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Studies on the wing petal morphology of the *Sophora* group

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Sophora group의 익판형태에 관한 연구

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Abstract

The wing petal morphology of *Sophora* group, including 37 species, 5 subspecies, 7 varieties of 10 genera except *Neoharmsia* from a total of 11 genera, was investigated. It was possible to classify the genera and species on the basis of the types of sculpturing and nervation, the size of claw and blade, the states of auricle and margin, etc. The wing morphology was quite variable in *Sophora*, however, it was not able to distinguish *Echinosophora* from the *Sophora* species.

Introduction

Since Darwin (1858), a wide variety of pollination mechanisms in the Papilionoideae have been described (Knuth, 1908; Leppik, 1966; Faegri & Van der Pijl, 1979; Arroyo, 1981). These mechanisms are supposedly resulted from the differences among floral characters such as the size, shape, color, number, arrangement of petals and flowers, the ability of nectar secretion, and the kind of scents, etc. (Stirton, 1981). But the floral biology of the Papilionoideae has hardly been studied except for the cultivated legumes (Free, 1970).

The papilionaceous flower exhibits a unique petal structure, which is composed of a standard, two wing and keel petals. Among them, the wing petals serve not only as a stage for bees to land but also as a lever to depress and raise the keels enclosing the reproductive organs

(Knuth, 1908).

Several authors reported specific ornamentations such as rows of wrinkles, lunae, rugae, lamellae and cavae on the outer surface of the wings in many genera.

Schlieden and Vogel (1839) drew an attention to the ornamentations or epidermal foldings on which they termed *alae foveolata-rugosae.* They reported such ornamentations in many genera of the Papilionoideae but their absence in the Caesalpinioideae and the Mimosoideae. Since then, several authors also described them from the Papilionoideae (Müller, 1883; Dahlgren, 1963; Nair & Sen, 1964; Polhill, 1976; Narang, 1977), however, the function of these ornamentations is still not well known. Besides the function as footholds to pollinators, they are likely to serve as the flower recognition cues to the pollinators by providing a variety of the position, arrangement and shape of these features (Kevan & Lane, 1985). It would be worthwhile to re-evaluate the evolutionary success of the papilionoid taxa on the anthecological perspectives.

The wing morphology was described from ten species of *Crotalaria* (Tewari & Nair, 1978) and from five species included *Cajanus cajan* (Tewari & Nair, 1979). Stirton (1981) surveyed the petal sculpturings from 377 genera and 1,156 species of the papilionoid legumes, and re-emphasized that the presence of the wing sculpturing is a prominent feature of this subfamily. Adey (1982) also investigated the petal surface ornamentations of the Genistinae. Monteiro *et al.* (1989) studied the wing sculpturings of *Lupinus.* Yet such a study on the tribe Sophoreae has hardly been conducted.

In addition to the palynological study of the *Sophora* group (Chung & Lee, 1990), which is a group of the tribe Sophoreae (Polhill, 1981a, b), the present authors aimed to survey their wing morphology and to relate the results with the taxonomy of the genera and species.

Materials and Methods

A total of 95 samples, from 37 species, 5 subspecies and 7 varieties of 10 genera excluding *Neoharmsia* endemic to Madagascar among 11 genera (*Echinosophora* was treated as an independent genus), were used (Table 1). Except 3 species and 2 varieties of 3 genera (*Maackia, Sophora, Echinosophora*) which were available in Korea, all the materials were taken from foreign herbaria and botanical gardens. Abbreviations of the herbaria followed Holmgren & Keuken (1974) except Z, which depicts National Herbarium and Botanic Garden, Causeway, Zimbabwe.

The morphology of wing petals was investigated with a stereomicroscope (Wild M5A) and drawn with a drawing tube. The size of wing petals, the length of blade × the width of the widest part of the blade, were measured from the drawings. The terminology for the wing petal morphology (Fig. 1) followed Tewari and Nair (1978) and Stirton (1981). The exposure of sculpturings (Fig. 1-6), was not accounted in this study because from the dried samples it was difficult to determine whether it was exposed or hidden.

Table 1. Number of taxa studied and the number of samples

Generic name (Total no. of spp.)	No. of examined spp./ssp./var.	No. of samples
Neoharmsia (2)	0/0/0	0
Sakoanala (2)	2/0/0	2
Bolusanthus (1)	1/0/0	2
Platycelyphium (1)	1/0/0	1
Ammodendron (ca.6)	1/0/3	8
Calpurnia (6∼8)	4/2/1	16
Maackia (ca.8)	3/0/2	8
Cladrastis (ca.6)	3/0/0	7
Salweenia (1)	1/0/0	1
Sophora (44∼49)	20/3/1	49
Echinosophora (1)	1/0/0	1
(80∼85)	37/5/7	95

Results

The size of wing petals of *Sophora* group is variable and ranging between 0.30×0.15cm (*Calpurnia intrusa*) and 2.55×0.75cm (*Sophora tetraptera*: Fig. 2-6). The length and attachment point of claw are different among the genera as well as among the species. The nervation in most taxa is palmate, whereas that of *Sakoanala* species, *Sophora affinis* (Fig. 2-4) and *S. japonoca* (Fig. 2-5) is pinnate or nearly pinnate.

The sculpturings locate in 15 arbitrarily divided zones (Fig. 3). Among the 10 genera studied, seven genera (*Bolusanthus, Platycelyphium, Ammodendron, Maackia, Cladrastis, Salweenia, Echinosophora*) exhibit the sculpturings, while *Sakoanala* does not. In *Calpurnia* and *Sophora,* the presence of sculpturings are different among the species. The localizations of sculpturings in *Ammodendron* and *Maackia* are highly consistent.

On the specific level, among the 49 taxa studied, 34 taxa (69%) exhibit the sculpturings which are fairly uniform within species (Stirton, 1981). In most of the species which exhibit the sculpturings, lamellate, lamellate-lunate and lunate types are intermingled, whereas the sculpturings of *Calpurnia aurea, Cladrastis* and *Salweenia* species consist of lunae only.

The orientation of sculpturings is inclined in all taxa. In *Calpurnia,* the upper margin of the petal is folded and sunken slightly.

There are four types in the auricle condition. In the order of frequency, the most of taxa (30 taxa, 61%) have the upper auricle only, the next many species (12 taxa, 25%) both upper

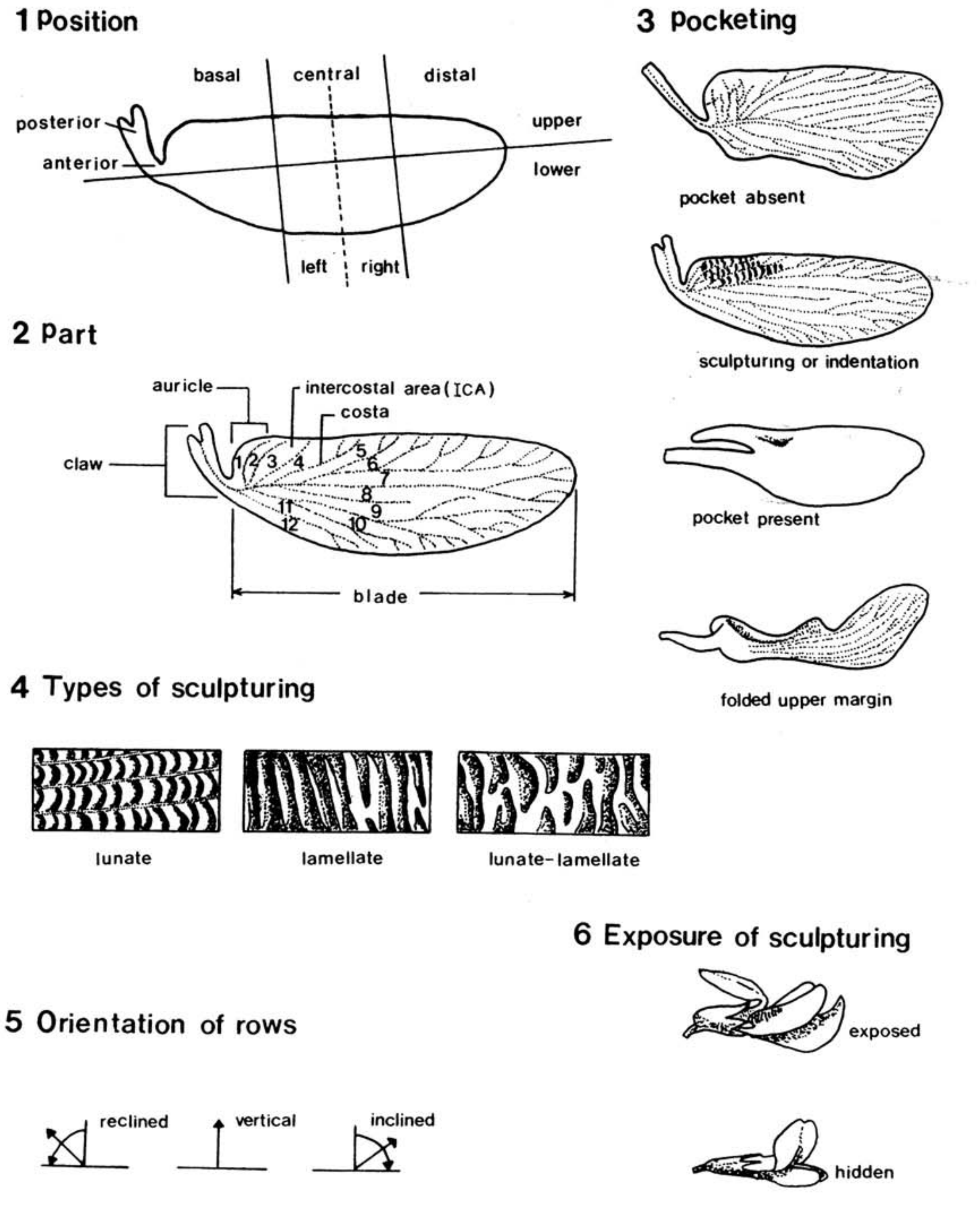


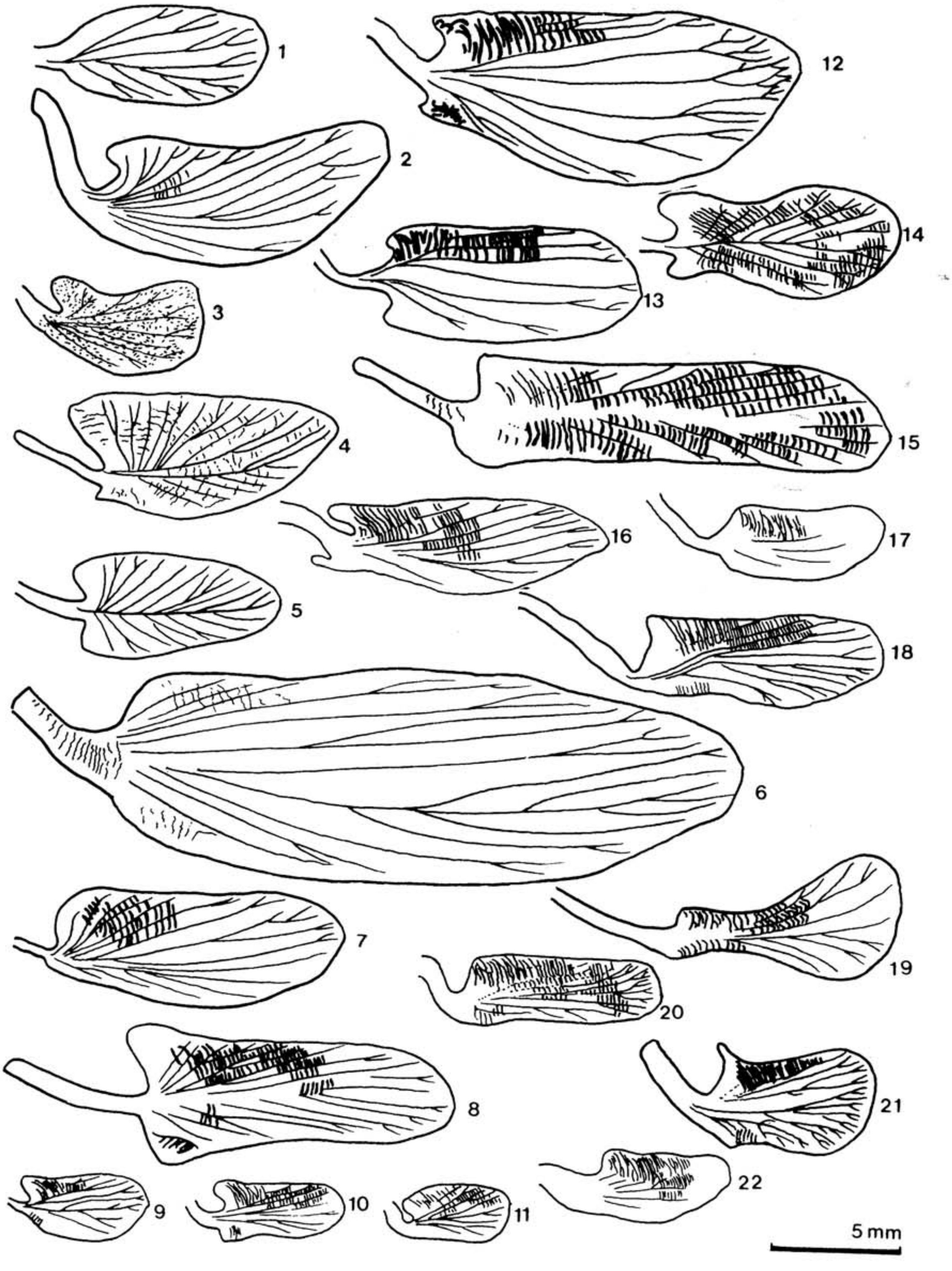
Fig. 1. Terminology used to describe wing petal morphology (After Tewari & Nair, 1978 and Stirton, 1981)

and lower auricles, the thirdly many species (5 taxa, 10%) want both auricles, and the least species (2 taxa, 4%) possess the upper auricle and the weak lower auricle (Fig. 4).

The conventional key to the genera studied is as follows.

Key to the genera on the basis of wing morphology

1. Auricles absent, nerves pinnate ········· *Sakoanala*
1. Auricles present, if absent, nerves palmate.
   2. Sculpturings absent or weak.
      3. Upper margin concavely curved ········· *Calpurnia*
      3. Upper margin straight or convexly curved.
         4. Nerves pinnate ········· *Sophora* (*S. affinis, S. japonica*)
         4. Nerves palmate ········· *Sophora* (*S. chrysophylla, S. tetraptera, S. microphylla, S. masafuerana, S. macrocarpa, S. tomentosa, S. tomentosa* ssp. *bahamensis*)
   2. Sculpturings prominent.
      5. Sculpturings consisting of lunae only.
         6. Claw ca. 1/2 long the blade ········· *Cladrastis*
         6. Claw 1/6-1/7 long the blade ········· *Salweenia*
      5. Sculpturings consisting of lamellae or lunae-lamellae.
         7. Blade small (<0.55cm).
            8. Sculpturings present at the upper base to upper left center ········· *Ammodendron*
            8. Sculpturings present at the upper base to distal part ········· *Maackia, Sophora praseri* ssp. *wilsoni*
         7. Blade large (>0.56cm).
            9. Both upper and lower auricles present.
               10. Sculpturings present at ICA 1-4 in upper parts.
                   11. Lunae at the lowest ICA present, blade length longer than 1.2cm ········· *Bolusanthus*
                   11. Lunae at the lowest ICA absent, blade length less than 1.0cm ········· *Platycelyphium*
               10. Sculpturings present at ICA 1-6 or more ········· *Sophora* (*S. secundiflora, S. arizonica, S. linearifolia*)
            9. Both auricles absent or only the upper one present ········· *Sophora* (the rest *Sophora* species)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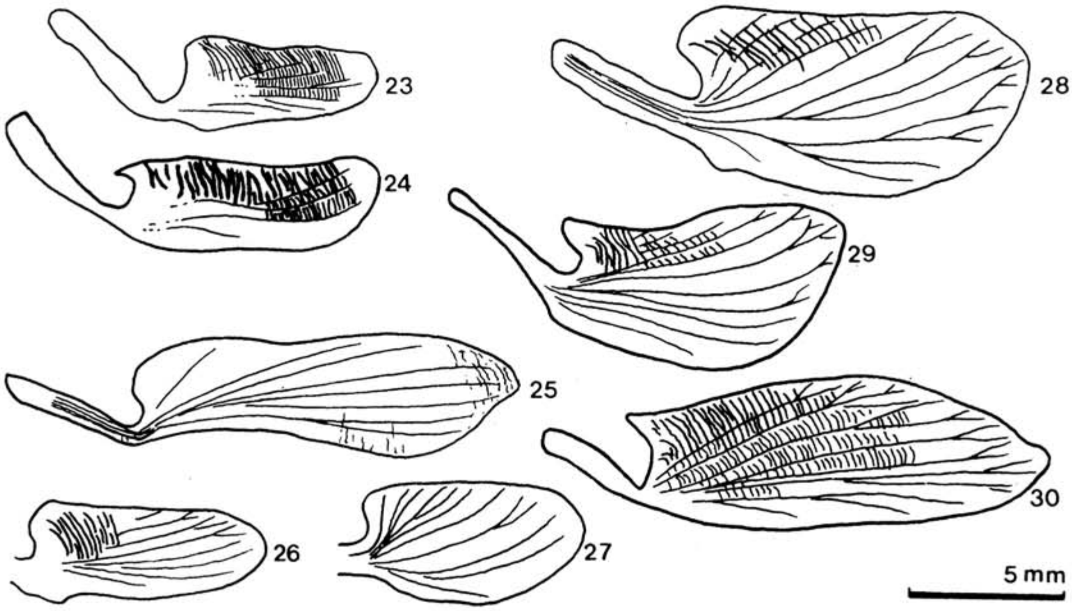


Fig. 2. Representative types of sculpturing patterns in some species of the *Sophora* group
1. *Sakoanala villosa* (K, Gentry 11934), 2. *Calpurnia aurea* ssp. *aurea* (Z, Browning 50), 3. *C. villosa* (K, Tayler 10368), 4. *Sophora affinis* (M, Correll 27180), 5. *S. japonica* (SKK, Lee s.n.), 6. *S. tetraptera* (MPU, ? ?), 7. *Salweenia wardii* (BM, Hanbory-Tracy 111), 8. *Cladrastis lutea* (U, Schouten s.n.), 9. *Ammodendron bifolium* (P, Ledebour s.n.), 10. *Maackia amurensis* var. *amurensis* (SKK, Chung s.n.), 11. *M. chinensis* (RSA, DeWolf & Bruns 2148), 12. *Bolusanthus speciosus* (M, Compton 28894), 13. *Platycelyphium voense* (HUJ, ? 312171), 14. *Sophora secundiflora* (P, Lindheimer 602), 15. *S. arizonica* (RSA, Bostick & Niles 3066), 16. *S. linearifolia* (F, Cabrera *et al.* 29656), 17. *S. pachycarpa* (M, Podlech 30905), 18. *S. davidii* (RSA, Bracelin 1359), 19. *S. nuttalliana* (NEB, Bates Neb177658), 20. *S. alopecuroides* (P, Bornmüller 3648), 21. *S. lehmannii* (P, Sintenis 162), 22. *S. praseri* ssp. *wilsoni* (F, Wilson 1067), 23. *S. flavescens* (SKK, Lee & Lee s.n.), 24. *S. velutina* (P, Delavay 507), 25-27. *S. tomentosa* (25. RSA, Long & Lakela 27548; 26. P. Jacquemin 940; 27. K, Ward 8608), 28. *S. stenophylla* (RSA, Reveal & Reveal 4457), 29. *S. mollis* ssp. *griffithii* (P, Bornmüller 3640), 30. *Echinosophora koreensis* (SKK, Chung s.n.)

Descriptions and Taxonomic Comments

1. ***Sakoanala*** R. Viguier (Fig. 2-1, Fig. 3-15, Figs. 4-1,2)

Blade 0.78-0.81 × 0.38-0.43cm in size. Claw short (1.5mm), attached to the middle base of the blade, the anterior part of the claw wider than the rest. Nervation pinnate. Sculpturings absent. Auricles absent (*S. villosa*: Fig. 2-1) or upper one weakly present (*S. madagascariensis*).

Specimens studied: *S. madagascariensis* R. Vig.-Madagascar, Capuron 23788-SF (P); *S. villosa* R. Vig.-Madagascar, Gentry 11934 (K)

The genus seems to be the most primitive on the wing morphology for many derived states such as the absence of auricle and sculpturings, the bilaterally symmetrical blade, etc. These features well match the system of Polhill (1981b) and the pollen morphological relationship (Chung & Lee, 1990).

2. ***Bolusanthus*** Harms (Fig. 2-12, Fig. 3-10, Fig. 4-4)

Blade 1.40 × 0.70cm in size. Claw slender (3.8mm), attached to the middle or slightly lower base of the blade. Nervation palmate. Sculpturings: At the upper base about 14 lamellae or lunae-lamellae and at the center 4-9 lunae present on the 1st to 4th intercostal areas (ICA 1-4), at the lower base about 7 lunae on the last ICA. Both auricles shortly deltoid.

Species studied: *B. speciosus* (Bolus) Harms-S. Africa, Bayliss 8976 (M), Compton 28894 (M)

3. ***Platycelyphium*** Harms (Fig. 2-13, Fig. 3-7, Fig. 4-4)

Blade 0.90 × 0.30cm in size. Claw slender (3.6mm), attached to the middle base of the blade, the anterior part wider than the rest. Nervation palmate. Sculpturings: At the upper base 8-9 lamellae present on ICA 1-4, 4-16 lunae at ICA 2-4. Both auricles shortly deltoid.

Species studied: *P. voense* (Engl.) Wild-Kenya, ? 312171 (HUJ)

The wing morphology of *Bolusanthus* and *Platycelyphium* suggests their close affinity on the basis of the presence of both auricles and palmate nerves, the same location of sculpturings at the upper base to upper center, etc. Such a relationship well matches the Polhill's system (1981b) in which they were located side by side although the position of the bract on the pedicel is different from each other. Their relatively primitive position, suppported by the pollen morphology (Chung & Lee, 1990), however, is not well supported by the wing morphology.

4. ***Ammodendron*** Fisch. ex DC. (Fig. 2-9, Figs. 3-4,6, Fig. 4-2)

Blade small (0.40-0.55 × 0.23-0.34cm). Claw very short (0.8mm), attached to the lower base of the blade, the anterior part wider than the rest. Nervation palmate. Sculpturings: At the upper base 7-17 lamellae present on ICA 1-3 except the auricle part, at the upper left center 4-9 lunae on ICA (2)3-(6), 3-13 lunae weak or obvious on the last ICA. Only the upper auricle present, roundly to shortly deltoid.

Species studied: *A. bifolium* (Pall.) Yakovlev-Altai, Ledebour s.n. (P), ?, ? BYU 262525 (BRY), USSR, Roldugin ? (M,RSA); *A. argenteum* (Pall.) Kuntze var. *lchmannianum* (Bunge) Zipsky-Turgai, Krascheninnikov 5192 (HUJ); *A. karelinii* Fisch. & Mey. var. *karelinii*-

Perousks, Krascheninnikov 1 (HUJ); *A. karelinii* Fisch. & Mey. var. *conollyi* (Bunge) Yakovlev-Uzbekistan, Pryakhin s.n.(K), Transcaspica, Bubyr 1886524 (F)

On the wing morphology, *Ammodendron* is a homogeneous group but is thought to be remotely related to other genera because it has a combitation of such characters as the small blade size and short claw, the absence of the lower auricle and the sculpturing location at the upper base to the upper left center. Such a position also matches the Polhill's system (1981b) as well as the palynological result (Chung & Lee, 1990).

5. ***Calpurnia*** E. Mey. (Figs. 2-2,3, Figs. 3-1,2,15, Fig. 4-2)

Blade 0.30-0.98×0.15-0.43cm in size, especially C. *intrusa* is the smallest in all the taxa studied, i.e. 0.30×0.15cm, the upper margin inwardly folded and concavely curved. Claw ca. 1/2-1/3 long the blade, attached to the lower base of the blade, the anterior part wider than the rest. Nervation palmate. Sculpturing absent in most species, but *C. aurea* (Fig. 2-2) has weak lunate sculpturings at the upper base and the upper center. Exceptionally, *C. villosa* (Fig. 2-3) has hairs over the blade. Only the upper auricle present, roundly to shortly deltoid.

Species studied: *C. aurea* (Ait.) Benth. ssp. *aurea*-S. Africa, Brown & Shapiro 275 (K), Rauh & Schlieben 9642 (M), Ethiopia, Dillon ? (MPU), cult., Wilson ? (A), Zimbabwe, Browning 50 (Z); *C. aurea* (Ait.) Benth. ssp. *sylvatica* (Burch.) Brummitt-S. Africa, Bayliss 8762 (A), Sidey 3262 (F); *C. aurea* Benth. var. *major* Oliv. et Bak.-Tanzania, Schlieben 4499 (P); *C. glabrata* Brummitt-S. Africa, Wells 2642 (M); *C. intrusa* E. Mey.-Natal, Wood 7739 (MPU), Basouto-land, Dieterlen 37 (MPU), S. Africa, Taat 320 (U), Tlanagan 1450 (GH), Sidey 2057 (F); *C. sericea* Harv.-Basouto-land, Dieterlen 584 (MPU); *C. villosa* Harv.- S. Africa, Tayler 10368 (K)

The wing morphology of *Calpurnia* exhibits its distinctness from other genera because of the absence of sculpturing and inwardly folded and concavely curved upper margin. Its close relationship to *Maackia* and *Cladrastis* exhibited by both general and pollen morphology (Polhill, 1981b; Chung & Lee, 1990), was not supported here.

The absence of sculpturings on the wing was regarded as a primitive state (Polhill, 1981a; Polhill *et al.,* 1981). In the present study, however, it is assumed that the absence of sculpturings in *Calpurnia* was resulted from the secondary reduction according to Stirton (1981) in which sculpturings are absent or reduced on the blade in the species which show petal modifications such as pocket, thickening and puckering of the upper margin and thickening and deep depression in the area of the auricle. On the basis of wing morphology, *C. villosa* seems like an entity separate from the rest of the species. Detailed studies need to be made for the taxonomic treatment.

6. ***Maackia*** Rupr. (Figs. 2-10,11, Figs. 3-7,12, Figs. 4-2,4)

Blade smallest among all the genera studied (0.40-0.53×0.18-0.20cm). Claw ca. 1/4-1/2 long the blade, attached to the middle base of the blade in most taxa, but to the lower base in *M. chinensis* (Fig. 2-11), the anterior wider than the rest, The claw width (0.6mm) of *M. chinensis* wider than that of other species. Nervation palmate. Sculpturings present at the upper base to the upper center in *M. faurei,* and present at the upper base to the upper distal parts in the other species. At the upper base 5-17 lamellae present on ICA 1-3(4), and then, changed into lunate-lamellate type, at the upper distal parts 3-36 lunae on ICA 4-8. Except *M. faurei,* 4-10 lunae very weak at the lower base and even at the lower center. Both upper and lower auricles present, roundly to shortly deltoid. The lower auricle is smaller than the upper one. Exceptionally, *M. chinensis* has the upper auricle only.

Species studied: *M. amurensis* Rupr. var. *amurensis* (다릅나무)-Korea, Chung s.n.(SKK); *M. amurensis* Rupr. var. *buergeri* (Maxim.) Schneider (개물푸레나무)-China, Licent 13421 (P), Japan, Togashi s.n.(U), Togashi MT 7101 (M); *M. chinensis* Takeda-cult. (native of China), DeWolf & Bruns 2148 (RSA), China, Wilson 709 (F); *M. fauriei* (Lev.) Takeda (솔비나무)-Korea, Chung s.n.(SKK); *M. lantaoensis* Merrill-Hong Kong, Taam 2134 (F)

Maakia is the closest to *Cladrastis* by the general morphology (Polhill, 1981b) and pollen morphology (Chung & Lee, 1990). Such a relationship is not supported in the present study because the former is characterized by the small blade and the lamellate-lunate sculpturings whereas the latter by the large blade and the lunate sculpturings.

7. ***Cladrastis*** Rafin. (Fig. 2-8, Figs. 3-3,6,10, Figs. 4-2,4)

Blade 0.53-1.32 × 0.30-0.70cm in size. Claw ca. 1/2 long the blade, slender regularly, attached to the middle base (*C. lutea*: Fig. 2-8, *C. shikokiana*) or to the lower base of the blade (*C. platycarpa*). Nervation palmate. Sculpturings: At the upper base 3-12 lunae present on ICA 2-5 (*C. shikokiana*), at the upper base and the upper left center 3-17 lunae on ICA 1-8, transcostal sparsely, at the lower base ca. 8 lunae present or not (*C. platycarpa*), or at the upper base and the upper center 2-29 lunae on ICA 1-10, at the lower base 2-7 lunae, transcostal sparsely (*C. lutea*). Both auricles shortly deltoid, but *C. platycarpa* has the rounded upper auricle only.

Species studied: *C. lutea* (Michaux f.) K. Koch-cult., ? ? (MPU), Schouten s.n.(U), U.S.A., Isely *et al.* BYU 150962 (BRY), Jennison 558 (P), Pittillo 5120 (M); *C. platycarpa* (Maxim.) Makino-Japan, Honda ? (GH); *C. shikokiana* (Makino) Makino- Japan, Quadota *et al.* 4295 (GH)

8. ***Salweenia*** Bak. f. (Fig. 2-7, Fig. 3-3, Fig. 4-2)

Blade 1.12 × 0.42cm in size. Claw ca. 1/6-1/7 long the blade, attached to the the lower base of the blade. Nervation palmate. Sculpturings: At the upper base 5-13 lunae present on ICA 2-6. Only the upper auricle present, weakly.

Species studied: *S. wardii* Bak.-Tibet, Hanbory-Tracy 111 (BM)

As shown in the key, *Cladratis* and *Salweenia* are closely related because they share a characteristic lunate sculpturing type which cannot be seen in any other genera. Their close relationship is also shown in the Polhill's system (1981b) in which they are positioned side by side although they are different each other by the fruit dehiscence, the leaflet morphology, etc.

9. ***Sophora*** L. (including ***Echinosophora*** Nakai, Figs. 2-4~6, 14~30, Figs. 3-5~11, 13~15, Figs. 4-1~4)

Sizes of wing petals are ranged from 0.53×0.25cm (*S. praseri* ssp. *wilsoni*: Fig. 2-22) to 2.55×0.76cm (*S. tetraptera*: Fig. 2-6). Claw ca. 1/11 (*S. tetraptera, S. macrocarpa*) - 4/5 (*S. flavescens*: Fig. 2-23) long the blade, attached to the lower base of the blade in the most taxa or to the middle base in some taxa (*S. tetraptera, S. microphylla, S. macrocarpa, S. secundiflora*: Fig. 2-14, *S. arizonica*: Fig. 2-15, *S. linearifolia*: Fig. 2-16, *S. pachycarpa*: Fig. 2-17). There are approximate equal frequence in *Sophora* species between which having claw with equal slender from anterior to proximal end and which having claw with wider anterior than the rest. Nervation palmate, except two species (*S. affinis*: Fig. 2-4, *S. japonica*: Fig. 2-5). Sculpturing types are very various from absence (Figs. 2-5,6,25) to presence on which sculptured over the wing petal (Figs. 2-14,15). Auricle conditions appear four all kinds which could be seen in *Sophora* group.

Species studied: *S. affinis* Torrey & A. Gray-U.S.A., Lindheimer 601 (P), Goodman 7014 (RSA), Correll 27180 (M), Palmer 13289 (K), Rose-Innes & Warnock 792 (F); *S. japonica* L. (회화나무)-Korea, Lee s.n.(SKK); *S. secundiflora* (Ortega) Lag. ex DC.-U.S.A., Lindheimer 602 (P), Warnock 46013 (RSA), Dillon 603 (F); *S. velutina* Lindl.-China, Delavay 507 (P); *S. velutina* Lindl. var. *zimbabweensis* J.B. Gillett & Brummitt-Zimbabwe, Browning 51 (Z); *S. chrysophylla* (Salisb.) Seem.-Hawaii, Lammers *et al.* 6771 (RSA), Carlson 3787 (F); *S. tetraptera* J.F. Miller-cult.(native of New Zealand) Bracelin 1173 (RSA), New Zealand, ? ? (MPU), ?, King ? (MPU); *S. microphylla* Ait.-New Zealand, Chapman ? (RSA); *S. masafuerana* (Phil.) Skottsh-Chile, Meyer 9418 (RSA); *S. macrocarpa* Sm.-Chile, Werdermann 678 (F); *S. mollis* (Royle) Graham ex Baker ssp. *griffithii* (Stocks) Ali-Iran, Bornm ller 3640 (P), Afghanistan, Podlech 20106 (M); *Echinosophora koreensis* Nakai (개느삼)-Korea, Chung s.n.(SKK); *Sophora alopecuroides* L.-Afghanistan, Podlech & Jarmal 28859 (M), Iran, Bornmüller 3648 (P); *S. nuttalliana* Turner-U.S.A., Bates Neb 177658 (NEB), Correll 35716 (K); *S. lehmannii* (Bunge) Kuntze-Transcaspia, Litwinow 410 (MPU), Sintenis 162 (P), Afghanistan, Podlech & Jarmal 29340 (M); *S. arizonica* S. Watson-U.S.A., Bostick & Niles 3066 (RSA); *S. flavescens* Ait. (고삼)-Japan, Murata & Koyama 178 (P), Korea, Lee & Lee s.n.(SKK); *S. leachiana* M.E. Peck-U.S.A., Chambers 3041 (RSA), Chambers 3027 (K); *S. linearifolia* Griseb.-Argentina, Cabrera *et al.* 29656 (F); *S. davidii* (Franchet) Skeels-

China, Wilson 841 (F), Delavay 505 (P), Hort. Bot. at Univ. of Cambrige, ? 422-55 (UPS), cult.(native of China), Bracelin 1359 (RSA); *S. pachycarpa* Schrenk ex C.A. Mey.-Afghanistan, Podlech 30905 (M), Taschkent, ? 258 (HUJ); *S. praseri* Prain ssp. *wilsoni* (Prain) Yakovlev-China, Wilson 1067 (F); *S. stenophylla* A. Gray- U.S.A., Reveal & Reveal 4457 (RSA), Hitchcock 3037 (K); *S. tomentosa* L.- U.S.A., Long & Lakela 27548 (RSA), Mexico, Fryxell 3654 (F), Argentina, Hatschbach & Sobral 47641 (F), Madagascar, Jacquemin 940 (P), S. Africa, Ward 8608 (K); *S. tomentosa* L. ssp. *bahamensis* Yakovlev-U.S.A., Killip 41529 (F).

The wing morphology of *Sophora* species is so variable that it was not possible to key out the genus into one group. Such a variability is seen in many other characters such as chromosome numbers (Goldblatt, 1981), general morphology (Polhill, 1981b) and pollen morphology (Chung & Lee, 1990), etc.

Sophora affinis (Fig. 2-4) seems to be very close to *S. japonica* (Fig. 2-5) on the basis of the wing characteristics such as the absence of sculpturings (*S. affinis* has many wrinkles on the wing surface) and pinnate nervation. These are well accorded with fruit characters (Tsoong, unpublished in Polhill 1981b), chromosome number (Goldblatt, 1981) and palynological result (Chung & Lee, 1990). It was suggested that these two species should belong to the subgenus *Styphnolobium* of *Sophora*. The wing petal chracteristics also suggest that the two species are primitive taxa within *Sophora* which has been regarded as a primitive genus in the *Sophora* group.

Sophora chrysophylla, S. tetraptera (Fig. 2-6), *S. microphylla, S. masafuerana* and *S. macrocarpa,* treated to belong to the subgenus *Edwardsia,* possess moderately larze-sized flowers, 2-lipped calyx, large wings (1.38×0.66 - 2.55×0.76cm), especially, the absence of sculpturings, weak wrinkles on the claw and on wing petal, and the absence or weak presence of auricles. These species are native to Chile, New Zealand and Hawaii among which except *S. masafuerana* (unreported), the rest four species are pollinated by birds, i.e. ornithophilous (Hamilton, 1916; Godley, 1975; Arroyo, 1981). These characteristics strongly suggest that these species should be treated in an independent genus distinct from *Sophora.* The present authors assumed that these species owing to the ornithophily would not need to develope or maintain the specialized structures such as sculpturings, marginal foldings and pockets which are elaborated in the melittophilous taxa. When we consider following aspects that, the first, the flowers visited by birds are usually red color, whereas the above species, which were belong to the subgenus *Edwardsia,* are yellow color, the second, the evolutionary trends in Papilionoideae (Polhill, 1981a) that from pollination by bees to by birds and to by bats as well as from regular calyx to calyx with the upper lobes joined higher and to subequally lobed or 2-lipped calyx, we could confirm the absence of sculpturings seen in the species which were belong to the subgenus *Edwardsia* to secondary simplication by reduction.

Sophora nuttalliana (Fig. 2-19) and *S. alopecuroides* (Fig. 2-20), which were treated as subgenus *Vexibia,* represent a close relationship on the wing morphology: Both species have a long claw, ca. 2/5-3/5 long the blade, attached to the lower base of the blade, palmate nervation, sculpturings located from the upper basal to the upper central parts, lamellate at ICA 1-2(3), lunate at ICA (3)4(-6), 3-17 lunae at the lowest ICA and the second lowest ICA, partially transcostal, and only the upper auricle present, shortly and dully.

Echinosophora koreensis Nakai (Fig. 2-30), treated as a Korean endemic genus (Nakai, 1923; Hutchinson, 1964), has the following wing morphology: 1.17×0.42cm in size, claw ca. 3/10-1/2 long the blade, attached to the lower base of the blade, equally wide from the anterior to the posterior end, palmate nervation, sculpturings located from the upper basal to the upper central parts, 12-27 lamellae on ICA 1-2, 5-23 lunae on ICA 3-7, and only the upper auricle present, shortly to acutely deltoid.

Echinosophora and *Sophora mollis* ssp. *griffithii* (Fig. 2-29), once treated in the same subgenus *Keyseringia* (Yakovlev, 1972), share many common features of wing morphology: similar wing petal sizes, the same claw attachment point, the similar ratio of claw length to blade length, palmate nervation, and the similar sculpturing localization and types. The wing morphology was not different enough to distinguish *Echinosophora* from the *Sophora* species which show a wide variation on the wing morphology. This fact well accords with chromosome number (Goldblatt, 1981; Kim, 1986) and palynological result (Chung & Lee, 1990) and does not support the taxonomic position of *Echinosophora* as an independent genus.

Sophora secundiflora (Fig. 2-14) seems to be the most advanced among the *Sophora* species for having the sculpturings which consisted of rugulose lamellae and lunae, covering the whole wing surface, having both auricles, and having the both blade margin incurved strongly.

Sophora tomentosa (Fig. 2-25) represents absence of sculpturings on the wing petal, weak wrinkles sparsely and a tendency that the upper margin of wing petals is slightly folded inward. Whereas, a sample of *S. tomentosa* which was collected from Madagascar (P, Jacquemin 940, Fig. 2-26) has sculpturings at the upper base prominently. And another sample of same species, which was collected from Natal, S. Africa (K, Ward 8608, Fig. 2-27) and was deposited with the name of *S. inhambanensis* Klotzsch originally, has not sculpturings, however, this morphology differs from Stirton's figure (1981, p. 785) that sculpturings are located from the upper basal to the upper central parts. These problems suggest that there is need to re-examination of taxonomic treatments of *S. tomentosa* species.

In the present study, 21 species, 3 subspecies and 1 variety of *Sophora* were investigated out of 45-50 species throughout the world. It would be needed to study all the species for a better taxonomic understanding of the genus.

Discussion

Although the results of the present wing morphology do not well support the taxonomic systems (Yakovlev, 1972; Polhill, 1981b) and palynological result (Chung & Lee, 1990), it

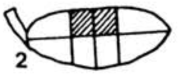
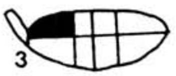
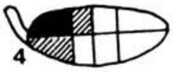
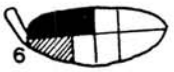
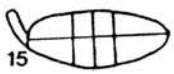
Location types of sculpture	No. of taxa (%)	Species name
 1	1 (2)	*Calpurnia aurea* ssp. *aurea*
 2	2 (4)	*Calpurnia aurea* ssp. *sylvatica, C. aurea* var. *major*
 3	2 (4)	*Cladrastis shikokiana, Salweenia wardii*
 4	1 (2)	*Ammodendron karelinii* var. *karelinii*
 5	3 (6)	*Sophora mollis* ssp. *griffithii, S. linearifolia, S. pachycarpa*
 6	5 (10)	*Ammodendron bifolium, A. argenteum* var. *lchmannianum, A. karelinii* var. *conollyi, Cladrastis platycarpa, Sophora lehmannii*
 7	4 (8)	*Platycelyphium voense, Maackia fauriei, Sophora stenophylla, Echinosophora koreensis,*
 8	1 (2)	*Sophora davidii*
 9	1 (2)	*Sophora praseri* ssp. *wilsoni*
 10	5 (10)	*Bolusanthus speciosus, Cladrastis lutea, Sophora alopecuroides, S. nuttalliana, S. leachiana*
 11	2 (4)	*Sophora velutina, S. velutina* var. *zimbabweensis*
 12	4 (8)	*Maackia amurensis* var. *amurensis, M. amurensis* var. *buergeri, M. chinensis, M. lantaoensis*
 13	1 (2)	*Sophora flavescens*
 14	2 (4)	*Sophora secundiflora, S. arizonica*
 15	15 (31)	*Sakoanala madagascariensis, S. villosa, Calpurnia glabrata, C. intrusa, C. sericea, C. villosa, Sophora affinis, S. japonica, S. chrysophylla, S. tetraptera, S. microphylla, S. masafuerana, S. macrocarpa, S. tomentosa, S. tomentosa* ssp. *bahamensis*

Fig. 3. Localization of sculpturing on wing petals of 49 taxa of *Sophora* group. Sculpturing occurs in 15 zones. Shading means weak sculpturing zone.

Auricle type	No. of taxa (%)	Species name
	5 (10)	*Sakoanala villosa, Sophora tetraptera, S. microphylla, S. macrocarpa, S. pachycarpa*
	30 (61)	*Sakoanala madagascariensis, Ammodendron bifolium, A. argenteum* var. *lchmannianum, A. karelinii* var. *karelinii, A. karelinii* var. *conollyi, Calpurnia aurea* ssp. *aurea, C. aurea* ssp. *sylvatica, C. aurea* var. *major, C. glabrata, C. intrusa, C. sericea, C. villosa, Maackia chinensis, Cladrastis platycarpa, Salweenia wardii, Sophora affinis, S. velutina, S. velutina* var. *zimbabweensis, S. alopecuroides, S. nuttalliana, S. lehmannii, S. flavescens, S. leachiana, S. davidii, S. praseri* ssp. *wilsoni, S. stenophylla, S. tomentosa, S. tomentosa* ssp. *bahamensis, S. mollis* ssp. *griffithii, Echinosophora koreensis*
	2 (4)	*Sophora chrysophylla, S. masafuerana*
	12 (25)	*Bolusanthus speciosus, Platycelyphium voense, Maackia amurensis* var. *amurensis, M. amurensis* var. *buergeri, M. fauriei, M. lantaoensis, Cladrastis lutea, C. shikokiana, Sophora japonica, S. secundiflora, S. arizonica, S. linearifolia*

Fig. 4. Types of auricle on wing petals of 49 taxa of *Sophora* group. 1: Both auricles absent, 2: Upper auricle present, lower auricle absent, 3: Upper auricle present, lower auricle weakly present, 4: Both auricles present

was possible to key out all the genera except *Sophora,* which exhibits a very wide variation of wing petal characters just as seen in the palynological study. The wing petal morphology including sculpturings was again proved as a very useful character (Tewari & Nair, 1978; Stirton, 1981).

It was known that there is a gradual development in which the wings develop auricles, become sculptured and the sculpturings are interlinked, e.g. from lunate to lamellate, and the nerves are changed from pinnate to palmate in the tribe Sophoreae (Polhill *et al.*, 1981) as well as shallow depressions, puckerings or pockets may play a role similar to that of sculpturings during the pollination (Stirton, 1981). However, it is uncertain whether these facts could be applied to the cases of some *Sophora* species with weak wrinkles on the blade and claw (*S. affinis, S. chrysophylla, S. tetraptera, S. microphylla, S. masafuerana, S. macrocarpa, S. tomentosa, S. tomentosa* ssp. *bahamensis*) or the wrinkles are simple vestiges by reduction. Also, the function of hairs on wing petal of *Calpurnia villosa* is need to study with a same viewpoint, however, the occurrence of hairs observed in *Sophora lehmannii* and *S. tomentosa* seems to be deciduous along the aging because the presence of hairs differs with samples.

Although the evolutionary trends appeared in certain tribes, for example Genisteae, where is a gradual shift from genera with typical lunate sculpturing through coalescing lunae into lamellate ridging and finally pockets. This scheme may, as a whole, be uncomfortably placed in the Genisteae. In such case, an alternative explanation would have to be looked for to explain their present position (Stirton, 1981). Similarly, careful consideration would have to taken into account on *Sophora* group.

Considering the facts that wing petals are not only independent character but also evolutionary product which was made by interaction between wing petal and its surrounding environmental factors by space-structure-function, it is not difficult to think that wing petal should trying to possess an optimal function and structure. The morphlogy of wing petals thus seems to be a useful indicator of evolutionary trends and may contribute to an understanding of reproductive biology of the Leguminosae as well as to an establishment of the natural system of the family.

적 요

*Neoharmsia*속을 제외한 *Sophora* group내의 10속, 37종, 5아종, 7변종의 익판의 형태를 조사하였다. Sculpturing을 중심으로 맥의 상태, Claw와 Blade의 길이, Auricle의 발달 정도, Margin의 특수화 여부 등을 사용하여 속간, 종간 구분이 가능하였으나, *Sophora*속은 다양성이 매우 넓게 나타났다. 개느삼속은 *Sophora*속의 종들의 변이내에 포함되어 독립 속으로서의 타당성은 지지되지 못하였다.

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