis is that *S. aquilanum* can be regarded as a taxon evolved during the Quaternary climate changes from the rest of the range of *S. nevadense*, a taxon that was once perhaps much more widespread to the east than it is today. Further taxonomic and phylogenetic studies on the whole *Sedum* series *Subrosea* are needed to clarify value and relationship of the taxa involved.

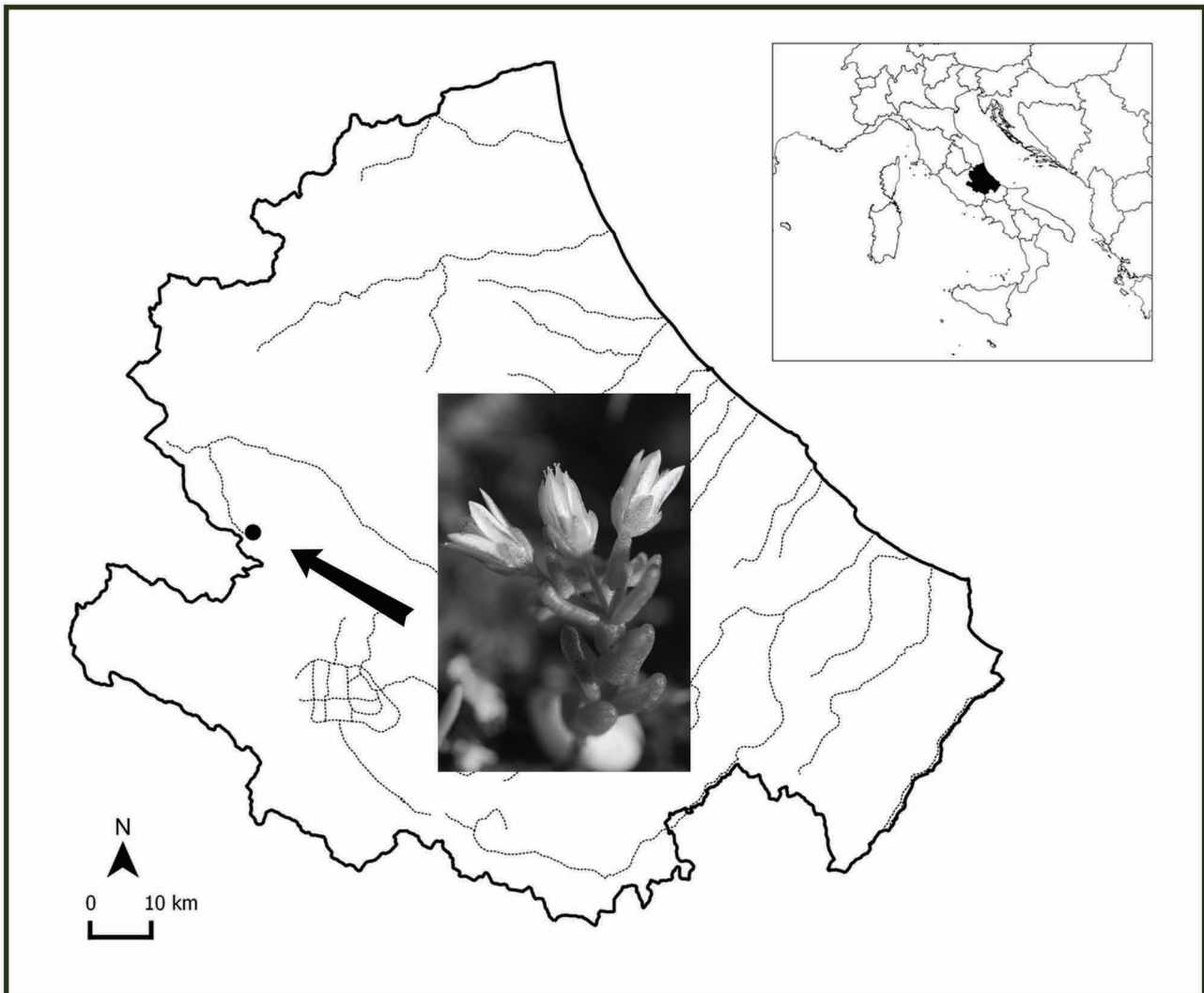


FIGURE 7. Known distribution of *S. aquilanum*. Inset: Position of Abruzzo in Italy and an inflorescence of *S. aquilanum*.

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## APPENDIX 1. Selected specimens of *Sedum nevadense*

ALGERIA. Fissures des falaises de la Vallée de Deglen. Massif de Ghar Rouban, 2 June 1936, *Faurel s.n.* (P barcode P02842028 [digital image!]); Paturages à la base du Djebel Mahmel, province de Constantine (Mts. Aurès), 7 June 1853, *Cosson s.n.* (Cosson pl. crit., P barcode P03198621 [digital image!]). FRANCE. Sur les taupinières et les endroits dépourvues d'herbe, dans les prés de Lagnes à Ampus (Var), 29 May 1880, *Albert 296* (LY as *S. pentandrum* Bor. [digital image!]) (as); Var: Dans les prés de Lagnerasc à Ampus, sur de petits tertres sablonneux, 29 May 1879, *Albert s.n.* (TLON as *S. pentandrum* Bor. [digital image!]). MOROCCO. MK: Alto Atlas, Oukaimeden, alrededores del pueblo, 31°12'18"N, 7°51'37"W, pastizal encharcado, areniscas, 2600 m, 30 June 2006, *Aizpuru et al. s.n.* (SALA no. 135480!, APP no. 40553!); Oukaimeden, a 5 Km del pueblo hacia Marrakech, 2380 m, 6 July 1997, *Aedo, Guemes, Munoz, Pedrol, Rio & Sequeira s.n.* (MA no. 595015!); Agadir: Djebel Siroua, cerca de Tizi n'Tleta, sobre roca silicea algo humeda, 2000 m, 18 May 1981, *Castroviejo, Fernandez Casas, Munoz, Garmendia & Susanna FC 4743* (MA 510663!); Moyen Atlas: [label unreadable] pelouses humides. 30 June 1939, *Maire & Weiller 883* (P barcode P02842965 [digital image!]); Moyen Atlas, Ari Hayan, pelouses humides, 2300 m, 26 June 1923, *Maire s.n.* (P barcode P03198620 [digital image!]). SPAIN. Castille: S.ta Maria la Redonda, champs. June 1908, *Fre. Elias 638* (FI no.



5612/1! as *S. nevadense* var. *jabalambrense*); Aragon: prairie de Jabalambre, alt. 2000 m environ, 14 July 1890, *Pau 2473* (FI no. 5612/3!); *ibidem* (P barcode P03190017 [digital image!]); *ibidem* (P barcode P03190018 [digital image!]); Regnum Granadense, Sierra Tejada, loco arenos, Parte septentr. Cacuminis, sol. calcar. 21-2200 m, 21 June [1879], *Huter, Porta & Rigo 1040* (FI no. 5512/2!); *ibidem* (FI no. 5512/4!); *ibidem* (G barcode G00382804 [digital image!]); *ibidem* (G barcode G00382805 [digital image!]); *ibidem* (G barcode G00382806 [digital image!]); *ibidem* (P barcode P02817519 [digital image!]); Aragon: prairie de Jabalambre, alt. 2000 m environ, 14 July 1890, *Pau 2473* (G barcode G00382802!); *ibidem* (G barcode G00382801 [digital image!]); Sierra Nevada, région alpine, dans le ruisseau du Barranco de Benalcaza. 4 July [1851], *Bourgeau 1175* (G barcodes G00386217!, G00386219 [digital image!], G barcode G00386218 [digital image!], P barcode P03190016! [digital image!]); Jabalambra in prato: alt. 2000 m, July 1896, *Pau s.n.* (G barcode G00382803 as *S. jabalambrense mihi* [digital image!]); Beteta Arroyo de Los Enebrales - 30 TWK9089 - Cubetas temporales sobre arcillas y arenas albenses 1520 m, 1 June 2006, *García Cardo s.n.* (MA no. 744103!); Leon, Camposagrado, 1100 m, pastizal terofítico con encharcamiento temporal - UTM 30TTN777323, 1100 m, 18 May 2007, *Puente & del Egidio s.n.* (MA no. 790024!); Checa, Sierra Molina Ayo. de los Huecos, 1520 m 30TXK0278, cubetas temporales sobre arcillas y arenas cretácicas, 1520 m, 18 June 2006, *García Cardo OGC-01423* (MA no. 744152!); Magina in pratis fluminis inter rupestr., 2000 m, 18 July 1925, *Cuatrecasas s.n.* (MA no. 51723!); Jaen: Cazorla: Sierra de Empanadas, 30SWG1997, fondo de dolina, 1900 m, 15 June 1976, *Munoz Garmendia & Soriano s.n.* (MA no. 481516!); Granada: Huemeja Sierra nevada Laguna Seca 30SWG0305 cervunal, 2250 m, 19 June 1992, *Aedo, Munoz Garmendia & Navarro CN-392* (MA no. 508822!); Jaen, Sierra de Cazorla in rup. al Poyo Cerezo, 15 June 1928, *Cuatrecasas s.n.* (MA no. 51722!); Castille: S.ta Maria la Redonda, champs, June 1908, *Fr. Elias s.n.* (MA no. 51726!); *ibidem* (P barcode P02817197 as *S. nevadense* var. *jabalambrense* Sen. & Pau [digital image!]); Cuenca: Cerro de San Felipe 30TWK97 fuente a 1670 m, 10 July 1979, *Lopez N 1616GF* (MA no. 320928! as *S. nevadense*); Teruel prov. de Teruel Sierra de griego pelouses, rare, 1800 m July 1896, *Reverchon* (MA no. 51698!); Cuenca, fuente del Aguerillo - 30TWK9458, Prados mesofilos con encharcamientos temporales, 1370 m, 21 May 2006, *García Cardo & Sanchez Maigat OGC-785* (MA no. 744092!); Ad lacum dictum Cerveriz (Saliencia, Somiedo, Asturias) iuxta rupes calcareas sed solo procul dubio acido, 8 July 1973, *Lainz s.n.* (MA no. 395297!); Segovia, termino de Fuentiduena (cualvo [?] claros), 890 m, 21 May 1988, *Romero s.n.* (MA no. 567436!); Teruel: Fuente, García, XK16, 10 July 1974, *Bondia & Lopez 1286GF* (MA no. 320957!); Alava: Parzoneria de Entzia, Sierra de Entzia, Italda, alto del Mojon, WN5939, pastos losas paranera en zona de hayedo, 1000 m, 24 June 1998, *Blanco, Carrasco, Martin-Blanco & Velayos 9152 MV* (MA no. 614749!); Cuenca: 30TXK1161, Zafrilla, Rincon de Palacios, cubetas y borde de arroyo temporal, 1630 m, 29 May 2007, *García Cardo OGC-01423* (MA no. 764441!); CU: Val Salobre pr. Valdelahuerta, 30TWK7495, comunidades anfíbias temporales oligotróficas, 1300 m, 23 June 2010, *García Cardo OGC-01423* (MA no. 827641!); Cu: Fuentes, dehesa de la Casa, 1060 m, 30SWK8315, bordes de charcos y prados humedos temporalmente encharcados sobre suelo arenosos, 1060 m, 25 May 2010, *García Cardo OGC-01333* (MA no. 827614!); Cu: Mariana, la Torre pr. Fuente del Poleo, prados y pastizales temporalmente encharcados, 30TWK7546, 950 m, 16 May 2010, *García Cardo OGC-01319* (MA no. 827623!); Soria: Retortillo de Soria, Arroyo de la Dehesa, pastos arenosos temporalmente encharcados sustrato silíceo, 1300 m, 17 June 2004, *Molina 30TVL9973* (MA no. 729643!); Valdegovia (VI) Boveda, La Campa de Valmontanez, Descespedamientos surcos de los caminos que se encharcan con aguas le lluvia, Calizas, UTM 30T-VN8253, 890 m, 1 July 1984, *de Betono & Alejandro 551.84* (MA 400675!); Sierra de la Malessa, les pelouses sur le calcaire, rare, 1900 m, June [1904], *Reverchon 770* (P barcode P02817198 [digital image!]).