NUMERICAL TAXONOMY OF *Cassia* sensu lato

Mr. Sahanat Pechsri

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science in Botany
Department of Botany
Faculty of Science
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อนุกรมวิธานเชิงตัวเลขของพืชสกุล *Cassia* sensu lato

นาย สหณัฐ เพชรศรี

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
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T_115008

สหณัฐ เพชรศรี : อนุกรมวิธานเชิงตัวเลขของพืชสกุล *Cassia* sensu lato (NUMERICAL TAXONOMY OF *Cassia* sensu lato) อ. ที่ปรึกษา : รศ. ดร. ทวีศักดิ์ บุญเกิด, 112 หน้า. ISBN 974-17-1905-1.

พืชสกุล *Cassia* L. s.l. จัดเป็นสกุลที่มีสมาชิกมากมีจำนวนชนิดประมาณ 600 ชนิด พบกระจายทั่วไปในเขตร้อนของโลก จากลักษณะสัณฐานวิทยาที่ซับซ้อนและยากต่อการตรวจหาชื่อจึงมีผู้ศึกษาสถานะทางอนุกรมวิธานของพืชกลุ่มนี้และเสนอว่าควรแบ่งพืชกลุ่มนี้ออกเป็น 3 สกุลคือ *Cassia* L. s. s. *Senna* Miller และ *Chamaecrista* Moench อย่างไรก็ตามยังคงมีผู้จัดพืชกลุ่มนี้ไว้ในสกุล *Cassia* L. s.l. เพียงสกุลเดียว การศึกษาครั้งนี้จึงได้ยืนยันสถานะทางอนุกรมวิธานของพืชกลุ่มนี้จำนวน 18 หน่วยอนุกรมวิธาน (taxa) จากตัวอย่างจำนวน 508 ตัวอย่าง โดยใช้เทคนิคทางอนุกรมวิธานเชิงตัวเลข 3 วิธีคือ การวิเคราะห์ปัจจัย การวิเคราะห์การจัดกลุ่มและการวิเคราะห์การจัดจำแนก ศึกษาลักษณะทางสัณฐานวิทยาทั้งลักษณะที่ใช้ในการสืบพันธุ์และลักษณะที่ไม่ใช้ในการสืบพันธุ์จำนวน 32 ลักษณะ ผลจากการวิเคราะห์ปัจจัยพบว่าลักษณะต่างๆ สามารถรวมกลุ่มเข้าเป็น 2 ปัจจัย ได้แก่ ปัจจัยของลักษณะที่เกี่ยวข้องกับการสืบพันธุ์และปัจจัยของลักษณะที่ไม่เกี่ยวข้องกับการสืบพันธุ์ ส่วนการวิเคราะห์การจัดกลุ่มนั้นพบว่าที่ค่า average taxonomic distance เท่ากับ 1.30 สามารถจำแนก *Cassia* s.l. ได้เป็น 4 กลุ่มคือ 1. *Chamaecrista* 2. *Senna alata* 3. *Senna* และ 4. *Cassia* s.s. โดยกลุ่มของ *Cassia* s.s. ได้รวมเอา *Senna spectabilis* เข้าไว้ด้วย ได้อภิปรายผลการจัดจำแนกเป็น 4 กลุ่ม แต่เมื่อนำผลการจัดกลุ่มที่ได้นี้ไปวิเคราะห์ด้วยการวิเคราะห์การจัดจำแนกพบว่าควรจัดจำแนกพืชกลุ่มนี้ออกเป็น 3 กลุ่มหรือ 3 สกุล โดยลักษณะที่มีความสำคัญในการจัดจำแนก คือ ความยาวของก้านชูอับเรณู ความยาวของผล ความยาวของก้านรังไข่ นอกจากนี้การสำรวจรวบรวมตัวอย่างครั้งนี้ได้พบ *Senna obtusifolia* ซึ่งยังไม่เคยมีรายงานว่าพบพืชชนิดนี้มาก่อนในประเทศไทย

ภาควิชา พฤกษศาสตร์		ลายมือชื่อนิสิต Sahanat Pechsri
สาขาวิชา พฤกษศาสตร์		ลายมือชื่ออาจารย์ที่ปรึกษา Thaweesakdi Boonkerd
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Cassia s. l. is one of the large genus of flowering plants, occurs naturally in the tropics around the world. It was found that some species are difficult to determine due to their morphological complexes. Accordingly, this genus was separated by some workers into three genera, namely *Cassia* L. s. s., *Senna* Miller and *Chamaecrista* Moench. However, some authors still placed all species in a single genus, i.e. *Cassia* s. l. In order to confirm their taxonomic status, 508 specimens of 18 taxa were investigated in this thesis by numerical taxonomic techniques. Three multivariate morphometric analyses, namely factor analysis, cluster analysis and canonical discriminant analysis were used. The total 32 vegetative and reproductive morphological characters were focused on these analyses. The results of factor analysis revealed that most vegetative and most reproductive characters were separated on the two factor components. In cluster analysis, the *Cassia* s.l. can be separated into four groups viz. *Chamaecrista, Senna alata, Senna* and *Cassia* s.s. at average taxonomic distance 1.30. Nevertheless, the fourth group also included *Senna spectabilis.* The four-cluster grouping was discussed. From overall canonical discriminant analyses, it can be concluded that there are three groups within the genus *Cassia* s.l., as was proposed by Irwin and Barneby earlier. The most important characters for canonical discriminant analysis are filament length, fruit length, ovary stalk length. In addition, *Senna obtusifolia* L., a new recorded species for Thailand, was found during specimen collections.

Department................Botany......................Student's signature...Sahanat Pechsri...

Field of study.............Botany......................Advisor's signature...Thaweesakdi Boonkerd...

Academic year ....2002.............Co-advisor's signature..

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LIST OF ABBREVIATION

ATD	=	anther diameter in mm (largest fertile stamen)
ATL	=	anther length in mm (largest fertile stamen)
BTL	=	bracteole length in mm
BTW	=	bracteole width in mm
BTWP	=	bistance from base to the widest point of leaflet
DLBP	=	bistance between first and second leaflet pair
FLD	=	blower diameter in mm
FMD	=	filament diameter in mm (largest fertile stamen)
FML	=	filament length in mm (largest fertile stamen)
FTL	=	fruit length
LMW	=	lamina width in mm
LWR	=	terminal leaflet length to width ratio
LS	=	terminal leaflet shape (calculated by BTW/TLL)
mm	=	millimeter
NOL	=	number of leaflet
OVD	=	ovary diameter in mm
OVL	=	ovary length in mm
OSL	=	ovary stalk length in mm
PCL	=	pedicel length in mm
PED	=	petiole diameter in mm
PET	=	petiole length in mm
POLL	=	petiolule length in mm
PSL	=	petals stalk length in mm (largest petal)
PTL	=	largest petal length in mm
PTW	=	largest petal width in mm
RCD	=	rachis diameter in mm (between 2-3 leaflet pair)
RCL	=	rachis length in mm
SPL	=	largest sepal length in mm

LIST OF ABBREVIATION

ABBREVIATION

SPW	=	largest sepal width in mm
STD	=	style diameter in mm
STL	=	style length in mm
s.l.	=	sensu lato
s.s.	=	sensu stricto
TLL	=	terminal leaflet length in mm
TLW	=	terminal leaflet width in mm

CHAPTER 1

INTRODUCTION

It is estimated that the total number of species in the world is to be around 5 to 30 millions, however about 1.4 millions species have been described. It is likely that the actual number is on the order of 13 to 14 million, most of them are insects and microscopic organisms in tropical regions (Jones and Luchsinger, 1986). New plant species are described and named according to International Code of Botanical Nomenclature (ICBN). However, we may never know how many there are because many of them will become extinct before being counted and described. So it is really needed to carry out taxonomic study of the existing plants as soon as possible. To do this task we need to have effective system of plant classification.

The aim of plant classification is to sort out the vast array of plant biodiversity in some categories of relevant order. The first person who invented the system of plant classification is Theophrastus (372 - 287 B.C.), he did know the structure of plants that were important for modern plant classification and had described more than 500 species. He also recognized more specific botanical characteristics, such as ovary position. So far, his work, "*History of Plants*", is the oldest botanical work. He was also the first person who classified plants by their habits or forms as trees, shrubs, undershrubs, and herbs (Lawrence, 1951; Jones and Luchsinger, 1986).

In 1758, when Linnaeus presented his "***Systema Naturae***", the idea was simply to bring some sort of order out of the confusion of known living forms. However, Linnaeus' system was an artificial system of classification, since it assigned organisms on the basis of any convenient characteristics. Anyhow, it is important to realize that the only natural group in the system of biological classification is the "species". Two species may be very similar, by justice of recent evolutionary descent from a common ancestor, causing us to group them into the same genus, but the concept of genus as well as higher taxa, *viz.* species, family, order, class and division, are created by human and eventually being the artificial system of classification (Bhattacharyya and Johri, 1998).

In the last two decades, new approaches to classification have arisen. Many plant classification systems were set up, unfortunately the same group of plant were placed on different category and rank by botanists due to different evidence, i.e., morphology, anatomy, palynology, embryology, cytology, ecology, reproductive biology, chemistry, phylogenetic and molecular characters (Stuessy, 1989). It seems likely that some plant genera are still on the move to a more new relevant family according to an up-to-date taxonomic information.

Cassia L. is one of the large genus of flowering plants. This genus occurs naturally in the tropics around the world. The members of this genus have some economical values, they are being utilized in many purposes such as medicinal plant, cultivated plant and timber (Soralum et. al., 1992; Phumipamorn and Dumkong, 1997). According to Irwin and Barneby (1981) the genus was divided into three genera, namely *Cassia* sensu stircto, *Senna* and *Chamaecrista*. However, some plant taxonomists, for example, Larsen et al. (1984) treated all species in a single genus in the Flora of Thailand.

Aim of the thesis

This thesis aims to investigate the important of morphological characters that will be useful to evaluate the taxonomic status of the *Cassia* sensu lato using numerical taxonomic analyses.

CHAPTER 2

NUMERICAL TAXONOMY

2.1 Definition

Biological classification is the concept restricted to the grouping of organisms by their structural attributes into taxa, from phylum (division) down to genus and species (Clifford and Stephenson, 1975). While, numerical taxonomy is the grouping of taxonomic units into taxa on the basis of their character states by numerical methods (Sneath & Sokal, 1973). Previously, Mayr (1966) designed the term "taxometrics", while Blackith and Reyment (1971) created the term "multivariate morphometrics" and Jardine and Sibson (1971) coined the term "mathematical taxonomy". The term includes the drawing of phylogenetic inferences from the data by statistical or other mathematical methods or other method, for example serology or paper chromatography, to the extent to which this is possible.

In fact that it has approach consists of a variety of numerical techniques, but they are not included in numerical taxonomy if their techniques cannot apply to problems of classification.

2.2 Principles of Numerical Taxonomy

The fundamental position of numerical taxonomy that are frequently called neo-Adansonian was originated from a french botanist, Michel Adanson (1727-1806). The followings are summary of Adason's opinions by Sneath and Sokal (1973).

- The greater the content of information in the taxa of a classification and the more characters on which it is based, the better a given classification will be.

- A priori, every character is of equal weight in creating natural taxa.
- Overall similarity between any two entities is a function of their individual similarities in each of the many characters in which they are.
- Distinct taxa can be recognized because correlations of characters differ in the groups of organisms under study.
- Phylogenetic inferences can be made from the taxonomic structures of a group and form character correlation, given certain assumptions about evolutionary pathways and mechanism.
- Classifications are based on phenetic similarity.
- Taxonomy is viewed and practiced as an empirical science. Organisms and characters are chosen and recorded.

These successive sequences are routine of the operation of numerical taxonomy.

- The resemblances between organisms are calculated. Estimation of resemblance is the most important and fundamental step in numerical taxonomy.
- Taxa are based upon these resemblances.
- Generalizations are made about the taxa.

2.3 Kind of Character

Characters employed in numerical taxonomy can be morphological, physiological, chemical, ecological as well as distributional characters.

2.4 The Advantages of Numerical Taxonomy

Sneath & Sokal (1973) has briefly cited the diverse advantages of numerical taxonomy such as:-

- Numerical Taxonomy has the power to integrate data from many sources: morphology, physiology, chemistry, amino acid sequences of protein, and more which is very difficult to do by classical taxonomy.

- The less highly skilled worker can be done due to numerical taxonomy are promoted the greater efficiency automation taxonomic process.
- Being quantitative, the methods provide greater discrimination along the spectrum of taxonomic differences and are more sensitive in delimiting taxa. Thus they should give better classifications and keys than can be obtained by the conventional methods.
- It is easily to use the data, which are coded in numerical form, for the creation of descriptions, keys, catalogs, maps, and other documents.
- The creation of explicit data tables for numerical taxonomy has already forced workers in this field to use more and better-described characters. This necessarily will improve the quality of conventional methods as well.
- Numerical taxonomy can reexamine the principles of taxonomy and of the proposes classification. This has benefited taxonomy in general, and has to lead to the posing of some taxonomic questions.
- A number of biological concepts are reinterpreted by numerical taxonomy and it can be used to solve the new biological and evolutionary problem.

2.5 The numerical techniques

In this thesis Factor Analysis (FA), Cluster Analysis (CA) and Canonical Discriminant Analysis (CDA) were used to solve the classification problem in Cassia s. l. in Thailand. Details of each technique are summarized as below (Anonymous,1997).

2.5.1 The Factor Analysis (FA)

The factor analysis was introduced by Charles Spearman who published "Two Factors Theory" in 1904. It was also called 'component analysis'. It is a statistical technique used to catalogue a relatively small number of factor that can be used to represent relationships among sets of many interrelated variables.

2.5.1.1 The goal of factor analysis

- To identify factors that are substantively meaningful.
- To reduce a large number of variables to a smaller number of factors.
- To test and confirm the accuracy of the measurement.

2.5.1.2 Step in a factor analysis

In general, four steps are usually processed in factor analysis.

- Firstly, the correlation matrix for all variables is computed. Variables that don't appear to be related to other variables can be identified from the matrix and associated statistic.
- The second step, factor extraction-the number of factor necessary to represent the data and the method for calculating them must be determined. The goal of factor extraction is to determine the factor. In the factor extraction phase, the number of common factors needed to adequately describe the data is determined. This decision based on eigenvalues and the percentage of the total variance accounted for by difference numbers of factors. A plot of the eigenvalues (the scree plot is helpful in determining the number of factors.) To identify the

factors, it is necessary to group the variables that have large loading for the same factors.

- The third step, rotation will be made with focusing on transforming the factor to make them more interpretable because the unrotated factor matrix is difficult to interpret. The goal of rotation is to transform complicated matrices into simpler matrices. If a rotation has achieved a simple structure, cluster of variable should occur near the end if the axes and at their intersection when its were plotted graph.
- Finally, scores for each factor can be computed for each case. The factor score can be used in subsequent analyses to represent the values of the factors. Plot of factor scores for pairs of factors are useful for detecting unusual observations.

2.5.2 The Canonical Discriminant Analysis (CDA)

The discriminant analysis was firstly introduced by Sir Ronald Fisher. It was the statistical technique most commonly used to investigate the problem in classification. The linear combinations of the independent variable are calculated and served as the basis for classifying cases into one of group. Thus, information contained in multiple independent variables is summarized in a single index. In discriminant analysis, the weights are estimated so that they resulted in the best separation between the groups.

The linear discriminant equation is as follow.

$$D = B_0 + B_1X_1 + B_2X_2 + \ldots + B_pX_p \quad \text{.................. (equation 2.1)}$$

The D is discriminator variable. The X's are the independent variable ($p \geq 1$) and the B's are coefficients estimated from the data. In discriminant analysis, the equation 2.1 was called Discriminant function or Fisher Discriminant function. If a linear discriminant function is to distinguish, the two groups must differ in their D values.

Therefore, the B's are chosen so that the values of the discriminant function differ as much as possible between the groups, or so that for the discriminant scores are a maximum. The discriminant score is the following ration.

$$\frac{\text{between-groups sum of square}}{\text{within-groups sum of square}} \quad \text{...................... (equation 2.2)}$$

2.5.2.1 The goal of canonical discriminant analysis

- To find the discriminant function which showed the relationship between discriminator variable (D) and independent variable (X's).
- To test the differentiation between two groups (Multivariate) by comparison of group centroid.
- Use the discriminant function in 1 to predicted or classified new case.

2.5.2.2 Step in a canonical discriminant analysis

Typically, five steps are carried out as follows.

- The independent variables which showing tendency to differentiate between group were selected.
- Sampling the representative of population or use the whole population.
- Accumulating data of independent variables, which were chosen in the first step.
- Discriminant function was created from data from step 2 and 3. The values of the discriminant function should be differed as much as possible between the groups, or so that for the discriminant scores are a maximum.

- Predicting or classifying new case using the discriminant function from step 4.

2.5.3 The cluster analysis (CA)

A statistical procedure employed to gather similar objects or cases and place them into groups is called a cluster analysis. The cluster analysis was previously used to classify various organisms in biology. Although both the discriminant analysis and the cluster analysis do the same thing in sorting objects or cases into group. However, the discriminant analysis do requires to know group membership for each case before processing the classification. In contrast, the cluster analysis doesn't need to know group membership of each case beforehand, but it arranges objects or cases by calculating the distance and similarity of objects or cases before classifying them into groups. In fact, selecting the variables to include in an analysis is always crucial. Poor or misleading findings may occur if important variables are excluded. In cluster analysis, the initial choice of variables determines the characteristics that can be used to identify subcategories.

The concepts of distance and similarity are basic to many statistical techniques. A measuring of how far apart of two objects are distance and the similarity is the assessments of closeness. The similarity values are large, but the distance values are small for cases that are similar.

There are many methods for calculating distances between objects and for grouping objects into a cluster. A commonly one is a sequential, agglomerative, hierarchical and nested (SAHN) clustering (Sneath and Sokal 1973). In this method, clusters are formed by grouping cases into bigger and bigger cluster until all cases are members of single cluster.

The outcome of the cluster analysis can be demonstrated with a display called a dendrogram. It is a diagramatic illustration of relationship based on degree of similarity morphology or otherwise (Clifford and Stephenson, 1975). The researcher will assigns a phenon line to divide a cluster on dendrogram. The number of phenon line on a dendrogram depends on a decision of the researcher.

2.5.3.1 The goal of cluster analysis

The goal of cluster analysis is to identify homogenous groups or clusters on concepts of distance and similarity.

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).

CHAPTER 4

MATERIALS AND METHODS

4.1 Specimen collections

Eighteen taxa of *Cassia* s.l. grew in Thailand were used for morphometric analyses. They are both indigenous and introduced species. All specimens were collected form the wild or cultivated plants from known localities in Thailand (Larsen, Larsen and Vidal, 1984) during June 2000 to May 2002. (Figure 4.1). Plant were determined based on key to species in Larsen et al. (1984). Specimens of each taxon were proved for identity by comparison to the voucher specimens deposited at BCU and BKF (Herbarium abbreviations according to Holmgren and Holmgren, 2003). Thirty specimens of each taxon were collected, including leaves, inflorescences and fruits (Figure 4.2). All measurements of macroscopic characters were carried out using electronic digital caliper (Keiba, model Three).

4.2 Details of each taxon

Description and other information, including vernacular name for each taxon was prepared, and based solely on specimens collected in this thesis. Pressed and dried plant specimens were prepared as described in Boonkerd et al. (1987) and deposited at BCU.

4.3 Data analysis

Five hundreds and eight (508) specimens were used for all analyses. In general, thirty-two quantitative characters of both vegetative and reproductive parts (Table 4.1) were subjected to factor, discriminant and cluster analyses. Otherwise will be noted in relevant text.

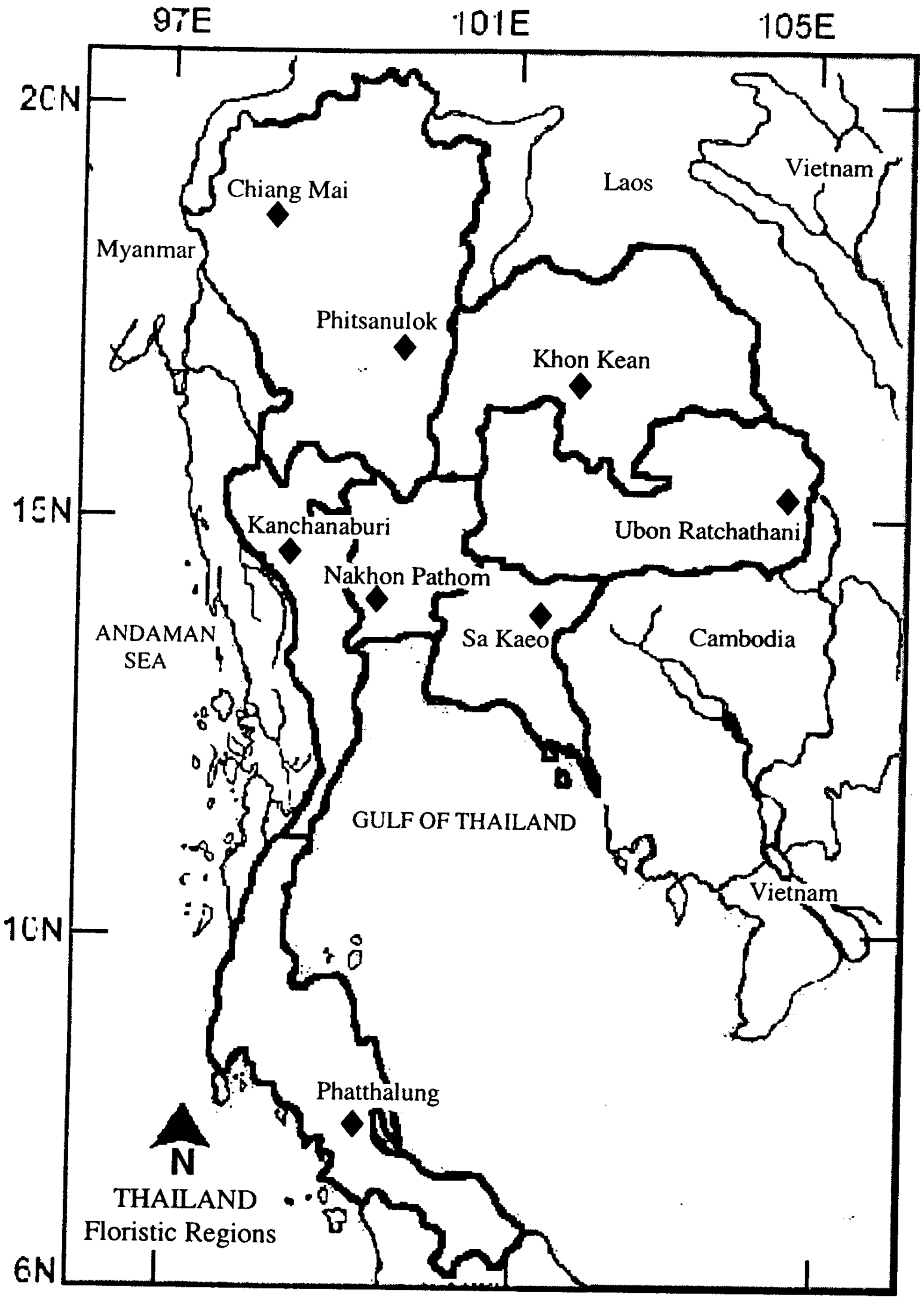


Figure 4.1 Collecting sites of *Cassia* s. l.

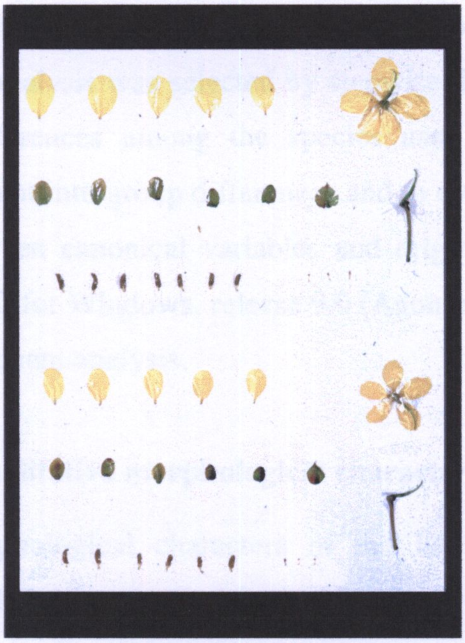


Figure 4.2 Preparation of dried plant specimens for measurements by digital caliper

Factor analysis was applied with no *a priori* grouping of specimens. First, all variables were standardized and the correlation matrix for all variables was computed. Then, in factor extraction, linear combination was calculated by principal component analysis (PCA) in order to find the number of factor. To transform complicated matrices into simpler matrices, factor rotation will be made. Finally, scores for each factor can be computed for each case. Procedure Data Reduction and Factor in SPSS/PC for Windows, release 9.0 (Anonymous, 1998) were used to run PCA.

A sequential, agglomerative, hierarchical and nested (SAHN) clustering (Sneath and Sokal 1973) was performed using average taxonomic distance and the unweighted pair-group method with arithmetic averages (UPGMA) implemented in NTSYS-pc package version 2.10m (Applied Biostatistics Inc., 1986-2000) to place individual specimens into groups. To reduce the effects of different scales of measurement for different characters, the values for each character were standardized using procedure STAND.

A subset of characters that maximized differences among the groups determined by cluster analysis was selected by stepwise discriminant analysis. To characterize mean differences among the species used canonical discriminant analysis to acquire insight into group differences and to estimate character weights from correlations between canonical variables and original variables. Procedure CLASSIFY in SPSS/PC for Windows, release 9.0 (Anonymous, 1998) was used to analyze a set of discriminant analysis.

4.4 Comparision of qualitative morphological characters of the *Cassia* s. l.

Qualitative morphological characters of the 18 taxa are tabulated and discussed with the result from numerical analysis for their importance in clarifying the taxonomic status of the *Cassia* s. l.

CHAPTER 5

RESULTS

5.1 Specimen collection

Eighteen out of twenty three taxa of *Cassia* s.l. were collected throughout the country (Figure 4.1). They are both wild and cultivated plants. The specimen were determined to species based on key to species in Larsen et al., (1984) and arranged within related genus according to Irwin & Barneby (1981) as shown in Table 5.1. In addition a new recorded taxon, *C. obtusifolia* L. was included in this study; it was not included in the flora of Thailand (Larsen et. al., 1984).

5.2 Details of each taxon

The following are the short description, vernacular names and specimens examined for each taxon. Taxa are followed Larsen et al. (1984).

1. *Cassia alata* L., Sp. Pl.: 378. 1753; Craib in Fl. Siam. En. 1: 508. 1928; K & S.S. Larsen and Vidal in Fl. C.L.V. 18: 86. 1980; K & S.S. Larsen and Vidal in Fl. Thailand 4 (1): 108. 1984.

Shrub, hairy. *Leaves* unipinnate; stipules auriculate, persistent, deltoid; pinnae 7-13 pairs, petioles 2-3 cm; pinnae elliptic-oblong, glabrous, apex and base rounded. *Racemes* axillary, densed; bracts caducous. *Flower* zygomorphic; sepals oblong, petals bright yellow, ovate-orbicular to spathulate, short-clawed; stamens 10, filaments thick in the two largest, 4 shorter; 4 reduced in size with minute anthers; ovary and style glabrous. *Pods* winged, thick, glabrous, black in color. (Fig. 5.3)

Vernacular: **Chum het thet (ชุมเห็ดเทศ)**; khi khak (ขี้คาก); mak kaling thet (หมากกะลิงเทศ).

Specimen examined: *S. Pechsri 55, C. Sombongse 7, U. Damsri 47* (BCU); *S.F. Maxwell 94-1220* (BKF)

2. ***Cassia bakeriana* Craib.**, Kew Bull. 1911: 45; Craib in Fl. Siam. En. 1: 508. 1928; K & S.S. Larsen and Vidal in Fl. Thailand 4 (1): 105. 1984.

Tree, densely hairy on all young parts. *Leaves* unipinnate; stipules lanceolate, attached in the middle; pinnae 7-11 pairs, petioles pubescent, rachis pubescent; pinnae oblong-oblanceolate, hairy, apex round with a small sharp point and base rounded. *Racemes* lateral; bracts lanceolate, apex long-pointed, hairy. *Flower* zygomorphic, pedicels pubescent; sepals ovate-lanceolate, pubescent, petals pinkish, ovate-lanceolate, short-clawed; stamens 10, filaments swollen in the middle in the three largest, 4 shorter; 4 reduced; ovary pubescent, style short. *Pods* terete, pubescent. (Fig. 5.1)

Vernacular: **Chaiyaphruk (ชัยพฤกษ์)**; kalapapruk (กัลปพฤกษ์).

Specimen examined: *W. Busapavanija 20, S. Pechsri 53* (BCU); *F. Konta* et. al. *4085* (BKF)

3. ***Cassia fistula* L.** Sp. Pl. : 377. 1753; Craib in Fl. Siam. En. 1: 509. 1928; K & S.S. Larsen and Vidal in Fl. C.L.V. 18: 79. 1980; K & S.S. Larsen and Vidal in Fl. Thailand 4 (1): 103. 1984.

Tree, glabrous. *Leaves* large; unipinnate; stipules small, caducous, deltoid; pinnae 4-6 pairs, petioles glabrous, rachis terete; pinnae ovate-oblong, glabrous, apex acute, base cuneate. *Racemes* axillary, pendent; bracts caducous. *Flower* zygomorphic, pedicel glabrous; sepals ovate-elliptic, petals yellow, ovate, short-clawed; stamens 10, 3 long, 4 shorter; 3 reduced in size with minute anthers; ovary strigulose, style velutinous. *Pods* terete, glabrous, black in color. (Fig. 5.1)

Vernacular: **Ratchapruk (ราชพฤกษ์)**; lom laeng (ลมแล้ง); chaiyapruk (ชัยพฤกษ์); khun (คูณ); lak khoei lak klua (ลักเคยลักเกลือ).

Specimen examined: *S.Poothong 41, Sinchai 653, S. Pechsri 51* (BCU); *Chararnmayu 434* (BKF)

4. ***Cassia garrettiana*** **Craib**, Kew Bull. 1912: 151; Craib in Fl. Siam. En. 2: 510. 1928; K & S.S. Larsen and Vidal in Fl. C.L.V. 18: 91. 1980; K & S.S. Larsen and Vidal in Fl. Thailand 4 (1): 112. 1984.

Tree. *Leaves* unipinnate; stipules caducous; pinnae 4–11 pairs, petioles 2-3 cm; pinnae lanceolate to ovate, glabrous, apex acuminate, base rounded. *Racemes* leafy on terminal; bracts ovate, caducous. *Flower* zygomorphic, pedicels pubescent; sepals elliptic, petals yellow, ovate, short-clawed; stamens 10, filament fattened in the two largest, 5 shorter; 3 reduced in size with minute anthers; ovary and style glabrous. *Pods* flat, glabrous, black in color. (Fig. 5.4)

Vernacular: **Samae san** (แสมสาร); khi lek khan chang (ขี้เหล็กคันชั่ง); khi lek phae (ขี้เหล็กแพะ); khi lek san (ขี้เหล็กสาร).

Specimen examined: *O. Thaithong 249, B. Na Songkhla 260, S. Pechsri 59* (BCU); FTP. 31411, Luang Vanpruk 53 (BKF)

5. ***Cassia grandis*** **L. f.**, Suppl.: 230. 1781; K & S.S. Larsen and Vidal in Fl. C.L.V. 18: 80. 1980; K & S.S. Larsen and Vidal in Fl. Thailand 4 (1): 105. 1984.

Deciduous tree, trunk with buttress. *Leaves* unipinnate; stipules minute; pinnae 10-20 pairs, petioles woolly; pinnae elliptic-oblong, subcoriaceous, glabrous, apex and base rounded. *Racemes* lateral; bracts caducous. *Flower* zygomorphic; sepals obovate-rounded, pubescent, reflexed, petals first red, later pink, finally orange, obovate, short-clawed; stamens 10, filaments recurved in the three largest, 5 shorter; 2 reduced in size with minute anthers; ovary silky tomentose, style short. *Pods* cylindric, woody, rugose, glabrous, black in color. (Fig. 5.1)

Vernacular: **Kalapruk (กาพพฤกษ์).**

Specimen examined: *S. Pechsri 52* (BCU); *T. Santisuk 1627, Th. S. et. al. 21* (BKF)

6. ***Cassia hirsuta*** **L.**, Sp. Pl.: 378 1753; K & S.S. Larsen and Vidal in Fl. C.L.V. 18: 92. 1980; K & S.S. Larsen and Vidal in Fl. Thailand 4 (1): 113. 1984.

Herb or undershrub, hirsute. *Leaves* unipinnate; stipules caducous, hairy; pinnae 3–5 pairs, the upper pairs largest, petioles long villous, sessile; pinnae lanceolate, hirsute, apex acute, base rounded. *Racemes* short, axillary; bracts hirsute. *Flower* zygomorphic, pedicels pubescent; sepals pubescent, petals yellow obovate, glabrous, short-clawed; stamens 10, filaments flat in the two largest, 4 shorter; 4 reduced in size with minute anthers; ovary greyish wooly, style glabrous. *Pods* falcate, hirsute. (Fig. 5.3)

Vernacular: **Rang jued ton (รางจืดต้น)**; phong pheng (โผงเผง); dap phit (ดับพิษ).

Specimen examined: *S. Pechsri 60 (BCU); FRDU & P.C. van Welzen 77, Prayun 3* (BKF)

7. ***Cassia javanica*** **L.** var. *javanica* , Sp. Pl.: 379. 1753, Craib in Fl. Siam. En. 1: 508, 509, 511. 1928; K & S.S. Larsen and Vidal in Fl. C.L.V. 18: 84. 1980; K & S.S. Larsen and Vidal in Fl. Thailand 4 (1): 107. 1984.

Deciduous tree. *Leaves* unipinnate; *Stipules* elliptic, falcate to pointed, attached in the middle; pinnae 7-16 pairs, petioles glabrous; pinnae elliptic-ovate to oblong, hairy, apex and base rounded. *Racemes* lateral, densed; bracts ovate-acute. *Flower* zygomorphic; sepals ovate-acute, dark red to reddish brown, petals first pink later dark red, finally pale, ovate, long-clawed; stamens 10, filaments recurved with a spherical enlargement near the middle in the three largest, 4 shorter; 3 reduced in size with minute anthers; ovary pubescent, style short. *Pods* terete, glabrous, black in color. (Fig. 5.1)

Vernacular: **Kalapapruk (กัลปพฤกษ์)**; chaiyaphruk (ชัยพฤกษ์); kalapruk (กาลพฤกษ์); khi lek yawa (ขี้เหล็กชวา).

Specimen examined: *Herb. Trip 893, S. Poothong 4, S. Pechsri 54* (BCU); *K. Larsen et. al. 30873, 33596* (BKF)

8. ***Cassia leschenaultiana*** **DC.**, Mem. Soc. Phys. Geneve 2: 132. 1824; Craib in Fl. Siam. En. 1: 511. 1928; K & S.S. Larsen and Vidal in Fl. C.L.V. 18: 106. 1980; K & S.S. Larsen and Vidal in Fl. Thailand 4 (1): 123. 1984.

Small shrub, densely greyish to yellowish pubescent. *Leaves* unipinnate; stipules linear, persistent; pinnae 35-47 pairs, petioles with discoid gland below the lowest pair of leaflets; pinnae falciform, side unequal, glabrous, apex and base rounded; rachis pubescent, canaculate. *Racemes* few, axillary; bracts caducous. *Flower* zygomorphic, pedicels pubescent; sepals oblong, yellow, shortly; stamens 9-10, filaments very short; ovary hairy, style recurved. *Pods* flat, dehiscent. (Fig. 5.5)

Vernacular: **Sa kham khom (ช่าขามคอม)**

Specimen examined: *S.Pechsri 50, 68* (BCU); *Deer 331, T. Smitinand 4966* (BKF)

9. ***Cassia obtusifolia*** **L.** Sp. Pl.: 378 1753.

Herb or undershrub, thinly pubescent. *Leaves* unipinnate; stipules caducous; pinnae 3 pairs, petioles 1-4 cm; rachis with 2 subulate gland between the lowermost pair of leaflets; pinnae obovate, glabrous, apex rounded, base acuminate. *Racemes* axillary; bracts linear. *Flower* zygomorphic; sepals ovate, petals orange-yellow, obovate, short-clawed; stamens 7, 3 longer, 4 shorter; 4 staminode; ovary pubescent; style glabrous. *Pods* linear, terete, falcate, glabrous. (Fig. 5.2)

Vernacular: **Chumhet thai (ชุมเห็ดไทย)**

Specimen examined: *S. Pechsri 77* (BCU)

10. ***Cassia occidentalis*** **L.** Sp. Pl.: 378 1753; Craib in Fl. Siam. En. 2: 512. 1928; K & S.S. Larsen and Vidal in Fl. C.L.V. 18: 93. 1980; K & S.S. Larsen and Vidal in Fl. Thailand 4 (1): 113. 1984.

Undershrub, glabrous. *Leaves* unipinnate; linear to acute; pinnae 4-5 pairs, petioles with large gland above the petiole joint; pinnae unequal-side, ovate to oblong; apex acuminate, base rounded. *Racemes* axillary, densed; bracts linear-acute, caducous. *Flower* zygomorphic; sepals ovate, petals yellow with violet veins, ovate, short-clawed; stamens 10, 2 longer, 4 shorter; 4 reduced with minute anthers; ovary tomentose, style glabrous. *Pods* flat, glabrous, brown in color. (Fig. 5.3)

Vernacular: **Phak hket (ผักเค็ด)**; chumhet lek (ชุมเห็ดเล็ก); khi lek phuak (ขี้เหล็กเผือก); phak het (ผักเห็ด); khang khet (คางเค็ด).

Specimen examined: *A. Chutinthorn 20, T. jonganurak 152, S. Pechsri 61* (BCU); *K. Bunchuai 120, D. Bunpheng 1* (BKF)

11. ***Cassia pumila*** **Lamk.** Enc. 1: 651. 1785; Craib in Fl. Siam. En. 1: 513. 1928; K & S.S. Larsen and Vidal in Fl. C.L.V. 18: 104. 1980; K & S.S. Larsen and Vidal in Fl. Thailand 4 (1): 120. 1984.

Small shrub, pubescent. *Leaves* unipinnate; stipules linear acute, persistent, rachis grooved in side; pinnae 13-17 pairs, petioles pubescent with a long stipitate gland below the lowest pair of leaflets; pinnae narrow elliptic, sessile, hairy along the midrib, upper glabrous, lower pubescent, apex and base rounded. *Racemes* axillary; bracts as the stipule but shorter. *Flower* zygomorphic, pedicels pubescent; sepals lanceolate, petals bright yellow, oblong-obovate, short-clawed; stamens 5-6; ovary tomentose, style glabrous. *Pods* flat, dehiscent, brown in color. (Fig. 5.5)

Vernacular: **Makham din (มะขามดิน)**; makham bia (มะขามเบี้ย).

Specimen examined: *S. Pechsri 67* (BCU); *G Murata et. al. 3863, J.F. Maxwell 86-1020* (BKF)

12. ***Cassia siamea*** **Lamk.**, Enc. 1: 648. 1785; Craib in Fl. Siam. En. 1: 513. 1928; K & S.S. Larsen and Vidal in Fl. C.L.V. 18: 887. 1980; K & S.S. Larsen and Vidal in Fl. Thailand 4 (1): 110. 1984.

Tree, pubescent on young branches. *Leaves* unipinnate; stipules minute, caducous; pinnae 7-11 pairs, petioles 2-3 cm; pinnae ovate-oblong, glabrous, apex and base rounded. *Racemes* terminal, large; bracts obovate with long acute apex. *Flower* zygomorphic, pedicels valentinous; sepals thick, oblong, petals yellow, broadly ovate, short-clawed; stamens 10, filaments straight in the two largest, 4-5 shorter; 3 reduced in size with minute anthers; ovary pubescent, style glabrous. *Pods* flat, glabrescent, longitudinally waved with raised sutures. (Fig. 5.4)

Vernacular: **Khi lek ban (ขี้เหล็กบ้าน)**; khi lek luang (ขี้เหล็กหลวง); khi lek (ขี้เหล็ก); khi lek yai (ขี้เหล็กใหญ่).

Specimen examined: *C. Siwasilp 9, K. Sridith 183, S. Pechsri 57* (BCU); *J.F. Maxwell 86-495, C Phegklai et. al. 3751* (BKF)

13. ***Cassia sophera*** **L.**, Sp. Pl.: 379. 1753; Craib in Fl. Siam. En. 1: 513. 1928; K & S.S. Larsen and Vidal in Fl. C.L.V. 18: 94. 1980; K & S.S. Larsen and Vidal in Fl. Thailand 4 (1): 115. 1984.

Shrub, glabrous. *Leaves* unipinnate; stipules ovate, caducous; pinnae 7-13 pairs, petioles with gland above the petiole joint; pinnae lanceolate, the upper largest, glabrous, apex acute, base rounded. *Racemes* axillary; bracts ovate, caducous. Flower zygomorphic; sepals ovate-rounded, petals yellow, obovate, short-clawed; stamens 10, 2 longer, 4 shorter; 4 reduced in size with minute anthers; ovary pubescent, style glabrous. *Pods* cylindric, glabrous, brown in color. (Fig. 5.3)

Vernacular: **Phak hket** (ผักเค็ด); phak wan ban (ผักหวานบ้าน); khi lek wan (ขี้เหล็กหวาน).

Specimen examined: *BNS 630, S. Pechsri 78, S.P. 62* (BCU); *S. Unjai 98, H.M. Burkill 1276* (BKF)

14. ***Cassia spectabilis*** **DC.**, Cat. Hort. Monsp.: 90. 1813; K & S.S. Larsen and Vidal in Fl. Thailand 4 (1): 110. 1984.

Tree, hairy on young parts. *Leaves* unipinnate; stipules linear, falcate, caducous; pinnae 9-15 pairs, petioles 2-3 cm; pinnae lanceolate, glabrous, apex acute, mucronate, base rounded. *Racemes* large, leafy on terminal; bracts ovate, caducous. *Flower* zygomorphic, pedicels valentinous; sepals unequal, oblong, petals yellow, ovate to spathulate, the lower one larger broad falcate, short-clawed; stamens 10, 7 large, 4 shorter; 3 reduced in size with reniform minute anthers; ovary and style glabrous. *Pods* terete, glossy, glabrous, black in color. (Fig. 5.4)

Vernacular: **Sawanapruk** (สุวรรณพฤกษ์); Khi lek American (ขี้เหล็กอเมริกัน).

Specimen examined: *S. Pechsri 56* (BCU); *H. & G.C. 148, N. Fukuoka* 62004 (BKF)

15. ***Cassia surattensis*** **Burm f. subsp.** ***glauca*** **(Lamk.) K. & S.S. Larsen**, Fl. C.L.V. 18: 102. - *C. glauca* Lamk. Craib in Fl. Siam. En. 1: 510. 1928; K & S.S. Larsen and Vidal in Fl. C.L.V. 18: 102. 1980; K & S.S. Larsen and Vidal in Fl. Thailand 4 (1): 120. 1984.

Deviate from var. *surattensis* by having 4-6 pairs of leaflets larger. Also inflorescence, floral parts and pods are larger. (Fig. 5.2)

Vernacular: **Trueng badan** (ตรึงบาดาล); phrueng badan (พรึงบาดาล); song badan (ทรงบาดาล).

Specimen examined: *Sinchai 663, S. Pechsri 66* (BCU); *J.F. Maxwell 88-1181, De 230* (BKF)

16. *Cassia surattensis* Burm f. subsp. *surattensis* K. & S.S. Larsen, Fl. Ind.: 97. 1768; Craib in Fl. Siam. En. 1: 511. 1928; K & S.S. Larsen and Vidal in Fl. C.L.V. 18: 100. 1980; K & S.S. Larsen and Vidal in Fl. Thailand 4 (1): 119. 1984.

Shrub, puberulous. *Leaves* unipinnate; linear-falcate, subpersistent; pinnae 7-9 pairs, petioles 1.5-3 cm; rachis with gland between the 2-3 lower pairs of leaflets, pinnae ovate-oblong, glabrous, apex and base rounded. *Racemes* axillary, densed; bracts ovate-acute. Flower zygomorphic; sepals ovate, petals yellow, obovate, short narrow clawed; stamens 10, filaments thick; ovary puberulous, filiform, recurved, style glabrous. *Pods* flat, glabrous, dehiscent. (Fig. 5.2)

Vernacular: **Song badan (ทรงบาดาล)**; khi lek ban (ขี้เหล็กบ้าน); khi lek wan (ขี้เหล็กหวาน).

Specimen examined: *C. Thanakorn 5, S. Pechsri 66, S.P. 74* (BCU); *P. Suvarnkoses, P. Hampanond* (BKF)

17. *Cassia timorensis* DC. , Prod. 2: 499. 1825; Craib in Fl. Siam. En. 1: 514. 1928; K & S.S. Larsen and Vidal in Fl. C.L.V. 18: 88. 1980; K & S.S. Larsen and Vidal in Fl. Thailand 4 (1): 111. 1984.

Tree with golden hairy throughout. *Leaves* unipinnate; stipules large, auriculate; pinnae 16-22 pairs, petioles 2-3 cm; rachis pubescent ; pinnae oblong; apex subacute to mucronate, base rounded; golden pubescent. *Racemes* axillary; pedicels pubescent; bracts ovate, caducous. Flower zygomorphic; sepals oblong-ovate with rounded apex, yellowish pubescent, petals yellow, ovate, short-clawed; stamens 10, 2 largest, 5 shorter; 3 reduced in size with minute anthers; ovary and style glabrous. *Pods* flat, glabrous, dehiscent, brown in color. (Fig. 5.4)

Vernacular: **Khi lek luat (ขี้เหล็กเลือด)**; khi lek dang (ขี้เหล็กแดง); khi lek khan chang (ขี้เหล็กคันชั่ง); khi lek pa (ขี้เหล็กป่า); khi lek dong (ขี้เหล็กดง); khi lek nang chi (ขี้เหล็กนางชี).

Specimen examined: *Herb. Trip 638, BNS 520, S. Pechsri 79* (BCU); *P.B. 65, T. Smitinand 8651* (BKF)

18. ***Cassia tora*** **L.**, Sp. Pl.: 376. 1753; Craib in Fl. Siam. En. 1: 514. 1928; K & S.S. Larsen and Vidal in Fl. C.L.V. 18: 96. 1980; K & S.S. Larsen and Vidal in Fl. Thailand 4 (1): 117. 1984.

Undershrub, hairy. *Leaves* unipinnate; stipules setaceous, caducous; pinnae 3 pairs, petioles 1-4 cm; rachis with gland between the 2 lower pairs of leaflets, pinnae obovate; apex rounded, base cuneate. *Racemes* axillary, densed; bracts linear-acute. Flower zygomorphic; sepals ovate, petals yellow obovate, short-clawed; stamens 7, 2 largest, 5 shorter; 3 staminode; ovary pubescent, style glabrous. *Pods* terete. (Fig. 5.2)

Vernacular: **Chumhet thai (ชุมเห็ดไทย)**; Chumhet na (ชุมเห็ดนา); Chumhet lek (ชุมเห็ดเล็ก); Chumhet khwai (ชุมเห็ดควาย).

Specimen examined: *O. Thaithong 201, V. Srisuvanatach 4, S. Pechsri 77* (BCU); *C. Phengklai et. al. 3320, K. Larsen et. al. 34189* (BKF)

Figure 5.1 Habit (a) and flower (b) of *Cassia* s. s., 1-*C. bakeriana* Craib; 2-*C. javanica* L.; 3-*C. fistula* L.; 4-*C. grandis* L.f. (Photo: coustesy of C. Khunwasi-1a, 2a, 3a)

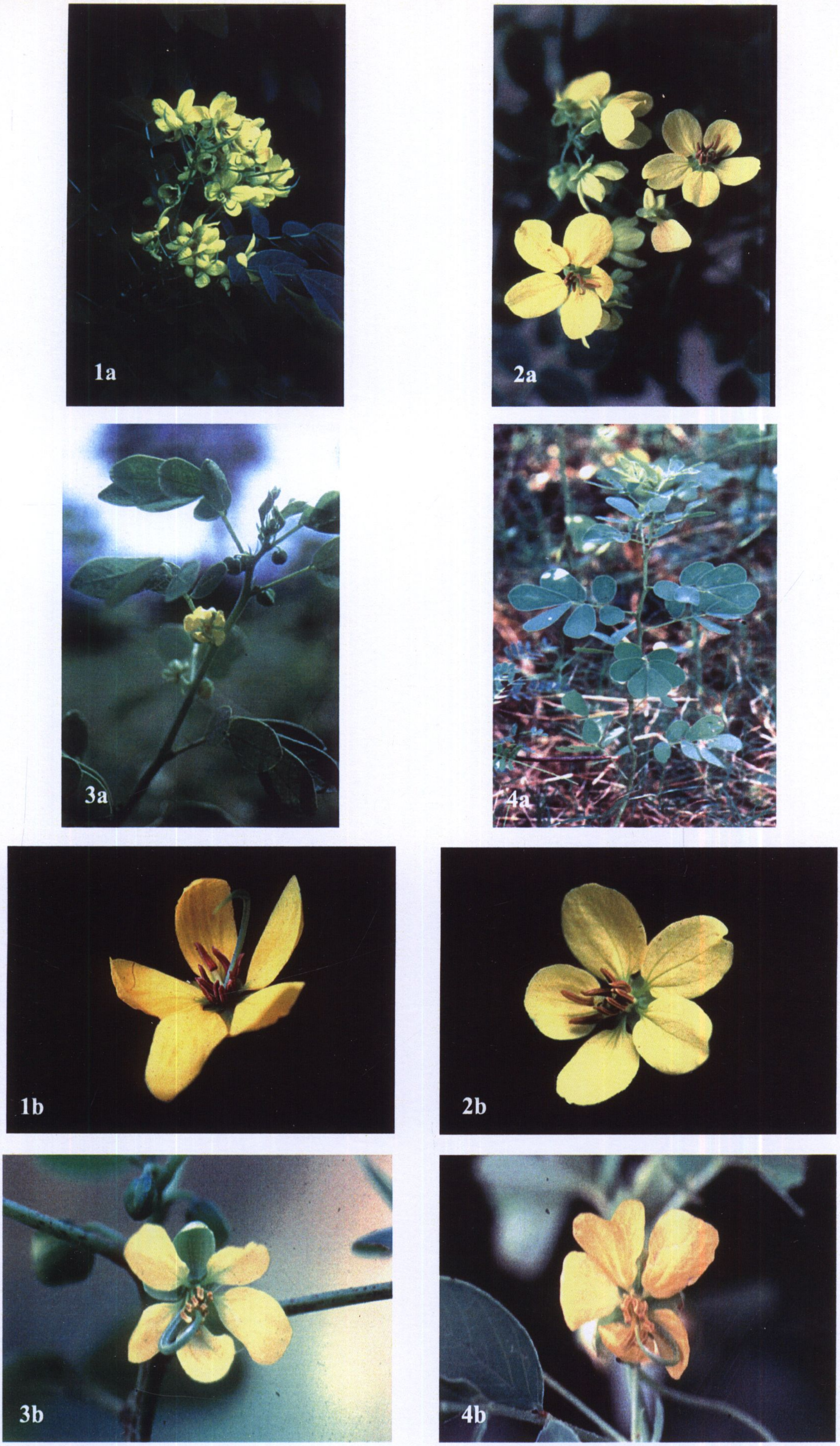


Figure 5.2 Habit (a) and flower (b) of *Cassia* (*Senna*), 1-*C. surattensis* Brum.f. subsp. *glauca* (Lamk.) K. & S.S. Larsen; 2-*C. suratttensis* Brum.f. subsp. *suratttensis*; 3-*S. tora* (L.) Roxb.; 4-*C. obtusifolia* L. (Photo: courtesy of M. kidyue)

Figure 5.3 Habit (a) and flower (b) of *Cassia* (*Senna*) 1-*C. alata* L.; 2-*C. sophera* L.; 3-*C. occidentalis* L.; 4-*C. hirsuta* L. (Photo: courtesy of M. kidyue-1b, 2b, 3b, 4b, C. Khunwasi-1a)

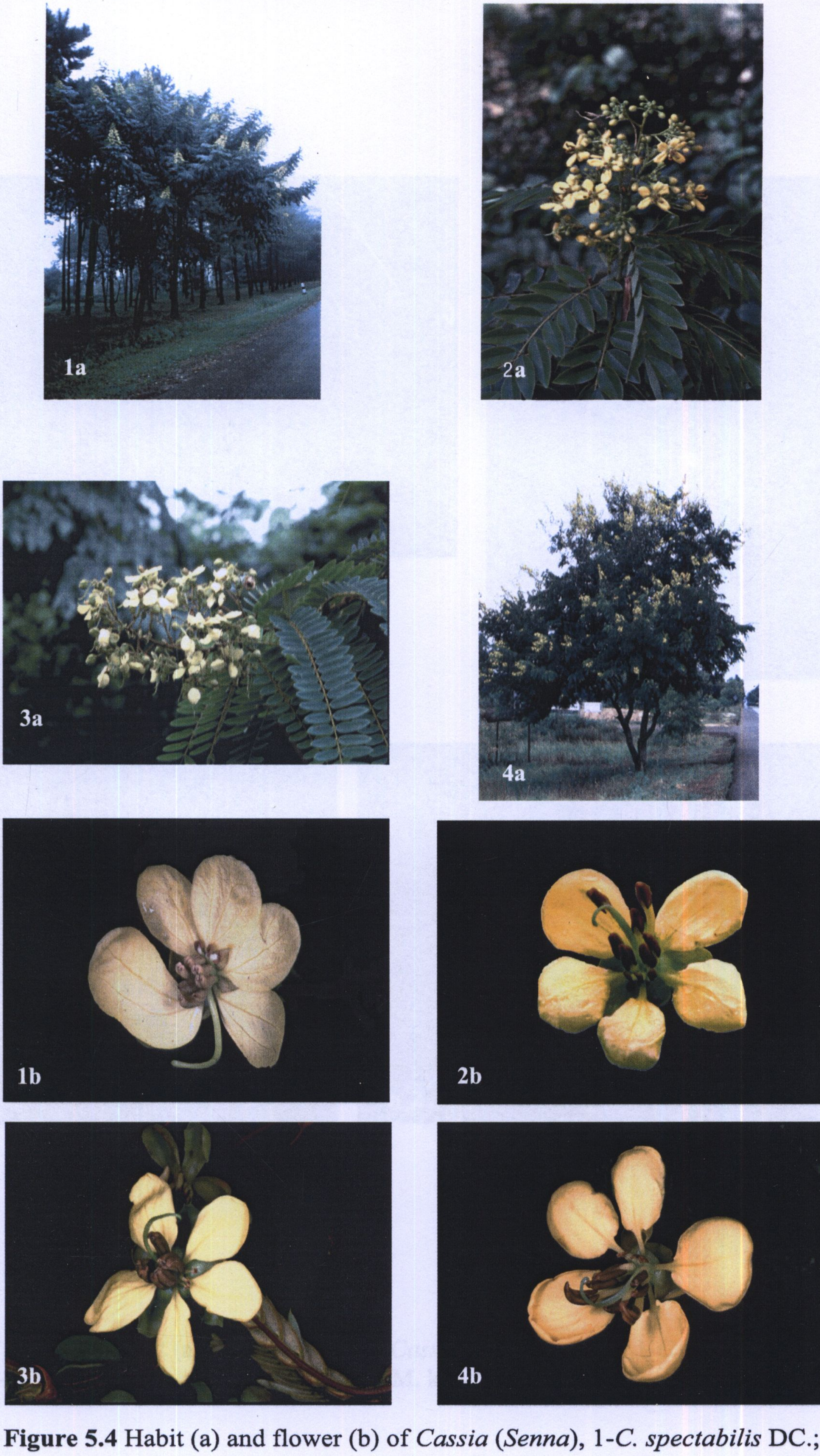


Figure 5.4 Habit (a) and flower (b) of *Cassia* (*Senna*), 1-*C. spectabilis* DC.; 2-*C. garettiana* Craib; 3-*C. timoriensis* DC.; 4-*C. siamea* Lamk. (Photo: courtesy of C. Khunwasi-3a, 4a)

Figure 5.5 Habit (a) and flower (b) of *Cassia* (*Chamaecrista*) 1-*C. leschenaultiana* DC.; 2-*C. pumila* Lamk. (Photo: courtesy of M. kidyue-1b)

5.3 Data analysis

5.3.1 Factor analysis

A principle components analysis (PCA) was applied to the 32 characters of 18 taxa of the *Cassia* s.l. with no *a priori* grouping. It was found that the total variance in the data described by these component was 85.6% (Table 5.2). Table 5.5 shows seven factor components. All characters have communality more than 0.5 (Table5.5). The next step was to identify these seven categories. The first component consisted of 9 characters, i.e. RCD, TLL, TWL, LMW, DBLP, BTWP, POLL, PET, and NOL. The second component also composed of 9 characters, viz. PCL, FLD, PTL, FTL, OVL, FML, OSL, PTW, and STD. The following characters:- BTW, BTL, PED, RCL, AND, and ANL confined to the third component. While the fourth component consisted of 3 characters, i.e. SPW, PSL, and SPL. The fifth component composed of FTD, FMD, and OVD. Whilst the members of the sixth component were LS and LWR. The last component composted by only one character, namely STL. It was found that the 1st and 6th components were represented vegetative characters (size) while the 2nd, 4th, 5th and 7th components were represented reproductive characters (size). Whilst the third component were the remainder of vegetative and reproductive characters (size). Factor loading of all characters in each component before rotation and after rotation is showed in Table 5.3 and 5.4.

5.3.2 Cluster analysis

The result of cluster analysis is showed in Figure 5.6. It can be seen that the dendrogram separated the 508 specimens into 4 groups at the 1.30 of average taxonomic distance. The first group is consisted of 2 species, i.e. *Cassia* (*Chamaecrista*) *pumila* and *Cassia* (*Chamaecrista*) *leschanaultiana*. The second group is solely *Cassia* (*Senna*) *alata*. While the third group is composed of 10 species of *Cassia* (*Senna*) which excluded *Cassia* (*Senna*) *alata* and *Cassia* (*Senna*) *spectabilis*. The last group is comprised of 5 species:- *Cassia fistula*, *C. javanica* var. *javanica*, *C. grandis*, *C. bakeriana* and *Cassia* (*Senna*) *spectabilis*.

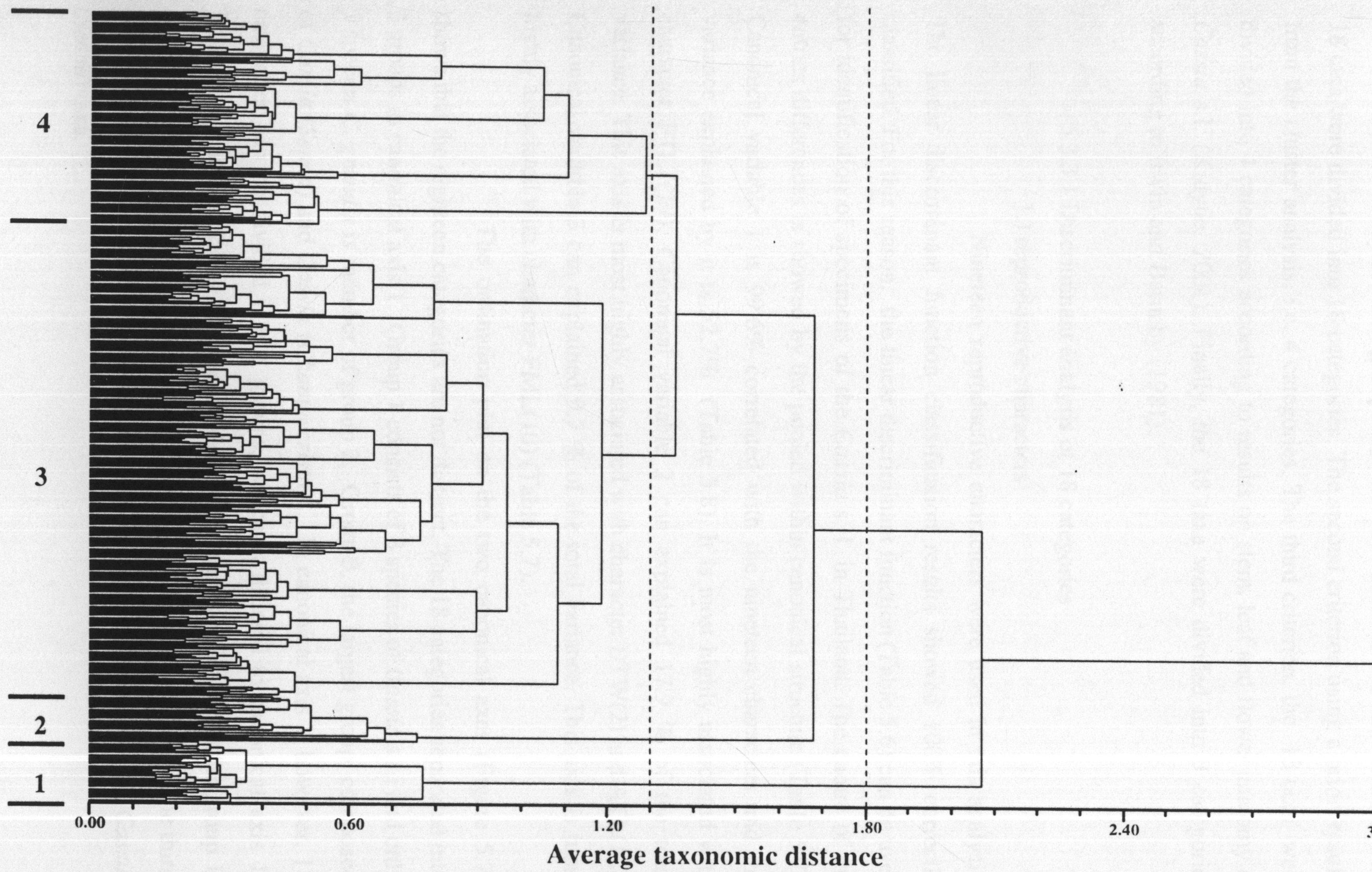


Figure 5.6 UPGMA clustering of 508 OTUs based on 32 Characters of *Cassia* s.l. in Thailand (1- *Cassia (Chamaecrista)*, 2- *C.(Senna) alata*, 3- *Cassia (Senna)*, 4- *Cassia* s.s. and *C.(Senna) spectabilis*,)

5.3.3 Canonical discriminant analysis

In this analysis, four groups criteria were used. In the first criterion, the 18 taxa were divided into 18 categories. The second criterion using a priori results from the cluster analysis, i.e. 4 categories. The third criterion, the 18 taxa were divided into 4 categories according to results on stem, leaf and flower anatomy of *Cassia* s.l. (Kidyue, 2001). Finally, the 18 taxa were divided into 3 categories according to Irwin and Barneby (1981).

5.3.3.1 Discriminant analysis of 18 categories

1.) reproductive characters

Nineteen reproductive characters were used in this analysis. The linear discriminant function classification results showed 100% correctly classified. For this reason, the linear discriminant function (Table 5.6) can be used for identification of specimens of the *Cassia* s. l. in Thailand. The nature of the entries differences is showed by the pooled within canonical structure (Table 5.7). Canonical variable 1 is 99.6% correlated with the nineteen characters and the variance explained by it is 52.7% (Table 5.8). It is most highly associated with character FTL (19). Canonical variable 2 can explained 17.9 % of the total variance. This axis is most highly associated with character BTW(2) and ATL(12). Canonical variable 3 can explained 9.7 % of the total variance. This axis is most highly associated with character FML(10) (Table 5.7).

The ordination plot on the two canonical axes (Figure 5.7) shows that the eighteen categories are not distinct. The 18 categories separated into 3 groups in canonical axis 1. Group 1 consists of 3 species of *Cassia* s.s.; and only 1 species *C. grandis* is member of group 2. Group 3, the largest group, composed of *Cassia* (*Senna*) and *Cassia* (*Chamaecrista*). In canonical axis 2, however, 18 categories can be divided into 3 groups, which is differed to canonical axis 1. This axis separated *Cassia* (*Chamaecrista*) *pumila* to a single species for group 1. Similarly, group 2 composed of only one species, *Cassia* (*Senna*) *alata*. The third group composed of 4 *Cassia* taxa, 1 *Cassia* (*Chamaecrista*) taxon and 11 *Cassia* (*Senna*) taxa.

2.) Vegetative characters

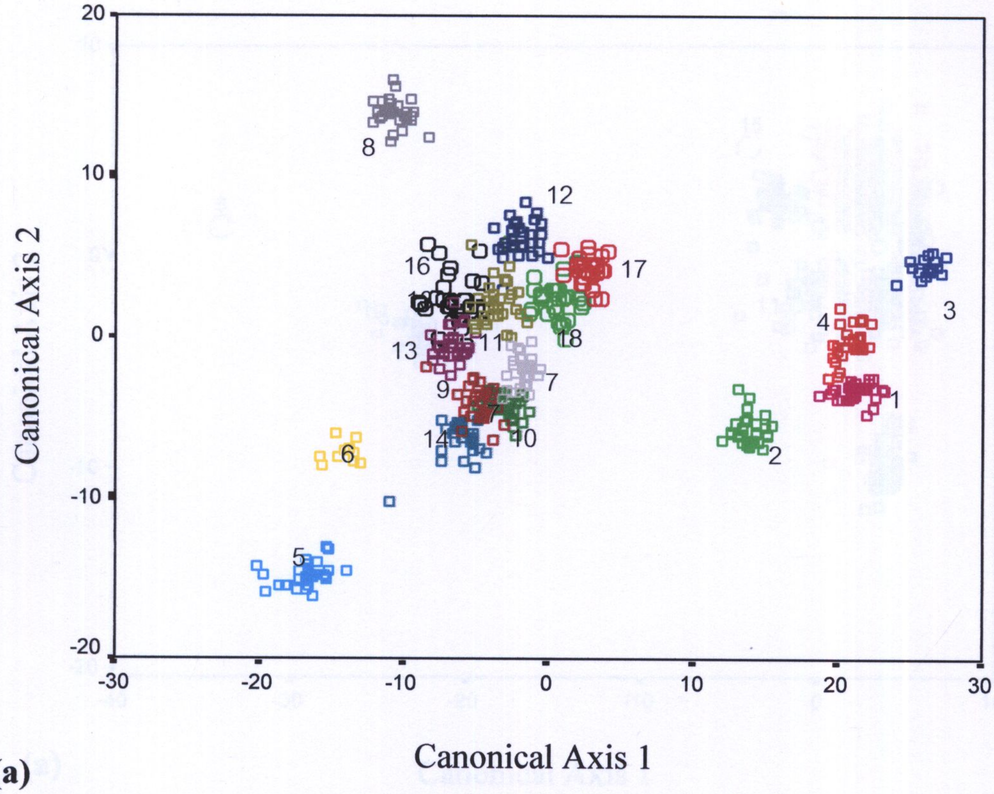
Thirteen vegetative characters were used in this analysis. The linear discriminant function classification results showed 96.3% correctly classified. For this reason, the linear discriminant function (Table 5.9) can be used for identification of specimens of the *Cassia* s. l. in Thailand. The nature of the entries differences is showed by the pooled within canonical structure (Table 5.10). Canonical variable 1 is 99.2% correlated with the thirteen characters and the variance explained by it is 57.4% .(Table 5.11). It is most highly associated with character TLW (8). Canonical variable 2 can explained 18.4 % of the total variance. This axis is most highly associated with character RCL(3) and NOL(6). Canonical variable 3 can explained 10.2 % of the total variance. This axis is most highly associated with character DBLP(5) (Table 5.10).

The ordination plot on the two canonical axes (Figure 5.8) shows that the eighteen categories are not distinct. The 18 categories separated into 2 groups in canonical axis 1. Group 1, the largest group, composed of 4 species of *Cassia* s.s. and 12 *Cassia* (*Senna*) taxa. Group 2 consists of 2 species of *Cassia* (*Chamaecrista*). In canonical axis 2, however, 18 categories can be divided into 2 groups which is differed to canonical axis 1. This axis separated *Cassia* (*Senna*) *gluaca* and *C.* (*Senna*) *surattensis* for group 1. Similarly, group 2 composed of 4 *Cassia* taxa, 2 *Cassia* (*Chamaecrista*) taxon and 10 *Cassia* (*Senna*) taxa.

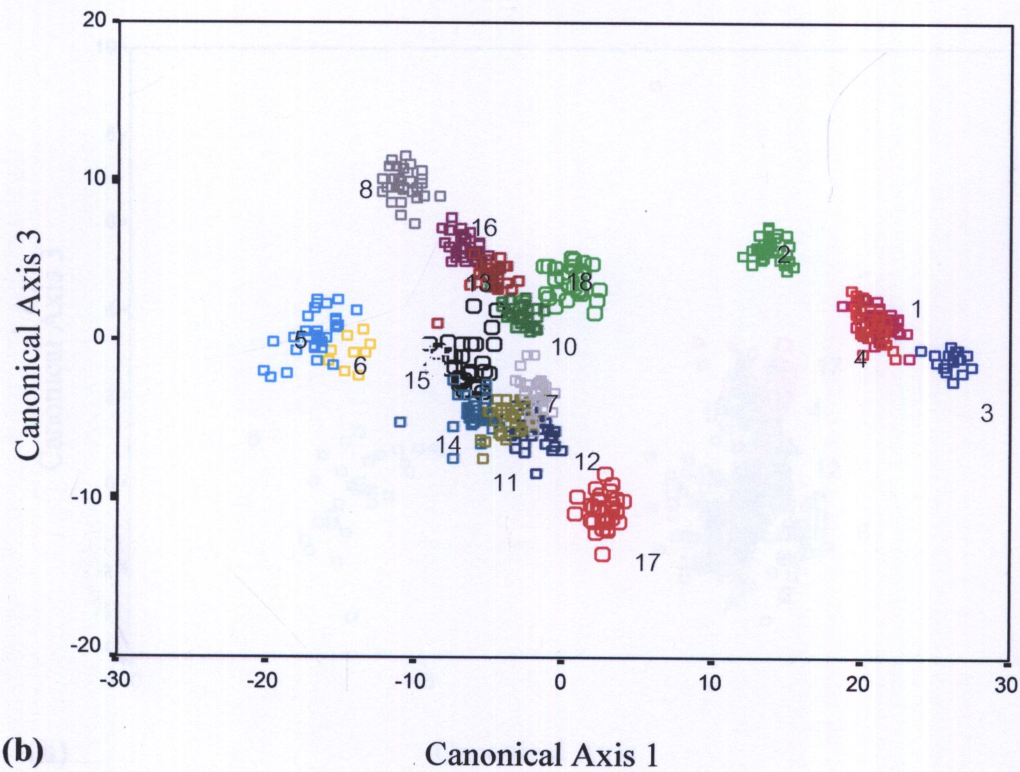
3.) Vegetative and reproductive characters

Thirty-two characters were used in this analysis. The linear discriminant function classification results showed 100% correctly classified. For this reason, the linear discriminant function (Table 5.12) can be used for identification of specimens of the *Cassia* s. l. in Thailand. The nature of the entries differences is showed by the pooled within canonical structure (Table 5.13). Canonical variable 1 is 99.7% correlated with the thirty-two characters and the variance explained by it is 42.1% (Table 5.14). It is most highly associated with character FML (23). Canonical variable 2 can explained 19.0% of the total variance. This axis is most highly associated with TLW (8), ATL (25), POLL (13) and PED (2). Canonical variable 3 can explained 11.8% of the total variance. This axis is most highly associated with character NOL (6), BTW (16) and RCL (3). The two variables LMW (12) and RCD (4) not used in the analysis (Table 5.13).

The ordination plot on the two canonical axes (Figure 5.7) shows that the eighteen categories are distinct. The 18 categories separated into 3 groups in canonical axis 1. Group 1 consists of 2 species of *Cassia* (*Chamaecrista).* Group 2, the largest group, composed of 12 species of *Cassia* (*Senna*). Group 3 composed of 4 *Cassia* s.s. taxa. In canonical axis 2, however, 18 categories can be divided into 3 groups, which is similar to canonical axis 1. This axis separated *Cassia* (*Chamaecrista*) *pumila* and *Cassia* (*Chamaecrista*) *leschenaultiana* to group 1. Similarly, group 2 composed of 12 species, *Cassia* (*Senna*) *alata.* The third group composed of 4 *Cassia* s.s. taxa namely *C. javanica*, *C. fistula*, *C. bakeriana* and *C. grandis.*



(a)



(b)

Figure 5.7 The ordination plot of 18 taxa (reproductive character) using 18 categories as priori groups, (a) - the ordination plot on the canonical axes 1 and 2, (b) - the ordination plot on the canonical axes 1 and 3 (1-4 *Cassia* s.s, 5-6 *Cassia* (*Chamaecrista*). 7-18 *Cassia* (*Senna*))

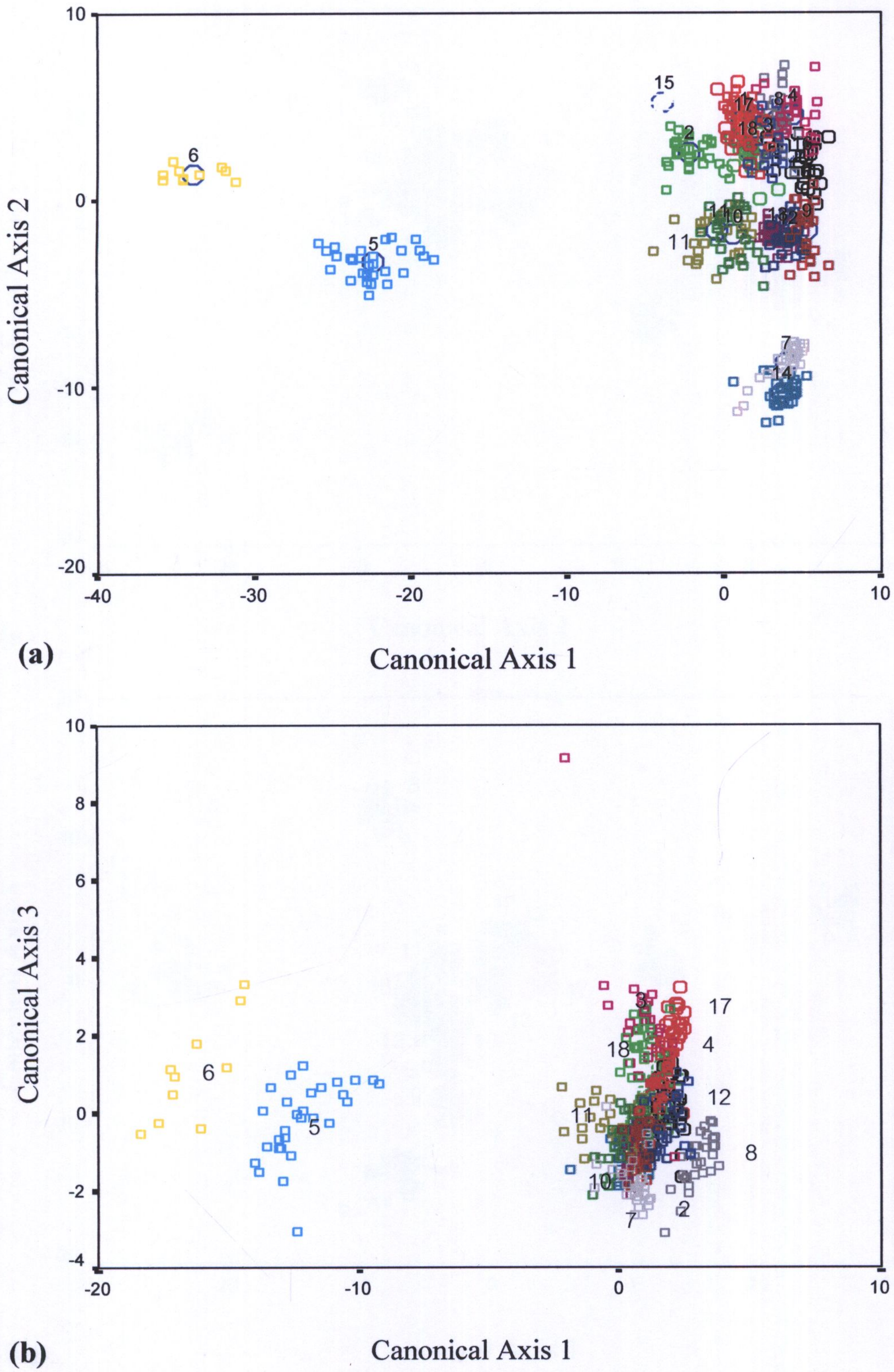
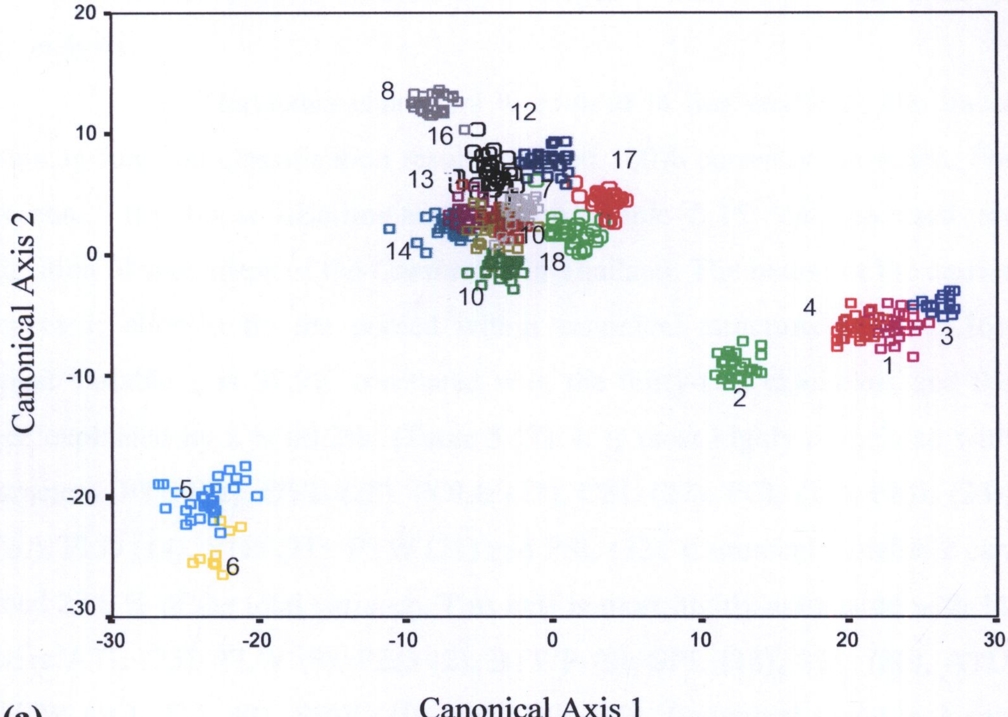
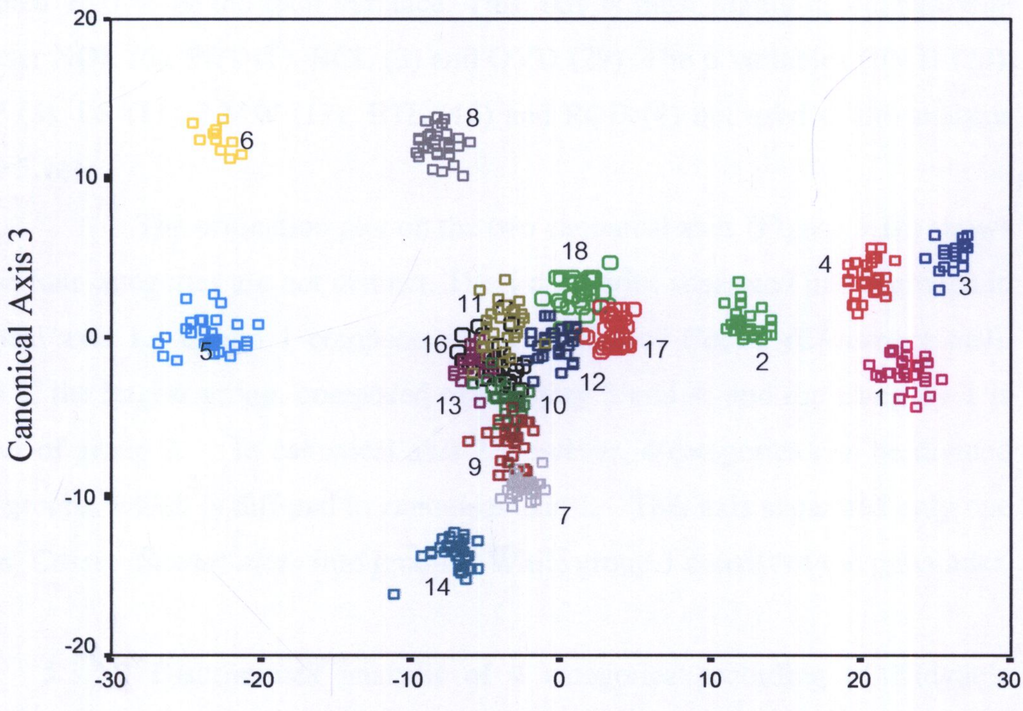


Figure 5.8 The ordination plot of 18 taxa (vegetative character) using 18 categories as priori groups, (a) - the ordination plot on the canonical axes 1 and 2, (b) - the ordination plot on the canonical axes 1 and 3 (1-4 *Cassia* s.s, 5-6 *Cassia* (*Chamaecrista*). 7-18 *Cassia* (*Senna*))



(a)



(b)

Figure 5.9 The ordination plot of 18 taxa (reproductive and vegetative character) using 18 categories as priori groups, (a) - the ordination plot on the canonical axes 1 and 2, (b) - the ordination plot on the canonical axes 1 and 33 (1-4 *Cassia* s.s, 5-6 *Cassia* (*Chamaecrista*). 7-18 *Cassia* (*Senna*))

5.3.3.2 Discriminant analysis of 4 categories according to the result of cluster analysis

Thirty-two characters were used in this analysis. The linear discriminant function classification results showed 100% correctly classified. For this reason, the linear discriminant function (Table 5.15) can be used for identification of specimens of the *Cassia* s. l. in Thailand. The nature of the entries differences is showed by the pooled within canonical structure (Table 5.16). Canonical variable 1 is 98.9% correlated with the thirty-two characters and the variance explained by it is 60.2% (Table 5.17). It is most highly associated with 12 characters FTL (32), OVL (28), POLL (13), OSL (27), PCL (17), FML (23), PTL (20), FLD (14), STD (31), PTW (21) and PSL (22). Canonical variable 2 can explained 23.8 % of the total variance. This axis is most highly associated with 11 characters ATL (25), TLW (8), PED (2), BTWP (9), SPL (18), STL (30), ATD (26), BTW (16), TLL (7), SPW (19) and LWR (10). Canonical variable 3 can explained 16.0 % of the total variance. This axis is most highly associated with character NOL (6), PET (1), RCL (3) and OVD (29). The 6 variables (FMD (24), DBLP (5), LS (11), LMW (12), BTL (15) and RCD (4) not used in the analysis (Table 5.16).

The ordination plot on the two canonical axes (Figure 5.10) shows that the four categories are not distinct. The 4 categories separated into 3 groups in canonical axis 1. Group 1 composts of 2 species of *Cassia (Chamaecrista)*). Group 2, the largest group, composed of category 3 and 4; and the category 1 is member of group 3. In canonical axis 2, however, 4 categories can be divided into 2 groups, which is differed to canonical axis 1. This axis separated only one species *Cassia* (*Senna*) *alata* into group 2. While group 1 consist of the remainder.

5.3.3.3 Discriminant analysis of 4 categories according to Kidyue's (2001)

The linear discriminant function classification results showed 100% correctly classified. For this reason, the linear discriminant function (Table 5.18) can be used for identification of specimens of the *Cassia* s. l. in Thailand.

The nature of the entries differences is showed by the pooled within canonical structure (Table 5.19). Canonical variable 1 is 98.8% correlated with the thirty-two characters and the variance explained by it is 56.3% (Table 5.20). It is most highly associated with character FML (23), FTL (32), OSL (27), OVL (28), FLD (14), PTL (20), PTW (21) and DBLP (5). Canonical variable 2 can explained 33.4% of the total variance. This axis is most highly associated with 14 characters (Table 5.19). Canonical variable 3 can explained 10.3 % of the total variance. This axis is most highly associated with 7 characters. The 4 variables OVD (29), PED (2), BTWP (8) and RCL (3) not used in the analysis.

The ordination plot on the two canonical axes (Figure 5.11) shows that the four categories are not distinct. The 4 categories separated into 3 groups in canonical axis 1. Group 1 consists of 2 species of *Cassia (Chamaecrista)*. Group 2 composed of *Cassia* (*Senna*) taxa. Group 3 composed of 4 species of *Cassia* s.s. taxa. In canonical axis 2, however, 4 categories can be divided into 3 groups which is similar to canonical axis 1. This axis separated of *Cassia (Chamaecrista) pumilar* and of *Cassia (Chamaecrista) leschenaultiana* to group 1. Similarly, group 2 composed of 12 species of *Cassia* (*Senna*) taxa. The third group composed of 4 species of *Cassia* s.s. taxa , i.e., *C. fistula, C. javanica, C. grandis* and *C. bakeriana.*

5.3.3.4 Discriminant analysis of 3 categories according to Irwin and Barneby (1981)

The linear discriminant function classification results showed 100% correctly classified. For this reason, the linear discriminant function (Table 5.21) can be used for identification of specimens of the *Cassia* s. l. in Thailand. The nature of the entries differences is showed by the pooled within canonical structure (Table 5.22). Canonical variable 1 is 99.6% correlated with the thirty-two characters and the variance explained by it is 63.8% (Table 5.23). It is most highly associated with 10 characters. Canonical variable 2 can explained 36.2% of the total variance. This axis is most highly associated with 16 characters (Table 5.22).

The 6 variables namely FMD (24), RCL (3), STD (31), SPW (19), PED (2) and ATD (26) not used in the analysis.

The ordination plot on the two canonical axes (Figure 5.12) shows that the three categories are distinct. The 3 categories separated into 3 groups in both of canonical axis 1 and canonical axis 2. Group 1 consists of 4 species of *Cassia* s.s. namely *C. fistula, C. javanica, C. grandis* and *C. bakeriana.* Group 2 composed of 12 species of *Cassia* (*Senna*) taxa. Group 3 composed of 2 *Cassia* (*Chamaecrista*).

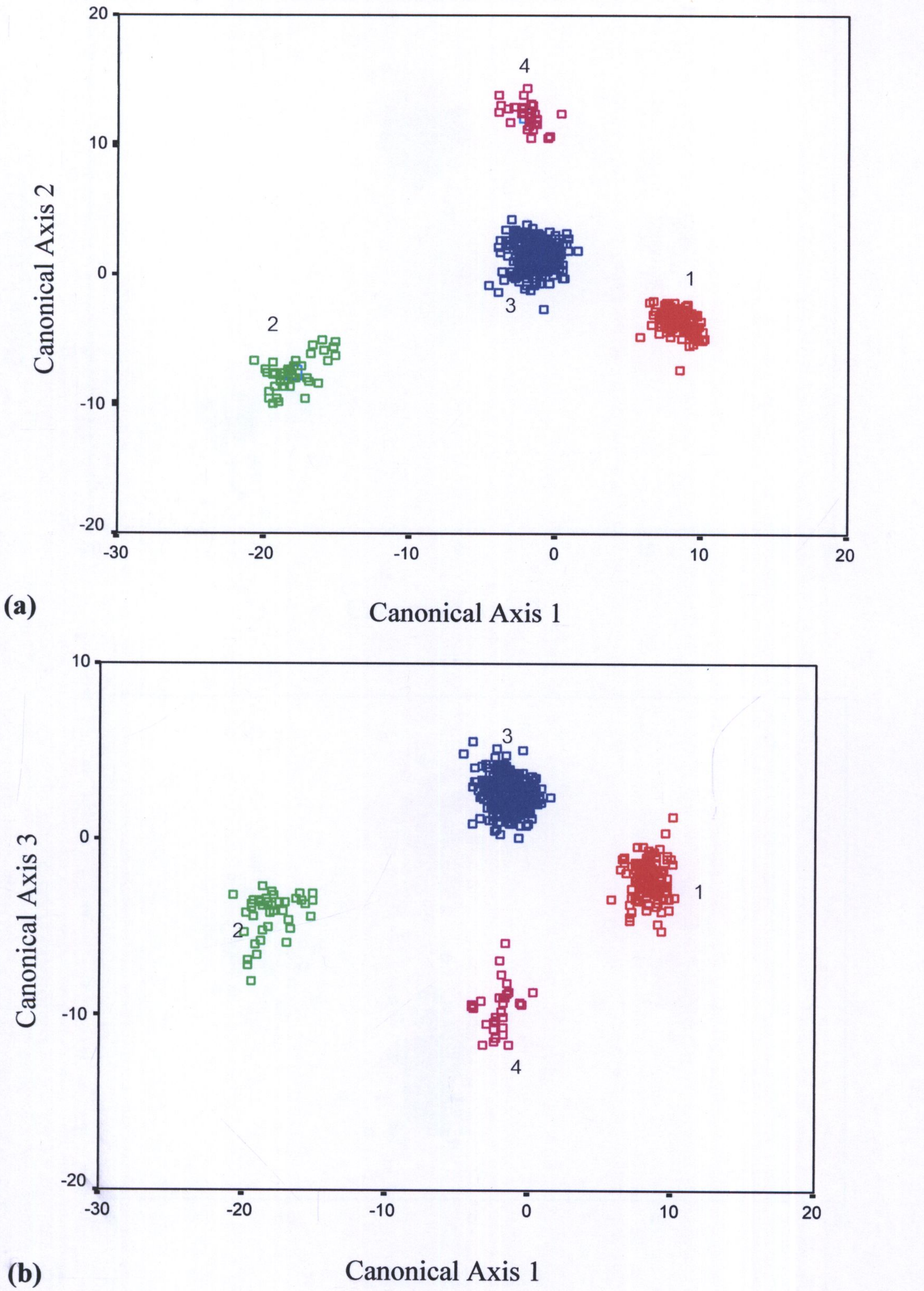


Figure 5.10 The ordination plot of 18 taxa, using 4 categories as priori groups (cluster analysis), (a) - the ordination plot on the canonical axes 1 and 2, (b) - the ordination plot on the canonical axes 1 and 3 (1- *Cassia* s.s, 2-*Cassia (Chamaecrista)*, 3-*Cassia (Senna)*, 4-*Cassia (Senna) alata*)

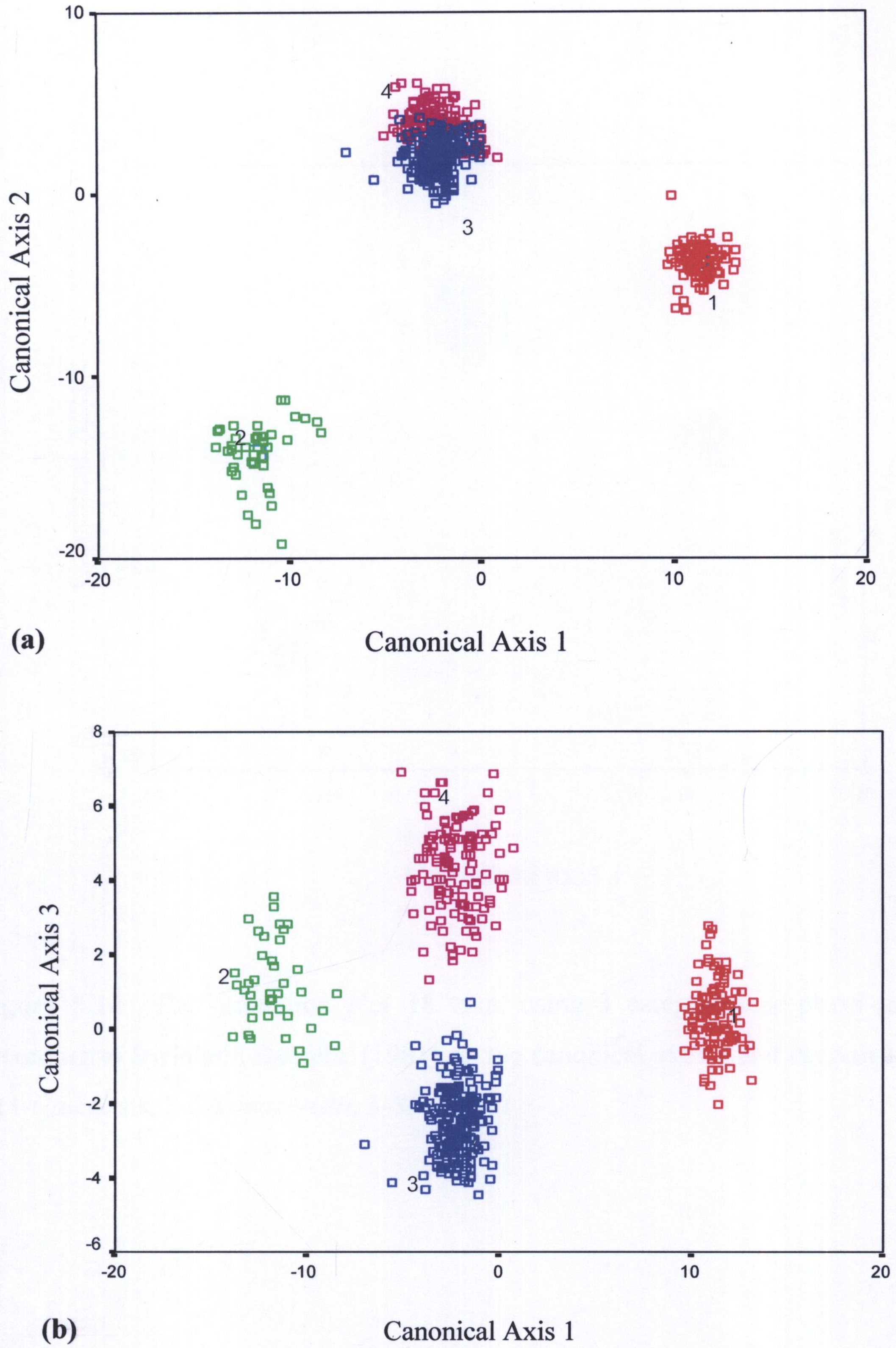


Figure 5.11 The ordination plot of 18 taxa, using 4 categories as priori groups according to Kidyu (2001), (a) - the ordination plot on the canonical axes 1 and 2, (b) - the ordination plot on the canonical axes 1 and 3 (1-*Cassia* s.s, 2-*Chamaecrista*, 3-*Senna* 1, 4-*Senna* 2)

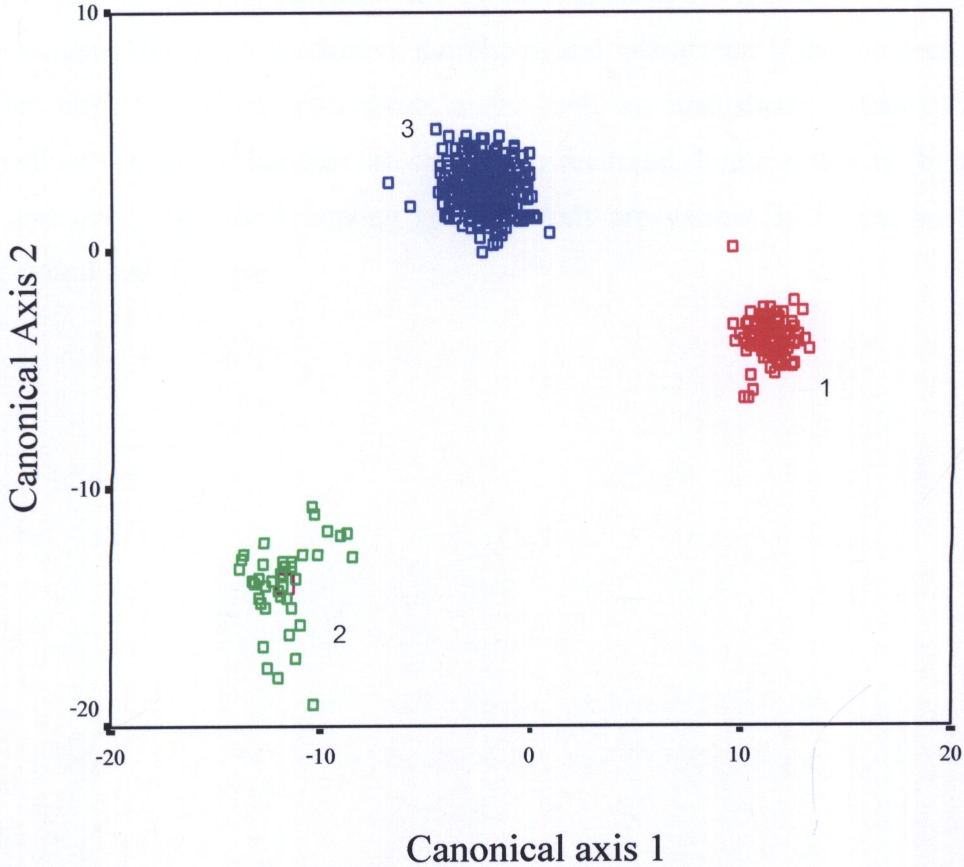


Figure 5.12 The ordination plot 18 taxa, using 3 categories as priori groups according to Irwin and Barneby (1981) on the canonical axes 1 and canonical axis 2 (1-*Cassia* s.s, 2-*Chamaecrista*, 3-*Senna*)

5.4 Comparision of qualitative morphological characters of the *Cassia* s. l.

Cassia L. is one of the largest genus of flowering plants including about 600 species, distributes worldwide in tropical regions (Kidyu, 2001). Table 5.26 shows comparison of 13 qualitative morphological characters. It can be seen that there are three habits, i.e. tree, shrub, undershrub, an smallshrub. Most species have yellow flowers. Filaments are straight or recurved. Indumentum on branch, style, and ovary also differ among species. Pods are various in forms, such as terete, cylindrical, flat, etc.

CHAPTER 6

DISCUSSION AND CONCLUSION

6.1 Specimen collection

In this chapter, plants names are referred to according to Irwin and Barneby (1981). In Flora of Thailand 23 taxa of the genus *Cassia* L. were enumerated (Larsen et. al.,1984). Many attempts have been made to collect all the species throughout the country (Figure 4.1). However, 18 out of 23 taxa were collected and used in this study (Table 5.1). The 5 missing taxa are *Cassia javanica* subsp. *nodosa* (Buch.-Ham. Ex Roxb.) K & S.S. Larsen, *C. agnes* (de Wit) Brenan, *C. fruticosa* Mill, *C. mimosoides* L., *C. bicapsularis* L. and *C. absus* L.. It should be noted that *Cassia fruticosa, C. bicapsularis* were not common and *Cassia absus* was only once collected from Khao Tao at Hua hin (Larsen et. al., 1984).

In addition to the 23 taxa mentioned in the Flora of Thailand, *Cassia obtusifolia* L., was found in a small population during specimen collection in Thong Pha Phum District, Kanchanaburi Province. From the description of species in 5.2, *Senna tora* and *S. obtusifolia* are very similar, but they can be distinguished in number of gland on rachis. It was found that *S. tora* has one gland and *S. obtusifolia* has two. *Senna obtusifolia* was reported in Flora of Malesiana (Larsen and Hou, 1996). In this respect, *Cassia obtusifolia* is a new recorded species for Thailand.

6.2 Numerical taxonomy

The numerical taxonomy can use to classify many living organism, for examples, ferns, flowering plants in any taxon such as family, genus, species and variety (Sneath and Sokal, 1987), such as *Pyrrosia* (Polypodiaceae), *Poa* (Poaceae), *Solidago* (Asterceae) so on and so forth (Rossarin, 1996; Semple, Chmielewski and Brammall, 1990; Giussani, Martinez and Collantes, 1996). In this study, quantitative characters of *Cassia* s. l. were used to analyze in three multivariate techniques:- factor analysis, cluster analysis and discriminant analysis.

6.2.1 Factor analysis

PCA is a useful tool for categorization of data, since it separates the dominating features in the data set. The eigenvalues for each principal component corresponds to the amount of total variance in the data described by this component (øieroset, 1999). Thirty-two quantitative characters were used in this analysis. It is found that 7 factor components have eigenvalue more than 1(Table 5.2). It shows that these 7 factor components are representatives of all variables or characters (see Supot Saengmanee, 1999: 173). In addition, factor loading (Table 5.3) and communality values (Table 5.2) of all variables are more than 0.5, these meant that variable in each factor have some relationships and suitable to use to explain the variance of the population (Supot Saengmanee, 1999: 173). It was found that 85.5% of the variance could be explained by 7 factors. The variables which contribute to the segregation along the first principal component are related to leaf size, i.e. RCD, TLL, TWL, LMW, DBLP, BTWP, POLL, PET, and NOL and along the second principal component are related to flower size, viz. PCL, FLD, PTL, FTL, OVL, FML, OSL, PTW, and STD. While the third principal component are related to the remainder of leaf and flower (size), i.e. BTW, BTL, PED, RCL, AND, and ANL. This result is in agreement with the multivariate analysis of variation in *Ranunculus decurvus* (Hook.f) Melville and *Ranunculus concinnus* (Hook.f) Melville (Menadue and Crowden, 1988). They concluded that there is no resolution into groups when all the specimens are considered.

6.2.2 Cluster analysis

The dendrogram split the 508 specimens into either two and four groups (Figure 5.4) at the 1.80 or 1.30 levels, respectively. In the two-cluster groupings, specimens classified as group 1 consisted of all members from *Chamaecrista pumila* and *Chamaecrista leschanaultiana.* Specimens classified as group 2 formed three subgroups. Subgroup 1 consisted of all member from *Senna* *alata*, subgroup 2 included all but S. alata and S. spectabilis. Subgroup 3 comprised *Senna spectabilis* and 4 species of *Cassia* s.s., *viz. C. fistula, C. javanica* var. *javanica, C. grandis, C. bakeriana.* In the four-cluster grouping, group 1 was the same as in the two cluster grouping and consisted of all members of the genus *Chamaecrista.* All member of *S. alata* were placed in group 2, group 3 included members from the 10 species of *Senna*, and excluding *S. alata* and *S. spectabilis,* and group 4 consisted all the Cassia s.s., and *Senna spectabilis*.

Both the two and four-cluster groups demonstrated a separation of the genus *Chamaecrista,* the clear cut separation of this genus from the remainder is probably due to their extreme difference in leaf and flower characters from the other. Whereas there are close relationships on the dendrogram among the *Senna* and *Cassia* s.s. The separation of *Senna alata* from its original group is probably caused by its largest leaf size among the *Cassia* s. l. in Thailand, though its flower characters are similar with other *Senna.*

In the case of *S. spectabilis*, this species is a medium-sized tree like all members of the genus *Cassia* s.s. that it was included in to the *Cassia* s.s. revealed a closer relationship to *Cassia* than *Senna*. Table 5.1 shows 18 taxa used in this study, it can be seen that the genus *Senna* has two habits, i.e. shrub and tree while the entire genus *Cassia* s.s. are trees. It seems likely that the tree members of the genus *Senna* and the genus *Cassia* s.s. are rather close. Such relationship is likely related to flower and leaf characters of *S. spectabilis* which are similar to the overall *Cassia* s.s. Within group 4, *S. spectabilis* shows a closer relationship with *C. javanica* var. *javanica, C. grandis, C. bakeriana* than *C. fistula.* The number of leaflets of *C. fistula* is less than *S. spectabilis* and leaf size of *C. fistula* are larger than *S. spectabilis* (Table 5.24). These leaf features may be in part made the two species slightly separated (Figure 6.1).

The result of four-cluster groups may be comparable to the results on stem, leaf and flower anatomy of the *Cassia* s. l. in Thailand by Kidyu (2001). He concluded that the *Cassia* s. l. should be divided into 4 groups. However, in his work the genus *Cassia* s.s. is not included *S. spectabilis*. Moreover, *C. alata* was still included in the group *Senna*.

6.2.3 Discriminant analysis

In this analysis, four criteria were used. In the first criterion, the 18 taxa were divided into 18 categories according to Larsen et al. (1984). The second criterion using a priori results from the cluster analysis, i.e. 4 categories. The third criterion, the 18 taxa were divided into 4 categories according to the result of stem, leaf and flower anatomy of the *Cassia* s.l. (Kidyue, 2001). Finally, the 18 taxa were divided into 3 categories according to Irwin and Barneby (1981).

From overall canonical discriminant analyses, it can be seen that the ordination plot on the two canonical axes (Fig 5.7a, Fig 5.8a, Fig 5.9a, Fig 5.10a, Fig 5.11a and Fig 5.12) shows that the 18 taxa of the *Cassia* s.l. are separated into 3-4 groups. The most important variable to separate the three groups on axis 1 is the filament length (FML) whereas lamina width (TLW), anther length (ATL), petiolule length (POLL) and petiole diameter (PED) are important character on axis 2. It can be concluded that the classification of the *Cassia* s.l. into 18 taxa of a single genus, *Cassia* L. as mentioned in the Flora of Thailand (Larsen et al., 1984) was not appropriate according to the results of canonical discriminant analyses from this study.

As the 4 categories of the canonical discriminant analysis are followed the result of cluster analysis. The ordination plot on the two canonical axes (Figure 5.10) shows that the four categories are not distinct. It was found that the four-cluster grouping according to the result of cluster analysis is not relevant with the result from canonical discriminant analysis.

When the 3 categories canonical discriminant analysis were conducted following the result of stem, leaf, and flower anatomy of the *Cassia* s.l. (Kidyue, 2001). 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). It can be concluded that 18 taxa of the *Cassia* s.l. were separated into three groups on both of canonical axis 1 and canonical axis 2. It was found that clusters of *Senna*-1 pooled with cluster of *Senna*-2 in both canonical axes. The result from this study indicated that *Cassia* s. l. in Thailand should divide into three groups, and the 4 grouping as was mentioned from the results of qualitative plant anatomy are still not pertinent.

As was mentioned in chapter 3, some workers recognized the three segregated genera, viz. *Cassia* s. s., *Senna* and *Chamaecrista* from the *Cassia* s. l., using characters of stamen, bracteole, seed coat, etc. (Irwin & Barneby, 1981; Lock, 1988; Mabberley, 1997). While using the 3 categories as a priori groups according to Irwin and Barneby (1981). The ordination plots of the canonical discriminant analysis (Figure 5.12) show that 18 taxa of the *Cassia* s. l. in Thailand was divided into three groups. All of the most highly associated characters with canonical axis 1 are characters of flower.

In all, there is justification to indicate the presence of three distinct genera in the *Cassia* s. l. based on the result of canonical discriminant analyses. Some recently works on this plant group also supported this numerical study. For example, Tucker (1996) investigated and compared features of inflorescence and floral organ initiation and development among one species of *Cassia* s. s., six species of *Senna* and two species of *Chamaecrista*, he concluded that distinction in floral ontogeny supported the segregation of these three genera. Recently, Ghareeb, Khalifa and Fawzi (1999) working on electrophoretic seed protein, chromosome number and morphological characters of 10 species of the genus *Cassia* s.l. belonging to subgenera *Fistula* and *Senna*. The results obtained from their work support the earlier taxonomic treatments of the genus *Cassia*.

6.3 Comparision of qualitative morphological characters of the *Cassia* s. l.

The *Cassia* s. l. have some common morphological characters. For example, they have uni-pinnately compound leaves, 5 petals and 5 sepals, 10 stamens (3 large, 4 smaller, and 3 reduced) and superior ovary with ovary stalk from the result of comparative morphological study of the 18 taxa (Table 5.26).

If we considered plant habit in the *Cassia* s. l. from the 18 taxa. There are three kinds of habit, viz. tree, shrub and herb. *Cassia* has only one habit, i.e. tree and *Chameacrista* is quite a small shrub while *Senna* owns both of tree and shrub.

C. grandis has three recurved filaments and small flowers. The diameter of flower and their leaflet size is comparable to *Senna*. Whereas morphological character of *C. javanica* and *C. bakeriana* are very close, these two species are frequently misidentified. However, the pubescence of leaf, ovary and fruit in *C. bakeriana* and the bigger size of flower diameter can distinguish them. *Senna spectabilis* has straight filament while flower diameter is close to *Cassia* s.s. due to it have spatulate petal. Moreover, *S. alata* obtains large leaflets which is nearly the same size as *C. fistula*.

In this study there are two pair of closely related taxa. The first pair is *Cassia surattensis* subsp. *surattensis* and *Cassia surattensis* subsp. *glauca*, all characters of these two species are comparable but they are differed in size which the first species smaller than the latter. The second pair is *S. tora* and *S. obtusifolia* are also very similar, but they can be distinguished in number of gland on rachis. It was found that *S. tora* has one gland and *S. obtusifolia* has two.

6.4 Numerical Taxonomy and closely related taxa

In section 6.3 two pairs of closely related taxa were noted. It is interesting to investigate how numerical taxonomy can recognize these related taxa. Figure 5.4 shows the result of UPGMA clustering of 508 OTUs based on 32 characters of the *Cassia* s.l. in Thailand. It can be seen that the condensed dendrogram could not demonstrate detailed position of each specimen. However, from the expanded dendrogram, Figure 5.4 can be slightly added some more details of the positions of (1) *Cassia surattensis* subsp. *surattensis*, and *Cassia surattensis* subsp. *glauca* (*Senna glauca*), and (2) *Senna tora* and *Senna obtusifolia* (Figure 6.1). Figure 6.1 shows specimens of *Cassia surattensis* subsp. *surattensis* and *Cassia surattensis* subsp. *glauca* are grouped in the *Senna* group, but in rather far apart clusters. It is indicated that the two taxa are distinct, probably at the level of species. However, this finding is only the result from quantitative characters. In contrast, *Cassia surattensis* subsp. *surattensis* and *Cassia surattensis* subsp. *glauca* are placed in the same species without infraspecific taxa (Larsen and Larsen, 1980; Hou, Larsen and Larsen, 1996). Hou, Larsen and Larsen (1996) also treated *Cassia surattensis* subsp. *surattensis* as *Senna surattensis* (Burm.f.) Irwin & Barneby without infraspecific taxa, but they did not mentioned *Cassia surattensis* subsp. *glauca*.

Figure 6.2 shows the ordination plot of 12 species of *Senna*. It can be seen that *Cassia* (*Senna*) *surattensis* subsp. *surattensis* (12) and *C.* (*Senna*) *suattensis* subsp. *glauca* (11) are not distinct. This result is in agreement with the treament of *Senna surattensis* without infraspecific taxa by Hou, Larsen and Larsen (1996) in Flora Malesiana.

In the case of *Senna tora* and *Senna obtusifolia* the dendrogram (Figure 6.1) shows a close relationship of this two species. As their undershrub habit (Table 5.1), these two species are in separate cluster with the other *Senna* species. This cluster grouping agrees well with the presently known species in the Flora Malesiana (Hou, Larsen and Larsen, 1996). From the result of canonical discriminant analysis, *Senna obtusifolia* (7) and *S. tora* (14) are slightly distinct. This result confirms a close relation of the two species.

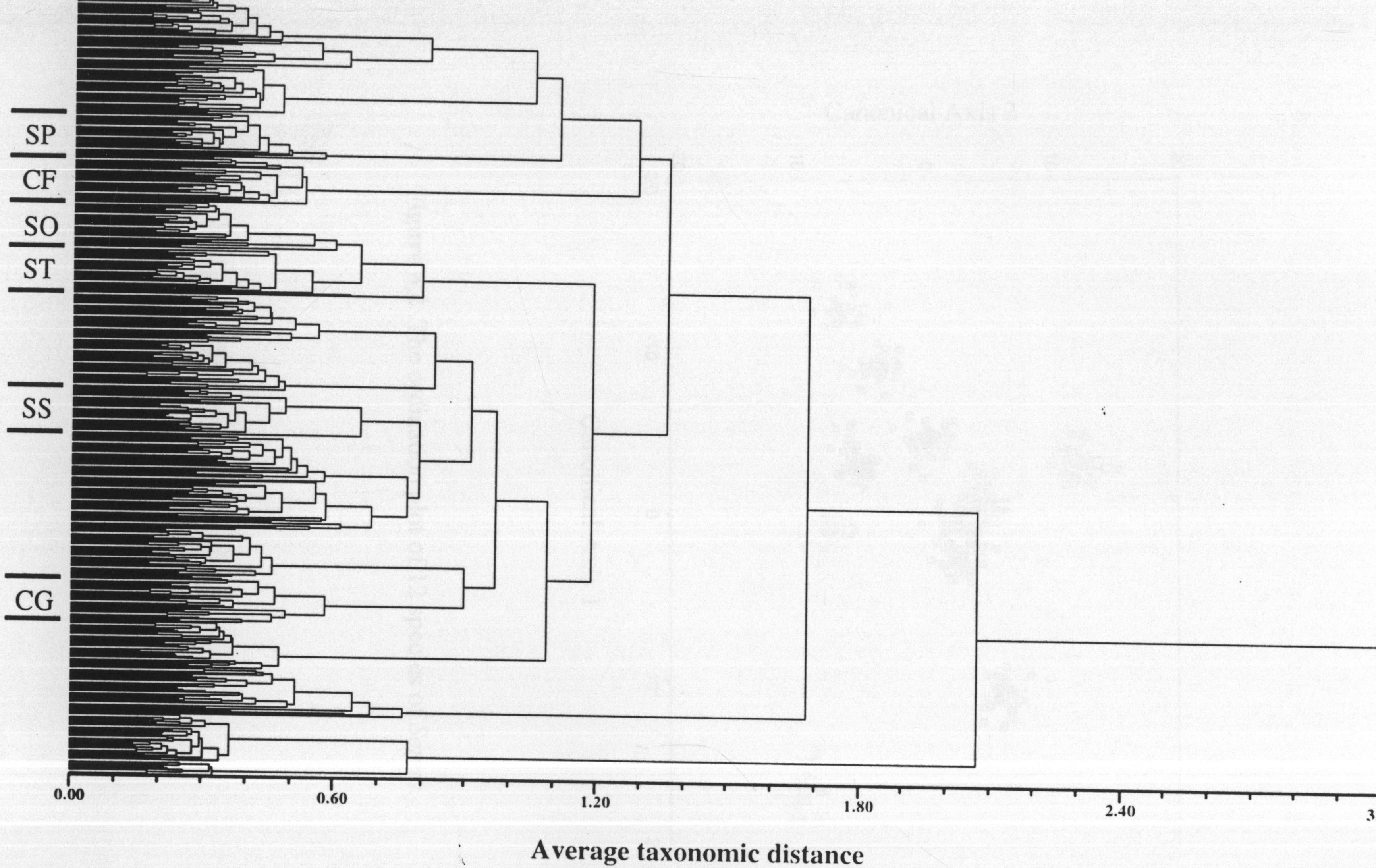


Figure 6.1 UPGMA clustering of 508 OTUs based on 32 Characters of *Cassia* s.l. in Thailand (SP- *C.(Senna) spectabilis*, CF-*C. fistula*, SO- *C.(Senna) obutusifolia*, ST- *C.(Senna) tora*, SS- *C.(Senna) surattensis* subsp. *surattensis*, CG-C. *surattensis* subsp. *gluca*)

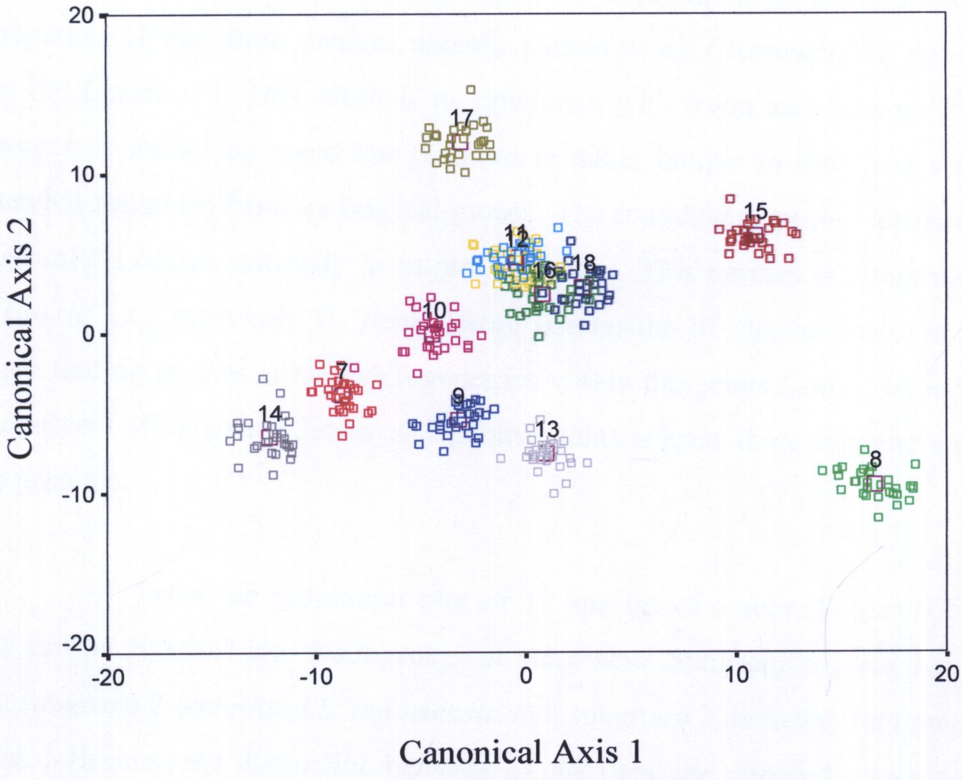


Figure 6.2 The ordination plot of 12 species of *Senna*.

6.5 Conclusion

Three techniques of numerical taxonomy were used to investigate the taxonomic status of 18 taxa in the *Cassia* s. l. in Thailand. It should be concluded that the results from numerical taxonomic study as well as the comparision of qualitative characters of the *Cassia* s. l. provide justification for recognition of the segregation of the three genera, namely *Cassia* s. s., *Chameacrista* and *Senna* from the *Cassia* s. l. This result is in agreement with Irwin and Barneby (1981). However, it should be noted that *S. alata* is rather unique in their leaf size and somewhat separated from its original group. The introduced species for road tree, *S. spectabilis* occurs naturally in tropical America. This species is rather close to the *Cassia* s.s., especially *C. fistula* from the results of cluster analysis. This present finding reveals some heterogeneities within the genus *Senna*. In addition, the treatment of the genus *Senna* as a genus retains at least three subgenera seems to be possible.

From the ordination plot of 12 species of *Senna* (Figure 6.2), the *Senna* can be divideed into 3 subgroups or subgenera. Subgroup 1 consisted of *S. alata*, subgroup 2 comprised *S. timoriensis*, and subgroup 3 included the remainder species. Because the distinction between *S. alata* and the remainder species was observed on canonical axis 1, which is 99.1% correlated with all the characters, and the variance explained by it is 31.0% (Table 6.1). However, the result of canonical discriminant analysis did not support the separation of *S. spectabilis* from the remainder.

Box plots of ten most important characters are demonstrated in Figure 6.3. It can be seen that filament length, fruit length and ovary stalk length are useful quantitative chartacters for discriminating the three genera. The following is an identification key to the genera of the former *Cassia* L. in Thailand.

1a The longest filament recurved, more than 2.5 cm long..... **1.** ***Cassia***

1b The longest filament straight, less than 1 cm long.......... 2

2a Ovary stalk more than 0.9 mm long, fruit more than 9 cm long.. **2.** ***Senna***

2b Ovary stalk less than 0.9 mm long, fruit less than 9 cm long.. **3.** ***Chamaecrista***

In all, numerical taxonomy can reexamine the principles of taxonomy and of the proposes classification. This has benefited taxonomy in general, and has to lead to the posing of some taxonomic questions as was noted by Sneath and Sokal, (1973).

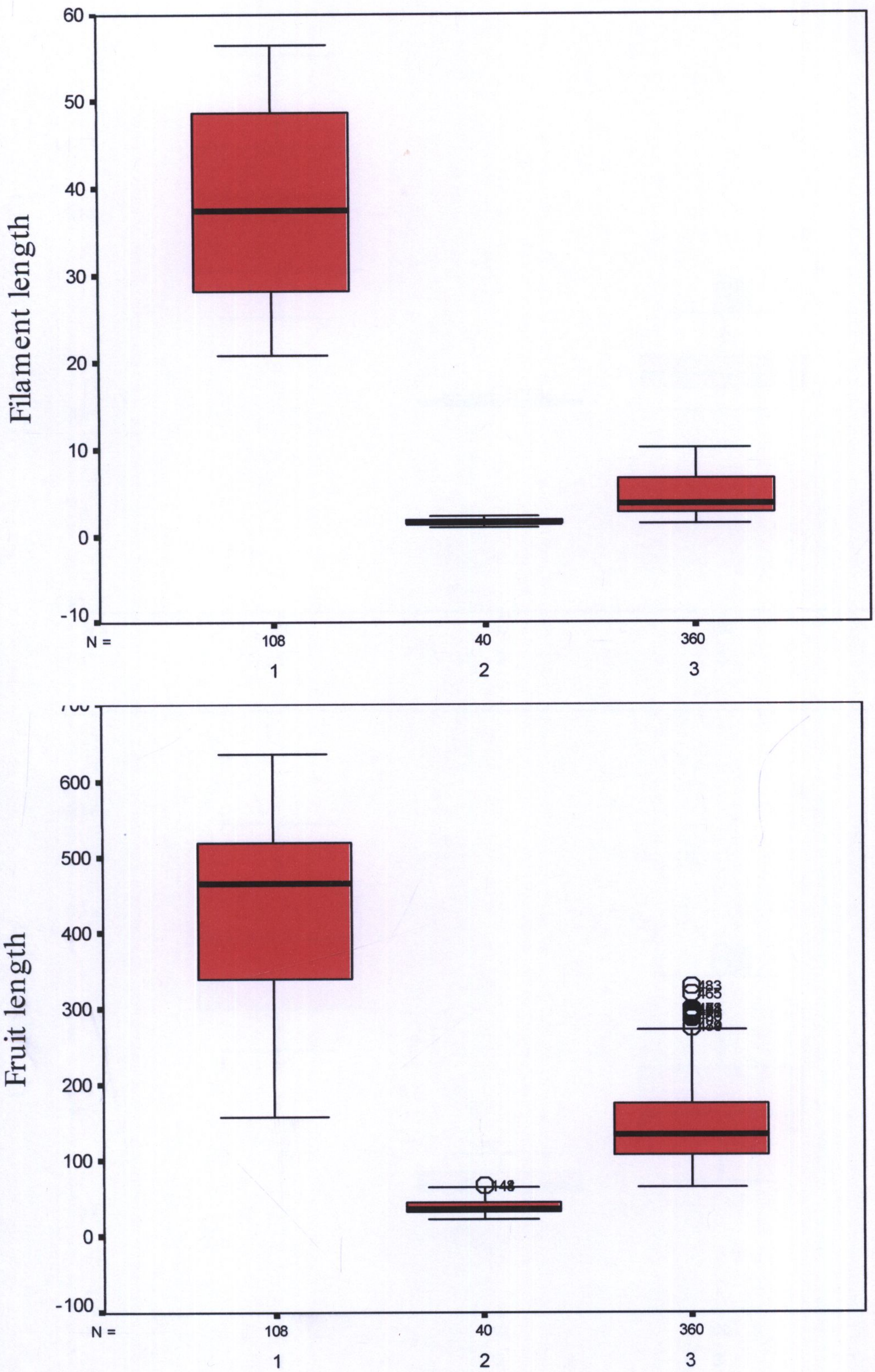


Figure 6.3 Boxplots of the ten more important characters of *Cassia* s.l. (1-*Cassia* s.s., 2-*Senna*, 3-*Chamaecrista*)

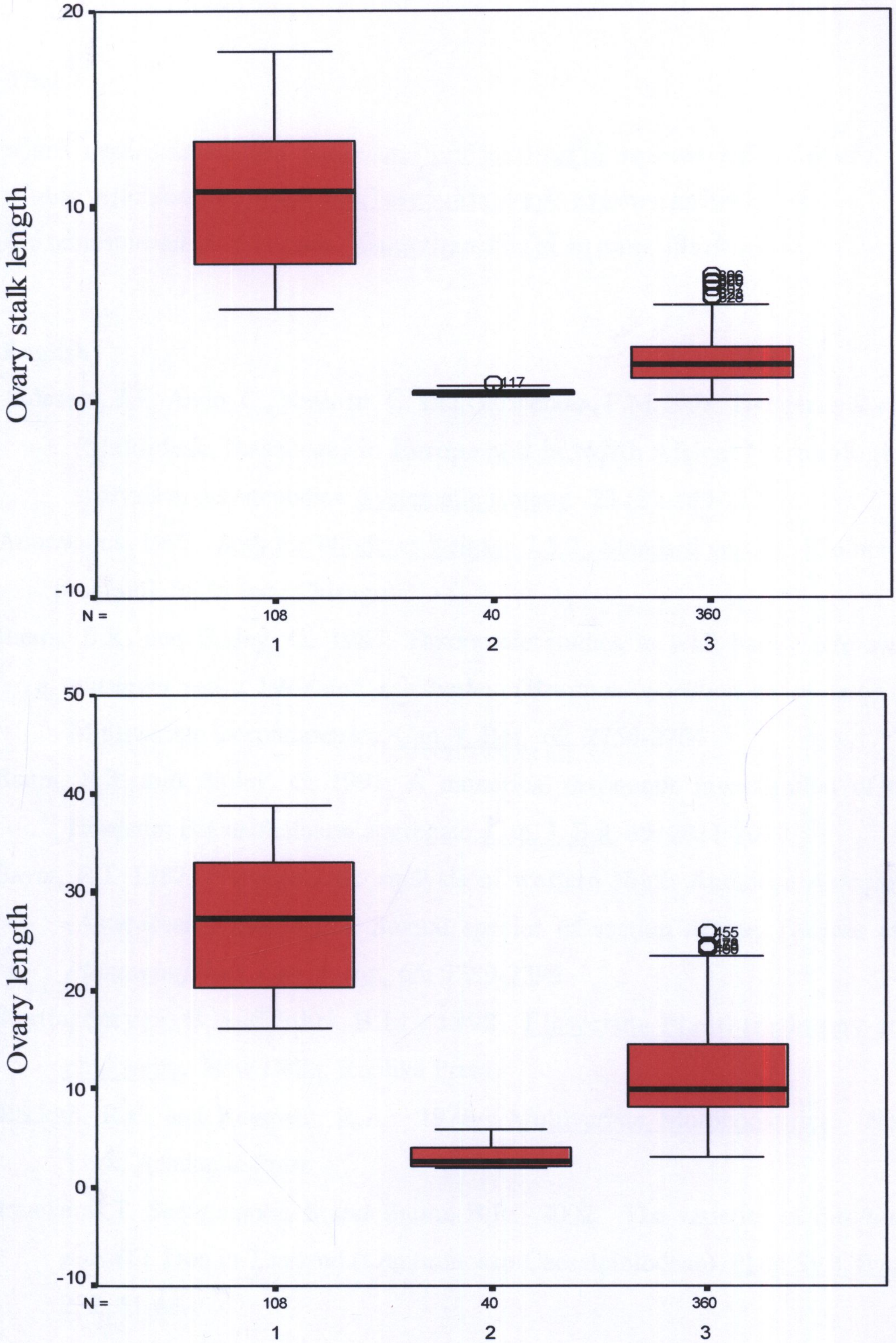


Figure 6.3 (continued)

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APPENDIX

APPENDIX

Table 4.1 Thirty-two characters, with their methods of scoring used in the study of *Cassia* s.l.

No.	Abbreviation	Characters
1.	PET	Petiole length in mm
2.	PED	Petiole diameter in mm
3.	RCL	Rachis length in mm
4.	RCD	Rachis diameter in mm (between 2-3 leaflet pair)
5.	DBLP	Distance between first and second leaflet pair
6.	NOL	Number of leaflet
7.	TLL	Terminal leaflet length in mm
8.	TLW	Terminal leaflet width in mm
9.	BTWP	Distance from base to the widest point of leaflet
10.	LWR	Terminal leaflet length to width ratio
11.	LS	Terminal leaflet shape (calculated by BTW/TLL)
12.	LMW	Lamina width in mm
13.	POLL	Petiolule length in mm
14.	FLD	Flower diameter in mm
15.	BTL	Bracteole length in mm
16.	BTW	Bracteole width in mm
17.	PCL	Pedicel length in mm
18.	SPL	Largest sepal length in mm
19.	SPW	Largest sepal width in mm
20.	PTL	Largest petal length in mm
21.	PLW	Largest petal width in mm
22.	PSL	Petals stalk length in mm (largest petal)
23.	FML	Filament length in mm (largest fertile stamen)
24.	FMD	Filament diameter in mm (largest fertile stamen)

Table 4.1 (continued)

No.	Abbreviation	Characters
25.	ATL	Anther length in mm (largest fertile stamen)
26.	ATD	Anther diameter in mm (largest fertile stamen)
27.	OSL	Ovary stalk length in mm
28.	OVL	Ovary length in mm
29.	OVD	Ovary diameter in mm
30.	STL	Style length in mm
31.	STD	Style diameter in mm
32.	FTL	Fruit length in mm

Table 5.1 List of taxa used for the study of *Cassia* s.l.

Taxon number	Taxa in Larsen et al., (1984)	Genus in Irwin and Barneby (1981)	Habit
1	*C. javanica* subsp. *javanica*	*Cassia* L.	tree
2	*C. grandis*	*Cassia* L.	tree
3	*C. bakeriana*	*Cassia* L.	tree
4	*C. fistula*	*Cassia* L.	tree
5	*C. pumila*	*Chamaecrista* Moench	smallshrub
6	*C. leschenualtiana*	*Chamaecrista* Moench	smallshrub
7	*C. obtusifolia*	*Senna* Miller	undershrub
8	*C. alata*	*Senna* Miller	shrub
9	*C. hirsuta*	*Senna* Miller	undershrub
10	*C. sophera*	*Senna* Miller	shrub
11	*C. surattensis* subsp. *surattensis*	*Senna* Miller	shrub
12	*C. surattensis* subsp. *gluaca*	*Senna* Miller	shrub
13	*C. occidentalis*	*Senna* Miller	undershrub
14	*C. tora*	*Senna* Miller	undershrub
15	*C. timoriensis*	*Senna* Miller	tree
16	*C. garrettiana*	*Senna* Miller	tree
17	*C. spectabilis*	*Senna* Miller	tree
18	*C. siamea*	*Senna* Miller	tree

Table 5.2 Initial eigenvalues of all characters.

Factor	Total	% of Variance	Cumulative %
1	12.892	40.287	40.287
2	5.317	16.615	56.902
3	3.391	10.597	67.500
4	2.325	7.267	74.767
5	1.457	4.552	79.319
6	1.257	3.927	83.246
7	1.090	3.405	86.651
8	.705	2.203	88.854
9	.617	1.928	90.782
10	.464	1.450	92.232
11	.356	1.113	93.345
12	.336	1.049	94.394
13	.241	.753	95.147
14	.217	.678	95.825
15	.188	.588	96.413
16	.160	.499	96.912
17	.148	.464	97.376
18	.125	.390	97.766
19	.108	.338	98.104
20	9.423E-02	.294	98.399
21	9.004E-02	.281	98.680
22	7.985E-02	.250	98.930
23	6.718E-02	.210	99.139
24	6.016E-02	.188	99.327
25	4.684E-02	.146	99.474
26	4.145E-02	.130	99.603
27	3.844E-02	.120	99.724
28	2.584E-02	8.074E-02	99.804
29	2.212E-02	6.913E-02	99.873
30	1.871E-02	5.848E-02	99.932
31	1.443E-02	4.509E-02	99.977
32	7.374E-03	2.304E-02	100.000

Table 5.3 Factor loading of 18 taxa based on 32 characters befor rotation

Character	Factor						
	1	2	3	4	5	6	7
LMW	.902		-.320				
TLL	.886		-.349				
DBLP	.865		-.280				
BTWP	.832	.212	-.224	.295			
TLW	.820	.232	-.380	.270			
PTW	.818			-.203	-.250		
ATD	.813		.366				
PTL	.765	-.375	.266		-.335		
PED	.738	.381		.351			
RCD	.734		-.463				
POLL	.720	-.263	-.386				
RCL	.719		.485				-.217
FLD	.651	-.531	.201		-.376		
OVL	.637	-.612		.219		-.227	
SPL	.632	.562					
PSL	.623		.251	-.245		-.516	
FMD	.581		.204		.253		.527
STD	.484	-.402	.374	-.274	.228	-.392	
FML	.529	-.723		.297		.222	
FTL	.625	-.674		.232			
ATL	.569	.664		-.264	-.234		
BTW	.384	.662	.450	.247			
PCL	.573	-.651			-.264		
OSL	.437	-.636	.212	.276			.322
BTL	.475	.610	.299	.348			
STL	.425	.553			-.302	.505	
NOL	-.256		.756		.351		
PET	.427		-.660	-.382			
LS	-.421			.616	-.359		.279
SPW	.455	.326		-.609		-.292	
LWR	-.294		.433	-.513	.312		-.315
OVD	.414		.349		.384		.488

Table 5.4 Factor loading of 18 taxa based on 32 characters after rotation

Character	Factor						
	1	2	3	4	5	6	7
TLL	.881	.277	.217				
RCD	.873						
TLW	.871		.361				
LMW	.865	.287	.245	.204			
DBLP	.816	.355	.272				
BTWP	.736	.238	.428				-.268
POLL	.729	-.446					
PET	.672		-.451			.311	
NOL	-.596		.375		.240	-.297	.329
PCL		.910					
FLD		.883		.287			
FTL	.286	.875				-.211	
FML	.247	.866		-.320			
OVL	.265	.848				-.291	
PTL		.822	.210	.411			
OSL		.802			.332		
PTW	.324	.633		.400	.222	.289	
STD		.531		.445		-.450	.316
BTW			.881			.235	
BTL			.858				
PED	.519		.751				
RCL	.220	.352	.751		.234		.227
ATD	.279	.403	.594	.307	.329		
ATL	.292		.554	.451		.543	
SPW				.837			
PSL	.202	.294	.289	.729			
SPL	.403		.436	.500	.394		
OVD			.259		.813		
FMD	.238			.250	.771		
STL	.207		.473			.736	
LWR	-.453						.767
LS	-.449			-.213			-.736

Table 5.5 Communality of all character

Character	Initial	Extraction
PET	1.000	.816
PED	1.000	.919
RCL	1.000	.878
RCD	1.000	.873
DBLP	1.000	.930
NOL	1.000	.784
TLL	1.000	.963
TLW	1.000	.957
BTWP	1.000	.891
LWR	1.000	.805
LS	1.000	.842
LMW	1.000	.965
POLL	1.000	.764
FLD	1.000	.926
BTL	1.000	.842
BTW	1.000	.902
PCL	1.000	.888
SPL	1.000	.803
SPW	1.000	.821
PTL	1.000	.941
PTW	1.000	.836
PSL	1.000	.794
FML	1.000	.956
FMD	1.000	.785
ATL	1.000	.932
ATD	1.000	.842
OSL	1.000	.836
OVL	1.000	.907
OVD	1.000	.753
STL	1.000	.840
STD	1.000	.818
FTL	1.000	.921

Note: extraction method = Principal Component Analysis.

Table 5.6 Classification function coefficients of 18 categories based on 19 reproductive characters.

Character	Taxa								
	1	2	3	4	5	6	7	8	9
FLD	2.432	.401	3.138	1.860	.229	.356	.580	-.639	.564
SPL	3.516E-02	9.645	.968	7.052	7.412	11.367	7.408	14.118	12.874
SPW	-6.633	-3.287	-8.648	-4.486	-2.488	-5.561	-1.271	-6.821	-2.324
PTL	2.989	-1.402	5.523	1.099	-1.384	-1.874	-.759	-.903	-2.621
PTW	-6.266	-2.646	-4.891	-2.414	.677	.642	-1.712	-8.560E-02	.859
PSL	2.819	-.536	-2.212	-2.808	1.684	1.453	4.366	8.000	6.968
FMD	50.059	56.493	48.149	48.589	7.441	18.786	20.402	26.439	46.584
ATL	-25.748	-23.496	-27.734	-24.301	-4.964	-2.557	-3.471	18.055	-1.360
ATD	50.003	32.806	62.205	41.992	10.410	10.146	18.416	56.682	20.843
OVD	-7.301	9.539	-2.484	-6.636	37.007	54.059	-1.602	27.092	44.259
STL	-2.167	-1.622	-2.117	.579	4.375	4.879	6.931	12.484	5.115
STD	52.432	32.526	68.614	43.620	13.998	28.343	1.835	5.183	31.922
BTL	22.990	15.230	-2.817	9.079	38.157	37.309	9.237	88.387	16.827
BTW	20.049	-14.920	33.515	-66.213	-69.265	-18.212	-27.263	75.281	-41.018
PCL	331.204	289.240	380.803	345.541	107.274	172.502	233.563	86.859	190.132
FML	261.910	264.638	253.194	274.017	-4.955	-59.601	10.753	-55.617	83.458
OSL	83.222	109.610	123.837	99.765	-46.234	-42.420	16.042	-10.931	-30.790
OVL	363.365	318.111	367.141	368.020	83.156	155.450	326.014	286.102	186.001
FTL	838.024	769.718	867.718	852.734	496.902	582.415	716.199	705.987	683.528
(Constant)	-1990.083	-1635.808	-2362.131	-2097.113	-492.741	-749.071	-1187.894	-1411.878	-1107.247

Table 5.6 (continued)

Character	Taxa								
	10	11	12	13	14	15	16	17	18
FLD	.780	1.697	1.480	.309	.821	1.017	.756	1.319	.698
SPL	9.035	5.642	8.124	8.331	9.400	10.122	10.499	6.109	5.468
SPW	-2.055	-3.441	-1.039	-3.006	-1.189	-.787	-.122	.736	-1.706
PTL	-2.985E-03	.232	.439	-1.554	-1.015	-.697	-1.814	2.828	-2.196
PTW	-1.259	-.852	-1.805	.308	-1.655	-2.196	-2.090	-3.627	-.505
PSL	-4.055	8.296	5.500	4.582	6.908	5.487	6.866	17.946	7.805
FMD	27.637	33.626	34.005	24.088	14.544	14.189	20.055	23.201	42.028
ATL	-1.552	.676	.108	.585	-8.409	7.733	11.185	-5.625	.679
ATD	32.371	21.423	29.860	24.604	18.077	43.449	23.053	42.101	37.127
OVD	13.837	9.750	3.575	15.771	11.166	23.062	26.234	-10.920	37.496
STL	5.068	1.761	11.070	6.292	5.642	12.393	13.023	.999	11.877
STD	14.806	19.822	-6.687	17.219	12.698	29.624	16.617	76.882	19.526
BTL	-21.010	18.255	-14.147	83.865	31.613	30.866	-30.100	-40.019	26.142
BTW	-24.442	25.974	25.026	12.438	-66.890	79.007	-10.113	1.291	-9.332
PCL	196.562	269.305	263.989	159.903	162.853	250.125	273.717	271.101	282.435
FML	95.909	-41.678	-64.424	64.880	-39.691	-102.791	-9.785	-44.184	87.776
OSL	8.640	59.835	67.163	-23.979	-1.969	-7.360	30.817	28.257	33.219
OVL	206.782	221.884	316.670	211.648	318.385	219.382	114.010	350.888	162.135
FTL	638.974	628.449	687.350	642.910	679.086	670.242	716.344	768.976	757.744
(Constant)	-970.118	-1030.311	-1268.586	-983.403	-1031.319	-1232.875	-1199.212	-1529.786	-1381.264

Table 5.7 Pooled within canonical structure of 18 categories based on 19 reproductive characters.

Character	Discriminant function							
	1	2	3	4	5	6	7	8
FTL	**.400**	.230	.049	.040	.366	.210	-.355	.260
BTW	-.034	**.575**	.238	-.181	-.431	-.257	.161	.280
ATL	-.093	**.560**	.164	.262	.136	.200	.030	-.393
FML	.557	-.029	**.575**	.133	-.048	.144	.056	-.279
OVL	.355	.270	-.143	**-.514**	.321	-.121	-.036	-.183
PCL	.283	.219	-.312	**.456**	-.069	-.001	-.031	.117
OSL	.322	.153	.033	.123	.073	**-.521**	.308	-.102
SPL	-.025	.289	.160	-.052	.348	.042	**.454**	-.241
STL	-.056	.320	.176	.320	-.010	-.075	**-.421**	-.214
PTL	.240	.333	-.153	-.059	-.226	.347	.192	**-.508**
PTW	.127	.234	.044	.035	-.044	.159	.301	**-.470**
FLD	.264	.251	-.199	.075	-.353	.270	.019	**-.449**
BTL	.009	.368	.388	-.234	-.272	.043	-.148	.126
PSL	.048	.203	-.102	-.079	.106	.316	.291	.137
OVD	.015	.080	.131	.068	.040	.150	.222	.162
SPW	-.014	.234	-.142	.081	.291	.072	.327	-.016
FMD	.049	.120	.173	.073	.119	.055	.395	.040
ATD	.101	.370	.177	.042	.124	.235	.148	-.136
STD	.096	.072	-.095	-.064	.053	.387	.259	.244

Table 5.7 (continued)

Character	Discriminant function								
	9	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
FTL	-.080	.150	-.003	-.229	-.083	.018	-.189	-.367	-.036
BTW	.110	-.229	-.087	-.039	.097	.103	-.303	-.144	-.042
ATL	.055	.033	-.397	-.190	-.016	-.107	.243	-.069	.090
FML	.115	-.104	-.274	.021	.017	.166	-.100	.057	-.071
OVL	.319	-.083	.016	.010	.200	-.161	.075	.007	.069
PCL	.443	-.183	-.039	-.009	-.106	-.355	.134	.323	-.160
OSL	-.389	.395	.093	.065	-.243	.180	-.031	-.175	.126
SPL	.298	-.249	.149	-.181	-.304	.349	-.044	.199	-.182
STL	.077	.063	.291	.255	.072	.292	-.335	.263	.262
PTL	.150	.121	-.017	.020	-.121	.163	-.328	.061	-.107
PTW	.468	.236	-.019	.302	-.121	-.171	-.333	-.152	-.086
FLD	.368	.025	.046	-.069	-.001	.445	.158	-.176	-.014
BTL	**.430**	.161	-.090	.119	-.396	.181	.181	.016	.026
PSL	-.015	**.485**	-.187	.081	.019	.321	-.134	.369	-.328
OVD	.097	.184	**.510**	-.126	.215	-.068	.006	-.306	-.135
SPW	.228	-.279	-.184	**.470**	-.051	.309	.025	-.380	-.057
FMD	.153	.179	.067	.126	**.530**	.029	.198	.166	.346
ATD	-.378	-.107	.246	.417	-.003	-.224	**.448**	.124	-.198
STD	-.002	-.110	.139	.069	-.233	.007	-.083	-.075	**.729**

Note: The number in **bold letter** represent the largest absolute correlation between each variable and any discriminant function

Table 5.8 Summary of canonical discriminant function of 18 categories based on 19 reproductive characters.

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Coorrelation	Wilk's Lambda	Chi-square	Df	Sig.
1	135.872	52.7	52.7	.996	.000	13666.473	323	.000
2	46.015	17.9	70.6	.989	.000	11263.519	288	.000
3	25.109	9.7	80.4	.981	.000	9382.566	255	.000
4	15.149	5.9	86.2	.969	.000	7788.941	224	.000
5	11.839	4.6	90.8	.960	.000	6429.997	195	.000
6	6.194	2.4	93.2	.928	.000	5183.094	168	.000
7	4.307	1.7	94.9	.901	.000	4219.159	143	.000
8	3.953	1.5	96.4	.893	.001	3403.864	120	.000
9	2.859	1.1	97.5	.861	.005	2622.275	99	.000
10	2.200	.9	98.4	.829	.018	1962.575	80	.000
11	1.673	.6	99.1	.791	.058	1394.390	63	.000
12	.899	.3	99.4	.688	.154	914.177	48	.000
13	.789	.3	99.7	.664	.292	600.973	35	.000
14	.446	.2	99.9	.555	.523	316.794	24	.000
15	.251	.1	100.0	.448	.756	136.751	15	.000
16	.049	.0	100.0	.216	.946	27.164	8	.000
17	.008	.0	100.0	.088	.992	3.771	3	.000

Table 5.9 Classification function coefficients of 18 categories based on 13 vegetative characters.

Character	Taxa								
	1	2	3	4	5	6	7	8	9
PET	-.386	.219	-3.358E-02	.276	8.796E-02	.355	.212	-.723	.236
RCD	43.650	43.911	40.419	53.956	52.308	54.863	42.514	50.783	57.693
DBLP	1.340	1.023	1.219	3.226	2.825	3.979	.133	1.524	.809
TLL	-4.382	-4.186	-4.538	-3.588	-1.388	4.094E-02	-4.692	-4.847	-4.369
BTWP	-11.138	-10.990	-10.924	-12.933	-10.265	-9.107	-10.315	-9.787	-11.716
LWR	221.672	226.851	224.712	212.866	161.123	122.343	227.687	216.616	223.108
LS	845.276	899.491	833.708	898.603	846.493	766.728	870.011	813.366	812.204
LMW	.990	.902	1.097	1.289	.660	.418	1.006	1.054	1.183
PED	-350.878	-404.008	-372.910	-376.488	-393.179	-397.526	-316.896	-316.915	-358.656
RCL	67.316	-13.935	57.524	30.284	-88.721	-114.348	-34.334	55.179	38.844
NOL	598.150	763.397	581.347	578.449	797.072	955.919	495.653	592.504	496.161
TLW	1669.480	1717.592	1701.524	1622.903	1137.269	800.603	1730.435	1719.850	1696.751
POLL	4.278	-5.605	-3.502	38.219	-90.706	-74.696	-29.860	-43.964	-4.189
(Constant)	-1769.421	-1869.619	-1782.518	-1781.150	-1204.366	-1169.831	-1611.305	-1834.838	-1679.121

Table 5.9 (continued)

Character	Taxa								
	10	11	12	13	14	15	16	17	18
PET	.237	.174	.233	.155	.429	-.119	.265	-7.074E-02	-3.097E-02
RCD	41.532	41.105	42.101	44.475	48.855	42.865	49.844	42.224	48.976
DBLP	.830	.244	.428	.834	.221	1.665	.950	.802	1.362
TLL	-4.701	-4.147	-4.666	-4.444	-4.754	-4.397	-4.562	-4.343	-4.526
BTWP	-10.737	-10.806	-10.626	-10.937	-10.220	-11.365	-11.732	-11.427	-11.002
LWR	242.461	219.435	224.168	224.702	230.133	219.730	222.375	235.300	228.408
LS	779.999	868.995	838.993	796.043	836.629	867.432	828.649	832.669	848.284
LMW	1.080	.944	1.014	1.050	.944	1.176	1.239	1.119	1.056
PED	-395.106	-389.935	-372.090	-356.105	-316.212	-390.355	-393.363	-383.826	-387.495
RCL	-1.308	19.403	13.109	48.364	-101.545	41.504	52.158	26.663	52.186
NOL	598.193	612.986	572.142	489.889	569.363	702.414	566.968	667.162	597.337
TLW	1731.333	1675.751	1740.572	1673.815	1763.466	1620.507	1718.795	1736.814	1679.617
POLL	-42.073	-12.590	6.382	-18.349	-22.703	-15.635	24.992	-7.306	7.277
(Constant)	-1728.609	-1692.557	-1725.691	-1630.891	-1591.691	-1783.839	-1791.666	-1865.627	-1776.471

Table 5.10 Pooled within canonical structure of 18 categories based on 13 vegetative characters.

Character	Discriminant function							
	1	2	3	4	5	6	7	8
TLW	**.639**	.169	-.239	-.460	-.027	.303	.064	-.421
RCL	.135	**.843**	.113	-.079	-.146	-.009	.063	-.191
NOL	-.371	**.674**	.456	-.021	.046	.256	-.263	.036
DBLP	.232	.389	**-.610**	-.311	-.158	.074	.450	-.011
LWR	-.118	.130	.108	**.514**	-.425	.257	.214	.352
BTWP	.207	.144	-.118	**-.508**	-.134	.320	.430	-.305
PED	.237	.315	-.004	**-.458**	-.160	.251	-.374	.290
POLL	.431	.283	-.216	-.033	**.508**	.041	-.200	.153
TLL	.248	.253	-.423	-.242	-.276	**.501**	.167	-.330
LMW	.256	.278	-.416	-.244	-.230	**.459**	.182	-.197
LS	-.102	-.202	.324	-.419	.435	-.096	**.586**	.121
RCD	.202	.054	-.282	-.374	-.074	.327	-.274	.026
PET	.184	-.048	-.295	.256	.098	.155	.172	-.283

Table 5.10 (continued)

Character	Discriminant Function				
	9	10	11	12	13
TLW	.059	-.084	.024	-.081	.065
RCL	-.067	.114	-.142	.277	.274
NOL	.027	.129	-.107	.094	.152
DBLP	-.136	.133	.150	-.148	.111
LWR	-.368	-.085	-.146	.330	-.066
BTWP	-.351	.055	-.246	.245	-.136
PED	-.090	.077	-.329	.243	.376
POLL	-.496	-.138	-.109	-.030	-.292
TLL	-.185	-.239	-.222	.177	-.039
LMW	-.004	.055	-.453	.190	-.212
LS	.050	.028	-.095	.313	-.039
RCD	-.097	.188	.337	**.611**	-.131
PET	-.070	.477	-.212	.310	**.542**

Note: The number in **bold letter** represent the largest absolute correlation between each variable and any discriminant function

Table 5.11 Summary of canonical discriminant function of 18 categories based on 13 vegetative characters.

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Coorrelation	Wilk's Lambda	Chi-square	df	Sig.
1	64.462	57.4	57.4	.992	.000	8247.861	221	.000
2	20.701	18.4	75.8	.977	.000	6192.666	192	.000
3	11.502	10.2	86.1	.959	.000	4680.152	165	.000
4	7.659	6.8	92.9	.940	.001	3438.697	140	.000
5	3.265	2.9	95.8	.875	.008	2377.722	117	.000
6	1.474	1.3	97.1	.772	.034	1664.878	96	.000
7	1.033	.9	98.0	.713	.084	1219.663	77	.000
8	.857	.8	98.8	.679	.170	870.931	60	.000
9	.508	.5	99.3	.580	.316	566.716	45	.000
10	.340	.3	99.6	.503	.476	364.882	32	.000
11	.216	.2	99.8	.421	.638	221.200	21	.000
12	.164	.1	99.9	.375	.775	125.232	12	.000
13	.109	.1	100.0	.313	.902	50.651	5	.000

Table 5.12 Classification function coefficients of 18 categories based on 32 characters.

Character	Taxa					
	1	2	3	4	5	6
PET	.502	.929	.888	1.137	.554	.893
DBLP	5.306	4.516	5.791	7.865	4.292	6.034
TLL	-3.483	-2.852	-3.462	-2.034	-.703	.389
BTWP	-10.349	-10.750	-10.252	-12.182	-8.963	-7.953
LWR	199.563	205.660	198.269	186.590	152.891	110.952
LS	827.128	904.170	829.891	887.416	809.190	720.898
FLD	2.249	.163	2.870	1.255	8.640E-02	.138
SPL	-4.179	4.620	-3.289	2.577	3.544	7.541
SPW	1.422	4.519	-.561	4.143	2.583	-1.947
PTL	5.592	1.049	8.498	4.111	.524	4.117E-02
PTW	-7.337	-3.555	-6.090	-2.999	-7.706E-02	-.403
PSL	-2.057	-4.974	-5.866	-7.816	-2.721	-4.086
FMD	72.273	78.200	72.761	84.514	27.950	51.036
ATL	-35.855	-32.621	-36.841	-34.526	-8.719	-3.939
ATD	43.671	27.419	56.802	39.225	7.783	8.675
OVD	-42.607	-27.051	-36.847	-37.681	11.277	28.277
STL	-2.846	-2.722	-2.895	.362	3.441	4.802
STD	55.277	37.461	77.058	52.275	16.866	22.929
LPED	-316.343	-373.172	-345.887	-328.439	-344.119	-353.148
LRCL	30.547	-33.666	19.450	-10.848	-128.235	-149.454
LNOL	632.084	777.182	612.144	602.653	802.162	953.082
LTLW	1537.040	1570.984	1543.463	1445.369	1069.714	690.237
LPOLL	-5.515	-4.070	-20.255	42.125	-80.384	-65.776
LBTL	-53.817	-63.562	-84.811	-69.429	-17.915	-.118
LBTW	73.389	43.057	90.148	-14.108	-21.506	22.016
LPCL	363.113	311.846	406.022	367.757	110.269	172.188
LFML	294.266	290.931	291.706	313.111	19.934	-40.606
LOSL	55.487	86.771	94.249	75.717	-48.221	-26.304
LOVL	412.834	353.960	416.390	437.266	93.595	192.807
LFTL	772.260	705.962	812.342	792.797	462.805	563.887
(Constant)	-3569.544	-3299.442	-3956.799	-3681.456	-1561.564	-1806.189

Table 5.12 (continued)

Character	Taxa					
	7	8	9	10	11	12
PET	1.026	.315	1.039	.961	.960	1.084
DBLP	3.159	4.811	3.921	3.898	3.234	4.016
TLL	-4.109	-3.365	-3.050	-3.673	-3.501	-3.941
BTWP	-8.746	-8.583	-10.381	-9.509	-9.478	-9.374
LWR	219.677	196.123	209.635	231.852	210.378	215.405
LS	815.236	791.919	786.995	751.867	832.480	802.640
FLD	.289	-.800	.135	.362	1.474	1.144
SPL	2.853	9.565	8.591	4.646	.900	3.322
SPW	6.687	1.083	5.750	5.653	4.134	7.037
PTL	1.723	1.612	-.229	2.620	2.606	3.036
PTW	-2.318	-1.233	.104	-2.463	-1.680	-2.575
PSL	3.108	3.561	4.456	-6.795	5.566	2.808
FMD	28.067	47.641	63.667	44.293	47.229	49.771
ATL	-11.961	8.638	-11.362	-10.285	-7.952	-9.303
ATD	13.699	51.093	17.457	28.769	16.138	24.722
OVD	-31.252	-3.382	15.737	-17.432	-24.307	-30.823
STL	5.462	10.883	4.194	4.096	.406	9.857
STD	11.800	12.845	44.379	23.253	27.439	.280
LPED	-263.864	-279.413	-292.192	-348.418	-344.131	-323.592
LRCL	-95.104	11.413	-9.448	-56.995	-46.036	-51.729
LNOL	537.570	595.432	493.939	634.471	667.539	628.176
LTLW	1656.199	1525.088	1578.615	1646.455	1605.503	1651.855
LPOLL	-21.657	-43.491	1.459	-42.296	-12.184	11.302
LBTL	-76.596	-3.659	-65.824	-105.755	-61.980	-97.661
LBTW	30.488	133.790	14.433	34.271	83.043	81.330
LPCL	263.149	107.715	214.144	223.179	293.112	293.971
LFML	33.078	-33.198	108.099	113.696	-18.731	-42.240
LOSL	-29.123	-41.767	-65.715	-24.970	28.308	29.763
LOVL	334.610	319.076	218.595	232.725	241.751	345.922
LFTL	655.921	639.497	616.950	575.730	568.016	623.717
(Constant)	-2601.292	-2889.259	-2533.845	-2505.369	-2541.721	-2803.293

Table 5.12 (continued)

Character	Taxa					
	13	14	15	16	17	18
PET	.966	1.145	.833	1.133	.974	.850
DBLP	3.725	2.618	4.991	3.930	4.321	4.741
TLL	-3.373	-4.130	-3.476	-3.441	-3.625	-3.370
BTWP	-9.791	-8.573	-9.844	-9.882	-9.855	-9.796
LWR	211.047	223.469	212.886	211.700	228.609	212.479
LS	774.313	778.495	824.574	772.728	790.666	821.104
FLD	-6.281E-02	.509	.734	.351	.915	.274
SPL	4.180	4.645	5.402	5.737	1.080	.877
SPW	4.773	6.691	6.909	7.896	8.895	6.127
PTL	.930	1.234	1.860	.624	5.340	.451
PTW	-.634	-2.097	-3.425	-2.880	-4.801	-1.354
PSL	2.350	5.609	.938	3.781	13.901	4.118
FMD	39.948	19.324	36.106	38.539	44.130	63.842
ATL	-8.748	-16.951	-1.429	1.148	-15.871	-8.812
ATD	20.789	13.438	38.064	18.677	37.561	32.970
OVD	-13.299	-19.511	-12.471	-7.396	-45.609	5.301
STL	5.415	4.002	11.804	11.945	-3.158E-03	11.193
STD	28.832	20.343	29.808	24.730	81.708	25.246
LPED	-306.500	-255.873	-328.334	-333.487	-338.065	-340.056
LRCL	-.363	-145.706	-31.344	-24.975	-30.996	-11.036
LNOL	505.997	582.984	750.564	613.340	705.655	629.027
LTLW	1563.606	1691.997	1529.759	1621.559	1662.165	1542.994
LPOLL	-15.374	-8.156	-14.519	24.606	-3.845	11.651
LBTL	2.693	-52.856	-45.395	-112.246	-126.870	-52.630
LBTW	68.028	-10.189	135.188	45.060	60.784	44.620
LPCL	183.872	196.414	282.877	300.817	301.372	307.997
LFML	89.604	-23.754	-83.439	9.799	-31.770	107.706
LOSL	-58.815	-47.682	-33.826	-2.172	-3.344	2.850
LOVL	242.329	319.965	265.612	149.861	391.474	203.553
LFTL	581.373	613.894	604.368	648.547	694.396	695.598
(Constant)	-2399.780	-2411.860	-2817.396	-2720.727	-3194.982	-2899.255

Fisher's linear discriminant functions

Table 5.13 Pooled within canonical structure of 32 characters.

Character	Discriminant function							
	1	2	3	4	5	6	7	8
FML	**.518**	-.165	.079	-.476	.013	-.232	-.077	-.142
TLW	.236	**.475**	-.143	-.307	-.060	.199	-.015	.105
ATL	-.029	**.424**	.301	-.145	.201	.069	-.114	-.006
POLL	.219	**.284**	-.059	-.119	.183	.127	.010	.144
PED	.118	**.204**	.122	-.149	-.123	.202	.124	-.005
NOL	-.030	-.227	**.562**	.180	.068	-.027	.444	-.161
BTW	.003	.291	**.510**	-.002	-.241	-.312	-.163	-.023
RCL	.164	.130	**.441**	-.103	.196	.083	.236	-.237
OVL	.348	.138	.019	.152	**-.454**	.293	.130	.046
PCL	.279	.079	.071	.310	**.389**	.008	-.174	.164
DBLP	.151	.132	.087	-.345	.136	**.433**	-.183	.052
LMWa	.111	.150	.035	-.171	.029	**.396**	-.010	-.008
TLL	.126	.162	.005	-.253	.059	**.392**	-.023	-.056
RCDa	.112	.142	-.031	-.132	-.128	**.160**	-.041	.039
FLD	.261	.084	.129	.217	.071	.087	**-.511**	-.178
PTL	.245	.142	.187	.177	-.029	.199	**-.362**	-.248
LWR	-.017	-.099	.070	.088	.166	-.058	.127	**-.420**
STD	.093	.008	.063	.097	.014	.203	.120	**-.247**
FTL	.392	.095	.058	-.038	-.027	.171	.152	.155
OSL	.307	.012	.099	.052	.008	-.180	.207	.344
SPL	.010	.229	.140	-.167	-.006	.201	.239	-.037
BTL	.035	.184	.343	-.245	-.273	-.117	-.274	-.027
BTWP	.090	.168	.042	-.185	-.136	.201	.021	.171
PSL	.062	.137	.085	.093	-.029	.195	.080	-.153
OVD	.020	.023	.110	-.099	.053	.038	.078	.008
PTW	.140	.126	.127	-.041	.043	.122	-.205	-.097
FMD	.059	.071	.096	-.140	.058	-.031	.161	-.051
ATD	.124	.198	.280	-.103	.020	.101	.134	-.099
LS	-.053	-.052	.014	.106	-.278	-.195	.062	.438
PET	.064	.100	-.161	-.104	.184	.077	-.069	-.014
STL	-.021	.223	.205	-.144	.197	-.069	-.231	.297
SPW	.014	.212	.041	.103	.139	.151	.222	-.096

Table 5.13 (continued)

Character	Discriminant function								
	9	10	11	12	13	14	15	16	17
FML	.080	-.077	.066	.097	-.009	-.133	.014	-.012	-.054
TLW	.186	-.100	-.305	-.268	-.053	.024	.132	.016	.026
ATL	.135	-.191	.002	.114	.026	-.337	.111	-.145	.279
POLL	-.079	.171	-.198	-.263	-.041	.107	-.249	.072	.240
PED	-.167	-.048	-.174	-.148	-.161	.026	.062	-.111	.164
NOL	-.118	-.002	-.075	-.097	-.084	.097	-.024	-.021	.115
BTW	.069	.330	.105	.008	-.107	-.169	-.064	.122	-.219
RCL	-.005	-.017	-.139	-.239	.072	-.048	-.011	-.068	.034
OVL	.131	.174	.308	.218	.034	-.089	-.156	-.186	.058
PCL	-.099	.199	.128	.193	.048	-.242	.301	-.196	.099
DBLP	.105	-.066	-.011	-.309	.190	-.010	.115	-.014	.102
LMWa	.165	-.126	-.091	-.072	.068	-.173	.090	.100	.089
TLL	.184	-.137	-.115	-.116	.113	-.181	.040	.094	.091
RCDa	.008	-.067	-.153	-.062	-.043	.004	.040	.109	.065
FLD	.204	.062	-.020	.116	-.134	.205	.030	.009	.117
PTL	.312	-.060	-.114	.188	-.011	.053	.048	.123	-.165
LWR	-.062	-.104	.337	.263	.293	-.130	-.132	.142	.254
STD	-.145	.128	-.147	.124	-.070	.064	.221	.239	-.089
FTL	**-.473**	-.174	-.068	.127	-.058	-.213	.009	.258	-.043
OSL	**.433**	-.201	-.195	-.005	.053	.085	-.154	.317	.028
SPL	**.344**	.262	.141	.158	-.331	.032	.231	.116	-.090
BTL	-.112	**.376**	-.013	-.022	.245	.025	.088	.339	.200
BTWP	.133	**-.222**	-.148	.052	.187	-.141	.152	.031	.064
PSL	-.017	.084	**-.518**	.136	.171	.021	-.129	.036	-.183
OVD	-.060	.110	-.193	**.464**	-.260	.289	.018	.026	.071
PTW	.396	.165	-.049	**.431**	.267	.048	.064	.056	-.123
FMD	.124	.157	-.183	**.419**	-.021	.169	-.235	-.369	.042
ATD	.028	-.328	.057	.179	.069	**.347**	.166	-.001	.096
LS	-.022	-.048	-.080	.141	.245	.079	**.480**	-.216	-.111
PET	.173	.162	.149	.058	-.017	-.167	.048	**.354**	-.007
STL	-.102	-.199	.219	.084	.027	.307	-.226	.132	**-.345**
SPW	.130	.217	.138	.084	.147	.089	.101	-.003	**-.302**

Note: The number in **bold letter** represent the largest absolute correlation between each variable and any discriminant function
a This variable not used in the analysis.

Table 5.14 Summary of canonical discriminant function of 18 categories based on 32 characters.

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Coorrelation	Wilk's Lambda	Chi-square	df	Sig.
1	155.171	42.1	42.1	.997	.000	17515.300	510	.000
2	70.046	19.0	61.1	.993	.000	15075.691	464	.000
3	43.309	11.8	72.9	.989	.000	13016.503	420	.000
4	28.468	7.7	80.6	.983	.000	11185.360	378	.000
5	19.216	5.2	85.8	.975	.000	9551.222	338	.000
6	12.724	3.5	89.3	.963	.000	8099.092	300	.000
7	10.395	2.8	92.1	.955	.000	6834.052	264	.000
8	8.942	2.4	94.5	.948	.000	5658.833	230	.000
9	5.340	1.4	96.0	.918	.000	4549.512	198	.000
10	4.410	1.2	97.1	.903	.001	3657.471	168	.000
11	3.738	1.0	98.2	.888	.003	2842.063	140	.000
12	2.035	0.6	98.7	.819	.013	2090.748	114	.000
13	1.596	0.4	99.1	.784	.040	1554.575	90	.000
14	1.237	0.3	99.5	.744	.104	1093.759	68	.000
15	0.779	0.2	99.7	.662	.232	704.866	48	.000
16	0.708	0.2	99.9	.644	.413	426.693	30	.000
17	0.417	0.1	100.0	.542	.706	168.242	14	.000

Table 5.15 Classification function coefficients of 4 categories according to the result of cluster analysis.

Character	Categories			
	1	2	3	4
PET	1.434	.851	1.390	.694
TLL	-4.159	-2.387	-4.262	-3.987
BTWP	-1.998	-.863	-1.427	-.248
LWR	140.732	76.703	136.204	120.234
FLD	3.847E-02	.801	.561	.141
SPL	11.094	8.006	11.094	13.717
SPW	-.471	-3.761	-2.922	-9.106
PTL	-1.910	-1.645	-3.366	-2.346
PTW	-1.130	1.920	1.341	1.132
PSL	5.998	.734	.869	-.628
ATL	-14.700	-6.744	-6.960	5.777
ATD	-29.423	-35.362	-33.295	-13.880
OVD	-81.099	-30.634	-47.250	-46.209
STL	-21.536	-7.499	-15.429	-18.561
STD	66.698	-1.980	22.525	12.737
PED	-323.282	-295.734	-299.597	-269.949
RCL	-58.152	-53.019	-88.200	-77.659
NOL	622.360	494.407	563.748	563.838
TLW	1226.298	773.724	1162.992	1140.903
POLL	-10.266	-57.912	-16.742	-56.788
BTW	27.219	-17.673	25.410	29.462
PCL	87.683	16.461	79.934	-25.407
FML	48.340	-4.112	16.580	-1.256
OSL	-63.681	-83.446	-81.168	-59.781
OVL	270.693	131.825	210.315	234.612
FTL	418.137	333.396	373.662	394.457
(Constant)	-1800.558	-843.657	-1425.628	-1541.561

Fisher's linear discriminant functions

Table 5.16 Pooled within canonical structure of 4 categories according to the result of cluster analysis.

Character	Discriminant function		
	1	2	3
FTL	**.287**	-.026	-.093
OVL	**.255**	.011	-.110
POLL	**.208**	.146	.098
OSL	**.190**	-.040	-.078
PCL	**.166**	-.086	.121
FML	**.160**	-.072	-.086
PTL	**.147**	.012	-.054
FLD	**.135**	-.036	.013
STD	**.130**	-.082	-.077
FMD[a]	**.127**	.026	-.098
PTW	**.110**	.069	-.027
PSL	**.093**	.071	-.065
DBLP[a]	**.088**	.088	-.058
LS[a]	**-.071**	.027	-.031
ATL	.022	**.297**	.004
TLW	.202	**.282**	.037
PED	.195	**.255**	-.189
BTWP	.123	**.234**	-.163
SPL	.056	**.223**	-.061
STL	-.013	**.192**	.034
ATD	.133	**.175**	-.154
BTW	.026	**.173**	-.069
LMW[a]	.100	**.131**	-.074
RCD[a]	.112	**.121**	-.052
TLL	.109	**.120**	-.084
SPW	.066	**.114**	.085
LWR	-.012	**-.108**	.021
NOL	-.019	-.092	**-.183**
PET	.075	.050	**.176**
BTL[a]	.010	.145	**-.147**
RCL	.111	.058	**-.142**
OVD	.020	.054	**-.067**

Note: The number in **bold** letter represent the largest absolute correlation between each variable and any discriminant function

a This variable not used in the analysis.

Table 5.17 Summary of canonical discriminant function of 4 categories according to the result of cluster analysis.

Function	Eigenvalue	% of Variance	Cumulative %	Canon. Corre.	Wilk's lamda	Chi-square	df	Sig.
1	46.312	60.2	60.2	.989	.000	4627.622	78	.000
2	18.350	23.8	84.0	.974	.004	2730.089	50	.000
3	12.280	16.0	100.0	.962	.075	1272.454	24	.000

Table 5.18 Classification function coefficients of 4 categories according to Manit (2001).

Character	Categories			
	1	2	3	4
PET	.750	.462	.852	.878
DBLP	1.890	2.041	1.190	1.392
TLL	-1.762	3.150E-02	-1.931	-2.077
BTWP	-10.946	-8.984	-9.256	-9.695
LWR	141.804	103.755	155.111	163.625
LS	744.025	667.473	652.105	679.443
LMW	.451	.102	.237	.310
FLD	1.498	.876	.997	.695
SPL	15.169	7.670	11.492	9.982
SPW	-1.675	3.954E-02	-.695	2.050
PTL	-4.799	-2.390	-4.958	-5.176
PTW	-2.751	.564	.628	2.352E-02
PSL	-23.919	-7.859	-13.042	-9.274
FMD	-35.116	-24.191	-20.644	-34.173
ATL	-14.941	-4.082	-2.096	-2.548
ATD	-18.622	-23.518	-22.800	-16.721
STL	-.763	6.933	2.374	4.984
STD	16.770	9.207	9.477	30.822
NOL	401.805	328.576	313.012	346.893
TLW	1028.352	677.624	1001.172	1028.449
POLL	-24.660	-73.207	-34.558	-25.063
BTL	121.293	69.983	102.957	107.791
BTW	-36.960	-68.892	-45.899	-53.278
PCL	177.246	93.373	158.217	188.550
FML	47.086	-51.459	-53.391	-67.500
OSL	9.080	-42.190	-35.788	-41.973
OVL	-7.826	-86.282	-31.652	-71.440
FTL	379.509	333.580	354.772	393.415
(Constant)	-1759.109	-1000.628	-1451.609	-1638.551

Fisher's linear discriminant functions

Table 5.19 Pooled within canonical structure of 4 categories according to Manit (2001).

Character	Discriminant function		
	1	2	3
FML	**.343**	-.065	-.026
FTL	**.326**	.095	.170
OSL	**.263**	.019	.050
OVL	**.211**	.071	-.088
FLD	**.135**	.046	.043
PTL	**.124**	.064	.033
OVD[a]	**.111**	-.022	.079
PTW	**.097**	.081	-.028
DBLP	**.084**	.048	.018
TLW	.140	**.244**	-.146
POLL	.185	**.239**	.038
SPW	-.003	**.224**	.123
ATL	-.028	**.189**	.054
PED[a]	.098	**.138**	.067
SPL	.014	**.126**	-.036
PET	.052	**.115**	-.074
STL	-.020	**.109**	.075
PSL	.038	**.104**	.082
LMW	.082	**.097**	-.002
BTWP	.076	**.094**	-.085
RCD[a]	.062	**.088**	-.058
TLL	.080	**.087**	-.025
BTW	.011	**.079**	.001
FMD	.064	**.068**	-.004
BTL	.032	**.052**	-.047
NOL	-.003	-.118	**.278**
RCL[a]	.111	.077	**.218**
PCL	.160	.086	**.216**
STD	.091	.026	**.175**
LWR	-.025	-.034	**.159**
ATD	.088	.110	**.114**
LS	-.027	-.058	**-.073**

Note: The number in **bold letter** represent the largest absolute correlation between each variable and any discriminant function

a This variable not used in the analysis.

Table 5.20 Summary of canonical discriminant function of 4 categories according to Manit (2001).

Function	Eigenvalue	% of Variance	Cumulative %	Canon. Corre.	Wilk's lamda	Chi-square	df	Sig.
1	41.599	56.3	56.3	.988	.000	4490.673	84	.000
2	24.665	33.4	89.7	.980	.005	2648.519	54	.000
3	7.576	10.3	100.0	.940	.117	1055.168	26	.000

Table 5.21 Classification function coefficients of 3 categories according to Irwin and Baneby (1981).

Character	Categories		
	1	2	3
PET	.958	.700	1.078
DBLP	.767	.919	5.448E-02
TLL	-.370	1.444	-.501
BTWP	-9.300	-7.634	-7.832
LWR	96.878	63.211	113.370
LS	672.146	610.881	592.206
LMW	-3.872E-02	-.372	-.253
FLD	2.520	1.776	1.922
SPL	14.307	7.040	10.714
PTL	-4.389	-2.162	-4.791
PTW	-2.527	1.073	1.213
PSL	-37.829	-21.386	-26.573
ATL	-16.933	-6.445	-4.351
OVD	3.337	16.197	16.576
STL	-9.582	-1.826	-6.434
NOL	237.059	169.929	153.073
TLW	852.139	515.852	836.349
POLL	-47.060	-88.718	-51.383
BTL	110.170	56.813	89.317
BTW	1.011	-29.924	-6.354
PCL	74.595	2.770	64.491
FML	117.562	8.322	11.163
OSL	23.990	-27.575	-21.085
OVL	80.610	-4.122	50.745
FTL	229.758	189.042	208.413
(Constant)	-1386.445	-680.913	-1120.097

Fisher's linear discriminant functions

Table 5.22 Pooled within canonical structure of 3 categories according to Irwin and Baneby (1981).

Character	Discriminant function	
	1	2
FML	**.341**	-.064
FTL	**.289**	.072
OSL	**.261**	.014
OVL	**.208**	.077
PCL	**.135**	.058
FLD	**.134**	.043
PTL	**.123**	.061
FMD[a]	**.104**	.021
RCL[a]	**.098**	.047
PTW	**.098**	.084
DBLP	**.084**	.047
STD[a]	**.071**	.020
OVD	**.025**	.012
TLW	.137	**.253**
POLL	.179	**.230**
SPW[a]	.060	**.185**
ATL	-.027	**.180**
SPL	.015	**.131**
PED[a]	.093	**.124**
PET	.052	**.122**
NOL	-.002	**-.118**
BTWP	.076	**.101**
STL	-.019	**.100**
ATD[a]	.066	**.098**
LMW	.082	**.098**
PSL	.037	**.094**
RCD	.050	**.093**
TLL	.080	**.090**
BTW	.011	**.080**
BTL	.032	**.056**
LS	-.026	**-.052**
LWR	-.023	**-.044**

Note: The number in **bold letter** represent the largest absolute correlation between each variable and any discriminant function

a This variable not used in the analysis.

Table 5.23 Summary of canonical discriminant function of 4 categories according to Irwin and Baneby (1981).

Function	Eigenvalue	% of Variance	Cumulative %	Canon. Corre.	Wilk's lamda	Chi-square	df	Sig.
1	41.387	63.8	63.8	.988	.001	3424.733	50	.000
2	23.529	36.2	100.0	.979	.041	1577.539	24	.000

Table 5.24 Means and standard deviation of 32 quantitative characters of the 18 taxa of *Cassia* s.l.

Charac ter	Taxa							
	C. javanica		*C. grandis*		*C. bakeriana*		*C. fistula*	
	mean	± SD	mean	± SD	mean	± SD	mean	± SD
PET	17.9483	3.7670	28.8187	7.4970	39.2683	12.2479	60.2190	8.0531
PED	2.5637	.4687	1.6080	.2234	2.0900	.3988	2.6527	.3399
RCL	264.4693	47.0217	203.0533	33.0136	247.3539	50.2431	239.3083	46.8152
RCD	.9443	.1348	.7427	.1371	.9717	.1390	1.7023	.1297
DBLP	22.8783	2.9254	10.6033	2.3224	29.5533	6.6199	57.2290	5.7519
NOL	12.1000	2.2027	16.2667	1.9815	8.6111	1.3346	5.4000	.6215
TLL	59.5030	7.3514	45.9550	5.9666	85.0172	9.0217	140.5913	20.2953
TLW	22.7790	2.3367	16.3147	2.5095	33.4989	7.7993	63.9587	9.0049
BTWP	30.6700	5.0718	31.1293	5.2057	44.2461	9.2030	55.9093	10.7640
LWR	2.6210	.2717	2.8333	.2195	2.6528	.5902	2.2113	.2409
LS	.5183	7.580E-02	.6753	4.732E-02	.5178	8.558E-02	.3987	5.544E-02
LMW	123.1027	13.6515	95.8010	11.1662	177.3050	17.6908	289.2843	39.8056
POLL	2.7610	.4906	1.6367	.2812	2.5072	.5297	6.2037	1.1583
FLD	62.5473	7.0642	24.7210	2.3055	87.5828	3.8396	60.9720	5.6153
BTL	7.3803	1.2109	4.0257	.9983	8.2122	.6591	4.6223	.3809
BTW	2.3487	.5618	1.3100	.3190	3.2161	.6779	.4580	5.653E-02
PCL	36.3750	5.1114	17.8663	2.1550	67.6633	6.3335	48.9927	8.8714
SPL	5.7910	.4246	9.9547	.6114	8.6172	.6156	10.3837	.9475
SPW	3.1490	.2373	5.6520	.6698	4.7467	.5033	6.2733	.6817
PTL	28.6997	3.0465	13.9367	.9098	43.3983	1.4831	29.7020	3.2191
PTW	12.5877	1.5754	10.8667	.6216	22.6722	.7738	19.4477	2.5470
PSL	2.3020	.4858	1.5797	.3033	2.7644	.5671	2.0203	.4149
FML	34.8927	2.8884	25.1323	2.4371	51.9944	2.8478	45.7960	4.8089
FMD	.6547	7.619E-02	.9373	.1318	.6900	.1134	.7243	.1361
ATNL	3.7963	.3689	2.6420	.2590	5.1839	.2223	4.7683	.2443
ATND	2.3243	.1739	2.0843	.2102	2.9622	.1875	2.4837	.1618
OSL	6.4277	.7121	12.8187	1.1581	15.2017	1.4141	9.2673	1.9492
OVL	25.8117	2.3280	18.4770	1.2135	34.5972	1.7297	31.7597	3.6086
OVD	.8907	9.322E-02	1.0380	.1232	1.1339	.1096	.9030	.1190
STL	2.6860	.3420	1.3450	.2519	4.1650	.5323	3.3590	.5903
STD	.6433	8.108E-02	.5500	9.067E-02	.7878	.1154	.6403	.1191
FTL	465.3970	73.1107	282.1187	52.5810	558.3861	54.7364	486.7637	39.5812

Table 5.24 (continued)

Character	Taxa							
	C. pumila		*C. leschenaultiana*		*C. obtusifolia*		*C. alata*	
	mean	± SD	mean	± SD	mean	± SD	mean	± SD
PET	4.1553	.5152	2.9440	.4259	38.3947	4.1869	19.3857	7.6918
PED	.4653	8.577E-02	.5510	2.514E-02	1.3920	.2385	5.6000	1.4663
RCL	34.1950	4.6175	63.4240	4.0985	32.5540	7.1091	414.2700	117.1687
RCD	.1970	5.305E-02	.1450	2.224E-02	1.0493	.2197	1.7527	.3691
DBLP	1.9433	.2831	.9340	.1092	12.9480	2.9353	39.5687	6.6074
NOL	14.9667	1.5196	42.2000	3.0478	3.0000	.0000	11.0000	1.4622
TLL	6.3397	1.1341	2.6650	.4516	54.1180	9.7317	116.7200	15.4636
TLW	2.0680	.3844	.7430	.1645	27.4780	5.1886	70.9963	11.2529
BTWP	4.3590	.8647	1.6740	.5025	39.3867	6.2630	72.1327	9.4398
LWR	3.0967	.3723	3.7640	1.0768	1.9753	.1197	1.6530	.1079
LS	.6877	7.070E-02	.6180	.1087	.7393	6.080E-02	.6190	2.857E-02
LMW	12.4857	2.3449	5.5220	.7375	117.7363	9.1037	239.2397	33.0390
POLL	.1813	5.002E-02	.1530	2.263E-02	1.4817	.3027	2.1223	.3201
FLD	9.3323	1.1470	15.0420	2.2560	27.7647	2.2323	28.0180	2.9703
BTL	2.1370	.4223	3.5070	.6067	3.3333	.4283	25.5490	2.7011
BTW	.3497	7.744E-02	1.1110	.2044	.8907	.2096	14.4513	2.6558
PCL	3.9920	.8497	8.7110	1.1380	18.0667	3.0836	5.5370	1.1243
SPL	4.2340	.6699	7.3320	.9838	7.6057	.6951	15.1107	1.0014
SPW	1.5023	.2931	2.1150	.5872	5.5953	.7239	7.1097	1.1262
PTL	4.7647	.6184	7.5210	1.1280	14.4263	1.2565	22.1603	1.3465
PTW	3.9320	.8447	6.3460	.7693	9.5113	1.0312	15.9633	1.6884
PSL	.5483	.1535	.7220	.1798	1.3333	.2422	3.0263	.7885
FML	1.5680	.3558	1.3230	.2453	3.4987	.4317	4.5043	.4513
FMD	.1577	2.991E-02	.3990	8.660E-02	.3230	7.278E-02	.9783	.1612
ATNL	1.5163	.3806	2.8440	.3707	4.8710	.4392	10.6760	.5666
ATND	.6290	8.946E-02	.7150	5.421E-02	1.3130	.1670	3.5880	.2599
OSL	.5100	.1558	.5000	.1082	1.5390	.3210	2.2693	.4472
OVL	2.5627	.5004	4.9640	.4402	15.4320	2.2961	14.6493	1.4531
OVD	.7087	7.262E-02	1.1530	.1365	.6133	6.509E-02	1.1897	.1752
STL	1.4970	.2615	2.0690	.4517	3.2143	.4059	7.0460	.5571
STD	.2907	5.777E-02	.4660	7.260E-02	.3400	5.079E-02	.4400	4.472E-02
FTL	34.3277	4.5550	60.4030	6.3781	170.1237	9.6868	160.5467	13.4859

Table 5.24 (continued)

Character	Taxa							
	C. hirsuta		*C. sophera*		*C surattensis* subsp. *surattensis*,		*C. surattensis* subsp. *glauca*	
	mean	± SD	mean	± SD	mean	± SD	mean	± SD
PET	52.0317	13.9899	43.1267	6.6956	31.3660	6.9106	39.4407	5.5660
PED	1.9577	.3460	1.0323	.2593	1.1040	.2286	1.4653	.2275
RCL	103.3653	22.7334	98.1573	27.0585	100.2567	27.2985	96.2477	18.8470
RCD	1.4823	.2276	.6260	.1487	.6060	.1381	.9463	.1339
DBLP	28.1123	4.5499	15.4550	2.8482	8.8947	4.1698	18.5687	2.7261
NOL	4.4000	.6215	6.6667	1.3476	7.9333	1.0483	5.6000	.5632
TLL	89.9603	10.2521	62.4183	12.7502	41.9237	9.5320	62.0793	14.3946
TLW	38.0887	4.2370	15.6080	3.6783	17.5380	3.4563	31.8403	4.3134
BTWP	33.0470	5.2410	24.1817	4.0974	27.1247	5.6990	36.8427	7.6258
LWR	2.3660	.1544	4.0497	.4283	2.3853	.2150	1.9353	.2284
LS	.3670	3.621E-02	.3923	4.329E-02	.6510	4.528E-02	.5963	4.972E-02
LMW	184.1030	22.8696	125.2863	23.5251	86.5903	19.1784	128.8160	29.0943
POLL	2.6420	.5399	.9823	.2141	1.4723	.2598	2.6933	.7189
FLD	32.1517	2.6381	34.6063	1.9576	48.7770	4.3050	49.0200	7.9910
BTL	4.4683	.8363	2.6197	.3212	5.6960	1.2797	4.4827	1.1734
BTW	.8033	.1898	.8367	.2250	2.9090	.6911	2.8760	.6171
PCL	12.2417	1.4974	12.2763	1.9879	24.5413	2.2681	25.7723	4.6010
SPL	12.0130	.9169	9.1597	.6285	8.5873	.5429	10.6873	1.4963
SPW	7.2460	.9363	5.9620	.6219	6.4147	.4321	8.5460	1.1467
PTL	16.6887	1.0299	17.8107	.9974	23.7863	2.2915	24.9670	4.1617
PTW	14.3303	1.5530	11.9283	1.0214	15.4187	1.4672	16.1630	1.9822
PSL	2.4167	.3538	.7717	.1533	2.5823	.3912	2.3090	.4737
FML	6.6480	.7773	6.9700	.4571	2.9757	.4698	3.0623	.7582
FMD	1.0487	.1906	.5980	.1570	.6477	.1518	.7233	.1530
ATNL	5.9030	.5904	5.8480	.2975	6.2057	.4686	6.7937	.7532
ATND	1.8227	.2837	2.1190	.1212	1.5753	.2468	2.1133	.1808
OSL	.9293	.1338	1.7303	.3101	3.1987	.5159	4.5523	.8918
OVL	8.4823	.4908	8.2680	.9317	9.5410	1.4002	16.8630	2.2700
OVD	1.2557	.1982	.7540	.1034	.8430	9.820E-02	.8583	.1279
STL	3.1200	.6328	3.3567	.2650	2.7173	.4791	5.9710	.8408
STD	.5743	7.238E-02	.3767	8.470E-02	.4417	5.180E-02	.3670	5.914E-02
FTL	126.3293	11.1319	96.5333	5.4048	89.5260	11.5259	132.9107	14.7112

Table 5.24 (continued)

Character	Taxa							
	C. occidentalis		*C. tora*		*C. garrettiana*		*C. timoriensis*	
	mean	± SD	mean	± SD	mean	± SD	mean	± SD
PET	46.8740	7.4116	37.0480	4.3929	23.3590	2.7670	49.3690	10.6503
PED	1.4737	.1660	1.4507	.3216	1.7663	.3419	1.8233	.2946
RCL	102.9940	13.5287	20.4943	3.0764	280.6297	38.7155	180.9533	46.2314
RCD	.9663	.1582	1.2500	.3278	.5500	.1246	1.1870	.1782
DBLP	24.7513	3.3582	7.9357	1.3606	15.2650	1.8171	28.5543	4.5106
NOL	4.7333	.4498	3.0000	.0000	18.7333	1.7006	6.6667	1.1842
TLL	72.7197	12.9168	47.4667	4.5344	35.5723	5.0030	83.7990	12.7555
TLW	26.4960	4.8730	25.9853	2.9267	11.1113	1.5059	38.4690	6.8025
BTWP	31.2603	6.9226	31.0370	2.7420	20.1950	3.1052	34.1723	5.2078
LWR	2.7553	.2448	1.8330	9.802E-02	3.2027	.1429	2.2047	.2927
LS	.4307	5.024E-02	.6563	3.508E-02	.5677	4.057E-02	.4097	4.529E-02
LMW	145.5890	26.4529	98.9013	9.2555	100.9373	13.0597	180.8643	25.6999
POLL	1.7993	.3834	1.6313	.3361	1.3577	.1816	3.9507	.7307
FLD	33.1937	3.9686	22.9643	2.7591	42.3380	4.2176	32.2980	3.9499
BTL	13.4340	2.6221	2.8543	.6339	11.2240	1.8919	2.9697	.7450
BTW	3.5130	.6729	.4250	.1256	10.1037	1.9536	1.0927	.2203
PCL	9.3737	1.9902	8.1233	1.7564	26.5847	3.3168	25.7860	4.7678
SPL	9.7383	.7787	7.7393	.7995	11.8537	.8552	9.9510	1.2354
SPW	5.8493	.6022	5.1877	.6903	9.3990	1.9094	7.3183	1.1674
PTL	17.6523	1.6345	11.2687	.8133	20.7720	1.9577	15.8373	1.8920
PTW	13.7867	2.0213	6.4863	.6041	12.8910	1.5072	9.6637	1.9531
PSL	1.7967	.4832	1.6567	.2780	1.8800	.3375	1.9403	.2652
FML	6.4820	.5819	1.8730	.2210	2.0463	.3402	3.5797	1.0401
FMD	.5680	.1043	.2633	4.999E-02	.5940	9.291E-02	.5230	.1117
ATNL	6.1807	.5394	2.8040	.3351	8.1457	.5319	8.1080	1.0375
ATND	1.5930	.1694	1.1363	.1265	2.6390	.2641	2.0587	.3166
OSL	.9973	.2844	1.2433	.3417	1.1520	.2337	2.4773	.5380
OVL	8.4880	1.0724	12.7567	1.4577	9.8777	1.1493	5.0187	1.1173
OVD	.7653	.1046	.7700	8.749E-02	1.0100	9.653E-02	.8983	.2396
STL	4.2737	.4592	1.9017	.2331	6.4427	1.4265	6.3100	1.0730
STD	.4110	7.836E-02	.4453	8.997E-02	.5710	9.474E-02	.4247	.1011
FTL	104.1227	7.5596	128.8970	18.8503	114.1463	7.6405	165.9977	34.3652

Table 5.24 (continued)

Character	Taxa					
	C. spectabilis		*C. siamea*		Total	
	mean	± SD	Mean	± SD	mean	± SD
PET	30.9720	5.0199	34.5880	5.8812	34.3488	15.8693
PED	2.3280	.3329	1.6983	.1990	1.8791	1.1737
RCL	270.4773	44.2274	210.8980	36.5662	166.6463	113.8679
RCD	.9500	.1237	1.0153	.1596	.9803	.4494
DBLP	18.9150	3.8738	25.2487	4.6244	20.9595	13.6512
NOL	13.3000	1.5790	9.1333	1.1366	9.5748	6.6774
TLL	84.9980	11.3263	68.0293	9.6757	66.3834	33.5210
TLW	23.7437	2.7227	21.7660	2.9912	28.0269	18.0539
BTWP	34.5537	4.8571	37.2640	6.2439	33.6833	15.8714
LWR	3.6013	.4762	3.1410	.3331	2.6404	.7260
LS	.4097	4.279E-02	.5477	5.029E-02	.5423	.1293
LMW	172.6240	21.0746	143.8710	20.8645	138.9836	67.4501
POLL	2.1837	.4689	2.6907	.6651	2.2054	1.4173
FLD	47.3553	3.4241	35.5307	3.8979	38.3359	17.0943
BTL	2.7163	.3897	6.1527	.9504	6.4820	5.7953
BTW	1.0953	.1955	1.5417	.5010	2.7936	3.7845
PCL	27.7060	3.4138	27.5550	4.4476	22.1038	14.9464
SPL	10.3463	.8594	8.0153	1.1795	9.3771	2.5822
SPW	10.4760	.8577	6.4010	1.6420	6.2383	2.3330
PTL	28.6510	1.9669	17.6127	2.0538	19.9182	8.2733
PTW	14.4870	1.8234	14.0833	2.2545	12.8306	4.4708
PSL	4.1830	.3981	2.3253	.4630	2.0416	.9297
FML	2.7987	.3474	8.3720	1.2290	11.3290	14.8525
FMD	.6253	.1552	.9290	.2879	.6403	.2782
ATNL	5.8820	.5335	7.2163	.6082	5.6348	2.2861
ATND	2.5287	.2520	2.6370	.4384	2.0469	.7454
OSL	2.3413	.3543	3.0357	.5916	3.7664	3.9701
OVL	22.4433	1.5754	7.3670	1.1772	14.1857	8.6736
OVD	.8533	.1048	1.1913	.1988	.9217	.2240
STL	1.3237	.1692	6.7217	1.1278	3.8075	2.0390
STD	.9080	.1018	.4827	.1118	.5040	.1742
FTL	243.1440	41.4154	232.7633	31.3960	200.1268	143.3869

Table 5.25 Means and standard deviation of 32 quantitative characters of the 3 taxa of *Cassia* s.l. according to Irwin and Barneby (1981)

Character	Taxa						Total	
	Cassia s.s.		*Chamaecrista*		*Senna*			
	mean	± SD	mean	± SD	mean	± SD	mean	± SD
PET	36.2631	18.2345	3.8525	.7221	37.1629	11.9930	34.3488	15.8693
PED	2.2440	.5679	.4868	8.383E-02	1.9243	1.2612	1.8791	1.1737
RCL	237.5676	49.4325	41.5023	13.5656	159.2748	119.3745	166.6463	113.8679
RCD	1.1034	.4059	.1840	5.222E-02	1.0318	.3974	.9803	.4494
DBLP	30.1230	18.6362	1.6910	.5082	20.3514	9.6249	20.9595	13.6512
NOL	10.8148	4.5388	21.7750	12.1032	7.8472	4.5691	9.5748	6.6774
TLL	82.5166	40.2344	5.4210	1.8974	68.3171	24.6552	66.3834	33.5210
TLW	34.2088	20.2352	1.7368	.6736	29.0934	15.7664	28.0269	18.0539
BTWP	40.0712	13.4028	3.6878	1.4144	35.0998	13.6913	33.6833	15.8714
LWR	2.5715	.4019	3.2635	.6755	2.5919	.7743	2.6404	.7260
LS	.5286	.1224	.6703	8.589E-02	.5322	.1280	.5423	.1293
LMW	170.7142	81.9850	10.7447	3.6797	143.7132	47.5668	138.9836	67.4501
POLL	3.3627	1.9539	.1743	4.618E-02	2.0839	.9063	2.2054	1.4173
FLD	55.7750	22.0650	10.7597	2.9021	36.1681	9.2589	38.3359	17.0943
BTL	5.8210	1.9303	2.4795	.7606	7.1250	6.6278	6.4820	5.7953
BTW	1.6795	1.0800	.5400	.3544	3.3782	4.3109	2.7936	3.7845
PCL	39.9533	18.1242	5.1718	2.2624	18.6303	8.7829	22.1038	14.9464
SPL	8.6944	2.0158	5.0085	1.5501	10.0673	2.2803	9.3771	2.5822
SPW	4.9784	1.3593	1.6555	.4644	7.1254	1.8723	6.2383	2.3330
PTL	27.3270	10.0861	5.4537	1.4280	19.3028	5.0911	19.9182	8.2733
PTW	15.6959	4.9002	4.5355	1.3371	12.8928	3.2766	12.8306	4.4708
PSL	2.1002	.5917	.5918	.1755	2.1851	.9258	2.0416	.9297
FML	38.0605	10.5138	1.5068	.3458	4.4009	2.1751	11.3290	14.8525
FMD	.7584	.1626	.2180	.1166	.6518	.2752	.6403	.2782
ATL	3.9769	1.0043	1.8483	.6917	6.5528	1.9388	5.6348	2.2861
ATD	2.4082	.3427	.6505	8.973E-02	2.0937	.7001	2.0469	.7454
OSL	10.4541	3.4854	.5075	.1441	2.1222	1.1345	3.7664	3.9701
OVL	26.8907	6.5333	3.1630	1.1575	11.5989	4.9568	14.1857	8.6736
OVD	.9756	.1450	.8198	.2149	.9169	.2398	.9217	.2240
STL	2.7469	1.0880	1.6400	.4011	4.3666	2.0799	3.8075	2.0390
STD	.6406	.1262	.3345	9.803E-02	.4819	.1666	.5040	.1742
FTL	435.9197	114.9881	40.8465	12.4728	147.0867	52.0012	200.1268	143.3869

Table 5.26 Comparision of 13 qualitative morphological characters of the *Cassia* s. l.

Character	*C. javanica*	*C. grandis*	*C. bakeriana*	*C. fistula*	*C. pumila*	*C. leschenaultiana*	*C. obtusifolia*	*C. alata*	*C. hirsuta*
Habit	tree	tree	tree	tree	smallshrub	smallshrub	undershrub	shrub	undershrub
Branches	glabrous	glabrous	hairy	glabrous	pubescent	pubescent	glabrous	pubescent	hirsute
Upper leaf surface	pubescent	glossy	hairy	glossy	glossy	glossy	glossy	glossy	hirsute
Foliar gland	absence	absence	absence	absence	presence	presence	presence	absence	presence
Inflorescence	raceme, lateral	raceme, lateral	raceme, lateral	raceme, axillary	few, axillary	few, axillary	raceme, axillary	raceme, axillary	raceme, axillary
Petals color	red	pink	pink	yellow	yellow	yellow	yellow	yellow	yellow
Staminode	absence	absence	absence	absence	absence	absence	presence	absence	absence
Filament	long, recurved	medium, recurved	long, recurved	long, recurved	very short	very short	medium, straight	medium, straight	medium, straight
Enlargement at middle of filament	presence	absence	presence	absence	absence	absence	absence	absence	absence
Anther opening	pore, slit	pore, slit	slit	pore, slit	pore, slit	pore	pore	pore	Pore
Ovary	pubescent	tomentose	pubescent	velutinous	tomentose	tomentose	pubescent	glabrous	hirsute
Style	pubescent	pubescent	pubescent	glabrous	glabrous	glabrous	glabrous	glabrous	glabrous
Pods	terete, glabrous	cylindrical, glabrous	terete, pubescent	terete, glabrous	flat, glabrous	flat, glabrous	terete, glabrous	winged, glabrous	terete, hirsute

Table 5.26 (continued)

Character	*C. sophera*	*C surattensis* subsp. *surattensis*,	*C. surattensis* subsp. *glauca*	*C. occidentalis*	*C. tora*	*C. garrettiana*	*C. timoriensis*	*C. spectabilis*	*C. siamea*
Habit	shrub	shrub	shrub	undershrub	undershrub	tree	tree	tree	tree
Branches	glabrous	puberulous	puberulous	glabrous	glabrous	puberulous	pubescent	pubescent	pubescent
Upper leaf surface	glossy	glossy	glossy	glossy	glossy	glossy	glossy	glossy	glossy
Foliar gland	presence	presence	presence	presence	presence	absence	absence	absence	absence
Inflorescence	corymb, axillary	raceme, axillary	raceme, axillary	few, terminal	raceme, axillary	raceme, terminal	raceme, axillary	raceme, terminal	panicle, terminal
Petals color	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow
Staminode	absence	absence	absence	absence	presence	absence	absence	absence	absence
Filament	medium, straight	medium, straight	medium, straight	medium, straight	medium, straight	medium, straight	medium, straight	medium, straight	medium, straight
Enlargmant at midle	absence	absence	absence	absence	absence	absence	absence	absence	absence
Anther opening	pore	slit	slit	pore	pore	pore	pore	pore, slit	pore
Ovary	pubescent	puberulous	puberulous	tomentose	pubescent	glabrous	glabrous	pubescent	pubescent
Style	glabrous	glabrous	glabrous	glabrous	glabrous	glabrous	glabrous	glabrous	glabrous
Pods	swollen, glabrous	flat, glabrous	flat, glabrous	swollen, glabrous	terete, glabrous	flat, glabrous	flat, glabrous	terete, glabrous	flat, glabrescent

Table 6.1 Summary of canonical discriminant function of 12 species of *Cassia* (*Senna*).

Function	Eigenvalue	% of Variance	Cumulative %	Canon. Corre.	Wilk's lamda	Chi-square	df	Sig.
1	57.691	31.0	31.0	.991	.000	8957.546	319	.000
2	40.527	21.8	52.7	.988	.000	7579.077	280	.000
3	28.976	15.6	68.3	.983	.000	6317.707	243	.000
4	17.180	9.2	77.5	.972	.000	5166.675	208	.000
5	14.369	7.7	85.2	.967	.000	4184.913	175	.000
6	8.164	4.4	89.6	.944	.000	3260.003	144	.000
7	6.967	3.7	93.3	.935	.001	2510.133	115	.000
8	5.670	3.0	96.4	.922	.005	1807.651	88	.000
9	3.190	1.7	98.1	.873	.032	1165.307	63	.000
10	2.189	1.2	99.3	.829	.134	680.336	40	.000
11	1.340	.7	100.0	.757	.427	287.755	19	.000

BIOGRAPHY

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