

Achene Morphology of *Polygonum s.l.* (Polygonaceae) in Thailand

CHORTIP KANTACHOT^{1*} AND PRANOM CHANTARANOTHAI²

¹Department of Biological Sciences, Faculty of Science, Ubon Ratchathani University, Ubon Ratchathani, 34190, THAILAND

²Applied Taxonomic Research Center, Department of Biology, Faculty of Science, Khon Kaen University, Khon Kaen, 40002, THAILAND

* Corresponding author. E-mail: khortip@gmail.com

Received: 29 July 2010; Accepted: 5 January 2011

ABSTRACT.— The achene morphology of 20 taxa in five sections of *Polygonum s.l.* from Thailand was studied and compared in detail using stereoscopic light and scanning electron microscopy. The achene of all Thai taxa is typically lenticular or triangular in shape. Three different morphological types are described according to the features of the achene surface; smooth-undulate, a star-like form and reticulate-papillae. Achene morphology of each type is described, compared, illustrated and discussed according to its taxonomic implications.

KEY WORDS: Achene, *Polygonum s.l.*, Thailand

INTRODUCTION

Polygonum s.l. (Polygonaceae) is a cosmopolitan genus of about 170 species, which are mainly distributed in the temperate northern regions but some species are found in the tropical and subtropical regions (Heywood et al., 2007). The genus *Polygonum s.l.* has been classified into different genera by different authors *Aconogonon*, *Bistorta*, *Fagopyrum*, *Fallopia*, *Koenigia*, *Persicaria*, *Pleuroteropyrum*, *Polygonum s.s.*, *Reynutria* and *Tiniaria* (Small, 1895; Hedberg, 1946; Haraldson, 1978), but the 17 existent species in Thailand belong to two genera, *Polygonum* and *Persicaria* (The Forest Herbarium, Royal Forest Department, 2001). *Polygonum s.l.* is characterized by the gamopetalae and swollen nodes, with sheathing stipules or ocrea. The genus occurs in various habitats from mountains, along roadsides, riversides and paddy fields. The infrageneric classifications of *Polygonum s.l.* have long been studied by

various taxonomists, such as Dammer (1892); Steward (1930); Hedberg (1946); Haraldson (1978); Anjen et al. (2003) and Lamb Frye and Kron (2003), using the inflorescence type, ocrea, achene and pollen morphology, leaf, petiole and stem anatomy and molecular analyses.

The features of the achene and seed morphology have been recognized as useful (informative) traits in species classification, providing relatively stable character sets which are valuable for comparative analysis at every taxonomic hierarchy (Heywood, 1969; Barthlott, 1981). Martin (1954) made a key of 22 *Polygonum* species based on the distinctive combinations of shape, size and surface of the achene, but this was without any taxonomic comments. Since then, SEM micrograph based analyses of achene morphology have been conducted in several systematic studies. The achene morphology of the *Polygonum* section *Polygonum* in Canada, studied in detail for delimitation of the taxa, revealed four discernable achene types; smooth, roughened, papillose and

TABLE 1. List of voucher specimens of *Polygonum s.l.* from Thailand used in this study. Location of voucher specimens provided, and herbarium acronyms given in parentheses.

Taxon	Voucher specimen
<i>Polygonum barbauma</i> var. <i>barbatum</i>	Thailand: Sakon Nakhon, C. Kantachot 312 (KKU) Thailand: Khamphaeng Phet, C. Kantachot 424 (KKU)
<i>P. barbatum</i> var. <i>gracile</i>	Thailand: Mae Hong Son, C. Kantachot 373 (KKU) Thailand: Maha Sarakham, C. Kantachot 397 (KKU)
<i>P. capitatum</i>	Thailand: Bangkok, C. Kantachot 421 (KKU)
<i>P. dichotomum</i>	Thailand: Chaiphaphum, C. Kantachot 283 (KKU) Thailand: Nong Khai, C. Kantachot 396 (KKU)
<i>P. glabrum</i>	Thailand: Sakon Nakhon, C. Kantachot 282 (KKU) Thailand: Mae Hong Son, C. Kantachot 375 (KKU)
<i>P. hydropiper</i>	Thailand: Khon Kaen, C. Kantachot 271 (KKU) Thailand: Chaiphaphum, C. Kantachot 304 (KKU)
<i>P. lapathifolium</i> var. <i>lapathifolium</i>	Thailand: Loei, C. Kantachot 260 (KKU) Thailand: Amnat Charoen, C. Kantachot 427 (KKU)
<i>P. lapathifolium</i> var. <i>lanatum</i>	Thailand: Chiang Mai, C. Kantachot 418 (KKU) Thailand: Kamphaeng Phet, C. Kantachot 423 (KKU)
<i>P. minus</i>	Thailand: Loei, C. Kantachot 267 (KKU) Thailand: Chiang Mai, C. Kantachot 327 (KKU)
<i>P. molle</i> var. <i>molle</i>	Thailand: Chiang Mai, C. Kantachot 252 (KKU)
<i>P. nepalense</i>	Thailand: Chiang Rai, C. Kantachot 331 (KKU) Thailand: Chiang Mai, C. Kantachot 344 (KKU)
<i>P. odoratum</i>	Thailand: Chiang Rai, C. Kantachot 318 (KKU) Thailand: Kanchanaburi, C. Kantachot 280 (KKU)
<i>P. plebeium</i>	Thailand: Loei, C. Kantachot 265 (KKU) Thailand: Mae Hong Son, C. Kantachot 371 (KKU) Thailand: Maha Sarakham, C. Kantachot 426 (KKU)
<i>P. pubescens</i>	Thailand: Tak, C. Kantachot 303 (KKU) Thailand: Chiang Mai, C. Kantachot 319 (KKU) Thailand: Chiang Rai, C. Kantachot 345 (KKU) Thailand: Mae Hong Son, C. Kantachot 354 (KKU)
<i>P. strigosum</i>	Thailand: Loei, C. Kantachot 290 (KKU) Thailand: Mae Hong Son, C. Kantachot 357 (KKU)
<i>P. tomentosum</i>	Thailand: Songkhla, C. Kantachot 234 (KKU) Thailand: Khon Kaen, C. Kantachot 253 (KKU) Thailand: Chachoengsao, C. Kantachot 274 (KKU) Thailand: Ubon Ratchathani, C. Kantachot 287 (KKU)
<i>P. viscosum</i>	Thailand: Roi Et, C. Kantachot 258 (KKU)
<i>Polygonum</i> sp. 1	Thailand: Yasothon, C. Kantachot 289 (KKU)
<i>Polygonum</i> sp. 2	Thailand: Lampang, C. Kantachot 241 (KKU) Thailand: Loei, C. Kantachot 266 (KKU)

striate-papillose (Wolf and McNeill, 1986). In addition, Decraene et al. (2000) pointed out that the achene morphology and anatomy in members of the Persicarieae and Polygoneae tribes are important for systematic implications. The thickness of the pericarp and its anatomy has been used

more than any other achene features as consistent characters to consider genera.

However, the achene morphology of Thai *Polygonum s.l.* has never been studied. The aim of this study is to survey the range of variability in achene characters for the *Polygonum* species of Thailand in order to

TABLE 2. Achene morphology of Thai *Polygonum s.l.*

Section	Taxa	Achene size (mm)			Shape ¹	Surface ²
		Length (L)	Width (W)	L / W		
<i>Aconogonon</i>	<i>Polygonum molle</i> var. <i>molle</i>	1.95 ± 0.23	1.89 ± 0.14	1.03 ± 0.10	Tri	Type 1
<i>Cephalophilon</i>	<i>P. capitatum</i>	1.54 ± 0.07	0.96 ± 0.07	1.60 ± 0.11	Tri	Type 1
	<i>P. nepalense</i>	1.67 ± 0.08	1.58 ± 0.07	1.06 ± 0.05	Len	Type 3
<i>Echinocaulon</i>	<i>P. dichotomum</i>	2.27 ± 0.14	2.07 ± 0.10	1.10 ± 0.09	Len	Type 1
	<i>P. strigosum</i>	3.01 ± 0.23	2.28 ± 0.11	1.32 ± 0.10	Tri	Type 2
<i>Persicaria</i>	<i>P. barbatum</i> var. <i>barbatum</i>	1.79 ± 0.20	1.28 ± 0.07	1.39 ± 0.08	Tri	Type 1
	<i>P. barbatum</i> var. <i>gracile</i>	1.99 ± 0.13	1.49 ± 0.08	1.33 ± 0.09	Tri	Type 1
	<i>P. glabrum</i>	2.44 ± 0.07	1.98 ± 0.11	1.23 ± 0.06	Len / Tri	Type 1
	<i>P. hydropiper</i>	2.27 ± 0.12	1.64 ± 0.10	1.38 ± 0.12	Tri	Type 1
	<i>P. lapathifolium</i> var. <i>lapathifolium</i>	1.87 ± 0.07	1.63 ± 0.11	1.14 ± 0.08	Len	Type 1
	<i>P. lapathifolium</i> var. <i>lanatum</i>	2.04 ± 0.11	1.80 ± 0.12	1.13 ± 0.06	Len	Type 1
	<i>P. minus</i>	1.32 ± 0.08	1.06 ± 0.06	1.25 ± 0.06	Len	Type 2
	<i>P. odoratum</i>	2.25 ± 0.08	1.52 ± 0.12	1.48 ± 0.08	Tri	Type 2
	<i>P. orientale</i>	2.55 ± 0.24	2.77 ± 0.21	0.92 ± 0.05	Len	Type 1
	<i>P. pubescens</i>	2.61 ± 0.19	1.68 ± 0.06	1.55 ± 0.10	Tri	Type 3
	<i>P. tomentosum</i>	2.76 ± 0.14	2.77 ± 0.18	1.00 ± 0.06	Len	Type 1
	<i>P. viscosum</i>	2.31 ± 0.14	1.89 ± 0.05	1.22 ± 0.07	Tri	Type 1
	<i>Polygonum</i> sp.1	2.87 ± 0.22	1.96 ± 0.80	1.46 ± 0.12	Tri	Type 2
	<i>Polygonum</i> sp.2	2.33 ± 0.10	1.61 ± 0.09	1.45 ± 0.10	Tri	Type 1
<i>Polygonum</i>	<i>P. plebeium</i>	1.41 ± 0.10	0.98 ± 0.12	1.03 ± 0.10	Tri	Type 1

¹ Achene shape as triangular (Tri) or lenticulate (Len).

² Surface ornamentation as smooth-undulate (Type 1), with pits lying as a star-like pattern (Type 2) or reticulate-papillose (Type 3).

establish their usefulness for future taxonomic work.

MATERIALS AND METHODS

Material used was collected from wild populations as shown in Table 1. Forty voucher specimens, representing 16 known species (18 varieties) and a further two new morphotypes (a total of 20 taxa), were collected, examined and are deposited at Khon Kaen University herbarium (KKU). Measurements and optical observations of at least 20 achenes for each specimen were carried out under an Olympus SZX9 stereo light microscope. For scanning electron microscopy (SEM), the lowest mature achene on each raceme or fascicle was selected. The dry perianth was removed and the achene was cleaned with 70% (v/v)

ethanol, dried and then mounted directly on stubs using carbon paper and coated with gold in a sputter coater for 75 seconds at a time and for three times. Morphological observations upon the middle part of the achenes were carried out with a LEO 1450VP SEM. The terminology of achene surface sculpturing mainly follows Wolf and McNeill (1986) and Decraene et al. (2000). Species and section names correspond to the classification of Steward (1930).

RESULTS

Among the 20 taxa examined, two basic morphological achene shapes were distinguished: triangular and lenticular, which are completely shiny or dull, black or dark brown, and both show a wide range of

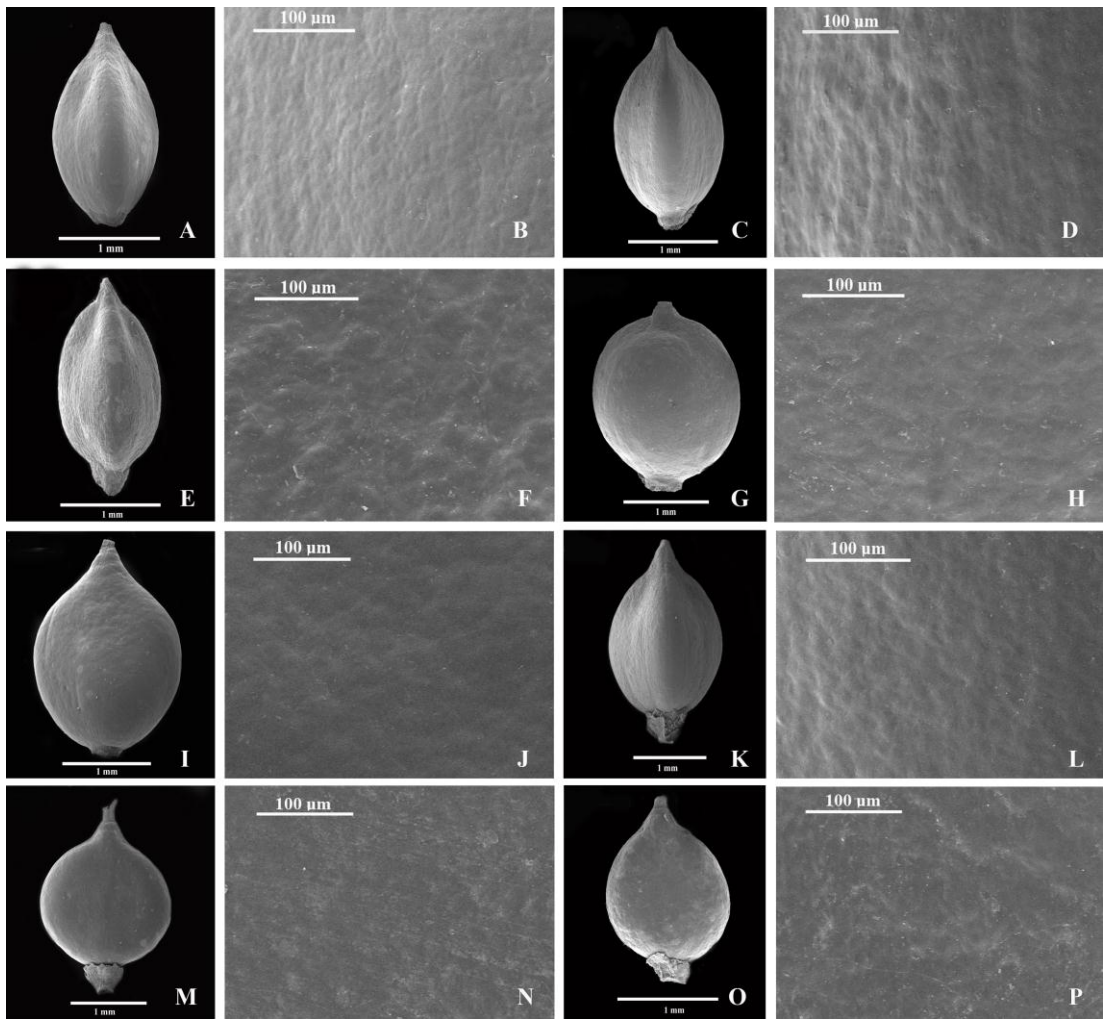


FIGURE 1. SEM micrographs of achenes in *Polygonum s.l.*: (A-B) *Polygonum barbatum* var. *barbatum*, (C-D) *Polygonum barbatum* var. *gracile*, (E-F) *Polygonum capitatum*, (G-H) *Polygonum dichotomum*, (I-J) *Polygonum glabrum*, (K-L) *Polygonum hydropiper*, (M-N) *Polygonum lapathifolium* var. *lapathifolium*, (O-P) *Polygonum lapathifolium* var. *lanatum*.

three discernable achene surface sculpturing patterns; smooth-undulate, a star-like form and reticulate-papillae (Figs. 1 - 3; Table 2). Achenes vary considerably in size, with the length ranging between 1.32 - 3.01 mm and the width from 0.96 - 2.77 mm. The length/width ratio, which was conserved between the two varieties in each of the two species, also showed considerable variation between species, ranging from 0.92 - 1.60,

but was more conserved than either of the two size parameters alone with 11/20 and 15/20 taxa falling within a 1.2 - 1.5 and 1.1 - 1.5 length/width ratio, respectively. As a result of the observations carried out using both stereoscopic microscope and SEM, three different achene morphology types can be recognized, and these are described below.

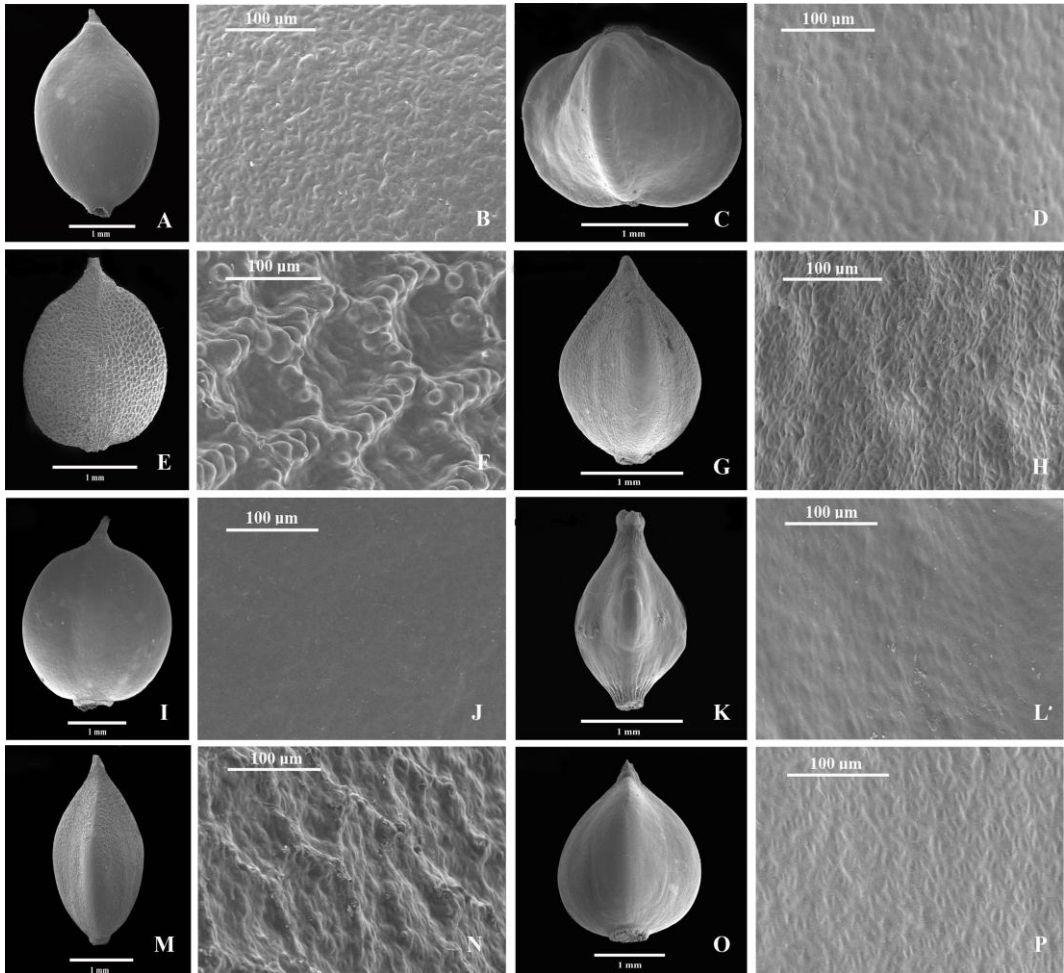


FIGURE 2. SEM micrographs of achenes in *Polygonum s.l.*: (A-B) *Polygonum minus*, (C-D) *Polygonum molle* var. *molle*, (E-F) *Polygonum nepalense*, (G-H) *Polygonum odoratum*, (I-J) *Polygonum orientale*, (K-L) *Polygonum plebeium*, (M-N) *Polygonum pubescens*, (O-P) *Polygonum strigosum*.

Type I: This type has a smooth to undulate surface, and the anticlinal cell walls show as more or less collapsed and of undulate form in surface view. This type is present in 14 of the 20 examined taxa of *Polygonum*; *P. barbatum* var. *barbatum*, *P. barbatum* var. *gracile*, *P. capitatum*, *P. dichotomum*, *P. glabrum*, *P. hydropiper*, *P. lapathifolium* var. *lapathifolium*, *P. lapathifolium* var. *lanatum*, *P. molle* var. *molle*, *P. orientale*, *P. plebeium*, *P. tomentosum*, *P. viscosum* and *Polygonum*

sp. 2 (Figs 1B, D, F, H, J, L, N, P; 2D, J, L; 3B, D, H).

Type II: The achene surface of this type appears with pits arranged as a star-like pattern, and was found in four of the 20 examined taxa; *P. minus*, *P. odoratum*, *P. strigosum* and *Polygonum* sp.1 (Figs 2B, H, P; 3F).

Type III: The achene surface of this third type exhibits a reticulate-papillose surface with tubercles forming as a network-like pattern. The presence of cells with such

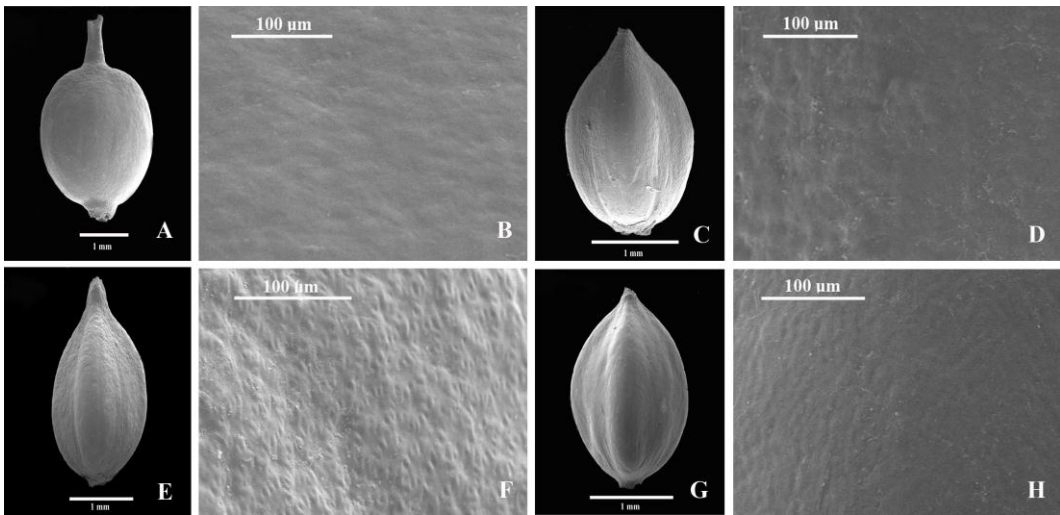


FIGURE 3. SEM micrographs of achenes in *Polygonum s.l.*: (A-B) *Polygonum tomentosum*, (C-D) *Polygonum viscosum*, (E-F) *Polygonum* sp.1, (G-H) *Polygonum* sp.2.

scattered papillae is only found in two of the 20 examined taxa; *P. nepalense* and *P. pubescens* (Fig. 2F, N).

DISCUSSION

In general, achenes of *Polygonum s.l.* are indehiscent and formed by two or three carpels, which corresponds to the number of styles. The achene is partly or completely enclosed by the persistent perianth. Two basic morphological achene shapes can be recognized within Thai *Polygonum s.l.*; lenticular and triangular achenes. Both achene shapes are often elongate and show the style base as a short beak.

The lenticular achene is rounded to ovate in outline, with the lateral faces of both sides typically concave, flat or convex. In total seven of the 20 examined Thai taxa were found to have a lens-shaped achene, being: *P. dichotomum*, *P. lapathifolium* var. *lapathifolium*, *P. lapathifolium* var. *lanatum*, *P. minus*, *P. nepalense*, *P. orientale* and *P. tomentosum* (Figs 1G, M, O; 2A, E, I; 3A).

The triangular achene shape, on the other hand, is more nearly pyramidal in outline. The relative width with the individual is either three equal or subequal convex sides with one convex side being broader than the other two or with one narrow concave side and two broad convex sides. This shape is typically found in the *Polygonum* section *Polygonum*, as described by Wolf and McNeill (1986). The Thai taxa with triangular achene, numbering 12 out of the 20, were: *Polygonum barbatum* var. *barbatum*, *P. barbatum* var. *gracile*, *P. capitatum*, *P. hydropiper*, *P. molle* var. *molle*, *P. odoratum*, *P. plebeium*, *P. pubescens*, *P. strigosum*, *P. viscosum*, *Polygonum* sp.1 and *Polygonum* sp.2 (Figs 1A, C, E; 2C, G, K, M, O; 3C, E, G). However, the achenes of one taxa, *P. glabrum*, are dimorphic, with most achenes being lenticular but are sometimes triangular in the two specimens, one from each of two localities.

The color of the mature achenes is shiny or dull black or dark brown, but this character is of low taxonomic significance.

The size for the achenes of all the 20 taxa studied lie between 1.32 - 3.01 mm (length) and 0.96 - 2.77 mm (width). *P. plebeium* has the smallest achene and *P. orientale*, *P. strigosum* and *P. tomentosum* have the largest achenes. Martin (1954) provided achene data for two taxa, that is *P. hydropper* and *P. orientale*, at 2.25 - 3 mm and 2.75 - 3.5 mm (length), respectively, and 1.75 - 2 mm and 3 - 3.5 mm (width), respectively, which are more or less similar size to those examined in this study.

SEM-based studies revealed three discernable types of achene surface in the middle part, (i) a smooth-undulate surface, (ii) one with pits lying in a star-like pattern and (iii) a reticulate-papillose. Whilst most taxa (14/20) exhibited the first type, one of the distinct features in *Polygonum s.l.* is the presence of cells with scattered papillae, yet this was found in only two of the 20 Thai taxa examined (*P. pubescens* and *P. nepalense*). This characteristic is common in the sections *Cephalophilon*, *Echinocaulon* and *Persicaria* (Decraene et al., 2000). Yurtseva (2001) discussed the morphological variation of achene papillae or verrucae in terms of the structure in the Russian species. The functions of the papillae are not quite clear, but are probably for the absorption of water for germination and might serve for penetration of water to the inside of cells. This characteristic is commonly found on the achene surface of plants in arid habitats. As mentioned, two of the 20 studied Thai taxa, *P. nepalense* and *P. pubescens* (Fig. 2F, N), share the morphology of the polygon surrounded by tubercles at the middle surface of achene, in which the variability has previously been interpreted as being due to the ecological aspects of surface sculpturing (Barthlott, 1981).

The close affinity taxa in *Polygonum s.l.* have already been reported by Steward (1930) and Anjen et al. (2003) on the basis of gross morphology. The comparison, therefore, of the following two pairs of species is discussed here:

(1) *Polygonum hydropper* and *P. odoratum*: both of these species are in the section *Persicaria*. The differences in the achene morphology between these two species was reported before by Steward (1930), who reported the finely granulate surfaces in *P. hydropper* and a distinctive smooth appearance in *P. odoratum*. However, our findings presented here do not agree with Steward's study. In contrast, we found that *P. odoratum* has anticlinal cell walls with numerous pits set in a star-like pattern. Yurtseva (2001) suggested that the differences between these two species in their achene shape, size, color and exocarp structure depended rather on their developmental maturity and environmental conditions. In this study we examined only two specimens of *P. hydropper* (one from each of two separate but not too distant localities) and a single specimen of *P. odoratum* (from a distant locality to the other species) and so we cannot exclude the possibility of such epigenetic (environmental) plasticity. During the early stage of development the achene is more or less equal in length to the perianth. The exocarps of these achenes show adaptations for a long-term preservation in soil, which are thick walls, firmly interlocked with the lobes and covered with wax layers.

(2) *Polygonum pubescens* and *Polygonum* sp. 2: The morphological similarities between *P. pubescens* and *Polygonum* sp. 2 are the presence of bristles at the apex of ocreae, 3-clefted style, filiform inflorescence and conspicuous rachis. However, the *Polygonum* sp. 2 is

characterized as an annual herb and its tepals are eglandular. The achene sculpturing of *P. pubescens* is a distinctly shallow reticulate-papillose, whereas an undulate with anticlinal cell walls formed as continuous ridges was found in *Polygonum* sp. 2.

In conclusion, the evaluation of the achene shape, size and sculpturing of the Thai species within the genus *Polygonum* s.l., as exemplified by the 20 taxa examined here, did not reveal any taxonomically useful (informative) characters for classification at the infrageneric level, and provide only weak support for the previous section classification of Dammer (1892) and Steward (1930). A more congruent infrageneric classification system of Thai *Polygonum* should be suggested, after additional informative characters among morphological, palynological, anatomical and molecular data have been accumulated. However, the achene morphology seems to be a useful diagnostic character set at the interspecific level, especially for supporting the distinctiveness between similar species. Finally, observation of the mature stage and the position of achene on the inflorescence should be carefully considered.

ACKNOWLEDGEMENTS

We wish to thank the director and staff of Khon Kaen University herbarium for access to material. We would like to thank the anonymous reviewers who contributed with helpful criticism of the manuscript.

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