

اهمیت آرایه شناسی صفات ریختی در گل گندم (تیره کاسنیان)

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چکیده. ریخت‌شناسی فندقه در *Centaurea* در ۴۹ آرایه مطالعه شده است. در این بررسی برای جداسازی بخش‌ها، ۱۹ صفت تشخیصی ارائه شده است. بر اساس این صفات بعضی بخش‌ها، مانند بخش *Cyanus* با داشتن ناف کرک‌دار از بقیه بخش‌ها جدا می‌شوند. با وجود اختلافات زیاد، *C. gilanica* و *C. leuzeoides* در بخش *Psephelloideae* قرار گرفتند، که بخشی شامل گونه‌های با تفاوت‌های زیاد است. همچنین *C. albonitens* در مقایسه با سایر گونه‌های بخش *Phaeopappus* از ویژگی‌های متفاوتی برخوردار است، به عنوان مثال ویژگی‌هایی مانند رنگ پاپوس و نسبت طول پاپوس به طول فندقه از سایر گونه‌های بخش جدا شده است. همچنین در بخش *Cynaroides* اختلافات زیادی در صفات ریختی گونه *C. phlomoides* در مقایسه با دیگر گونه‌های *Centaurea* مشاهده شد. این گونه بر اساس صفاتی چون پاپوس کوتاه و طول ناف از بقیه گونه‌های این بخش جدا می‌شود. بنابراین، براساس یافته‌های این تحقیق، صفات ریختی فندقه فقط می‌توانند برای جدایی آرایه‌ها در سطح گونه مورد استفاده قرار گیرند. در این مقاله، کلید شناسایی بخش‌ها و همچنین عکس‌های فندقه در آرایه‌های انتخابی ارائه شده است.

واژه‌های کلیدی. ایران، پاپوس، فلورا ایرانیکا، کلیدشناسایی، مرکبان

Taxonomic significance of achene morphology in the genus *Centaurea* L. (Asteraceae)

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Abstract. Achene morphology of 49 taxa of the genus *Centaurea* L. was studied in terms of 19 different characteristics. On the basis of the variation in these features, some sections, such as sect. *Cyanus* with hairy hilum, were separated. Despite various differences, *C. leuzeoides* and *C. gilanica* were categorized in the section *Psephelloideae*, a section with lots of character variations within its species. Also, *C. albonitens* has different characteristics in comparison with other taxa within section *Phaeopappus*, for example features such as pappus color and the ratio of pappus length to that of achene separated the species from other members of the section. The last but not the least, highly different characteristics were observed in the achene morphology of *C. phlomoides* as compared with other species in section *Cynaroides*. Differences such as short pappus and hilum length were found to separate *C. phlomoides* from other members of sect. *Cynaroides*. In conclusion, on the basis of the findings of this research, most achene morphological characteristics can be appropriately used as key features for the differentiation of sections in the genus *Centaurea*. An identification key based on the features of the achene, images related to the achene of the studied species were also presented.

Keywords. Compositae, Flora Iranica, identification key, Iran, pappus

INTRODUCTION

Centaurea L. (Asteraceae), with 350 to 600 species of herbaceous thistle-like plants in the world (Heywood, 1979; Hickey & King, 1981), is found only in the North of the equator, mostly in the Eastern hemisphere. The Middle-East and its surrounding regions are particularly species-rich with regard to the genus *Centaurea* (Davis *et al.*, 1988; Wagenitz, 1980). This genus belongs to subtribe *Centaurinae*, Tribe *Cardueae*, subfamily *Carduoideae* and family Asteraceae (Judd *et al.*, 2008; Bremer *et al.*, 2009). Based on Flora Iranica (Wagenitz, 1980), *Centaurea*, with 88 species in the Iranian plateau, is divided into 28 sections. The infrageneric classifications of the genus *Centaurea* were mainly based on features such as plant duration, characteristics of involucre (shape of phyllaries, cilia, terminal spine tipped or non spine tipped of bracts), and color of florets and position of leaves. Moreover, flower colors and heights were the other criteria considered to be taxonomically important. *Centaurea* is one of the largest genera in Iran with almost 89 species, of which 76 species are endemic (Wagenitz, 1980; Ghahreman & Attar, 1999; Shabestari *et al.*, 2013a, 2013b; Negaresh *et al.*, 2014). This genus is a bushy plant with ciliate (*C. depressa* M.Bieb.) or spiny (*C. kandavanensis* Wagenitz) phyllaries with white, yellow, pink or purple flowers. Some phyllaries overlapped in several rows, with tips variously spiny or mucronate and margins pinnate or entire. The stems of the plants are long and erect (*C. cheiranthifolia* Willd.), rarely acaulescent (*C. rhizantha* Tchich.), short (*C. aucheri* (DC.) Wagenitz) or prostrate (*C. incanescens* (DC.) Sch.Bip.). Leaves are entire, pinnatifid, pinnatisect, with different shapes, and are covered with gray hairs (gray-tomentose), rarely dense arachnoid (*C. luristanica* Rech.f.) or glabrous (*C. koeieana* Bornm.). Achenes are oblong, rarely triangular, 2.5-3.5 mm long, with apex flattened, tapered to a rounded, having a laterally notched base. Pappus are often white (colorful pappus is an exception, as seen in some species like *C. aucheri*), composed of unequal, stiff, minutely barbellate or tiny, flat scales (Fig. 1) (Wagenitz, 1980). As it was mentioned before, the achene characteristics have not been studied thoroughly, or rarely considered to be taxonomically important (Maleev, 1971; Boissier, 1875; Wagenitz, 1975, 1980; Shabestari *et al.*, 2013a, 2013b; Bona, 2014; Negaresh *et al.*, 2014; Ranjbar & Negaresh, 2014). In this paper, achene variation in 49 taxa (44 species and 5 subspecies) belonging to 24 sections was investigated. The criteria were highly focused on the achene and pappus characteristics, and the study has

been concluded with achene-based identification key for the sections of the genus *Centaurea*.

MATERIALS & METHODS

Achenes of 44 species and five subspecies of 24 sections belonging to the genus *Centaurea* were collected from specimens preserved in the Central Herbarium of Tehran University (TUH), as shown in Table 1. The sections *Phalolepis* (Cass.) DC., *Grossheimia* (Sosn. & Takht.) Dittrich and *Czerniakovskya* (Czerep.) Wagenitz have been excluded from the study, since no proper specimens of these sections were available.

Then, achenes were studied and photos were taken by means of a Dinolite hand-held digital microscope with a magnification of 180x.

In order to investigate the characteristics of achene in the specimens studied, 19 criteria were sorted out. The selected characteristics included features such as appendage length and color, hilum length, achene length, pappus-achene connection length, color and shape of achene, pappus and inner pappus type, and ratio of the length of pappus to that of achene. The complete list of the characteristics studied is presented in Table 2.

RESULTS

As it is shown in Tables 2 and 3, 19 criteria were taken into consideration in characterizing and sorting out the differences among the 49 taxa studied (44 species and 5 subspecies). Some of these characteristics and their importance are explained below.

- Appendage of hilum: the first and the most important characteristic key which separates the taxa studied into two main parts, based on whether they have appendiculate hilum or exappendiculate hilum.
- Color of appendage: section *Stizolophus* (Cass.) DC. (*C. balsamita* Lam.) becomes distinct by red-brown appendage among all other sections.
- Achene's shape: it varies among the taxa studied; some are oblong (*C. behen* Lam.), fusiform (*C. amadanensis* Sch.Bip.) or urceolate (*C. kotschyi* (Boiss.) Hayek), while others are triangular (*C. glastifolia* L.), elliptic (*C. geluensis* Boiss. & Hausskn. ex Boiss.) or rectangular (*C. gaubae* (Bornm.) Wagenitz).
- Achene's size: most of the taxa studied have normal size (2.5-3.5 mm long), while some can be seen in inflated form, for example *C. zuvandica* (Sosn.) Sosn. in sect. *Psephellus* (Cass.) DC. and *C. incanescens* (Fisch. & C.A.Mey. ex DC.) Sosn. in sect. *Amblyopogon* Fisch. & C.A.Mey. ex DC.



Fig 1. Different types of achene and pappus. **A.** *Centaurea balsamita* subsp. *kermanensis* (Bornm.) Wagenitz. **B.** *C. iberica* Trevir. ex Spreng. **C.** *C. luristanica* Rech.f. **D.** *C. ustulata* DC. **E.** *C. albonitens* Turill, **F.** *C. leuzeoides* Walp.

- Pappus length: pappus are shorter than the achene in the first group (*C. phlomoides* Boiss. & Hausskn. ex Boiss.), while in the second group the pappus are longer than the achene (*C. luristanica*), and in the

third group the lengths of achene and pappus are equal (*C. bruguierana* Hand.-Mazz.). Differences in pappus length among different sections as well as within certain sections is also observed (*C. iberica* and

Table 1. Voucher specimens used in achene characterization.

| Species | Locality | Height (m) | Collector & Herbarium number |
|---|--|------------|---|
| <i>Centaurea lachnopus</i> Rech.f. | Semnan: ca 15 from Semnan to Firouz kuh | 1130 | Ghahreman, Mozaffarian 5822 (TUH) |
| <i>C. balsamita</i> subsp. <i>balsamita</i> Lam. | Golestan: Golestan National Park | s.n. | Ghahreman, Mozaffarian, Attar 25438 (TUH) |
| <i>C. balsamia</i> subsp. <i>balsamita</i> Lam. | Azarbayejan: Marand to Evoghli, Kushksary to Erelan | 1360 | Ghahreman, Mozaffarian 9747 (TUH) |
| <i>C. balamita</i> subsp. <i>balsamia</i> Lam. | Azarbayejan; Urmieh, Balanesh | 1350 | Ghahreman, Attar 21319 (TUH) |
| <i>C. balsamita</i> subsp. <i>balsamita</i> Lam. | Kermanshah: 40 km, to Paveh | 1550 | Attar, Dadjou, Mehdigholi, Okhovat 14237 (TUH) |
| <i>C. balsamita</i> subsp. <i>kermanensis</i> (Bornm.) Wagenitz | Khorasan: Neishabour road, Mt. Binaloud Kouh | 1250 | Ghahreman, Attar 21916 (TUH) |
| <i>C. balsamita</i> subsp. <i>kermanensis</i> (Bornm.) Wagenitz | Fars: Shiraz, Psargad | 1845 | Ghahreman, Attar 22515 (TUH) |
| <i>C. aggregata</i> Fisch. & C.A.Mey. | Kermanshah: 5 km after Paveh to Nasoud | 1550 | Ghahreman, Attar, Mehdigholi 22376 (TUH) |
| <i>C. aggregata</i> Fisch. & C.A.Mey. | Kermanshah: 50 km Paveh | 1550 | Ghahreman, Attar 21202 (TUH) |
| <i>C. aggregata</i> Fisch. & C.A.Mey. | Kordestan: Ghorv: to Sanandaj: 45 km to Sanandaj | 1500 | Ghahreman, Attar 19647 (TUH) |
| <i>C. aggregata</i> Fisch. & C.A.Mey. | Kordestan: Marivan to Sanandaj from old road Gardane Geran | 1320 | Ghahreman, Mozaffarian 18303 (TUH) |
| <i>C. ovina</i> Pall. ex Willd. | Azarbayejan: Ardebil, 10 km to Ahar | 1370 | Attar, Dadjou 17237 (TUH) |
| <i>C. ovina</i> Pall. ex Willd. | Azarbayejan: Ardebil to Germe, 10 km to Germe | 1860 | Attar, Dadjou 14679 (TUH) |
| <i>C. ammocyanus</i> Boiss. | Alborz: Near Hashtgerd, 30 km WD Karaj | 1250 | Esfandiari 11445-TUH |
| <i>C. pulchella</i> Ledeb. | Azarbayejan: Tabriz on the road to Lighvan | 2280 | Ghahreman, Mozaffarian 17376 (TUH) |
| <i>C. pulchella</i> Ledeb. | Khorasan: mt. Kashmar | 1060 | Ghahreman, Attar 27324 (TUH) |
| <i>C. hyrcanica</i> Bornm. | Mazandaran: Nowshahr, Kheiroud forest | 20 | Syadati, Moradi 40196 (TUH) |
| <i>C. hyrcanica</i> Bornm. | Gilan: Ispili | 1580 | Syadati 18489 (TUH) |
| <i>C. kotschyi</i> (Boiss.) Hayek | Mazandara: road of Karaj - Chalous | 40 | Nazaryan 33460 (TUH) |
| <i>C. kotschyi</i> (Boiss.) Hayek | Tehran: Chalous road, slope of Kandavan | s.n. | Ghahreman, Mozaffarian 9780 (TUH) |
| <i>C. isphanica</i> Boiss. | Isfahan: Shahreza, Samirom, Kouhravi, | 2450 | Ghahreman, Mozaffarian 18233 (TUH) |
| <i>C. rhizantha</i> Tchich. | Azarbayejan: Arasbaran, protected Area, Kouhe Kalan | 1105 | Attar, Dadjou 17671 (TUH) |
| <i>C. rhizantha</i> Tchich. | Azarbayejan: Marand, Zunuz, between Zunuzagh and Kuhkamar | 1700 | Ghahreman, Mozaffarian 17405 (TUH) |
| <i>C. glastifolia</i> L. | Azarbayejan: Marand road of Zunuz | 1700 | Ghahreman, Attar 21296 (TUH) |
| <i>C. glastifolia</i> L. | Azarbayejan: Khoy road of Ghotur, Razi, 2 km of bus station | 1160 | Ghahreman, Attar 21992 (TUH) |
| <i>C. aucheri</i> subsp. <i>aucheri</i> (DC.) Wagenitz | Kordestan: Sanandaj, 28 km to Divan Darreh | 1840 | Attar, Dadjou, Mehdigholi, Okhovat 14293 (TUH) |
| <i>C. aucheri</i> subsp. <i>aucheri</i> (DC.) Wagenitz | Hamadan: Kubardar Ahang to Ghohord, Keitou, Kouhe Keiton | 1800 | Mozaffarian 64603 (TUH) |
| <i>C. aucheri</i> subsp. <i>aucheri</i> (DC.) Wagenitz | Azarbayejan sharqi: N slopes of Mishov-Dagh, south of the road | 1400 | Podlesh, Zarre 55267 (TUH) |
| <i>C. aucheri</i> subsp. <i>szowittsii</i> (Boiss.) Wagenitz | Azarbayejan: Gardane Yam, Mishodagh | 1400 | Ghahreman, Aghostin, Sheikholeslami 11444 (TUH) |
| <i>C. aucheri</i> subsp. <i>szowittsii</i> (Boiss.) Wagenitz | Markazi: 70 km NW of Saveh village of Bandamir | 1920 | Ghaffari, 4681 (TUH) |
| <i>C. aucheri-elbursensis</i> Wagenitz | Azarbayejan: Myaneh, Bostanabad, 35 km Bostanabad | 1740 | Ghaffari, 11627 (TUH) |
| <i>C. albonitens</i> Turrill | Azarbayejan: Sirvan, from Yam to Tabriz | 1900 | Ghahreman, Aghostin, Sheikholeslami 11477 (TUH) |
| <i>C. albonitens</i> Turrill | Azarbayejan: Tabriz, 20 km to Marand | 1360 | Ghaffari, 6642 (TUH) |
| <i>C. geluensis</i> Boiss. & Hausskn. ex Boiss. | Lorestan: Khorramabad, Sefidkou | 1720 | Veis Karami 23715 (TUH) |
| <i>C. gigantea</i> Sch.Bip. ex Boiss. | Lorestan: Khoramabad, road of Sefid Dasht | 1142 | Ghahreman, Attar, Dadjou 21840 (TUH) |

Table 1. continue ...

| Species | Locality | Height (m) | Collector & Herbarium number |
|---|--|------------|--|
| <i>C. imperialis</i> Hausskn. ex Bornm. | Kordestan: Marivan to Baneh 50 km to Baneh | 1540 | Ghahreman, Attar 19667 (TUH) |
| <i>C. phlomooides</i> Boiss. & Hausskn. ex Boiss. | Kermanshah: Pavah | 1550 | Attar, Mirtadzadini 19857 (TUH) |
| <i>C. amadanensis</i> subsp. <i>gymnoclada</i> (Jaub. & Spach) Negaresh | Kordestan, Marivan, Ghamishlu | 1320 | Ghahreman, Attar 19650 (TUH) |
| <i>C. amadanensis</i> subsp. <i>amadanensis</i> Sch.Bip. | Lorestan: Khorramabad, 50 km after bifurcation of Khorramabad- Sefid Dasht | 1142 m | Ghahreman, Attar, Ghaffari 21839 (TUH) |
| <i>C. nemecii</i> Nábelek | Kordestan: Sanandaj, Salavat Abad pass | 1700 m | Ghahreman, Mozaffarian 18295 (TUH) |
| <i>C. koeieana</i> Bornm. | Lorestan: Khorramabad, Delbar | 1100 m | Veis Karami 23712 (TUH) |
| <i>C. pabotii</i> Wagenitz | Chaharmahal-e- Bakhtiari Lordegan to Dashte Armand | 1585 m | Mozaffarian 54658 (TUH) |
| <i>C. behen</i> Lam. | Lorestan: Khorramabad, Cham-Divan, Chal-e-Ahmad | 1440 m | Veis Karami 23713 (TUH) |
| <i>C. solstitialis</i> Asso | Azarbayejan: between Ardebil-Kivy | 1480 m | Sheikholeslami 11510 (TUH) |
| <i>C. pseudosinaica</i> Czerep. | Hormozgan: Bandar Abbas, near Sarkhon, Radar site | 75 m | Ghahreman, Mozaffarian 5357 (TUH) |
| <i>C. iberica</i> Trevir. ex Spreng. | Gilan: Langroud. Chamkhaleh | -26 m | Naghinezhad 27549 (TUH) |
| <i>C. iberica</i> Trevir. ex Spreng. | Gilan: Lngroud, Chamkhaleh | -26 m | Naghinezhad 27548 (TUH) |
| <i>C. bruguierana</i> Hand.-Mazz. | Khuzestan: Mahshahr | | Ghahreman & Attar23340 (TUH) |
| <i>C. bruguierana</i> Hand.-Mazz. | Kordestan: inter Gilan e Gharb and Ghasre Shirin | 360 m | Ghahreman 11456 (TUH) |
| <i>C. sosnowskyi</i> Grossh. | Gilan: between Ispili and Leih | 1580 m | Saiydi 18490-(TUH) |
| <i>C. kandavaniensis</i> Wagenitz | Golestan: before Nardin to Tange rah | 465 m | Ghahreman, Attar 21930-(TUH) |
| <i>C. luristanica</i> Rech.f. | Khuzestan: Ize, Darre Sansan | | Attar, Dadjou 17723-(TUH) |
| <i>C. leuzeoides</i> Walp. | Gorgan: Golestan National park, Almeh | - | Ghahreman, Mozaffarian 5903 (TUH) |
| <i>C. gilanica</i> Bornm. | Hamedan: Famenin; Ghorveh, Karafs, Mnts N.E of Karafs | 1790 m | Mozaffarian 64542 (TUH) |
| <i>C. zuvandica</i> (Sosn.) Sosn. | Mazandaran: Kandavan road of Chalous-Haraz, Yoush | 2230 m | Ghaffari 21229 (TUH) |
| <i>C. phaeopappoides</i> Bordz. | Azarbayejan: Siah cheshme Baron village, around Zarzor Chuch | 1750 m | Mozaffarian 71130 (TUH) |

C. hyalolepis Boiss. in section *Calcitrapa* DC.).

- Pappus color: most pappus are cream, brown or milky white, but species in section *Phaeopappus* (DC.) O.Hoffm. (except *C. albonitens*), *Psephelloideae* (Boiss.) Sosn. and *Xanthopsis* are distinguished by their purple or black pappus.

- Inner dense pappus: this characteristic can be seen in sections *Hyalea*, *Mesocentron* (*C. solstitialis*), *Tetramorphaea*, *Acrocentron*, *Psephelloideae* (*C. leuzeoides*), *Odontolophoideae*, *Xanthopsis* (DC.) Wagenitz & Hellwig and *Cyanus* (Miller) DC. (except *C. elbrusensis* Boiss. & Buhse).

Pappus form: pappus, either short or long, has different forms, most of which in ray form are separated from other taxa (*C. aucheri*), while some others are dense and straight (*C. ispanhanica* Boiss.). Though *C. albonitens* in section *Phaeopappus* with broom-shaped pappus and *C. incanescens* in section *Amblyopogon* with short truncate and oblique pappus are very different among all species studied in other sections.

- Connection area of pappus to achene: it is mostly denticulate or rarely entire (*C. gilanica* Bornm.).

The section *Cyanus* has hairy hilum area, except for the *C. elbursensis*.

As it is observed in Tables 2 and 3, there are differences in achene's characteristics among sections, even in one unique *C. lachnopus* Rech.f. in sect. *Centaurea* with distinct white appendage coming out of hilum (Fig. 2 A).

The members of sect. *Acrolophus* (Cass.) DC. & *Ammocyranus* Boiss. are similar in achene characteristics, and based on Wagenitz (1980), these species have apparent similar morphology too (Fig. 2 D, E & F). Based on Tables 2 and 3, hilum in *C. hyrcanica* Bornm. in sect. *Jacea* (Miller) DC., is concave, semi-circular and no appendage can be seen in it (Fig. 2 H).

In sect. *Rhizocalathium* Tzvelev (Fig. 2 J, K & L) appendage is seen out of hilum (similar to sect. *Centaurea*), and a narrow brown margin is seen in the bottom of achene in hilum opening.

Sect. *Phaeopappus* (*C. aucheri* with three subspecies) are similar, especially in having purple pappus and the length of pappus in comparison with achene length (Fig. 3 N- P), while *C. albonitens* in the same section

Table 2. Characterizations used for achene differentiation (measurement in mm).

Abbreviations: **App**=appendage, **App.L**=appendage length, **App.C**=appendage color, **H**=hilum, **H.L**=hilum length, **A.L**=achene length, **A.W**=achene width, **A.C**=achene color, **A.S**=achene shape, **int**=intangible, **-**=glabrous, **+/-**=pubescent, **+**=normal, **++**=fairly high, **+++**=highly.

| Section | species | Hair | App. | App.L | App.C | H | H.L | A.L | A.W | A.C | A.S |
|-----------------------|---|------|------|-------|----------------|------------------|------|------|------|--------------------------|--------------------------------------|
| <i>Centaurea</i> | <i>C. lachnopus</i> | - | + | 1.3 | white | + | 1.3 | 7.4 | 1.6 | light brown | oblong |
| <i>Stizolophus</i> | <i>C. balsamita</i> subsp. <i>balsamita</i> | - | + | 0.7 | red | + | 0.7 | 4.4 | 1.5 | dark brown | oblong- attenuate towards base |
| | <i>C. balsamita</i> subsp. <i>kermanensis</i> | - | + | 0.7 | red | + | 0.7 | 3.9 | 1.3 | light grey | oblong |
| <i>Acrolophus</i> | <i>C. ovina</i> | +/- | + | 0.2 | white | + | 0.5 | 3.2 | 1.4 | brown | oblong |
| | <i>C. aggregata</i> | +/- | + | 0.3 | white | + | 0.6 | 2.8 | 1.4 | brown | cup-shaped |
| <i>Ammocyanus</i> | <i>C. ammocyanus</i> | +/- | + | 0.6 | grey | + | 0.6 | 2.9 | 1.2 | golden cream | attenuate towards base |
| <i>Hyalea</i> | <i>C. pulchella</i> | + | - | - | - | + | 0.1 | 2.7 | 1.1 | greyish brown | attenuate to base |
| <i>Jaceae</i> | <i>C. hyrcanica</i> | +/- | - | - | - | + conca ve | 1.03 | 3.12 | ½ | cream | oblong- attenuate towards base |
| <i>Cheirolepis</i> | <i>C. kotschyi</i> | - | - | - | - | + | 0.5 | 6.01 | 2.71 | cream | urceolate |
| <i>Rhizocalathium</i> | <i>C. rhizantha</i> | - | + | 0.6 | white | + | 0.6 | 6.1 | 1.9 | yellow | urceolate |
| | <i>C. ustulata</i> | - | + | 1.3 | cream white | + | 1.3 | 5.9 | 2.3 | cream-gold | oblong |
| | <i>C. isphanica</i> | - | + | 2.2 | dark brown | + | 2.2 | 10.4 | 2.4 | honey brown | oblong- attenuate towards base |
| <i>Chartolepis</i> | <i>C. glastifolia</i> | + | - | - | - | + | 0.6 | 1.9 | 0.8 | dark oblong | oblong |
| <i>Phaeopappus</i> | <i>C. aucheri</i> subsp. <i>aucheri</i> | - | + | 1 | white | + | 1.15 | 5.8 | 3.1 | light brown | oblong inflated |
| | <i>C. aucheri</i> subsp. <i>szowitzii</i> | - | + | 1.1 | white | + | 1.19 | 7.3 | 2.7 | light brown | Oblong- attenuate towards base |
| | <i>C. aucheri</i> subsp. <i>elbursensis</i> | - | +/- | - | - | - | - | 6.9 | 1.7 | light brown | oblong |
| | <i>C. albonitense</i> | - | + | 0.6 | white | + | 0.6 | 2.9 | 1.09 | dark brown | oblong |
| <i>Cynaroides</i> | <i>C. regia</i> | - | - | - | - | + | 0.9 | 7.9 | 3.03 | shiny cream | oblong |
| | <i>C. imperialis</i> | +/- | + | 0.9 | white | + | 0.5 | 5.4 | 1.8 | dark brown | rectangular |
| | <i>C. gigantea</i> | +/- | - | - | - | + | 0.9 | 5.8 | 3 | shiny cream | oblong |
| | <i>C. phlomooides</i> | + | + | 1.4 | white | + | 2.4 | 7 | 2.7 | brown | rectangular |
| | <i>C. geluensis</i> | ++ | - | - | - | + | 1.1 | 4.1 | 1.16 | grayish cream | fusiform |
| <i>Paraphysis</i> | <i>C. amadanensis</i> | - | + | 1.3 | white | + | 1.3 | 6.9 | 2.8 | yellowish cream | rectangular |
| | <i>C. nemecii</i> | + | + | 0.8 | white | + | 0.8 | 5.6 | 3.3 | shiny white | oblong |
| <i>Microlophus</i> | <i>C. behen</i> | + | - | - | - | + | 0.7 | 4.5 | 1.89 | small & cream | oblong |
| | <i>C. pabotii</i> | ++ | - | - | - | + | 0.8 | 4.4 | 2.03 | cream | oblong |
| | <i>C. koeieana</i> | ++ | - | - | - | + | 1.1 | 2.1 | 0.4 | gray brown | urceolate |
| <i>Mesocentron</i> | <i>C. solstitialis</i> | - | - | - | - | + | 0.5 | 2.5 | 1.2 | cream with black spot | oblong |
| | <i>C. pseudosinaica</i> | - | + | 1 | yellow | + | 1 | 2.8 | 1.4 | cream | oblong |
| <i>Calcitrapa</i> | <i>C. iberica</i> | + | - | - | - | + | 0.6 | 3.3 | 1.4 | yellow cream | oblong |
| | <i>C. hyalolepis</i> | + | - | - | - | + | int | 2.5 | 0.9 | yellow cream | oblong |

Table 2. continue ...

| Section | species | Hair | App. | App.L | App. C | H | H.L | A. L | A. W | A.C | A.S |
|------------------|---------------------------|----------|------|-------|--------|---|------|------|------|----------------|--------------|
| Tetramorphaea | <i>C. bruguierana</i> | + | - | - | - | + | 0.3 | 2 | 0.9 | yellow caramel | oblong |
| Acrocenteron | <i>C. sosnowskyi</i> | ++ | - | - | - | + | 1.5 | 5.4 | 2.3 | amber colored | oblong |
| | <i>C. kandavanensis</i> | +++ | - | - | - | + | 1.2 | 5.4 | 2.3 | amber colored | oblong |
| | <i>C. luristanica</i> | +++ | - | - | - | + | 1.05 | 6.2 | 2.5 | amber colored | oblong |
| Psephelloideae | <i>C. leuzeoides</i> | - | - | - | - | + | 1.07 | 8.1 | 2.9 | shiny white | fatty oblong |
| | <i>C. gilanica</i> | +/- | + | 1.01 | white | + | 1.01 | 6.8 | 2.7 | yellow honey | oblong |
| Psephellus | <i>C. zuvandica</i> | + | + | 1.4 | white | + | 1.4 | 5.3 | 2.6 | yellow cream | urceolate |
| Amblyopogon | <i>C. incanescens</i> | - | - | - | - | + | 2.5 | 7.3 | 4.17 | cream white | urceolate |
| Odontolophoideae | <i>C. phaeopappoides</i> | + pilose | + | 0.7 | white | + | 0.8 | 3.8 | 1.6 | light brown | elliptic |
| Uralepis | <i>C. gaubea</i> | + pilose | + | 1.2 | white | + | 1.2 | 2.8 | 1.3 | yellow honey | rectangular |
| Xanthopsis | <i>C. xanthocephala</i> | - | + | 1.2 | white | + | 1.3 | 6.8 | 2.5 | amber colored | elliptic |
| Cyanus | <i>C. cyanus</i> | + | + | 2 | white | + | 2.3 | 4.6 | 2.4 | yellow brown | triangular |
| Cyanus | <i>C. cheiranthifolia</i> | - | + | 1.1 | white | + | 1.5 | 4.4 | 2.08 | yellow cream | oblong |
| | <i>C. depressa</i> | + | + | 2.9 | white | + | 2 | 4.9 | 2.6 | light brown | oblong |
| | <i>C. elbursensis</i> | + | + | 1.9 | white | + | 2.1 | 5.6 | 1.7 | brown | oblong |
| | <i>C. triumfetti</i> | + | + | 1.4 | white | + | 1.5 | 4.8 | 1.9 | black yellow | oblong |



Fig. 2. A. *Centaurea. lachnopus*. B. *C. balsamita* subsp. *balsamita*. C. *C. balsamita* subsp. *kermanensis*. D. *C. aggregate*. E. *C. ovina*. F. *C. ammocyanus*. G. *C. pulchella*. H. *C. hyrcanica*. I. *C. kotschyi*. J. *C. rhizantha*. K. *C. ustulata*. L. *C. isphahanica*.

is observed to have white cream pappus (Fig. 3 Q). Moreover, outer pappus are shorter in comparison with the inner part.

C. nemecii Nábělek in sect. *Paraphysis* (DC.) Wagenitz has bright milky achene, and similar color in short outer pappus and long inner pappus (Fig. 3 X). Sect. *Microlophus* (Cass.) DC. is noticeable in terms of the angled form of its hilum (Fig. 4 A & B). Achene of *C. koeieana* in sect. *Microlophus* is covered with dense hairs (Fig. 4 C). *C. iberica* in sect. *Calcitrapa* is distinguished by short and scarce hairs on its hilum (Fig. 4 F).

Species belong to sect. *Acrocentron* (Cass.) DC. are fully covered with soft hairs and have inner dense pappus (I.D.P) which is observable in all of the three species of the section, especially in *C. sosnowskyi* Grossh. which has scaly inner dense pappus (Fig. 4 I). *C. zuvadica* (Fig. 5 N) in sect. *Psephellus* is similar to members of sects. *Centaurea* and *Rhizocalathium* in that it has clear

appendage, out of hilum, and similar to the members of section *Microlophus* in that it has truncate hilum.

C. leuzeoides (Fig. 4 L) in sect. *Psephelloideae* has black pappus, shiny white achene and inner dense pappus.

The achene in *C. incanescens* is large and inflated with a concave semi-circular hilum, short, dense, truncate and oblique pappus (Fig. 5 O). *C. phaeopappoides* (Fig. 5 P) in sect. *Odontolophoideae* is similar to the members of the sect. *Centaurea*, *Rhizocalathium* and *Psephellus* as its appendage is out of hilum.

Three sects. *Phaeopappus*, *psephelloideae* (*C. gilanica*, Fig. 5 M) and *Xanthopsis* have purple pappus. As it was mentioned above, species in sect. *Cyanus*, especially *C. cheiranthifolia*, *C. triumphetti*, and *C. depressa* have hairs on their hilum (Fig. 5 S, U and V), while the presence of hairs on the hilum is scarce in other sections.

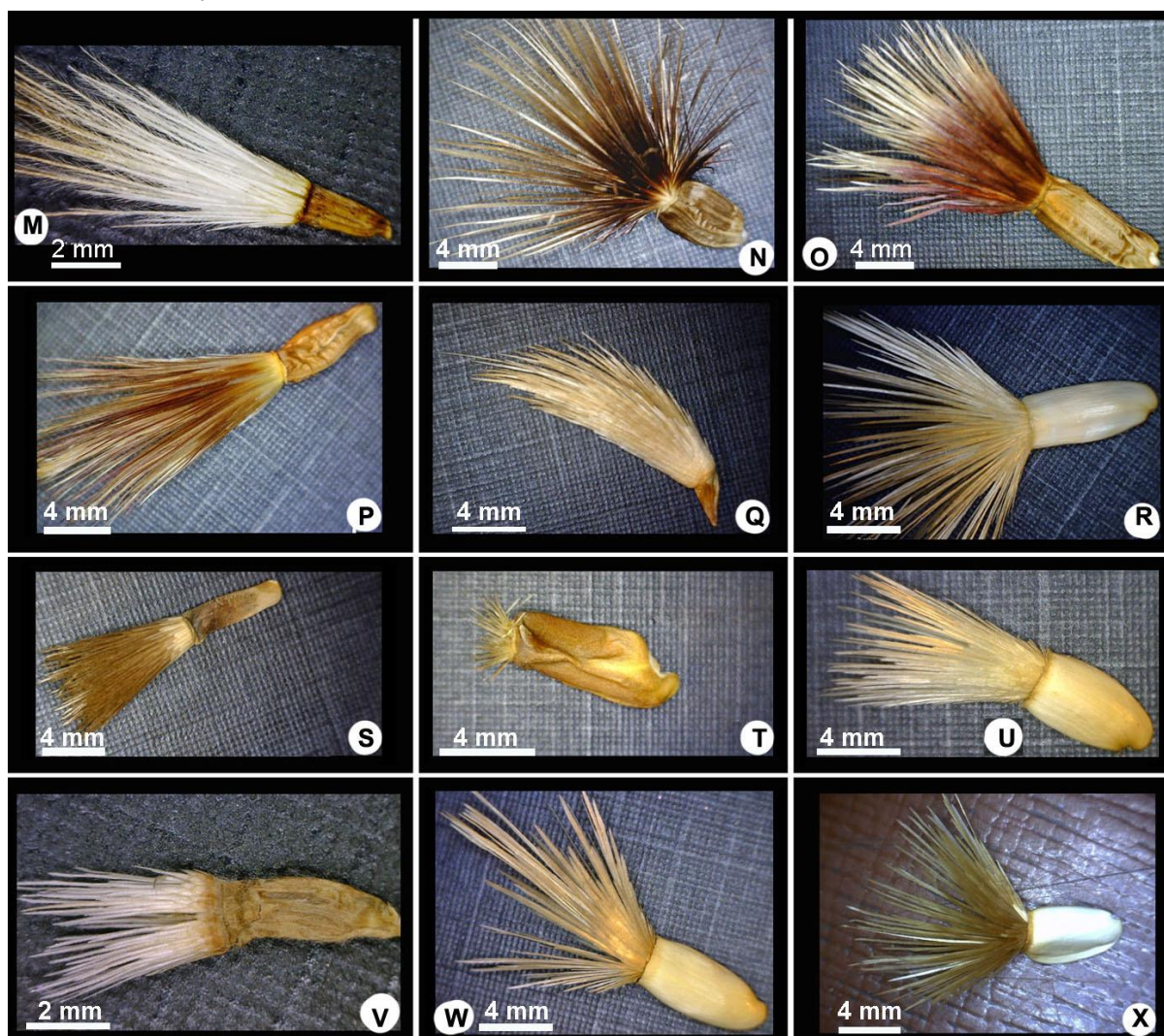


Fig. 3. M. *Centaurea glastifolia*. N. *C. aucheri* subsp. *aucheri*. O. *C. aucheri* subsp. *szowitsii*. P. *C. aucheri* subsp. *elburzensis*. Q. *C. albonitens*. R. *C. regia*. S. *C. imperialis*. T. *C. phlomoides*. U. *C. gigantea*. V. *C. geluensis*. W. *C. amadanensis*. X. *C. nemeci*.

Table 3. Characteristics used for achene differentiation (measurement in mm).

Abbreviations: P.L=pappus length, P.C= pappus color, P.F=pappus form, P.T=pappus type, I.D.P=inner dense pappus, ND= not denticulate, Co.L= connection length, Co.C=connection color, Co.F=connection form, P.L/A.L=pappus length/achene length, S=scabrous, D=denticulate, P= plumose, = glabrous, +/-=pubsent, +=normal, ++=fairly high, +++=highly.

| Section | species | P.L | P.C | P.F | P.T | I.D.P | Co.L | Co.C | Co.F | P.L/A.L |
|-----------------------|---|-------|-----------------|--------------------|----------|-------|------|-----------------------|------|---------|
| <i>Centaurea</i> | <i>C. lachnopus</i> | 11 | milky white | straight | S | - | 2.3 | dark brown, margined | D | 1.5 |
| <i>Stizolophus</i> | <i>C. balsamita</i> subsp. <i>balsamita</i> | 4.3 | brownish cream | straight | S | - | 1.5 | light cream, margined | D | 0.9 |
| | <i>C. balsamita</i> subsp. <i>kermanensis</i> | 2.7 | Brownish golden | straight | S | - | 1.2 | light cream, margined | D | 0.7 |
| <i>Acrolophus</i> | <i>C. ovina</i> | 0.9 | white | straight | S | - | 1.12 | light cream no margin | D | 0.2 |
| | <i>C. aggregata</i> | 3.1 | white | straight | S | - | 1.2 | brown margined | D | 1.1 |
| <i>Ammocyanus</i> | <i>C. ammocyanus</i> | 3.4 | white | straight | S | - | 1.05 | golden cream margined | D | 1.1 |
| <i>Hyalea</i> | <i>C. pulchella</i> | 4.2 | shining white | straight | S | + | 1.1 | no margin | D | 1.9 |
| <i>Jaceae</i> | <i>C. hyrcanica</i> | 1.3 | yellow | short& straight | S | - | 0.9 | no margin | D | 0.4 |
| <i>Cheirolepis</i> | <i>C. kotschyi</i> | 13.01 | brown | ray form | P | - | 2.2 | cream margin | D | 2.1 |
| <i>Rhizocalathium</i> | <i>C. rhizantha</i> | 1.86 | white | straight | S | - | 1.3 | no margin | D | 0.3 |
| | <i>C. ustulata</i> | 2.4 | honey brown | short & ray form | S | - | 1.6 | no margin | D | 0.4 |
| | <i>C. ispanhanica</i> | 3.9 | honey brown | short & straight | S | - | 2.1 | no margin | D | 0.4 |
| <i>Chartolepis</i> | <i>C. glastifolia</i> | 9.3 | cream white | straight | highly P | - | 0.6 | brown margin | D | 4.8 |
| <i>Phaeopappus</i> | <i>C. aucheri/ aucheri</i> | 12 | brown purple | highly ray form | P | - | 2.3 | cream margin | D | 2 |
| | <i>C. aucheri/ szowitsii</i> | 12.02 | cream, purple | ray form | P | - | 2.3 | brown margin | D | 1.6 |
| | <i>C. aucheri/ elbursensis</i> | 15.4 | cream purple | straight spreading | S | - | 1.8 | dark brown margin | D | 2.2 |
| | <i>C. albunitense</i> | 13 | white | broom shape | S | - | 1.4 | white brown margin | D | 4.5 |
| <i>Cynaroides</i> | <i>C. regia</i> | 11.5 | cream | ray form | S | - | 2.9 | no margin | D | 1.5 |
| | <i>C. imperialis</i> | 9 | white, inner | straight | S | - | 1.7 | dark margin | D | 1.6 |
| <i>Cynaroides</i> | <i>C. gigantea</i> | 9.2 | white | straight | S | - | 2.5 | no margin | D | 1.5 |
| | <i>C. phlomoides</i> | 2.2 | white honey | short & ray form | S | - | 1.5 | yellow margined | D | 0.3 |
| | <i>C. geluensis</i> | 4.2 | cream white | ray form | S | - | 1.08 | red brown margined | D | 1.02 |
| <i>Paraphysis</i> | <i>C. amadanensis</i> | 11 | cream | ray form | S | - | 2.5 | dark brown margined | D | 1.5 |
| | <i>C. nemecii</i> | 10.4 | golden honey | ray form | S | - | 2.4 | golden margined | D | 1.8 |
| <i>Microlophus</i> | <i>C. behen</i> | 6.5 | white | semi straight | S | - | 1.6 | no margin | D | 1.5 |
| | <i>C. pabotii</i> | 5.3 | white | straight | S | - | 1.6 | no margin | D | 1.2 |
| | <i>C. koeieana</i> | 5.5 | white | straight | S | - | 1.5 | brown margined | D | 2.6 |
| <i>Mesocentron</i> | <i>C. solstitialis</i> | 4.6 | white | ray form | S | + | 1.1 | no margin | D | 1.8 |
| | <i>C. pseudosinaica</i> | 3.6 | honey color | semi ray form | S | - | 1.2 | no margin | D | 1.2 |
| <i>Calcitrapa</i> | <i>C. iberica</i> | 1.16 | white | short & semi ray | S | - | 1.01 | dark brown margined | D | 0.3 |
| | <i>C. hyalolepis</i> | 3.2 | white | semi ray | S | - | 0.9 | yellow margin | D | 1.3 |

Table 3. continue ...

| Section | species | P.L | P.C | P.F | P.T | IDP | Co.L | Co.C | Co.F | PL/AL |
|-------------------------|---------------------------|------|---------------|-----------------------|-----|-----|------|---------------------|------|-------|
| <i>Tetramorphaea</i> | <i>C. bruguierana</i> | 2.2 | white | semi ray | S | + | 0.2 | brown margin | D | 1.08 |
| <i>Acrocenteron</i> | <i>C. sosnowskyi</i> | 8 | honey cream | ray form | S | + | 1.93 | no margin | D | 1.48 |
| | <i>C. kandavanensis</i> | 8.3 | white | semi ray form | S | + | 1.81 | no margin | D | 1.5 |
| | <i>C. luristanica</i> | 17.8 | milky white | semi ray | S | + | 2.3 | no margin | D | 2.8 |
| <i>Psephelloideae</i> | <i>C. leuzeoides</i> | 10 | black | ray form | S | + | 2.7 | no margin | D | 1.2 |
| | <i>C. gilanica</i> | 7.7 | cream purple | semi ray form | S | - | 2.1 | brown margin | ND | 1.1 |
| <i>Psephellus</i> | <i>C. zuvandica</i> | 0.5 | yellow | too short & ray form | S | - | 1.6 | brown margin | D | 0.1 |
| <i>Amblyopogon</i> | <i>C. incanescens</i> | 1.7 | white | dense & diagonal | S | - | 2.2 | black, brown margin | D | 0.2 |
| <i>Odontolophoideae</i> | <i>C. phaeopappoides</i> | 2.2 | brown honey | ray form | S | + | 1.6 | honey margin | D | 0.5 |
| <i>Uralepis</i> | <i>C. gaubea</i> | 7.4 | white | semi ray form | S | - | 1.6 | red brown margin | D | 2.6 |
| <i>Xanthopsis</i> | <i>C. xanthocephala</i> | 2.2 | purple | short & semi ray form | S | + | 1.3 | black margin | D | 0.3 |
| <i>Cyanus</i> | <i>C. cyanus</i> | 6.4 | white | ray form | S | + | 2.1 | cream margin | D | 1.3 |
| <i>Cyanus</i> | <i>C. cheiranthifolia</i> | 1.3 | amber colored | short & semi ray form | S | + | 1.7 | red brown margin | D | 0.3 |
| | <i>C. depressa</i> | 6.2 | white | semi ray form | S | + | 2.1 | cream margin | D | 1.3 |
| | <i>C. elbursensis</i> | 18 | cream white | semi ray form | S | - | 2.2 | dark brown margin | D | 3.2 |
| | <i>C. triumphetti</i> | 1.5 | amber colored | short & straight | S | + | 1.6 | light margin | D | 0.3 |

DISCUSSION

The character states used for achene characterization in different species of the genus *Centaurea* are thoroughly investigated, and some of them were found to be major key features. Character states derived from the presence of hair on the achene, the presence of appendage, the length and color of the appendage, the length of hilum, the length of achene and its color, the length of pappus, especially in comparison with the length of achene, the presence of inner dense pappus as well as the color and form of the connection area of hilum were found to be important.

Due to the Flora Iranica (Wagenitz, 1980), the identification key generated for the separation of the groups (A-I) were based on characters such as the form and color of appendage and bracts, the number of cilia, the form of leaves, the presence or absence of terminal spine and the duration of the plant. In

this paper, the identification key for 24 sections of the genus *Centaurea* is constructed on the basis of the achene specifications. Three groups are considerably distinct and recognized. Group A is distinguished by having the achene with large and highly observable prominent appendage coming out of hilum. Group B is specified by having the achene with appendage enclosed by the hilum. Moreover, Group C is specified by the absence of appendage in achene’s hilum.

Group A: Achene with large and highly prominent appendage out of hilum

1. Hilum appendage red.....sect. *Stizolophus*
- Hilum appendage white.....2
2. Achene with margin in connection to pappus3
- Achene with no margin in connection to pappus.5
3. Achene hairy on its surface.....4
- Achene glabrous.....sect. *Centaurea*

4. Inner pappus dense and scale like.....
sect. *Odontolophoideae*
 - Inner pappus loose.....sect. *Psephellus*
 5. Pappus shorter than the achene
sect. *Rhizocalathium*
 - Pappus longer than the achene
sect. *Mesocentron* = *C. pseudosinaica*

Group B: Achene with small appendage, but not prominent in coming out of hilum

1. Achene with margin in connection to pappus.....2
 - Achene without margin in connection to pappus...
sect. *Acrolophus* = *C. ovina*
 2. Pappus length / achene length more than 1..... 3
 - Pappus length / achene length less than 1..... 4
 3. Hilum truncate.....sect. *Uralepis*
 - Hilum round.....5
 4. Achene denticulate in pappus connection area....6
 - Achene not as above.....sect. *Cyanus* = *C. cyanus*
 5. Hilum scabrous.....7
 - Hilum smooth8
 6. Pappus with inner dense row.....
sect. *Cynaroides* = *C. depressa*
 - Pappus without inner dense row.....
sect. *Cyanus* = *C. elbursensis*
 7. Pappus with inner dense row.....sect. *Xanthopsis*
 - Pappus without inner dense.....
sect. *Cynaroids* = *C. phlomoides*
 8. Achene hairy.....10
 - Achene glabrous.....9
 9. Pappus purple.....sect. *Phaeopappus*
 - Pappus not purple.....
sect. *Paraphysis* = *C. amadanensis*
 10. Pappus purple..sect. *Psephelloideae* = *C. gilanica*
 - Pappus not purple.....11
 11. Achene shiny white...sect. *Paraphysis* = *C. nemecii*
 - Achene Brown12
 12. Pappus length more than 5 mm.....
sect. *Cynaroides* = *C. imperialis*
 - Pappus length less than 5 mm.....13
 13. pappus with inner dense row.....
sect. *Cyanus* = *C. cheiranthifolia*
 - Pappus with no inner dense.....
 ...sect. *Ammocyanus*, sect. *Acrolophus*=*C. aggregata*

Group C: Achene without appendage

1. Pappus with inner dense row.....2
 - Pappus with no inner dense row.....5
 2. Achene scarcely hairy.....sect. *Hyalea*
 - Achene glabrous.....3
 3. Achene margined on pappus connection area.....sect. *Tetramorphaea*
 - Achene no margined.....4
 4. Achene white, pappus black.....
sect. *Psephelloideae* = *C. leuzeoides*

- Achene cream-colored, pappus white.....
sect. *Mesocentron* = *C. solstitialis*
 5. Achene hairy6
 - Achene glabrous.....sect. *Cynaroides* = *C. regia*
 6. Hilum hairy.....sect. *Calcitrapa*
 - Hilum glabrous7
 7. Achene margined on pappus connection area.....9
 - Achene no margined.....8
 8. Hilum concave.....10
 - Hilum angled.....sect. *Microlophus*
 9. Achene-pappus small opening.....sect. *Jaceae*
 - Achene-pappus large opening.....
sect. *Cynaroides* = *C. gigantean*
 10. Pappus longer than the achene11
 - Pappus shorter than the achene or the same.....12
 11. Achene hairy.....sect. *Chartolepis*
 - Achene glabrous.....sect. *Cheirolepis*
 12. Pappus truncate-oblique.....sect. *Amblyopogon*
 - Pappus not as above.....
sect. *Cynaroides* = *C. geluensis*

According to Tables 2 and 3, some differences are observed in some species among sections. In sect. *Acrolophus*, in *C. ovina* (Fig. 2 E) no margin is seen in achene pappus connection area, while *C. aggregata* (Fig. 2 D) has a brown margin. Moreover, based on Tables 2 and 3, in *C. ovina*, pappus length is shorter than the achene length, while in *C. aggregata* pappus is longer. Therefore, the ratio of pappus length to achene length is more than 1. One important point to mention is that the similarity between sects. *Acrolophus* and *Ammocyanus*, based on the features studied in Flora Iranica (Wagenitz 1980), is mirrored in the high similarity between *C. ammocyanus* (Fig. 2 F) and *C. aggregata* in the section mentioned, in the features studied here (Tables 2 & 3). In sect. *Phaeopappus*, despite the categorization of *C. albonitens* with *C. aucheri* in the mentioned section, white broom form pappus is seen (Fig. 3 Q), though the other subspecies are interesting and recognized by having ray form purple pappus (Fig. 3 N, O & P). Moreover, pappus in *C. albonitens* is much longer in comparison with achene length.

Sect. *Cynaroides* is one of the most varied sections, as many different character states were observed among its five species. *C. regia* is the only species among all others with no hairs on its achene surface (Fig. 3 Q), while the others have hairs as *C. imperialis* (Fig. 3 R) and *C. gigantea* (Fig. 3 T) are specified by having scarce hairs and *C. phlomoides* (Fig. 3 R) and *C. geluensis* (Fig. 3, V) are fully covered with hairs on their achene surface.

In sect. *Cynaroides*, the species *C. phlomoides* has distinct morphological differences in the characters studied compared with other species of the section.

In addition, different bracts and capitulum size are additional morphological traits to convince us to separate *C. phlomoides* from the other members of this section and treat it as a new section.

Three species namely *C. regia*, *C. geluensis* and *C. gigantea* have no appendage, while the other species do. Moreover, *C. regia* and *C. gigantea* have no margin. In all species in sect. *Cynaroides*, pappus is obviously longer than the achene, however, pappus length in *C. phlomoides* is much shorter than the achene length. Furthermore, according to Tables 2 and 3, hilum length in *C. phlomoides* is much longer than the others. The ratio of pappus length to achene length is less than one in the mentioned species, while in others it is more than 1.

In sect. *Paraphysis*, *C. amadanensis* has no hairs on the achene (Fig. 3 W), and the color of the achene is creamy, but in *C. nemecii* achene is hairy and white (Fig. 3 X). These two species are morphologically close to each other, however, they are separated on the basis of the presence of pedicel in *C. amadanensis* or the lack of pedicel in *C. nemesi*.

In sect. *Microlophus*, achenes in species *C. behen*, *C. pabotii* and *C. koeiana* (Fig. 4 A, B and C) were thoroughly investigated. In all these three species, the surface of achene is hairy, but achene in *C. koeiana* is overwhelmingly hairy. Also, in the two species mentioned first, the form of hilum is corner angled, while hilum in *C. koeiana* is scanned. Moreover, the length of

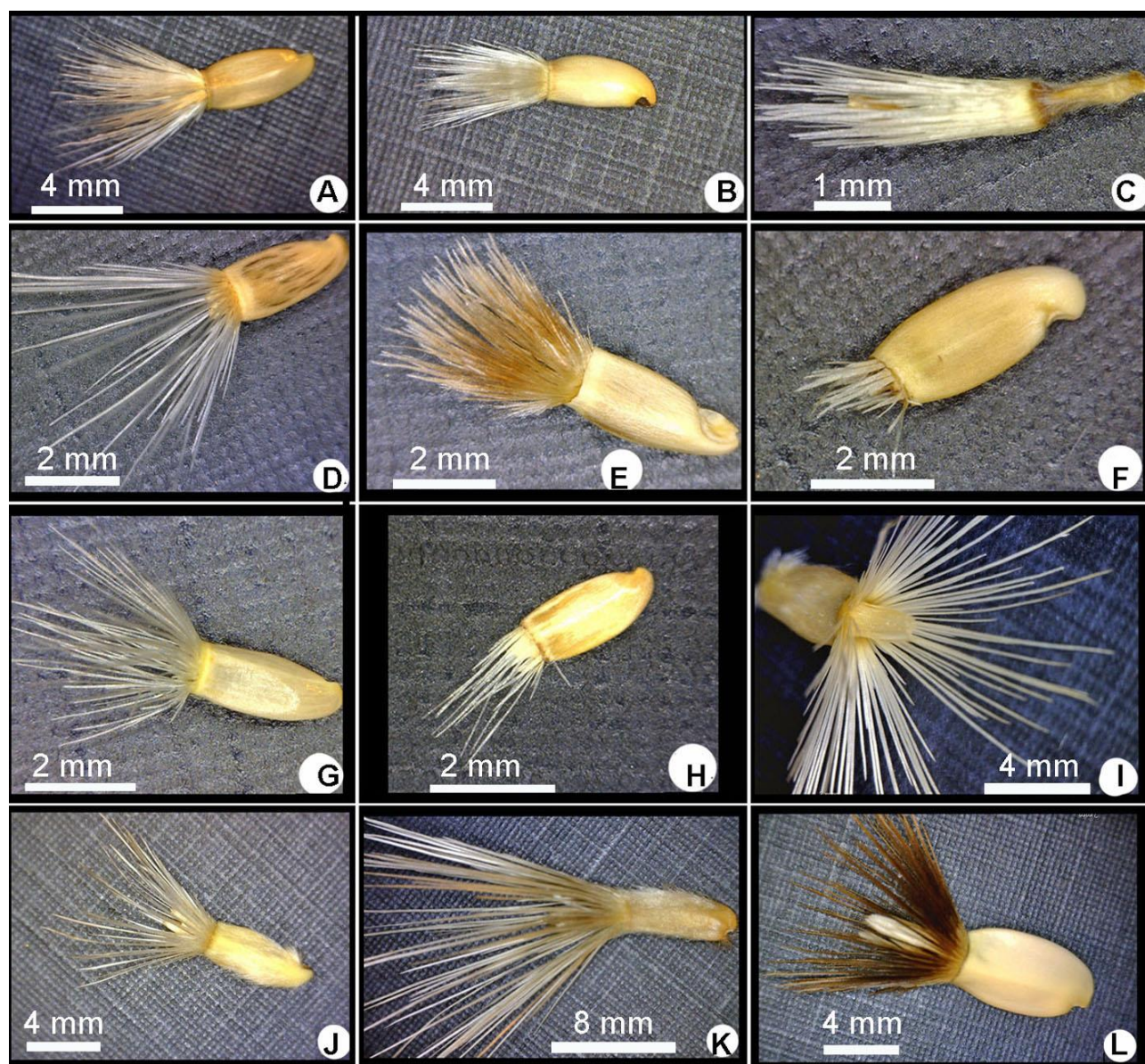


Fig. 4. A. *Centaurea behen*. B. *C. Pabotii*. C. *C. Koeiana*. D. *C. solstitialis* subsp. *solstitialis*. E. *C. pseudosinaica*. F. *C. iberica*. G. *C. hyalolepis*. H. *C. bruguierana*. I. *C. sosnowskyi*. J. *C. kandavanensis*. K. *C. luristanica*. L. *C. leuzeoides*.

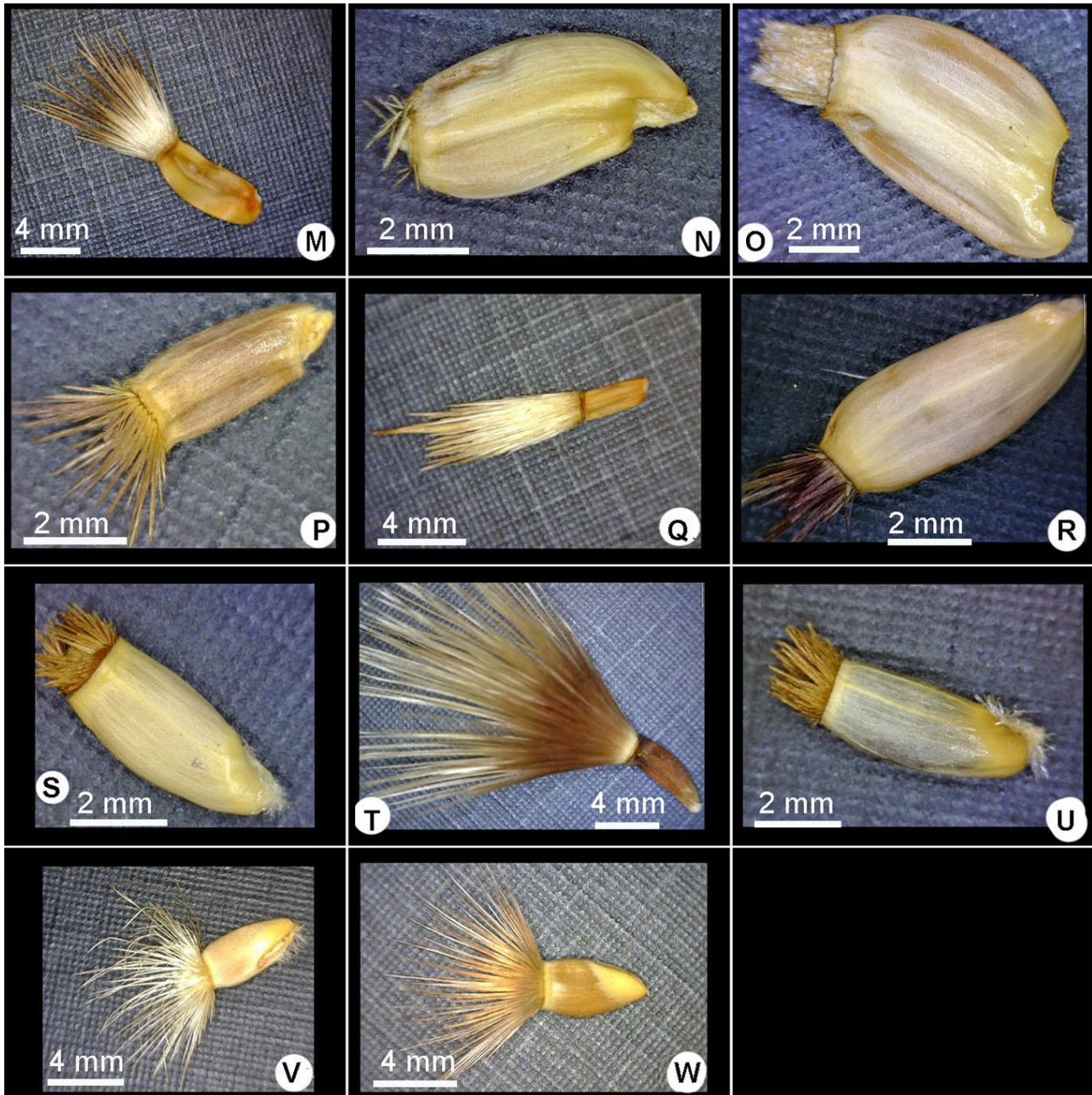


Fig. 5. M. *Centaurea gilanica*. N. *C. zuvandica*. O. *C. incanescens*. P. *C. phaeopappoides*. Q. *C. gaubae*. R. *C. xantocephala*. S. *C. cheiranthifolia*. T. *C. elburzensis*. U. *C. triumfettii*. V. *C. depressa*. W. *C. cyanus*.

pappus is almost 3 times more than achene length. This section is homogenous in the characters studied. The appendage of bracts is without hilum and all flowers are yellow. Their achenes are also very similar.

In sect. *Mesocentron*, an interesting reversed relation is seen in the presence of inner dense pappus and appendage. It means that, in *C. solstitialis* (Fig. 4 D), no appendage is seen but the inner dense pappus is obvious with white achene, while *C. pseudosinaica* (Fig. 4 E) is seen with prominent appendage, no inner dense pappus and brown achene. These two species are similar in that they have yellow flowers and 'bract appendage' that

leads to long acute spines, but different because of their geographical distribution, as the first one is an Irano-Turanian element while the second one is a Sahara-Sindian element. Their achenes are completely different.

In sect. *Calcitrapa*, two species namely *C. iberica* (Fig. 4 F) and *C. hyalolepis* (Fig. 4 G) are thoroughly investigated. The most important criteria to be used in the comparison between these two is the length of pappus. This means that, in the first species, the length of pappus is shorter than that of the achene, while in *C. hyalolepis* the pappus is longer. Therefore, the ratio is more than 1 in the former, but less than 1 in the latter. In addition, short

amount of hairs can be seen in hilum area of *C. iberica*.

Sect. *Psephelloideae*, is a group with a lot of differences among its species. *C. leuzeoides* (Fig. 4 1): 1-lacks hairs on achene, 2-lacks appendage, 3-shiny white achene, 4- has black pappus, 5-lacks margin in pappus-achene connection area, 6- has denticulate pappus-achene connection form, 7- has inner dense pappus

C. gilanica (Fig. 5 M): 1. has hairs on achene surface, 2. has appendage, 3. the achene color is yellow brown, 4. has cream-colored purple pappus, 5. has brown margin in pappus-achene connection area, 6. Achene-pappus connection is not denticulate, 7. lacks inner dense pappus.

Sect. *Amblyopogon* with only one species, *i.e.* *C. incanescens*, have the largest hilum as compared with all other sections, short, dense and in diagonal form pappus (Fig. 5 O).

Sect. *Xanthopsis*, besides *phaeopappus*, is famous for its purple pappus.

The other interesting section is *cyanus*: the species thoroughly observed included *C. cheiranthifoli*, *C. depressa*, *C. cyanus*, *C. elbursensis* and *C. triumfettii*. The prominent differences investigated were addressed as follows.

In *C. cheiranthifolia* (Fig. 5 S) no hairs were seen on achene, while the others have hairs on their achene.

Hilum length in *C. cyanus* (Fig. 5 W) is the biggest in comparison with other species in this section. The achene shape in *C. cyanus* (Fig. 5 W) is triangular while others have oblong shape. *C. elbursensis* (Fig. 5 T) is the only species in this group without inner dense central pappus, while others have the feature. Pappus in *C. cheiranthifolia* (Fig. 5 S) and *C. triumfetti* (Fig. 5 U) are shorter than the achene, while in other species of the mentioned section, pappus are long enough to consider. Interestingly, in *C. elbursensis*, pappus is much longer in comparison with achene length.

Based on the discussion, despite the fact that each section contains a lot of species with many similarities in achene's morphology, many differences in species in many of those sections have been observed.

Based on the studied morphological traits, especially the morphology of achene, these traits are useful for the delimitation of the species. Although a new key has been provided for categorizing the sections, achene morphological traits were found to be inadequate. In each section type, achenes are different among some species even when similarities were observed in other morphological traits.

Morphologically, some traits such as the presence or absence of appendage of bracts, central bract

appendage form, the number of cilia around appendage, the color of cilia and the color of flowers can be useful for the delimitation of sections. In addition, achene characteristics can be useful for the delimitation of the species in the genus *Centaurea*.

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