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COMPARATIVE MORPHO-ANATOMICAL STUDY OF CYPSELAS IN SOME SPECIES OF THE TRIBE HELIANTHEAE (ASTERACEAE)

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ABSTRACT

A comparative study of morphology and anatomy of mature cypselas in 14 species belonging to 10 genera, such as BIDENS, CHRYSANTHELLUM, COREOPSIS, COSMOS, ECHINACEA, GAILLARDIA, GLOSSOGYNE, HELIANTHUS, TITHONIA and XANTHIUM under the tribe Heliantheae (Asteraceae) was undertaken under light and scanning electron microscopes. Morphologically the form and structure of cypselas, carpopodia and pappus are diacritical for characterization of taxa. In all species pericarp is well differentiated into 2 zones. Cells of the epicarp are usually tangentially elongated, provided with yellow or brown substances. Mesocarp is mainly differentiated into 4 zones. Number and distribution of vascular traces, phytomelan layer and secretory cavities are taxonomically significant in certain taxa. An artificial taxonomic key using the detailed morphological, anatomical and SEM observations on the mature cypselas are provided.

Key Words : Asteraceae-Heliantheae-Morphology-Anatomy of cypselas.

INTRODUCTION

The tribe Heliantheae is considered as one of the most primitive and largest tribes of the family Asteraceae by Cronquist (1955). The tribe Heliantheae has been included in the subfamily Asteroideae by Bremer (1996). According to Karis (1993 b), the Heliantheae (*s. lato*) is paraphyletic having about 300 genera and Heliantheae (*s. str.*) is largely monophyletic.

The morphological and anatomical features of cypselas and their role in taxonomy for the tribe Heliantheae have been studied by several workers like Misra (1973), Pandey (1976,1977), Saenz (1981), Robinson (1981), Stuessy and Liu (1983), Pandey *et al.* (1986), and Karis (1993a, 1993b). The present study is to supplement these observations.

MATERIALS AND METHODS

Dried mature cypselas of 10 species were obtained from 3 herbaria of the world. Mature cypselas of 4 species were collected by the first author. These are presented in the following table.

Table-Taxa investigated and the source of origin of cypsela.

Taxa investigated	*Source*
1. *Bidens biternata* (Lour.) Merr. & Sher.; *Coreopsis biternata* Lour. ; *B. decomposita* Wall. ex DC. *B. pilosa auct. non* L. var. *bipinnata* (L.). Hook.f.	India, Uttar Pradesh, Nainital, *S. Mukherjee* 6 (Kln. Herb.*).

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Table contd.

	Taxa investigated	*Source*
2.	*Bidens cernua* L.	Switzerland, Zurich, Nr. 354 (Z).
3.	*B. pilosa* L. var. *pilosa* ; *B. chinensis auct. non.* Willd.	India, Uttar Pradesh, Nainital, *S. Mukherjee* 7 (Kln. Herb.).
4.	*Chrysanthellum americanum* (L.) Vatke ; *C. indicum* DC.	India, West Bengal, Suri, *S. Mukherjee* 8 (Kln. Herb.).
5.	*Coreopsis tinctoria* Nutt.	Switzerland, Zurich, *Nr.* 381 (Z).
6.	*Cosmos sulphureus* Cav.	Switzerland, Zurich, *Nr.* 382 (Z).
7.	*Echinacea purpurea* Moench.	Switzerland, Zurich, *Nr.* 385 (Z).
8.	*Gaillardia aristata* Pursh	Switzerland, Zurich, *Nr.* 395 (Z).
9.	*Glossogyne bidens* (Retz.) Alston ; *Zinnia bidens* Retz. ; *Glossogyne pinnatifida* DC.	India, West Bengal, Darjeeling, *S. Mukherjee* 9 (Kln. Herb.).
10.	*G. tenuifolia* Cass.	Australia, Queensland, *S. Coll.*, s.n. (BRI).
11.	*Helianthus annuus* L.	Switzerland, Zurich, *Nr.* 398 (Z).
12.	*Tithonia diversifolia* (Hemsl.) A. Gray ; *Mirasolia diversifolia* Hemsl.	Australia, Queensland, *S. Coll.* s.n. (BRI).
13.	*T. rotundifolia* (Mill.) Blake ; *Tagetes rotundifolia* Mill. ; *Tithonia tagetiflora* Lamk.	Zimbabwe, Salisbury, *M. Mavi* 17 (SRGH).
14.	*Xanthium pungens* Wallroth.	Australia, Queensland, *S. Coll.* s.n. (BRI).

*Kln. Herb. - is here written as abbreviated form of the herbarium, Department of Botany, University of Kalyani, Kalyani-741235, Nadia, West Bengal ; of course it is not mentioned under the text of "Index Herbariorum" (Holamgren *et al.*, 1981).

For morphological study, dry mature and softened cypselas were studied under stereo-dissecting microscope. Cypselas were softened following Mukherjee and Sarkar (1994). Both microtome as well as free hand sections were obtained of softened cypselas for anatomical studies. Sections were stained with safranin-fast green combination and mounted in canada balsam (Johensen, 1904). For SEM study, at least 5 matured and dry cypselas for each of the species were mounted on the stub using Durofix adhesive. The cypselas were gold coated and scanned under the scanning electron microscope at RSIC, Bose Institute, Calcutta and USIC in the University of Burdwan. Magnifications were known from the indicator scales of the photographs. Terminology was adopted from Kynclova (1970), Barthlott (1981), Short *et al.* (1989) and Mukherjee (1991).

OBSERVATIONS AND DISCUSSION

Cypselar Morphology : The Heliantheae is one of the largest and morphologically the most diverse tribes of the Asteraceae. Cypselas are often straight or slightly curved, seldom conspicuosly curved (Coreopsis). Shapes of the cypselas vary, *e.g.* suborbicular (*Coreopsis*- Fig. 2A-C) or wide obovate (*Helianthus* Fig. 3 I). Surface structure of cypselas in taxonomically useful for identification of taxa. Cypsela surface is more or less glabrous (*Bidens biternata*- Fig. 3 L.), (*Chrysanthellum* Fig. 1 I,J), (*Glossogyne* - Fig. 3A) and (Xanthium) or

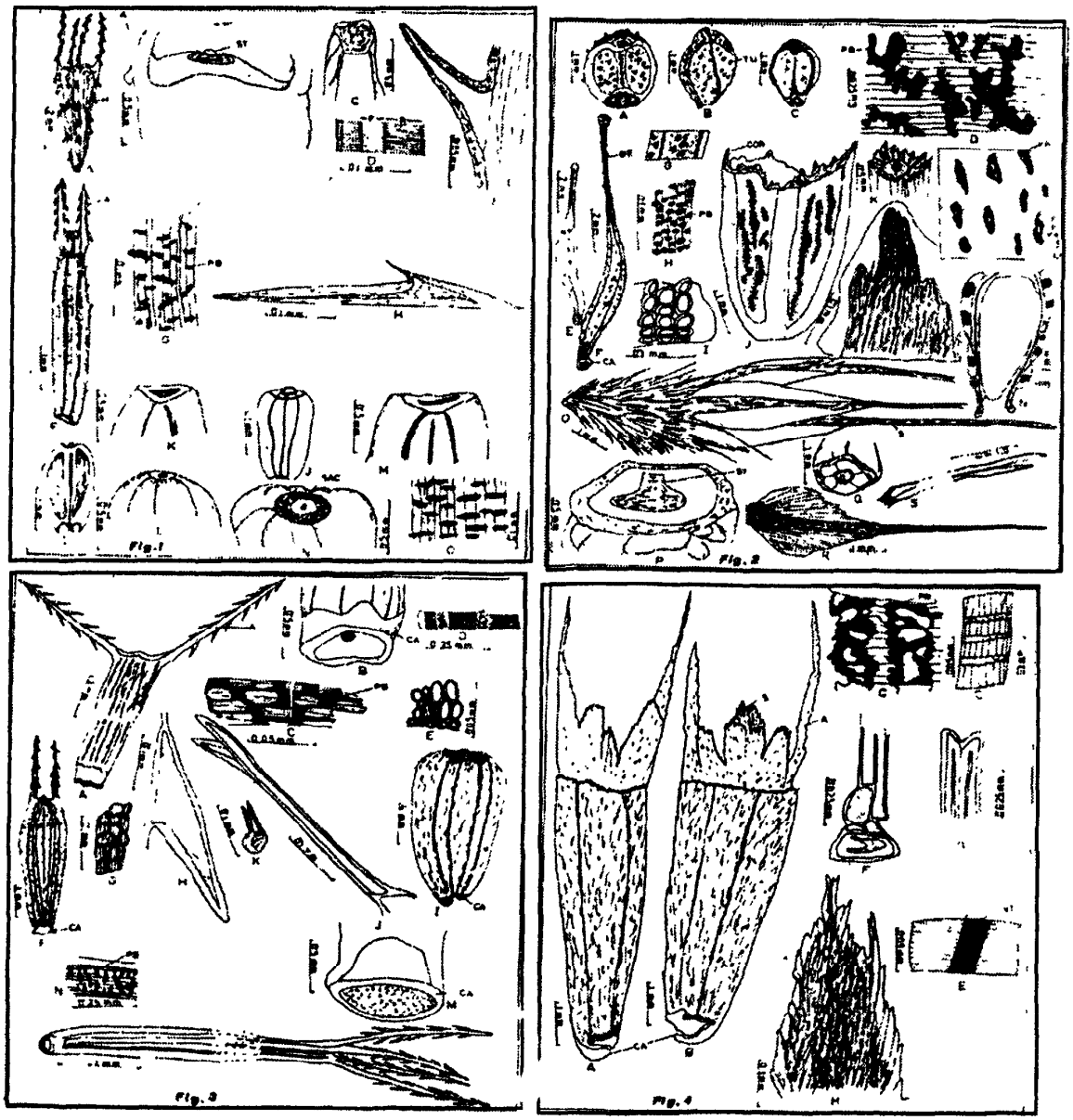


Fig.-1. - A-E, *Bidens cernua* L. A. Disc cypsela ; B - Cypselar apical part ; C - Cypselar basal Part ; D - Part of cypselar wall after clearing, showing ribs and furrow ; E - Retrorsely barbed hair of awn. F-H- *B. pilosa* L. F - Disc cypsela ; G-Part of cypselar wall after clearing, showing phytomelan braces ; H - Retrorsely barbed hair of awn. I - O - *Chrysanthellum americanum* (L.) Vatke, I - Disc cypsela ; J - Ray cypsela ; K - Disc cypselar basal part ; L - Disc cypselar apical part ; M - Ray cypselar basal part ; N - Ray cypselar apical part ; O - Part of cypselar wall after clearing, showing phytomelan braces.

Fig.-2. A-D-*Coreopsis tinctoria* Nutt. A-Disc cypsela (anterior side) ; B-Disc cypsela (posterior side) ; C - Ray cypsela; D - Part of cypselar wall after clearing, showing phytomelan braces. E - I - *Cosmos sulphureus* Cav. E - Ray cypsela ; F-Disc cypsela ; G-Cypselar surface ; H-Cypselar wall after clearing, showing phytomelan braces ; I-Carpopodial cells. J-N- *Echinacea purpurea* Moench, J-Cypsela ; K- Cypselar apical part ; L - Part of pappus corona ; M - Cypselar wall after clearing, showing phytomelan braces ; N-L.S of cypsela. O-S- *Gaillardia aristata* Pursh, O-Cypsela ; P.Q-Cypselar apical part ; R - Pappus awned scale (setae) ; S-Cypselar hair.

Fig.-3. A-E- *Glossogyne bidens* (Retz.) Alston, A-Cypsela ; B - Cypselar basal part ; C - Cypselar wall after clearing, showing the distribution of phytomelanin. D-Cypselar surface ; E - Carpopodium cells. F - H - *G. tenuifolia* Cass. F - Cypselar ; G - Cypselar wall after clearing ; H - Hair of awn. I - K - *Helianthus annuus* L. I - Cypsela ; J, K-Cypselar hairs. L-N - *Bidens biternata* (Lour.) Merr. & Sher. L - Disc cypsela ; M - Cypselar base ; N - Cypselar wall after clearing, showing phytomelan braces.

Fig. - 4. A-H-*Tithonia diversifolia* (Hemsl.) A.Gray, A - Ray cypsela ; B - Disc cypsela ; C - Cypselar wall after clearing, showing the distribution of phytomelanin ; D - Cypselar wall showing rib - like and furrow -like structures (Diagrammatic) after clearing ; E - Testal region showing vascular trace ; F - Base of cypselar hair ; G - Apex of cypselar hair ; H - Pappus scale.

tuberculate (COREOPSIS) - Fig 2A,B) or wrinkled and channelled (*Echinacea*- Fig. 2J.) or pubescent in others.

The surface possesses marginal setae only in *Bidens cernua* (Fig, 1A) and *B. pilosa* (Fig. 1F) or numerous short conical hairs in COSMOS (Fig. 7BI, B2) or very long brown acroscopic twin hairs in GAILLARDIA (Fig. 2 S) and TITHONIA (Fig. 4F, G) or short white adpressed twin hairs in HELIANTHUS (Fig. 3J, K). Marginal setae of *Bidens* are significant because these hairs greatly vary from species to species. These are deflexed (*B. cernua*-Fig. 1A) or acroscopic (*B. pilosa* Fig. 1F) or absent (*B. biternata* Fig. 3L). Morphological structures of cypselas in this tribe have been studied thoroughly by Saenz (1981).

After clearing the cypselar wall, epicarp shows phytomelan braces or phytomelan deposition in the following forms i) braces are ellipsoid, horizontally elongated *e.g. Bidens biternata* (Fig. 3N), *B. pilosa* (Fig. I,G) and CHRYSANTHELLUM (Fig. 10) ; ii) braces are circular bordered pit-like *e.g.*: COSMOS (Fig. 2H) ; iii) braces are large irragularly lobed *e.g. Coreopsis* (Fig. 2D); iv) braces are small, lobbed, vertically elongated *e.g.* : ECHINACEA (Fig. 2M) ; v) deposition is reticulate *e.g.* GLOSSOGYNE (Fig. 3C). Therefore, these characters can used for identification of taxa, at least at the generic level.

Stylopodium is usually absent or if present, is not significant taxanomically. Carpopodium may be absent (*Bidens cernua, B. pilosa,* CHRYSANTHELLUM, COREOPSIS, GAILLARDIA AND XANTHIUM) or present and usually complete ring like (other taxa). In *Bidens biternata* (Fig. 3M), carpopodium is bilobed and completely ring like while in GLOSSOGYNE (Fig. 3B) it is in the form of few or multilobed complete ring. *Carpopodium* occurs in two opposite semicircular sections in HELIANTHUS (Fig. 3I) or in 2 opposite unequal lobed sections in TETHONIA (Fig. 4A, B). Haque and Godward (1984) have reported carpopodium in Heliantheae.

Varied forms of pappus are noticed in the tribe. Pappus is absent in CHRYSANTHELLUM, COREOPSIS and XANTHIUM or decidous in HELIANTHUS. Pappus is represented by 3-4 retrorsely bearded awns (*Bidens*-Fig. 1A, F), 2 retrorsely barbed awns (*Glossogyne*-Fig. 3A, F), or cupshaped corona. (*Cosmos*-Fig, 2E,F) or a thick corona with toothed margins (*Echinacea*-Fig. 2J,K). In *Gaillardia* (Fig. 2, O,R) pappus is formed by 5 or 6 long awned scales, whereas in *Tithonia* (Fig. 4A, B,H) pappus is composed of 2 long awns with lobed stiff scales in between them. Pappus seems to be of importance in differentiating the two species of GLOSSOGYNE studied. Awns are divergent in *G. bidens* (Fig. 3A) and upright in *G. tenuifolia* (Fig. 3F).

SEM photographs of cypselas show the following features : i) *Bidens pilosa* (PM 1A)-cypsela surface papillate ; pipillae heteromorphic, nearly traingular, often pointed at the apex ; cell outlines not differentiated ; a short stylopodium and retrorsely barbed (four) pappus bristles found at the upper part of cypsela as crown ; ii) *Coreopsis tinctoria* (PM 1 B-D) cypsela-surface tuberculate and verrucate ; verruca more conspicuous on posterior side and knob like in appearance ; periclinal walls of the surface cells shallow ; iii) *Cosmos sulphureus* (PM 1 E, F)-cypsela surface conspicuously striated ; periclinal walls of the cells shallow, anticlinal walls slightly wavy ; hairs sparsely distributed, persistent more or less triangular, upwardly directed ; carpopodium complete ring like, without visible cell outlines ; iv) *Echinacea pupurea* (PM 1 G,H) Cypselar surface cells very conspicuous, rectangular ± homomorphic, anticlinal walls

vertically channelled ; carpopodium complete ring like ; pappus represented by a corona with toothed margin ; v) *Gaillardia aristata* (PM 1 I,J) cypselar surface cells not visible but the surface densely covered by stiff, slender, acroscopic, persistent hairs ; pappus represented by six long awned scales ; surface of the scales tubular and papillate, ± triangular, with pointed apex ; vi) *Helianthus annuus* (PM 1 K,L) cypselar surface virtically striated without having any distinct cell boundary ; short hairs sparsely appresed throughout the surface ; vii) *Tithonia diversifolia* (PM 1M) cell outlines of cypselar surface not visible ; hairs long, densely oriented with two equal terminal ends; viii) *T. rotundifolia* (PM 1N)-cell outlines of cypselar surface visible with thick, straight anticlinal walls and shallow perclinal walls ; hairs similar to *T. diversifolia*, but sparsely oriented ; ix) *Xanthium pungens* (PM 1 O)-cells of the cypselar surface very much conspicuous, tetrangular to polygonal with straight anticlinal and shallow periclinal walls.

Cypselar Anatomy : Cypselas are usually rhomboid, sometimes triangular or elliptic in CS, often with lobes or without lobes. Lobes may be conspicuous or inconspicuous and the number is 4 in *Bidens cernua* or 6 in *Chrysanthellum* or 8-10 in *B. biternata. B. pilosa*, Cosmos and Gaillardia. In Glossogyne the number of lobes varies from 12-16, while in Tithonia, lobes are numerous and inconspicuous.

Cypsela wall is significantly thick in Echinacea, Helianthus and Tithonia among the studied species. In all species the pericarp is well differentiated into 2-zones. Epicarpic cells are small or large, usually tangentially elongated, provided with yellow or brown substances. Three to four celled shaggy triangular hairs and multicelled triangular shaggy hairs are seen on the epicarpic zone of Cosmos (Fig. 7 B2) and Coreopsis (Fig. 7A3) respectively. Characteristic fibrous thickenings reported to be present in the epidermal cells of the members of Heliantheae (Misra, 1973 ; Pandey, 1976, 1977) have not been seen in the studied taxa, nor they have been reported by Maheshwari Devi and Ranjalkar (1980), Pandey *et al.*, (1986) in the members of Heliantheae.

Mesocarpic zone is massive and broadly composed of the following layers, i) Outer hypodermal parenchymatous zone is one or many layered, (Bidens-Fig. 5 A2, B2, ; 6 A2 ; Chrysanthellum-Fig. 6 B3 ; Echinacea - Fig. 8 A2 ; Gaillardia Fig. 9 A2, A3 ; and Helianthus Fig. 10 B2), where cells are sometimes pitted ; ii) Phytomelan layer : a non celler, black, carbonised resinous layer in the form of a continuous ring (Chrysanthellum Fig-6 B2, ; Coreopsis - Fig. 7A2, A3 ; Cosmos Fig. 7B 2 ; Glossogyne Fig. 9 B2 and Xanthium - Fig. 12 A3) or discrete layer (Bidens - Fig. 5 A2, B2 ; 6A2 and Tithonia - Fig. 11 A1, A2, B2, B3) ; iii) Sclerenchymatous tissue, usually, continuous or discrete (Bidens cernua - Fig. 5 B2 ; Echinacea - Fig. 8 A1 ; Gaillardia - Fig. 9 A1, A2 ; Helianthus Fig. B1, B2 and Tithonia- Fig. A2, B3) ; iv) Inners most layer, represented by intact or collapsed parenchyma cells.

Outer hypodermal parenchymatous cells are characteristic in Chrysanthellum (Fig. 6B1, B3), since these are multiseriate, radially elongated and pitted. In Gaillardia - Fig. 9 A2, A3), this zone is represented by a single layer of radially elongated palisade cells, having Ca-oxalate crystals, while in Helianthus (Fig. 10 B1, B2) cells are very small, minutely pitted and tangentailly elongated. The above three genera could be identified by observing this zone only.

Although the presence of phytomelan layer is a common character of the tribe Heliantheae,

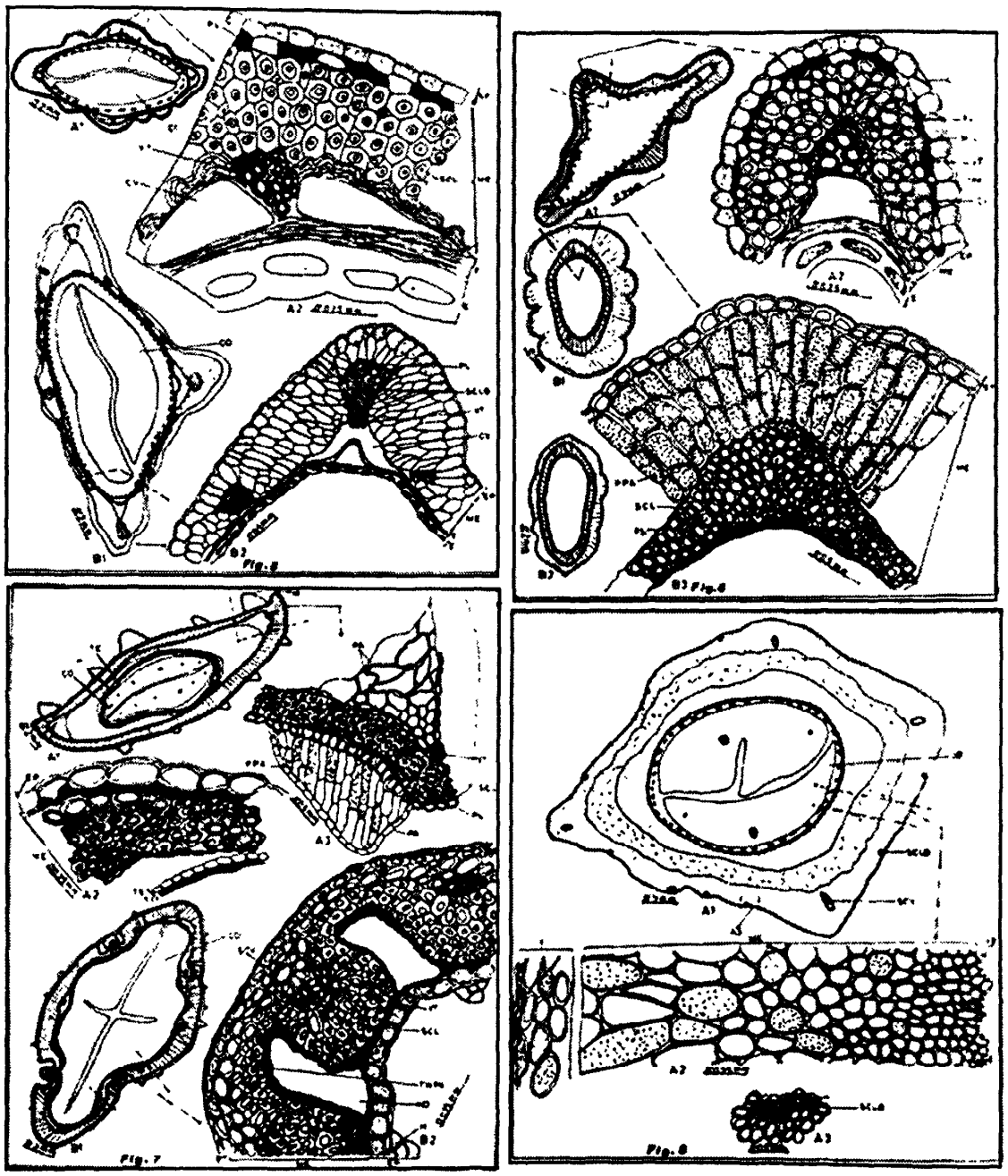


Fig - 5-11. Cross Section of Cypselas..

Fig.- 5. A1, A2 - *Bidens biternata* (Lour.) Merr. & Sher. A1 - Diagrammatic ; A2 - A part of cypselar wall at the anterio-posterior lobe. B1, B2- *B. cernua* L. B1 - Diagrammatic ; B2 - A part of cypselar wall at the lateral lobe.

Fig.- 6. A1, A2 - *Bidens pilosa* L. A1 - Diagrammatic ; A2 - A part of cypselar wall at the anterio-posterior lobe. B1 - B3 - *Chrysanthellum americanum* (L.) Vatke, B1, B2 - Diagrammatic ; B3 - A part of cypselar wall at the lateral lobe.

Fig.-7. A1-A3 - *Coreopsis tinctoria* Nutt. A1 - Diagrammatic ; A2, A3 - Part of cypselar wall. B1 - B2 - *Cosmos sulphureus* Cav. B1- Diagrammatic ; B2 - A part of cypselar wall near the anterio-posterior lobe.

Fig.-8. A1-A3 - *Echinacea purpurea* Moench, A1 - Diagrammatic ; A2 - A part of cypselar wall ; A3 - Outer part of pericarp showing sclerenchymatous brace.

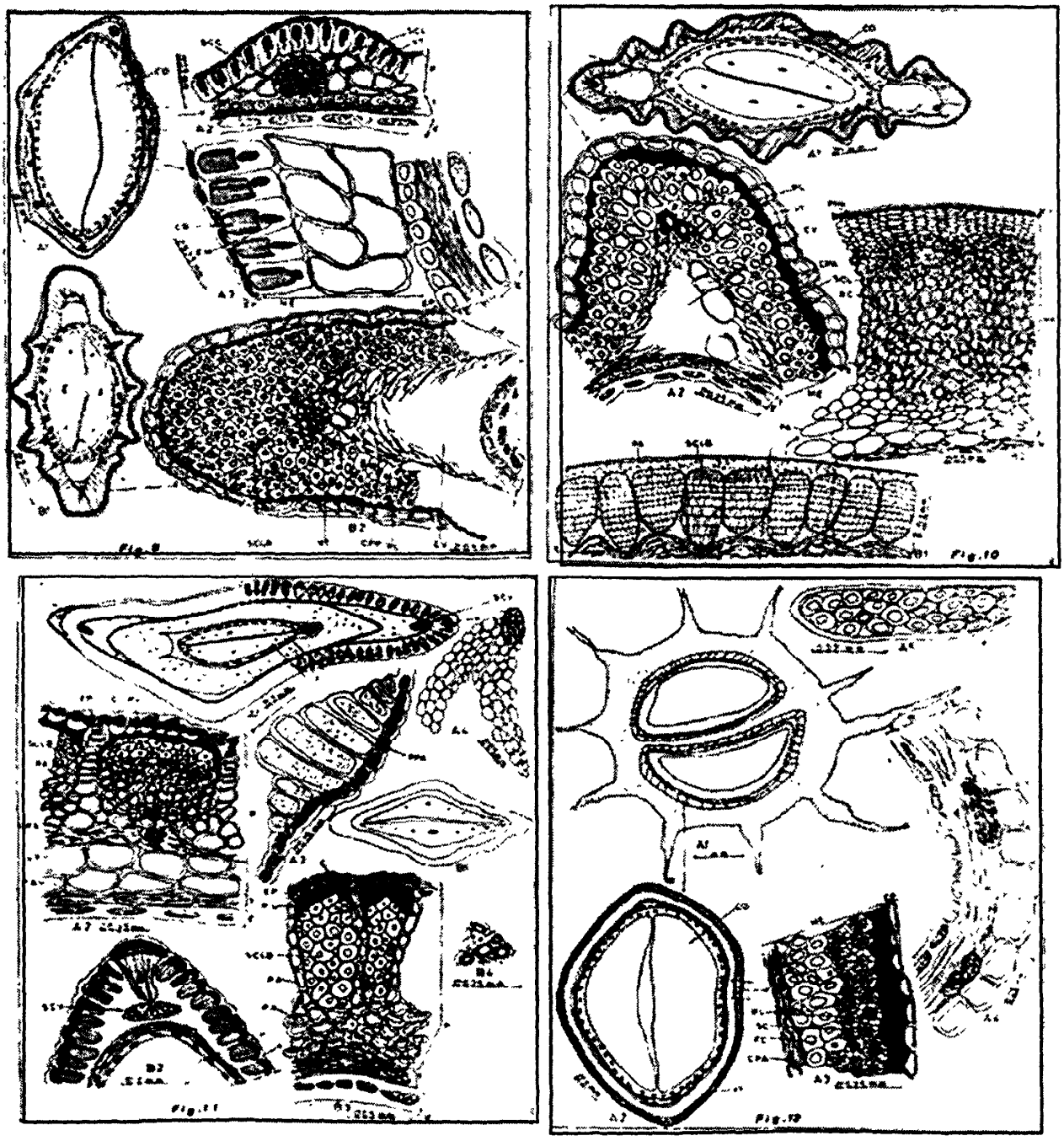


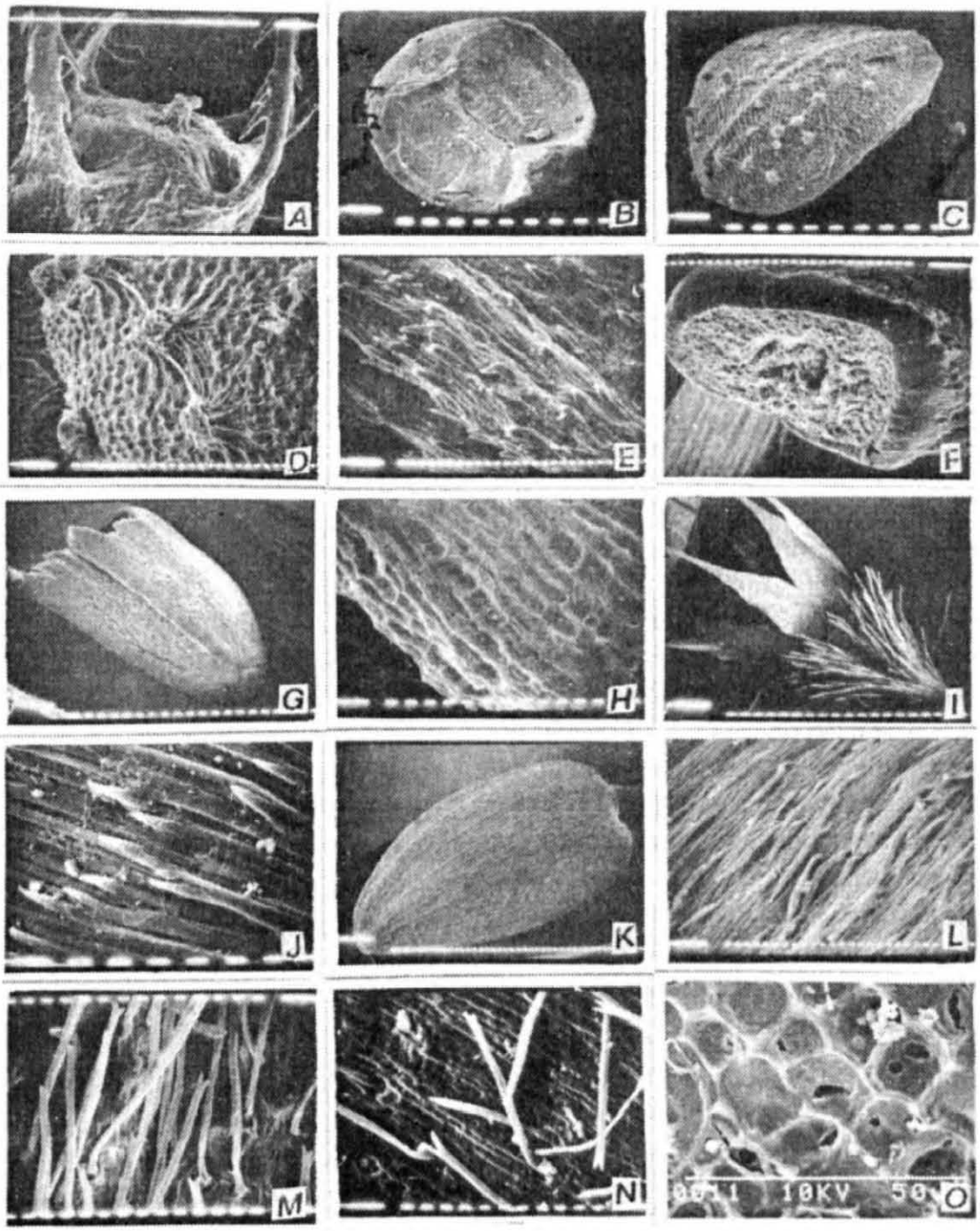
Fig. - 9. A1-A3 - *Gaillardia aristata* Pursh, A1 - Diagrammatic, A2 - A part of cypselar wall at the anterio-posterior lobe ; A3- A part of cypselar wall at the furrow. B1, B2 - *Glossogyne bidens* (Retz.) Alston, B1 - Diagrammatic ; B2 - A part of cypselar wall at the lateral lobe.

Fig.-10 A1-A2 - *Glossogyne tenuifolia* Cass. A1 - Diagrammatic ; A2 - A part of cypselar wall at the lateral lobe. B1, B2 - *Helianthus annuus* L. B1 - Diagrammatic in part ; B2 - A part of cypselar wall.

Fig.-11 A1-A4 - *Tithonia diversifolia* (Hemsl.) A. Gray, A1 - Diagrammatic ; A2 - A part of cypselar wall ; A3 - Outer part of pericarp at the lateral side showing pitted parenchymatous cells ; A4 - Inner part of pericarp at the lateral side showing secretory cavity. B1 - B4 - *T. rotundifolia* (Mill.) Blake, B1 - Diagrammatic ; B2 - Diagrammatic in part ; B3- A part of cypselar wall ; B4 - Vascular trace (within the large lateral sclerenchymatic brace).

Fig.-12 Cross section of female capitulum showing the section of two cypselas.

A1-A5 - *Xanthium pungens* Wallroth, A1 - Diagrammatic (female capitulum) ; A2 - Diagrammatic (cypsela) ; A3 - A part of pericarp ; A4 - A part of testa and endosperm ; A5 - Vascular trace within the testa.



PM 1. A-O SEM photographs of cypsalas :

A - *Bidens pilosa* L. Apical part, × 100. B - D - *Coreopsis tinctoria* Nutt. B - Anterior side of disc cypsela, × 50 ; C Posterior side of disc cypsela, × 50 ; D Tuberculate and verrucate posterior side of disc cypsela, × 200 ; E, F - *Cosmos sulphureus* Cav. E - Surface, × 200 ; F - Carpopodium, × 200. G,H - *Echinacea purpurea* Moench, G-Cypsela, × 25 ; H - Surface, × 400. I, J - *Gaillardia aristata* Pursh, I - Cypsela, × 25 ; J - Surface of awned scale, × 800. K,L - *Helianthus annuus* L. K - Cypsela, × 12; L - Surface, × 200. M - *Tithonia diversifolia* (Hemsl.) A. Gray, Surface, × 400. N - *T. rotundifolia* (Mill.) Blake, Surface, × 400. O - *Xanthium pungens* Wallroth, Surface.

it is not found in HELIANTHUS (Fig. 10 B1, B2) which has been supplied by the Zurich Herbarium (Nr. 398). Large cavity exists within the phytomelon zone in COSMOS (Fig. 7 B1, B2). This layer is U shaped in TITHONIA (Fig. 11 A2, B3). Pandey (1989) has reported that "phytomelan is secreted by the glandular activity of hypodermal cells". This statement appears partially true, based upon the present observations, because phytomelan layers exist both in subepicarpic region as well as inside the parenchymatous region as well as inside the parenchymatous (outer mesocarpic) hypodermal region. Therefore, phytomelan layer is formed by the glandular activity of either epicarpic cells or by the hypodermal cells.

Sclerenchymatous layer is very small, subepicarpic in ECHINACEA (Fig. 8 A1, A3). Sclerenchyma bundles are separated by a wide parenchymatous zone in *B. cernua* (Fig. 5 B2), GAILLARDIA (Fig. 9 A1, A2), ECHINACEA (Fig. 8 A1), or 1-3 seriate ray parenchyma cells in HELIANTHUS (Fig. 10 B2) and TITHONIA (Fig. 11 A2, B3). Sclerenchymatous zone is prominently composed of 2 types of cells (*i.e.* sclerosed and fibrous) in TITHONIA (Fig. 11 A2, B3) and XANTHIUM (Fig. 12 A3). The arrangement of ray cells in the two species of TITHONIA (Fig. 11 A2, B3) is quite different and is a diacritical character for the species.

Vascular traces occur within the inner parenchymatous zone or inside the sclerenchymatous tissue of the pericarp. Number of traces varies from 2-10 or numerous. The mode of distribution of the trace is unique in COSMOS (Fig. 7B1, B2). Large cavities are found in BIDENS (Fig. 5 A2, B2 ; 6 A2) and GLOSSOGYNE (Fig. 9 B1, B2). Secretory cavity exists in the pericarp of COSMOS (Fig. 7B2), ECHINACEA (Fig. 8A1) and TITHONIA (Fig. 11 A1, B2).

Testal zone is often represented by a layer of collapsed thin walled cells or 1 - layered testal epidermal cells together with or without inner collapsed cells. In ECHINACEA (Fig. 8A2) outer testel zone is multilayred and pitted parenchymatous. Four large vascular traces are found within the testal zone in XANTHIUM (Fig. 12 A4) only.

Endosperm is often uniseriate or absent in CHRYSANTHELLUM (Fig. 6 B3), COREOPSIS (Fig. A1, A2), COSMOS (Fig. 7 B1, B2) and *Helianthus* (Fig. 10 B1, B2) as noticed by Saenaz (1981) in some taxa of Heliantheae. Grau and Hope (1985) have reported that the occurance of upto 3 cell layers of endosperm in the cypsela of majority of the Asteraceae.

CONCLUSION

Cronquist (1955) and Stuessy (1977) considered the tribe Heliantheae as one of the most primitive tribes of Asteraceae. All the tribes except Calenduleae are directly developed from this tribe as mentioned by Cronquist (1955), whereas Bremer (1996) has mentioned that the tribe Heliantheae is one of the most highly evolved groups. On the basis of the present study, it is not clear that whether the tribe is primitive or advanced, but the tribe has some advanced features of cypselas like (i) retrorsely barbed awns or setae or scales (ii) presence of ray cells and pitted parenchyma cells ; (iii) distribution of phytomelan layer.

Phytomelanin is a unique type of resinous substance, which is ususlly present in the members of the tribe Heliantheae, Helenieae, Eupatorieae and ARNICA, an unusual genus of the tribe Senecioneae by Mukherjee (1991). In respect of this feature Heliatheae is close to Eupatorieae and Helenieae and also to some extent with the Senecioneae, but apart from Astereae, Anthemideae, Arctotideae and Inuleae as has been indicated by Cronquist (1995), on the morphological ground. Very

recently Bremer (1996) has also shown that tree tribes Heliantheae, Helenieae and Eupatorieae form informal Helianthoid group or super tribe within the sub family Asteroideae. A close relationship between the Eupatorieae and the Heliantheae (s.l.) is also obtained from the result of cladistic analyses based on chloroplast DNA restriction site data by Janes *et al.* (1990,1991) and Watson *et al.* (1991) from the morphological characters as shown by Karis (1993a). Regarding the affinity with Senecioneae, Karis (1993b) has also pointed out that "the Senecioneae is the only tribe that have been identified as the sole sister group of the Heliantheae *s. lato*, both in morphological and molecular cladistic analyses."

Morphologically, the colour and size are less diagonstic than shape of cypselas. Similarly surface ornamentation, pappus structure and carpopodium are valuable than stylopodium. SEM features of cypselas are taxonomically less significant. Number of cypselar lobes is greatly variable from species to species. Epicarpic cells usually have yellow or brown substances which have been also reported by Maheshwari Devi and Padma (1985), Pandey and Singh (1982) from the members of the tribe Heliantheae. Rarely epicarpic cells have shaggy hairs (COSMOS, COREOPSIS). Such type of hairs have been reported by Sahu (1982) in PARTHENIUM. Mesocarpic zone usually bears 4 types of tissues. Similar pattern of tissue differentiation in the pericarp have been noticed in the members of the tribe Heliantheae by Saenz (1981). Pandey and Singh (1982). Testal zone and endosperm are not usually diacritcal except in few cases *i.e.* ECHINACEA and XANTHIUM.

The plant *Cosmos sulphureus* Cav. is presently known as *Bidens sulpurea* (Cav.) Sch.-Bip. Cypselar morpho-anatomical features are quite distinct from the outer studied species of BIDENS having conspicuous long beak, phytomelan braces circular bordered pit like, cup shaped corona, 3-4-celled shaggy hairs, sclerenchyma tissue in the form of continuous ring and large cavity within the phytomelan zone. Therefore, the plant *Cosmos sulphureus* (Cav.) Sch.-Bip. has justifiably been transferred to the genus BIDENS.

Based on the above observations, it can be concluded that the members of the tribe Heliantheae are with diverse morphological and anatomical features of cypselas. These characters are a mixture of both primitive and advanced features. Thus the tribe cannot be considered as one of the most primitive tribes of Asteraceae as stated by Cronquist (1955).

KEY TO THE SPECIES

1a. 2-cypselas enclosed in a beaked utricle formed by hardened involucre and covered with hooked spines ; testa and endosperm completely separated from the pericarp ; testal zone possesses 4 large vascular traces ... *Xanthium. pungens*

b. Cyselas not in utricle ; testa and endosperm attached with the pericarp or partially free from the pericarp ; testal zone does not possess 4-large vascular traces ... 2

2a. Cypsela long beaked ; pericarp with numerous ± circular, bordered pit-like phytomelan braces ; each large pericarp lobe (2-lateral lobes and 2 anterio-posterior lobes) contains 3 - vascular traces in CS ; 3 -4 celled, shaggy hairs exist on the cypsela surface ... *Cosmos sulphureus*

b.	Cypsela ± truncate at the apex ; paricarp exhibits ellipsoid or irregularly lobed, or reticulate phytomelan braces or phytomelan braces absent ; each pericarp lobe possesses single vascular trace or absent in CS ; shaggy - hairs multicellular or absent	...	3
3a.	Cypsela with retrorsely barbed awns	...	4
b.	Cypsela without retrorsely barbed awns	...	8
4a.	Awns 3-4 , number of lobes in cypselas 4-9 in CS ; pericarp exhibits elongated ellipsoid phytomelan braces which may be absent	...	5
b.	Awns 2 ; number of cypsela 12 - 16 in CS ; pericarp with reticulation of phytomelanin	...	7
5a.	Cypsela cuneate at the base ; marginal setae deflexed ; sclerenchymatous tissues form bundles, separated by massive parenchymatous tissues in CS	...	*Bidens cernua*
b.	Cypsela truncate at the base ; marginal setae absent or acroscopic ; sclerenchymatous zone continuous in CS.	...	6
6a.	Disc cypselas 14.0 - 17.0 mm long ; carpopodium present, marginal setae absent ; lateral awns conspicuosly larger than the anterio posterior awns	...	*Bidens biternata*
b.	Disc cypselas 4.0 - 5.0 mm long ; carpopodium absent, marginal setae absent ; lateral awns conspicuously larger than the antrio - posterior	...	*Bidens pilosa*
7a.	Awns divergent ; disc cypselas 7.0 - 8.0 mm long ; diameter of carpopodium as wide as the base of the cypsela ; cypsela lobes about 12 in CS ; sclerotic layer 7 - 10 cells thick at the lateral lobe	...	*Glossogyne bidens*
b.	Awns straight ; not divergent ; disc cypselas 4.0 - 5.0 mm long ; diameter of carpopodium much wider than the base of the cypsela ; cypsela lobes about 14 - 16 in CS ; sclerotic layer 4-6 cells thick at the lateral lobe.	...	*Glossogyne tenuifolia*
8a.	Sclerenchymatous tissues continuous in CS of cypselas	...	9
b.	Sclerenchyma tissue arranged in the form of discrete bundle in CS of cypselas	...	10
9a.	Disc cypselas suborbicular incurved, tuberculate on both faces ; pericarp with irregularly lobed phytomelan braces ; cypsela not lobed, with multicellular shaggy hairs in CS	...	*Coreopsis tinctoria*
b.	Disc cypselas oblong, straight, glabrous ; pericarp with ellipsoid phytomelan braces ; cypsela 6-lobed, without shaggy hairs in CS	...	*Chrysanthellum americanum*
10a.	Cypsela surface vertically channelled at the faces ; cypselar pappus coronate ; sclerenchyma braces very small	...	*Echinacea purpurea*
b.	Cypsela surface not channelled at the faces ; cypselar pappus may be awned scales (setae), scales or awns ; sclerenchyma braces conspicuous	...	11
11a.	Crystals present in the pericarp in CS ; cypsela very densely covered by slender about 1.25 mm long twin hairs (characteristic in Asteraceae) ; pappus of 5 or 6 awned scales (setae) ; carpopodium absent	...	*Galliardia aristata*
b.	Crystals absent in the pericarp in CS ; cypsela sparsely or densely covered by short upto 0.5 mm long twins hairs, pappus not as above ; carpopodium present	...	12

12a. Phytomelan layer not found ; outer mesocarp many layered, pitted parenchymatous, in CS ; pappus of 2, small, deciduous scales ; cypsela not lobed ... *Helianthus annuus*

b. Phytomelan layer found ; outer mesocarp unilayered, parenchymatous or replaced by phytomelan layer in CS ; pappus of 2 long persistent lateral awns with lobed scales between them ... 13

13a. Parenchymatous hypodermal layer absent ; sclerenchyma cell ± circular ;ray parenchyma cells radially elongated, not smaller towards the periphery ;cells walls of the inner mesocarpic parenchyma are wavy in CS. ... *Tithonia rotundifolia*

b. Parenchymatous hypodermal layer present ; sclerenchyma cells ± angular ; ray parenchyma cells tangentially elongated and smaller towards the periphery ; cell walls of the inner mesocarpic parenchyma are ± straight in CS ... *Tithonia diversifolia*

ABBREVIATIONS USED IN FIGURES

A=Awn ; BE=Beak ; C=Cuticle ; CA=Carpopodium ; CAP=Collapsed parenchyma ; CO=Cotyledon ; COR=Corona ; CR=Crystal ; CS=Cross section ; CV=Cavity ; E=Endosperm ; EM = Ergastic material ; EP=Epicarp ; FIG=Figure ; H=Hair, HO=Hollow ; ME=Mesocarp ; P=Pericarp ; PA=Parenchyma ; PB=Phytomelan brace ; PL=Phytomelan layer ; PM=Photomicrograph (by SEM) ; PPA=Pitted parenchyma ; R=Ray cells ; S=Scale ; SCC=Secretory ; SCL=Sclerenchyma brace ; SCV-Secretory cells cavity ; ST=Stylopodium ; T=Testa ; TE=Testa epidermis ; TI=Testal inner zone ;TU = Tubercle ; TWPA= Thick-walled parenchyma; VT=Vascular trace.

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