NOTES ON THE TOXICITY OF *Sphenoclea zeylanica*

By *Robert F. Raffauf*[1] *and Akifumi Higurashi*[2]

The genus *Sphenoclea* was described by Gaertner in 1788 (15). Its affinities and family placement have continued ever since to be a source of taxonomic uncertainty, as a few randomly chosen botanical references –from monographic, floristic, general studies and dictionaries– would indicate.

In 1835, von Martius included *Sphenoclea* in the Sphenocleaceae (37), and a year later Lindley placed it in the Campanulaceae as a "Sub-order", Sphenocleaceae. He wrote that "this remarkable plant is very much like a campanulaceous genus in structure; but its exalbuminous seeds, the absence of collecting hairs from its styles, and the round sub-sessile anthers seem to indicate the type of a different order; and the peculiar habit of the only known species seems to confirm the propriety of the separation" (22). Bentham and Hooker assigned it in 1873 to the Campanulaceae (7), as did Engler and Diels in 1936 (13). In 1959 and 1973 Hutchinson maintained the genus in the Campanulaceae (19, 20) although the floristic works of Hutchinson and Dalziel in 1931 and 1963 retained it as a member of the Sphenocleaceae (21, 22). Cronquist in 1968 (10) and Takhtajan in 1969 (27) recognized the Sphenocleaceae, assigning the family to the Campanulales. Later, in 1981 Cronquist wrote: "*Sphenoclea* is embryologically and palynologically much like the Campanulaceae, and its relationship here seems reasonably certain" (11).

A number of floristic works have likewise differed as to the placement of *Sphenoclea.* Examples of this opinion over the past century are shown by several references: Blanco (8) in 1837, Danguey (12) in 1930 and Wright in 1850 (31) maintained the genus in the Sphenocleaceae. Wagenitz, however, as late as 1954, while assigning it to the Campanulaceae, expressed the opinion that its position in this family is uncertain and that apparently it may not even belong in the Campanulales (30).

In 1948, the late Airy-Shaw (3) placed the genus in the Sphenocleaceae stating that this family "ought to be positioned as a 'half-way house' between the Phytolaccaceae and the Primulaceae. Usually, however, it is treated as a genus of the Campanulaceae or as a closely related distinct family. The last possibility is maintained here". In 1960, he treated the genus as a tribe of the Campanulaceae (4); and in 1966, in his edition of Willis' *Dictionary of Flowering Plants and Ferns,* he qualified *Sphenoclea* as a "peripheral Centrosperm group with possible connections to Phytolaccaceae (*cf.* habit, anatomy) and even the Lythraceae (*cf.* Peplis, etc.)... the widely assumed connection with Campanulaceae is probably illusory".

Two years later (5), he characterized the Sphenocleaceae as "an isolated group, probably marginally related to the Centrospermae, e.g., Phytolacca (*cf.* habit, anatomy) and perhaps the Primulaceae (*cf.* capsule). Included by Bentham and Hooker and Engler and Prantl in the Campanulaceae probably due to convergence of superficial technical characters".

It was Agardh (2) who, as early as 1958, suggested that *Sphenoclea* might be related to the Lyth-

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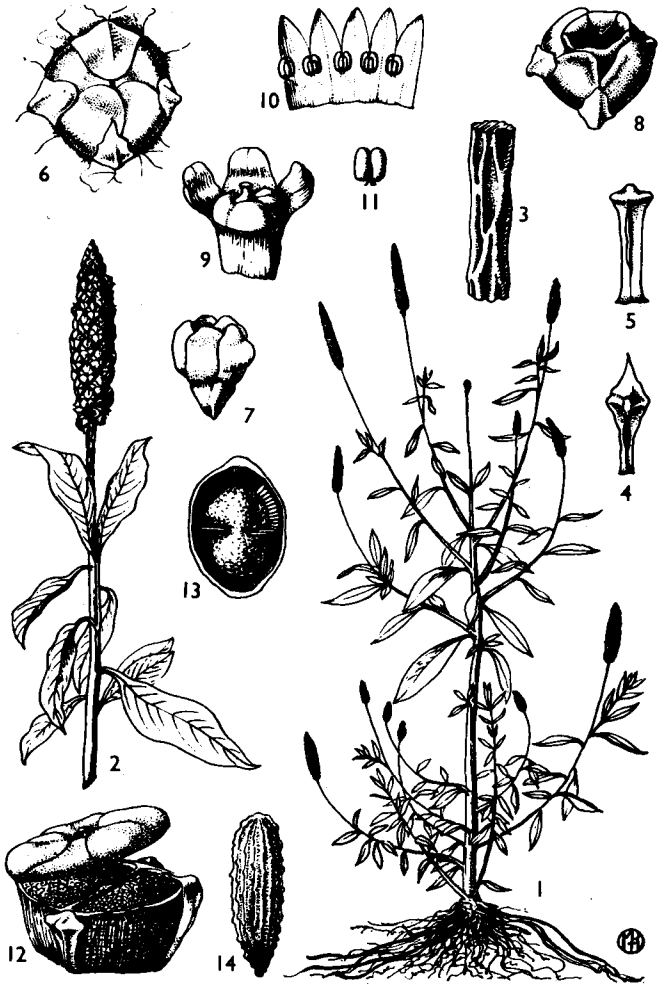

Sphenoclea zeylanica. 1) Habit; 2) part of flowering branch; 3) rhachis of inflorescence, showing scars left by fallen capsules; 4) bract; 5) bracteole; 6) flower bud, apical view; 7) bud beginning to open, side view; 8) flower, showing opening corolla, oblique view; 9) gynoecium and calyx, with two sepals removed, showing cuneate base; 10) corolla opened; 11) stamen; 12) fruit, partially dehisced; 13) transverse section of fruit; 14) seed. Courtesy Crown Agents for Oversea Governments and Administrations (Published in *Flora of Tropical East* Africa: Airy Shaw – *Sphenocleaceae,* 1968).

raceae, a concept that has subsequently been intimated. Heywood (18), for example, recently has felt that *Sphenoclea* is so aberrant that it should not be included in the Campanulaceae in the restricted sense and has assigned it to the Sphenocleaceae with the annotation that "certain characters suggest affinity with the Lythraceae".

On the basis of anatomical studies, Metcalf and Chalk (24) in 1950 allocated *Sphenoclea* to the Campanulaceae but indicated that "there are ample reasons for restoring the family Sphenocleaceae to include the genus".

Since almost nothing is known of the chemistry of *Sphenoclea,* chemotaxonomy cannot as yet be of help. In 1964, Hegnauer (17) placed the genus –probably on the basis of morphology– in the Campanulaceae, but he emphasized that its position in the family is doubtful and pointed out that the complete lack of chemical data made it impossible to assist in defining its affinities. Gibbs (16) in 1974 could add only that *Sphenoclea* "does not accumulate aluminum" and that it "probably lacks raphides".

We are accepting Sphenocleaceae as a distinct monotypic family related to the Campanulaceae.

Sphenoclea zeylanica Gaertn., Fruct. Sem. Pl. 1 (1788) 113, pl. 24, fig. 5.

Pongatium zeylanicum (Gaertn.) Kuntze, Rev. Gen. Pl. 2 (1891) 381.

Rapinia herbacea Lour., Fl. Cochinch. 1 (1790) 127.

Gaertnera pangati Retz., Obs. Bot. 6 (1791) 24.

Pongatium indicum Lam., Encycl. 1 (1797) 444.

Pongatium spongiosum Blanco, Fl. Filip. (1837) 86.

Reichelia palustris Blanco, Fl. Filip. (1837) 220.

Sphenoclea pongatium A. DC. in DC., Podr. 7 (1839) 548.

Only one other species of *Sphenoclea* has been recognized: *S. Dalzielli* N.E. Brown of West Africa from Senegal to the Central African Republic.

Sphenoclea zeylanica has spread throughout the humid tropics of both hemispheres. It is widely distributed in Colombia, as indicated by the following collections in the Economic Herbarium of Oakes Ames and the Gray Herbarium, both at Harvard University, and the Herbario Nacional de Colombia in Bogotá.

Sphenoclea zeylanica, a weedy annual, grows abundantly on the sandy banks of islands in the upper Amazon in the vicinity of sand bars or sandy edges of the low islands; this weed takes over in some areas to the exclusion of almost all other plants.

In 1946, in the Leticia area of Colombian Amazonia, cattle were being poisoned. At that time, Dr. Richard Evans Schultes was engaged in botanical research in the region, and the Ministerio de Economía Nacional in Bogotá requested that he look into the problem. The cattle lost the use of their legs; the head could not be held upright; there was excessive salivation and sometimes swelling of the tongue; the animals eventually died.

Because of poor pasturage on the higher land in the Leticia area, owners of cattle in the area usually drove their animals through the water, or carried them over on barges to the flat parts of the islands to fatten up on the lush grasses that normally cover the sandy banks. The cattle were returned to the poorer pastures when the rivers rose and flooded the low islands.

There are in the vicinity of Leticia two types of islands: 1) older islands, some parts of which are annually flooded along very narrow strands and 2) younger islands –some only several years old– which are low, fully flooded and with wide strands. *Sphenoclea zeylanica* does not grow on the

narrow strands of the older islands; the younger islands usually have dense stands of grasses on the wide strands, but peripheral to the grasses and immediately adjacent to the water's edge, *Sphenoclea* takes over in dense stands. It was soon discovered that only the cattle driven to the younger islands that had this plant were affected.

When the report that the cattle not be put on the islands where *Sphenoclea zeylanica* grew was implemented, the deaths ceased.

In Leticia, the plant is known as *borrachero* ("intoxicant") or *borrachito* ("little intoxicant"), indicating that the local people realized that it had toxic properties, even though they did not associate the plant with the intoxication of the cattle.

In Indonesia, *Sphenoclea zeylanica*, known in Java by the native name *goonda*, or *goenda*, is valued as a pot herb (9). Ochse (25) is very explicit about its edibility: "In 'Tropische Groenten', I warned against eating *Sphenoclea* but wrongly so. Afterwards it appeared that it is frequently eaten as *lalab*, that it is very fit for this purpose and is sold as food in the native markets. At first I did not dare to share the opinion of Sphenoclea expressed by Heyne[3], ... but now I am better informed. The truth was here best served by the interchange of ideas". He reports that "young plants of *Sphenoclea* are eaten whole, whilst of old plants the young shoots are consumed, always, however, steamed or at least immersed for a moment in boiling water. They serve as *lalab* with the rice table. This *lalab* is slightly bitter but otherwise rather savoury and tender".

In distinguishing between the two plants known as *goonda* (*Sphenoclea zeylanica* and *Hydrolea zeylanica* (L.) Vahl.), he further states: "I warned against the use of *Sphenoclea zeylanica* Gaertn. This warning has appeared to be unfounded. Both kinds of *goonda* are harmless, at least when steamed or cooked". This statement would seem to leave some uncertainty that these plants were harmless in the fresh condition.

It is perhaps of interest, insofar as the toxic effects are concerned, that, for human consumption,

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3 *Cf.* Heyne, K. *Nuttige Planten van Nederlandsch Indie.* Dept. van Landboruv, Nijverheid en Handel, Batavia. 2 (1927) 1428.

Sphenoclea zeylanica. Solid growth on bank of island at lowest water. Habitat from which *Schultes, Raffauf et Soejarto 24046* was collected: Island 8 miles above Leticia, Río Amazonas, Colombia. Photograph Richard Evans Schultes.

Inflorescence of *Sphenoclea zeylanica*. Leticia, Río Amazonas, Comisaría del Amazonas, Colombia. Photograph: R. F. Raffauf.

this plant is always steamed or subjected to boiling water, whereas its poisoning of animals seems to be associated with the ingestion of fresh, uncooked material. In this connection, however, it should be pointed out that an herbarium collection from Texas states that *Sphenoclea zeylanica* is eaten by cattle. If this observation be correct, might not the toxic properties of the plant in the Leticia area of the Amazon possibly be due to the selective concentration of a minor element present in the sands or waters and not found in many other localities? This one reference to the ingestion by cattle is found on an herbarium specimen in the Gray Herbarium of Harvard University: *V.L. Cory 50767*, Texas, Hardin County, 2 miles southeast of Saratoga, November 13, 1945 –"Leaf green plant, 3-4 dm. tall, growing in shallow water in roadside ditch, a favorite forage plant of cattle".

Airy-Shaw of the Royal Botanic Gardens, Kew, was kind enough to search through the specimens of that institution and, in a letter dated November 11, 1968, he wrote the following information concerning the toxicity of *Sphenoclea zeylanica*.

"I have now looked at every sheet of *Sphenoclea* present in our herbarium, and on only one is there a definitive statement on toxicity. This is an old collection of Mann from the River Cameroon, N. Nigeria, in January 1861 (*Mann 749*), where he has the note: 'Plant poisonous'. On a sheet from N. Rhodesia (*Vesey-Fitzgerald 4313*) there is a statement 'Not grazed', and one from Zambia (*B. L. Mitchell 2792*) bears the statement 'Not eaten'. My colleague Peter Taylor tells me that, when he was in East Africa with Edgar Milne-Redhead some years ago, he noticed that hippopotami would not eat *Sphenoclea*.

"Apart from these scanty indications we have been unable to trace any relevant information. These conflicting statements are very curious. As of course you will know, *Sphenoclea* is regularly eaten as a pot-herb, with rice, in Indonesia. Can it be that the plant is only toxic to cattle when eaten *with* some other plant? It would perhaps be interesting to discover what else is growing with it in those parts of the upper Amazon where trouble occurs. I may add that when looking through our material I found no statement of *Sphenoclea* being relished by cattle, such as the one you quote from Texas".

In view of this discrepancy –the use of the plant as food in Southeast Asia and its toxicity in the Amazon region– we undertook to determine wheter or not extracts of *Sphenoclea zeylanica*

Sphenoclea zeylanica, showing the complex root system of the plant. Isla de Ronda, Río Amazonas, Comisaría del Amazonas, Colombia. Photograph: R. E. Schultes.

Dense stands of *Sphenoclea zeylanica* line the strands of the younger "islands" in the upper Amazon region. Isla de Ronda, Río Amazonas, Comisaría del Amazonas, Colombia. Photograph: R. F. Raffauf.

Sphenoclea zeylanica in a deeply flooded area of Isla de Ronda, Río Amazonas, Comisaría del Amazonas, Colombia. Photograph: R. E. Schultes.

Sphenoclea zeylanica grows in the Amazon in areas subjected to three or four months of deep flooding. Isla de Ronda, Río Amazonas, Comisaría del Amazonas, Colombia. Photograph: R. E. Schultes.

produced any overt biological effects that could be construed as toxicity to animals.

Two different samples of plant material were available for chemical and pharmacological study. Colombian material was collected by R.E. Schultes in April 1969 from an island in the Amazon River about eight miles west of Leticia; a sample from Louisiana was made available through Prof. J.W. Thieret, then at the University of Southeastern Louisiana, Lafayette, Louisiana, whose assistance is gratefully acknowledged. Vocher specimens representative of both collections have been deposited in the herbarium of Economic Botany in the Botanical Museum of Harvard University.

Pharmacological evaluation. Lyophilized 50% aqueous alcoholic extracts of the ground, whole plants were suspended in gum acacia and administered to mice by both the intraperitoneal and oral routes. Observations were made on general behavior, appearance, response to pain stimulation (tail pinch), evidence of neurological deficit (roller bar) and, finally, death, using equivalent groups (n = 10) of normal animals as controls. No significant gross pharmacological effects were observed after oral administration of either the Colombian or the Louisiana plant extracts at dose levels of 1000 and 2000 mg/Kg respectively. On the other hand, intraperitoneal administration of these extracts at levels of 1000, 500 and 250 mg/Kg produced marked evidence, within 5-10 min., of irriation and toxicity which included writhing, hind leg paralysis, depression, analgesia, ptosis, piloerection, neurological deficit and abnormal defecation and urination. The severity of the symptoms decreased with time, persisting for as long as 24 hours at the highest dose; all (10/10) animals died within 48 hours at 1000 mg/Kg, 2/5 at 500 and none at 250 mg/Kg.

Preliminary Chemical Notes. Positive tests for alkaloids, albeit in small amounts, were obtained on both fresh material in the field and on dried plant in the laboratory by methods described earlier (26). Tests for free sterols and triterpenes were done according to Arthur (6); tests for tannins were based on the methods reviewed by Farnsworth (14); methods for the detection of saponins, cardenolides and bound sugars were based on those of Abisch and Reichstein (1). The results indicated the presence in *Sphenoclea* of small amounts of alkaloids, triterpene saponins, and minor amounts of free triterpenes. These results are not inconsistent with those previously published on the constituents of the few genera of Campanulaceae which have been examined (28). No major differences were obserbed in the responses to the chemical tests by the two samples of the plant.

The isolation and characterization of the major constituents of *Sphenoclea zeylanica* and a more definitive study of the pharmacological properties of these substances will be reported at a later date.

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BIBLIOGRAPHY

1 ABISCH, E. and T. REICHSTEIN in Helv. Chim. Acta 43 (1960) 1844.

2 AGARDH, J. G. *Theoria Systematis Plantarum.* C.W. K. Gleerup, Lund (1858).

3 AIRY-SHAW, H.K. in *Flora Malesiana.* Koeltz, Koenigstein, Germany 4 (1948) 27.

4 AIRY-SHAW, H.K. in *Flora Malesiana.* Koeltz. Koenigstein, Germany 6 (1960) 109.

5 AIRY-SHAW, H. K. *Sphenocleaceae* in Milne-Redhead and Polhill, *Flora of Tropical East Africa.* Crown Agents for Overseas Governments and Administration, London (1968).

6. ARTHUR, H. R. "Some Plants of North Borneo" in Journ. Pharm. Pharmacol. 6 (1954) 66.

7 BENTHAM, G. and J. D. HOOKER. *Genera Plantarum.* Reeve & Co., London 2 (1873).

8 BLANCO M. *Flora de Filipinas: según el Sistęma Sexual de Linneo.* Imp. Sto. Thomas, Manila (1837).

9 BURKILL, I. H. *A Dictionary of the Economic Products of the Malay Peninsula.* Crown Agents for the Colonies, London 2 (1935) 2063.

10 CRONQUIST, A. *The Evolution and Classification of Flowering Plants.* Houghton Mifflin, Boston (1968) 300-301.

11 CRONQUIST, A. *An Integrated System of Classification of Flowering Plants.* Columbia University Press, New York (1981) 982-983.

12 DANGUEY, P. in H. Le Comte *Flore Generale de L'Indo-Chine.* Masson et Cie, Paris 3 (1930) 690-692.

13 ENGLER, A. and L. DIELS. *Syllabus der Pflanzenfamilien.* Gebrüder Borntraeger, Berlin, Ed. 2 (1936) 366.

14. FARNSWORTH, N. R. "Biological and Phytochemical Screening of Plants" in Journ. Pharm. Sci. 55 (1966) 225.

15 GAERTNER, J. *De Fructibus et Seminibus Plantarum* 1 (1788) 113, t. 24.

16 GIBBS, R. D. *Chemotaxonomy of Flowering Plants.* McGill-Queen's University Press, Montreal 2 (1974) 1190.

17 HEGNAUER, R. *Chemotaxonomie der Pflanzen.* Birkhäuser Verlag, Basle. 3 (1964) 344.

18 HEYWOOD, V. H. *Flowering Plants of the World.* Mayflower Books, New York (1978) 256.

19 HUTCHINSON, J. *Families of Flowering Plants.* Clarendon Press, Oxford. Ed. 2, 1 (1959) 476-477.

20 HUTCHINSON, J. *Families of Flowering Plants.* Clarendon Press, Oxford. Ed. 3 (1973) 587-589.

21 HUTCHINSON, J. and J.M. DALZIEL. *Flora of West Tropical Africa.* Crown Agents for the Colonies, London. 2 (1931) 190-191.

22. HUTCHINSON, J. and J. M. DALZIEL [Ed. F. N. Hepper]. *Flora of West Tropical Africa* Ed. 2, 2 (1963) 307-309, t. 272.

23 LINDLEY, J. *A Natural System of Botany.* Longman, Rees, Orme, Brown, London. Ed. 2 (1836) 238.

24 METCALFE, C. R. and L. CHALK, *Anatomy of the Dicotyledons.* Oxford University Press 2 (1950) 815-816.

25 OCHSE, J. J. *Vegetables of the Dutch East Indies.* Archipel. Drukkerij, Buitenzorg, Java. (1931) 94, 349.

26 RAFFAUF, R. F. "A Simple Field Test for Alkaloid-Containing Plants" in Econ. Bot. 16 (1962) 171.

27 TAKHTAJAN, A. (Trans. C. Jeffrey). *Flowering Plants —Origin and Dispersal.* Olives and Boyd, Edinburgh (1969) 232.

28 TREASE, G. E. and W. C. EVANS. *A Textbook of Pharmacognosy.* Ballière, Tindall, London. Ed. 12 (1983) 224.

29 VON MARTIUS, C. P. F. *Conspectus Regni Vegetabilis.* J. L. Schrag, Nurnberg, No. 162 (1835) 35.

30 WAGENITZ, G. in Engler and Prantl, *Die Natürlichen Pflanzenfamilien.* Gebrüder Borntraeger, Berlin. Ed. 12 (1954).

31 WRIGHT, R. *Illustrations of Indian Botany.* American Mission Presss, Madras. 2 (1850) t. 138.