# CHAPTER 3

# LITERATURE REVIEW

## 3.1 Previous works using numerical taxonomy

Previously, numerical taxonomy or morphometric analysis has been successfully employed to clarify the taxonomic problems of plants, animals as well as microorganisms by many workers worldwide. Some of their works are reviewed below.

Baum and Bailey (1984) have used numerical taxonomy to investigate the taxonomic problems in *Hordeum* L. section *Hordeastrum* Doell (*H. murinum* L., *H. marinum* Hunds and their allies), and reported that these species were divided into three groups on the basis of lodicules and epiblast characters. Then, they have studied *H. brevisubulatum* (Trin.) Link in 1991; additional observations were made in the field in Turkey, Iran, and China. They inferred that the following morphological species, *H. bogdanii* Wilenski, *H. brevisubulatum* Link, and *H. turkestanicum* Nevski, are worth of recognition and found that *H. roshetzii* Bowden is very close to *H. brevisubalatum* Link.

Bayer (1987) used numerical taxonomy to study eight sexual species of *Antennaria* of western North America. The 5 taxa are both diploid and polyploid cytotype whereas 3 species are strictly sexually reproductive diploids. In the same way, Downie and McNeill (1980) studied in *Euprasia randii* Reeks complex. They used 13 characters from 291 specimens from 59 populations, the result supported the recognition species. Likewise, Standley (1987) used numerical taxonomy to analyze *Carex* species complex, it was believed that this complex contsisted of some infraspecific taxa, in North America, in this study he confirmed that it can not be divided into separated species.

Morphological variations within and among six populations of *Trillium erectum* L. in southern Ontario were studied by Ringius and Chmielewski (1987), they found high difference among populations and appeared to be determined by complex relationships among variables that are unique to each population.

Semple, Chmielewski and Brammal (1990) studied *Solidago nemoralis* Aiton and *Aster umbellatus* Mill. species complex, A multivariate morphometric study of 362 plants by 11 characters of *A. umbellatus* complex were carried out. The result indicated that four species level groups can be recognized:- *A. infirmus* Michx., *A. reticulartus* Pursh, *A. sericocarpoides* (Small) K. Schum, and *A. umbellatus* Mill.. Within *A. umbellatus* Mill., the result supported the recognition of two varieties:- *pubens* and *umbellatus*. Moreover, Zona (1991) used leaf characters to differentiate taxa in *Haenianthus* Grisbach and found that it is less useful than previously believed. Nevertheless, two species can be recognized, *H. incrassatus* (Sw.) Grisbach and *H. salicifolius* Grisbach. The latter species has two varieties, *H. salicifolius* var. *salicifolius* of Cuba and Haiti, and *H. salicifolius* var. *obovatus* (Krug & Urban) Knoblauch. of Cuba, and Poerto Rico.

Forster and Liddle (1991) recognized five subspecies within *Hoya australis* complex using qualitative and quantitative characters of both vegetative and reproductive structures. *H. australis* subsp. *oramicola* P.I. Forst. & Liddle was newly described and the new combinations *H. australis* subsp. tenuipes (K. Hill) P.I. Forst. & Liddle (1991) and the new combinations *H. australis* subsp. *tenuipes* (K. Hill) P.I. Forst. & Liddle (*H. oligotricha* subsp. *tenuipes* K.Hill) and *H. australis* subsp. *rupicola* (K. Hill) P.I. Forst. & Liddle (*H. rupicola* K.Hill) were proposed. Chatrou (1997) used cluster analysis to reveal the patterns of macro-morphological variation in a species complex of *Malmea* (Annonaceae). Of 53 characters, 24 were important for clustering 238 herbarium specimens into 12 clusters. A new subspecies, *M. depressa* subsp. *abscondita* Chatrou, was described. Moreover, *M. gaumeri* (Greenm.) Lundell and *M. leiophylla* (Donn. Sm.) Lundell were suggested as synonym of *M. depressa*. While, cluster analysis and principal components analysis of 66 morphological characters from 103 populations of the *Lobelia cardinalis* L. complex failed to disclose groups of populations. The complex comprises a single species, *L. cardinalis*, and that this species should not be divided into infraspecific taxa. (Thompson and Lammers, 1997).

Likewise, 215 accessions of 30 taxa in the *Solanum brevicaule* Bitter complex and 42 accessions of six taxa outside the complex were determined using

53 morphological characters. Principal Component Analysis and Discriminant Analysis were used, but, the outcomes were unable to support 30 taxa, suggesting a single variable complex (van den Berg et al., 1998).

Aldasoro et al. (1998) carried out a multivariate morphometric study from 127 herbarium specimens and nine populations of the genus *Sorbus*. The principal component analysis, discriminant analysis and cluster analysis of morphological, anatomical and cytological data were carried out. The results showed that twelve species could be easily recognized in the area.

It was reported that *Simarouba amara* (Donn. Sm.) Lundell was frequently confused with two other continental species, *S. glauca* and *S. versicolor*. Cluster and Principal Component Analyses were applied to verify the distribution and variation of the diagnostic characters proposed in the preceding revision, i.e. anther size, stamen appendage, indument, leaflet surface, and venation features. *S. glauca* and *S. versicolor* were found to be morphologically closer than *S. amara*. Overlapping of characteristics in boundary populations of the three species was also found. (Franceschinelli, 1998)

In northern America, the cosmopolitan *Pteridium aquilinum* (L.) Kuhn is represented largely by var. *latiusculum* (Desv.) Huttén and var. *pseudocaudatum* Domin. Twelve quantitative and qualitative morphological characters were examined in 262 specimens using PCA and Cluster analysis to assess the taxonomic relationship between these two varieties. When the qualitative characters were used alone or in conjunction with some of the quantitative traits, the samples grouped into two distinct clusters corresponding to the two recognized varieties. The morphological study also supports a taxonomic treatment at the varietal level. (Speer and Hilu, 1998).

Furthermore, infraspecific morphological variation was investigated in *Eriastrum densifolium* (Benth) H. Mason. To assess the five currently recognized subspecies, vegetative and floral characters were analyzed at the species and population level by using cluster analysis. The herbarium specimens, field collections, and common garden plants were used. The only exception was a group of plants distinguished from the remainder of the species by corolla tube length.

This group of individuals matches the circumscription of *E. densifolium* subsp. *sanctorum* (Milliken) H. Mason. The other four recognized subspecies failed to form distinct morphological groups in all analyses. (Brunell and Whitkus,1998)

Hess and Stoynoff (1998) used cluster analisis and discriminant analysis examined vegetative and reproductive characters in *Quercus shumardii* var. *acerifolia* E.J. Palmer and comparing with *Q. shumardii* Buckl., *Q. buchleyi* Dov. & Nixon, *Q. texana* Buckl., and the maple-leaf oak. Cluster analyses segregated maple-leaf oak form *Q. shumardii* Buckl. and the other two recognized taxa. Based upon these numerical analyses and the evaluation of descriptive character, *Q. acerifolia* Hort. ex Petz. & Kirchn. was shown to be a distinct species. Nelson and Elisens (1999) performed cluster analysis; principal component analysis and canonical variate analysis based on 16 morphological character form 33 populations represent all taxa and ploidy levels of the genus *Chelone*. This work recognized three diploid species without infraspecific taxa in this complex. Kephart et al. (1999) used principal component analysis and discriminant analysis to determine whether quantitative morphology could effective distinguish varieties, population, and subpopulations of the polymorphic species, *Silene douglasii* Hook.. A phonetic analysis of 354 plants samples from 16 populations using vegetative characters (e.g., leaf width and pubescence) were the most effective characters to distinguish the var. *rupinae*, whereas reproductive character (e.g., calyx width, petal dimensions) were more useful for var. *oraria* and var. *douglasii*.

Labrecgue and Brouillet (1995) studied *Aster novi-belgii* L. complex using discriminant analysis and principal component analysis, and found that these plants could be separated into variety lavel, *Aster novi-belgii* var. *crenifolus* (Fernald) Labrecque & Brouillet and *Aster novi-belgii* var. *villicalis* (A. Garay) B. Boivin.

Vekemans and Lefebvre (1995) investigated herbarium specimens *of Armeria maritima* Mill. using discriminant analysis, cluster analysis, principal component analysis and two way nested analysis, and reported three subspecies of,

*A maritima* ssp. *californica* (Boiss.) A. E. porsild, *A. maritima* ssp. *sibirica* (Turcz. ex Boiss) Hylander and *A. maritima* ssp. *interior* (Raup) Lefebvre & Vekem.

Giussani, Martinez and Collantes (1996) used numerical taxonomy to studied morphological character of 4 species of *Poa* and included these species into *P. rigidifolia* Steud. complex.

In Thailand, some biosystematic studies were carried out using numerical techniques. For example, Precha Pratapa (2533 BE) studied the ecological genetics of *Afgekia sericea* Craib and *Afgekia mahidolae* Burt & Chermsirivathana in order to find the relationship of these two species by performing morphological, physiological, and cytogenetical characters analysis. Using Canonical discriminant analysis he found that 16 morphological characters from 100 specimens collected in the field could be used to separate the two species. However, there were some overlaps in their morphological characters. He concluded that the two species have some morphological relationships, but have been adapted to its own natural habitats for a long time.

The biosystematics of the populations of *Melastoma villosum* Lodd. in Thailand was studied by Seelanan (1992). Canonical discriminant analysis, Cluster analysis and Principal component factor analysis were utilized. It can be concluded that the variations within and between populations of *Melastoma villosum* are inadequate to distinguish any populations as an infraspecific taxon or a new separated species. Likewise, the biosystematics of the populations of *Pyrrosia eberhardtii* (Christ) Ching was studied by Polawatn (1996). The results on *Pyrrosia eberhardtii* can be interpreted in the same way. Recently, Boonkerd, Saengmanee and Baum (2002) examined 200 specimens of the *Bauhinia pottsii* complex using 43 quantitative characters. Cluster analysis and canonicl discriminant analysis were performed. It was found that these characters collectively support the four varieties as defined by qualitative characters.

### 3.2 Taxonomic history of *Cassia* L. sensu lato

*Cassia* L. has long been recognized as a heterogeneous genus. First of all is the studying of Bentham (1871) (in Irwin and Barneby, 1981) who considered and pointed out that there were three groups within this genus, *viz. Cassia, Senna* and *Lasiorhegma*. Then in 1981 Irwin and Barneby have revised the genus in the New World. In their study, tribe *Cassieae* was splited into five subtribes, *Ceratoniinae, Dialiinae, Dupaquetiinae, Labicheinea,* and *Cassiinae*. Furthermore, plants in subtribe Cassiinae were further classified into three genera, namely *Cassia* L. *Senna* Miller, and *Chamaecrista* Moench, using characteristic of filament and the presence or absence of bracteoles. Moreover, the genus *Chamaecrista* were further segregated into six sections, *viz.* sect. *Apoucouita*, sect. *Grimaldia*, sect. *Absus*, sect. *Xerocalyx,* sect. *Caliciopsis* and sect. *Chamaecrista*. In an attempt to investigate the classification proposed by Irwin and Barneby (1981), Graham and Barker (1981) have studied pollen morphology in the Caesalpinioideae. However, they found that pollen of the Cassiinae is relatively uniform.

Lock (1987) studied wild as well as cultivated species of *Cassia* sensu lato in Africa. He followed Irwin and Barneby's classication (1981), three segregated genera *Cassia* sensu stricto, *Senna* and *Chamaecrista* were recognised. Then, Tucker (1996) studied the trends in evolution of floral ontogeny in *Cassia* sensu stricto, *Senna* and *Chamaecrista*. He found that the three genera were distinguished in their floral ontogeny (floral position in the inflorescence, the presence of bracteole, the position of the first sepal initiation, order of petal initiation, asymmetric initiation, anther morphology, and time of carpel initiation).

However, Larsen et al. (1984) revised the Leguminosae-Caesalpinioideae for the Flora of Thailand Project. They placed 21 species and 2 subspecies of indigenous as well as introduced species in the subtribe Cassiinae into the genus *Cassia* L. Then, Larsen , Larsen and Hou (1996) revised the Leguminosae-Caesalpinioideae for the Flora Malesiana, this time they followed Irwin and Barneby (1981) classication, so the three genera, i.e. *Cassia* sensu stricto, *Senna* and *Chamaecrista*, were recognised in the Malesiana region.

Recently, Kidyue (2001) investigated the classification proposed by Irwin and Barneby (1981). This research was the comparative anatomy of stem, leaf, and flower of *Cassia* s.l. grew in Thailand. Seventeen species and 3 subspecies out of 22 species and 4 subspecies of *Cassia* s.l. in Thailand were employed. He separated the *Senna* into Senna-1 and Senna-2 according to habit (tree or shrub) and the stomatal distribution on leaves (hypostomatic or amphistomatic leaf ).