Achene wall anatomy and surface sculpturing of *Launaea* Cass. (Compositae: Cichorieae) with notes on their systematic significance

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ABSTRACT: This is the first study to deal in-depth with the achene ultra-structure of the genus *Launaea* Cass. in Egypt. It focuses on 12 taxa belonging to 10 species of this genus. The achene wall anatomy and surface sculpturing of those taxa were studied using scanning electron microscopy (SEM). Important aspects of the investigated taxa based on the achene characters as well as SEM micrographs of the achene surface and anatomical sections are given. Main and secondary costa of the inner achenes are used for easy differentiation between *L. intybacea* and *L. massauensis*

Keywords: *Launaea*, achene, SEM, taxonomy, morphology, anatomy

The taxonomy of the genus *Launaea* Cass. has always been problematic due to its confusing taxonomic history. This is reflected in the number of species that have been described. *Launaea* consists of 55 species and is mainly distributed in the S. Mediterranean area and in Africa and S.W. Asia (Kilian, 1997). In Egypt, *Launaea* is the largest genus (by 10 species) of the tribe Cichorieae (Zareh, 2005). Forsskål and Niebuhr (1775) recorded *L. spinosa* (Forssk.) Sch. Bip. ex Kuntze and *L. mucronata* (Forssk.) Muschl.; Boissier (1875) reported 10 taxa for the flora of Egypt, viz. *L. spinosa*, *L. nudicaulis* (L.) Hook. F., *L. massauensis* (Fresen.) Sch. Bip. ex Kuntze, *L. procumbens* (Roxb.) Ramayya & Rajagopal, *L. capitata* (Spreng.) Dandy, *L. angustifolia* subsp. *arabica* (Boiss.) N. Kilian, *L. fragilis* (Asso) Pau subsp. *fragilis*, *L. fragilis* (Asso) Pau subsp. *tenuiloba* (Boiss.) Zareh & Mohamed, *L. mucronata* (Forssk.) Muschl. and *L. cassiniana* (Jaub. & Spach) Kuntze. Muschler (1912) added *L. fragilis* and *L. arabica* (Boiss.) H. Lindb.. Amin (1957) in her thesis sited *L. intybacea* (Jacq.) Beauverd from Egypt, and finally Kilian (1997) reported *L. amal-amine* N. Kilian from Suez and Sinai. Recently, the genus has been subdivided in four sections, i.e., sect. *Acanthosonchus* (Sch. Bip.) O. Hoffm. (*L. spinosa* and *L. acanthodes*), sect. *Microrhynchus* (Less.) O. Hoffm. (*L. nudicaulis*, *L. intybacea* and *L. massauensis*), sect. *Launaea* (*L. capitata*) and sect. *Zollikoferia* (Pomel) O. Hoffm. (*L. angustifolia*,

L. fragilis, *L. mucronata* and *L. cassiniana*) (Kilian, 1997).

Flowers in *Launaea* are yellowish with pubescent corolla tubes. Achenes brownish, blackish, or grayish; it may be homomorphic with 5 main ribs, accompanied by 2 secondary ribs (rarely undistinguished) or heteromorphic with inner achenes 4-main ribbed and marginal achenes 5-main ribbed. It also has pappus white, persistent or deciduous, homomorphic with setaceous rays or dimorphic with downy outer and setaceous inner rays.

Carpological characters enable most Cichorieae species to be identified even when no flowers are present (Blanca and Guardia, 1997). Other suitable applications include the 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 of concern (Blanca and Guardia, 1997).

The term achene was defined by Wagenitz (1976) as a dry type of indehiscent monospermous fruit derived from an inferior ovary. Achene features have been successfully used for the taxonomic classification of a wide range of Compositae groups (Lavialle, 1912; Briquet, 1916, 1930; Dittrich, 1968; Grau, 1980; Mouradian, 1995; Dittrich, 1996; Jan and Mukherjee, 2012; Zareh et al., 2016; Zareh, 1987). They have also been used for a number of different taxonomic levels for the tribe Lactuceae (Ownbey, 1950; Stebbins, 1953;

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Richardson, 1976; Tomb, 1977; De la Guardia and Blanca, 1987; Blanca and Guardia, 1997; Jan and Mukherjee, 2013).

In *Launaea*, the achenes morphology exhibits great diversity, and, as in the entire tribe, provides the most useful features for classification (Kilian, 1997). Appropriate descriptions of certain aspects of the achene morphology in *Launaea*, however, are rare in the literature, particularly concerning achene ribbing patterns. In the cross-sections of achenes, such deviations can be observed much more clearly (Kilian, 1997).

Anatomical sections of the achene were first employed by Lavialle (1912), who studied nearly 83 species of 15 genera of Compositae. Briquet (1916) studied the achene anatomy of the complexes *Chrysanthemum* and *Anthemis*. Achene anatomy studies have proved to be very rewarding to delimit the various taxa (Dittrich, 1968; Merxmüller and Grau, 1977; Haque and Godward, 1984; Mateu and Guemes, 1993; Abid and Kaiser, 2002; Zhu et al., 2006; Abid and Kaiser, 2008; Zareh, 1987). The most recent contribution to the knowledge on achenes anatomy in *Launaea* was provided by Kilian (1997), who studied the achene anatomies of representatives of all sections, only five species of which are represented in this study.

Studies on achene anatomies will be carried out to determine the strength of the systematic position of 12 taxa in the genus *Launaea* from Egypt. The major achene characteristics, including testa's epidermis pattern, are described in detail.

Materials and Methods

The plants used in achene studies were *L. spinosa*, *L. acanthodes* (Boiss.) Kuntze, *L. nudicaulis*, *L. intybacea* (Jacq.) Beauverd, *L. massauensis*, *L. capitata*, *L. angustifolia* subsp.

angustifolia, *L. angustifolia* subsp. *arabica*, *L. fragilis* subsp. *fragilis*, *L. fragilis* subsp. *tenuiloba*, *L. mucronata* and *L. cassiniana* (Table 1).

Dry achene materials for SEM were prepared by mounting them directly onto clean stubs using double-sided adhesive tape, followed by coating with gold in a JEOL JFC 1100E ion-sputtering device and then an examination using a JEOL JSM 5400 LV scanning electron microscope operated in an accelerated mode. The terms of Stearn (1966), Stant (1973), Barthlott (1981) and Boesewinkel and Bouman (1984) were used to describe the achene coat characteristics.

For the achene anatomy, dry achenes were boiled in water and then sectioned at 10–15 µ after being embedded in paraffin wax using a method described by Johansen (1940). The sections were stained using safranin (2% in 50% ethanol) and light green (1% in 95% ethanol). They then then permanently mounted in Canada Balsam.

The terminology of the achene wall anatomy essentially follows Lavialle (1912), Esau (1977), Kaul and Singh (1982) and Pak et al. (2001). The applied abbreviations to denote the details of the different layers of the achenes are as follows: e: epidermis, pm: primary mid rib, sm: secondary mid rib, par: parenchyma, scl: sclerenchyma, vb: vascular bundle, ec: endocarp, and sc: seed coat.

Results and Discussion

The achene of *Launaea* were brownish, blackish, or grayish; cylindrical to columnar; compressed or not, 2.5–8.0 × 0.4–2.0 mm; subterete or prismatic; apex truncate, cuneate or attenuate; base truncate, tubular or horned; glabrous or

Table 1. Voucher information for morphological examination of *Launaea* species in Egypt.

Taxon	Voucher information
<i>L. spinosa</i> (Forssk.) Sch. Bip. ex Kuntze	El Tur, 13.Jan.1930, <i>EL-Hefnawi s.n.</i> (CAIM)
<i>L. acanthodes</i> (Boiss.) Kuntze	Wadi Telah, 7.Oct.1983, <i>Fayed & Zareh s.n.</i> (ASTU)
<i>L. nudicaulis</i> (L.) Hook. F.	Wadi Hagol, 13.April.2010, <i>Zareh & Aboul-Ela s.n.</i> (ASTU)
<i>L. intybacea</i> (Jacq.) Beauverd	Wadi Laseitit, 7.Feb.1962, <i>Täckholm et al. 1687</i> (CAI)
<i>L. massauensis</i> (Fresen.) Sch. Bip. ex Kuntze	Wadi Abu Ghusun, 7.March.1989, <i>Zareh & Fargali s.n.</i> (ASTU)
<i>L. capitata</i> (Spreng.) Dandy	AL-Oimed, 5.April.2012, <i>Zareh & Aboul-Ela s.n.</i> (ASTU)
<i>L. angustifolia</i> (Desf.) Kuntze subsp. <i>angustifolia</i>	Alamein Alexandria road, 10.April.2010, <i>Zareh & Aboul-Ela s.n.</i> (ASTU)
<i>L. angustifolia</i> subsp. <i>arabica</i> (Boiss.) N. Kilian	Siwa, 29.Dec.1969, <i>Zahrán s.n.</i> (CAI)
<i>L. fragilis</i> (Asso) Pau subsp. <i>fragilis</i>	Sidi Abdel Rahman, 4.April.2012, <i>Zareh & Aboul-Ela s.n.</i> (ASTU)
<i>L. fragilis</i> subsp. <i>tenuiloba</i> (Boiss.) Zareh & Mohamed	Alexandria-Matrouh, K. 137, 4.April.2012, <i>Zareh & Aboul-Ela s.n.</i> (ASTU)
<i>L. mucronata</i> (Forssk.) Muschl.	Wadi Hagol, 13.April.2010, <i>Zareh & Aboul-Ela s.n.</i> (ASTU)
<i>L. cassiniana</i> (Jaub. & Spach) Kuntze	Mersa Alam-Abu Ghusun road, 8.March.1989, <i>Zareh & Faraghali s.n.</i> (ASTU)

Table 2. External morphology of *Launaea* achenes.

Taxon	Dimension (mm)	Achene morphism	Apex	Base	Marginal achenes							Anticlinical wall	Periclinical wall
					Primary rib number	Secondary rib number	Shape	Color	Surface	Epidermal cell shape	Secondary cell wall		
<i>L. spinosa</i>	3.0–3.5 × 0.6–0.9	subhomo	truncate	horned	5	2	oblong-obovate	dark brown	transversely wrinkled	reticulate	obscure with obtuse projections	straight raised	concave
<i>L. acanthodes</i>	7–8 × 0.8–0.9	subhomo	attenuate	truncate	5	2	oblanceolate	brownish	transversely wrinkled	reticulate	fusiform with acute projections	straight raised	concave
<i>L. nudicaulis</i>	3–3.5 × 0.6–0.7	hetero	truncate	truncate	5	2	oblong	dark brown to black	acuminate wrinkles	irregular	undiffer.	straight raised	concave
<i>L. intybacea</i>	3–3.5 × 0.5–0.7	hetero	attenuate	truncate	5	2	sub-cylindrical	brown	acute wrinkles	bone-shaped	undiffer.	depressed straight	concave
<i>L. massauensis</i>	2.5–3 × 0.5–0.7	hetero	attenuate	truncate	5	2	sub-cylindrical	black	acute wrinkles	bone-shaped	undiffer.	depressed straight	concave
<i>L. capitata</i>	2.5–3 × 1.0–1.5	hetero	truncate	truncate	5	2	oblong	pale yellow	acute wrinkles	rectangular	undiffer.	raised straight	concave
<i>L. angustifolia</i> subsp. <i>angustifolia</i>	4–6 × 0.3–0.6	hetero	truncate	horned	5	2	cylindrical	grayish brown	papillose (less connate)	undiffer.	densely papillae	undiffer.	undiffer.
<i>L. angustifolia</i> subsp. <i>arabica</i>	2.5–3 × 1.5–2.0	hetero	truncate	horned	5	2	cylindrical	grayish brown	papillose (connate)	isodimetric	densely papillae	raised-straight	concave
<i>L. fragilis</i> subsp. <i>fragilis</i>	4–6 × 0.5–0.6	hetero	truncate	horned	5	2	cylindrical	brown	papillose	undiffer.	densely papillae	undiffer.	undiffer.
<i>L. fragilis</i> subsp. <i>temuloba</i>	4–6 × 0.5–0.7	hetero	truncate	horned	5	2	cylindrical	brown	papillose	undiffer.	densely papillae	undiffer.	undiffer.
<i>L. mucronata</i>	4–5 × 0.4–0.8	hetero	truncate	tubular	5	2	cylindrical	grayish to dark brown	papillose	undiffer.	densely papillae	undiffer.	undiffer.
<i>L. cassiniana</i>	4–6 × 0.5–0.8	hetero	truncate	tubular	5	2	cylindrical	brown	papillose	undiffer.	densely papillae	undiffer.	undiffer.

Table 2. Continued.

Taxon	Inner achene						Pappus					
	Primary rib number	Secondary rib number	Shape	Color	Surface	Epidermal cells	Secondary cell wall	Anticlinal wall	Periclinal wall	Morphism	Persistent	Length (mm)
<i>L. spinosa</i>	4	2	columnar	brown	weakly wrinkled	reticulate	obscure with obtuse projections	raised straight	flat	hetero	Persistent	6–7
<i>L. acanthodes</i>	4	2	columnar	yellow	weakly wrinkled	reticulate	fusiform with acute projections	raised straight	flat	hetero	deciduous	6–7
<i>L. nudicaulis</i>	4	undiff.	columnar	yellow	tuberculose wrinkles	regular reticulate	undiff.	raised straight	concave	hetero	Persistent	6–9
<i>L. intybacea</i>	4	weakly differ.	columnar	yellow	weakly wrinkled	bone-shaped	undiff.	depressed straight	concave	hetero	Persistent	6–9
<i>L. massauensis</i>	4	rarely differ.	cylindrical	pale yellow	smooth	rectangular	undiff.	raised straight to sinuous	concave	hetero	Persistent	6–9
<i>L. capitata</i>	4	rarely differ.	cylindrical	pale yellow	smooth	elongate rectangular	undiff.	raised straight	concave	homo	deciduous	4–7
<i>L. angustifolia</i> subsp. <i>angustifolia</i>	4	2	cylindrical	yellowish	smooth	elongate	undiff.	raised straight	undiff.	hetero	Persistent	4–7
<i>L. angustifolia</i> subsp. <i>arabica</i>	4	2	columnar	yellowish	papillose	isodimetric	densely papillae	raised straight	concave	homo	Persistent	4–6
<i>L. fragilis</i> subsp. <i>fragilis</i>	4	2	cylindrical	yellowish	smooth	elongate	undiff.	raised straight	undiff.	hetero	Persistent	7–10
<i>L. fragilis</i> subsp. <i>tenuiloba</i>	4	2	cylindrical	yellowish	smooth	elongate	fine papillae	raised straight	concave	hetero	Persistent	5–6
<i>L. mucronata</i>	4	2	cylindrical	brownish	smooth	elongate	fine papillae	raised straight	concave	hetero	Persistent	7–8
<i>L. cassiniana</i>	4	undiff.	cylindrical	brownish	smooth	elongate	fine papillae	raised straight	concave	homo	deciduous	7–10

papillose; homomorphic with 5 main ribs, accompanied by 2 secondary ribs (rarely undistinguished) or heteromorphic with inner achenes 4-main ribbed and marginal achenes 5-main ribbed, ribs smooth or transversely wrinkled; epidermal cells reticulate, bone-shaped or undifferentiated with straight raised or depressed anticlinal walls and concave periclinal walls, secondary cell wall rarely obscure in outlines with obtuse projections. Pappus was white, persistent or deciduous, homomorphic with setaceous rays or dimorphic with downy

outer and setaceous inner rays. The morphological criteria of the achenes are summarized in Table 2.

Anatomically, pericarp was thick, laterally compressed; 4–5 stranded, each strand composed of a large main costa accompanied with 2 slightly smaller secondary costae; main and secondary costae separated and slightly or clearly differentiated in size; exocarp composed of a single epidermal layer; mesocarp of main and secondary costae with 2–25 layers of parenchyma and 3–18 layers of sclerenchyma cells,

Fig. 1. Scanning electron micrograph of marginal *Launaea* achenes. **A.** *L. acanthodes*. **B.** *L. spinosa*. **C.** *L. nudicaulis*. **D.** *L. intybacea*. **E.** *L. massauensis*. **F.** *L. capitata*. **G.** *L. angustifolia* subsp. *angustifolia*. **H.** *L. angustifolia* subsp. *arabica*. **I.** *L. fragilis* subsp. *fragilis*. **J.** *L. fragilis* subsp. *tenuiloba*. **K.** *L. mucronata*. **L.** *L. cassiniana*.

additional smallish groups of sclerenchymatous cells between main and secondary costae may present; each main costae is corresponding with a vascular bundle; endocarp composed of one layer of parenchyma. The anatomical criteria of the achenes are summarized in Table 3.

The mature achenes of *Launaea* exhibit great diversity and have proved to be the most useful characters for the distinction of some of the studied taxa. This diversity appears in the shape, size, colour, apex, base, epidermal cells and indumentum. The

achenes of the studied taxa are commonly heteromorphic except for the two species of sect. *Acanthosonchus* (*L. spinosa* and *L. acanthodes*), which are subhomomorphic. The studied achenes are commonly $\pm$ cylindrical (oblong, oblanceolate or cuneate); only *L. capitata* and *L. angustifolia* exhibit winged achenes (Figs. 1, 2). Furthermore, the achene colour proved to be of a good taxonomic value, with most of the investigated marginal achenes being brown in colour, except for both *L. capitata*, which exhibits pale yellow achenes, and *L.*

Fig. 2. Scanning electron micrograph of inner *Launaea* achenes. **A.** *L. acanthodes*. **B.** *L. spinosa*. **C.** *L. nudicaulis*. **D.** *L. intybacea*. **E.** *L. massauensis*. **F.** *L. capitata*. **G.** *L. angustifolia* subsp. *angustifolia*. **H.** *L. angustifolia* subsp. *arabica*. **I.** *L. fragilis* subsp. *fragilis*. **J.** *L. fragilis* subsp. *tenuiloba*. **K.** *L. mucronata*. **L.** *L. cassiniana*.

massauensis, with black achenes.

Most of the examined achenes have an approximate size of $2-6 \times 0.5-1.3$ mm (including the beak if present); in *L. massauensis* and *L. procumbens*, the achenes are apparently small, being $2-3 \times 0.5-0.7$ mm in size, while in *L. acanthodes* and *L. capitata*, the achenes are large at $4-8 \times 0.9-1.3$ mm.

The achene apex of the investigated taxa was found to be truncate, except for three species (*L. acanthodes*, *L. intybacea* and *L. massauensis*) which are characterized by an attenuate apex. In addition, the achene base proved to be tubular in two

species (*L. mucronata* and *L. cassiniana*), horned in three species (*L. spinosa*, *L. angustifolia* and *L. fragilis*) and truncate in the remaining five species. Nevertheless, the achenes of the studied species are commonly wrinkled except for the species of sect. *Zollikoferia* (*L. amal-aminiae*, *L. angustifolia*, *L. fragilis*, *L. mucronata* and *L. cassiniana*), which are characterized by papillose marginal achenes and wrinkled or smooth inner achenes (Figs. 3, 4).

Within the differentiated epidermal cells of marginal achenes, the anticlinal boundaries are generally undifferentiated in the

Fig. 3. Scanning electron micrograph of marginal *Launaea* achenes surface. **A.** *L. acanthodes*. **B.** *L. spinosa*. **C.** *L. nudicaulis*. **D.** *L. intybacea*. **E.** *L. massauensis*. **F.** *L. capitata*. **G.** *L. angustifolia* subsp. *angustifolia*. **H.** *L. angustifolia* subsp. *arabica*. **I.** *L. fragilis* subsp. *fragilis*. **J.** *L. fragilis* subsp. *tenuiloba*. **K.** *L. mucronata*. **L.** *L. cassiniana*.

species of sect. *Zollikoferia* (i.e., *L. angustifolia*, *L. fragilis*, *L. mucronata* and *L. cassiniana*), raised straight in *L. spinosa*, *L. acanthodes*, *L. nudicaulis* and *L. capitata*, and depressed straight in *L. intybacea* and *L. massauensis*, while the anticlinal boundaries of the inner achene are generally raised straight in all of the species except *L. massauensis*, being slightly sinuous margins. On the other hand, the periclinal walls are generally concave except for *L. spinosa* and *L. acanthodes* (Figs. 3, 4).

The pappus characters are much more useful for differentiation between some taxa; the setaceous type is only absent in *L. angustifolia* subsp. *arabica*, and the downy type is absent in four species (*L. acanthodes*, *L. cassiniana*, *L. procumbens* and *L. capitata*), with the pappus of the two later species having a pappus disk. Additionally, the pappus is persistent at the achene apex in all species except for *L. procumbens*, *L. capitata* and *L. cassiniana*, which are deciduous.

Fig. 4. Scanning electron micrograph of inner *Launaea* achenes surface. **A.** *L. acanthodes*. **B.** *L. spinosa*. **C.** *L. nudicaulis*. **D.** *L. intybacea*. **E.** *L. massauensis*. **F.** *L. capitata*. **G.** *L. angustifolia* subsp. *angustifolia*. **H.** *L. angustifolia* subsp. *arabica*. **I.** *L. fragilis* subsp. *fragilis*. **J.** *L. fragilis* subsp. *tenuiloba*. **K.** *L. mucronata*. **L.** *L. cassiniana*.

Table 3. Anatomical features of *Launaea* achenes.

Taxon	Pericarp	Additional strand	Marginal achenes						Inner achenes					
			Number		Main costa		Secondary costa		Number		Main costa		Secondary costa	
			Main costa	Secondary costa	Paren.	Scler.	Paren.	Scler.	Main costa	Secondary costa	Paren.	Scler.	Paren.	Scler.
<i>L. spinosa</i>	thick, laterally compressed	absent	5	10	2–5	8–12	4–6	4–6	4	8	2–5	8–12	4–6	4–6
<i>L. nudicaulis</i>	thick, weakly compressed	present	5	10	2–5	8–12	4–6	4–6	4	8	10–15	3–5	4–6	4–6
<i>L. intybacea</i>	thick, weakly compressed	present	5	10	2–5	8–12	4–6	4–6	4	8	10–15	3–5	4–6	4–6
<i>L. massauensis</i>	thick, compressed	present	5	10	4–8	7–12	5–7	3–6	4	8	12–18	4–8	10–12	3–6
<i>L. capitata</i>	very thick, compressed	present	5	10	20–25	7–10	7–12	4–7	4	8	25–30	7–12	15–20	6–10
<i>L. angustifolia</i> subsp. <i>angustifolia</i>	very thick, not compressed	absent	5	10	2–5	12–18	4–6	6–8	4	8	2–5	12–18	3–5	5–7
<i>L. angustifolia</i> subsp. <i>arabica</i>	thick, not compressed	absent	-	-	-	-	-	-	4	8	3–6	10–18	3–6	5–8
<i>L. fragilis</i> subsp. <i>fragilis</i>	thick, not compressed	absent	5	10	4–8	7–12	5–7	5–10	-	-	-	-	-	-
<i>L. fragilis</i> subsp. <i>tenuloba</i>	very thick, weakly compressed	absent	5	10	9–11	7–9	3–6	4–7	4	8	10–15	7–9	3–6	4–7
<i>L. mucronata</i>	thick, weakly compressed	absent	5	10	3–5	6–9	4–7	5–7	4	8	6–9	4–7	6–9	3–5
<i>L. cassiniana</i>	thick, weakly compressed	absent	5	10	5–7	7–11	4–7	6–10	4	8	12–15	7–11	11–14	6–10

The present investigation showed that the anatomical features of *Launaea* achenes are of minor taxonomic value. The presence of additional groups of sclerenchyma cells between the main and secondary costae proved to be useful and reliable for the distinction between the sections. In the studied species of sect. *Microhynchus* (*L. nudicaulis*, *L. intybacea* and *L. massauensis*) and sect. *Launaea* (*L. capitata*), they are often present, whereas they are absent in the species of sect. *Acanthosonchus* and *Zollikoferia*, according to the study of Kilian (1997).

Kilian (1997) studied the anatomical features of *L. intybacea* and did not study *L. massauensis*. It is easy to differentiate anatomically between the two species on the basis of the difference between the main and secondary costa of the inner achenes; the first is characterized by separated and clearly differentiated costa while the latter is not differentiated. Thus, we follow Täckholm (1974) with regard to *L. intybacea* as conspecific. Furthermore, the anatomical characters can be used easily to distinguish certain taxa (Figs. 5, 6). *L. capitata* is characterized by 2–3 large, distinct wrinkled wings, and *L. angustifolia* subsp. *arabica* has a papillate wing. Nevertheless,

the pericarp thickness of the inner achenes can be used to differentiate between the much closer species of *L. mucronata* and *L. cassiniana*; the first is composed of 9–16 parenchyma and sclerenchyma layers while the latter is much thicker and composed of 17–26 layers (Figs. 5, 6).

Key to the taxa

1. Marginal achenes pale yellow, broadly 2–3-winged *L. capitata*
1. Marginal achenes brownish to black, not winged (rarely 1-angeled) 2
2. Marginal achenes surface wrinkled 3
3. Achene subhomomorphic, main and secondary costae without additional groups of sclerenchyma cells between them 4
4. Achene apex truncate, with obscure secondary cell wall and antrose obtuse projections; pappus persistent *L. spinosa*
4. Achene apex attenuate with fusiform secondary cell wall and triangular acute projections; pappus deciduous *L. acanthodes*

Fig. 5. Diagrammatic transverse section of marginal *Launaea* achenes. **A.** *L. spinosa*. **B.** *L. nudicaulis*. **C.** *L. intybacea*. **D.** *L. massauensis*. **E.** *L. capitata*. **F.** *L. angustifolia* subsp. *angustifolia*. **G.** *L. angustifolia* subsp. *arabica*. **H.** *L. fragilis* subsp. *fragilis*. **I.** *L. fragilis* subsp. *tenuiloba*. **J.** *L. mucronata*. **K.** *L. cassiniana*. e: epidermis, pm: primary mid rib, sm: secondary mid rib, par: parenchyma, scl: sclerenchyma, vb: vascular bundle, ec: endocarp, sc: seed coat.

Fig. 6. Diagrammatic transverse section of inner *Launaea* achenes. **A.** *L. spinosa*. **B.** *L. nudicaulis*. **C.** *L. intybacea*. **D.** *L. massauensis*. **E.** *L. capitata*. **F.** *L. angustifolia* subsp. *angustifolia*. **G.** *L. angustifolia* subsp. *arabica*. **H.** *L. fragilis* subsp. *fragilis*. **I.** *L. fragilis* subsp. *tenuiloba*. **J.** *L. mucronata*. **K.** *L. cassiniana*. e: epidermis, pm: primary mid rib, sm: secondary mid rib, par: parenchyma, scl: sclerenchyma, vb: vascular bundle, ec: endocarp, sc: seed coat.

3. Achene heteromorphic, main and secondary costae with additional groups of sclerenchyma cells between them 5
5. Marginal achenes oblong, truncate, not beaked *L. nudicaulis*
5. Marginal achenes sub cylindrical, tapering or beaked 6
6. Marginal achenes brown, epidermal cells of inner achenes bone-shaped with depressed straight anticlinal walls *L. intybacea*
6. Marginal achenes black, epidermal cells of inner achenes rectangular with raised straight to sinuous anticlinal walls ... *L. massauensis*
2. Marginal achenes surface papillose 7
7. Achenes 1-angled, marginal achenes silky, hirsute at angles, base 5-notched and with 5 projections 8
8. Inner achenes glabrous, marginal papillose; pappus dimorphic of setaceous and silky hairs *L. angustifolia* subsp. *angustifolia*
8. All achenes papillose; pappus monomorphic of silky hairs *L. angustifolia* subsp. *arabica*
7. Achenes cylindrical, not silky or hirsute, base truncate 9
9. Achenes longer than 6 mm long, innermost achenes 4-horned at base 10
10. Pappus as long as or slightly shorter than achene *L. fragilis* subsp. *fragilis*
10. Pappus longer than the achene *L. fragilis* subsp. *tenuloba*
9. Achenes shorter than 5 mm long, all achenes not horned at base 11
11. Pappus persistent, dimorphic; inner achenes with pericarp of 9–16 layers *L. mucronata*
11. Pappus deciduous, monomorphic; inner achenes with pericarp of 17–26 layers *L. cassiniana*

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