Ethiop. J. Biol. Sci. **Vol. 13 (Supp.): 91-101, 2014**
© The Biological Society of Ethiopia, 2014 **ISSN: 1819-8678**

HOW TO STUDY THE ASTERACEAE (COMPOSITAE) WITH SPECIAL REFERENCE TO THE ASTERACEAE OF FEE

Mesfin Tadesse[1]

ABSTRACT: The Asteraceae is one of the largest families of flowering plants. It includes a large number of genera and species with rapid rates of radiation and possibly also of evolution. Members of the family have also been studied in connection with the effect of climate change on character evolution in plants. Some of the features of the family that have enabled such rapid radiation and possible speciation reside within the group of flowers that are produced commonly at the ends of branches and stems. Hence, an illustrated guide on how to study the morphology, particularly flower morphology, of the Asteraceae is provided to help beginners in plant taxonomic or systematic studies. A review of the accumulated information about the chemistry and biology of the family is also provided. Project ideas, review topics and taxa needing further field as well as laboratory work particularly for graduate level study are included.

Key words/phrases: Asteraceae, Biology, Chemistry, Flower morphology, Review and project ideas, Species.

INTRODUCTION

I. General morphology, characters with systematic value and related families

General morphology

The Asteraceae (Compositae) is known by the aggregated flowers often occurring at the ends of branches or stems. The technical term for such a group of flowers is capitulum (Fig. 1; plural capitula) which is macroscopic (visible to the naked eye). Aggregation of flowers occurs on usually flat surface called receptacle. It is also referred to as the banner of the family Asteraceae. Other taxa with similar morphology in the Flora of Ethiopia and Eritrea (FEE) area and which might be confused with it are Dipsacaceae, and Apiaceae (flowers macroscopic, solitary, inflorescence arranged in an umbel). Outside of the FEE area, it might be confused with the Calyceraceae, a family found in southern South America and Goodeniaceae, a family found mainly in Australia. The difference is that in the Asteraceae, the capitula are indeterminate.

---

[1] The Ohio State University, Department of Evolution, Ecology and Organismal Biology, Museum of Biological Diversity, 1315 Kinnear Road, Columbus, Ohio, 43212-1157, U.S.A. E-mail: tadesse.1@osu.edu

The flowers are often microscopic or tiny (often referred to as florets), and are in groups. Members of the subfamily Cichorioideae are known for producing milky fluid (latex) from their leaves and stems. Other taxa that produce latex and that are found in FEE are members of the Euphorbiaceae, which are often distinguished by their succulent habit, solitary flowers and fruits with 3 locules (spaces). The fruit in Asteraceae is one-seeded and dry. It is called a cypsela or achene. Taxa with similar achene morphology in FEE are Cyperaceae (grass-like), Apiaceae (flowers solitary, ovary superior), and *Ranunculus* (flowers solitary, ovary superior).

The capitulum. The capitulum is made up of the following units: Involucre – enclosure of the tiny flowers around the receptacle, made of bracts; Involucral bracts – also called phyllaries, separate or fused (cup-like) bracts: leaf-like or bract-like, uniform, graded monomorphic, dimorphic or differentiated; when differentiated, the outer series are usually green and the inner series with colored striations. Useful characters that need to be studied or recorded about the phyllaries include: shape, striations (resin-filled tubes), fusion of parts, layering and number per layer, margins (scarious, fringed, spiny, etc.), hairiness and type of hair (Figs. 1 and 2).

The receptacle. Useful characters about the receptacle may be derived by studying texture (smooth versus cob-webby), shape (flat, convex, conical, columnar), presence/absence of bracts (pales or paleae) – these often observed by removing a few florets, bract size, shape, pubescence, and sometimes colour.

Floret. The florets in the Asteraceae may occur on the exterior or around the perimeter of the receptacle, next to the phyllaries, as well as in the central area. The exterior florets are called ray florets and the interior are called disk florets or all florets may be similar, in which case they are called ligulate florets.

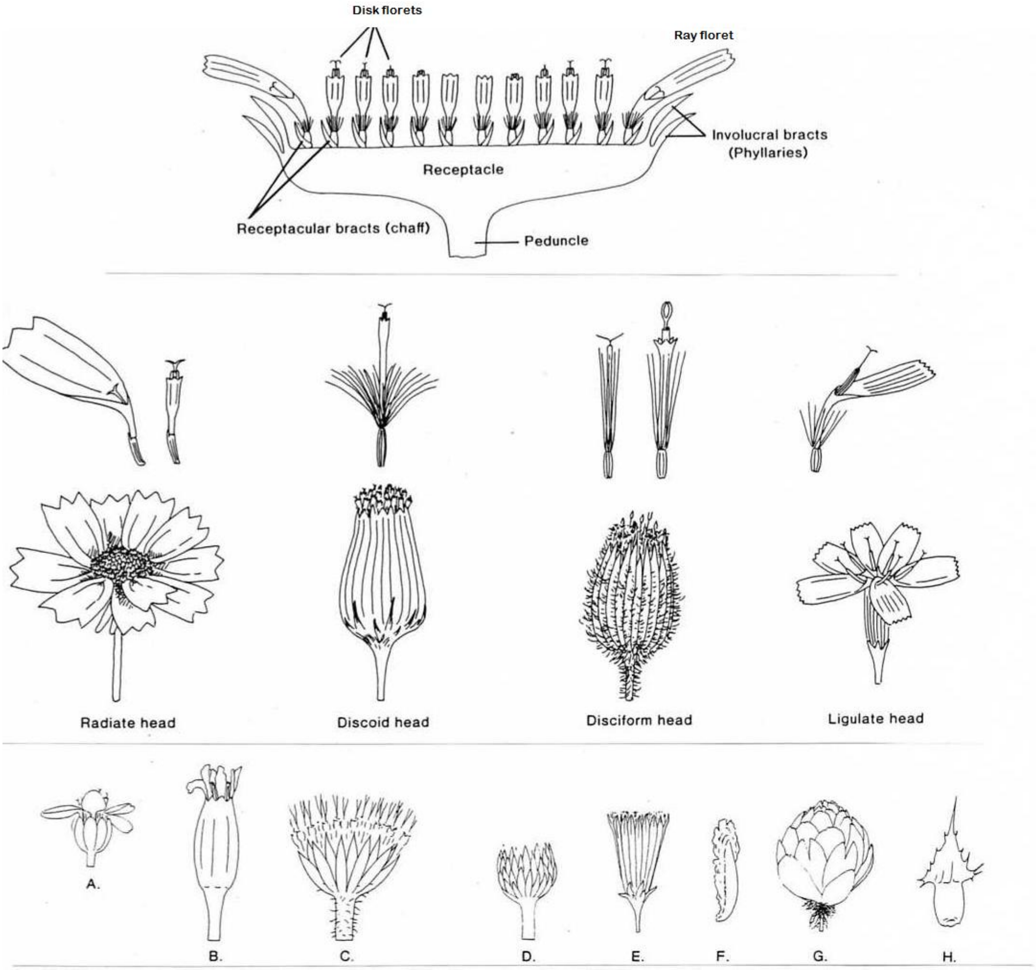

Fig. 1. Top row - the capitulum in longitudinal section showing relational positions of the phyllaries, ray and disk florets. Middle row - types of capitula with component florets (radiate has both ray and disk florets; discoid has similar tubular florets; disciform has dissimilar tubular florets with the corolla of the outermost florets described as filiform and with or without rays; ligulate florets). Bottom row - involucral types: **A**. uniseriate, separate phyllaries; **B**. uniseriate, fused phyllaries; **C**, **D** & **G**. 2 to multiseriate with only basally connate phyllaries, in **G**. phyllaries are scarious at margins; **E**. uniseriate phyllaries (erect) with spreading bractlets or calyculi (*Senecio*); **F** & **H**. phyllaries with scarious (**F**) and fringed (**G**) margins. Adapted from Walters & Keil, 1975, with permission from the publishers.

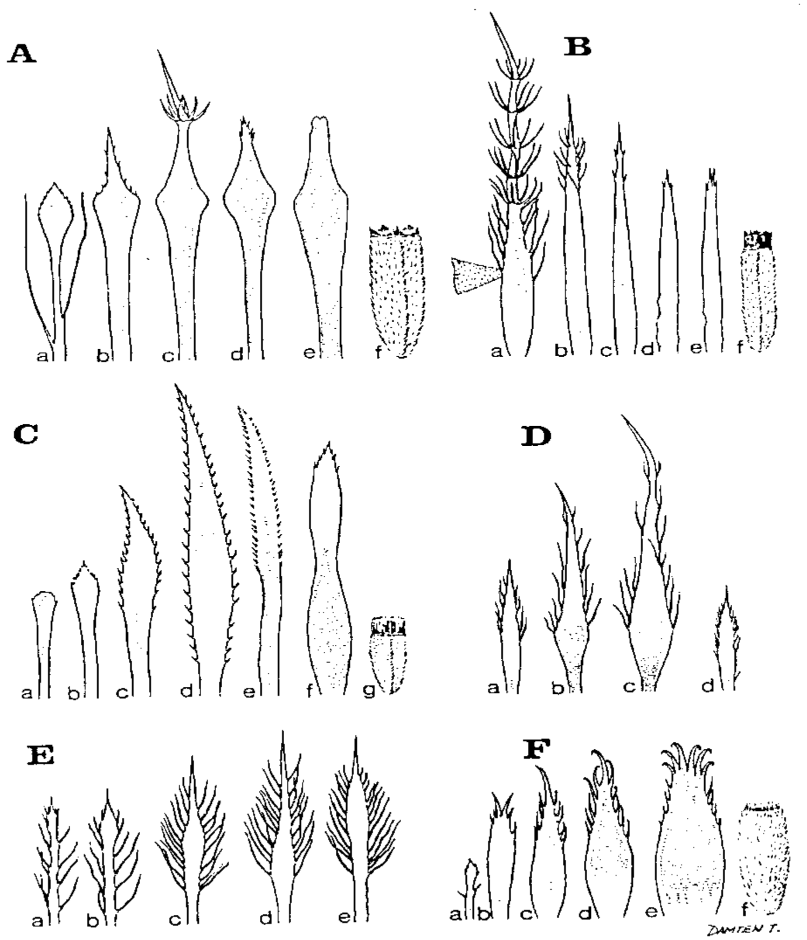

Fig. 2. Phyllaries and achenes of *Echinops* spp.: **A** = *E. hispidus*, **B** = *E. ellenbeckii*, **C** = *E. amplexicaulis*, **D** = *E. buhaitensis*, **E** = *E. angustilobus*, **F** = *E. hoehnelii.* Adapted from Flora of Ethiopia, vol. 4(2) (Mesfin Tadesse, 2004).

Ray florets are present in many, but absent in some taxa. They may be regular or filiform (i.e., hair-like and without stamens). The regular ray florets are made up of an ovary, a tubular corolla tube, and a flat corolla (limb). The ovary may be with or without pappus and pistil. It may be fertile, producing an achene or sterile (empty and whitish). The ovary, if fertile, will produce an achene (a fruit). The characters of the fruit, in any taxonomic study, should be recorded. The short tubular corolla tube may be with or without a pistil and the relatively longer, flat corolla limb is usually 3- to weakly 5-lobed at the apex and hairy or glabrous on both surfaces. Rarely, it may possess a short, flat, backwardly curled corolla on the anterior end. Taxonomically useful characters to measure are size (length x width), colour, tone (2-toned versus 1), shape, and hairiness. The filiform ray floret may be made up of an ovary and a tubular corolla, the limb is often absent, but, if present, it is represented by two slender lobes. In such cases, the **filiform ray floret** appears similar to disk floret but has only a pistil (no stamens) and the pistil may be fertile or sterile, e.g., *Conyza*.

Disk florets are absent only in a few groups in the Asteraceae. They are regular florets with an ovary (with or without pappus) with style, tubular corolla, and inserted stamens (Fig. 3). The ovary may be fertile, producing an achene, or sterile (empty and whitish). If fertile, the achene character should be recorded. For the tubular corolla measure size, number of lobes, size of lobes, hairiness and type of hair. About the anthers, note if the base is with or without tail (Fig. 4), if base is with short or long tail, measure its length, and note the apex (pointed or dome-shaped). About the style branches (Fig. 4), note whether these are with or without a ring of hairs at the branching point, the shape of the apex (truncate, conical, penicillate), sweeping hairs (present or absent), sizes, and whether they are restricted or found throughout the length of the branches, whether the branches are spreading or adherent at anthesis (flowering time).

Ligulate florets are present only in members of the subfamily Cichorioideae and each is composed of an ovary with or without pappus, corolla (tubular and with a limb with 5-apical lobes), connate anthers around the pistil and pistil with 2 branches. The entire capitulum is made up of only these types of flowers.

Fruit. The fruits in the Asteraceae, called achenes or cypsela, are one-seeded, dry, indehiscent (not split open when mature; also character in Goodeniaceae, not found in FEE) and the surfaces may be smooth, striated, or ribbed, hairy, warty or glabrous, flat (compressed). Shape-wise, they may be quadrangular (prismatic), triangular (at least in upper parts), navicular (boat-shaped – with outer surface convex, and ventral surface flat or slightly concave and with a raised median rib), cylindrical or flat. The apex may be epappose (without pappus) or pappose. When epappose, it may be circular and devoid of any outgrowth and when pappose, it may be provided with 2 or more awns, paleae or aristae. The awns and aristae may be upwardly (antrorsely) or backwardly (retrorsely) barbed and the paleae usually associated with them may be flat or slightly 3-angled at base. When pappose, the bristles may be few to numerous and they may be smooth, barbellate (with short stiff hairs) or plumose (Fig. 4).

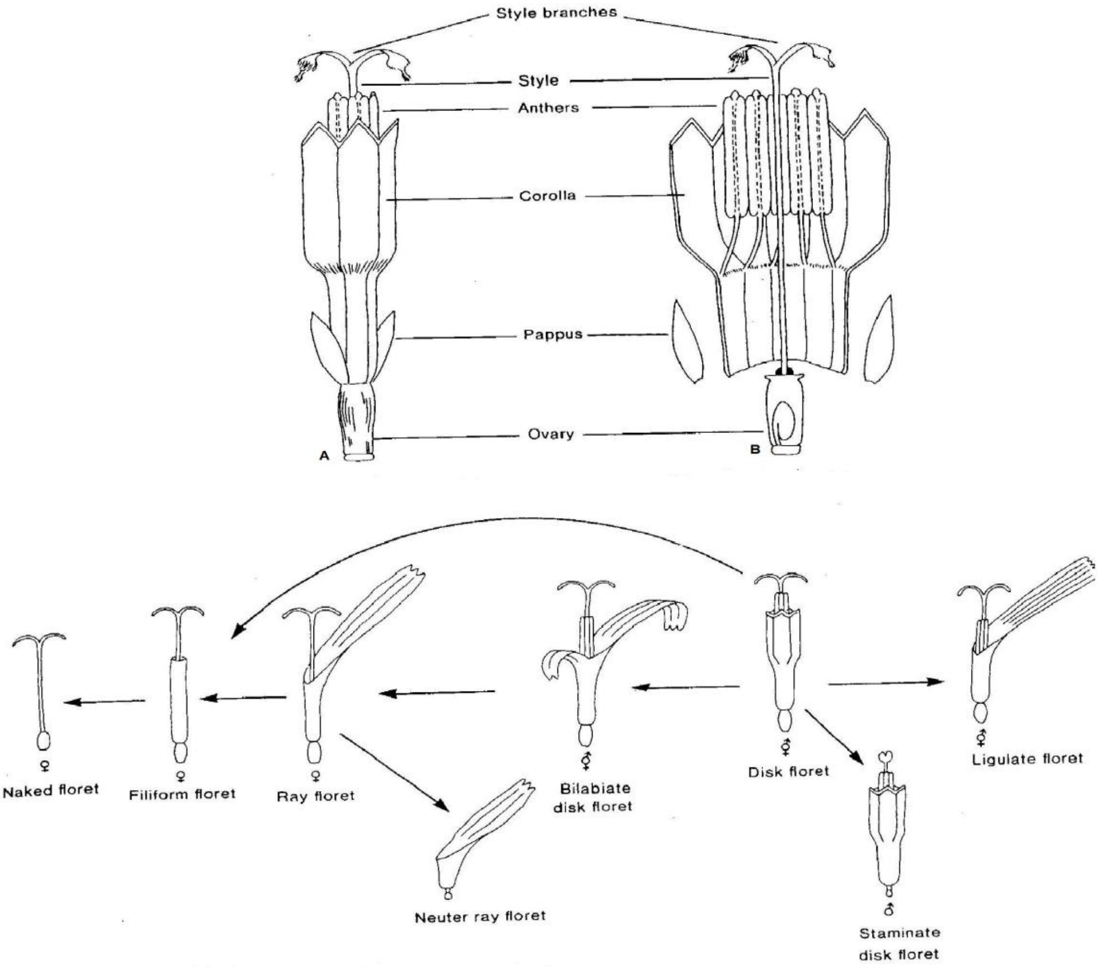

Fig. 3. Top row – Disk florets: **A**. Intact. **B**. dissected longitudinally to show fused anthers but separate filaments, note place of insertion of filaments on the corolla tube and also the single style with two bifurcating branches with sweeping hairs. The ovary is inferior with one locule and one basal ovule. Bottom row – putative scheme for the evolution of the Compositae florets with the radially symmetric disk floret having given rise to all other types. Adapted from Walters & Keil, 1975, with permission from the publishers.

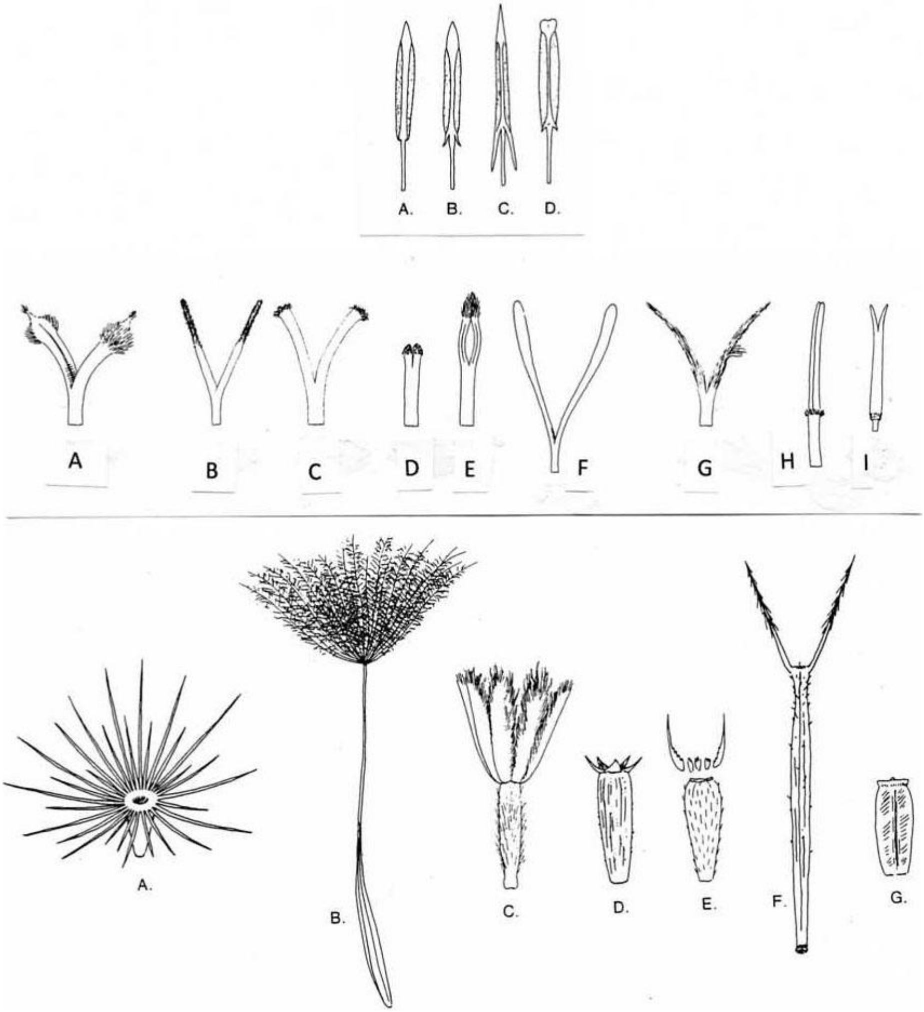

Fig. 4. Top row – variation in anthers. Middle row – variation in style branches: **A**. *Bidens*; **B** & **G**. *Vernonia*; **C**. *Senecio*; **D**. *Osteospermum*; **E**. *Aster*; **F**. *Ageratum*; **H**. *Centaurea*; **I**. *Arctotis*. Bottom row – variation in achene and pappus: **A**. pappus of simple bristles; **B**. beaked achene with pappus of plumose (featherlike) bristles; **C**. pappus of fringed scales; **D**. pappus of a crown of low scales (awns); **E**. pappus of deciduous or persistent scales with 2 prominent than the others; **F**. pappus of backwardly barbed aristae (awns); **G**. achene without a pappus (epappose) and with a circular corona. Adapted, with some modification, from Walters & Keil, 1975 with permission from the publishers.

II. Studies on anatomy, chemistry, cytology, molecular phylogeny and palynology

Anatomy. Much of the anatomical study on the Asteraceae was focused on island endemics because of interest on insights they provide on rates of radiation and evolution of characters. Examples are *Fitchia* (found in French

Polynesia), *Tolpis* (in Canary Islands) and *Argyroxiphium* (in Hawaii), which received a lot of attention. Some members of *Tolpis* are in the FEE area. “The diversity of endemic plants found on oceanic islands is the result of the three processes of dispersal, establishment, and the evolutionary diversification of progeny of the colonizers.” (Carlquist, 1974).

Chemistry. In Asteraceae, alkaloids are known only from three tribes (Cardueae, Eupatorieae and Senecioneae). The role of secondary metabolites in the evolution and diversification of the Asteraceae is still unknown. The Asteraceae studied chemically from FEE are *Artemisia*, *Bidens*, *Echinops*, and *Laggera*. The chemistry of the Asteraceae was summarized in 1977 in ‘Biology and Chemistry of the Compositae” and based on the chemical data, Heliantheae was considered basal and Barnadesieae to be a derived lineage and, today, it is kept as a primitive group within the Asteraceae based on a chloroplast genome that is shared by all members of the family except the Barnadesieae. The first phylogenetic analysis of the Asteraceae, based on phytochemical data, was produced by Calabria *et al*. in 2007 and a summary of the current knowledge was provided by the same authors in 2010 (Calabria *et al*., 2010).

Cytology. Members of the Asteraceae studied cytologically from FEE and other Floras in Africa are *Ambrosia*, *Artemisia*, *Bidens*, *Carduus*, *Dicoma*, *Echinops*, *Gerbera* and *Tarchonanthus*. An index to chromosome numbers of the Asteraceae is now available online (http://www.lib.kobe-u.ac.jp/products/asteraceae/index.html) – 2008. Much focus has been placed on chromosome number studies with inferences on ancestral base numbers. Base numbers of $x = 2$ to $x = 19$ are reported (most common $x = 9$; also found in Goodeniaceae, where $x = 8$ or 9, while in Calyceraceae, $x = 8$). This led to a phylogenetic hypothesis based on chromosome base numbers (mainly studies between 1960 and 1980). Semple and Watanabe (2010) provided a hypothesis on chromosome base number evolution superimposed on a proposed phylogenetic tree of the Asteraceae.

Molecular phylogeny. A major shift in the systematics of the Asteraceae occurred in the late 1980s and early 1990s based on the work of Jansen *et al*. on DNA sequence data of chloroplast genes (Jansen *et al*., 1987; 1988; 1991; 1996). This was followed by studies on the nuclear ribosomal ITS region. Genera of Asteraceae studied so far and also found in the FEE are *Berkheya*, *Bidens*, *Dicoma*, *Distephanus*, *Erythrocephalum*, *Gonicaulon*, *Ochrocephala*, *Plectocephalus*, *Rhaponticum*, *Silybum*, *Tarchonanthus* and *Vernonia* (list is not exhaustive). After the publication of the above works, the Heliantheae was no longer considered basal in the family. A part of the Mutisieae is now considered basal in the Asteraceae and the Vernonieae and Eupatorieae were placed far apart in the phylogenetic trees.

Palynology. Scanning Electron Microscopy (SEM) still provides a lot of useful information about pollen grains of the Asteraceae. Mature pollen grains in Asteraceae are 3-celled (2-celled in Calyceraceae and Menyanthaceae), spinulose (with small spines) or smooth (also in Calyceraceae). New terminology for the pollen grains has developed recently. “When optimized on the super-tree, pollen morphological characters provide a synapomorphy for almost every internal branch of Compositae phylogeny.” (Blackmore *et al*., 2010). Many of the genera found in the FEE have been studied palynologically.

III. Future projects and genera needing further review

The Asteraceae are found throughout the continents except Antarctica and are found from sea level to the highest points of mountains. This diversification is assumed to be related to their ability to inhabit various types of environments by altering their genetic mechanisms. Some high altitude Asteraceae have been the subject of studies on the effect of ultra-violet radiation on organelles, cells and tissues. Thus, there appears to be no reason not to study them in relation to climate change and hence the following ideas are suggested for future studies in Ethiopia as well as anywhere else in the world.

Future project ideas: 1. Do closely related groups of species in Asteraceae show similar ability to track climate change with flowering time? 2. Do annual and perennial species show different abilities to track climate change with flowering time? 3. Do native and invasive species show differing shifts in flowering time associated with warming? 4. Are differences in ability to shift flowering time with warming associated with changes in abundance in annual species? 5. Are species with less ability to track climate change decreasing in abundance? 6. Are species rapidly tracking climate change increasing in abundance? Any or all of these might be offered as graduate-level theses projects.

Genera needing further review: The following genera of Asteraceae in FEE can be reviewed (number of species is given in parenthesis): *Vernonia* (49), *Sphaeranthus* (8), *Helichrysum* (23), *Conyza* (25), *Senecio* (25), *Emilia* (12), and *Kleinia* (16). Characters and distributions of Asteraceae along altitudinal gradients as indicators of climate change can be a good longlasting project. The evolution of woodiness in Asteraceae and wood anatomy of tree *Vernonia* species can be studied.

IV. Current classification of the Asteraceae

The Asteraceae is subdivided into 12 subfamilies (2 are “under discussion”) and 43 tribes (11 of these are treated in the “Heliantheae alliance”, e.g., Crawford *et al*., 2009). In the FEE, there are 4 subfamilies and 21 tribes. The Ethiopian mountains support a good percentage of composites: **36 genera** introduced, 12 naturalized; **6 genera endemic**.

The following are major developments in the classification of the Asteraceae: **1977** - *Proceedings of the conference (1975) on the Biology and Chemistry of the Compositae* (Heywood *et al*., 1977); **1994** - Asteraceae: *Cladistics and Classification* (Bremer, 1994); **1996** - *Proceedings of the International Compositae Conference, Kew* (vol.1: D.J.N. Hind and H.J. Beentje; vol. 2: P.D.S. Caligari and D.J.N. Hind); **2002** - *Phylogenetic classification of the Compositae* (Panero and Funk, 2002); **2006** - Global Working Checklist of the Compositae, http://www.compositae.org; **2007** - *Compositae: The Families and Genera of Vascular Plants* (Anderberg and Eldenas, 2007); **2009** - *Systematics, Evolution and Biogeography of Compositae* (Funk *et al*., 2009).

REFERENCES

Anderberg, A.A. and Eldenas, P. (2007). Tribe Inuleae Cass. In: **The Families and Genera of Flowering Plants, 8**, pp. 374–379 (Kadereit, J.W. and Jeffrey, C., eds.). Springer, Berlin, Germany.

Blackmore, S., Wortley, A.H., Skvarla, J.J. and Robinson, H. (2010). Evolution of pollen in Compositae. In: **Systematics, Evolution, and Biogeography of Compositae**, pp. 121–130 (Funk, V.A., Susanna, A., Stuessy, T.F. and Bayer, R.J., eds.). IAPT, Vienna, Austria, Sheridian Books, Inc., Ann Arbor, Michigan.

Bremer, K. (1994). **Asteraceae: Cladistics and Classification**. Timber Press, Portland.

Calabria, L.M., Emerenciano, V.P., Scotti, M.T. and Mabry, T.J. (2010). Secondary chemistry of the Compositae. In: **Systematics, Evolution, and Biogeography of Compositae**, pp. 73–78 (Funk, V.A., Susanna, A., Stuessy, T.F. and Bayer, R.J., eds.). IAPT, Vienna, Austria, Sheridian Books, Inc., Ann Arbor, Michigan.

Carlquist, S. (1974). **Island Biology**. Columbia University Press, New York.

Crawford, D.J., Mesfin Tadesse, Mort, M.E., Kimball, R.T. and Randle, C.P. (2009). Coreopsideae. In: **Systematics, Evolution, and Biogeography of Compositae**, pp. 713–730 (Funk, V.A., Susanna, A., Stuessy, T.F. and Bayer, R.J., eds.). IAPT, Vienna, Austria, Sheridian Books, Inc., Ann Arbor, Michigan.

Funk, V.A., Susanna, A., Stuessy, T.F. and Bayer, R.J. (eds.) (2009). **Systematics, Evolution, and Biogeography of Compositae**. IAPT, Vienna, Austria, Sheridian Books, Inc., Ann Arbor, Michigan.

Heywood, V.H., Harborne, J.B. and Turner, B.L. (eds.) (1977). **The Biology and**

Chemistry of the Compositae. Vol. 1. Academic Press, London.

Hind, D.J.N., Beentje, H.J. and Caligari, P.D.S. (eds.) (1996). Compositae: Systematics, Biology and Utilization. In: **Proceedings of the International Compositae Conference, Kew, 1994, Vol. 1 & 2**. Royal Botanic Gardens, Kew.

Jansen, R.K., Smith, E.B. and Crawford, D. J. (1987). A cladistic study of North American Coreopsis (Asteraceae: Heliantheae). *Plant Syst. Evol.* **157**: 73–84.

Jansen, R.K. and Palmer, J.D. (1988). Phylogenetic implications of chloroplast DNA restriction site variation in the Mutisieae (Asteraceae). *Amer. J. Bot*. **75**:751–764.

Jansen, R.K., Michaels, H.J. and Palmer, J.D. (1991). Phylogeny and character evolution in the Asteraceae based on chloroplast DNA restriction site mapping. *Syst. Bot.* **16**: 98–115.

Jansen, R.K. and Kim, K.J. (1996). Implications of chloroplast DNA data for the classification and phylogeny of the Asteraceae. In: **Proceedings of the International Compositae Conference, 1994, Vol. 1,** pp. 317–339 (Hind, D.J.N. and Beentje, H.J., eds.). Compositae Systematics, Royal Botanic Gardens, Kew.

Mesfin Tadesse (2004). Asteraceae (Compositae). In: **Flora of Ethiopia and Eritrea**. **Vol. 4 (2)**, pp. 1–408 (Hedberg, I., Friis, I. and Edwards, S., eds.). National Herbarium, Addis Abeba, Ethiopia and Uppsala University, Sweden.

Panero, J.L. and Funk, V.A. (2002). Toward a phylogenetic sub familial classification for the Compositae (Asteraceae). *P. Biol. Soc. Wash.* **115**: 909–922.

Semple, J.C. and Watanabe, K. (2010). A review of chromosome numbers in Asteraceae with hyphotheses on chromosomal base number evolution. In: **Systematics, Evolution, and Biogeography of Compositae**, pp. 61–72 (Funk, V.A., Susanna, A., Stuessy, T. F. and Bayer, R.J., eds.). IAPT, Vienna, Austria, Sheridian Books, Inc., Ann Arbor, Michigan.

Walters, D.R. and Keil, D.J. (1975). **Vascular Plant Taxonomy**. 3rd ed. Kendall/Hunt Publishing Co., Dubuque, Iowa.