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The genus *Ammannia* L. (*Lythraceae*) in Egypt

Abstract

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The morphology, anatomy of the stems, leaves, SEM of pollen and seed coat surfaces are used to reassess the taxonomic relationships between *Ammannia* species. The species occurring in Egypt are systematically revised. The results clearly indicate considerable differences between the studied species. The study revealed the presence of five distinct species. On the bases of the observed morphological and anatomical differences *Ammannia baccifera* is differentiated into 2 different varieties. These varieties are *Ammannia baccifera* var. *baccifera* L. and *Ammannia baccifera* var. *attenuata* (Hochst. ex A. Rich.) Z. Turki. A key to the species is provided.

Key words: Pollen grains, Seeds, SEM.

Introduction

The genus *Ammannia* comprises 25 cosmopolitan species, mostly of wet areas. These species are reported as weeds of the rice fields or in water or marshy habitats. They are frequently reported in literature as constant members of the rice weed communities (Chakravarty 1957; Mahapatra & al. 1965). *Ammannia* species are common and specific weeds in rice fields (Imam & Kosinová 1972).

Täckholm & Drar (1944) stated that *Ammannia* species were introduced into Egypt together with the rice grains imported from India. In Egypt, Imam and Kosinová (1972) recorded three species of *Ammannia*: *A. aegyptiaca* Willd., *A. attenuata* Hochst. ex A. Rich. and *A. auriculata* Willd.. Täckholm (1974) reported the presence of five species: *A. auriculata* including *A. auriculata* var. *bojeriana* Koehne, *A. multiflora* Roxb., *A. attenuata*, *A. baccifera* L. (= *A. aegyptiaca*), and *A. senegalensis* Lam. which comprises two varieties: *A. senegalensis* var. *confertiflora* Koehne and *A. senegalensis* var. *diffusa* Koehne. Boulos (1995) and El Hadidi & Fayed (1994/95) reported the same species as in Täckholm but without any varieties. Boulos (2000) reported the presence of only four species: *A. auriculata*, *A. aegyptiaca*, *A. baccifera*, and *A. senegalensis*, excluding *A. multiflora*, and treated *A. attenuata* as a synonym to *A. baccifera*.

Donoghue & Sanderson (1992) stressed on the importance of utilizing different criteria in reassessment of relationships between *Ammannia* taxa, and that few criteria can be misleading.

So, the present contribution involves a detailed study of morphological, anatomical and SEM of both pollen grains and seeds of *Ammannia* species collected from natural habitats, representing the range of the genus in Egypt.

Materials and methods

The present study is based on collections kept in Cairo University Herbarium (CAI), and fresh material collected from localities of different regions in Egypt and deposited in Menofiya University Herbarium (MNF).

Samples for anatomy of the stem and mature leaves were chosen from fresh material (Table 1). All assessments were made on all plants at similar developmental stages (fruiting stage) and in comparable positions of each plant. Fresh material was fixed in F.A.A. [5:5:90]. After fixation stems and leaves were transformed in ethyl alcohol series, and then embedded in paraffin wax. The stems and leaves were sectioned at 10-15 μm ; sections were dehydrated in alcohol-xylol series. Sections were stained in safranin and light green according to Sass (1961). The transverse sections were examined and photographed by Zeiss research microscope. A planimeter was used for estimation of the percentage of each tissue to the total section area according to Abd EL-Rahman & al. (1976), Pandey (1982) and Abd El-Gawad & al. (1989).

The macromorphological characters of about 50 specimens of pollen & seed for each taxon were studied by the aid of light-microscope. SEM study of the investigated material was carried out by mounting dried material on brass stubs and coated with a thin layer of gold using JEOL JSM 530P SEM at the electron microscopic unit, Faculty of Science, Alexandria University.

For data analysis, 52 macromorphological characters were coded and used for creating the data matrix (Table 2). Phenograms illustrating the relationship between the studied taxa were then constructed by calculating the average taxonomic distance (dissimilarity) by using the NTSys. program package for IBM-pc as described by Rohlf (1989).

Table 1. Localities of the studied taxa of *Ammannia* collected by the author and deposited in Menofiya university herbarium (used for anatomy, pollen and seed studies).

Taxon	Date of collection	Locality
<i>Ammannia aegyptiaca</i>	2. 10. 2003	Damanhour, Behayra governorate
	3. 10. 2004	Bahnaby, Sharqiya governorate
<i>A. auriculata</i>	3. 10. 2004	MeetGhamr, Dakahliya governorate
<i>A. baccifera</i>	2. 10. 2003	Damanhour, Behayra governorate
<i>A. multiflora</i>	3. 10. 2004	Bahnaby, Sharqiya governorate
<i>A. senegalensis</i>	25. 9. 2003	Ganah village, Kafr El Sheikh governorate

Table 2. Data matrix of the selected macromorphological characters.

Characters	Diagnosis	1	2	3	4	5	6	7
Habit	Erect	1	1	1	1	1	1	0
	Erect or decumbent	0	0	0	0	0	0	1
	Branched	1	1	1	0	1	1	1
	Unbranched	0	0	0	1	0	0	0
Height	Herb	1	0	1	1	1	0	0
	Suffruticose	0	1	0	0	0	1	1
	20-40 cm	0	0	0	1	1	0	1
Leaf shape	40-60 cm	1	0	1	0	0	0	0
	60-100 cm	0	1	0	0	0	1	0
	Linear	0	1	0	0	0	0	0
Leaf base	Lorate-linear	1	0	0	0	0	1	0
	Lorate	0	0	1	0	1	0	0
	Lorate-oblong	0	0	0	1	0	0	1
	Cordate	0	0	0	1	0	0	0
Upper surface	Uriculate	0	1	0	0	0	1	0
	Attenuate	1	0	1	0	0	0	0
	Obtuse	0	0	0	0	1	0	1
	Minutely scabrous	0	1	0	0	0	0	0
Cimes	Glabrous	1	0	1	1	1	1	1
	Pedunculate-very lax	0	0	0	1	0	0	0
	Pedunculate- lax	1	0	0	0	0	1	1
	Pedunculate- dense	0	1	1	0	0	0	0
Flowers	Sessile	0	0	0	0	1	0	0
	Pediceled	1	0	1	1	0	1	1
	Subsessile	0	1	0	0	0	0	0
Hypanthium	Sessile	0	0	0	0	1	0	0
	1-1.5 mm long	1	0	1	1	1	0	1
	1.8-3 mm long	0	1	0	0	0	1	0
	1- 1.5 mm width	1	0	1	1	1	0	0
	1.5- 2.5 mm width	0	1	0	0	0	1	0
	8 ribbed	0	1	0	0	0	0	0

Table 2. (continued.)

Hypanthium	10 ribbed	0	0	0	0	0	0	0
Epicalyx	Obscure	1	0	1	1	1	1	1
	Minute	1	1	0	1	0	0	1
	Horn-like	0	0	1	0	1	1	0
Petals	Absent	1	0	1	0	1	0	1
	4, Purple-pink	0	1	0	1	0	1	0
Stamens	4 in number	1	1	1	0	1	0	1
	8 in number	0	0	0	1	0	1	0
	Yellow	1	0	1	0	1	0	1
	Purple	0	1	0	1	0	1	0
Capsule	Reddish	1	1	1	1	1	1	1
	Yellow	0	0	0	0	0	0	0
	1-1.5 mm diameter	1	0	1	0	0	0	0
	1.5-2 mm diameter	0	0	0	1	1	1	1
	3- 4 mm diameter	0	1	0	0	0	0	0
	As long as hypanthium	0	1	0	1	1	0	0
Style length	Exceeding hypanthium	1	0	1	0	0	1	1
	0.3-0.5 mm	1	0	1	0	1	0	1
	0.5-1.0 mm	0	0	0	0	0	0	0
	1.5-1.8 mm	0	0	0	0	0	1	0
	2.8-3.0 mm	0	1	0	1	0	0	0

Description of the genus *Ammannia*

Annual herbs, up to 150 cm height; stems solid, more or less quadrangular, erect or with lower branches decumbent, glabrous; leaves opposite and commonly decussate, sessile or pseudopetiolate; base attenuate, cordate or auriculate; flowers in peduncled or sessile axillary cymes, usually 4-merous; floral tube campanulate or urceolate, globose in fruit, more or less 4-angled; calyx teeth 4, with 4 horn-shaped small appendages; petals 4, rose-purple, small and caducous or absent; stamens 4(8) inserted within the floral tube with filiform filaments; ovary globose, style absent or short; capsule globose, included or exceeding the hypanthium, irregularly dehiscent; seeds many, obpyramidal, one face rounded and the other irregularly concave.

Results

I: MACROMORPHOLOGICAL STUDIES

1: *Ammannia aegyptiaca* Willd., Enum. Pl. Hort. Berol. 1: 6, t. 6 (1803); Boulos, Flora of Egypt (2000)

Syn.: *Ammannia baccifera* subsp. *aegyptiaca* (Willd.) Koehne

Type: collected from Damietta, Egypt.

Erect, branched herb, stem suffruticose at the base, up to 40 cm high; leaves lorate, 4-6 cm length, 0.6-0.8 mm width, with obtuse-cuneate bases; cymes sessile-subsessile with dense, glomerate flowers; hypanthium 1-1.5 mm length and width, ribs obscure, epicalyx horn-like; petals absent, stamens 4, yellow; capsule reddish yellow, 1.5-2.0 mm diameter included in the hypanthium.

Common in rice fields, during harvest time.

Representative specimens: Nile Delta: Behayra Governorate, El Rahmaniya, 2. 10. 2003, Z. Turki (MNF); Damanhour, 8. 10. 1971, M. Imam (CAI); *ibid.*, 2. 10. 2003, Z. Turki (MNF); Bahnaby, Sharqiya Governorate, 3. 10. 2004, Z. Turki (MNF); El Senbellawain, Dakahliya Governorate, 3. 10. 2004, Z. Turki (MNF).

Oasis: Dakhla oasis, 30. 10. 1971, Imam & al. (CAI)

Distribution: Africa (Angola, Egypt, Ethiopia, Sudan, Zaire); Asia and introduced to Europe.

2: *Ammannia auriculata* Willd., Enum. Pl. Hort. Berol. 1P: 7, t. 7. (1803); Täckholm, Stud. Fl. Egypt (1974); Boulos, Flora of Egypt (2000)

Syn.: *Ammannia senegalensis* auct. non Lam. 1791: C. B. Clarke

Type: Described on material cultivated in Berlin coming from Rosetta in Egypt (B-Willd. 3081).

Erect branched herb, stem suffruticose at the base, up to 100 cm high; leaves linear, 6-9 cm length, 0.6-1.0 cm width; leaf base uriculate; cymes with peduncles up to 3 mm long; flowers dense, subsessile with pedicels 1-2 mm long; hypanthium 1.8-3 mm length, 2 mm width, with 8-ribs, epicalyx minute, petals 4, pink, stamens 4, purple, capsule reddish, up to 4.0 mm diameter, as long as hypanthium, style length up to 3.0 mm.

Representative specimens: Nile Delta: Ganah village, Kafr El Sheikh Governorate, 25. 9. 2003, Z. Turki (MNF); *ibid.*, 2. 10. 2004 (MNF); Meit Ghamr, Dakahliya Governorate, 3. 10. 2004, Z. Turki (MNF).

Faiyum Region: Near Sannoris, 12. 10. 1969, Imam & al. (CAI).

Oases: Bahariya Oasis, El Gidida village, 2. 11. 1971, Imam & al. (CAI).

Distribution: Widely distributed throughout tropical and warm temperate regions.

3: *Ammannia baccifera* L., Sp. Pl. 120. (1753); Täckholm, Stud. Fl. Egypt (1974); Boulos, Flora of Egypt (2000).

Type: Described from China.

Erect or procumbent, branched herbs, up to 40 cm high; leaves narrow oblong-lorate, 3-4 cm length, 0.6-0.8 cm width; leaf base at lower leaves attenuate, at upper leaves obtuse or cuneate; cymes peduncled, lax; flowers pediceled; hypanthium 1-1.5 mm length and width, ribs

obscure; epicalyx minute; petals absent; stamens 4, yellow; capsule reddish yellow, 1-1.5 mm diameter, exceeding hypanthium, style length up to 0.5 mm; seeds 0.5 mm, brownish.

Representative specimens: Nile Delta: Ganah village, Kafr El Sheikh Governorate, 25. 9. 2003, Z. Turki (MNF); Damanhour, 3. 10. 2003, Z. Turki (MNF); Meet Ghamr, Dakahliya Governorate, 3. 10. 2004, Z. Turki (MNF); El Senbellawain, Dakahliya Governorate, 3. 10. 2004, Z. Turki (MNF); Bahnaby, Sharqiya Governorate, 3. 10. 2004, Z. Turki (MNF).

Faiyum region: Near Sannoris, 12. 10. 1969, Imam & al. (CAI).

O: Bahariya Oasis, El Gidida village, 2. 11. 1971, Imam & al. (CAI).

A very variable species in rice fields.

A. baccifera var. *attenuata* (Hochst. & A. Rich.) Z. Turki, comb. nov.

Syn.: *Ammannia attenuata* Hochst. & A. Rich., Tent. Fl. Abyss. 1: 278 (1847).

Of similar shape, but leaves linear, up to 15 cm length, 1.0-1.4 mm width, all leaves with attenuate bases; capsule 1.5-2.0 mm diameter.

Grows with the type in the same fields.

Distribution: Africa, Afghanistan, Pakistan, India, China, Australia.

4: *Ammannia multiflora* Roxb., Fl. Ind. (ed. Carey & Wall.). 1:447. (1820); Täckholm, Stud. Fl. Egypt (1974).

Type: Described from the vicinity of Calcutta, India.

Erect mostly unbranched herb, up to 40 cm high; leaves narrow oblong-lorate, 3-4(4.5) cm length, 0.6-0.8(1.2) cm width; leaf base cordate-auriculate; cymes long peduncled, peduncles up to 8 mm long, very lax; flowers few, long pediceled, pedicels 4-6 mm long; hypanthium 1-1.5 mm length and width, ribs obscure, epicalyx minute; petals 4, pink; stamens 8, purple; capsule reddish, up to 2.2 mm diameter, as long as hypanthium; style length up to 3.0 mm.

Representative specimens: Nile Delta: Etaï El Barood, Behayra Governorate, 25. 9. 2003, Z. Turki (MNF); Bahnaby, Sharqiya Governorate, 29. 9. 2003, Z. Turki (MNF).

Distribution: tropical and subtropical Africa, Asia, Australia.

5: *Ammannia senegalensis* Lam., Illustr. 1: 311, n. 155, t. 77, f. 2 (1791); Täckholm, Stud. Fl. Egypt (1974); Boulos, Flora of Egypt (2000).

Erect branched herb, stem suffruticose at the base, up to 100 cm high; leaves lorate-linear, 5-8 cm length, 0.8-1.0 cm width; leaf base uriculate; cymes peduncled, lax, peduncles up to 4 mm long; flowers numerous, pediceled, pedicels 3-5 mm long; hypanthium up to 2.0 mm length and width, ribs obscure, epicalyx horn-like; petals 4, pink; stamens 8, purple; capsule reddish, up to 2.0 mm diameter, exceeding hypanthium; style length up to 1.5 mm.

Representative specimens: Nile Delta: Ganah village, Kafr El Sheikh Governorate, 25. 9. 2003, Z. Turki (MNF); El Senbellawain, Dakahliya Governorate, 3. 10. 2004, Z. Turki (MNF).

Distribution: North Africa, Northeast and West tropical Africa.

II: ANATOMICAL STUDIES

The anatomical investigations of the stem and leaf of the studied taxa is represented in table (3) and plates (1 and 2) respectively.

A: Stem anatomy

1- *Ammannia aegyptiaca*

The outline of the stem in cross section is circular, ridges obscure; 1.8-2.0 mm in diameter. Epidermis consists of one layer, with barrel shaped cells, covered with thin cuticle;

Table 3. Anatomical characters of stems and leaves of the *Ammannia* species in Egypt.

Character		1	2	3	4	5	6	
Stem	outline	Circular	+	-	-	-	-	-
		Tetragonal	-	-	+	+	+	+
		pentagonal	-	+	-	-	-	-
	Ridges	Obscure	+	+	-	-	-	-
		Ridged	-	-	+	+	-	-
		Long ridged	-	-	-	-	+	-
		Biforked ridge	-	-	-	-	-	+
	Epidermal cells	Barrel	+	-	+	+	-	+
		Tetragonal	-	+	-	-	+	-
	Cortex	Thickness mm	0.1 4	0.2	0.2 2	0.0 9	0.7	0.0 6
		Druses	-	+	+	+	-	-
	phloem	Outer	0.0 3	0.0 4	0.2 4	0.0 2	0.0 4	0.1 8
			0.0 6	0.0 2	0.0 8	0.0 2	0.0 8	0.0 8
		Druses	-	+	+	+	-	+
		Sand crystals	-	-	-	-	+	-
	Xylem	Thickness mm	0.2	0.4 6	0.3	0.2	0.2 6	0.8
		Vessel diameter mm	0.0 2	0.0 3	0.0 4	0.0 4	0.0 2	0.0 6
	Pith	Width mm	1.0	1.9	0.2	0.8	0.5	1.1
	Leaf	Width at midrib μm	640	420	360	260	200	300
		Vascular tissue shape	Crescent	-	-	-	+	+
Triangular			-	-	+	-	-	-
Semi cylindrical			+	+	-	-	-	-
location		Middle	+	+	+	+	-	+
		Near epidermis	-	-	-	-	+	=
Width μm		160	40	160	80	60	100	
No. of vascular strands		25	20	12	15	10	20	
Palisade tissue thickness μm		40	20	40	40	20	100	
Spongy tissue thickness μm		60	40	60	20	20	100	

hypodermis is one thick-walled layer. Cortex 0.14 mm, consists of hexagonal thin or thick-walled parenchyma cells without druses; pericycle is in the form of a discontinuous layer of fibers; outer phloem 0.03 mm; xylem 0.2 mm thick, vessels angular, vessel diameter 0.02 mm; inner phloem 0.06 mm; pith 0.96-1.0 mm wide, more or less isodiametric parenchyma.

2- *Ammannia auriculata*

The outline of the stem in cross section is circular, slightly pentagonal with obscure ridges; 3-3.8 mm in diameter. Epidermis one layer, with cells more or less tetragonal in shape, covered with thin cuticle. Cortex 0.16-0.2 mm, of irregular parenchyma cells with few druses; pericycle of continuous 2-3 layers of stone cells; outer phloem 0.04 mm with druses; xylem 0.46 mm thick, vessels angular, vessel diameter 0.03 mm; inner phloem 0.02 mm; pith 1.9 mm wide, more or less isodiametric thin walled parenchyma.

3- *Ammannia baccifera* var. *baccifera*

The outline of the stem in cross section is tetragonal, slightly ridged; 3.4-3.8 mm in diameter. Epidermis one layer, with barrel-shaped cells, covered with thin cuticle. Cortex 0.20-0.22 mm, of aerenchyma cells without druses; pericycle of discontinuous, 2-3 layers of stone cells; outer phloem 0.24 mm with dense druses; xylem 0.26-0.3 mm thick, vessels angular, vessel diameter 0.04 mm; inner phloem 0.08 mm; pith 2.0 mm wide, more or less hexagonal parenchyma.

Ammannia baccifera var. *attenuata*

The outline of the stem in cross section is tetragonal, 3-3.8 mm in diameter with 4 distinguished ridges; cortex 0.06-0.09 mm, of irregular parenchyma cells with few druses; outer phloem 0.02 mm with druses, xylem 0.16-0.2 mm thick, inner phloem 0.02 mm; pith 0.8 mm wide, more or less hexagonal parenchyma.

4- *Ammannia multiflora*

The outline of the stem in cross section is tetragonal, 1.0 mm in diameter, with 4- elongated ridges;. Epidermis one layer, with tetragonal-barrel shaped cells, covered with thin cuticle. Cortex 0.5-0.7mm, of irregular aerenchyma cells without druses; pericycle of discontinuous 2-3 layers of fibers; outer phloem 0.04 mm with crystals; xylem 0.26 mm thick, vessels angular, vessel diameter 0.02 mm; inner phloem 0.08 mm; pith 0.5 mm wide, more or less isodiametric thin walled parenchyma.

5- *Ammannia senegalensis*

The outline of the stem in cross section is tetragonal, 2.5-3.0 mm in diameter, with long biforked ridges. Epidermis one layer, with barrel-shaped cells, covered with thin cuticle. Cortex is very narrow, 0.04-0.06 mm, of irregular aerenchyma cells without druses; pericycle of discontinuous 1-2 layers of fibers; outer phloem 0.1 mm with druses; xylem 0.8 mm in diameter, vessels angular, vessel diameter 0.06 mm; inner phloem 0.08 mm; pith 1.1 mm wide, more or less isodiametric thin walled parenchyma.

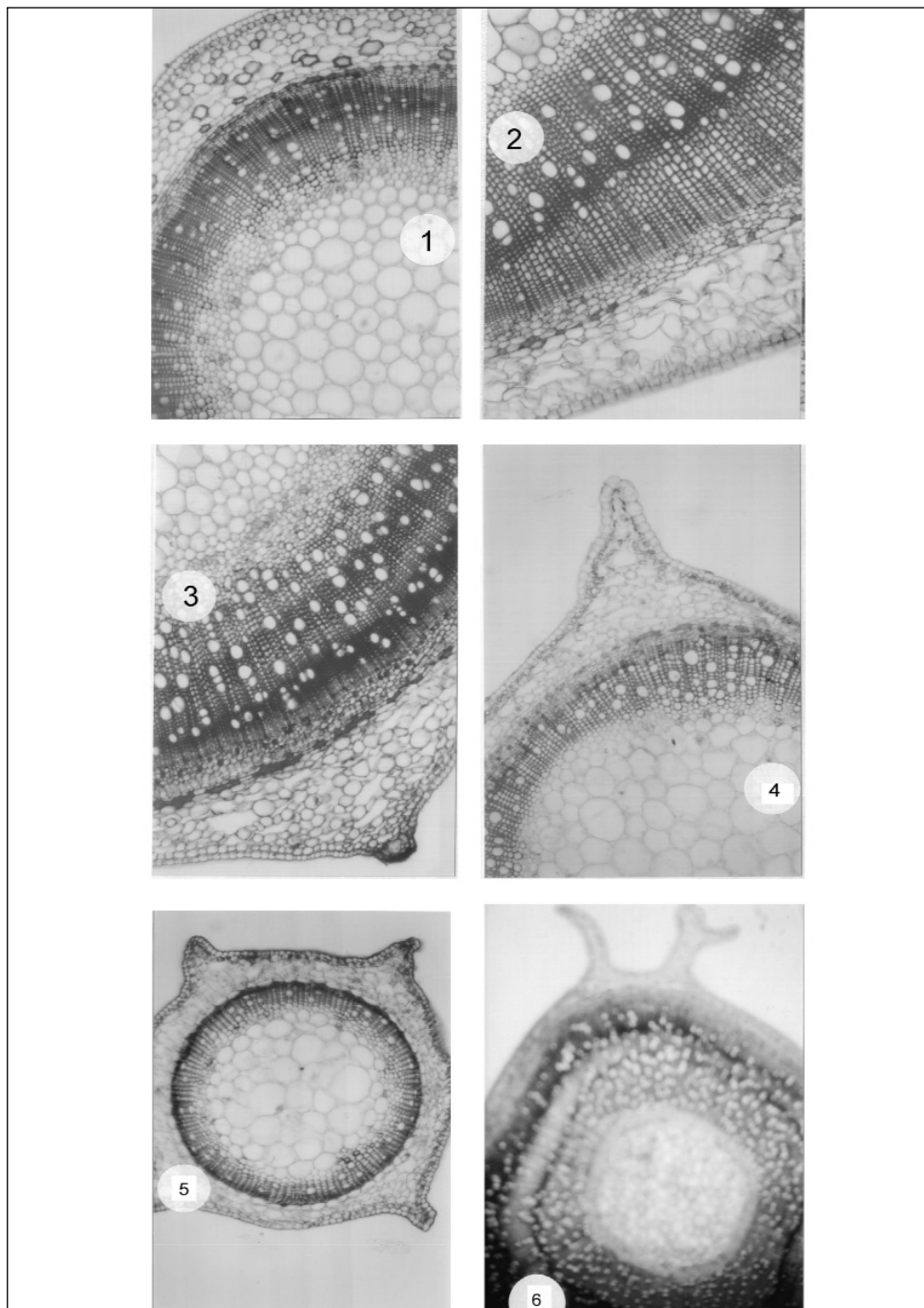


Plate 1. Stem anatomy of the studied taxa: **1** *Ammannia aegyptiaca*; **2** *A. auriculata*; **3** *A. baccifera* var. *baccifera*; **4** *A. baccifera* var. *attenuata*; **5** *A. multiflora*; **6** *A. senegalensis*.

B: Leaf anatomy**1: *Ammannia aegyptiaca***

The outline in cross section is flattened; 640 μm wide at the midrib region. Adaxial surface is generally flat or slightly concave, abaxial portion of midrib generally round shape. Epidermis, one thin cutinized layer, cells tangentially elongated except the adaxial facing the midrib region which is radially elongated. Hypodermis of slightly pigmented unilayered collenchyma. Leaves dorsiventral; palisade cells forming a continuous series of slightly elongated cells except at adaxial region facing the main vein; palisade tissue is about 40 μm wide; the spongy tissue consists of slightly chlorophyllous parenchyma cells, about 60 μm wide. The stellar structure is formed of about 25 vascular bundles of bicollateral type, a semicylindrical in shape, located in the middle of the midrib region, of about 160 μm widths.

2: *Ammannia auriculata*

The outline and anatomical features are built on the same plan as those in *A. aegyptiaca* except in the following:

Width at the midrib is 420 μm ; vascular tissue has a semicylindrical shape, located in the middle of the midrib region, about 40 μm widths; palisade tissue is 20 μm widths and spongy tissue is 40 μm widths; vascular strands 20.

3: *Ammannia baccifera* var. *baccifera*

The outline and anatomical features are built on the same plan as those in *A. aegyptiaca* except in the following:

Width at the midrib is 360 μm ; vascular tissue has a more or less triangular shape, located in the middle of the midrib region, about 160 μm width; palisade tissue is 40 μm widths and spongy tissue is 60 μm widths; vascular strands 12.

A. baccifera* var. *attenuata

Width at the midrib is 260 μm ; vascular tissue has a crescent shape, located in the middle of the midrib region, about 80 μm widths; palisade tissue is 40 μm widths and spongy tissue is 20 μm widths; vascular strands 15.

4: *Ammannia multiflora*

The outline and anatomical features are built on the same plan as those in *A. aegyptiaca* except in the following:

Width at the midrib is 200 μm ; vascular tissue has a crescent shape, located near the upper epidermis, about 60 μm width; palisade tissue is 20 μm widths and spongy tissue is 20 μm widths; vascular strands 10.

5: *Ammannia senegalensis*

The outline and anatomical features are built on the same plan as those in *A. aegyptiaca* except in the following:

Width at the midrib is 300 μm ; vascular tissue has a crescent shape, located in the middle of the midrib region, about 100 μm width; palisade tissue is 100 μm widths and spongy tissue is 100 μm widths; vascular strands 20.

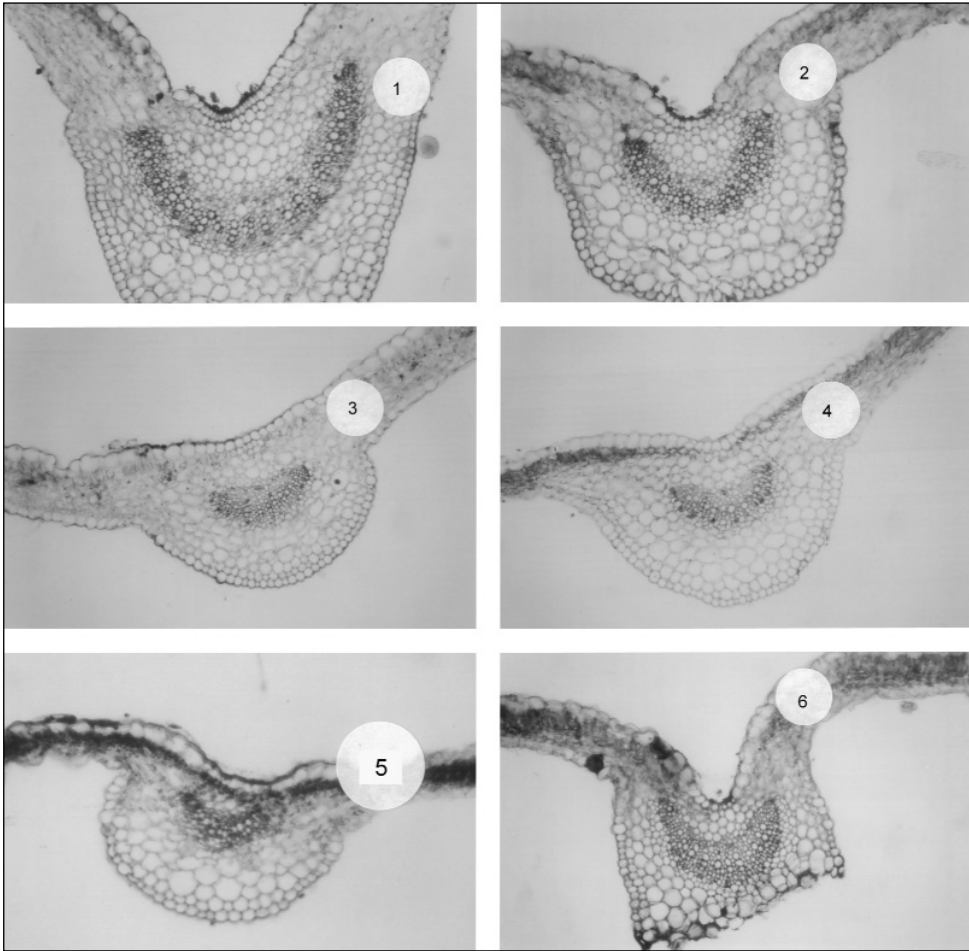


Plate 2. Leaf anatomy of the studied taxa: **1** *Ammannia aegyptiaca*; **2** *A. auriculata*; **3** *A. baccifera* var. *baccifera*; **4** *A. baccifera* var. *attenuata*; **5** *A. multiflora*; **6** *A. senegalensis*.

III: Pollen grains

Table (4) and plate (3) show that the pollen polar axis ranges from 5.9 μm in *Ammannia aegyptiaca*, to 9.6 μm in *A. multiflora* and *A. senegalensis*, while the equatorial axis ranges from 2.6 μm in *A. baccifera* to 6.6 μm in *A. multiflora*. According to Erdtman (1972), these results indicate that the pollen grains of all investigated species are of small size. On the other hand, the P/E ratio ranges from 1.31 in *A. aegyptiaca* to 2.62 in *A. baccifera*. Accordingly, the pollen grains are subprolate in *A. aegyptiaca*; prolate in *A. auriculata*, *A. multiflora*, and *A. senegalensis* and perprolate in *A. baccifera*. The aperture type was found to be stephanocolporate in all examined species. The colpi are usually long reaching the poles.

Table 4. Summary of pollen grain size and shape.

Species	Polar axis (µm)	Equatorial axis (µm)	P/E	Shape
<i>Ammannia baccifera</i> var. <i>attenuata</i>	6.8	2.6	2.62	Perprolate
<i>A. auriculata</i>	9.2	5.2	1.77	Prolate
<i>A. baccifera</i> var. <i>baccifera</i>	9.4	4.4	2.14	Perprolate
<i>A. multiflora</i>	9.6	6.6	1.45	Prolate
<i>A. aegyptiaca</i>	5.9	4.5	1.31	Subprolate
<i>A. senegalensis</i>	9.6	5.6	1.71	Prolate

Differences in exine morphology have been recorded among the examined species. In *A. auriculata*, *A. multiflora* and *A. senegalensis*, the exine is striate. In *A. baccifera* the exine is rugulate to finely reticulate, while in *A. aegyptiaca*, the exine is psilate. In all studied species, mesocolporate exine is pilate.

IV: SEM of the spermoderm (Table 5 & Plate 4)

SEM of the epidermal cells clarifies the texture and reticulation of their anticlinal (radial) walls, the appearance of the outer periclinal walls and the persistency of the primary cell walls.

The seed surface reticulation is with tetragonal-pentagonal epidermal cells having straight or undulate anticlinal walls with different thickening types. Taking into consideration the thickening of the anticlinal walls, and the appendages they carry, the following types are recorded: straight hairy in *A. baccifera*; slight undulates either glabrous in *A. auriculata*, or papillate in *A. multiflora*, *A. aegyptiaca* and *A. senegalensis*. The relief of cell boundaries, may be normal in *A. auriculata* and *A. senegalensis* or channelled in *A. baccifera*, *A. multiflora* and *A. aegyptiaca*. The anticlinal wall thickness may be thin in *A. senegalensis*; slightly thick in *A. auriculata* and *A. baccifera* and thick in *A. multiflora* and *A. aegyptiaca*. Two types of the height of the wall can be recognized: slightly raised in *A. baccifera* and *A. aegyptiaca*; and raised in *A. auriculata*, *A. multiflora* and *A. senegalensis*. The outer periclinal wall shape in surface view, may be flat in *A. baccifera*, slightly concave in *A. aegyptiaca* or deeply concave in *A. auriculata*, *A. multiflora* and *A. senegalensis*; the surface texture can be distinguished into three types: smooth with few striations in *A. baccifera*, striated in *A. auriculata*, *A. multiflora* and *A. aegyptiaca* and highly striated in *A. senegalensis*.

Discussion

In the present study, the leaf base, presence or absence of petals, number of stamens, the length of the style and the fruit characters are considered to be of systematic value in differentiating the studied taxa. The leaf base is variable between the different taxa, it is auriculate-subcordate in *A. auriculata*, *A. senegalensis* and *A. multiflora*, attenuate or pseudopetiolate in *A. baccifera*. In *A. auriculata*, *A. multiflora* and *A. senegalensis*, four

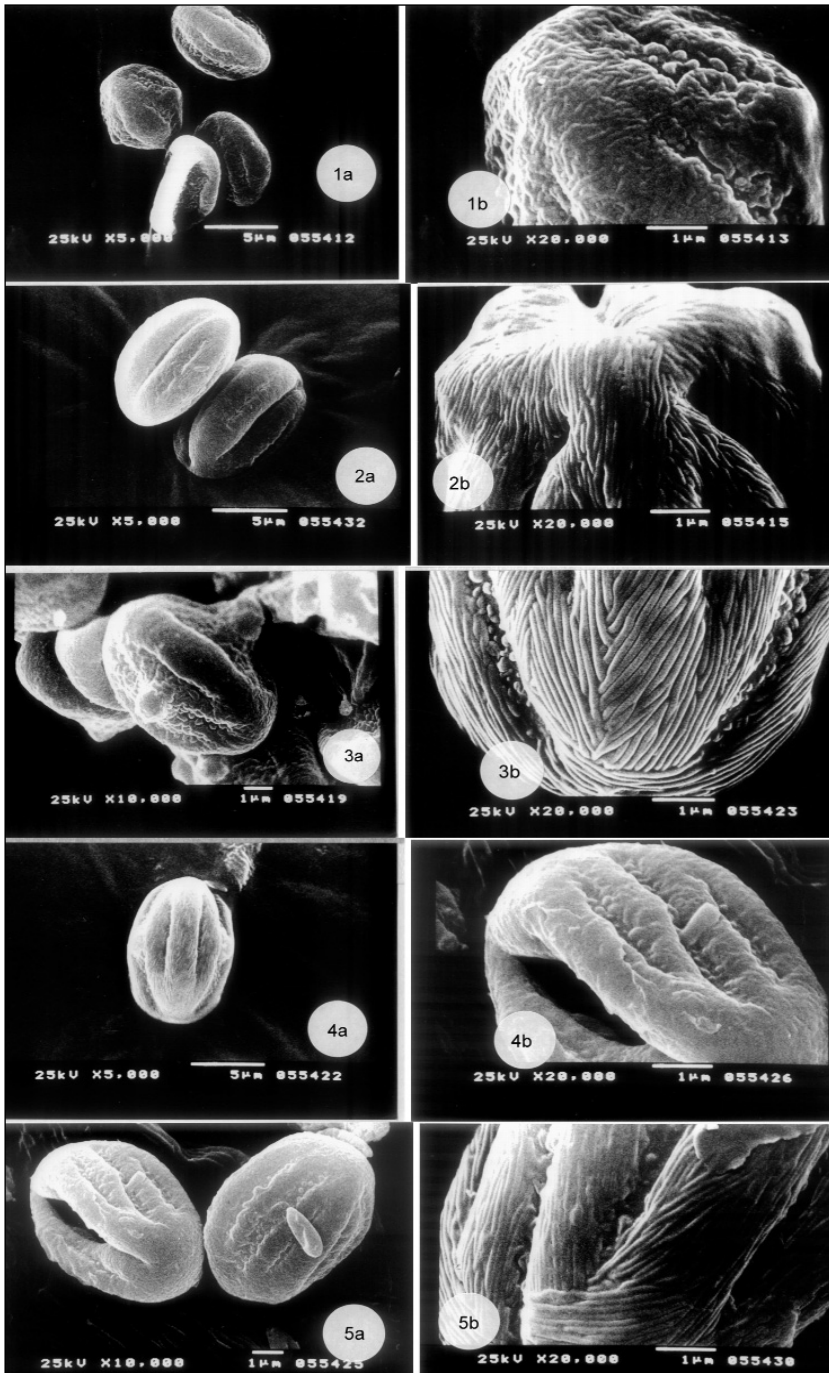


Plate 3. Scanning electron micrographs of the studied taxa: 1) *Ammannia baccifera*; 2) *A. auriculata*; 3) *A. multiflora*; 4) *A. aegyptiaca*; 5) *A. senegalensis*.

petals are present, while in *A. aegyptiaca* and *A. baccifera* the petals are absent. The number of stamens is 8 in *A. multiflora* and *A. senegalensis* while it is only 4 in the other taxa.

The fruit diameter may be 1-1.5 mm in *A. baccifera*; 1.5-2 mm in *A. aegyptiaca*, *A. multiflora* and *A. senegalensis* and up to 4 mm in *A. auriculata*. The insertion of the flowers on the stem indicates variability between the studied taxa; the cymes are sessile and compact in *A. aegyptiaca* and peduncled with dense or lax flowers in the other taxa. Täckholm (1974) considered the style length as the main character of the identification. The present study indicates that the style length varies between different taxa, it may be less than 0.5 mm in *A. aegyptiaca*, *A. baccifera* and *A. senegalensis* or up to 3 mm in *A. auriculata* and *A. multiflora*.

Täckholm (1974), El Hadidi & Fayed (1994-1995) and Boulos (1995) treated *A. baccifera* and *A. attenuata* as two distinct species, while Boulos (2000) treated *A. attenuata* as a synonym to *A. baccifera*. In the present study, all specimens seen of *A. attenuata* proved to be *A. baccifera*. They agree completely with *A. baccifera* except for their leaves which are longer (length and width), with all leaves with attenuate base and the capsule is slightly broader. These differences are not significant to separate them into different species. So, *A. attenuata* is treated here as variety in *A. baccifera*.

Table 5. Summary of SEM spermoderm investigations: 1) *Ammannia baccifera*; 2) *A. auriculata*; 3) *A. multiflora*; 4) *A. aegyptiaca*; 5) *A. senegalensis*.

Characters/Taxon		1	2	3	4	5	
Over all seed coat pattern	Reticulate	+	+	-	-	-	
	Irregular reticulate	-	-	+	+	+	
Epidermal cell	shape	Tetra-pentagonal	+	+	-	-	-
		Illdefined	-	-	+	+	+
	Size	polymorphic	-	-	+	+	+
		Monomorphic	+	+	-	-	-
	Hairs	Present	+	-	-	-	-
Absent or papilate		-	+	+-	+-	+-	
Anticlinal walls	Undulation	Straight	+	-	-	-	-
		Wavy	-	+	+	+	+
	Relief of cell boundaries	Normal	-	+	-	-	+
		Channeled	+	-	+	+	-
	Thickness	Thin	-	-	-	-	+
		Slightly thick	+	+	-	-	-
		Thick	-	-	+	+	-
	Height	Flat	-	-	-	-	-
		Slightly raised	+	-	-	+	-
Raised		-	+	+	-	+	
Periclinal	Surface	Flat	+	-	-	-	-
		Slightly concave	-	-	-	+	-
		concave	-	+	+	-	+
	Texture	Striated	-	+	+	+	-
		Highly striated	-	-	-	-	+
		Smooth with few steria	+	-	+	-	-

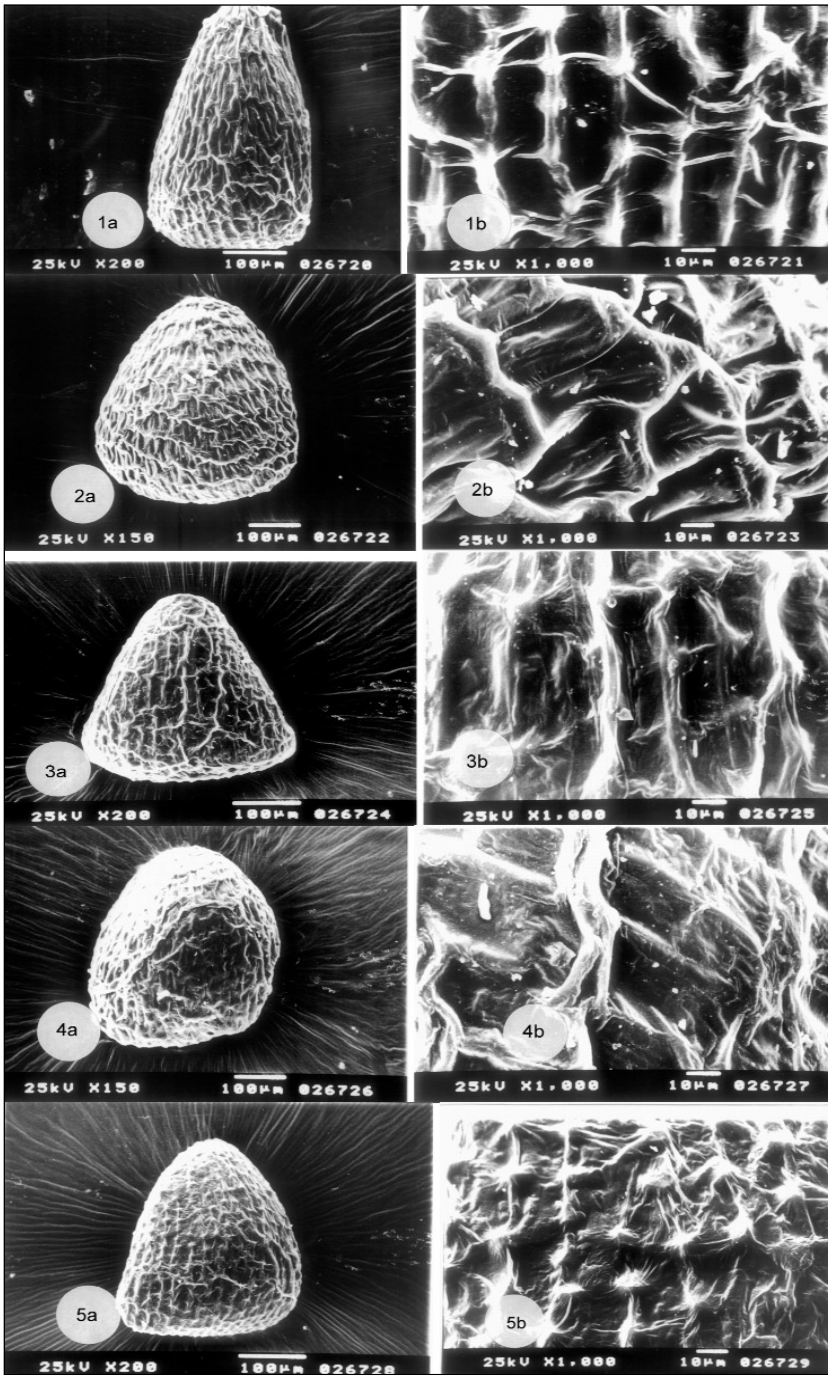


Plate 4. SEM Micrograph of spermoderm surface of the studied taxa: 1) *Ammannia baccifera*; 2) *A. auriculata*; 3) *A. multiflora*; 4) *A. aegyptiaca*; 5) *A. senegalensis*.

Ammannia aegyptiaca was reported as a synonym to *A. baccifera* by Täckholm (1974) while Boulos (2000) treated it as a distinct species. *Ammannia aegyptiaca* has sessile flowers in compact, glomerate cymes and is a distinct species.

The present investigation shows that the variations in some micro-morphological characters are useful in the differentiation between the studied taxa. The stem outline is circular with undulated margin in *A. aegyptiaca* and *A. auriculata* or tetragonal with slight ridges in *A. baccifera* var. *baccifera*; tetragonal with 4 ridges in *A. baccifera* var. *attenuata* and *A. multiflora* or biforcked in *A. senegalensis*. The width of vascular tissue differs in the different taxa, ranges from 0.13 mm in *A. multiflora* to 0.98 mm in *A. senegalensis*. Waly (1999) detected that wood anatomical characters may prove their value in the taxonomy of the related species. The pith is also variable in width between the different taxa; it ranges from 0.05 mm in *A. multiflora* to 2.0 mm in *A. baccifera* var. *baccifera*.

The anatomical features of leaves of the studied taxa are built on the same plan with some differences in both midrib width which ranges from 200 µm in *A. multiflora* to 640 µm in *A. aegyptiaca*; number of vascular strands which varies from 10 in *A. multiflora* to 25 in *A. aegyptiaca* and location which may be close to upper epidermis or in the middle of the midrib region. Palisade/spongy tissue ratio is also different in different taxa. Keating (1984) reported that midrib shape, dermal and mesophyll features of the leaf of many genera included in the *Myrtales* were most discriminating when examining these taxa.

Palynological investigations show that the shape of the pollen in all studied taxa usually varies from subprolate, prolate to perprolate. The variation in the exine sculpturing is taxonomically significant. The exine sculpturing is striate in *A. auriculata*, *A. multiflora* and, *A. senegalensis*; regulate to reticulate in *A. baccifera* and psilate in *A. aegyptiaca*.

Kasetsinsombat & al. (2000) reported that pollen morphology has a taxonomic value and can be used as supporting evidence to the morphological and phylogenetic studies. Barthlott & Voit (1979) reported that anticlinal undulations in the seed exine are of high taxonomic significance and often characterize races between the species and genus level. Barthlott (1981) reported that characters of cell boundaries in seed coat can often be used to characterize groups of related species, genera or taxonomic categories up to the family level.

SEM spermoderm investigations indicate the presence of differences between the studied taxa represented in the relief of cell boundaries and characteristics of both periclinal and anticlinal walls.

Table 6. The proposed treatment, based on numerical analysis.

Groups	Taxa	Cluster	Series
GR ₁	<i>Ammannia auriculata</i>	C ₁	S ₁
GR ₂	<i>A. multiflora</i>	C ₂	
GR ₃	<i>A. senegalensis</i>		
GR ₄	<i>A. aegyptiaca</i>	C ₃	S ₂
GR ₅	<i>A. baccifera</i>		

So, in the studied taxa, the micro-morphological characters, the pollen grains and seed coat morphology are used for their taxonomic significance when combined with other morphological characters (leaf, floral and fruit characters).

The relationships between the studied taxa based on morphological data as based on the average taxonomic distance (dissimilarity) is represented in Table (6). The phenogram constructed according to analysis of 52 macromorphological characters revealed the delimiting of the studied taxa into two major phenetic lines. In the first line at a distance of about 1.75 the studied taxa are separated into two series. The first series include *A. auriculata*, *A. multiflora* and *A. senegalensis*. At a distance of about 1.39 two clusters were distinguished; the first include *A. auriculata* which is distinguished from the other taxa and characterized by its auriculate clasping leaves, style up to 3.0 mm, hypanthium 8 ribbed, capsule up to 4 mm diameter, included in the hypanthium. The second cluster is distinguished at a distance of about 1.32 into two groups including the species *multiflora* and *senegalensis*. The first group includes *A. multiflora* which is characterized by unbranched habit, peduncles up to 6 mm and petals up to 1mm long. The second group includes *A. senegalensis* which characterized by branched habit, peduncles up to 4 mm long, style up to 1.5 mm, hypanthium ribs obscure, capsule up to 2.0 mm diameter, exceeding the hypanthium. The second series includes one cluster which is distinguished at 1.72 into two groups. The first group includes *A. aegyptiaca*, characterized by leaf base obtuse-cordate, sessile flowers in compact glomurate clusters while the second group including *A. baccifera* characterized by leaf base attenuate or rounded flowers pediceled in lax or dense peduncled cymes.

All species collected in Egypt from rice fields grown in approximately the same habitat conditions. Similar habitat conditions and different groupings reflect genetic diversity of the examined taxa.

The present study shows that the genus *Ammannia* in Egypt is represented by five species: *A. aegyptiaca*, *A. auriculata*, *A. baccifera* (with two varieties: *A. baccifera* var. *baccifera* and *A. baccifera* var. *attenuata*), *A. multiflora* and *A. senegalensis*.

Key to Egyptian species

- 1. Petals 4; style 1.5 – 3.0 mm2
- 1. Petals absent; style 0.2 – 0.5 mm4
- 2. Unbranched herb up to 40 cm high; peduncles up to 6 mm; petals up to 1 mm long.....*A. multiflora*
- 2. Densely branched suffruticose herb, up to 100 cm high, peduncles up to 4 mm; petals up to 2 mm long.....3
- 3. Leaf base auriculate; style up to 3.0 mm; hypanthium 8-ribbed, capsule up to 4 mm diameter, included in the hypanthium; stamens 4.....*A. auriculata*
- 3. Leaf base obtuse-cordate; style up to 1.5 mm; hypanthium ribs obscure; capsule up to 2.0 mm diameter, exceeding the hypanthium; stamens 8*A. senegalensis*
- 4. Leaf base obtuse-cordate; flowers sessile in compact glomurate clusters.....*A. aegyptiaca*
- 4. Leaf base attenuate or rounded; flowers pediceled in lax or dense peduncled cymes*A. baccifera*

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