Morphometric Relationships among Three Populations of *Afgekia sericea* Craib (Fabaceae) in Thailand

Thaweesakdi Boonkerd[1]

This study examines morphological variation among three populations of *Afgekia sericea*, which grows wild in N.E. Thailand. Fifteen characters of both vegetative and reproductive parts were examined in 400 specimens using univariate and multivariate analyses. Cluster analysis and canonical discriminant analysis did not result in recognizable grouping of OTUs on a population basis. However, the standard size of the typical papilionaceous flower-form of the bean family tends to be useful as a diagnostic character for population-diversity study.

Key words: Morphometric analyses, *Afgekia sericea*, populations.

[1] *Department of Botany, Faculty of Science, Chulalongkorn University, Bangkok 10330, Thailand.*

ความสัมพันธ์ด้านมอร์โฟเมตริกระหว่างสามประชากรของถั่วแปบช้าง ในประเทศไทย

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ได้ตรวจสอบความแปรผันทางสัณฐานระหว่างสามประชากรของถั่วแปบช้าง ซึ่งเป็นพืชที่พบขึ้นตามธรรมชาติในภาคตะวันออกเฉียงเหนือ ของประเทศไทย โดยการวิเคราะห์ตัวแปรตัวเดียวและตัวแปรพหุคูณจากส่วนที่ไม่เกี่ยวกับเพศและส่วนที่เกี่ยวกับเพศ 15 ลักษณะ จำนวน 400 ตัวอย่าง ผลการวิเคราะห์การจัดกลุ่มและการวิเคราะห์การจัดจำแนกไม่สามารถแยกประชากรทั้งสามจากกันได้ อย่างไรก็ตามขนาดของกลีบกลางของดอกมีแนวโน้มว่าจะเป็นลักษณะที่มีประโยชน์ที่จะใช้ในการทำรูปวิธานจำแนกประชากรของถั่วแปบช้างได้

คำสำคัญ การวิเคราะห์ทางสัณฐาน ถั่วแปบช้าง ประชากร

INTRODUCTION

The genus *Afgekia*, a member of the bean family (Fabaceae), was established by W.G. Craib in 1927, in honor of Dr. A.F.G. Kerr, who was a distinguished plant taxonomist for the Flora of Thailand Project (Craib, 1925-1931). *Afgekia* was a monotypic genus since the finding of *Afgekia sericea* Craib was based on a collection from Nakhon Ratchasima, N.E. Thailand. It was also a species endemic to Thailand until recently it was reported from Ha Giang, Vietnam (Missouri Botanical Garden, 2000). An additional endemic species, *A. mahidolae* Burtt & Chermsirivathana was found on a limestone hill in Kanchanaburi which is about 320 km west of the habitat of *A. sericea*. Burtt & Chermsirivathana (1971) also noted that the whole breadth of the Chao Phraya River separates the two species. A third species, *A. filipes* (Dunn) R. Geesink was transferred from *Adinobotrys filipes* Dunn by Geesink (1984). It is distributed from south China to northern Thailand. So far, these three species of *Afgekia* have their own limited distribution in Thailand.

Afgekia sericea Craib is a perennial climber on trees, usually at or near the margins of dry dipterocarp forest at low and medium altitudes, and in Thailand it is apparently confined to the Korat Plateau of N.E. Thailand. It became a rare species due to fragmentation of its natural habitats by increasing needs of land for agricultural purposes, housing and road construction. So far, only one population is in the protected area of the Sakaerat Research Experiment Station in Nakhon Ratchasima Province (Figure 1). As a member of Fabaceae, *Afgekia sericea* has papilionate flowers with two lips: the upper lip, the 'standard,' is formed by an adaxial petal, and the lower lip is formed by the other four petals, which also enclose the androecium and gynoecium. The stamens are collectively the androecium, and each stamen typically consists of a slender filament bearing the pollen-containing anther. The pistils collectively are the gynoecium. Each pistil consists of a stigma, an elongate style, and an ovary. The androecium and gynoecium are usually hidden in the 'keel' formed by the two abaxial petals, while the two lateral petals, the 'wings,' are often in some way laterally connected with the keel (Lawrence, 1963).

A preliminary study of this species detected some variations in dimensions of leaves and floral parts among samples collected from different sites. The purpose of this investigation was to determine quantitatively the levels of morphological variation among three populations of *Afgekia sericea*, and to evaluate the taxonomic status of these three populations based on statistical analyses of the morphologies, before they are probably wiped out from the remnants of their natural habitat in the near future.

MATERIALS AND METHODS

Plant material

Field-collected specimens from 400 individuals were selected from three sites in N.E. Thailand. Two populations of *Afgekia sericea* were sampled from the Sakaerat Research Experiment Station, Pak Thong Chai District and a population along highway 201 in Sekeaw District, Nakhon Ratchasima province. Another population was taken from Thepsathit District in Chaiyaphum province (Figure 1). Great care was taken to avoid damage to the main population.

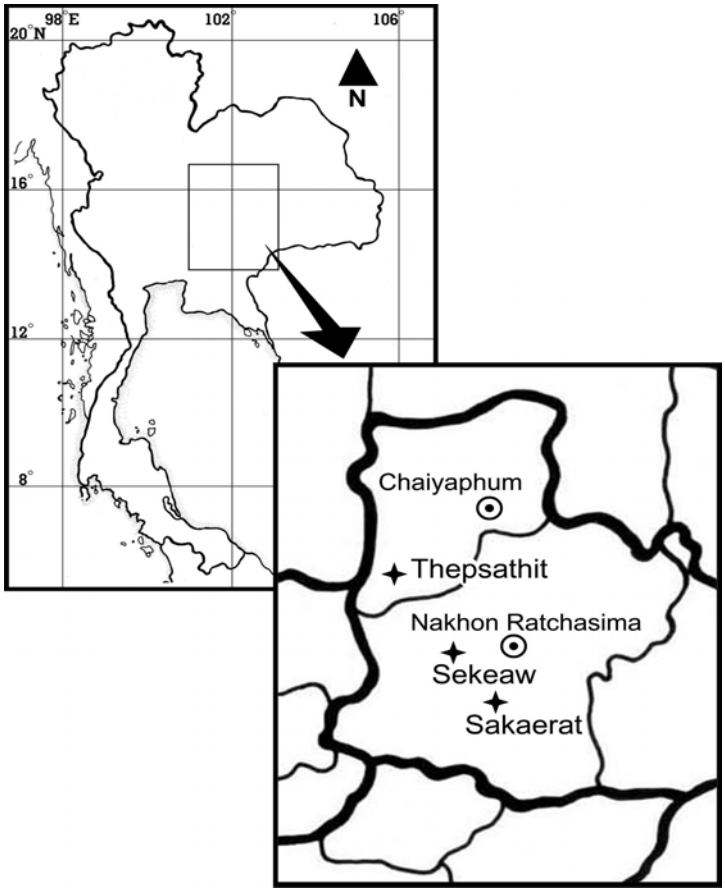

Figure 1. Map showing the location of three collecting sites of *Afgekia sericea*.

Data Collection and Numerical Analysis

Seven vegetative and eight reproductive characters were used to examine patterns of variation among and within these three populations of *Afgekia sericea* (Table 1).

To determine the contribution of morphological characters to the variation of these three populations, 15 characters were analyzed by cluster analysis using the average taxonomic distance among the 400 specimens (Rohlf and Sokol, 1965). A sequential, agglomerative, hierarchical and nested (SAHN) clustering (Sneath and Sokal, 1973) was performed using the unweighted pair-group method with arithmetic averages (UPGMA), which is available in the NTSYS-pc package (version 2.0K; Rohlf, 1998). The purpose of this analysis was to place individual specimens into groups (clusters) suggested by the data, but not defined a priori.

Canonical discriminant analysis was performed to characterize mean differences among the populations, to acquire discernment into group differences and to estimate character weights from correlations between canonical variables and original

variables. Correct classification rates were used as an indicator of separation among the populations. Computations and graphics were carried out using SAS Release 6.12.

To determine the range of variation between and within populations on each character, univariate analysis was performed. Boxplots of the most important characters were carried out using SPSSpc-FW (Anonymous, 1997).

Table 1. Morphological characters used in the multivariate study of *Afgekia sericea* populations (all measurements in cm).

	Character	Abbreviation
Vegetative	Rachis length	RCL
	Petiole length	PTL
	Stipule length	SPL
	Stipule breadth	SPB
	Top leaflet length	TLL
	Top leaflet breadth	TLB
	Petiolet length	PLL
Reproductive	Calyx lobe length	CLL
	Standard breadth	SDB
	Standard length	SDL
	Keel breadth	KLB
	Keel length	KLL
	Wing breadth	WGB
	Stamen length	STL
	Pistil length	PTL

RESULTS

Cluster analysis based on all 15 characters did not result in groups that are in agreement with the *Afgekia sericea* populations. The means and ranges of the 15 characters assessed for the three populations are listed in Table 2. It is evident that the population of Sakaerat tends to have the largest values for most of the characters.

The ordination plot on the two canonical axes shows that the three entities are not distinct. The high degree of overlapping is well established (Figure 2). The nature of the population differences is shown by the canonical structure within each population (Table 3). Canonical variable 1 is 80.0% correlated with all the characters and the variance explained by it is 85.7%, so this axis is the most important for the determination of the population diversity. Canonical variable 1 (axis 1) is most highly associated with standard length and standard breadth, respectively. Canonical variable 2 (axis 2) is most highly associated with petiole length, and pistil length, respectively, in a comparable fashion. The F values (Table 3) also indicate by their magnitude the relative order of importance of the characters in general. Significant differences ($P<0.05$) the mean values among populations in were observed in all characters measured. However, most measurements for each population fall in the ranges of the others as can be seen from the boxplots of the eight most important

characters (Figure 3). Standard sizes in *Afgekia sericea*, i.e., standard length and standard breadth, have the highest weight for separation. It appears therefore to be useful as a diagnostic character to distinguish the populations. The other characters listed have progressively lower weight factors.

The linear discriminant function classification results (Table 4) classified 74.5% correctly in total. Although the rate of correct classification for the population of Sakaerat is 87%, those for the other two populations are lower. Correct classification percentages for populations of Sekeaw and Thepsathit are 66% and 72.5%, respectively.

Table 2. Means and standard deviations of the characters in the three populations of *Afgekia sericea.*

Character	Sakaerat		Sekeaw		Thepsathit	
	mean	S.D.	mean	S.D.	Mean	S.D.
Calyx lobe length	1.5395	0.1953	1.3675	0.1687	1.3643	1.3643
Filament length	3.3925	0.2899	3.3600	0.2315	3.1610	0.4279
Keel breadth	0.7895	9.081E-02	0.6955	6.556E-02	0.7077	0.1412
Keel length	2.5340	0.1707	2.3450	0.1718	2.2810	0.1716
Petiolet length	0.2395	5.472E-02	0.2695	7.974E-02	0.2130	7.285E-02
Pistil length	3.5240	0.1969	3.5165	0.1880	3.2900	0.3720
Petiole length	3.2480	0.5315	3.0850	0.5591	2.6927	0.7566
Rachis length	14.271	2.2648	14.276	1.7170	14.914	2.3717
Standard breadth	2.1120	0.1764	1.7420	0.2294	1.7258	0.2465
Standard length	3.0210	0.2565	2.5560	0.2943	2.3670	0.2688
Stipule breadth	0.3725	0.1050	0.3395	9.328E-02	0.3060	0.1541
Stipule length	1.6465	0.3901	1.5857	0.3200	1.4130	0.4029
Top leaflet breadth	1.7935	0.4494	1.5195	0.4646	1.3844	0.4891
Top leaflet length	4.5675	1.0462	3.8290	1.0246	3.4685	1.0935
Wing breadth	1.5005	0.1497	1.4245	0.1564	1.3013	0.1935

DISCUSSION

There is no evidence or reason for suspecting that the three populations belong to different entities. The evidence comes from both univariate and multivariate analyses of the 15 quantitative vegetative and reproductive characters. There is good reason to suppose that pollinating Hymenoptera and especially bees have largely influenced the evolution of the papilionate flower in Fabaceae. Many living papilionate flowers are highly adapted to these pollinators. The standard, keel and wings form a landing platform for insect pollinators (Endress, 1994). However, its present restricted distribution on the Korat Plateau (N.E. Thailand) would promote the stability of a primary gene pool comprising and constituting entirely wild forms due to the high morphological similarity of the populations. It can be postulated that in the past this species may have thrived throughout the tableland of N.E. Thailand.

Evidence comes from the present remnants of tiny populations of this species elsewhere in this region of the country.

Among the fifteen characters studied the standard size of the papilionaceous flower seems to show some variations between the three populations. It was observed that the Sakaerat population tends to have larger values than the other two populations for most of the characters. The big size of floral structures may in part promote pollination by various bees (Endress, 1994). Ringius and Chmielewski (1986) reported high phenotypic variation among six populations of *Trillium erectum* in southern Ontario. They found a correlation of several morphological characters with underlying bedrock. Some morphological differences in *Afgekia sericea* may be due in part to the fertility of soils of each natural habitat. However, this study did not include information on edaphic variation. The possible correlation between these factors and morphological variation will have to await future study.

CONCLUSION

The results of the present investigation do not support the recognition of infraspecific varieties in *Afgekia sericea*. However, this study is performed only within populations in Thailand. The other populations of this species in Vietnam are not included.

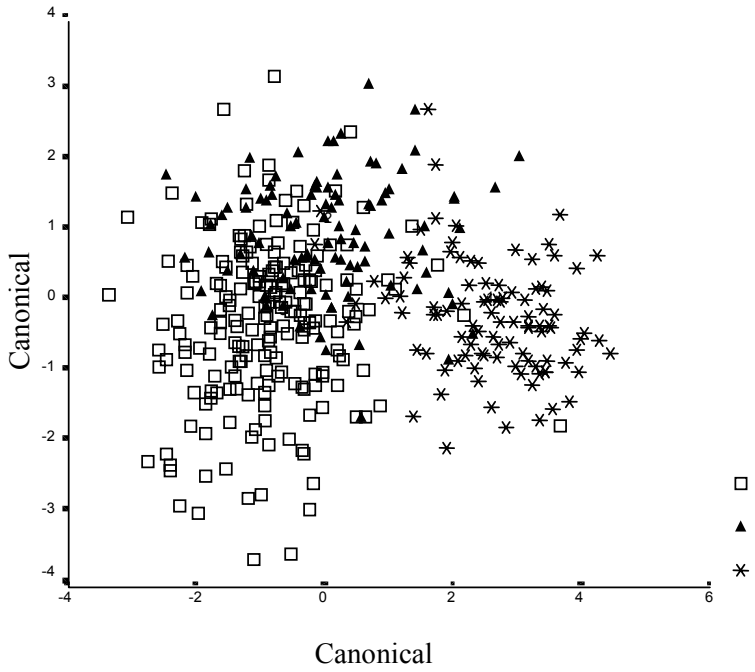

Figure 2. Ordination plots of samples from the three populations of *Afgekia sericea* obtained by canonical discriminant analysis.

Table 3. Canonical structure, F values with their probabilities, and correlations between the two canonical variables and the original variables.

Character	Axis 1	Axis 2	F	Prob.
Calyx lobe length	0.329	-0.162	39.730	0.000
Filament length	0.185	0.332	18.580	0.000
Keel breadth	0.231	-0.207	21.444	0.000
Keel length	0.454	0.043	73.144	0.000
Petiolet length	0.244	0.327	21.754	0.000
Pistil length	0.220	0.470[2]	30.189	0.000
Petiole length	0.087	0.569[1]	27.303	0.000
Rachis length	-0.081	-0.180	4.237	0.015
Standard breadth	0.539[2]	-0.235	106.123	0.000
Standard length	0.735[1]	0.139	192.492	0.000
Stipule breadth	0.153	0.117	9.052	0.000
Stipule length	0.177	0.255	14.878	0.000
Top leaflet breadth	0.263	0.078	24.892	0.000
Top leaflet length	0.315	0.092	35.498	0.000
Wing breadth	0.335	0.364	47.444	0.000

Superscripts 1 and 2 denote the first and second important characters for axis 1 and axis 2.

Table 4. *Afgekia sericea* classification resulting from the linear discriminant analysis.

Original group	Classified group		
	Sakaerat	Sekeaw	Thepsathit
Sakaerat	**87**	12	1
Sekeaw	12	**66**	22
Thepsathit	3.5	24	**72.5**

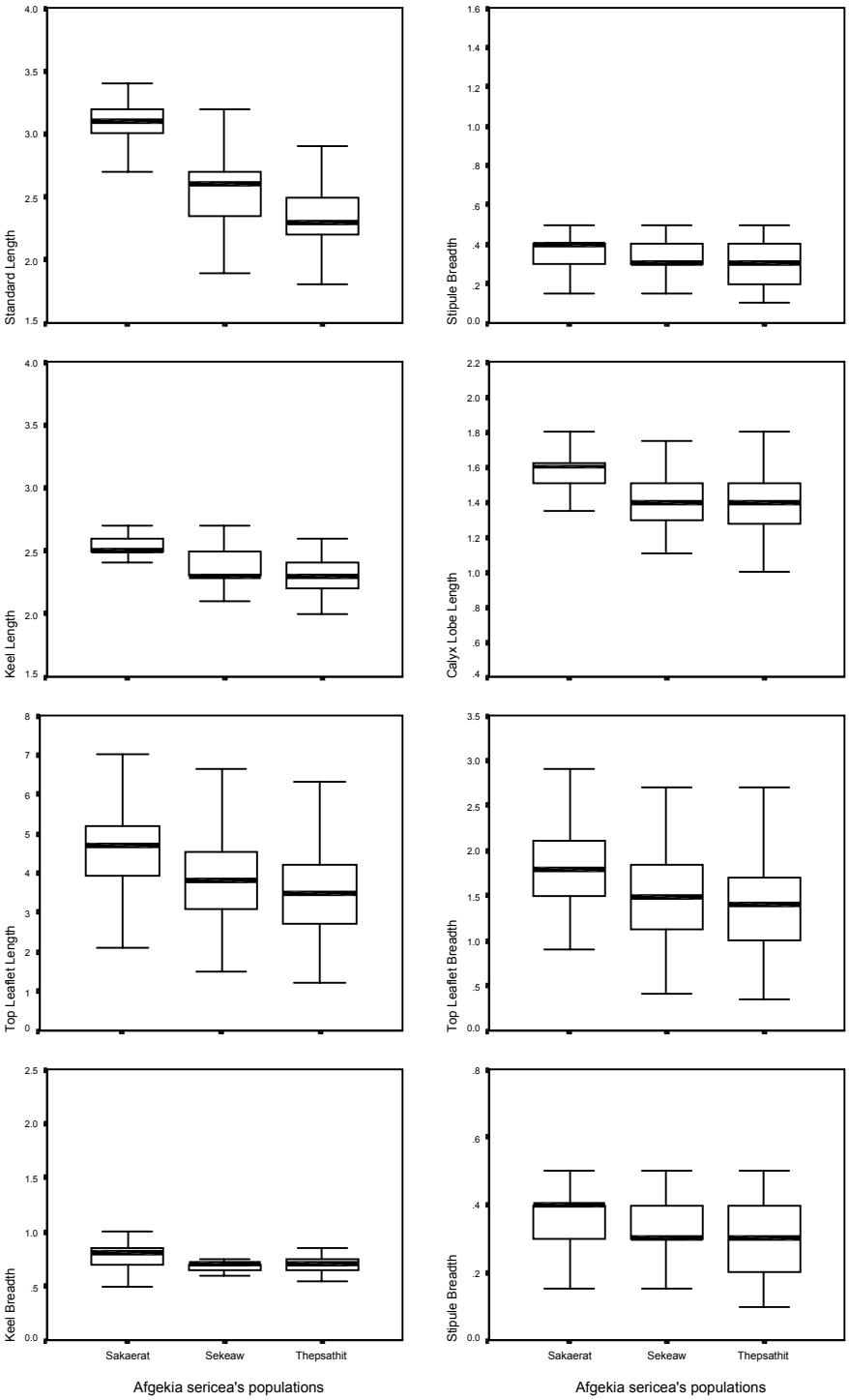

Figure 3. Boxplots of eight morphological characters which have high correlations with canonical axis 1.

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