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Comparative studies on *Orobanche cernua* L. and *O. cumana* Wallr. (Orobanchaceae) in the Iberian Peninsula

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The systematic treatment of *Orobanche cumana* Wallr. and *O. cernua* L. is controversial. Whereas some authors consider *O. cumana* as an infraspecific taxon of *O. cernua*, others treat it as a separate species. Furthermore, the nomenclature of the sunflower broomrape is unclear, and both names are found without qualification in the literature. The objective of the present study has been to evaluate the distribution, morphology, and ecology of *O. cernua* and *O. cumana* in the Iberian Peninsula, as well as their seed oil fatty acid profile, which is a trait of great chemotaxonomic value. *O. cernua* was found parasitizing wild Compositae, mainly *Artemisia* spp., whereas *O. cumana* was exclusively found on cultivated sunflower. Both species clearly differ in morphological traits, especially plant height and build, length and structure of the inflorescence, corolla length and colour. Both species are characterized by contrasting seed oil fatty acid profiles, with high oleic acid concentration in *O. cernua* and high linoleic acid concentration in *O. cumana*. The evaluation of both taxa in the Iberian Peninsula gives additional support to those authors that treat them as separate species.

ADDITIONAL KEY WORDS:—broomrape – fatty acids – parasitic plants – seed oil – sunflower – taxonomy.

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INTRODUCTION

Orobanche cernua L. was described by Carl Linnaeus, on materials collected by Pehr Löfling (Loefling) near Aranjuez, central Spain (Loefling, 1758). It parasitizes different species of the Compositae, being most frequently found on plants of the genus *Artemisia*. The main distribution area for this species is the Mediterranean region to central Asia (Reuter, 1847; Beck-Mannagetta, 1930). Following the International Code of Botanical Nomenclature (Greuter, 1988) we use the authority *O. cernua* L. instead of the more traditional *O. cernua* Loefl., as proposed by López-González (1990).

The description of *O. cumana* was made by Wallroth (1825), on plants collected in desert areas of south-western Asia and south-eastern Europe. Beck-Mannagetta (1930), who considered this species as a variety of *O. cernua*, reported central Asia to south-eastern Europe as the main distribution area for *O. cumana*. Originally, *O. cumana* parasitized *Artemisia* spp. exclusively (Venkov & Bozoukov, 1994). After the introduction of the sunflower (*Helianthus annuus* L.) cultivation in Europe, plants of *O. cumana* were detected for the first time parasitizing this crop in north-eastern Bulgaria in 1935 (Encheneva & Shindrova, 1994). In the Iberian Peninsula, it was first described parasitizing cultivated sunflower in 1958 (Díaz-Celayeta, 1974). Since then, *O. cumana* has spread over the whole sunflower cultivation area (*c.* 1 million ha in central- and southern Spain) representing currently a serious problem limiting sunflower productivity (Alonso *et al.*, 1996).

Orobanche cernua L. and *O. cumana* Wallr. have been traditionally considered as very closely related taxa. Thus, *O. cumana* has been recognized as an infraspecific taxon of *O. cernua* (Beck-Mannagetta, 1890, 1930; Rechinger, 1943; Greuter, Burdet & Long, 1989), or both names have been used as synonymous by some authors (Bonnier, 1926; Chater & Webb, 1972; Bischof, 1978; Pignatti, 1982). Other authors, however, have classified both taxa as separate species (Reuter, 1847; Jackson, 1895; Joel, 1987; Uhlich, Pusch & Barthel, 1995; Kreutz, 1995). In parallel with the lack of agreement among botanists, some plant pathologists refer to sunflower broomrape as *O. cernua* (e.g. Díaz-Celayeta, 1974; González-Torres, Jiménez-Díaz & Melero-Vara, 1982; Castejón-Muñoz, Romero-Muñoz & García-Torres, 1991; Parker, 1994; Alonso *et al.*, 1996; Sukno, Melero-Vara & Fernández-Martínez, 1999), whereas others use *O. cumana* (e.g. Petrov, 1968; Cherzhentseava, 1978; Vrânceanu *et al.*, 1986; Joel, 1988; Abu-Irmaileh, 1994; Antonova & Ter-Borg, 1996).

Despite the mentioned discrepancies, recent molecular studies clearly support the separation of *O. cernua* and *O. cumana* into different species (Katzir *et al.*, 1996; Paran, Gidoni & Jacobsohn, 1997; Joel, Portnoy & Katzir, 1998; Pujadas & Thalouarn, 1998).

The fatty acid profile of the seed oil has great systematic value in the plant kingdom (Gibbs, 1974), and there are many studies reporting phylogenetic relationships paralleled by differences in the fatty profile of the seed oil (e.g. Velasco & Goffman, 1999; Aitzetmüller, Tsevegüren & Werner, 1999). This trait has not yet been evaluated in the Orobanchaceae.

In this paper we report a comparative evaluation of *O. cernua* and *O. cumana* in the Iberian Peninsula, describing their morphology, distribution, habitat, phenology, and seed oil content and fatty acid composition.

MATERIAL AND METHODS

Material studied

Unless otherwise cited, plant material of *O. cernua* and *O. cumana* was collected by the first author. Voucher specimens are deposited in the Herbarium of the University of Córdoba (COA), Spain. Furthermore, the following herbaria have been consulted: ABH, ALME, BC, BCC, BCF, COA, Cº LA SALLE DE ALMERIA, GDA, GDAC, JACA, JAEN, HBIL, MA, MACB, MAF, MGC, MUB, SEV, VAB & VAL.

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SPAIN. Alicante: Confrides, Sierra Aitana, pr. Font de l'Abre, 1200 m, YH3582, 18.v.1992, *J.L. Solanas, De La Torre & Crespo* (ABH 14832). Dehesa de Campoamor, Orihuela, XH93O4, 100 m, 31.v.1996, *S. Espinar et al.* (ABH 31825). Serra del Portitxol, on *Artemisia campestris*, 2.iv.1958, *A. et O. de Bolòs* (BC 261398). Sierra de Orihuela, 30SXH71, 15.iv.1984, *T. Molero & A. Rovira* (BCF 39860). Almeria: La Hoya, 16.iii.1958, *Hno. M. Mauricio & R. Sagredo* (ALME 1721). Serón, Las Menas, on *Artemisia* sp., 1300 m, 11.viii.1958, *Hno. M. Mauricio & R. Sagredo* (ALME 1718). Tabernas, Venta de los Yesos, growing on *Artemisia* in wheatfield, 30SWG60, 520–550 m, 3.vi.1967, *P. W. Ball, A. O. Chater, I. K. Ferguson & B. Valdés* (ALME 1705 and SEV 4861). NW Almería, Barranco de Cerro Caguela, N side of Rambla de Belén, stony slopes, limestone, 30SWG47, 100–300 m, 6.vi.1967, *P. W. Ball, A. O. Chater, I. K. Ferguson & B. Valdés* (ALME 1706 and SEV 4860). Between Tabernas and Gérgal, Yesoncillo de Enmedio, on gypsaceous soils, 30SWG40, 500–600 m, 30.iv.1983, *R. Lázaro Suau* (ALME s/n). Near Los Cuernos, 30SWG6465, 1500 m, 8.vi.1988, *M. Cueto* (ALME s/n). Tabernas, on *Artemisia barrelieri*, 30SWF4898, 400 m, 29.iv.1989, *A. Pujadas & P. Poyato* (COA 13632). Níjar, 30SWF7191, 17.iii.1990, *A. Pujadas et al.* (COA 13464). Salinas Cabo de Gata, 30SWF7069, 3 m, 17.iii.1990, *A. Pujadas et al.* (COA 17366). Cabo de Gata, Cerro Vela Blanca, 30SWF7364, 20 m, 17.iii.1990, *A. Pujadas et al.* (COA 17368). Los Genoveses, Cabo de Gata, 30SWF3976, 250 m, 17.iii.1990, *A. Pujadas et al.* (COA 17369). San José, 30SWF7968, 10.vii.1990, *A. Pujadas* (COA 17358). Yesera de Gafarillos, Sorbas, 30SWF8702, 18.iv.1992, *E. Hernández & P. Contreras* (COA 17365). Barriada de Alcora, 30SWF2391, 760 m, 13.v.1993, *A. Pujadas, A. Lora & M. Mazariegos* (COA 17359). Cerro del Buho, Tabernas, on *Artemisia barrelieri*, 30SWG5202, 14.v.1993, *A. Pujadas, A. Lora & M. Mazariegos* (COA 17360). Cerro Santa Fe, on *Artemisia barrelieri*, 30SWF7670, 350 m, 23.iii.1994, *A. Pujadas* (COA 17355). Enix, on *Artemisia barrelieri*, 30SWF3879, 7.iv.1994, *A. Pujadas* (COA 17363). Cerro Majada Redonda, on *Launaea lanifera*, 30SWF8174, 300 m, 13.iv.1994, *A. Pujadas* (COA 17353). N del Barranco del Sabinar, cortijo El Rincón de Martos, 30SWF7470, 300 m, 19.iv.1994, *A. Pujadas* (COA 17356). Barranco El Palmer, 30SWF3976, 250 m, 22.iv.1994, *A. Pujadas* (COA 17370). Cerro El Fraile, on *Artemisia barrelieri*, 30SWF8271, 40 m, 2.v.1994, *A. Pujadas* (COA 17371). El Garbanzal, on *Artemisia barrelieri*, 30SWF7874, 200 m,

6.v.1994, *A. Pujadas* (COA 17352). Las Pocicas, on *Artemisia glutinosa*, 30SWG7548, 700 m, 11.v.1994, *A. Pujadas* (COA 17349). Arroyo del Saliente, Los Cerricos, Oria, 30SWG7254, 1000 m, 11.v.1994, *A. Pujadas* (COA 17372). Santuario El Saliente, on *Artemisia glutinosa*, 30SWG7453, 900 m, 16.v.1994, *A. Pujadas* (COA 17350). Barranco del Tartel, Sierra de Gádor, on *Artemisia barrelieri*, 500 m, 22.v.1994, *A. Pujadas* (COA 17351). Cerro de Mónsul, 30SWF7667, 200 m, 1.vi.1994, *A. Pujadas* (COA 17357). Tabernas, Venta de los Yesos, 30SWG6204, 18.v.1996, *A.Pujadas* (COA 20595). Sierra Nevada, Alhabia, on *Launaea lanifera* Pau, 430 m, 5.iv.1997, *J. Pusch* (COA 23584). Cueva de los Ubedas, 30SWF6385, 16.vi.1998, *L. Plaza* (COA 25549). Palacio de Arboleas, 23.iv.1982, *P. Sánchez* (GDAC 14360). Adra to La Parra, 17.iv.1990, *M. J. Martínez & L. Gutiérrez* (GDAC 35199). Las Menas, Serón, on *Artemisia* sp., 1300 m, s/f, *R. Sagredo* (Hº LA SALLE s/n). Between Rioja and Tabernas, 19.iv.1967, *R. Sagredo* (Hº LA SALLE s/n). Venta de los Yesos, 2 km from Uleila, 19.iv.1967, *R. Sagredo* (Hº LA SALLE s/n). El Fonte, Cortijo, 19.iv.1967, *R. Sagredo* (Hº LA SALLE s/n). Aguadulce, 19.iv.1968, *R. Sagredo* (Hº LA SALLE s/n). Faro Cabo de Gata, 3.v.1968, *R. Sagredo* (Hº LA SALLE s/n). Los Castaños, 14.iv.1973, *R. Sagredo* (Hº LA SALLE s/n). Serrata, 20.iv.1973, *R. Sagredo* (Hº LA SALLE s/n). Tabernas, near Rambla de Tabernas, 30SWG60, 450 m, 2.iii.1955, *P. Montserrat* (JACA 5255). Carboneras, Presa de Agua Amarga, 10 m, 12.v.1982, *A. Charpin & C. Defferrard* (MA 294125). Cabo de Gata, 10.vi.1985, *M. S. Sanz, A. Nebot & F. Boisset* (VAB 904408). Cáceres: Hervás, on *Artemisia glutinosa*, vi, *M. Rivas Mateos* (MAF 36157). Castellón: Segorbe, on *Artemisia herba-alba* var. *valentina*, 19.v.1928, *C. Pau* (BC 822104, MA 114871 and MAF 36156). Segorbe, Monte Castelli, on *Artemisia valentina* Lam., 1880, *C. Pau* (MA 114873). Segorbe, on *Artemisia valentina,* 1918, *C. Pau* (MA 114872). Granada: Castell de Ferro, Cala Rijana, on *Launaea lanifera* Pau, 28.ii.1995, *A. Pujadas & P. Poyato* (COA 17627). Monachil, Base del Trevenque, Cortijo de la Fuente del Hervidero, on *Artemisia campestris* subsp. *glutinosa*, 30SVG5304, 1360 m, 13.vii.1997, *A. Pujadas* (COA 23548). Cuenca del Benimar, Ugíjar, VF9489, 1.v.1984, *J. Guirado* (GDAC 28833). Lanjarón, La Alpujarra, 1902, *C. Pau* (MA 114870). Between El Marquesado and Alquife, hillsides with pines, on shales, VG 9011, 1700 m, 16.vi.1988, *B. Valdés et al.* (SEV s/n). Huesca: Serreta Negra de Fraga, 14.v.1977, *Martín & Molero* (BCF 39859). Fraga, 31TBF7399, 330 m, 31.v.1960, *P. Montserrat* (JACA 14160). Candasnos, La Valcuerna, 31TBF5094, 350 m, 5.v.1971, *P. Montserrat* (JACA 92471). Sariñena, Laguna, 30TYM3430, 280 m, 3.vi.1980, *P. & G. Montserrat* (JACA 121580). Ballerías, 30TYM34, 370 m, 22.v.1988, *G. & J. Montserrat* (JACA 88888). Monzón, 31TBG6742, 360 m, 13.v.1988, *J. A. Sesé* (JACA 607088). Alcolea de Cinca, La Codera, on *Artemisia herba-alba*, 31TBG6219, 220 m, 14.iv.1995, *J. V. Ferrández* (JACA 515595). Albalatillo, 30TYM3619, 260 m, 12.vi.1995, *L. Villar, J. A. Sesé & C. Pedrocchi* (JACA s/n). Jaén: Cabra del Santo Cristo, Base de las Atarillas, 30SVG7377, 10.v.1996, *A. Pujadas & A. Lora* (COA 22113). Jódar, Chozón del Lobo, on *Artemisia barrelieri* Besser, 30SVG7578, 10.v.1996, *A. Pujadas & A. Lora* (COA 22121). Cabra del Santo Cristo, Las Ramblas, on *Artemisia barrelieri* Besser, 30SVG7477, 14.vi.1996, *A. Pujadas* (COA 20592). Cabra del Santo Cristo, Las Jarosas, on *Artemisia barrelieri* Besser, 30SVG7681, 14.vi.1996, *A. Pujadas* (COA 20593). Bélmez de Moraleda, base of Sierra de la Cruz, on *Artemisia barrelieri* Besser, 30SVG6978, 760 m, 14.vi.1996, *A. Pujadas*, COA 20594. Cabra del Santo Cristo, Loma del Campillo, VG-78, 800 m, 11.v.1979, *C. Fernández López* (JAEN 79463). La Rioja: Briones, vi.1939, *s/l.* (BCF 39892). Logroño to Fuenmayor, on *Artemisia herba-alba*, v.1920, *Zubia* (MA 114865).

Lérida: Segrià, near Alcarrás, on *Artemisia herba-alba*, 11.vi.1962, *F. Masclans* (BC 597186). Tossal de Prop de Miralcamp, CG20, 10.vi.1987, *A. Mayoral* (HBIL 7144). Madrid: Aranjuez, on *Artemisia valentina*, 25.v.1919, *C. Vicioso* (BC 46699). Valdemoro, v.1915, *C. Vicioso* (MA 114861). Murcia: Cabo de Palos, Cala Reona, 30SYG0267, on *Artemisia barrelieri* Besser, 18.v.1996, *A. Pujadas* (COA 22114). Lorca, on *Artemisia* spp., -s/f-, *Cánovas* (GDA s/n). Sierra de Columbares, XG7399, 400 m, 14.iii.1980, *F. Alcaraz* (MUB 2885). Base of Pico Mirabete, 30.v.1985, *J. M. Estremera* (MUB 24335). Lorca, XG1578, 450 m, 1.v.1996, *A. Robledo-Miras* (MUB 17220). Cehegín, Sierra de la Puerta, 30SXH 0826, 550 m, 3.v.1986, *C. Selma* (MUB 28633). Jumilla, El Cabezo, 27.iv.1991, *A. I. Jiménez-Piqueras* (MUB 39770). Palencia: Castillo de Magaz, 30TUM8049, 24.vii.1988, *C. López & A. Romero-Abelló* (MACB 50326). Tarragona: Delta de L'Ebre, Cap a L'Aufacada, CI10, on dunes near the sea, 16.v.1983, *C. Benedí & J. Molero* (BCF 39409). Teruel: Tornos, Gallocanta, 30TXL2835, 1000 m, on *Artemisia* cf. *gallica*, 5.vii.1972, *P. Montserrat & L. Villar* (JACA 438372). Las Parras de Martín, Soto de la Solana, on *Artemisia* sp., 22.vi.1881, *Badal* (MA 114868). Toledo: Ontígola, 30SVK4829, 600 m, 15.vi.1959, *P. Montserrat* (JACA 35559). Seseña, Dehesa Nueva del Rey, 30TVK4332, on *Artemisia barrelieri*, 23.v.1998, *A. Pujadas* (COA 24660). Valencia: Font del Plà, Ermita de Santa Bàrbara, Bocairent, 30SYH09, 800 m, on *Artemisia campestris*, 21.v.1988, *J. R. Nebot* (VAB 901747). Zaragoza: Chiprana, La Laguneta Salada, on *Artemisia herba-alba*, 21.v.1954, *O. de Bolós & J. Br.-Blq.* (BC 128440). Laguna de Pito, Monegros, 23.v.1988, *A. Carrillo & J. M. Ninot* (BCC s/n). Los Monegros, Osera-Monegrillo, 30TYM0102, 250 m, 1.vi.1956, *P. Montserrat* (JACA 9856). Sástago, Monte de Rueda, 30TYL2376, 180 m, 12.v.1959, *P. Montserrat* (JACA 21659). Bárdenas Reales, c. Tres Mugas, 30TXM3283, 16.v.1988, *D. Gómez* (JACA 60988). Mequinenza, Val de Beauradó, gypsaceous soil, on *Artemisia herba-alba*, 31TBF7586, 130 m, *J. V. Fernández* (JACA 517895). Daroca, 27.vi.1909, *C. Vicioso* (MA 114867). Calatayud, Campiel, 7.vi.1910, *C. Vicioso* (MA 114866). Valdehurón, Calatayud, 28.v.1988, *J. A. U.* (VAB 940396).

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Cádiz: Puerto Serrano, on cultivated sunflower (*Helianthus annuus* L.), 3.vi.1989, *J. Oliveira* (COA 13524). Jerez de la Frontera, .vii.1995, *J. Fernández Escobar,* CA195 (COA 28285). Córdoba: Córdoba, Finca Ruano, on cultivated sunflower, 9.vi.1993, *F. Cartujo* (COA 17472). Córdoba, Parque Cruz Conde, 16.vi.1994, *P. Blanco* (COA 17471). Córdoba, near Airport, on cultivated sunflower, 30.vi.1996, *A. Lora* (COA 22078). Córdoba, Huerta de San Luis, on cultivated sunflower, 30SVG4092, 2.vii.1996, *A. Lora & A. Pujadas* (COA 22077). Córdoba, Cortijo del Pardito, on cultivated sunflower, 30SUG4377, 16.vii.1996, *A. Moyano & A. Pujadas* (COA 22115). Puente Genil, .vii.1994, *J. Alvarado*, CO194 (COA 28286). Córdoba, .vii.1996, *J. M. Melero*, CO196 (COA 28287). Cuenca: Villarejo de Penesteban, .viii.1992, *J. M. Melero*, CU192 (COA 28288). Alcázar del Rey, .ix.1994, *J. M. Melero*, CU494, (COA 28289). Km. 17,800 of Cuenca road, 2.viii.1978, *M. Velayos* (MACB 47083). Granada: Atarfe, on cultivated sunflower (oilseed), 14.ix.1995, *A. Pujadas* (COA 17629). Málaga: Antequera, on cultivated sunflower (oilseed), 3.vi.1989, *J. Oiveira* (COA 13569). Campillos, on cultivated sunflower (confectionery), 13.vi.1989, *J. Oliveira* (COA 13525). Between Campillos and Antequera, 20 km, on cultivated sunflower (oilseed), 13.vi.1989, *J. Oliveira* (COA 13568). Near Laguna de Fuente de Piedra,

TABLE 1. Analysed populations for seed oil content and fatty acid composition of *Orobanche cernua* and *O. cumana* from the Iberian Peninsula

Species	Province	Reference
O. cernua	Almería	COA 13632
O. cernua	Almería	COA 13464
O. cernua	Almería	COA 17358
O. cernua	Almería	COA 17365
O. cernua	Almería	COA 17359
O. cernua	Almería	COA 17360
O. cernua	Almería	COA 17355
O. cernua	Almería	COA 17363
O. cernua	Almería	COA 17353
O. cernua	Almería	COA 17356
O. cernua	Almería	COA 17370
O. cernua	Almería	COA 17352
O. cernua	Almería	COA 17349
O. cernua	Almería	COA 17372
O. cernua	Almería	COA 17350
O. cernua	Almería	COA 17351
O. cernua	Almería	COA 20595
O. cernua	Almería	COA 23584
O. cernua	Granada	COA 17627
O. cernua	Granada	COA 23548
O. cernua	Jaén	COA 22113
O. cernua	Jaén	COA 22121
O. cernua	Jaén	COA 20592
O. cernua	Jaén	COA 20593
O. cernua	Jaén	COA 20594
O. cernua	Murcia	COA 22114
O. cernua	Toledo	COA 24660
O. cumana	Cádiz	COA 28285
O. cumana	Córdoba	COA 22077
O. cumana	Córdoba	COA 22115
O. cumana	Córdoba	COA 28286
O. cumana	Córdoba	COA 28287
O. cumana	Cuenca	COA 28288
O. cumana	Cuenca	COA 28289
O. cumana	Sevilla	COA 28295
O. cumana	Sevilla	COA 28296
O. cumana	Sevilla	COA 28290
O. cumana	Sevilla	COA 28293
O. cumana	Sevilla	COA 17460
O. cumana	Sevilla	COA 28292
O. cumana	Sevilla	COA 22079
O. cumana	Sevilla	COA 22080
O. cumana	Sevilla	COA 28291
O. cumana	Sevilla	COA 28294

on cultivated sunflower, 8.vi.1995, *A. Lora & A. Pujadas* (COA 17628). SEVILLA: El Coronil, on cultivated sunflower, 16.vi.1986, *L. García Torres* (COA 13636). Morón to El Coronil, 9 km, on cultivated sunflower (oilseed), 2.vii.1987, *J. Oliveira* (COA 13624). El Coronil to Morón, 7 km, on cultivated sunflower (oilseed), 2.vii.1987, *J. Oliveira* (COA 13633). El Coronil to Utrera, 15 km, on cultivated sunflower (confectionery), 2.vii.1987, *J. Oliveira* (COA 13645). Osuna, 1.vii.1988, *J. Oliveira*, COA 28295. El Coronil to Montellano, 10 km, on cultivated sunflower (oilseed), 1.vii.1988, *J. Oliveira* (COA 13533). El Coronil to El Arahal, 12 km, on cultivated sunflower (confectionery), 1.vii.1988, *J. Oliveira* (COA 13629). El Coronil to Acabalas,

10 km, on cultivated sunflower (oilseed), 1.vii.1988, *J. Oliveira* (COA 13643). Montellano, on cultivated sunflower (confectionery), 13.vi.1989, *J. Oliveira* (COA 13618). Osuna, vii.1989, *J. Oliveira* (COA 28296). Écija, Sotillo Gallego, vii.1993, *J. M. Melero,* SE193 (COA 28290). Écija, Finca Pavía, vii.1994, *J. Fernández*, SE194 (COA 28293). Écija to Herrera, 24 km, on cultivated sunflower, 18.v.1995, *A. Pujadas* (COA 17460). Écija, Finca Mencía, vii.1996, *J. M. Melero*, SE296 (COA 28292). Écija to Estepa, 3 km, 1.vii.1996, *A. Pujadas, A. Lora & A. Jiménez* (COA 22079). Herrera to Écija, 3 km, 1.vii.1996, *A. Pujadas, A. Lora & A. Jiménez* (COA 22080). Aznalcázar, near Guadiamar river, on cultivated sunflower, 29SQB4232, 22.xii.1998, *A. Pujadas & M. del Río* (COA 27749). Cañada del Rosal, vii.1998, *J. A. Sainz deTejada* (COA 28291). Écija, viii.1998, *J. A. Sainz de Tejada* (COA 28294).

The study of the geographical distribution of *O. cumana* has been complemented with information from Díaz-Celayeta (1974), Velayos-Rodríguez (1978), González-Torres *et al.* (1982), and Castejón-Muñoz, Romero-Muñoz & García-Torres (1989).

Analysis of seed oil content and fatty acid composition

Seed oil content and its fatty acid composition were analysed in a set of 44 accessions for which enough seed was available. It included 27 accessions of *O. cernua* and 17 accessions of *O. cumana* (Table 1). They were determined by gas-liquid chromatography (GLC) of fatty acid methyl esters with heptadecanoic acid (17:0) as internal standard. About 10 mg seeds were placed in a 2-ml vial. The seeds were crushed, as finely as possible with a stainless steel rod, and 0.8 ml petrolether was added. The vials were closed with teflon covers and maintained in a waterbath at 45°C for 8 h. After that the petrolether was evaporated overnight. Fatty acid methyl esters were prepared following the procedure of Garcés & Mancha (1993) and analysed on a Perkin Elmer gas chromatograph model Autosystem (Perkin Elmer Corporation, Norwalk, CT) equipped with a 2-m long column packed with 3% SP-2310/2% SP-2300 on Chromosorb WAW (Supelco Inc., Bellefonte, PA, USA). The oven, detector, and injector temperatures were 185, 250, and 275°C, respectively. The carrier gas was nitrogen, at a flow of 23 ml min^{-1}. Fatty acids were identified by comparison of retention times with standards. Individual fatty acids were expressed as a percentage of the total fatty acids.

RESULTS AND DISCUSSION

Morphological description

Orobanche cernua L. in Loefl., Iter. Hisp. 152 (1758).
= *O. hispanica* Boiss., Voy. Bot. Espagne 2: 476 (1839–1845).
Iconography. Figure 1; Coste (1937: 71, fig. 2825); Kreutz (1995: 78–79); Pignatti (1982: 610).

PLANT 15–32 cm tall. STEM usually thick, with a diameter of (3)5–8(9) mm, in the middle, bulbous at the base (9–20 mm), glandular-pubescent, yellowish to pale violet. LEAVES deltate below (8–11 × 5–8 mm), and oval-lanceolate above (6–11 × 4–7 mm).

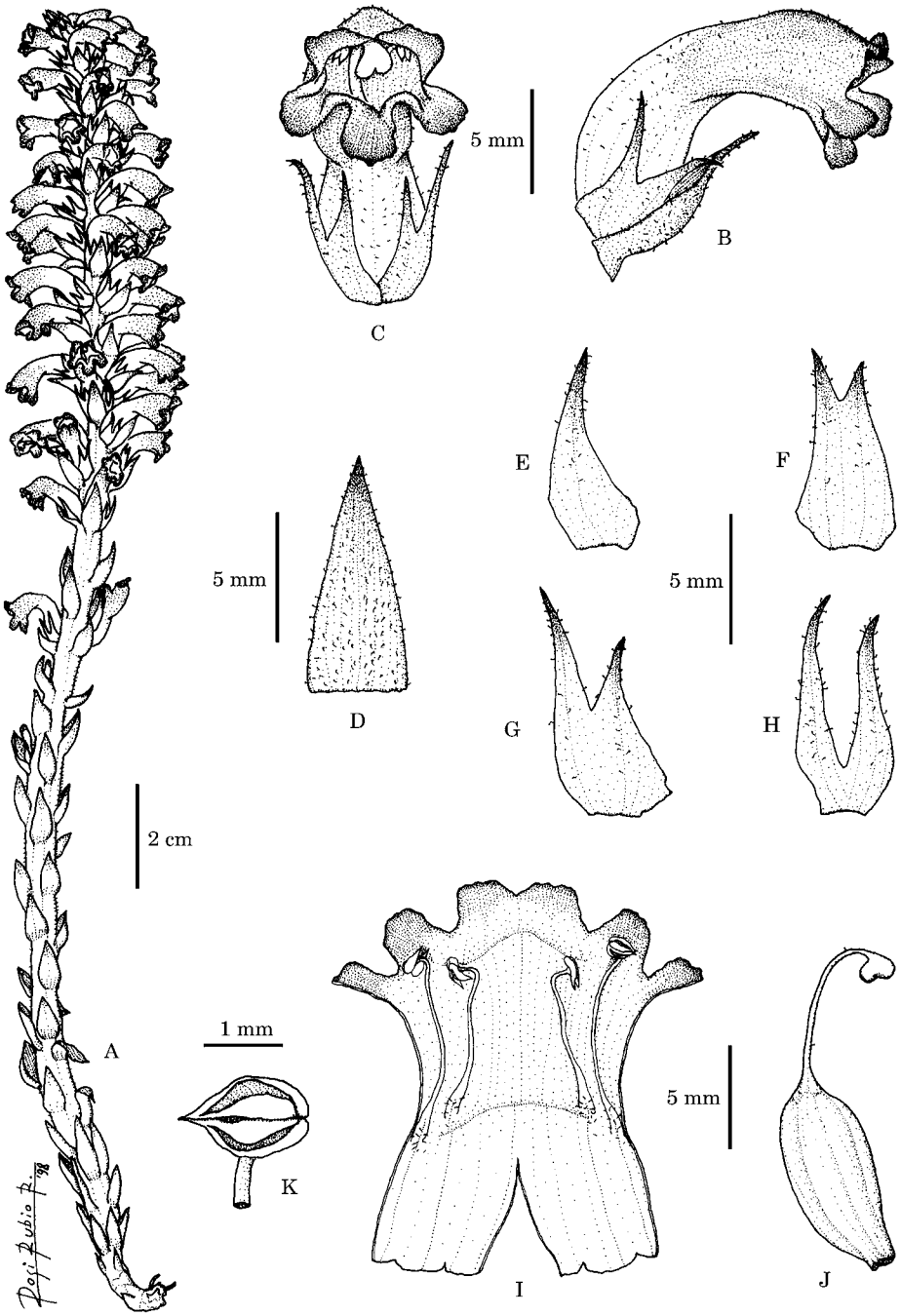

Figure 1. *Orobanche cernua* L., Almería, Níjar, Cerro Majada Redonda, COA 17353. A, appearance. B, flower, side view. C, flower front view. D, bract. E, F, G, H, calyx segments. I, open corolla and androecium. J, gynoecium. K, anther.

INFLORESCENCE (4)6–17(23) × (1.8)2–3(3.5) cm, dense, seldom lax at the base. BRACTS (5)7–9(12) × 3.5–5 mm, ovate to lanceolate. CALYX 6–10 mm long; calyx segments free, bifid (cleft 2.5–4 mm) to deeply bifid (cleft up to 7 mm), sometimes bidentate (cleft up to 2.5 mm), seldom entire, with subulate teeth. COROLLA (13)15–18 mm long, erect to erecto-patent, inflated at the base, constricted and straight in the middle, arched forward, dorsal line geniculated above the insertion of the stamens, sparsely glandular-pubescent, white at the base, blue, dark violet or purple in upper part. Upper lip of the corolla bilobed; lobes of the lower lip of the corolla 2–2.2 × 2.3–2.5 mm, subequal, obovate, not ciliate. STAMENS, adaxial with filaments 6–7 mm long, inserted obliquely (5)7–8 mm above the base of the corolla, glabrous or pubescent in the lower part; abaxial stamens with filaments 7–9 mm long, inserted (3)4–6.5 mm above the base of the corolla, glabrous, glabrescent or with woolly hairs at the base. FILAMENTS without glandular hairs below the anthers. ANTHERS (1.1)1.4–1.5 mm long, glabrous or subglabrous (few hairs up to 0.25-mm long), white, with apiculum of 0.1–0.3 mm. OVARY 7–11 mm long, glabrous or sparsely pubescent, with few glandular hairs distributed in the ventral side. STYLE with glandular hairs, sometimes subglabrous or glabrous. STIGMA bilobed, white.

Orobanche cumana Wallr., *Orob. Gen. Diask.* 58 (1825)
= *O. cernua* auct. non L. nec Loefl.
= *O. cernua* subsp. *cumana* (Wallr.) Soó, Feddes Repert. 83: 187 (1972).
= *O. cernua* var. *cumana* (Wallr.) Beck, Biblioth. Bot. 19: 143 (1890).

Iconography. Figure 2; Reichenbach (1829: DCXCI, fig. 926); Kreutz (1995: 90–91)

PLANT (35)40–65 cm tall. STEM slender with a diameter of (3.5)5–8(10) mm in the middle, clavate or slightly bulbous at the base (9–20 mm), glandular-pubescent, whitish. LEAVES deltate below (8–12 × 6–7 mm), and oval-lanceolate above (9–13 × 4–8 mm). INFLORESCENCE, (15)22–30(38) × (2)2.5–3(3.5) cm, lax, sometimes dense in the upper third. BRACTS 7–10 × 4–7 mm, ovate-lanceolate. CALYX (5)7–9 mm long; calyx segments free, entire, seldom bifid (cleft up to 0.5 mm) with markedly unequal subulate teeth. COROLLA (16)19–22 mm long, not or slightly inflated at the base, patent, markedly curvate, dorsal line inflected, sparsely glandular-pubescent, white at the base, white or pale blue in the upper part. Upper lip of the corolla bilobed; lobes of the lower lip of the corolla 2.2–2.5 × 2–2.2 mm, subequal, obovate, not ciliate. STAMENS, adaxial stamens with filaments 6–10 mm long, inserted 6–9 mm above the base of the corolla, glabrous, seldom glabrescent at the base; abaxial stamens with filaments 7–11(13) mm long, inserted (4)4.5–(6)6.5 mm above the base of the corolla, with a bunch of hairs at the base. FILAMENTS with sessile glandular hairs below the anthers. ANTHERS are white, (1.2)1.4–1.6 mm long, hairy (hairs up to 0.25-mm long) at the base of the line of fusion, white, with apiculum c. 0.2 mm. OVARY 8–10 mm long, glabrous. STYLE with short glandular hairs. STIGMA bilobed, white.

Orobanche cumana plants are easily recognized because they are taller, more slender, and with longer and laxer inflorescence than those of *O. cernua*. *O. cumana* also presents paler corollas (white vs pale blue) than the corollas of *O. cernua* (blue, dark violet or purple). Both species also exhibited clear differences for the corolla length and the degree of bending of its dorsal line. A comparative summary of the main morphological differences between both species is presented in Table 2.

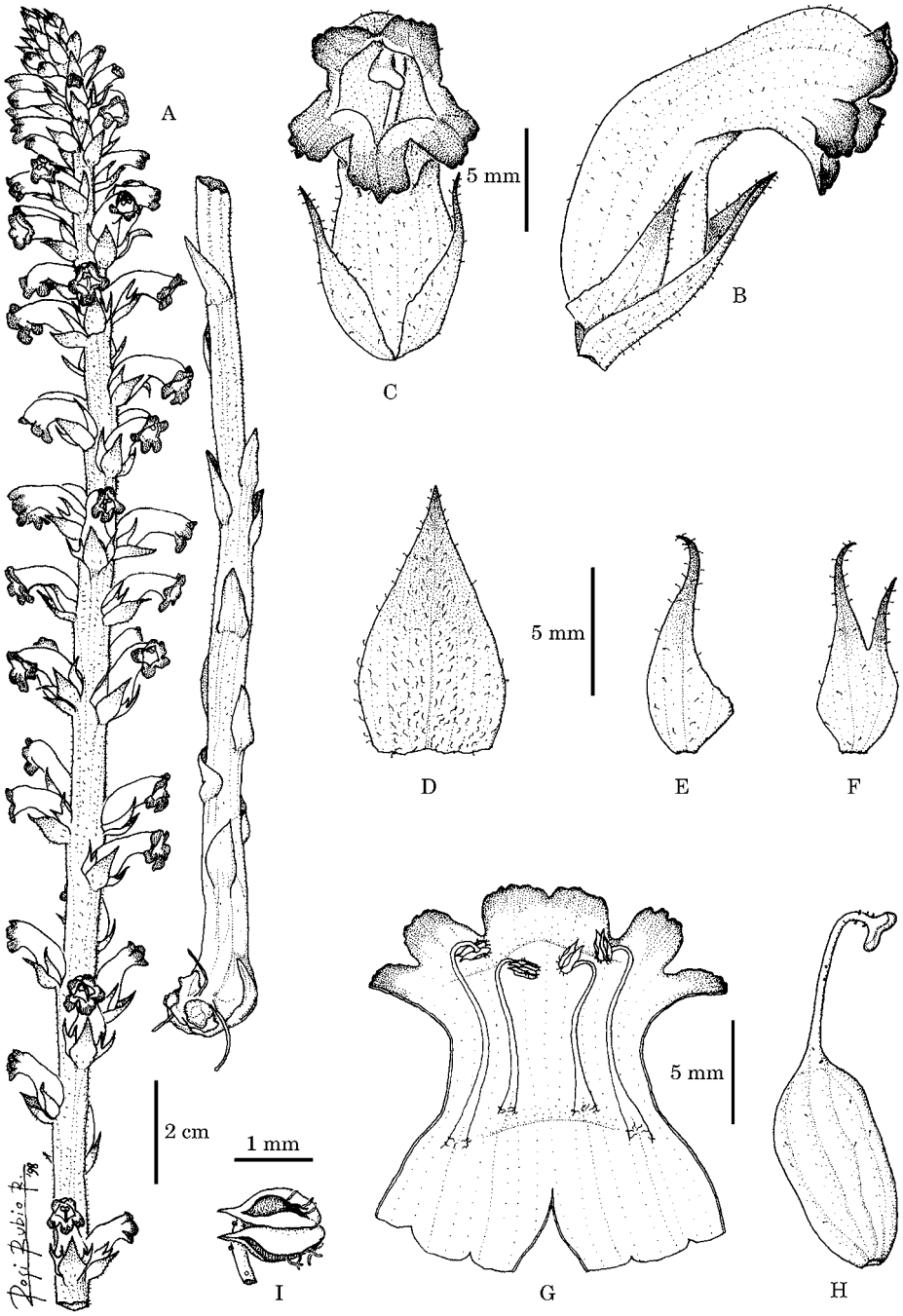

Figure 2. *Orobanche cumana* Wallr., Córdoba, Cortijo del Pardito, COA 23745. A, appearance. B, flower, side view. C, flower front view. D, bract. E, F, calyx segments. G, open corolla and androecium. H, gynoecium. I, anther.

TABLE 2. Morphological differences between *Orobanche cernua* L. and *O. cumana* Wallr.

Trait	*O. cernua*	*O. cumana*
Plant (cm)	15–32	(35)40–65
Upper leaves (mm)	6–11	9–13
Inflorescence (cm)	(4)6–17(23)	(15)22–30(38)
Inflorescence, structure	Dense, seldom lax at the base	Lax, sometimes dense at the apex
Calyx (mm)	6–10	(5)7–9
Calyx segments	Bifid to bidentate, seldom entire	Entire, sometimes bifid
Corolla (mm)	(13)15–18	(16)19–22
Corolla, position	Erect to erecto-patent	Erecto-patent to patent
Corolla, dorsal line	Geniculate	Inflected
Corolla, upper part, colour	Dark blue to violet	Whitish to pale blue
Filaments, apex	Glabrous	Sessile glandular hairs
Anthers	Glabrous or subglabrous	Hairy
Ovary	Glabrous or sparsely pubescent	Glabrous
Style	With glandular hairs to glabrous	With glandular hairs
Hosts	*Artemisia* spp., *Launaea lanifera*	*Helianthus annuus*
Habitat	Loamy gypsaceous soils	Alluvial loamy soils
Altitude (m)	0–1500	0–800
Anthesis	March to June	June to August

Habitat, distribution and phenology

Orobanche cernua was found on loamy gypsaceous soils, in arid areas of degraded, xerothermic scrub, parasitizing *Artemisia* spp. (*A. barrelieri* Besser, *A. campestris* L. subsp. *glutinosa* [J. Gay ex DC.] Batt., *A. caerulescens* L. subsp. *gallica* [Willd.] K. M. Perss., *A. herba-alba* Asso) and *Launaea lanifera* Pau, at altitudes between sea level and 1500 m. Anthesis was from March to June. The main distribution areas for this species in the Iberian Peninsula are the north-east, east, and south-east but it is also found in the central region (Fig. 3).

Orobanche cumana was exclusively found on cultivated land, as a parasite of sunflower (*Helianthus annuus* L.), on alluvial loamy soils at altitudes between sea level and 800 m. Anthesis was from June to August. It is distributed throughout the area of cultivation of sunflower in the central and southern Iberian Peninsula (Fig. 3).

The above results indicate that *O. cernua* and *O. cumana* have a different distribution within the Iberian Peninsula, where they are adapted to different ecological niches. They do not coexist but their distribution areas are nearly in contact in central and southern Spain. The possibility of cross-pollination is very low due to differences in anthesis period. No populations of *O. cernua* have been detected on cultivated sunflower nor have plants of *O. cumana* been reported parasitizing wild species in the Iberian Peninsula, despite the fact that both *O. cumana* was introduced and sunflower cultivation commenced in Spain some decades ago (Díaz-Celayeta, 1974).

Oil content and fatty acid composition

The analysed populations of *O. cernua* and *O. cumana* were characterized by similar levels of seed oil content, but clearly differed in their fatty acid composition (Table 3). Oleic acid was the predominant fatty acid in the seed oil of all populations of *O. cernua*, ranging from 49.6% to 68.1%, whereas linoleic acid was predominant in

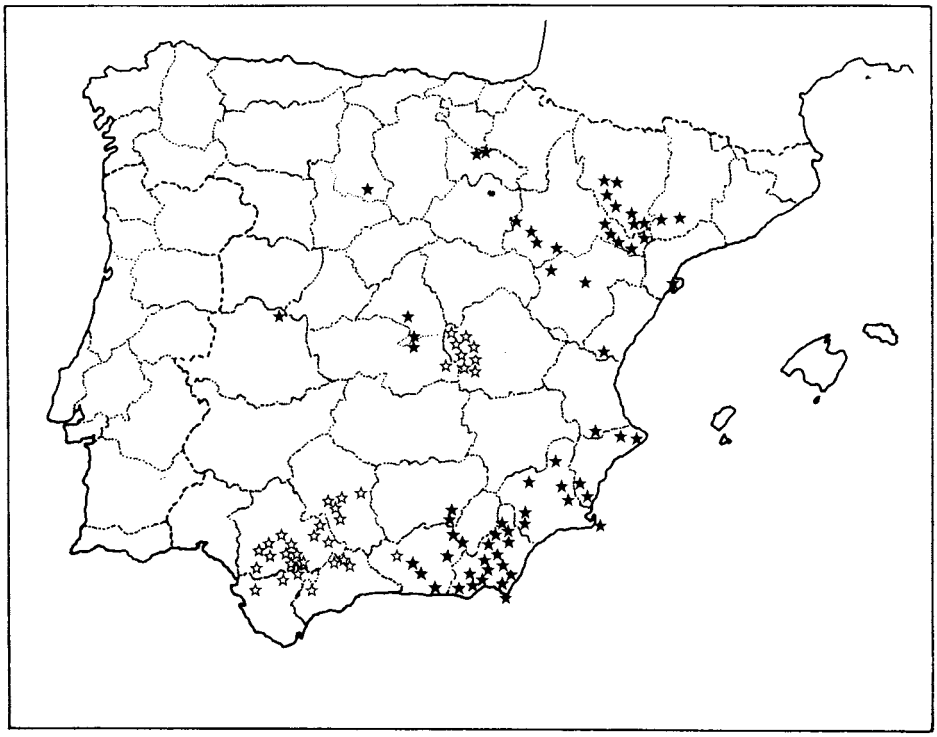

Figure 3. Distribution of *Orobanche cernua* (★) and *O. cumana* (☆).

Table 3. Number of analysed populations, seed oil content (% fresh seed weight), and fatty acid composition (% of the total fatty acids) of *Orobanche cernua* and *O. cumana* from the Iberian Peninsula

	O. cernua				*O. cumana*			
Trait	*n*	Mean	Min.	Max.	*n*	Mean	Min.	Max.
Oil	27	20.2	10.7	32.1	17	18.3	11.1	29.1
Palmitic acid	27	5.0	3.4	6.9	17	2.9	1.7	4.5
Stearic acid	27	1.9	1.0	4.2	17	1.3	1.0	1.9
Oleic acid	27	57.9	49.6	68.1	17	34.8	29.7	43.4
Linoleic acid	27	35.2	26.1	39.6	17	61.0	53.0	66.3

O. cumana, with concentrations from 53.0% to 66.3% (Table 3). Both species also differed in their concentrations of the saturated palmitic and stearic acid, which were present at higher concentrations in *O. cernua*. Figure 4 shows the frequency distribution for linoleic acid concentration in the analysed populations, which clearly reveals the differences for this trait between both species. There are previous studies revealing that quantitative differences in the seed oil fatty acid proflile may act as chemotaxonomic markers, for example in the genera *Linum*, Linaceae (Rogers, 1972) and *Epilobium*, Onagraceae (Velasco & Goffman, 1999). Although the significance and potential contribution of this trait to the infrageneric classification of *Orobanche* has not been yet defined, the consistent differences for seed oil fatty acids between

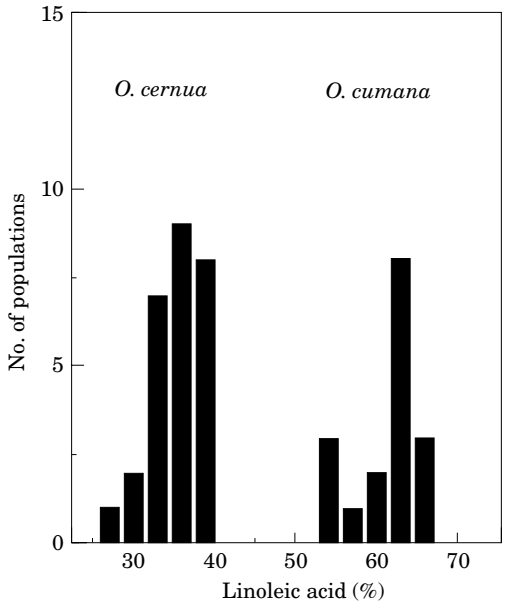

Figure 4. Frequency distribution of linoleic acid concentration (% of the total seed oil fatty acids) in 27 populations of *Orobanche cernua* and 17 populations of *O. cumana*.

O. cernua and *O. cumana* populations in the Iberian Peninsula might be relevant for the classification of both taxa.

CONCLUSIONS

Our evaluation of *O. cernua* and *O. cumana* populations in the Iberian Peninsula revealed significant differences between both species. *Orobanche cumana* is an allochthonous species of the Iberian Peninsula, with its main distribution area in central Asia and eastern Europe. In contrast, *O. cernua* is an autochthonous species mainly distributed in the Mediterranean basin and in markedly arid areas eastwards. The results of the present study revealed that the populations of both taxa in the Iberian Peninsula show clear ecological, morphological and biochemical differences, thus giving additional support to those authors considering them as separate species.

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