



Fruit morphology in *Tragopogon* L. (Compositae: Lactuceae) from the Iberian Peninsula

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Achenes of all the *Tragopogon* species from the Iberian Peninsula were examined by means of scanning-electron microscopy and stereomicroscopy. The achenes of the eight species are described, illustrated and compared. The results are contrasted with the systematics of this genus. The isolated position of *T. lamottei* with regard to the other seven species is noted. A key is provided to enable the different species to be distinguished.

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ADDITIONAL KEY WORDS:—achene – fruit-coat – identification key – polyploidy – SEM – systematics.

CONTENTS

Introduction	319
Material and methods	320
Results	321
Discussion	325
Key to <i>Tragopogon</i> species of the Iberian Peninsula based on achene features	326
Acknowledgements	326
References	327
Appendix	328

INTRODUCTION

The genus *Tragopogon* L. comprises approximately 100 species distributed throughout Europe, temperate Asia and North Africa, principally in southwestern to central Asia, with a number of widely introduced species (Bremer, 1994). In the Mediterranean region the highest diversity within this genus is found towards the east; Rechinger (1977) catalogued 37 species for the flora of Iran (17 endemic to the area), none of which reached Europe. Although some twenty species are listed in *Flora Europaea*, Richardson (1976) limits the presence in the Iberian Peninsula to

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only four, whereas Blanca & Díaz de la Guardia (1996) listed eight species for the same area (*T. porrifolius* L., *T. angustifolius* Bellardi ex Willd., *T. crocifolius* L., *T. castellanus* Levier in Leresche & Levier, *T. pratensis* L., *T. pseudocastellanus* Blanca & C. Díaz, *T. lamottei* Rouy, and *T. dubius* Scop.). *T. hybridus* L. has been excluded from the genus, as it is considered to belong to the monotypic genus *Geropogon* L. (Wilson, 1982; Díaz de la Guardia & Blanca, 1988a,b).

The genus comprises annual, biennial or mostly perennial herbs, with entire and parallel-veined leaves, involucre bracts in one row, and achenes (cypselas) muricate or scabrous, almost always with a long beak. Habitats range from rocky places and semi-deserts to montane grasslands, pastures and cultivated ground.

Achene features have been successfully used for the taxonomic clarification of a wide range of *Compositae* groups (Lavialle, 1912; Briquet, 1916, 1930a,b; Grau, 1980; Dittrich, 1968, 1969, 1970, 1985, 1996; Mouradian, 1995, etc). They have also been used for a number of different taxonomic levels for the tribe *Lactuceae* (Ownbey, 1950; Stebbins, 1953; Richardson, 1976; Tomb, 1977; Díaz de la Guardia & Blanca, 1987; Blanca & Díaz de la Guardia, 1996, etc).

Scanning electron microscopy (SEM) facilitates the observation of structures that would be difficult to observe by other means, and numerous authors (e.g. Seavey, Magill & Raven, 1977; Juan, Pastor & Fernandez, 1994) have demonstrated the importance of SEM in the study of the surface features of fruits and seeds.

In this paper the results of a study of fruit-coat morphology using SEM are reported. It is shown that in the genus *Tragopogon* detailed analysis of the achenes enables the Iberian taxa to be separated, providing excellent taxonomic characters that may be used to distinguish species, in conjunction with more orthodox methods (e.g. ligule colour, peduncle thickness or the number of involucre bracts). Furthermore, carpological factors enable samples to be identified even when no flowers are present. Other suitable applications include identification of herbarium specimens in which the thickness of the peduncle may have been exaggerated by over-pressing, or specimens with an unusual number of bracts for the species concerned.

MATERIAL AND METHODS

The material used for this study was mainly collected directly from wild populations, but occasionally achenes were obtained from wild herbarium specimens. In all cases, mature achenes from the peripheral flowers of the capitulum were used. Mature fruits were measured and low-magnification observations were made with a ZEISS stereomicroscope. Fruit length data are based on the measurement of 50–100 fruits per taxon.

For SEM, the achenes of all species were directly mounted on stubs using colloidal silver, coated with gold/palladium in a vacuum evaporator and observed with a DSM950 ZEISS SEM. Microphotographs were taken of the body of the achene, the apex of the beak (and annulus) and the transitional area between the two.

The terminology of fruit-coat surface sculpturing basically follows Stearn (1973) and Font Quer (1979). A list of representative voucher specimens is held in the Herbarium of the University of Granada (GDAC). The locations from which materials were obtained are shown in the Appendix.

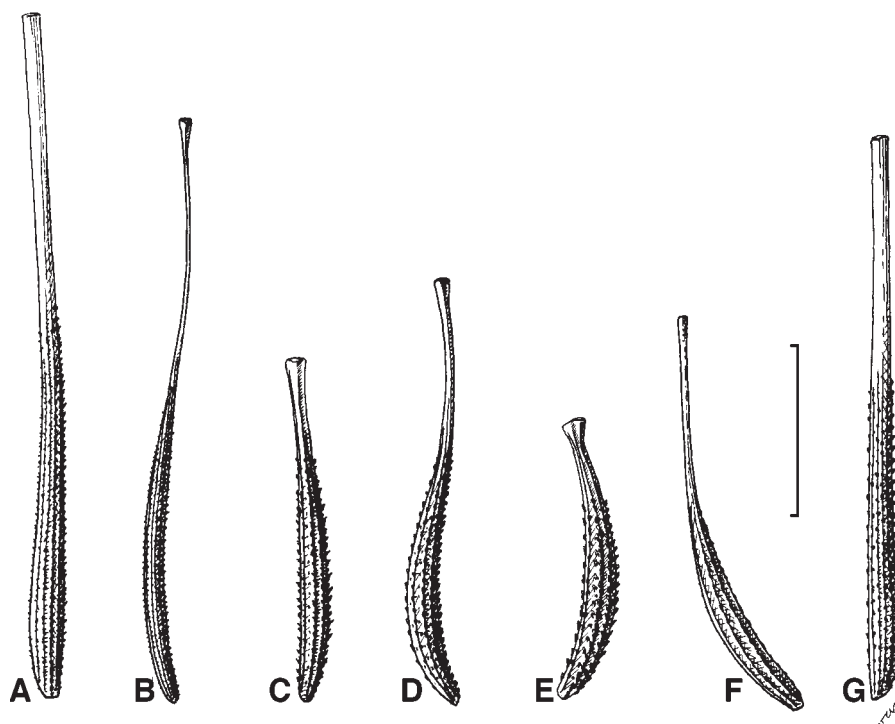


Figure 1. General view of the achenes (excluding pappus) of: A, *T. porrifolius*; B, *T. angustifolius*; C, *T. crocifolius*; D, *T. castellanus*; E, *T. pratensis*; F, *T. lamottei*; G, *T. dubius*. Scale bar = 1 cm.

RESULTS

The mature achenes of all the species examined range in size from 17 to 45 mm (including beak); the smallest are presented by *T. pratensis* (17–22 mm; Fig. 1E) and the largest by *T. porrifolius* (35–45 mm; Fig. 1A). They are fusiform in outline, glabrous, with 5–10 ribs, usually scabrous or muricate-pappilous, tapering towards a long tetragonal or subcylindrical beak, often club-shaped at the apex; annulus woolly or glabrous. The pappus is composed of two rows of setaceous, feathery hairs; *T. crocifolius*, *T. upratensis* and *T. pseudocastellanus* present the shortest pappus (15–23 mm), whereas in the remaining species the pappus ranged from 20 to 30 mm, except in *T. lamottei* where it may be somewhat shorter (18–24 mm).

The body of the achene is curved to a greater or lesser degree, except in *T. porrifolius* (Fig. 1A) and *T. dubius* (Fig. 1G), where it is virtually straight. In *T. porrifolius*, *T. angustifolius* and *T. dubius* the 10 ribs are almost equal, whereas in the other species there are 5–7 primary ribs (5 barely discernible ones in *T. lamottei*; Fig. 8A). The ornamentation of the intercostal gaps is reticulate or reticulate/scalelike, except in *T. dubius* (Fig. 9A), which presents an exceptional character with highly decurrent ornamentation, such that the intercostal gaps, for example, are totally hidden.

The tapering of the body of the achene towards the beak may be either sharp (e.g. *T. lamottei*; Figs 1F and 8B) or more gradual (e.g. *T. porrifolius*; Figs 1A and 2B).

The beak is usually of similar length to that of the body of the achene and seldom longer (e.g. *T. angustifolius*, Fig. 1B); in *T. crocifolius* (Fig. 1C) and *T. pratensis* (Fig. 1E)

the beak reaches only half the body length of the achene. The beak is usually tetragonal and to some extent swollen at the apex (e.g. Fig. 3C), with the exception of *T. porrifolius* (Fig. 2C) and *T. lamottei* (Fig. 8C), which have a subcylindrical beak with no apical swelling. The beak is relatively thick in *T. uporriifolius* (Fig. 11A) and *T. dubius* (Fig. 1G), and filiform in *T. angustifolius* (Fig. 1B) and *T. lamottei* (Fig. 1F); in the remaining species it is somewhere between these two extremes.

The achene features of the eight *Tragopogon* species present in the Iberian Peninsula are as follows.

Tragopogon porrifolius L. (Figs 1A and 2)

Achenes 35–45 mm long (body 16–24 mm, beak 14–24 mm), only slightly curved or straight, gradually tapering towards a beak, relatively thick. Body with 10 ribs, all quite similar and to some extent scabrous or muricate. Prickles not curved. Intercostal gaps irregularly reticulate/scalelike. Subcylindrical beak, with 8 striae, longitudinal, barely discernible; no apical swelling. Annulus somewhat woolly.

Tragopogon angustifolius Bellardi ex Willd. (Figs 1B and 3)

Achenes 30–40 mm long (body 15–18 mm, beak 14–21 mm), somewhat curved, gradually tapering towards a beak, relatively slender. Body with 10 fairly similar ribs, scabrous. Prickles slightly hooked. Intercostal gaps reticulate/scalelike. Beak filiform, tetragonal, notably club-shaped at the apex. Annulus woolly.

Tragopogon crocifolius L. (Figs 1C and 4)

Achenes 18–25 mm long (body 13–18 mm, beak 6–8 (–10) mm), slightly curved, gradually tapering towards the beak. Body with 5 primary ribs, scabrous, alternating with 5 less prominent secondary ribs with less marked ornamentation. Prickles hooked at the apex. Intercostal gaps reticulate. Beak tetragonal, with winged keels, club-shaped at the apex. Annulus glabrous or slightly woolly.

Tragopogon castellanus Levier in Leresche & Levier (Figs 1D and 5)

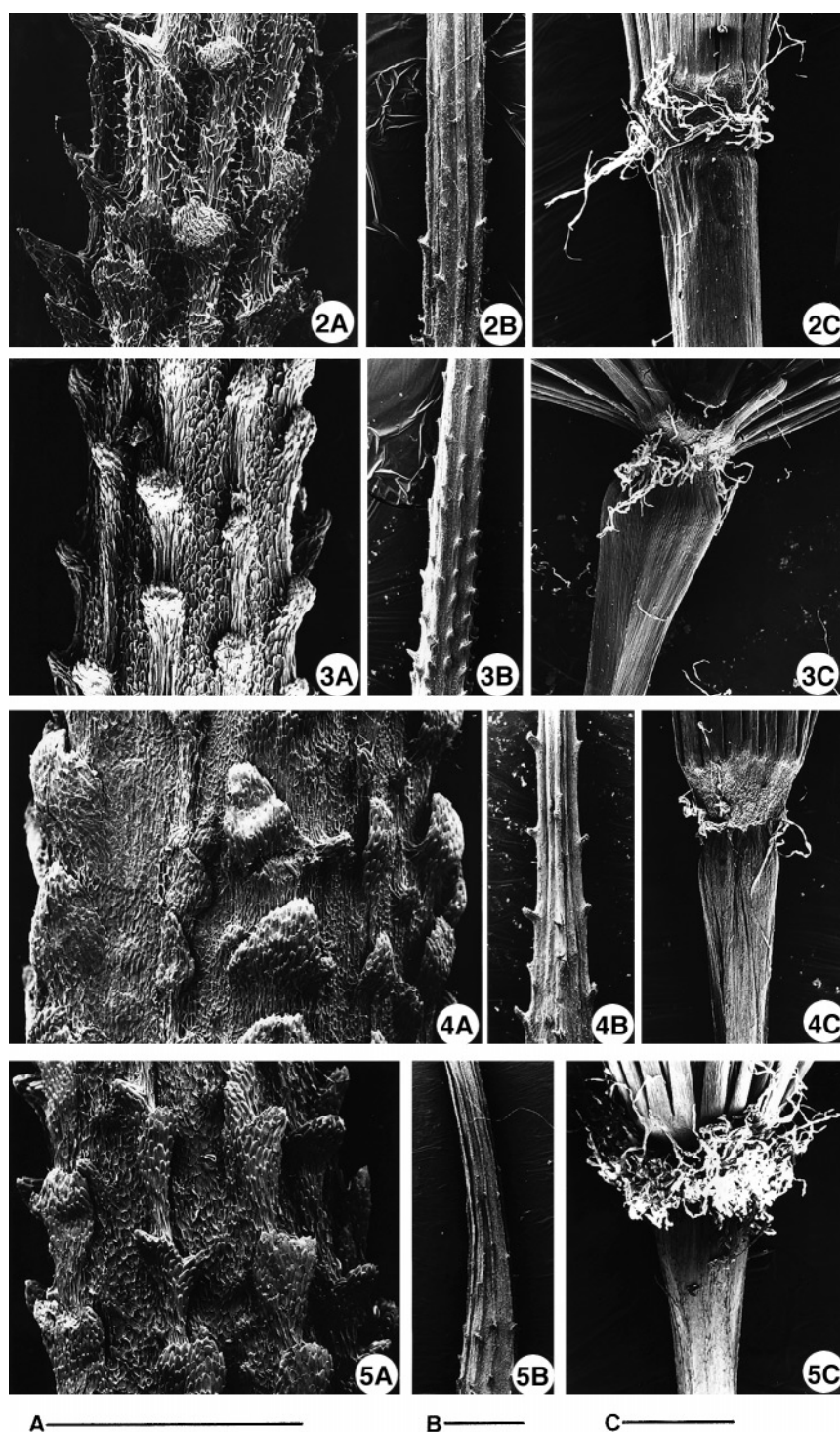
Achenes 23–30 mm long (body 14–17 mm, beak 8–11 mm), curved, tapering sharply towards a filiform beak. Body with 5–7 muricate primary ribs, alternating with 5 less prominent secondary ribs with less marked ornamentation. Intercostal gaps reticulate. Beak tetragonal, with keels winged or acute, club-shaped at the beak. Annulus densely woolly.

Tragopogon pratensis L. (Figs 1E and 6)

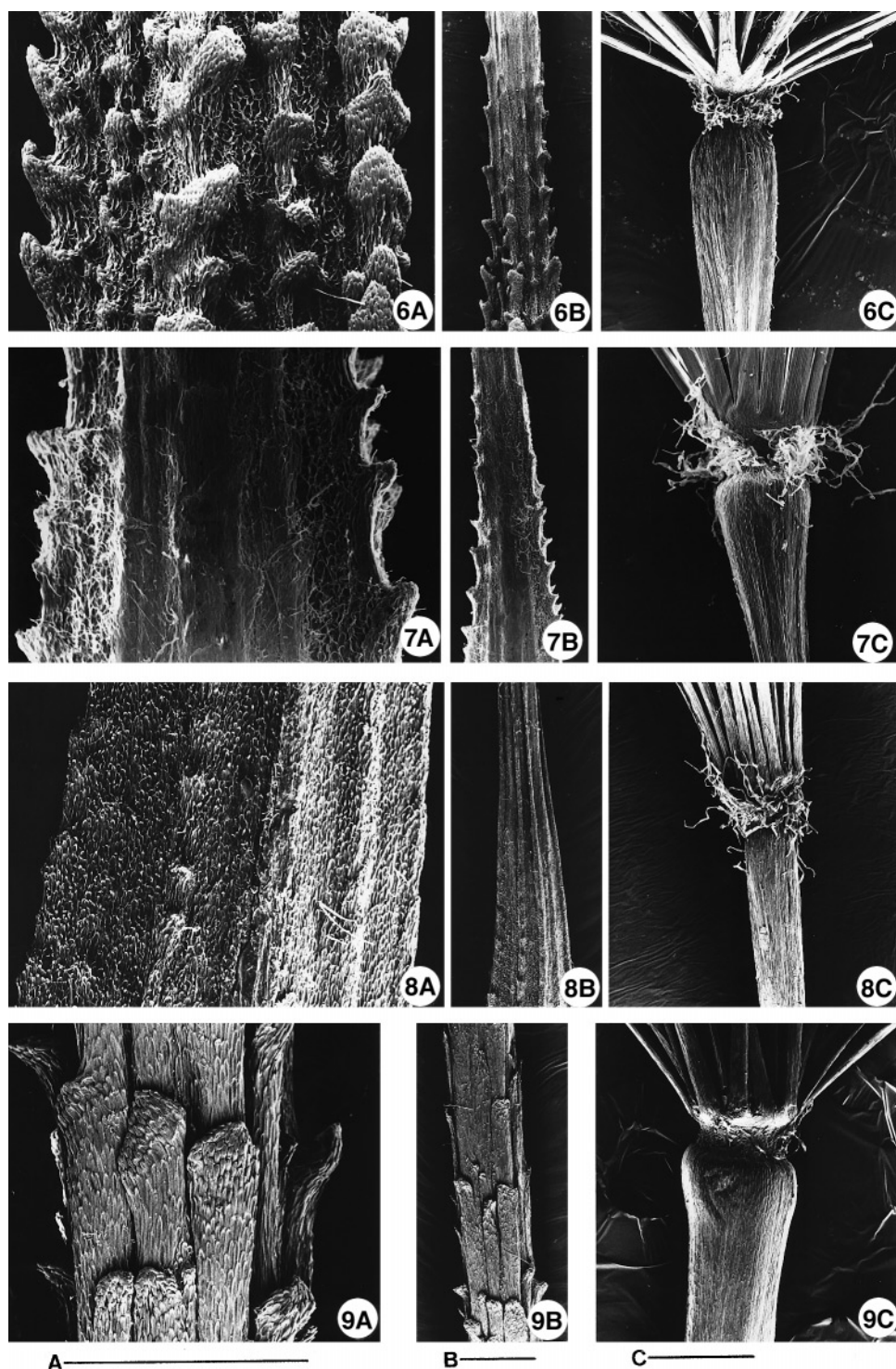
Achenes 17–22 mm long (body 12–16 mm, beak 4–6 mm), similar to those of *T. crocifolius*; beak with keels winged or acute and annulus shortly woolly.

Tragopogon pseudocastellanus Blanca & C. Díaz (Fig. 7)

Achenes 20–25 mm long (body 12–14 mm, beak 7–10 mm), curved, sharply tapering towards the beak. Body with 5–7 muricate primary ribs, alternating with 5 less prominent secondary ribs with less marked ornamentation; intercostal gaps reticulate. Beak tetragonal, with keels winged or acute, notably club-shaped at the apex. Annulus woolly.



Figures 2–5. SEM details of the achenes of: 2, *T. porrifolius*; 3, *T. angustifolius*; 4, *T. crocifolius*; 5, *T. castellanus*. A, detail of body; B, body/beak transitional area; C, apex of beak and annulus. Scale bars = 1 mm.



Figures 6–9. SEM details of the achenes of: 6, *T. pratensis*; 7, *T. pseudocastellanus*; 8, *T. lamottei*; 9, *T. dubius*. A, detail of body; B, body/beak transitional area; C, apex of beak and annulus. Scale bars = 1 mm.

Tragopogon lamottei Rouy (Figs 1F and 8)

Achenes 22–28 mm (body 10–15 mm, beak 10–14 mm), curved, sharply tapering towards a filiform apex. Body with 5 scarcely marked ribs, slightly muricate or simply ridged, alternating with 5 intercostal gaps, longitudinally striate. Surface uniformly reticulate/scalelike. Beak subcylindrical, with 8 striae, barely discernible, longitudinal, and no swelling at the apex. Annulus woolly.

Tragopogon dubius Scop. (Figs 1G and 9)

Achenes 15–35 mm long (body 13–16 mm, beak 12–18 mm), straight, gradually tapering towards a relatively thick beak. Body with 10 ribs, muricate, with ornamentation longitudinally decurrent, which often obstruct observation of the intercostal gaps. Beak slightly tetragonal or subcylindrical, somewhat bulbous at the apex. Annulus glabrous or nearly glabrous.

DISCUSSION

Observation of the achenes of the genus *Tragopogon* using SEM and stereomicroscopy has revealed numerous valid characters for the separation and identification of the different taxa. Thus, the size, body shape, number of ribs, prickles, ornamentation of the intercostal gaps, type of tapering (sharp or gradual) where the body and beak meet, shape of beak and degree of swelling at the apex, and pubescence of the annulus are features that characterize the species.

With regard to the systematics of this genus, few authors have separated subgenera or sections, particularly for the eastern flora (e.g. Boissier, 1875; Lipschitz, 1964; Rechinger, 1977), resulting in rather unsatisfactory and somewhat artificial groups. In the floras for western Europe, the species are almost invariably grouped by flower colour (e.g. Richardson, 1976), following the criteria of Boissier (l.c.) who distinguished two subsections for this genus: *Rubriflora* (ligules lilac, violet, purple or reddish-purple), which would include *T. porrifolius*, *T. angustifolius*, *T. crocifolius* and *T. castellanus* of the species studied here, and *Flaviflora* (ligules yellow, sometimes orange-reddish) which would include *T. pratensis*, *T. pseudocastellanus*, *T. lamottei* and *T. dubius*. However, the achene features disagree significantly with such a systematic arrangement: for example, *T. porrifolius* (ligules purple) and *T. dubius* (ligules yellow) have achenes which share many similar features, as also occurs with the pair *T. crocifolius* (ligules reddish-violet to purple) and *T. pratensis* (ligules pale yellow).

T. lamottei, a little known or studied species, has sometimes been considered as a synonym of *T. pratensis* (see Diaz de la Guardia & Blanca, 1988c). Owing to its achene features it stands out as being rather different from the other species studied, and has little in common with *T. pratensis*. These results agree with karyological studies, as the karyotype of *T. lamottei* (Diaz de la Guardia & Blanca, 1988c) is significantly different from that of *T. pratensis* (Dvorak, Trnka & Dadakova, 1978; Diaz de la Guardia & Blanca, 1988a–c) and other species of the genus (e.g. *T. porrifolius* and *T. crocifolius*, cf. Diaz de la Guardia & Diaz de la Guardia, 1992, and *T. dubius*, cf. Dvorak *et al.*, 1978). All these species present $2n=12$, but whilst *T. lamottei* has 4 chromosomes with centromere in the median region, 6 submedian and 2 subterminal (4m + 6sm + 2st), the remaining species all present a chromosome formula of 6m + 6sm.

Lastly, the polyploidy of two of the species studied implies no appreciable increase in achene size in relation to the most closely related species, in contrast with pollen size, which is clearly greater in polyploid species (Díaz de la Guardia & Blanca, 1988d; Blanca & Díaz de la Guardia, 1996). Thus, *T. castellanus* ($2n=24$; cf. Wilson, 1983, and Díaz de la Guardia & Blanca, 1990) has achenes of similar size to those of *T. crocifolius* ($2n=12$), although other details of the achenes enable both species to be distinguished. The same occurs between *T. pseudocastellanus* ($2n=24$; cf. Blanca & Díaz de la Guardia, 1996) and *T. pratensis* ($2n=12$). Moreover, the morphological features of the achenes of the two polyploid species, *T. castellanus* and *T. pseudocastellanus* are so similar that it is far from easy to tell them apart.

The results obtained from the present study indicate that in order to obtain adequate systematics for the genus *Tragopogon* schemes must be devised that integrate information from several sources, among which achene features will without doubt play a key role, since those features considered in the present paper are alone sufficient to distinguish the species of the Iberian Peninsula. The key presented below enables the species studied to be separated.

KEY TO *TRAGOPOGON* SPECIES OF THE IBERIAN PENINSULA BASED ON ACHENE FEATURES

1. Annulus glabrescent; body ornamentation longitudinally decurrent and appressed, hiding the intercostal gaps *T. dubius*
- 1'. Annulus woolly to some extent; intercostal gaps clearly visible 2
2. Achenes 34–45 mm long 3
- 2'. Achenes 17–30 mm long 4
3. Beak subcylindrical, not swollen at apex *T. porrifolius*
- 3'. Beak tetragonal, notably club-shaped at apex *T. angustifolius*
4. Body with ribs barely discernible, non-ornamented; beak not swollen at the apex *T. lamottei*
- 4'. Body with ribs prominent, ornamented; beak club-shaped at the apex 5
5. Body length less than double that of the beak; sharply tapering towards beak 6
- 5'. Body length more than double that of the beak; gradually tapering towards beak 7
6. Achenes 23–30 mm long; beak filiform and annulus densely woolly *T. castellanus*
- 6'. Achenes 20–25 mm; beak slender, non-filiform and annulus slightly woolly *T. pseudocastellanus*
7. Annulus generally glabrescent *T. crocifolius*
- 7'. Annulus woolly *T. pratensis*

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APPENDIX

T. porrifolius.

SPAIN: Cordoba, Rute, 29.v.1982, *Diaz de la Guardia*, GDAC 27515; Córdoba, Sierra Morena, 13.vi.1992, *Melendo*, GDAC 38903; Granada, crtra. Murcia, 20.v.1982, *Diaz de la Guardia*, GDAC 32261; Granada, Hueter, 16.vi.1985, *Diaz de la Guardia*, GDAC 35323; Granada, Orgiva, 23.iv.1983, *Cueto*, GDAC 15318; Granada, Sierra de Cazulas, 12.vi.1990, *Diaz de la Guardia & Blanca*, GDAC 35323; Granada, Sierra de Elvira, 27.vi.1991, *Diaz de la Guardia*, GDAC 35322; Granada, Sierra de Jurena, Huescar, 6.vi.1989, *Romero*, GDAC 32264; Granada, Sierra de Mecina, 10.vi.1981, *Diaz de la Guardia*, GDAC 32263; Granada, Sierra Nevada, 4.vi.1981, *Diaz de la Guardia*, GDAC 32262; Granada, Silla del Moro, iv.1967, *Vano*, GDAC 907; Jaen, Banos de la Encina, 26.v.1981, *Diaz de la Guardia*, GDAC 27514; Malaga, Campillos, 1.v.1983, *Diaz de la Guardia & Valle*, GDAC 32256.

T. angustifolius

SPAIN: Cordoba, Sierra Morena, 30.iv.1992, *Melendo*, GDAC 38887; Córdoba, Sierra Morena, 3.v.1992, *Melendo & Cano*, GDAC 38907; Granada, Bermejales, 19.v.1983, *Cueto*, GDAC 15321; Granada, Iznalloz, 12.v.1989, *Garcia & Gutierrez*, GDAC 33919; Granada, between Pinar and Iznalloz, 26.v.1983, *Cueto*, GDAC 15322; Granada, Sierra de Baza, 9.vi.1983, *Torres, Blanca & Morales*, GDAC 25764; Granada, Sierra de Cazulas, 1.vii.1981, *Diaz de la Guardia*, GDAC 32268; Granada, Sierra de Cazulas, 4.vi.1990, *Diaz de la Guardia & Blanca*, GDAC 35319; Granada, Sierra de Elvira, 26.vi.1991, *D&nodot;az de la Guardia*, GDAC 35318; Granada, Sierra de Guillimona, 17.vii.1983, *Cueto*, GDAC 15324; Granada, Sierra de Hueter, 12.v.1981, *Diaz de la Guardia*, GDAC 32267; Granada, Sierra Nevada, 7.vi.1990, *Diaz de la Guardia*, GDAC 35317; Granada, Sierra Nevada, 26.v.1990, *Diaz de la Guardia & Blanca*, GDAC 35320.

T. crocifolius

SPAIN: Albacete, between Alcaraz and Riopar, 10.vii.1982, *Diaz de la Guardia*, GDAC 27510; Huesca, Jaca, 3.viii.1982, *Diaz de la Guardia*, GDAC 27509; Granada, Lanjaron, 30.vi.1982, *Diaz de la Guardia*, GDAC 27511; Granada, Pto. Mora, 18.vi.1983, *Cueto*, GDAC 15309; Granada, Pto. Ragua, 10.vi.1981, *Diaz de la Guardia*, GDAC 32276; Granada, Sierra de Alfacar, 25.vi.1984, *Diaz de la Guardia*, GDAC 27512; Granada, Sierra de Baza, 8.vi.1983, *Cueto*, GDAC 15311; Granada, Sierra de Baza, 29.vi.1983, *Cueto*, GDAC 15312; Granada, Sierra de Baza, 29.vi.1984, *Torres, Blanca & Morales*, GDAC 25763; Granada, Sierra de Guillimona, 17.vii.1983, *Cueto*, GDAC 15313; Granada, Sierra Nevada, 26.vi.1985, *Gutierrez*, GDAC 27532; Jaen, Sierra de Segura, 8.vii.1982, *Diaz de la Guardia & Valle*, GDAC 32277.

T. castellanus

SPAIN: Guadalajara, Algora, 2.viii.1982, *Diaz de la Guardia & Valle*, GDAC 26373; Guadalajara, Atienza, 12.vii.1983, *Diaz de la Guardia & Valle*, GDAC 26371; Guadalajara, between Sigüenza and Alcolea, 12.vii.1983, *Diaz de la Guardia & Valle*, GDAC 26377; Leon, Aviaños, 28.vii.1990, *Garcia*, GDAC 35330; Leon, Herreros, 21.vi.1982, *s/l*, GDAC 26374; Leon, Pto. Ventana, 14.vii.1990, *Garcia*, GDAC 35329; Soria, Medinaceli, 6.viii.1982, *Valle & Blanca*, GDAC 26372; Valladolid, Casas Nuevas, 21.vi.1982, *s/l*, GDAC 26376.

T. pratensis

SPAIN: Almeria, Sierra de Filabres, 10.vi.1990, *Blanca & Cueto*, GDAC 35327; Almeria, Sierra de

Gador, 27.vi.1990, *Blanca & Cueto*, GDAC 35325; Granada, Sierra de Cázulas, 18.vii.1982, *Díaz de la Guardia & Blanca*, GDAC 35306; Granada, Sierra de Cázulas, 4.vi.1990, *Díaz de la Guardia*, GDAC 35309; Granada, Sierra Nevada, 10.vii.1991, *Díaz de la Guardia & Salas*, GDAC 35328; Jaen, Sierra de Cazorla, 21.vi.1990, *Díaz de la Guardia*, GDAC 35311; Jaen, Sierra de Magina, 19.vi.1983, *Díaz de la Guardia & Blanca*, GDAC 35305; Jaen, Sierra de la Pandera, 9.vi.1990, *Blanca*, GDAC 35326; Jaen, Sierra del Pozo, 20.vi.1990, *Díaz de la Guardia*, GDAC 35308; Jaen, Sierra de Segura, 8.vii.1982, *Díaz de la Guardia & Valle*, GDAC 35324; Jaen, Torredelcampo, 17.vi.1983, *Ortiz & Blanca*, GDAC 35307.

T. pseudocastellanus

SPAIN: Leon, Cabrillanes, San Felix de Arce, 30.viii.1986, *García*, LEB 36275.

T. lamottei

SPAIN: Huesca, Benasque, 27.vii.1983, *Ortega*, GDAC 24638; Huesca, between Isaba and Zuriza, 3.viii.1982, *Díaz de la Guardia & Valle*, GDAC 24635; Huesca, Jaca, 4.viii.1982, *Díaz de la Guardia*, GDAC 24639; Huesca, Roncal, 3.viii.1982, *Díaz de la Guardia & Valle*, GDAC 24634; Huesca, Sayen, Diyisoria de la Magdalena, 7.viii.1982, *Díaz de la Guardia*, GDAC 24637; Leon, Busdongo, 1.vii.1994, *Lainz & Díaz Alonso*, GDAC 38859; Leon, San Felix de Arce, 26.vi.1994, *Lainz & Delgado*, GDAC 38861; Leon, Truchas, 22.vi.1982, *Valle & Blanca*, GDAC 24636; Leon, Villamanín, 1.vii.1994, *Díaz Alonso*, GDAC 38860.

T. dubius

SPAIN: Granada, Sierra de Cázulas, 12.vi.1990, *Díaz de la Guardia & Blanca*, GDAC 35314; Jaen, El Oasis, 27.v.1984, *Ortiz & Blanca*, GDAC 35315; Jaen, Sierra de Segura, 7.vi.1989, *Díaz de la Guardia & Blanca*, GDAC 35313; Leon, Villadangos del Paramo, 18.vii.1989, *García*, GDAC 35316; Malaga, Antequera, 8.v.1976, *Guerra*, GDAC 4693.