Swertia chirayita – an overview

P. Joshi[1,*] and V. Dhawan[2]

[1]TERI School of Advanced Studies and [2]The Energy and Resources Institute, Darbari Seth Block, Habitat Place, Lodhi Road, New Delhi 110 003, India

Swertia chirayita **is a medicinal plant indigenous to temperate Himalaya. Its medicinal usage is reported in Indian pharmaceutical codex, the British and the American pharmacopoeias and in different traditional systems of medicines such as the Ayurveda, Unani and Siddha. The plant is used as a bitter tonic in treatment of fever and for curing various skin diseases.** ***S. chirayita*** **has an established domestic (Indian) and international market, which is increasing at a rate of 10% annually. The plant available in the market many a times is adulterated and substituted by close relatives of chirata.**

This article briefly reviews the botany, pharmacology, biochemistry, market demand and trade of the plant. This is an attempt to compile and document information on different aspects of ***S. chirayita*** **and highlight the need for research and development.**

Keywords: Amarogentin, bitter, hypoglycemic, swerchirin, *Swertia chirayita*.

AMONG the different species of *Swertia* reported in India, *Swertia chirayita* is considered the most important for its medicinal properties. The bitterness, antihelmintic, hypoglycemic and antipyretic properties are attributed to amarogentin (most bitter compound isolated till date)[1], swerchirin, swertiamarin and other active principles of the herb. Herbal medicines such as Ayush-64, Diabecon, Mensturyl syrup and Melicon V ointment[2–4] contain chirata extract in different amounts for its antipyretic, hypoglycemic, antifungal and antibacterial properties. Despite a descent hold in the herbal industry, the plant is still collected from the wild; it is sparsely cultivated and negligible efforts have gone into developing proper agro-techniques of the plant. Little research has been done to identify the existing diversity among different populations of *S. chirayita*. The lacunae in the related research field raise concerns regarding the vulnerability of the species, emphasizing the need for research.

Swertia chirayita – the plant

Swertia chirayita (Roxb. ex Fleming) H. Karst. is also mentioned in the literature as *Swertia chirata*, Buch.-Ham.; *Ophelia chirata* Grisebach.; *Agathotes chirayita* Don.; *Gentiana chirayita* Roxburgh[5–8] and *Gentiana floribunda* Don[8]. It is known by an array of names, suggesting its widespread use. Chirata is called Anaryatikta, Ardhatikta, Bhunimba, Chiratika, Chiratitka, Haima, Jvarantaka, Kairata, Kandatiktaka, Kiranta, Kirataka, Kirata Tikta, Naditikta, Naipala, Nepalanimba, Nidrari, Ramasenka, Sannipatha, Sutiktaka, Trinanimba, and Viktaka[5,6] in Sanskrit, Cherayata in Patna, Chirrato and Chiraita in Nepal, Chiraita and Kiraita in Mumbai, Chirayatin in Gujarat, Chireta in Bengal, Nilaveppa in Kerala, and Sekhagi in Burma. It is also called Chiaravata (Urdu); Qasabuzzarirah (Arab, Farsi); Charayatah (Deccan); Nelabevu (Kannada); Nenilawandi, Nilavembu, Shirattakuchi (Tamil). The trade name of *S. chirayita* is chiretta[5,6].

The plant is a native of temperate Himalayas, found at an altitude of 1200–3000 m (4000 to 10,000 ft), from Kashmir to Bhutan, and in the Khasi hills at 1200–1500 m (4000 to 5000 ft)[6,8]. It can be grown in sub-temperate regions between 1500 and 2100 m altitudes[9]. The genus *Swertia* Linn. consists of annual and perennial herbs. There is no consistency in the literature citing the habit of *Swertia chirayita*. Some authors have described chirata as an annual[5,6] and others as biennial or pluri-annual[10]. It is not clear whether the plant behaves differently due to climatic conditions or varying genotypes. The plant can be grown in a variety of soils with sandy loam rich in carbon and humus. It is also found in open ground and recently slash-and-burnt forests[10]. *S. chirayita* has an erect, about 2–3 ft long stem, the middle portion is round, while the upper is four-angled, with a prominent decurrent line at each angle. The stems are orange brown[5] or purplish in colour[9], and contain large continuous yellowish pith. The root is simple, tapering and stout, short, almost 7 cm long and usually half an inch thick[8,9] (Figure 1).

Cytological work done on the species is poor. Khoshoo and Tandon[11] used pollen-mother cells for cytological studies in some Himalayan species of *Swertia*. The authors counted thirteen bivalents at metaphase I, and observed that one of them was bigger than the rest.

Flowering in *S. chirayita* is in the form of numerous small, axillary, opposite, lax cymes arranged as short branches and the whole inflorescence is 2 ft long. Flowers are small, stalked, green-yellow, tinged with purple colour, rotate and tetramerous[6,9] (Figure 1). The corolla is twice as long as the calyx and divided near the base into four ovate–lanceolate segments. The upper surface of the petal has a pair of nectaries covered with oblong scales and ending as fringes[9]. Fruit is a small, one-celled capsule with a transparent yellowish pericarp. It dehisces from above, septicidally into two valves. Seeds are numerous, minute,

*For correspondence. (e-mail: poojaj@terischool.ac.in)

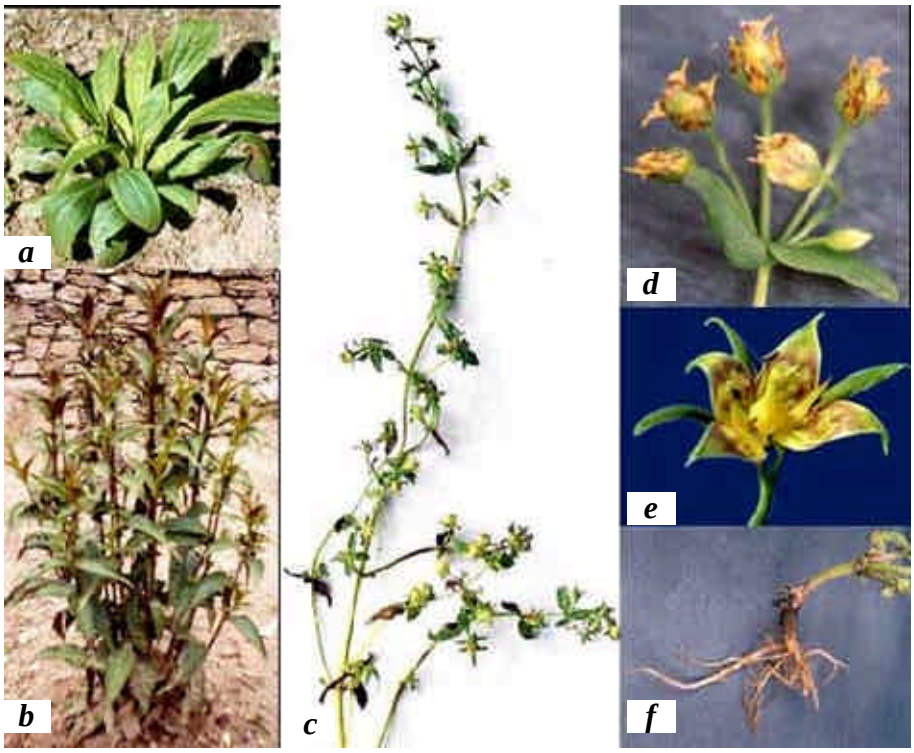

Figure 1. *Swertia chirayita*: ***a***, Plant in vegetative phase; ***b***, A 2 ft tall plant before flowering; ***c***, Flowering twig; ***d***, Flowering panicle during seed set; ***e***, Single tetramerous flower; ***f***, Root of a mature two-year-old plant.

many-sided and angular. Floral characteristics such as colourful corolla and presence of nectaries support cross-pollination in the species. Generally, bees (Apoidae, Hymenoptera) are the pollinators of *S. chirayita*[11].

The plant is harvested for the drug industry when it sets into flowering in July–September[5,9]. Seed setting commences around October–November and seeds germinate immediately after shedding. Only a few scattered reports in the literature suggest germination studies and nursery practices of *S. chirata*[12,13]. Ninety-one per cent seed germination was reported after 3°C chilling treatment for fifteen days[12], whereas another study reported a maximum of 81% germination[13]. An observation at the post-germination growth stage revealed that *S. chirata* is a slow-growing species[13]. Low germination percentage and viability of the seeds, long gestation periods and delicate field-handling are some of the factors which discourage commercial cultivation of the plant[14].

Medicinal uses of *S. chirayita*

S. chirayita belongs to family Gentianaceae, which records the occurrence of taxonomically informative molecules, namely iridoids, xanthones, mangiferin and C-glucoflavones[15]. Reviews detailing the chemical constituents of the *Swertia* genus have been reported[16–18]. The widespread uses of *S. chirayita* in traditional medicines have resulted in considerable chemical analysis of the plant, and active principles which attribute the plant its medicinal properties have been identified and isolated (Tables 1 and 2). The entire plant is used in traditional medicine; however the root is mentioned to be the most powerful part[6]. The plant is gathered during the late stages of flowering, commonly tied up in flattish bundles about 3 ft long and 1.5 to 2 lbs in weight[9] and is sold in the market as dried brownish stems with root and leaves intact.

S. chirayita is used in British and American pharmacopoeias as tinctures and infusions[19]. According to Ayurvedic pharmacology[20], chirata is described as bitter in taste (*rasa*). The thermal action (*virya*) of chirata is defined as cooling (*shita*). Chirata is light (*laghu*), i.e. easily digestible, and *ruksha* (*dry*). These characteristics drain heat from the blood and liver. Its use has also been mentioned in Unani medicine[21]. Concoction of chirata with cardamom, turmeric and kutki is given for gastrointestinal infections, and along with ginger it is considered good for fever[6]. When given along with neem, manjishta and gotu kola, it serves as a cure for various skin problems. It is used in combination with other drugs in cases of scorpion bite[22].

The concerns

The widespread use of *S. chirayita* in traditional medicine reflects its pharmacological importance. However, existing populations of *S. chirayita* are diminishing. Hence accord-

Table 1. Secondary metabolites of *Swertia chirayita*

Compound	Chemical nature	Reference
1,3,5,8-tetrahydroxyxanthone	Xanthone	38
1,3,7,8-tetrahydroxyxanthone	Xanthone	38
1,3,8-trihydroxy-5-methoxyxanthone	Xanthone	38
1,5,8-trihydroxy-3-methoxyxanthone	Xanthone	38
1,8-dihydroxy-3,5-dimethoxyxanthone/swerchirin	Xanthone	38–40
1,8-dihydroxy-3,7-dimethoxyxanthone/7-*O*-methylswertanin	Xanthone	38, 40
1-hydroxy-3,5,8-trimethoxyxanthone	Xanthone	38, 41
1-hydroxy-3,7,8-trimethoxyxanthone	Xanthone	38, 41
2,5-dihydroxyterephthalic acid	Aromatic carboxylic acid	42
21-*a*-H-hop-22(29)-en-3-*b*-ol	Triterpenoid	43
Amarogentin	Seco-iridoid glycoside	41, 44
Amaroswerin	Seco-iridoid glycoside	41, 45
Chiratanin	Dimeric xanthone	46
Chiratenol	Hopane triterpenoid	43, 47
Chiratol/1,5 dihydroxy 3,8-dimethoxyxanthone	Xanthone	40, 48, 49
Decussatin	Xanthone	40, 48, 49
Enicoflavine	Triterpenoid alkaloid	40, 48, 50
Episwertenol	Triterpenoid	43
Erythrodiol	Hexane extract	47, 51
Gammacer-16-en-*b*-ol	Triterpenoid	45
Gentianine	Triterpenoid alkaloid	50
Gentiocrucine	Triterpenoid alkaloid	50
Kairatenol	Hexane extract	48
Lupeol	Triterpene alcohol	52
Mangiferin	Xanthone	39, 42
Mangostin	Xanthone	53
Oleanolic acid	Triterpenoid	46, 54
Pichierenol	Swertane terpenoid	52
Sweroside	Seco-iridoid glycoside	42, 46
Sweroside-2′-*O*-3″,5″-trihydroxy biphenyl-2″ carboxylic acid ester	Seco-iridoid glycoside	46
Swerta-7,9(11)-dien-3-*b*-ol	Swertane terpenoid	52
Swertanone	Triterpenoid	44
Swertenol	Triterpenoid	44
Swertianin/1,7,8-trihydroxy-3-methoxyxanthone	Xanthone	50, 51
Syingaresinol	Lignan	42
Taraxerol	Triterpene alcohol	44
Ursoilic acid	Triterpenoid	44
b-Amyrin	Triterpenoid alcohol	54
b-Sitosterol-3-*b*-D-glucoside	Sterol	46
Ø-Taraxasterol or heterolupeol	Hexane extract	51

ing to the new International Union for Conservation of Nature and Natural resources (IUCN) criteria, *S. chirayita* has been categorized as critically endangered[23,24]. This leads to a need for conservation of the plant. *S. chirayita* has been prioritized by the National Medicinal Plant Board (Government of India) for conservation and cultivation in Uttranchal[25], emphasizing the need to develop agro-technology packages.

The novel technique of *in vitro* conservation and micropropagation can help in conservation and production of a large number of disease-free, true-to-type plants. Wawrosch *et al.*[26] reported shoot regeneration from root explant. Ahuja *et al.*[27] have optimized media condition for faster propagation of *S. chirayita*. Attempts have been made to standardize root cultures for production of active metabolites under *in vitro* conditions[28]. Root culture studies have been taken up in related species of *Swertia*[29,30]. However, there exists a need to translate these *in vitro* studies to the field for practical applications.

Considering the range of different niches occupied by the plant, there is a possibility that many ecotypes and/or chemotypes of *S. chirayita* exist. It would be interesting to study the morphological, molecular and biochemical variations among different populations for *S. chirayita*. These studies become more relevant in case of species akin to chirata, because diversity is often unevenly distributed among populations. Some of these populations/niches may be particularly significant in terms of the amount of diversity they possess[31]. Thus populations with maximum diversity can be identified and isolated for conservation without any duplication within the conserved germplasm.

S. chirayita enjoys a good domestic and international market. The medicinal plant sector in India is unorganized and it is difficult to get a regular update of statistics *vis-à-*

vis the demand and supply, collection and economics of chirata. The only available data regarding collection and trade of the plant are for the year 1990–1991 with respect to Nepal[32] and for the year 2001–02 for India[33,34]. The plant has a huge demand in the medicinal market and is an important factor for the economy of Nepal. About 45% of chirayita in the Himalayan region is collected from Nepal[34].

The trade and economics of chirata is also affected by adulterants of the herb. *Andrographis paniculata* (green chirayita)[35], *Exacum tetragonum* Roxb., *E. bicolor* Roxb., *E. pedunculatum* Linn., *Slevolgia orientalis* Griesb., *Swertia alata* Royle., *S. angustifolia* Buch.-Ham., *S. bimaculata* Hook. f. and Thoms., *S. ciliata* G. Don, *S. densifolia* Greisb., *S. elegans* Wight., *S. lawii* Burkill., *S. minor* Griesb., *S. paniculata* Wall., *S. multiflora* Dalzell., are adulterants found along with true chiretta[5]. *S. minor* Griesb. is used as a substitute for chirata in treatment of malaria and other fevers[5]. However, substitutes such as *S. angustifolia* Buch.-Ham. and *S. alata* Royle. are inferior to *S. chirayita* in terms of bitterness[5]. Karan *et al.*[36] and Bhatia *et al.*[37] reported comparative evaluation of morphological characters and chromatographic fingerprint profile for xanthones and secoiridoid bitters of *S. chirayita* along with other species of *Swertia*. The true chirata can be distinguished from other substitutes and adulterants by its intense bitterness, brownish-purple stem (dark colour), continuous yellowish pith and petals with double nectaries. Verma and Kumar[38] reported variation in germplasm of *S. chirata* using isozyme polymorphism. Such studies highlight the importance of having diagnostic keys for evaluating the authenticity of the available material. This will help in identifying and documenting authentic samples, isolating superior chemotypes, and establishing and cultivating them for industrial use without adulteration. There is tremendous scope for reducing pressure on chirata populations by identifying and promoting the use of superior substitutes of chirata.

Table 2. Biological activities attributed to *S. chirayita*

Activity	Reference
Alternative	7, 55
Antihelmintic	56
Antileishmaniak	57
Anticholinergic	58
Anticonvulsant	59
Antiedemic	60
Antiinflammatory	45, 61–63
Antimalarial	64
Antipyretic	60
Antitubercular	65
Astringent	22
Bitter	40
Cardio stimulant	60
Cholagogue	6
Choleretic	60
CNS depressant	39
Emollient	7, 54
Hepatoprotective	66
Hypnotic	7, 56
Hypoglycemic/antidiabetic	67–72
Laxative	7, 56
Secretagogue	6
Stomachic	22
Tonic	22
Undersedative	6
Vermifuge	6

Conclusion

Thus there is still a wide scope for exploring different aspects of *S. chirayita*. Discrepancies remain about the habit of the plant. There are no established agro-techniques for promoting its cultivation. Only preliminary studies have been done to provide information regarding germination and viability of chirata seeds. The threatened status of the herb calls for establishing sustainable harvesting methods for *S. chirayita.* There are, of course, no established varieties or lines of chirata. A strong need is felt to screen the different chemo-types of chirata growing at different phyto-geographical locations. Similarly, biodiversity studies at morphological, biochemical and genetic levels will enable the research community to realize the extent of variability within the existing germplasm of *S. chirayita* and hence help in conservation of the plant.

1. Karan, M., Vasisht, K. and Handa, S. S., In *Supplement to Cultivation and Utilisation of Medicinal Plants* (eds Handa, S. S. and Kaul, M. K.), RRL, Jammu-Tawi, 1996, pp. 349–354.
2. Edwin, R. and Chungath, J. I., Studies in *Swertia chirata. Indian Drugs*, 1988, **25**, 143–146.
3. Valecha, N., Devi, U. C., Joshi, H., Shahi, V. K., Sharma, V. P. and Lal, S., Comparative efficacy of ayush-64 vs chloroquine in vivax malaria. *Curr. Sci.*, 2000, **78**, 1120–1122.
4. Mitra, S. K., Gopumadhavan, S. and Muralidhar, T. S., Effect of D-400, an ayurvedic herbal formulation on experimentally-induced diabetes mellitus. *Phytother. Res.*, 1996, **10**, 433.
5. Anon, In *The Wealth of India: Raw Materials*, Publication and Information Directorate, CSIR, New Delhi, 1982, vol. X, pp. 78–81.
6. Kirtikar, K. R. and Basu, B. D. (eds), *Indian Medicinal Plants*, Allahabad, 1984, vol. III, pp. 1664–1666.
7. Duke, J. A., In *Handbook of Medicinal Herbs*, CRC Press, Washington DC, 2002, p. 190.
8. Clarke, C. B., In *The Flora of British India* (ed. Hooker, J. D.), L. Reeve and Co, London, 1885, vol. IV, p. 124.
9. Bentley, R. and Trimen, H., *Medicinal Plants* (eds Bentley, R. and Trimen, H.), J and A Churchill, London, 1880, p. 183.
10. Edwards, D. M., The marketing of non-timber forest product from the Himalayas: The trade between East Nepal and India. Rural development Forestry Network. *Rural Dev. For. Network*, 1993, pp. 1–21.
11. Khoshoo, T. N. and Tandon, S. R., Cytological, morphological and pollination studies on some Himalayan species of *Swertia*. *Caryologia*, 1963, **16**, 445–477.
12. Raina, R., Johri, A. K. and Srivastava, L. J., Seed germination studies in *Swertia chirata* L. *Seed Res.*, 1994, **22**, 62–63.
13. Basnet, D. B., Evolving nursery practices and method of cultivation of high value medicinal plant *Swertia chirata* Ham. *Environ. Ecol.*, 2001, **19**, 935–938.

14. Badola, H. K. and Pal, M., Endangered medicinal plant species in Himachal Pradesh. *Curr. Sci*., 2002, **83**, 797–798.
15. Jensen, S. R. and Schripsema, J., *Gentainaceae – Systematics and Natural History* (eds Struwe, L. and Albert, V.), Cambridge University Press, London, 2002, pp. 573–632.
16. Wang, Y. and Yang, J., *Chem. Abstr.*, 1992, **116**, 211106r.
17. Rahman, I. and Arfan, M., *J. Chem. Soc. Pak.*, 1997, **19**, 240.
18. Pant, N., Jain, D. C. and Bhakuni, R. S., *Indian J. Chem. B*, 2000, **39**, 565–586.
19. http://www.ibiblio.org/herbmed/eclectic/kings/swertia-chir.html
20. Joshi, S. G. (ed.), *Medicinal Plants*, Oxford and IBH, New Delhi, 2000, p. 216.
21. Mukherji, B. (ed.), *Indian Pharmaceutical Codex, Indigenous Drugs*, CSIR, New Delhi, 1953, vol. I, pp. 64–65.
22. Nandkarni, K. M. (ed.), *Indian Materia Medica*, Bombay Popular Prakashan, Bombay, 1976, vol. I, pp. 1184–1186.
23. Anon, Biodiversity Conservation Prioritization Project, Conservation assessment and management plan (CAMP) for endemic medicinal plants in India. CIMAP, Lucknow, 1997.
24. Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Official documents: appendices I, II and III.
25. http://www.nmpb.nic.in
26. Wawrosch, C., Maskay, N. and Kopp, B., Micropropagation of the threatened Nepalese medicinal plant *Swertia chirata* Buch.-Ham. ex Wall. *Plant Cell Rep*., 1999, **18**, 997–1001.
27. Ahuja, A., Koul, S., Kaul, B. L., Verma, N. K., Kaul, M. K., Raina, R. K. and Qazi, G. N., Media compositions for faster propagation of *Swertia chirayita.* 2003, WO 03/045132 A1.
28. Keil, M., Hartle, B., Guillaume, A. and Psiorz, M., Production of amarogentin in root cultures of *Swertia chirata*. *Planta Med*., 2000, **66**, 452–457.
29. Ishimaru, K., Sudo, H., Satake, M., Matsunaga, Y., Hasegawa, Y., Takemoto, S. and Shimomura, K., Amarogentin, amaroswerin and four xanthones from hairy root cultures of *Swertia japonica*. *Phytochemistry*, 1990, **29**, 1563–1565.
30. Kitamura, Y., Dono, M., Miura, H. and Sugii, M., Production of swertiamarin in cultured tissues of *Swertia pseudochinensis*. *Chem. Pharm. Bull.*, 1988, **36**, 1575–1576.
31. Rao, V. R. and Hodgkin, T., Genetic diversity and conservation and utilization of plant genetic resources. *Plant Cell Tiss. Org. Cult.*, 2002, **68**, 1–19.
32. HMG Nepal, Foreign Trade and Statistics, Department of Customs, Ministry of Finance, Kathmandu, 1992.
33. Brinckmann, J., *Medicinal Plants and Extracts*, Market News Service, ITC, UNCTAD, WTO, 2003, No. 8.
34. Shah, S. P., Aspects of medicinal plant conservation in Nepal. In XVI International Botanical Congress, Abstr. no. 5227, Poster no. 2453, 1999.
35. Girach, R. D., Aminuddin and Khan, S. A., Andrographis paniculata – A possible substitute for *Swertia chirata* in Southeastern India. *Int. J. Pharmacog.*, 1994, **32**, 95–97.
36. Karan, M., Vasisht, K. and Handa, S. S., Morphological and chromatographic comparison of certain Indian species of *Swertia*. *JMAPS*, 1997, **19**, 995–963.
37. Bhatia, A., Karan, M. and Vasisht, K., Morphological and chemotypic comparison of certain Indian species of *Swertia*. *JMAPS*, 2003, **25**, 336–343.
38. Verma, N. K. and Kumar, A., Isozyme polymorphism and genetic diversity among *Swertia* species-endangered medicinal plants of Himalayas. *Indian J. Plant Gen. Res.*, 2001, **14**, 74–77.
39. Ghosal, S., Sharma, P. V., Chaudhuri, R. K. and Bhattacharya, S. K., Chemical constituents of Gentianaceae V: Tetraoxygenated xanthones of *Swertia chirata* Buch.-Ham. *J. Pharm. Sci*., 1973, **62**, 926.
40. Dalal, S. R. and Shah, R. C., Swerchirin, a novel xanthone from *Swertia chirata. Chem. Ind.*, 1956, **7**, 664.
41. Asthana, P. K., Sharma, N. K., Kulshreshtha, D. K. and Chatterjee, S. K., A xanthone from *Swertia chirayita. Phytochemistry*, 1991, **30**, 1037–1039.
42. Chakravarty, A. K., Mukhopadhyay, S., Moitra, S. K. and Das, B., Syringareinol, a hepatoprotective agent and other constituents from *Swertia chirata. Indian J. Chem. B*, 1994, **33**, 405–408.
43. Hatjimanoli, M., Favre-Bonvin, J., Koauadji, M. and Mariotte, A. M., *J. Nat. Prod.*, 1988, **51**, 997.
44. Chakravarty, A. K., Mukhopadhayay, S. and Das, B., Swertane terpenoids from *Swertia chirata. Phytochemistry*, 1991, **30**, 4052–4087.
45. Korte, F., Amarogentin, ein neuer bitterstoff aus. charakteristische Pflanzeninhaltstoffe IX. Mitteil. *Chem. Ber*., 1955, **88**, 704–705.
46. Chaudhuri, P. K. and Daniewshi, W. M., Unambiguous assignments of the ^{1}H and ^{13}C chemical shifts of the major bitter principles of *Swertia chirata* by 2D NMR study and characterization of other constituents. *Pol. J. Chem.*, 1996, **69**, 1514–1519.
47. Mandal, S. and Chaterjee, A., Structure of chiratanin, a novel dimeric xanthone. *Tetrahedron Lett.*, 1987, **28**, 1309–1310.
48. Chakravarty, A. K., Mukhopadhyay, S., Masuda, K. and Ageta, H., Chiratenol, a novel rearranged hopane tritepenoid from *Swertia chirata*. *Tetrahedron Lett.*, 1992, **31**, 7649–7652.
49. Purushothaman, K. K., Sarada, A. and Narayanaswami, V., Chemical examination of *Swertia chirata*. *Leather Sci.* (*Madras*), 1973, **20**, 132–134; Purushothaman, K. K., Sarada, A. and Narayanaswami, V., Chemical examination of kiratatikta (*Swertia chirata*). *JRIM*, 1973, **8**, 23–28.
50. Purushothaman, K. K., Sarada, A. and Narayanaswami, V., *Chem. Abstr.*, 1973, **79**, 113218b.
51. Sharma, P. V., Alkaloids of *Swertia chirata. Indian J. Pharm. Sci.*, 1982, **44**, 36.
52. Chakravarty, A. K., Mukhopadhyay, S., Masuda, K. and Ageta, H., More of swertane triterpenoids from *Swertia chirata* Buch.-Ham. *Indian J. Chem. B*, 1992, **31**, 70–71.
53. Mandal, S. *et al*., Antiinflammatory action of *Swertia chirata. Fitoterapia*, 1992, **63**, 122–128.
54. Sharma, P. V., Triterpenoids of *Swertia chirata. Indian J. Pharm. Sci.*, 1983, **45**, 222.
55. Duke, J. A., Godwin, M. J. B., duCellier, J. and Duke, P. A. K., *Handbook of Medicinal Herbs* (ed. Duke, J. A.), CRC Press, Washington DC, 2002, p. 190.
56. Ray, S., Majumder, H. K., Chakravarty, A. K., Mukhopadhyay, S., Gil, R. R. and Cordell, G. A., Amarogentin, a naturally occurring secoiridoid glycoside and a newly recognized inhibitor of topoisomerase I from *Leishmania donovani*. *J. Nat. Prod.*, 1996, **59**, 27–29.
57. Medda, S., Mukhopadhyay, S. and Basu, M. K., Evaluation of the *in vivo* activity of and toxicity of amarogentin, an antileishmanial agent, in both liposomal and niosomal forms. *J. Anti Micro Chemother.*, 1999, **44**, 791–794.
58. Rafatullah, S., Tariq, M., Mossa, J. S., Al-Yahya, M. A., Al-Said, M. S. and Ageel, A. M., Protective effect of *Swertia chirata* against indomethacin and other ulcerogenic agent-induced gastric ulcers. *Exp. Clin. Res.*, 1993, **19**, 69–73.
59. Bhattacharya, S. K., Reddy, P. K. S. P., Ghoal, G., Singh, A. K., and Sharma, P., Chemical constituents of Gentianaceae. XIX. CNS-depressant effects of swertiamarin. *Indian J. Pharm. Sci.*, 1976, **65**, 1547–1549.
60. Blaschek, W., Hansel, R., Keller, K., Reichling, J., Rimpler, H., and Schneider, G., *Hager's Handbuch der Pharmazeutischen Praxis*, Auflage Band 2 (L-Z), Springer-Verlag, Berlin, 1998, p. 858.
61. Islam, C. N., Bandyopadhyay, S. K., Banerjee, M. K. and Das, P. C., Preliminary studies on the anti-inflammatory effects of *Swertia chirata* in albino rats. *Indian J. Pharmacol.*, 1995, **27**, 37–39.
62. Kumar, I. S., Yadav, A. K., Saxena, A. and Paul, B., Modulation of interleulin-1, Interleukin-4, interleukin-6 interleukin-10, tumor

necrosis factor-*a*, and interferon-*g* by aqueous extract of *Swertia chirayita*. *Indian J. Pharmacol*., 2002, **34**, 141–155.
63. Banerjee, S., Sur, T. P., Das, P. C. and Sikdar, S., Assessment of the antiinflammatory effects of *S. chirata* in acute and chronic experimental models in male albino rats. *Indian J. Pharmacol*., 2000, **32**, 21–24.
64. Goyal, H., Sukumar, S. and Purushothaman, K. K., Antimalarials from Indian medicinal plants. *J. Res. Ayur. Sid.*, 1981, **2**, 286.
65. Kamatsu, M., Tomimori, T. and Naoko, M., *Chem. Abstr.*, 1971, 143990g.
66. Mukherjee, S., Sur, A. and Maiti, B. R., Hepato-protective effect of *Swertia chirata* on rats. *Indian J. Exp. Biol.*, 1997, **35**, 384–388.
67. Mukherjee, B. and Mukherjee, S. K., Blood sugar lowering activity of *Swertia chirata* Buch.-Ham extract. *Int. J. Crude Drug Res.*, 1978, **25**, 97.
68. Bajpai, M. B., Asthana, R. K., Sharma, N. K., Chaterjee, S. K. and Mukherjee, S. K., Hypoglycemic effect of swerchirin from hexane fraction of *Swertia chirayita*. *Planta Med.*, 1991, **57**, 102.
69. Chandrashekar, B., Bajpai, M. B. and Mukherjee, S. K., Hypoglycemic activity of *Swertia chirayita* (Roxb ex Flem) Karst. *Indian J. Exp. Biol*., 1990, **28**, 616–618.
70. Saxena, A. M. and Mukherjee, S. K., Mechanism of blood lowering action of *Swertia chirayita*: effect of impure swerchrin (SWI) on insulin release from isolated beta cells of the pancreas. *J. Micro. Biotechnol*., 1992, **7**, 27–29.
71. Saxena, A. M., Bajpai, M. B., Murthy, P. S. and Mukherjee, S. K., Mechanism of blood sugar lowering by a swerchirin-containing hexane fraction (SWI) of *Swertia chirayita*. *Indian J. Exp. Biol*., 1993, **31**, 178–181.
72. Grover, J., Yadav, S. and Vats, V., Medicinal plants of India with anti-diabetic potential. *J. Ethnopharmacol*., 2002, **81**, 81–100.

ACKNOWLEDGEMENTS. We thank Dr R. K. Pachauri, Director General, TERI for infrastructure support. The Senior Research Fellowship from Council of Scientific and Industrial Research, New Delhi to P.J. is acknowledged. We thank the anonymous reviewers for their helpful comments.

Received 29 April 2004; revised accepted 19 April 2005