

## FRUIT ANATOMY OF THE GENUS BUPLEURUM L. (APIACEAE) IN IRAN

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Received 2013. 07. 20. Accepted for publication 2014. 02.12

Ghahremaninejad, F., Hoseini, E. & Mozaffarian, V. 2014. 06. 31: Fruit anatomy of the genus *Bupleurum* L. (Apiaceae) in Iran.- *Iran. J. Bot.* 20 (1): 51-70. Tehran.

The genus *Bupleurum* L., with about 185-195 species, is the second largest genus of the family Apiaceae Lindl. It includes 35 species in the Iranian plateau, 15 of which are thrived in Iran. Three species out of these, i.e., *B. wolffianum*, *B. flexile* and *B. ghahremanii*, are endemic to Iran. In this study, the fruit anatomy of all *Bupleurum* species in Iran, except *B. wolffianum*, for which specimens were not available, were studied for the first time. Some of the most taxonomically important fruit characteristics were found to be: mericarp shape in transverse section, characteristics of ribs, ratio of mericarp width to thickness, existence of oil ducts, quantity of vallecular and commissural vittae, ratio of height to width of dorsal rib, and shape of endocarp in transverse section. Important features for each species were described and an identification key was also provided. Anatomical studies also confirmed the anatomical and morphological differences between Sect. *Perfoliata* and other members of the genus. Absence of vittae in Sect. *perfoliata* may be correlated with broad leaves, dilated, rounded and perfoliate leaf bases. In addition, two distinct subgroups were shown in respect to different number of vallecular vittae in each furrow. These features may be applied as the basic classification aspects for further investigation on the genus *Bupleurum*.

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**Keywords:** Umbelliferae, mericarp, anatomical study, taxonomy, SW Asia

آناتومی میوه جنس *Bupleurum* L. (کرفسیان) در ایران

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جنس *Bupleurum* L. با ۱۸۵-۱۹۵ گونه، دومین جنس بزرگ خانواده چتریان است. این جنس در فلات ایران ۱۵ گونه دارد. سه گونه آنها، یعنی *B. wolffianum*، *B. flexile* و *B. ghahremanii* انحصاری ایران هستند. در این مطالعه، آناتومی میوه همه گونه های موجود در ایران، به جز *B. wolffianum* که نمونه آن در دسترس نبود، برای اولین بار مورد بررسی قرار گرفته است. برخی از مهمترین ویژگی های تاکسونومیکی میوه عبارتند از: شکل مریکارپ در برش عرضی، ویژگی ظاهری پره ها، نسبت عرض به ضخامت مریکارپ ها، وجود مجاری ترشچی، تعداد مجاری بین پره ای و بین مریکاری، نسبت ارتفاع به عرض پره میانی و شکل اندوکارپ در برش عرضی. ویژگی های مهم هر گونه شرح داده شد. همچنین کلید شناسایی نیز تهیه گردید. نتایج آناتومیک تفاوت آناتومی و ریختی سکسیون *Perfoliata* از سایر گونه های جنس را تایید کرد. فقدان مجاری ترشچی در این جنس ممکن است با برگ های متسع و ساقه محصور در سکسیون *Perfoliata* همبسته باشد. ضمناً، دو زیرگروه متمایز دیگر نیز بر مبنای شمار مجاری ترشچی بین پره ای نشان داده شدند. این ویژگی ها می توانند به عنوان عواملی اساسی در رده بندی جنس *Bupleurum* در تحقیقات آتی به کار روند.

### INTRODUCTION

*Bupleurum* L. is one of the largest and most diverse genera of the family Apiaceae Lindl., and is widely

distributed in Asia and the world. Despite its wide distribution in temperate regions of the northern hemisphere, some species are restricted to small areas.

*Bupleurum* includes approximately 185-195 species worldwide, 155 of which belong to Asia (Pimenov & Leonov 2004).

This distinct genus can easily be recognized by its simple and undivided leaves and conspicuous bracts and bracteoles. *Bupleurum* species are, however, notoriously difficult to identify due to wide morphological variation of the populations of each species.

According to Flora Iranica (Rechinger & Snogerup 1988), the genus includes 34 species in the Iranian plateau (Iran, Afghanistan, W Pakistan, N Iraq, SE Azerbaijan and S Turkmenistan), of which 13 species have been mentioned to exist in Iran, 2 of which are endemics: *B. wolffianum* Bornm. and *B. flexile* Bornm. & Gauba.

After the publication of Flora Iranica, one new endemic species was added to the flora of Iran in 1991: *B. ghahremanii* Mozaff. (Mozaffarian, 2007). In addition, another species, *B. brevicaule* Schldtl. was recorded from W Iran in due course (Matin & Mousavi 1992), raising the number of the Iranian species to 15.

Iranian species of *Bupleurum* belong to two major sections: *Perfoliata* Godr. and *Eubupleura* Briquet. On the basis of Zohary's classification of phytogeographical regions (Zohary 1973), they are generally floristic elements of Irano-Anatolian province of the Irano-Turanian region.

On the basis of the Flora Iranica treatment (Rechinger & Snogerup 1988), the classification of Iranian *Bupleurum* includes four natural groups (Grex A, B, C and D). Grex A, equal to sect. *Perfoliata* Godr., includes *B. rotundifolium*, *B. croceum* and *B. lancifolium*. Grex B, equal to sect. *Eubupleura* Briquet. p.p. subsect. *Glumacea* Boiss., includes *B. aleppicum* and *B. brevicaule*. Grex C, equal to sect. *Eubupleura* subsect. *Juncea* Briquet, includes *B. semicompositum*, *B. marschallianum*, *B. leucocladum*, *B. haussknechtii*, *B. kurdicum* and *B. gerardii*. Grex D, equal to sect. *Eubupleura* subsect. *Nervosa* (Godr.) Briquet., includes *B. wolffianum*, *B. flexile*, *B. exaltatum* and *B. ghahremanii*.

Grex A, B and C include annuals, normally one-stemmed with thin roots. Grex A is characterized by broad leaves, the upper ones to be perfoliate. Grex B and C are united by narrow and more or less linear leaves, but Grex B has large, more or less excavate bracteoles which enclose flowers. On the other hand, Grex C is distinguished with narrow, small and herbaceous bracteoles. Grex D is known to include perennial species which have several stems rising from a woody stock.

Fruit anatomy and morphology in Apiaceae are mentioned as essential factors for the taxonomy of the

family due to variable external and internal features of fruits, especially in significant references such as Morison's *Plantarum Umbelliferarum* (1672), Koch's *Generum Tribuumque Plantarum Umbelliferarum* (1824) and De Candolle's *Prodromus Systematis Naturalis Regni Vegetabilis* (1830).

Overall similarities in the structural plan of the fruit in family Apiaceae (Berco & Broască 2012) made it possible to execute comparative anatomical studies at ultrageneric and infrageneric levels. The value of structural data, such as the fruit anatomy and micromorphology in taxonomy of the family was emphasized and some of the carpological features were marked as synapomorphies (Liu et al. 2006).

Fruit anatomical-based studies were also utilized either to revise infrageneric delimitations and identification of new taxa, e.g., in genus *Pimpinella* L. (Khajepiri et al. 2009), or to confirm previous suggestions, e.g. the study of Turkish members of the genus *Ferulago* W. D. J. Koch (Urusak & Kizilarsalan 2013).

Although the characterization of the decisive features of *Bupleurum* species is considerably difficult, the importance of the genus led to numerous taxonomical studies. However, there are few examples of reported studies on fruit anatomy of the genus *Bupleurum*, and one of the rare examples is the study executed on species of NE China (Liu et al. 2003). The micromorphological traits of fruit surface were also mentioned as important factors in infrageneric classification of genus *Bupleurum* (Özcan 2004).

Despite the undoubted usefulness and practical value of classical diagnostics based on common morphological characteristics, using fruit anatomy in this genus may be regarded as a more efficient confirmation step for the identification of unknown taxa.

As Snogerup & Snogerup (2001) had stated, ornamentation and anatomy of fruits differ more between closely related taxa in *Bupleurum* than in any other part of Umbelliferae (Apiaceae). The outcome of this paper is expected to confirm this statement.

## MATERIALS AND METHODS

The fruit anatomy of all species of the genus *Bupleurum* in Iran, except *B. wolffianum* for which specimens were not available, was studied. Revealing the anatomical characteristics needs studying mature fruits from different sources for each species. In the case that there was only one sample available, we examined two distinct umbels from different branches to avoid probable anomalies. This study is based on herbarium specimens from the following herbaria: T, TARI and W(Thiers, continuously updated). The list of

Table 1. *Bupleurum* specimen examined in this study.

<i>B. aleppicum</i>	Iran, Kurdistan, Sanandaj, 1500 m, Jacobs 6988 (W). Iraq, Mosul, Near Zakho, Rechinger, 10703 (W).
<i>B. brevicaulle</i>	Iraq, Baban near Alkosh, Field & Lazar 3172 (W).
<i>B. croceum</i>	Iran, Kermanshah, Mahidasht, Chagha Zard, Sanei 35196 (TARI). Hamedan, Bahai 6668 (W).
<i>B. exaltatum</i>	Iran, Tehran, Damavand, north of the city, 2450 m, Mozaffarian 54104 (TARI). Karaj to Chalus versus Nisind, Jardine 881 (W).
<i>B. flexile</i>	Iran, Mazandaran, Kelardasht, Roudbarak, 1660 m, Foroughi 8779 (TARI).
<i>B. gerardii</i>	Iran, Gilan, Manjil, 30 km of Rustam Abad to Dogahe, 1150 m, Mozaffarian & Nouruzi 33949 (TARI). Khorassan, Bujnurd, Babaman, 1000 m, Mozaffarian 83686 (TARI). Qom province, Qom, Anonymous 34079 (T).
<i>B. ghahremanii</i>	Iran, Mazandaran, South of Ramsar, East of Lapasar, 2950 m, Ronemark & Maassoumi 21645 (TARI).
<i>B. haussknechtii</i>	Iran, Tehran, between Tehran and Jajrud, 1590 m, Aellen 1298 (W).
<i>B. kurdicum</i>	Iran, Chaharmahal-e Bakhtiary, Naghon, Chahartagh, 2200 m, Mozaffarian 77346 (TARI). Chaharmahal-e Bakhtiary, Dashtak, between Ardal and Gardan-e Charri, 1820 m, Mozaffarian 74544 (TARI).
<i>B. lancifolium</i>	Iran, Ilam, Ilam, 400-450 m, Jacobs 6291 (W). Khuzestan, Dehdez, 1300m, Mozaffarian 63162 (W).
<i>B. leuocladum</i>	Iran, Chaharmahal-e Bakhtiary, Sorkhun, 1200 m, Mozaffarian 54900 (TARI). Iraq, Near Iranian Border, 20km North of Bedra to Mandal, Rechinger, 9692 (W).
<i>B. marschallianum</i>	Iran, Mazandaran, Alamdeh, Manouchehr kala, 20 m, Mozaffarian 45537 (TARI). Ramsar, Near Ramsar Hotel, Gholami Zarif 13887 (T). Gilan, between Bandar-e Anzali and Rasht, Seashore, 20 m, Assadi & Akhani 61666 (TARI).
<i>B. rotundifolium</i>	Iran, Arak, Shazand, Hafte Emarat village, Barzegar 35595 (T). Khorassan, Jozak, 72 km of west of Bujnurd to Gorgan, 1100 m, Rechinger, 53757 (W). Tehran, 12 km south of Damavand, Akhorbedin, 1800 m, Mozaffarian 53825 (TARI).
<i>B. semicompositum</i>	Iran, Bushehr, 70 km of Bushehr port to Ameri port, 3-10 m, Ronemark & Mozaffarian 27053 (TARI). Khuzestan, Ca. 25 km from Ahvaz to Bandar-e Emam, near Coriate, 20 m, Mozaffarian 53499 (TARI).

examined specimens is presented in table 1.

Specimens were placed in tubes filled with distilled water, then transferred to bain-marie, at 60 degrees of centigrade for 36 hours for rehydration. Then they were treated by FAA (formaldehyde-acetic acid-alcohol) for a minimum of 24h and transferred to 70% methanol for long time preservation. After each step, specimens were washed with distilled water. Freehand sections were made by means of commercial razor blade. Sections were unstained by 50% javelle water for about 45 minutes, washed with distilled water for 30 minutes and treated with 10% acetic acid for 10 minutes. To stain the prepared samples, Alum carmine solution and methyl green solutions were used. Samples were studied by the use of a ZEISS standard light microscope and photographs were taken by means of a Cannon G5 Camera. Fruit terminology of the studied species is based on Kljuykov et al. (2004) and Swink & Wilhelm (1994). Sectional and subsectional names are based on Wolff (1910).

## RESULTS

Based on the obtained images and assigned terminology, anatomical features of each species are described as follows. A summary of more important and decisive anatomical features of mericarp in these 14 species of Iranian *Bupleurum* is prepared in table 2. An identification key for separation of the Iranian species based on anatomical features are provided in table 3.

### General description of *Bupleurum* fruits.

Fruits are ovate, elliptic, ovate-oblong or subglobose in shape. Mericarps are two, homomorphic or heteromorphic in some cases due to abortion or developmental failure of one mericarp; round or pentagonal in transverse section; slightly compressed dorsally, terete or slightly compressed laterally; primary ribs equal, ribs primary only. Epidermal

Table 2. Summary of structural features of Iranian species of *Bupleurum*.

<i>Bupleurum</i> species	Compression of mericarp	Shape of mericarp in t.s.	Shape of endocarp in t.s.	Number of VV.			Surface of exc.	Mericarp T/W ratio	Median rib H/W ratio	Prominency of ribs	Shape of ribs	VB arrangement	
				Obsolete	Solitary	2-5 per furrow						At primary rib	middle of primary
<i>B. rotundifolium</i>	•	•	•	•	•	•	•	0.77	0.62	•	•	•	•
<i>B. croceum</i>	•	•	•	•	•	•	•	0.90	0.77	•	•	•	•
<i>B. lancifolium</i>	•	•	•	•	•	•	•	1.05	0.88	•	•	•	•
<i>B. aleppicum</i>	•	•	•	•	•	•	•	0.67	0.30	•	•	•	•
<i>B. brevicaule</i>	•	•	•	•	•	•	•	0.98	0.35	•	-	-	•
<i>B. semicompositum</i>	•	•	•	•	•	•	•	0.87	-	•	-	-	•
<i>B. marschallianum</i>	•	•	•	•	•	•	•	0.88	0.75	•	•	•	•
<i>B. leucocladum</i>	•	•	•	•	•	•	•	0.98	0.35	•	-	-	•
<i>B. haussknechtii</i>	•	•	•	•	•	•	•	1.02	0.40	•	•	•	•
<i>B. kurdicum</i>	•	•	•	•	•	•	•	1.25	1.50	•	•	•	•
<i>B. gerardii</i>	•	•	•	•	•	•	•	1.01	0.60	•	•	•	•
<i>B. exaltatum</i>	•	•	•	•	•	•	•	1.01	0.38	•	•	•	•
<i>B. flexile</i>	•	•	•	•	•	•	•	1.40	1.05	•	•	•	•
<i>B. ghahremanii</i>	•	•	•	•	•	•	•	0.96	0.35	•	•	•	•

surface is glabrous, pubescent or tuberculate. Median rib is obsolete, keeled or winged, obtuse, apiculate or acute; lateral ribs are two, obsolete, keeled or winged, obtuse, apiculate or acute; marginal ribs are two, obsolete, keeled or winged, obtuse, apiculate or acute. Exocarp adhering, includes small cells with thin walls, non-lignified; single layer to multilayer hypodermal collenchyma present. Mesocarp is consisted of regular to large in size parenchymatous cells with some collenchyma cells near vascular bundles. Vittae obsolete or vallecular and commissural in mature fruit; vallecular vittae obsolete, solitary or 2-5 in each furrow; commissural vittae obsolete, 2, 4 or 6, situated between marginal ribs; intrajugal vittae obsolete. Vascular bundles are 5, at primary rib bases. Endocarp is single layer, bilayer to multilayer, consists of parenchymatous cells, non-lignified, shape of endocarp round or hexagonal in transverse section (Fig. 1).

**Grex A (Sect. *Perfoliata* Godr.)**

***B. rotundifolium* L.**

Mericarps round in transverse section, slightly compressed dorsally. Epidermal surface glabrous. Thickness to width ratio of mericarp 0.77. Median rib keeled, small and acute; height to width ratio of median rib 0.62; lateral and marginal ribs are two, keeled, small and acute. Exocarp with single layer to bilayer hypodermal collenchyma cells. Mesocarp with regular parenchymatous cells. Vittae obsolete in mature fruit. Endocarp single layer, round in transverse section (Fig. 2).

***B. croceum* Fenzl.**

Mericarps pentagonal in transverse section, slightly compressed dorsally. Epidermal surface glabrous. Thickness to width ratio of mericarp 0.90. Median rib

Table 3. Anatomical identification key for the Iranian species of the genus *Bupleurum*.

1	Vittae obsolete in mature fruit.....	2
-	Vittae vallecular and commissural.....	4
2	Mericarp round.....	<i>B. rotundifolium</i>
-	Mericarp pentagonal.....	3
3	Surface of exocarp glabrous.....	<i>B. croceum</i>
-	Surface of exocarp tuberculate.....	<i>B. lancifolium</i>
4	Vallecular vittae solitary.....	5
-	Vallecular vittae 2 to 5.....	9
5	Mericarp round.....	6
-	Mericarp pentagonal.....	7
6	Exocarp pubescent.....	<i>B. haussknechtii</i>
-	Exocarp tuberculate.....	<i>B. marschallianum</i>
7	Exocarp pubescent.....	<i>B. leucocladum</i>
-	Exocarp glabrous.....	8
8	Median rib keeled.....	<i>B. aleppicum</i>
-	Median rib obsolete.....	<i>B. brevicaule</i>
9	Mericarp compressed laterally.....	10
-	Mericarp not compressed laterally.....	11
10	Mericarp oblong to round.....	<i>B. flexile</i>
-	Mericarp pentagonal.....	<i>B. kurdicum</i>
11	Exocarp pubescent.....	<i>B. semicompositum</i>
-	Exocarp glabrous.....	12
12	Endocarp round.....	13
-	Endocarp hexagonal.....	<i>B. gerardii</i>
13	Commissural vittae 4.....	<i>B. ghahremanii</i>
-	Commissural vittae 6.....	<i>B. exaltatum</i>

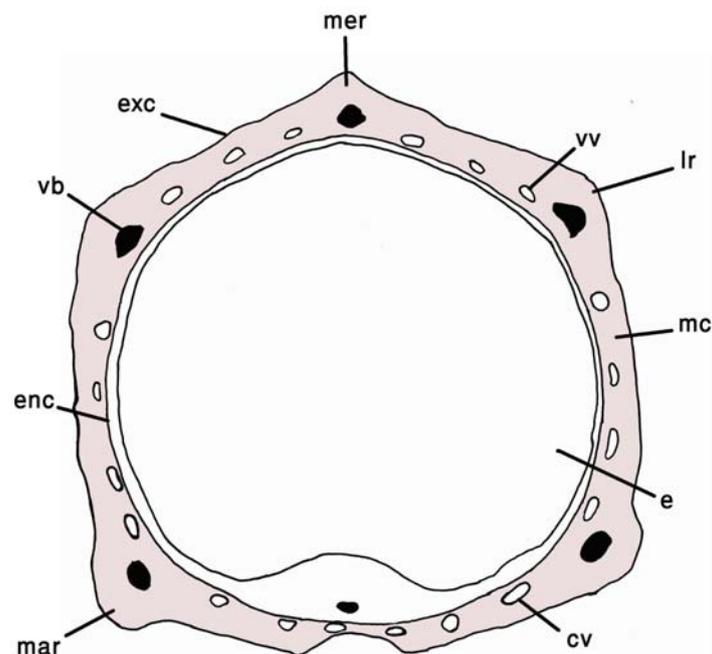


Fig. 1: Schematic structure of fruit in genus *Bupleurum*, showing applied terminology. cv= commissural vittae, e= endosperm, enc= endocarp, exc= exocarp, lr= lateral rib, mar= marginal rib, mc=mesocarp, mer= median rib, vb= vascular bundles, vv= vallecular vittae.

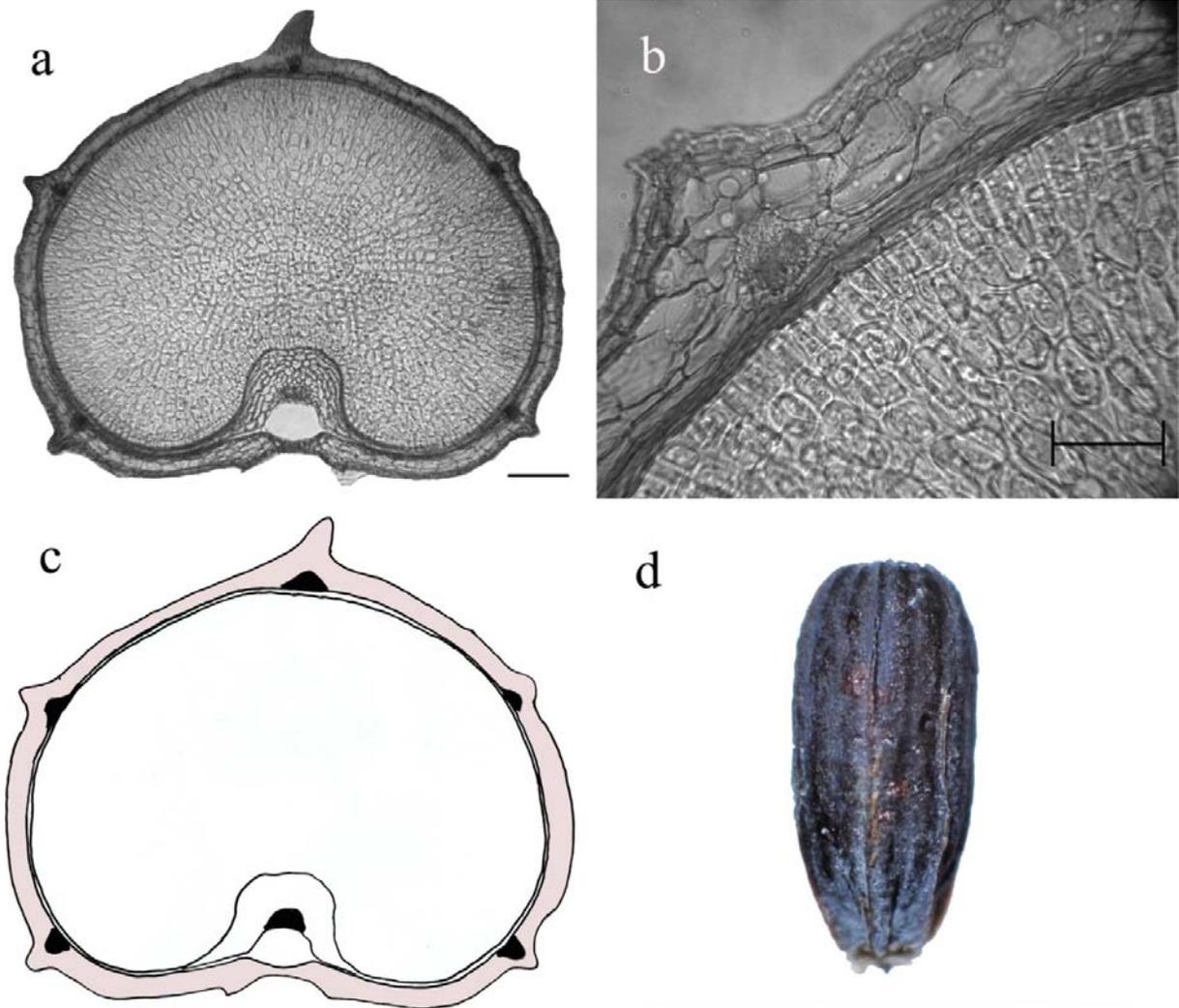


Fig. 2. Mericarp structure in *B. rotundifolium*. Scale bar= 0.2mm (a) and 0.05mm (b); Schematic drawing (c) and appearance of fruit (d)

winged, large and broadly acute; height to width ratio of median rib 0.77; lateral and marginal ribs winged, large and broadly acute. Exocarp with multilayer hypodermal collenchyma cell. Mesocarp with large parenchymatous cells. Vittae obsolete in mature fruit. Endocarp multilayer, hexagonal in transverse section (Fig. 3).

***B. lancifolium* Hornem.**

Mericarps pentagonal in transverse section; terete. Epidermal surface tuberculate. Thickness to width ratio of mericarp 1.05. Median rib winged, apiculate; height to width ratio of median rib 0.88; lateral and marginal ribs winged, apiculate. Exocarp with multilayer hypodermal collenchyma cells. Mesocarp with large

parenchymatous cells. Vittae obsolete in mature fruit. Endocarp single layer to bilayer, hexagonal in transverse section (Fig. 4).

**Grex B (sect. *Eubupleura* Briquet p.p; subsect. *Glumacea* (Boiss.) Wolff.)**

***B. aleppicum* Boiss.**

Mericarps pentagonal in transverse section; slightly compressed dorsally. Epidermal surface glabrous. Thickness to width ratio of mericarp 0.67. Median rib keeled, obtuse; height to width ratio of median rib 0.30; lateral and marginal ribs keeled, obtuse. Exocarp with multilayer hypodermal collenchymatous cells.

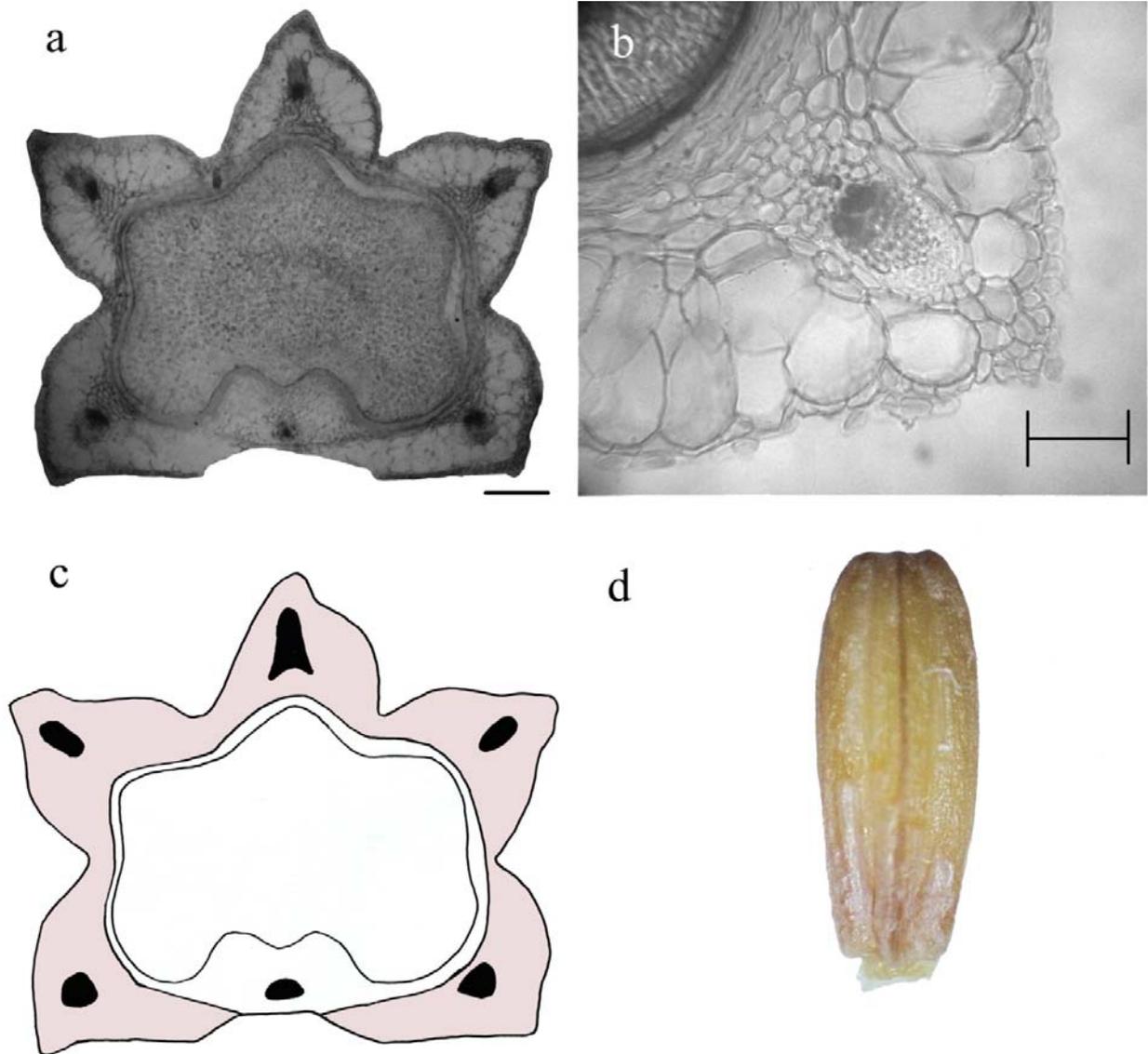


Fig. 3. Mericarp structure in *B. croceum*. Scale bar= 0.2mm (a) and 0.05mm (b); Schematic drawing (c) and appearance of fruit (d)

Mesocarp with regular parenchymatous cells. Vittae vallecular and commissural. Vallecular vittae solitary in each furrow; commissural vittae 2, situated between marginal ribs; intrajugal vittae obsolete. Endocarp single layer to bilayer, pentagonal in transverse section (Fig. 5).

***B. brevicaule* Schldl.**

Mericarps pentagonal in transverse section; terete. Epidermal surface glabrous. Thickness to width ratio of mericarp 0.98. Median rib obsolete, broadly acute; height to width ratio of median rib 0.35; lateral and marginal ribs obsolete. Exocarp with multilayer

hypodermal collenchyma cells. Mesocarp with regular parenchymatous cells. Vittae vallecular and commissural. Vallecular vittae solitary in each furrow; commissural vittae 2, between marginal ribs; intrajugal vittae obsolete. Endocarp multilayer, hexagonal in transverse section (Fig. 6).

**Grex C (sect. *Eubupleura* Briquet p.p. subsect. *Juncea* Briquet.)**

***B. semicompositum* L.**

Mericarps round in transverse section; slightly compressed dorsally. Epidermal surface pubescent.

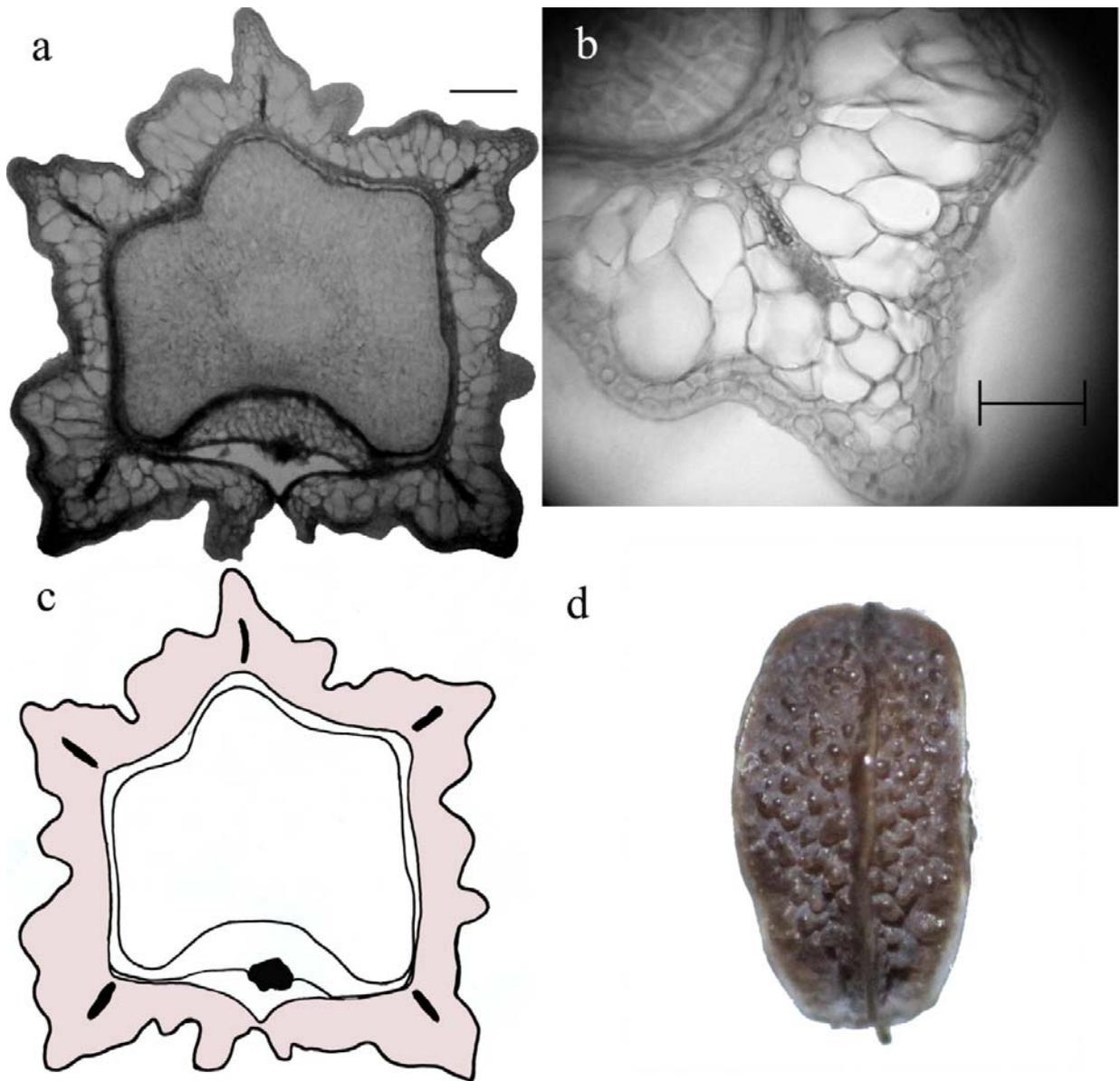


Fig. 4. Mericarp structure in *B.lancifolium*. Scale bar= 0.2mm (a) and 0.05mm (b); Schematic drawing (c) and appearance of fruit (d)

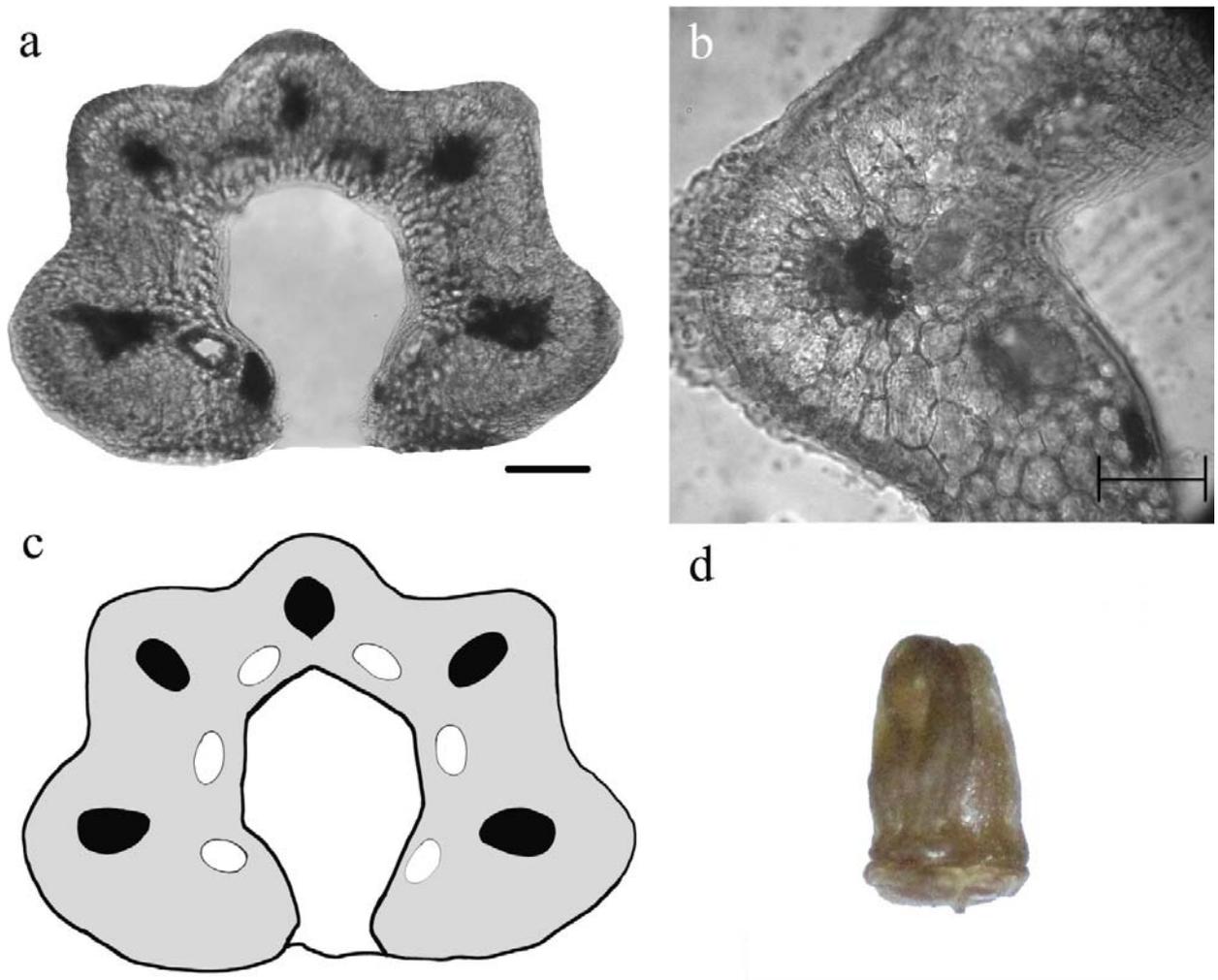


Fig. 5. Mericarp structure in *B.aleppicum*. Scale bar= 0.1mm (a) and 0.05mm (b); Schematic drawing (c) and appearance of fruit (d)

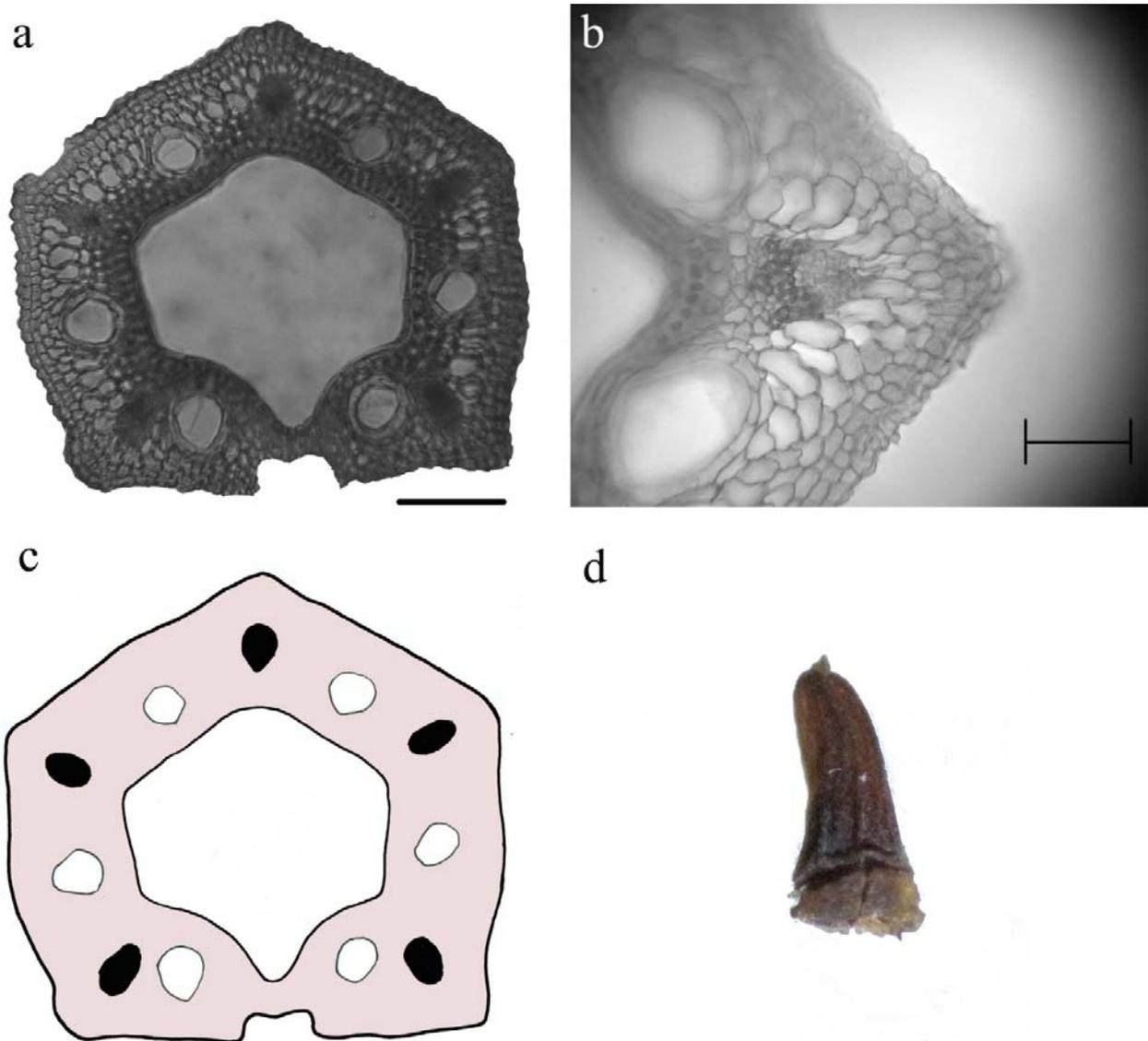


Fig. 6. Mericarp structure in *B. brevicaulis*. Scale bar= 0.1mm (a) and 0.05mm (b); Schematic drawing (c) and appearance of fruit (d)

Thickness to width ratio of mericarp 0.87. Median, marginal and lateral ribs obsolete. Exocarp with single layer to multilayer hypodermal collenchyma cells. Mesocarp with regular parenchyma cells. Vallecular vittae 3 in each furrow; commissural vittae 3 to 4, situated between marginal ribs; intrajugal vittae obsolete. Vittae vallecular and commissural. Endocarp single layer, round in transverse section (Fig. 7).

***B. marschallianum* C.A.Mey.**

Mericarps round in transverse section; slightly compressed dorsally. Epidermal surface tuberculate. Thickness to width ratio of mericarp 0.88. Median rib

keeled, small and acute; height to width ratio of median rib is 0.75; lateral ribs keeled, small and acute. Exocarp with single layer to multilayer hypodermal collenchyma cells. Mesocarp with regular parenchyma cells. Vittae vallecular and commissural. Vallecular

vittae solitary in each furrow; commissural vittae 2, situated between marginal ribs; intrajugal vittae obsolete. Endocarp single layer to bilayer, round in transverse section (Fig. 8).

***B. leucocladum* Boiss.**

Mericarps pentagonal in transverse section; terete.

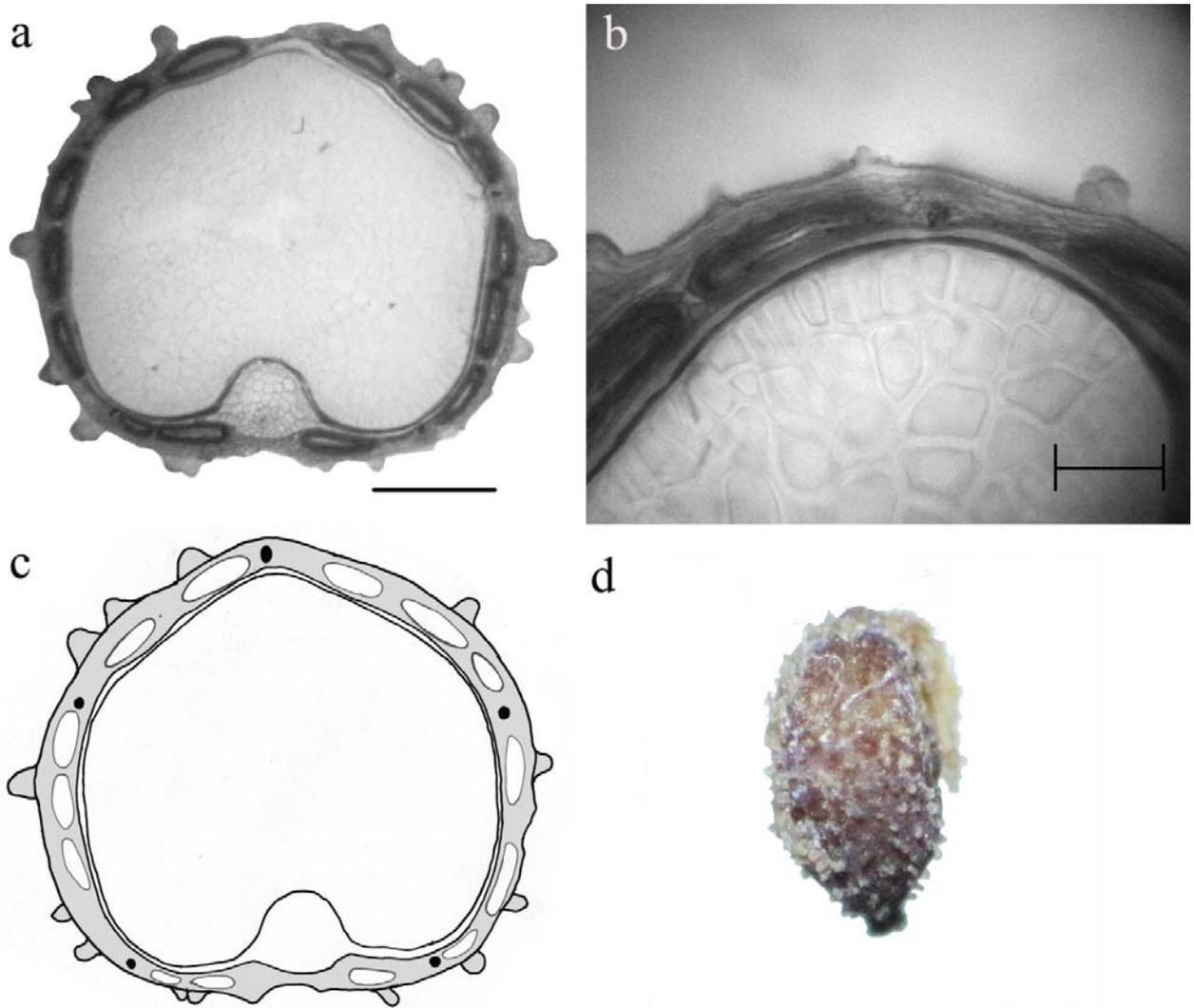


Fig. 7. Mericarp structure in *B.semicompositum*. Scale bar= 0.1mm (a) and 0.05mm (b); Schematic drawing (c) and appearance of fruit (d)

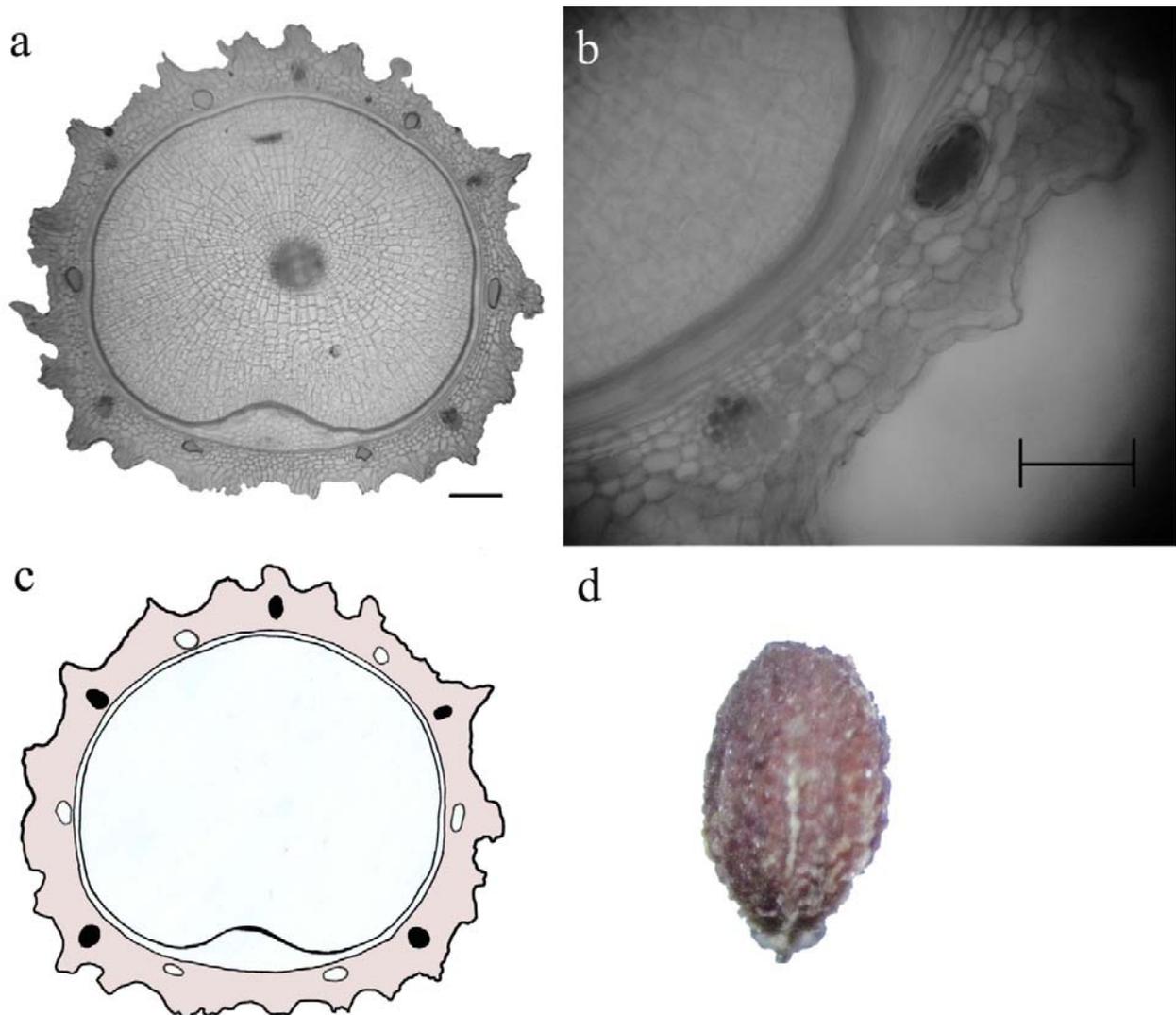


Fig. 8. Mericarp structure in *B. marschallianum*. Scale bar= 0.1mm (a) and 0.05mm (b); Schematic drawing (c) and appearance of fruit (d)

Epidermal surface pubescent. Thickness to width ratio of mericarp 0.98. Median rib obsolete; height to width ratio of median rib 0.35; lateral and marginal ribs obsolete. Exocarp with multilayer hypodermal collenchyma cells. Mesocarp with regular to large parenchymatous cells. Vittae vallecular and commissural. Vallecular vittae solitary in each furrow; commissural vittae 2, situated between marginal ribs; intrajugal vittae obsolete. Endocarp bilayer to multilayer, hexagonal in transverse section (Fig. 9).

***B. haussknechtii* Boiss.**

Mericarps pentagonal in transverse section; terete. Epidermal surface pubescent. Thickness to width ratio

of mericarp 1.02. Median rib keeled, obtuse; height to width ratio of median rib is 0.40; lateral and marginal ribs keeled, obtuse. Exocarp with multilayer hypodermal collenchyma cells. Mesocarp with regular parenchyma cells. Vittae vallecular and commissural. Vallecular vittae solitary in each furrow; commissural vittae 2, situated between marginal ribs; intrajugal vittae obsolete. Endocarp single layer to bilayer, hexagonal in transverse section (Fig. 10).

***B. kurdicum* Boiss.**

Mericarps pentagonal in transverse section; slightly compressed laterally. Epidermal surface glabrous. Thickness to width ratio of mericarp 1.25. Median rib

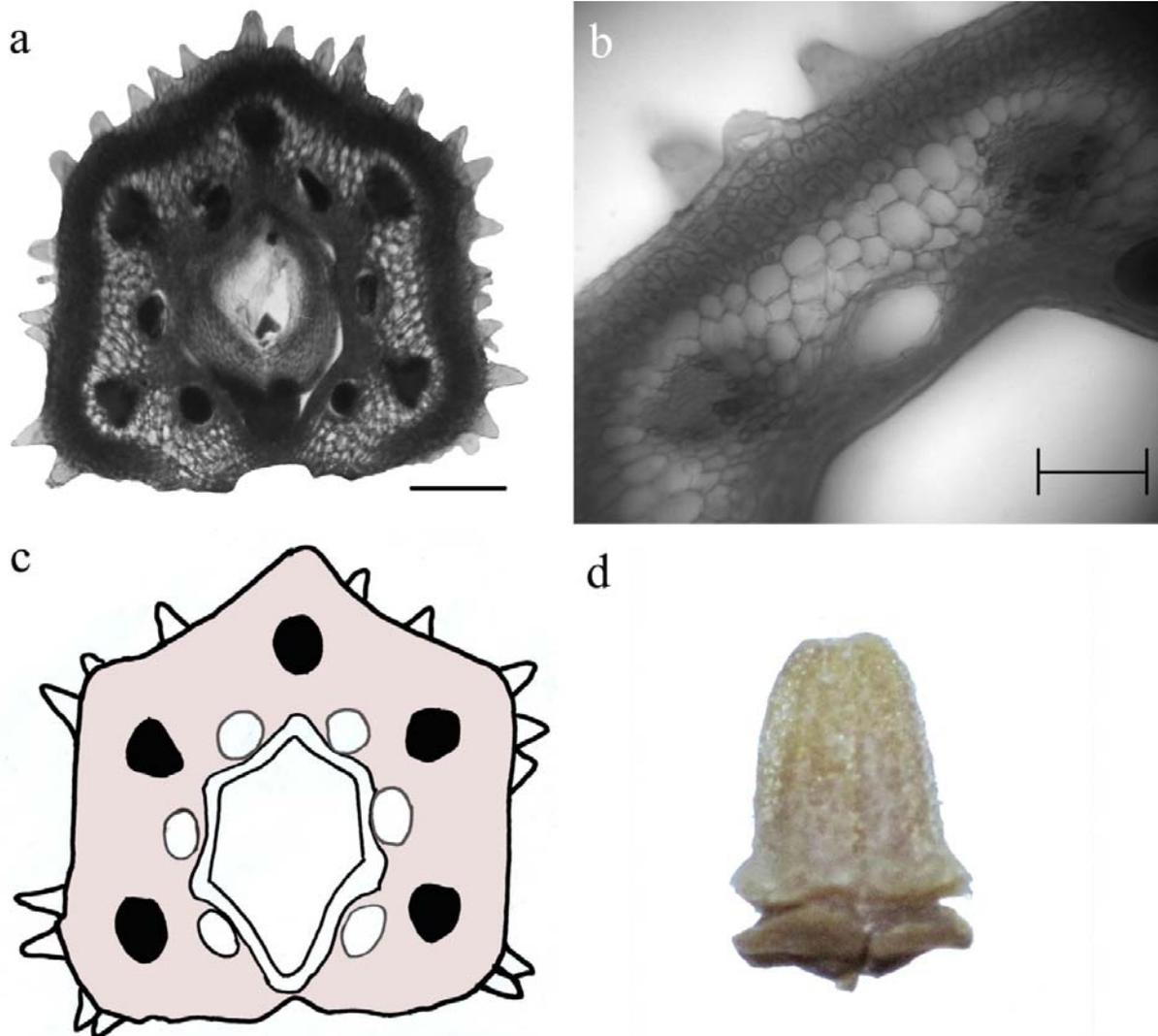


Fig. 9. Mericarp structure in *B. leucocladum*. Scale bar= 0.1mm (a) and 0.05mm (b); Schematic drawing (c) and appearance of fruit (d)

winged, large and broadly acute; height to width ratio of median rib 1.50; lateral and marginal ribs winged, large and broadly acute. Exocarp with multilayer hypodermal collenchyma cells. Mesocarp with regular parenchymatous cells. Vittae vallecular and commissural. Vallecular vittae 5 in each furrow; commissural vittae 4 to 6, situated between marginal ribs; intrajugal vittae obsolete. Endocarp single layer to bilayer, hexagonal in transverse section (Fig. 11).

***B. gerardii* All.**

Mericarps pentagonal in transverse section; terete. Epidermal surface glabrous. Thickness to width ratio of mericarp 1.01. Median rib keeled, acute; height to width ratio of median rib 0.60; lateral and marginal ribs

keeled, acute. Exocarp with multilayer hypodermal collenchyma cells. Mesocarp with regular parenchyma cells. Vittae vallecular and commissural. Vallecular vittae 4 to 5 in each furrow; commissural vittae 4, situated between marginal ribs; intrajugal vittae obsolete. Endocarp single layer to bilayer, hexagonal in transverse section (Fig. 12).

**Grex D (sect. *Eubupleura* Briquet p.p. subsect. *Nervosa* Godr.)**

***B. exaltatum* M. Bieb.**

Mericarps round in transverse section; terete. Epidermal surface glabrous. Thickness to width ratio of mericarp 1.01. Median rib keeled, broadly acute; height to width ratio of median rib 0.38; lateral and marginal

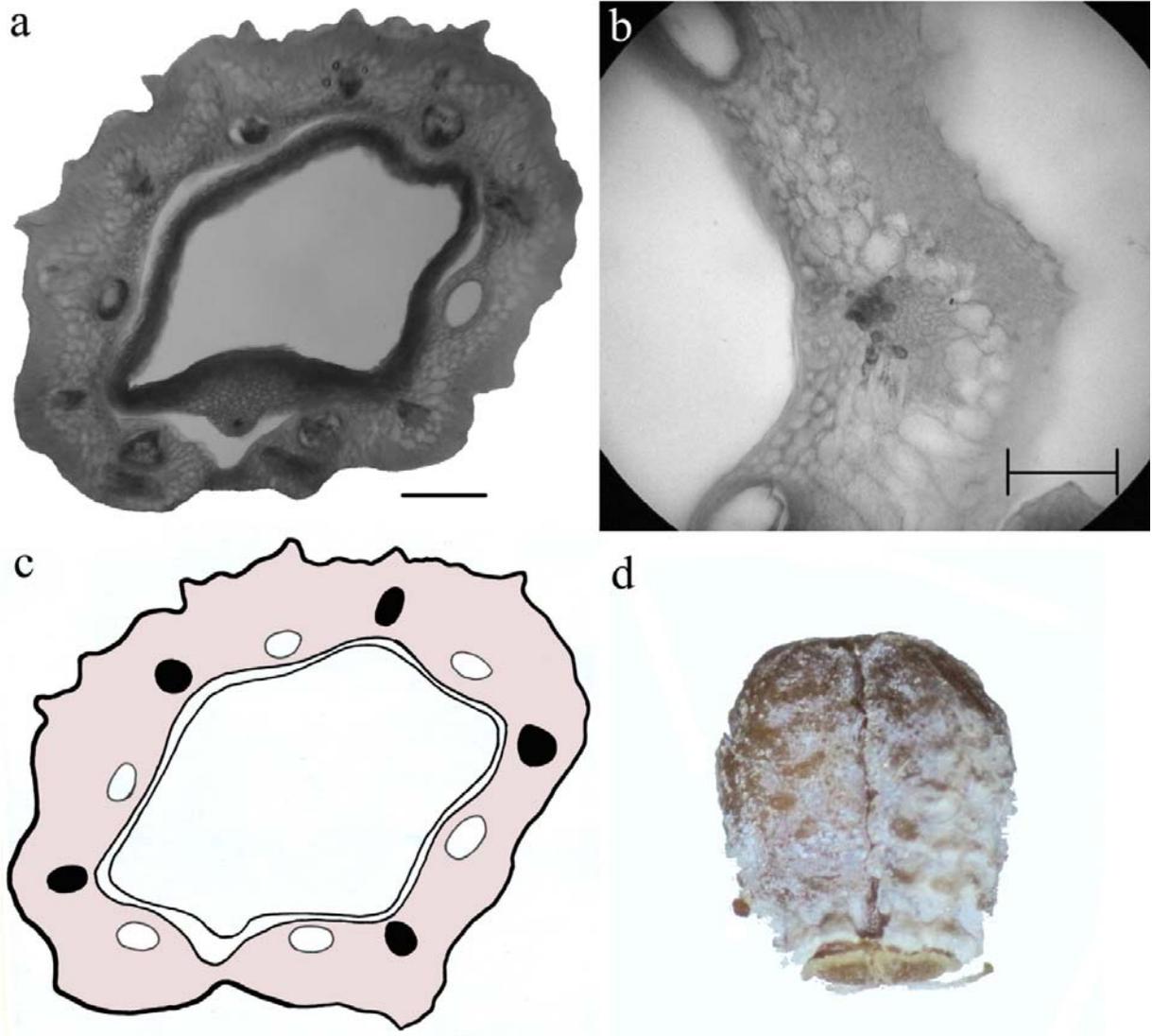


Fig. 10. Mericarp structure in *B.hausknechtii*. Scale bar= 0.1mm (a) and 0.05mm (b).; Schematic drawing (c) and appearance of fruit (d)

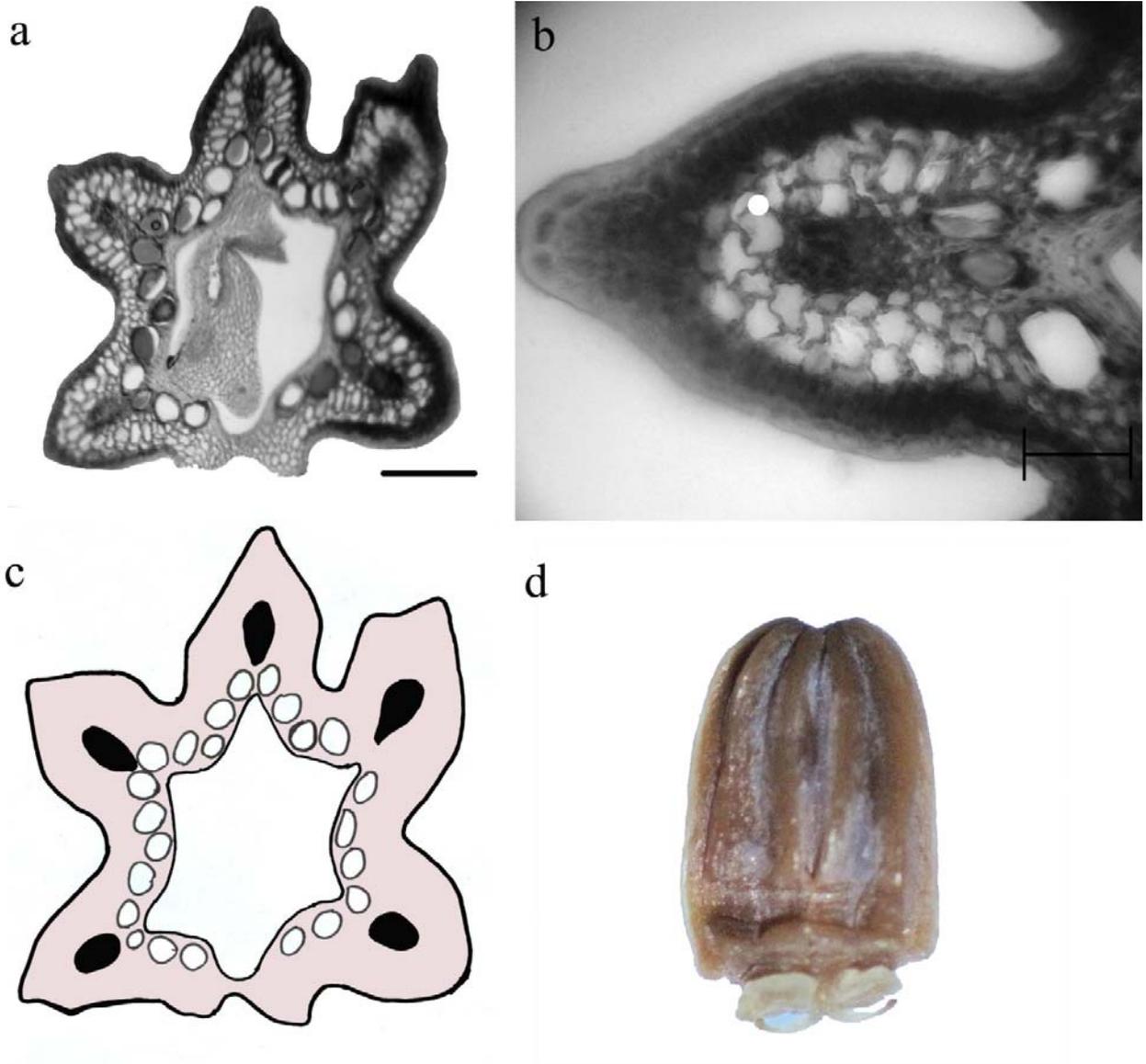


Fig. 11. Mericarp structure in *B.kurdicum*. Scale bar= 0.1mm (a) and 0.05mm (b); Schematic drawing (c) and appearance of fruit (d)

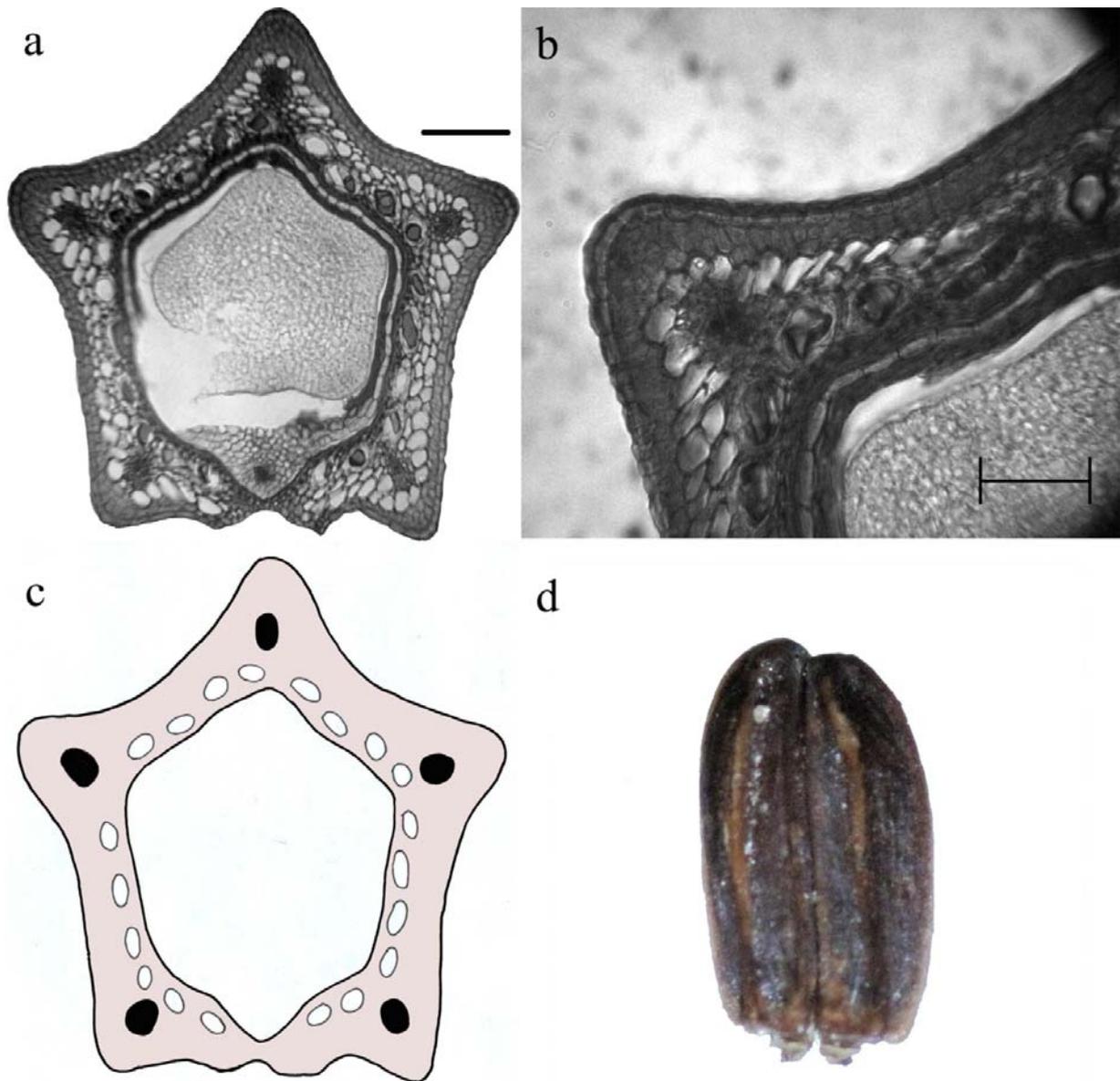


Fig. 12. Mericarp structure in *B. gerardii*. Scale bar= 0.1mm (a) and 0.05mm (b); Schematic drawing (c) and appearance of fruit (d)

ribs keeled, broadly acute. Exocarp with multilayer hypodermal collenchyma cells. Mesocarp with parenchymatous cells. Vittae vallecular and commissural. Vallecular vittae 3 to 4 in each furrow; commissural vittae 4 to 6, situated between marginal ribs; intrajugal vittae obsolete. Endocarp single layer to bilayer, round in transverse section (Fig. 13).

***B. flexile* Bornm. & Gauba**

Mericarps oblong to round in transverse section; slightly compressed laterally. Epidermal surface glabrous. Thickness to width ratio of mericarp 1.40.

Median rib winged, narrowly acute; height to width ratio of median rib 1.05; lateral and marginal ribs winged, narrowly acute. Exocarp with single layer to multilayer hypodermal collenchyma cells. Mesocarp with regular parenchyma cells. Vittae vallecular and commissural. Vallecular vittae 4 to 5 in each furrow; commissural vittae 4, situated between marginal ribs; intrajugal vittae obsolete. Endocarp bilayer, oblong to round in larger mericarp in transverse section (Fig. 14).

***B. ghahremanii* Mozaff.**

Mericarps round in transverse section; terete.

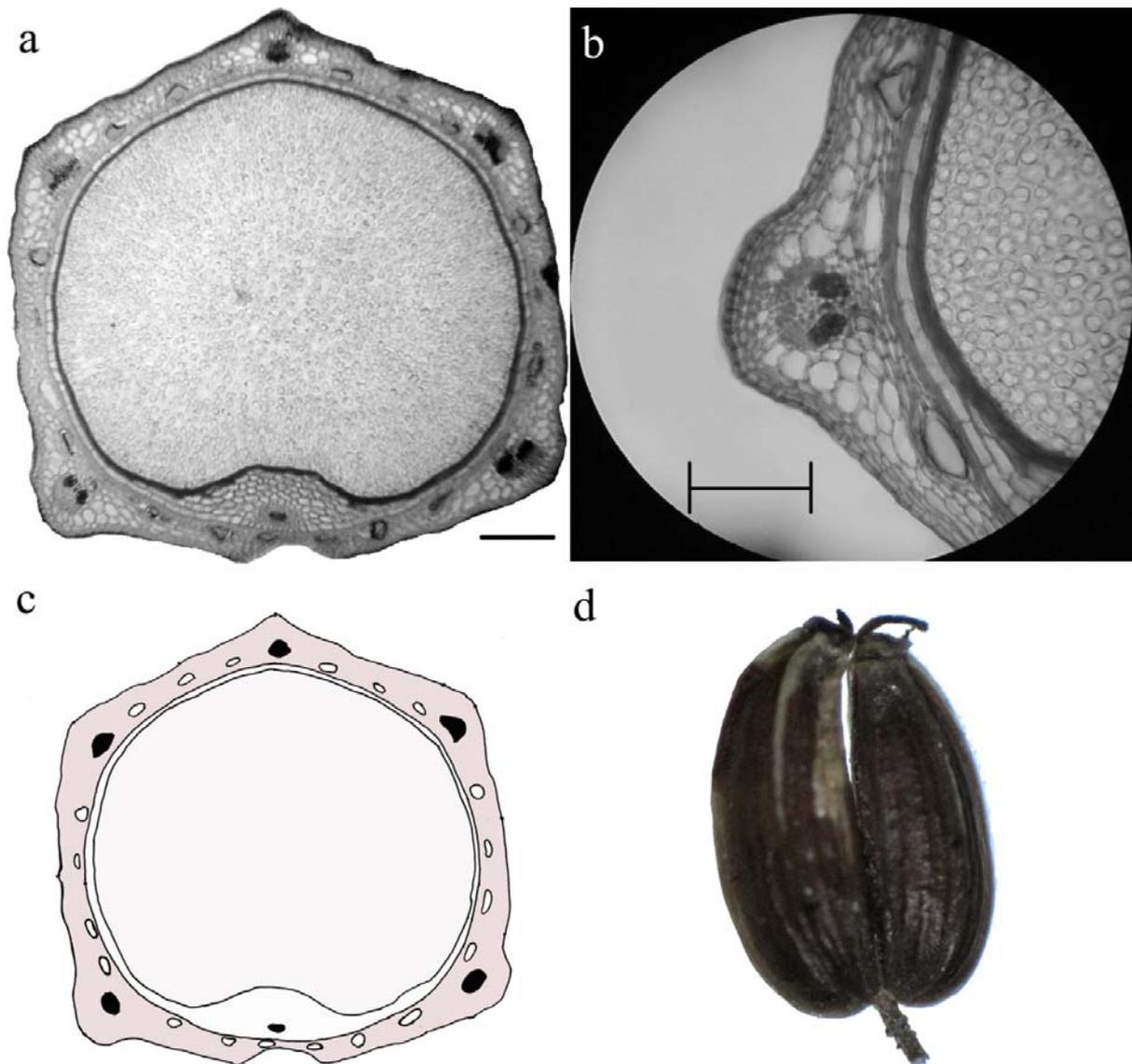


Fig. 13. Mericarp structure in *B.exaltatum*. Scale bar= 0.1mm (a) and 0.05mm (b); Schematic drawing (c) and appearance of fruit (d)

Epidermal surface glabrous. Thickness to width ratio of mericarp 0.96. Median rib keeled, acute; height to width ratio of median rib 0.35; lateral and marginal ribs keeled, acute. Exocarp with single layer to multilayer hypodermal collenchyma cells. Mesocarp with regular parenchyma cells. Vittae vallecular and commissural. Vallecular vittae 3 to 4 in each furrow; commissural vittae 4, situated between marginal ribs; intrajugal vittae obsolete. Endocarp single layer, round in transverse section (Fig. 15).

## DISCUSSION

According to the present study, 14 Iranian species of the genus *Bupleurum* can be separated into two groups on the basis of the absence or presence of vallecular vittae in their fruits.

The first group, with no vallecular or commissural vittae, includes *B. rotundifolium*, *B. lancifolium* and *B. croceum*. This group is equal to sect. *Perfoliata* Godr., Grex A in Flora Iranica treatment. The absence of vallecular and commissural vittae could be paired

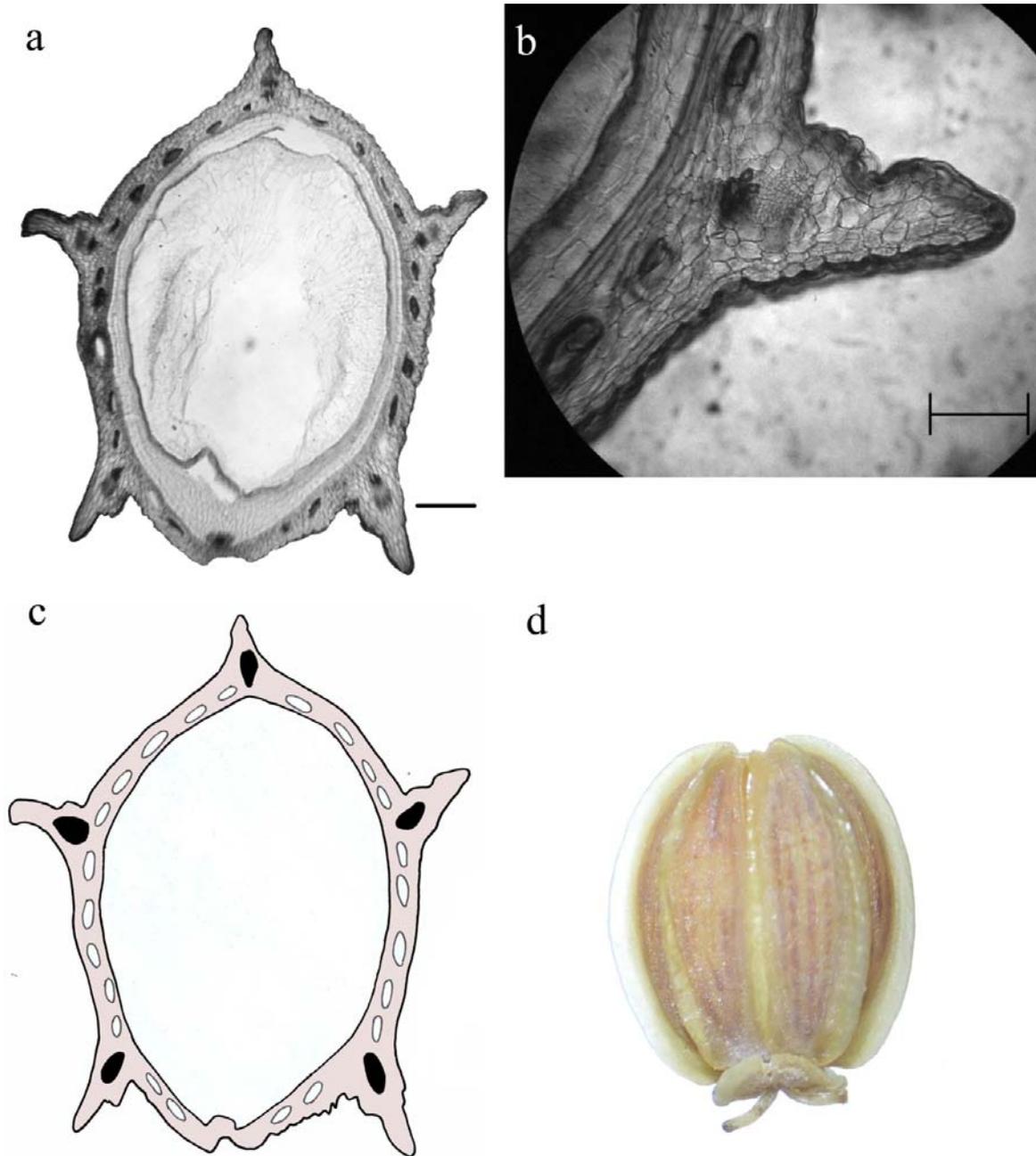


Fig. 14. Mericarp structure in *B. flexile*. Scale bar= 0.1mm (a) and 0.05mm (b); Schematic drawing (c) and appearance of fruit (d)

with broad leaves and dilated, rounded and perfoliate leaf bases.

The second group has vallecular and commissural vittae and includes members of sect. *Eubupuleura*. This group can be divided into two subgroups, on the basis of the number of vallecular vittae in each furrow. The first subgroup, with solitary vallecular vittae in each

furrow, includes *B. allepicum*, *B. marschallianum*, *B. haussknechtii*, *B. leucocladum* and *B. brevicaule*. The second subgroup, with 2-5 vallecular vittae in each furrow, includes *B. semicompositum*, *B. kurdicum*, *B. gerardii*, *B. ghahremanii*, *B. flexile* and *B. exaltatum*. Neither subgroup is equal to any previous classification of genus *Bupleurum*. However, it should be

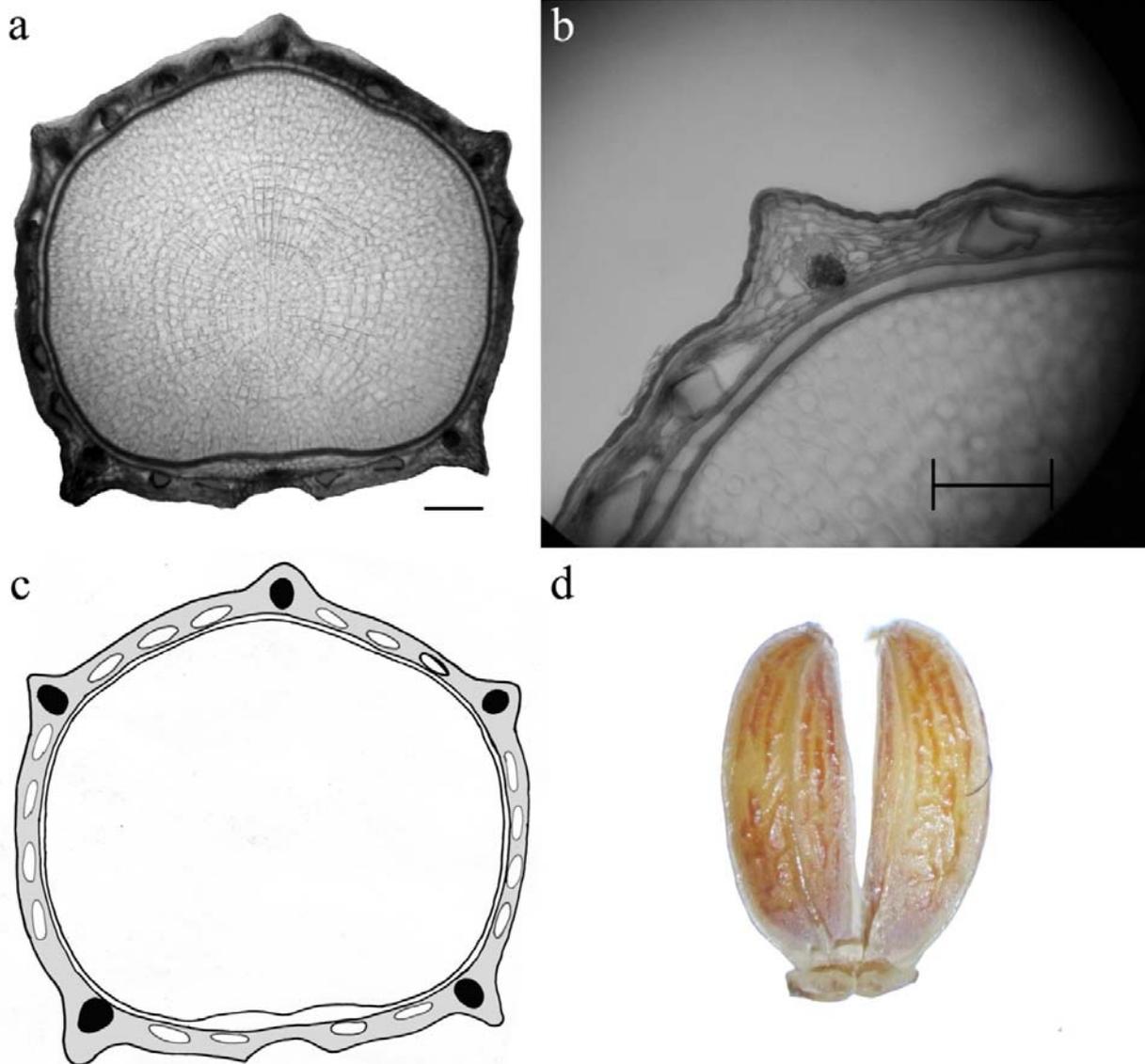


Fig. 15. Mericarp structure in *B. ghahremanii*. Scale bar= 0.1mm (a) and 0.05mm (b); Schematic drawing (c) and appearance of fruit (d)

emphasized that coordination of anatomical and morphological traits of fruit with other morphological features may help to arrange a more accurate and practical classification of this taxon.

Despite to the fact that Liu et al.'s (2003) study on genus *Bupleurum* is still innovative and inspiring, the results of this study did not confirm some aspects of their hypothesis. Separation of sect. *Eubupleura* and sect. *longifolia* based on the shape of mericarp, (respectively pentagonal with prominent ribs and round with not prominent ribs) as a key characteristic, as they stated in their paper, is against the results of the current study. For example, both *B. semicompositum* and *B.*

*marschallianum* belong to the same section and subsection (i.e. sect. *Eubupleura* subsect. *Juncea*), have round mericarps with obsolete or slightly keeled ribs and similar typical characteristics of their subsection such as narrow, small and herbaceous bracteoles. But these species are different in the number of vallecular vittae in each furrow and the state of exocarp surface.

Moreover, the terms "5-angular" (pentagonal) and "round" to describe the mericarp shape, which were used in conclusion of Liu et al. (2003) was found not to be always clear, since the prominence of the ribs may interrupt the total view of mericarps and may change the outcome. To prevent such cases, it is preferred to

divide the state of the ribs (obsolete, keeled or winged) and the state of the mericarp shape (pentagonal or round), based on the existence or absence of clear angles between straight lines and apply suitable terms to describe the situation.

In controversial cases, for example *B. ghahremanii*, where the prominence of the ribs highly interrupt the shape of the mericarp, it is preferred to use the endocarp shape as a parallel characteristic. Therefore it can be concluded that Liu et al.'s (2003) description of the state of mericarp is not so certain, since the prominence of the ribs counts more eminent than the exact shape of mericarp.

It should be noted that, despite the previous assumptions about the absence of winged ribs in the fruits of the genus *Bupleurum* (Liu et al., 2006), *B. croceum*, *B. lancifolium*, *B. kurdicum* and *B. flexile* have winged ribs.

The high variation observed in anatomical features of fruit in the genus *Bupleurum* should be considered to construct inclusive hypothesis, but inadequate information currently available may interrupt further suggestions. Thus, it should be indicated that any further classification needs enough samplings of each species belonging to various sections in order to reduce the effects of regional and ecological variation. Using more practical and accurate terminology to describe the results is undoubtedly essential and acquiring adequate and certain information to make the cases clearer is inevitable. Until then, any classification and diagnostics based on fruit anatomies of regional samples of *Bupleurum* species should not be regarded strictly as inclusive treatment.

### ACKNOWLEDGEMENT

The authors wish to thank directors of T, TARI and W herbaria for providing the plant materials for this study.

### REFERENCES

- Bercu, R., & Broască, L. 2012: Comparative Histoanatomical aspects of the fruit of some Apiaceae I.indl. Fruit used for theranautic purposes- Annals of the Romanian Society for Cell Biology 17, 265-270.
- Candolle, A. P. De, 1830: Umbelliferae.- In: Prodrromus systematis naturalis regni vegetabilis, vol 4, pp. 55-250. Paris.
- Khajepiri, M., Ghahremaninejad, F., & Mozaffarian, V. 2010: Fruit anatomy of the genus *Pimpinella* L.(Apiaceae) in Iran- Flora 205(5): 344-356.
- Kljuykov, E.V., Liu, M., Ostromuva, T.A., Pimenov, M.G., Tilney, P.M. & Van Wyk, B. E. 2004: Toward a standardized terminology for taxonomically important morphological characters in the Umbelliferae. -South Afr. J. Bot. 70: 488-496.
- Koch, W.D.J.1824: Generum tribuumque plantarum umbelliferarum nova dispositio. -Nova Acta Acad. Caesareae Leopoldino Carolinae Germanicae Nat. Curiosorum 12: 55-156.
- Liu, M. R., Plunkett, G. M., Lowry, P. P., Van Wyk, B. E. & Tilnev. P. M. 2006: The taxonomic value of fruit wing tvbes in the order Apiales- American Journal of Botany 93(9): 1357-1368.
- Liu, M., Shi, L., Van Wyk, B. E. & Tilney, P.M. 2003: Fruit anatomy of the genus *Bupleurum* L. (Apiaceae) in northeastern China and notes on systematic implications- South Afr. J. Bot.69: 151-157.
- Matin, F., & Moussavi, M. 1992: *Bupleurum brevicaule* (Umbelliferae), a new record from Iran- Iran. J. Bot. 5: 65-67.
- Morison, R.1672: Plantarum umbelliferarum distributio nova, per tabulas cognationis et affinitatis, ex libro Naturae observata et detecta. -Oxford.
- Mozaffarian, V.2007: *Bupleurum*. In Assadi, M. et al. Flora of Iran, vol. 54: 280-296. -Research Institute of Forests and Rangelands, Tehran.
- Özcan. T. 2004: Analvsis of the fruit surfaces in *Bupleurum* L.(Umbelliferae) with SEM- Plant Systematics and Evolution 247(1-2): 61-74.
- Pimenov, M.G. & Leonov, M.V. 2004: The Asian Umbelliferae Biodiversity Database (ASIUM) with particular reference to South-West Asian taxa. - Turk. J. Bot. 28:139-145.
- Rechinger, K.H. & Snogerup, S. 1988. *Bupleurum*. In: Rechinger, K.H. (ed.), Flora Iranica, vol. 162: Umbelliferae, 1988. Akademische Druck-U. Verlagsanstalt, Graz, pp. 269-298.
- Snogerup S. & Snogerup B. 2001: *Bupleurum* L. (Umbelliferae) in Europe-1. The annuals, *B.* sect. *Bupleurum* and sect. *Aristata*. -Willdenowia 31: 205-308.
- Swink, F. & G. Wilhelm. 1994: Plants of the Chicago region. 4<sup>th</sup> edition. -Indianapolis; Indiana academy of science.
- Thiers, B. (continuously updated). Index Herbariorum: A global directory of public herbaria and associated staff. New York Botanical Garden's Virtual Herbarium. <http://sweetgum.nybg.org/ih/>
- Urusak, E. A., & Kizilersalan, Ç. 2013: Fruit anatomy of some *Ferulago* (Apiaceae) species in Turkey- Turk. J. Bot. 37: 434-445.
- Wolff, H. 1910: Umbelliferae-Apioideae-*Bupleurum*, *Trinia* et reliquae Ammineae heteroclitae. In: Engler, A., Pflanzenr. 43. - Berlin.
- Zohary, M. 1973. Geobotanical foundations of the Middle East. vols. 1-2. Stuttgart: Fischer.

