CHAPTER I
INTRODUCTION

1. Introduction

The Compositae or Asteraceae are the largest flowering plant family with ca. 24,000 species divided into 12 subfamilies, and 1600-1700 genera (Funk *et al.*, 2009). The family is also among the most widespread with taxa on every continent except Antarctica and on many island chains throughout the world as well. Similarly, both habit and habitat are highly variable. Growth forms range from annual and perennial herbs < 5 cm to shrubs, vines and trees over 40 m tall. Species are found in nearly every type of habitat as well from aquatic to dry and from sea level to >3500 m. In general Compositae are most common in open areas, but there are also many shade tolerant species (Funk *et al.*, 2005).

The family also includes many economically important species. For example, lettuce, artichoke, and endive are widely consumed vegetables and sunflower and safflower seeds provide large quantities of oil. Additionally, chrysanthemums, marigolds, bachelor buttons, daisies and many other species are cultivated as garden ornamentals (Jansen and Palmer, 1987).

Along with their uses in food and for decoration some members of the family also produce a variety of defensive compounds. For example, one of the best known is pyrethrum a widely applied commercial insecticide. Other compounds known as sesquiterpene lactones are extremely bitter to the taste and have been shown to be effective against mammalian and insect herbivores, and, are often antifungal and cytotoxic; and some can even prevent insect larvae from reaching sexual maturity (Keeley and Robinson, 2009).

Many of these same compounds have medicinal value(s) for humans as well. Species of Vernonieae have been reported as sources of traditional medicine in many cultures (Keeley and Robinson, 2009). For example, the Yi in China use *Vernonia saligna* (Wall.) DC. in the treatment of sore throat, cough, tuberculosis and uterus prolapse (Huang *et al.*, 2003). In India *V. cinerea* Less. (now *Cyanthilliium cinerium*

(Less.) H. Rob., *V. roxburghii* Less., *V. teres* Wall. and *Elephantopus scaber* L. to cure fevers and as a tonic for as well as a cure for stomaches (Kirtikar *et al.*, 1984). The book The Medicinal Plants of Thailand (Saralamp *et al.*,1996) reports *V. elliptica* DC. (now *Tarlmounia elliptica* (DC.) H.Rob., S.C.Keeley, Skvarla & R.Chan) is useful for treating chronic gastro-intestinal aliments and ridding children of intestinal parasites (Saralamp *et al.*, 1996). Additionally, the crude extract and solvent fractions of the leaves and bark of *V. tenoreana* Oliv. showed broad spectrum activity against *Staphylococcus aureus*, *S. faecalis*, *Bacillus subtilis*, *B. cereus*, *Shigella dysenteriae* and *Klebsiella pneumonia* (Ogundare *et al.*, 2006). Antifungal activity of the compound zaluzanin D, from the aerial parts of *V. arborea* Buch.-Ham. (now *Strobocalyx arborea* (Buch.-Ham.) Sch.Bip) has also been found to be effective against six plant-pathogenic fungi (Krishna, 2003) and a steroidal saponin, vernonioside G (1), isolated from the roots of *V. cumingiana* Benth., is used in traditional Chinese medicines to anti-inflammatory activity (Liu *et al.*, 2005).

The Vernonieae are in the subfamily Cichorioideae which traditionally also includes the Liabeae, its sister tribe, the Cichorieae and the Arctitoidinae. Recent work by Funk *et al.* (2009) have expanded the subfamily to include several additional subtribes, however, there has been little actual change in phylogenetic relationships as most of the newly recognized subtribes are composed of genera that were previously included in one of the four original tribes of the subfamily. The Vernonieae originated in Madagascar/Africa and is now found widely throughout both the Old and New Worlds. The greatest concentration of taxa is in east Africa and Brazil, in their respective hemispheres. The tribe include ~130 genera and 1,300 species (Keeley & Robinson, 2009; and various recent papers by Robinson and collaborators (e.g., Robinson *et al.*, 2008; Robinson *et al.*, 2009; Robinson & Skvarla, 2009). However, until recently most species were within the large and morphologically complex genus *Vernonia* (e.g., Gleason, 1906; Ekman, 1914; Gleason, 1922; Gleason, 1923a; Jones, 1977; Keeley & Jones, 1977; Keeley & Jones, 1979; Jeffrey, 1988; Robinson and colleagues (1960-2010) and Keeley and colleagues (1979-2009)). Bremer (1994) summed up this situation as "the *Vernonia* problem" identifying it as the major stumbling block to understanding relationships within the tribe. Not only has it been difficult to distinguish taxa inside and outside of *Vernonia s.l.*, it has been

equally difficult to separate species from each other even within small geographically circumscribed areas, and conversely, to group taxa at higher levels to erect subtribes. It was not until DNA sequence data became available that it was possible to understand subtribal relationships (Keeley *et al.*, 2007; Keeley & Robinson, 2009). As a result of the refractory nature of the Vernonieae at every taxonomic level, it has been dubbed the "evil tribe" (Funk *et al.*, 2005; Keeley *et al.*, 2007).

Recent work by Robinson (1999b; 2007) and Keeley and Robinson (2009) based on molecular and morphological characters have resulted in substantial subtribal reorganization and the recognition of numerous (new) taxonomic entities. As of 2009, 20 subtribes were recognized on the basis of DNA sequence data, morphology, pollen type, chromosome number and to a lesser degree, secondary chemistry. The best understood and most clearly defined subtribes are those found in the New World. This is because various taxonomic groups such as that of North American *Vernonia* of North America (Gleason, 1906, 1922, 1923b) and studies like those of the West Indian Vernonieae (Ekman, 1914; Keeley & Jones, 1977; Keeley, 1978) are available and contain detailed information allowing them to be placed accurately within the framework. On the other hand, the number of the Old World subtribes are few and their delimitations less certain. This is due to lack of study of Vernonieae and many other plant groups throughout large areas of Africa and Asia. It is expected that the number of the Old World subtribes will increase as taxa are studied in greater depth (Robinson, *pers. comm.*).

The relationships among Vernonieae taxa of many Asian, Indo-Chinese and Malaysian Vernonieae lack any kind of treatment beyond the earliest naming and describing. That there are also >500 species in this region has made understanding the relationships among Vernonieae taxa extremely challenging as well. The present study is designed to address this deficiency for Thailand. Using morphological and molecular characters for the Vernonieae in Thailand it is possible to provide better and clearer species delimitations and to pursue other aspects, which may affect relationships at many levels within the tribe.

2. General morphology of Vernonieae (Keeley and Robinson, 2009)

2.1 Habits are annual or perennial herbs, shrubs, vines or trees. Stem and foliage are variously pubescent.

2.2 Leaves are usually entire and alternate, rarely opposite or whorled, sessile and petiolate, margins serrate or entire.

2.3 Capitulescences and secondary inflorescences are cymose with cymiform, corymbiform, paniculate occasionally reduced to solitary capitula (Figure 1.1).

2.4 Capitula are homogamous with 1 – 400 flowers, sessile or pedunculate. Florets are perfect (Figure 1.2). The flower colour is purple, pink or white. Corollas are actinomorphic and funnel form with lobe is longer than wide or rarely zygomorphic, then with unequal lobes. Involucres are campanulate to cylindrical, bracts are typically imbricate in 2–9 series; scarious or leafy, persistent or deciduous (Figure 1.3A). Receptacles are flat or convex, smooth or pitted, sometimes with pales, spines or partitions. Anthers are calcarate with a sagittate base, auricles obtuse or acute, frequently tailed, apical appendages acute, and with or without glands (Figure 1.4A). Style branches are spreading, semi-cylindrical, slender, tips acute or obtuse, sometimes recurved, outer surfaces pubescent with acute or blunt trichomes, inner surfaces with stigmatic papillae, but lacking other trichomes, base glabrous (Figure 1.4B).

2.5 Achenes are terete, angled or occasionally flattened, rarely dimorphic, typically with 3–20 ribs; outer surfaces glabrous or pubescent (Figure 1.3B). Pappus are persistent or deciduous, usually with capillary bristles, rarely coroniform, squamellose or with flattened or twisted segments, in two series typically the outer of short bristles or squamellae, the inner of long bristles; both series remain firmly attached at maturity.

2.6. Pollen are highly ornamented, lophate, sublophate, echinate or psilate (Figure 1.5).

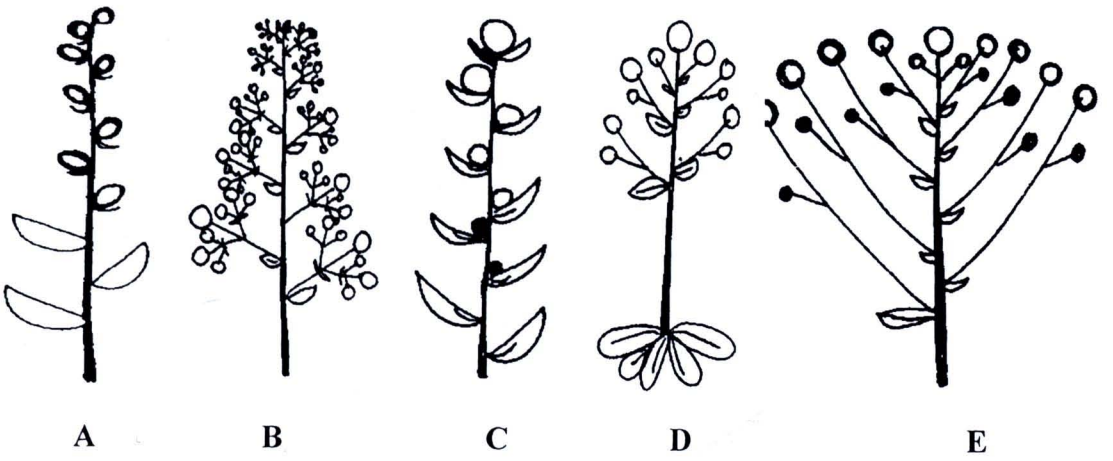


Figure 1.1 Capitulescences in Vernonieae; **A.** Spicate, **B.** Paniculiform, **C.** Solitary, **D.** Scapose, **E.** Corymbiform.

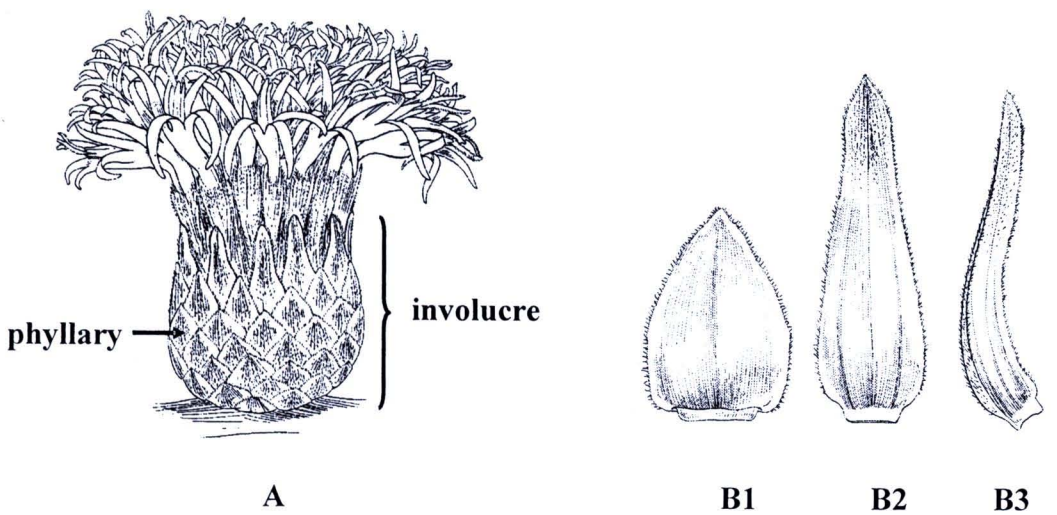


Figure 1.2 Capitula of Vernonieae; **A.** Discoid capitula, **B1 – B3.** Phyllaries. (Modified from Robinson, 1999a).

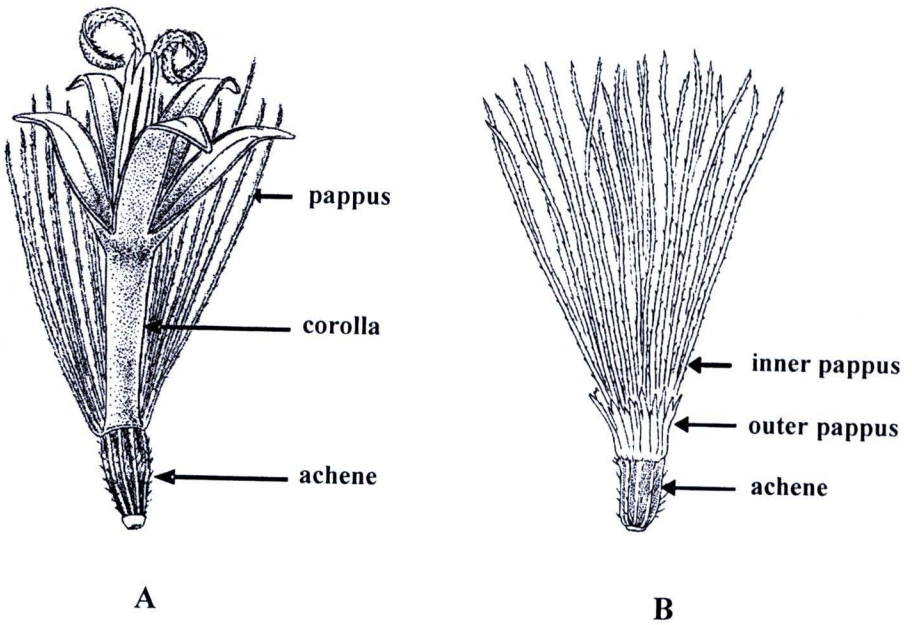


Figure 1.3 Floret and achene of Vernonieae **A.** Floret, **B.** Pappose achene (Modified from Robinson, 1999a and Robinson and Skvarla, 2006).

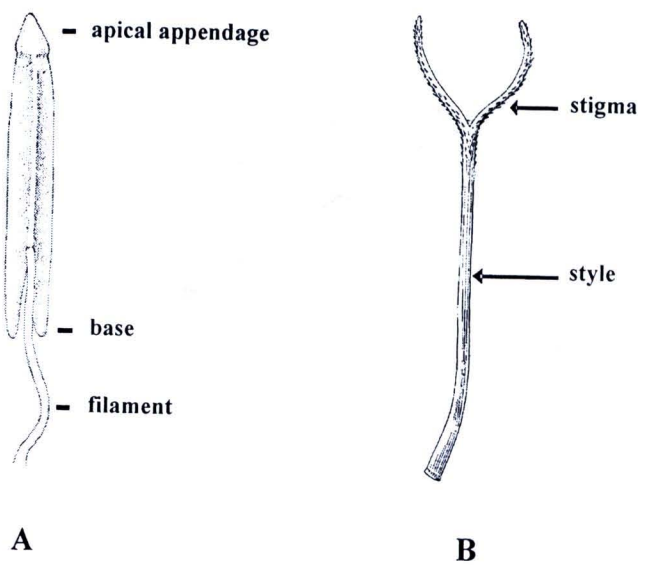
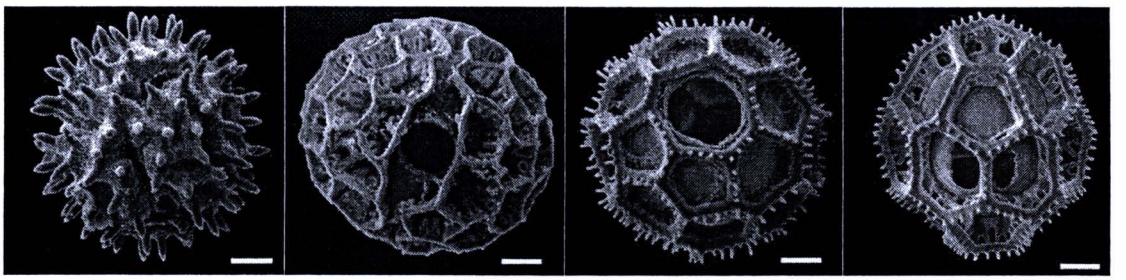


Figure 1.4 Stamen and pistil of Vernonieae; **A.** Stamen, **B.** Pistil (Modified from Robinson, 1999a).



A B C D

Figure 1.5 Pollen types of Vernonieae

A. Echinate 3-colporate **B.** Lophate 3- colporate

C. Lophate 3-porate **D.** Lophate 6-porate

(Applied from Bunwong and Chantaranothai, 2008).

3. Objectives

3.1 To enumerate the existing genera and species of Vernonieae in Thailand, construct taxonomic keys to them and record ecological and distributional data for each.

3.2 To examine the relationships within members of the tribe using morphometric analysis.

3.3 To construct a phylogeny of Thai Vernonieae using nuclear ribosomal internal transcribed spacer (ITS) and chloroplast DNA sequence data.

4. Scope of study

Morphological, ecological and distributional data for Vernonieae in Thailand were obtained from field collected specimens and herbaria. The studies were carried out between June 2007 and May 2010.

5. Anticipated benefits

This study will provide fundamental information on the tribe Vernonieae in Thailand using morphological and molecular data in a phylogenetic framework.

6. Institutional Resources

6.1 Morphological studies were carried out at the Department of Biology, Faculty of Science, Khon Kaen University. Specimens were obtained from field collections in Thailand and from herbarium specimens at the University of Aarhus (AAU), Botanischer Garten und Botanisches Museum Berlin-Dahlem, Zentraleinrichtung der Freien Universität Berlin Herbarium (B), Professor Kasin Suvatabhandhu, Chulalongkorn University (BCU), Department of Agriculture Bangkok (BK), Royal Forest Department Forest Herbarium (BKF), The Natural History Museum (BM), University of Copenhagen (C), Royal Botanic Garden Edinburgh (E), Conservatoire et Jardin botaniques de la Ville de Genève (G), Royal Botanic Gardens, Kew (K), Khon Kaen University (KKU), Nationaal Herbarium Nederland, Leiden University branch (L), Muséum National d'Histoire Naturelle Herbier National de Paris (P), Prince of Songkla University (PSU), Queen Sirikit Botanic Garden (QBG), and the Smithsonian Institution United States National Herbarium (US). The field collections are kept at KKU, QBG and US.

6.2 The molecular studies were investigated at the Botany Department, University of Hawaii at Manoa, Hawaii, USA.