Sesbania grandiflora

Scientific Name

***Sesbania grandiflora* (L.) Pers.**

Synonyms

Aeschynomene coccinea L. f., *Aeschynomene grandiflora* (L.) L., *Agati coccinea* (L. f.) Desv., *Agati grandiflora* (L.) Desv., *Coronilla coccinea* (L. f.) Willd., *Coronilla grandiflora* (L.) Willd., *Coronilla grandiflora* Boiss, *Dolichos arborescens* G. Don, *Dolichos arboreus* Forssk., *Emerus grandiflorus* (L.) Kuntze, *Resupinaria grandiflora* (L.) Raf., *Robinia grandiflora* L., *Sesban coccinea* (L.f.) Poir, *Sesban grandiflora* (L.) Poir., *Sesban grandiflorus* Poir., *Sesbania coccinea* (L.f.) Pers.

Family

Fabaceae, also placed in Papilionaceae

Common/English Names

Agathi, Agati Sesbania, August Flower, Australian Corkwood Tree, Corkwood Tree, Flamingo Bill, Grandiflora, Hummingbird Tree, Scarlet Wisteria Tree, Sesban, Sesbania, Swamp Pea, Tiger Tongue, Vegetable-Hummingbird, West Indian Pea, West Indian Pea Tree, White Dragon Tree

Vernacular Names

Arabic: Saysabān
Burmese: Pauk-Pan, Pauk-Pan-Hpyu
Caribbean: Colibri Vegetal, Fleur Papillon
Chamorro: Caturay, Katurai
Chinese: Ta-Hua, Tien-Tsing, Da Hua Tian Jing, Mu Tian Jing
Creole Patois: Pwa Valet, Pwa Valye
Czech: Sesbánie Velkokvětá
Dutch: Agati
French: Agati A Grandes Fleurs, Fagotier, Colbri Vegetal, Fagotier, Fleur Papillon, Papillon, Pois Valette, Pois Vallier, Pois Valliere
German: Kolibribaum, Turibaum, Scharlach Baumwisterie
Hawaiian: Ohai Ke‘Oke‘O
India: Bak Phool (Assamese), Agasthi, Agati, Agusta, Bagphal, Bak, Bak, Bak Phool, Bake, Bakphool, Buko (Bengali), Agathio (Gujarati), Agasati, Agast, Agasti, Agastoya, Agust, Agusta, Bak, Balmota, Basma, Basna, Chogache, Gaach-Munga, Hadaga, Hadga, Hathia, Hathya, Hatiya, Jalt, Jayanti, Jhijan (Hindi), Agace, Agache, Agaci, Agase, Agasemara, Agashi, Agasi, Agastya, Bakapushpa, Chinna Daare, Chogache, Kempagase (Kannada), Agati, Agatti, Agaty, Akatti, Argati, Argatti, Athi, Atti (Malayalam), Houwaimal (Manipuri), Agasta, Agastha, Agasthi, Agasthiya, Agasti, Agastiya, Agathi, Agati, Agosto, Akatti, Chopchini, Haadga, Hatga, Jainti, Shevari, Shewari, Sirimonta (Marathi), Vranari (Oriya), Agasthya, Agasta,

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Agasti, Agastih, Agastivaka, Agastya, Agastyah, Agati, Anari, Buka, Dirghaphalaka, Dirghashimbi, Kanali, Kharadhvansi, Kumbhayoni, Kumbhayonih, Kusuma, Muni, Munidruma, Munidrumah, Munipriya, Munipushpa, Munitaru, Pavitra, Raktapushpa, Shighrapushpa, Sthulapushpa, Surapriya, Vaka, Vakrapushpa, Vakrapuspa, Vakrapuspah, Vamari, Vangasena, Vangasenah, Vranapaha, Vranari (Sanskrit), Acaiyam, Accam, Acci, Acham, Acokam, Acotakatti, Agathi, Agathi Keerai, Agaththi, Agati, Agatti, Akacam, Akaci, Akaddi, Akatti, Akattikkirai, Alakiyal, Alakucivappi, Alakucivappimaram, Ampalacai, Ampalakaimaram, Anali, Aracamiyam, Argati, Arokkiyamatar, Arpakaimaram, Arrokkiyamatar, Athi, Attikkirai, Avappittaniti, Avappittanti, Cakanpanni, Cantirantankacci, Cayanti, Cenkutamaram, Cevvakatti, Cevvakattimaram, Chittakathi, Civappakatti, Civappi, Iyaktam, Kacikavakatti, Kakanaman, Karikam, Karikamaram, Kariram, Karunchempa, Kilimukkumaram, Kilimukkumram, Kiraiyakattimaram, Kopavairini, Kotikkalmaram, Kunali, Kunkumapperikamaram, Malaiyinmunimaram, Malaiyinmunivam, Malaiyinmunivanmara, Malaiyinmunivanmaram, Mayilmunimaram, Mayilmunivam, Mayilmunivan, Mulakariyam, Mulakiyam, Muni, Munipattiri, Munippuntu, Munitalam, Munittorumam, Munitturumam, Mutanki, Nattakatti, Paluppuccarruccattukkati, Pantukam, Pantukamaram, Pattiyamuriccan, Pavalaakatti, Pavalavakatti, Pavalavakattimaram, Peragatti, Pintaputpam, Piraimalar, Pocaki, Pocakimaram, Pocam, Pukal, Pukalmaram, Sevvagatti, Tanavakamaram, Tetcanamuli, Tetcanamurtti, Tirakkappalakam, Tirkkappalakam, Turucu, Tuvatacipattiri, Tuvatecipattiri, Ullulattitam, Uppi, Utumparam, Vaka, Vakai, Vanitam, Vankacenakam, Vellakatti, Vinpakam, Vinpakavakatti, Vintai, Vittari, Vittaru, Vitteri, Vittineruppu, Vittutti, Vittuttimaram, Yatakam (Tamil), Agasi, Agathi, Agise, Agisi, Anaga, Aneesay, Anisay, Aushika, Avasinara, Avesi, Avise, Avisey, Avishi, Avisi, Bakapushpam, Bakku-Pushapamu, Erraagasi, Erraavisi, Erragise, Ettagise, Patta, Suka Nasam, Sukanaasamu, Sukanasamu, Tella-Suiminta, Tellaavesi, Tellaavisi, Tellayavise, Thellayavise, Yerraavesi (Telugu), Agast (Urdu)

Indonesia: Bunga Turi, Kembang Turi (Flowers), Daun Turi, Turi, Tuwi, Toroy (Leaves), Turi Bang (Javanese for red-flowered form), Turi Berem (Sundanese for red-flowered form), Turi Putih (Javanese for white-flowered form), Turi Bodas (Sundanese for white-flowered form), Toroj (Madurese)

Japanese: Agachi, Shiro-Gochou

Khmer: Ângkiëdèi, Pka Angkea Dey

Korean: A Ga Ti, We-Seu-Teu-In-Di-An-Kong-Na-Mu

Laotian: Kh'ê: Kha:W

Malaysia: Turi, Geti, Kacang Turi, Petai Belalang, Sesban, Sesban Getih

Nepali: Agasti

Palauan: Katurai

Persian: Sīsabān

Philippines: Diana (Bagobo), Katurai, Katudai (Ibanag), Katudia, Katodai (Iloko), Gauai-Gauai (Panay Bisaya), Katurai (Pangasingan), Kambang-Turi (Sulu), Katuray, Katurai

Portuguese: Agasto, Sesbânia

Russian: Sesbania Krupnotsvetkovaia

Samoan: Sepania

Slovakian: Sezbánia Veľkokvetá

Spanish: Baculo, Cresta De Gallo, Gallito, Paloma, Pico De Flamenco, Zapaton Blanco

Sri Lanka: Katurumurunga Kolle (Leaves, Sinhalese), Katurumurunga Mala (Flowers, Sinhalese), Attikkirai (Tamil)

Tahitian: Afai, Ofai, Ouai, Oufai

Thailand: Khae Daeng (Chiang Mai), Dok Khae Baan, Kae-Ban, Khae, Ton Kae (Central)

Tibetan: A Ga Sta

Vietnamese: So Đũa

Origin/Distribution

The species is native to South Asia and Southeast Asia with possibly Indonesia as the centre of diversity. It is closely related to the Australian species, *Sesbania formosa*. The species is now distributed pantropically in Africa, Central America, Florida, Hawaii, Southwest China, Northern Australia, the Caribbean and the Pacific Islands.

Agroecology

The tree is found in open fields, near roadsides or waterways, and dikes between the rice fields from sea level to occasionally 1,200 m altitude in its native range. The plant is cultivated in orchards or as backyard trees in remote areas as an ornamental but has a tendency to naturalize. It is adaptable to tropical conditions in areas with mean annual temperatures of 22–30 °C and mean annual rainfall of 2,000–4,000 mm. It prefers a bimodal rainfall distribution, with rapid growth in the wet, but is drought tolerant withstanding extended dry periods of up to 9 months. It is frost sensitive and is intolerant of protracted period of low cool temperatures. It grows on a wide range of soils including alkaline, saline, acid soils with pH down to 4.5, heavy clays and poorly drained and low fertility soils. It is tolerant to brief periods of flooding.

Edible Plant Parts and Uses

In Asia, young leaves, flowers and young pods are used in curries and soups, lightly fried, steamed or boiled (Burkill 1966; Ochse and Bakhuizen van den Brink 1980; JIRCAS 2010). The young, tender pods are cooked similarly to other green beans. The leaves and young tender pods are used as flavouring items in the cuisine of South India (Yadav et al. 2010). In Sri Lanka, the leaves are sometimes added to 'sodhi', a widely eaten, thin coconut gravy. In India, the tender leaves, young green pods and flowers are eaten alone as a vegetable or mixed into curries or salads. The young leaves are chopped and sautéed, perhaps with spices, onion or coconut milk. Seeds are high in protein (33.7 %) and are eaten as famine food in India.

In India, flowers may be dipped in batter and fried in butter. Flowers after removal of the bitter stamens are eaten as vegetables raw or cooked in Southeast Asian countries, namely, Thailand, Laos, Kampuchea, Vietnam, Malaysia, Indonesia and the Ilocos region of the Philippines and also in Bihar, India. In Thailand young shoots and leaves are blanched and eaten with chilli paste '*nam prik kapi*' or 'nam prik plaa raa' (JIRCAS 2010). Young flowers are used as an ingredient in sour curry soups such as 'kaeng som'. The flowers are also consumed raw. They are also fried with pork or shrimps or mixed with flour and fried. In the Philippines, unopened white flowers are a common vegetable, steamed or cooked in soups and stews after removal of the stamen and calyx (Stuart 2012). In Vietnam the flowers are used in soups or stir-fry with meat (Tanaka and Nguyen 2007). In Peninsular Malaysia, the leaves are cooked in coconut milk (lemak) or curry (Saidin 2000), and the flowers are commonly used raw in 'ulam' (Mackeen et al. 1997) or cooked as vegetables as are the young pods (Saidin 2000). In Sarawak, one popular dish is 'duan turi' cooked in coconut gravy with shrimp paste, dried pounded shrimps, pumpkin and chillies (Voon et al. 1988). In Indonesia young leaves and pods eaten as sepan (steamed vegetables) and the flowers are used for making sayor or lalab. 'Petjel' (sauce) can be made of the flowers by adding 'sambal kacang' (Ochse and Bakhuizen van den Brink 1980).

Botany

A small, open-branched, unarmed, perennial tree 5–9 m tall with drooping branches (Plates 1 and 2) and 30 cm trunk with heavily nodulated roots. Leaves glaucous, deep green, pinnately compound to 30 cm long with 20–40 pairs of opposite to alternate leaflets (Plates 1, 2, 3 and 4). Leaflet oblong, to elliptical, obtuse apex, about 2–3 cm long. Inflorescences arise from leaf axils in lax racemes of 2–4 flowers, bracts lanceolate, deciduous, 3–6 mm long. Flowers white or deep pink to red, quite large, 7–9 cm long, corolla with standard and wings, staminal tube and glabrous ovary and style (Plates 1, 2, 3, 4, 5 and 6). Pods pendent, slender, long, 30–55 cm, cylindric, green, indehiscent containing 15–50 seeds. Seed sub-reniform, 6.5 mm × 5 mm × 3 mm, dark brown.

Plate 1 Leaves, fruit and white flowers

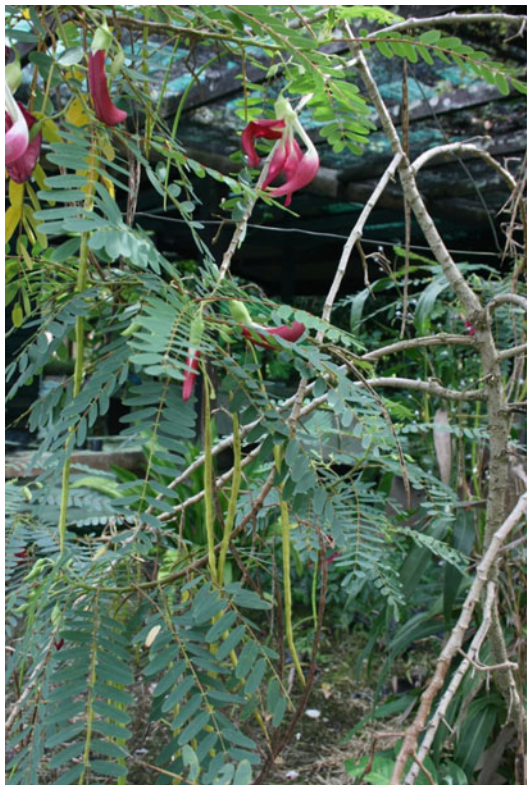

Plate 2 Leaves, fruit and red flowers

Plate 3 Close view of flower and leaf

Plate 4 Tender, leafy shoot used as vegetable

Plate 5 Red and white flowers sold as vegetables

Nutritive/Medicinal Properties

Leaf Nutrients and Phytochemicals

The leaves and flowers of agathi (*Sesbania grandiflora*) were found to be rich in minerals and vitamins. The leaves were reported to contain per 100 g edible portion, 8.4 g protein, 11.8 g carbohydrate, 3.1 g fat, 2.2 g fibre,

Plate 6 Mass of white flowers sold in local markets as vegetables

5,400 µg carotene, 169 mg vitamin C, 0.21 mg vitamin B1, 0.09 mg vitamin B2, 1.2 mg niacin, 3.1 g minerals, 1,130 mg Ca, 80 mg P and 3.9 mg Fe (Devi et al. 2007). Duke (1983) reported that per 100 g ZMB (zero-moisture basis), the leaves contained 321 cal, 36.3 g protein, 7.5 g fat, 47.1 g carbohydrate, 9.2 g fibre, 9.2 g ash, 1,684 mg Ca, 258 mg P, 21 mg Na, 2,005 mg K, 25,679 µg β-carotene equivalent, 1.00 mg thiamine, 1.04 mg riboflavin, 9.17 mg niacin and 242 mg ascorbic acid. The flowers contain per 100 g ZMB, 345 cal, 14.5 g protein, 3.6 g fat, 77.3 g carbohydrate, 10.9 g fibre, 4.5 g ash, 145 mg Ca, 290 mg P, 5.4 mg Fe, 291 mg Na, 1,400 mg K, 636 µg β-carotene equivalent, 0.91 mg thiamine, 0.72 mg riboflavin, 14.54 mg niacin and 473 mg ascorbic acid (Duke 1983). Voon et al., (1988) reported the leaves to contain per100 g edible portion energy 85 kcal, moisture 78.2 %, protein 6 g, fat 0.9 g, carbohydrate 10.9 g, fibre 2.1 g, ash 2 g, P 2 mg, K, 308 mg, Ca 96 mg, Mg 65 mg, Fe 164 µg, Mn 33 µg, Cu 33 µg, Zn 6.6 mg and vitamin C 15.5 mg.

Physicochemical studies of the leaves revealed loss on drying (0.6 %), total ash (10.75 %), acid-insoluble ash (0.045 %), alcohol-soluble extractive (21.7 %) and water-soluble extractive (30.72 %) (Yadav et al. 2010). The leaves were reported to contain alkaloids, saponins, phenols and proteins.

Flower Phytochemicals

The flowers were reported to contain ZMB per 100 g, 345 cal, 14.5 g protein, 3.6 g fat, 77.3 g carbohydrate, 10.9 g fibre, 4.5 g ash, 145 mg Ca, 290 mg P, 5.4 mg Fe, 291 mg Na, 1,400 mg K, 636 µg β-carotene equivalent, 0.91 mg thiamine, 0.72 mg riboflavin, 14.54 mg niacin and 473 mg ascorbic acid (Duke 1983).

Raj and Nagarajan (1984) isolated kaempferol-3-rutinosides from the flowers. Kalyanagurunathan et al. (1985) isolated three active compounds: methyl ester of oleanolic acid, nonacosan-6-one and flavonol glycosides type of molecules, kaempferol-3-rutinosides from the flowers. The flowers were found to have various chemical compounds that could be grouped as flavonoid, anthraquinone, and glycoside (Krasaekoopt and Kongkarnchanatip 2005). Red agati petal (rose-pink to red) of 3 cm length was found to have the highest total anthocyanin content (455 µg/g FW) while hypocotyl of 7-day-old, light-grown Red Agati seedlings also had high anthocyanin content (290 µg/g FW) (Bodhipadma et al. 2006). It was concluded that the hypocotyl of light-grown Red Agati seedlings would be an attractive alternative source of anthocyanins to the petal as the seedlings can be raised and be made available throughout the year.

Yang et al. (2008) found the edible red and white flowers to contain 10.6 %, 10.6 % DM, and 20.4, 22.4 mg/100 g FW of total flavonoids, respectively. The red flower contained (per 100 g FW) 10.1 mg quercetin and 10.3 mg kaempferol while the white flowers contained only 22.4 mg kaempferol and no quercetin. It was found that 70 % alcoholic extract of flowers of *Sesbania grandiflora* had 64.0 mg/g of total phenol equivalent to catechol and 28.80 mg/g of flavonoid content equivalent to quercetin (Shanmukha et al. 2012). The methanol flower extract was found to contain abundant flavonoids, and tannins, alkaloids and anthraquinone glycosides, triterpenes, gums and mucilage (Arthanari et al. 2012). The total polyphenolic content in the acetone flower extract was found to be 49.1 µg/mg and the flavonoid content was 12.86 µg/mg (Munde-Wagh et al. 2012).

Seed Phytochemicals

Seeds (ZMB) were reported to contain 36.5 % CP, 7.4 % fat, 51.6 % total carbohydrate and 4.5 % ash (Duke 1983). The seed oil contains 12.3 % palmitic, 5.2 % stearic, 26.2 % oleic and 53.4 % linoleic acids. The seed testa, which constitutes 20 % of the seed, contains 5.2 % moisture, 1.3 % ash, 0.8 % fat, 2.7 % crude fibre, 0.1 % free reducing sugars, 1.4 % sucrose, 2.8 % nitrogen, 6.3 % pentosans and 65.4 % carbohydrates.

The seed was found to have a galactomannan, with a D-galactose-D-mannose ratio of 1:2 (Srivastava et al. 1968). Methylation of the polysaccharide, followed by hydrolysis, afforded 2,3,4,6-tetra-*O*-methyl-D-galactose, 2,3,6-tri-*O*-methyl-D-mannose and 2,3-di-*O*-methyl-D-mannose in equimolecular proportions. Periodate oxidation of the polysaccharide, followed by reduction and hydrolysis, gave glycerol (1 mol) and erythritol (1.8 mol). The seeds were found to contain kaempferol 3,7-diglucoside, (+)-leucocyanidin and cyanidin 3-glucoside (Andal and Sulochana 1986). The seeds were reported to contain alkaloids, a cyanoglucoside and canavanine (Wenas 1989).

The seed oil of *S. grandiflora* was found to contain (mg/100 g) 258.21 mg total tocopherol, 47.04 mg α-tocopherol, 2.09 mg β-tocopherol, 201.06 γ-tocopherol and 8.02 mg δ-tocopherol, and 74.06 % β-sitosterol, 9.21 % campesterol, 2.06 % Δ^7-avenasterol, 3.02 % stigmasterol, 7.65 %Δ^5-avenasterol and 4 % unidentified sterol (Shareef et al. 2012).

Root Phytochemicals

The roots were found to contain indole acetic acid (IAA), gibberellic acid-like substances (GAs), cytokinin-like substances (CKs) and abscisic acid-like substances (ABA) (Bhowmick and Basu 1984). A steroid was isolated from the roots (Mandey et al. 2003). Three isoflavonoids, isovestitol, medicarpin and sativan, along with another known compound, betulinic acid, were isolated from the root (Hasan et al. 2012). A new biaryl natural product, l,l′-binaphthalene-2,2′-diol, and two known isoflavonoids, isovestitol and sativan, were isolated from the roots (Noviany et al. 2012).

Gum exudates from *S. grandiflora* were found to compose of strongly dextrorotatory, acidic arabinogalactans (Anderson and Wang 1990).

Antioxidant Activity

Studies by Ramesh and Begum (2008) suggested that supplementation with aqueous suspension of *S. grandiflora* reversed the cigarette smoke-induced oxidative damage in rats through its antioxidant potential. Cigarette smoke-enhanced levels of protein carbonyl and activities of cytochrome P450, NADPH oxidase and xanthine oxidase and cigarette smoked-induced decreases in levels of total thiol, protein thiol, non-protein thiol, nucleic acids and tissue protein in the lung, liver, kidney and heart of cigarette smoke-exposed rats were altered and normalized by the extract. The results provided further support for the traditional use of *S. grandiflora* in the treatment of smoke-related diseases. The methanol flower extract of *S. grandiflora* exhibited maximum radical scavenging activity in vitro on nitric oxide, superoxide and hydroxyl radical, and these values were significantly higher over positive standards butylated hydroxyanisole and butylated hydroxytoluene (Loganayaki et al. 2012).

Antidiabetic Activity

Two alpha-glucosidase inhibitors named SGF60 and SGF90 were isolated from the *Sesbania grandiflora* flowers (Boonmee et al. 2007). SGF90 matched a beta-glucosidase from *Arabidopsis thaliana.* SGF60 was similar to p27SJ, a protein from *Hypericum perforatum* and found to suppress HIV-1 gene expression.

Anticancer Activity

Studies showed that a protein fraction, SF2 (Sesbania Fraction 2), isolated from *S. grandiflora*

flowers inhibited cell proliferation and induced apoptosis as evidenced by DNA fragmentation and externalization of phosphatidyl serine in Dalton's lymphoma ascites (DLA) and colon cancer cells (SW-480) (Laladhas et al. 2010). In-vivo studies using ascites and solid tumour models strongly confirmed in-vitro findings as SF2 administration increased the life span and decreased the tumour volume in mice bearing tumour. In-vivo toxicological evaluation revealed the pharmacological safety of SF2, suggesting that it may serve as a potential anti-cancer drug candidate. Administration of *Sesbania grandiflora* ethanol leaf and flower extracts exerted significant decrease in tumour volume, viable cell count and tumour weight and elevated the life span of Ehrlich ascites carcinoma-bearing mice (Sreelatha et al. 2011). Haematological profile such as RBC, haemoglobin and lymphocyte count reverted to normal level in the extract-treated mice. The extracts significantly decreased the levels of lipid peroxidation and significantly increased the levels of GSH, SOD and CAT. The flower extract of *S. grandiflora* inhibited proliferation of human leukaemic cells by inducing autophagy and apoptosis (Roy et al. 2012).

Seven 'ulam' (raw traditional vegetables) extracts, namely, *Anacardium occidentale*, *Garcinia atroviridis*, *Sesbania grandiflora*, *Barringtonia racemosa*, *Polygonum minus*, *Kaempferia galanga* and *Etlingera elatior* displayed cytotoxic activity against the HeLa (human cervical carcinoma) cell line with CD_{50} values in the range of 10–30 μg/ml (Mackeen et al. 1997). The 'ulam' vegetables demonstrated potential as 'functional food' in view of the significant therapeutic and nutritive benefits. The methanol flower extract of *S. grandiflora* exhibited potential cytotoxic activity against human cervical cancer cell line HeLa (IC50 value of 0.13 mg/ml) (Loganayaki et al. 2012).

Antibacterial Activity

Aqueous flower extract exhibited into antibacterial activity against *Bacillus cereus*, *Escherichia coli* and *Staphylococcus aureus* (Krasaekoopt and Kongkarnchanatip 2005). The methanol flower extract of *Sesbania grandiflora* in combination with oxytetracycline exhibited synergistic antibacterial activity against 12 different Gram-positive and Gram-negative bacteria, namely, *Shigella sonnei*, *Escherichia coli*, *Shigella boydii*, *Rhodococcus terrae*, *Micrococcus flavum*, *Flavobacterium devorans*, *Brevibacterium leuteum*, *Bacillus licheniformis*, *Salmonella typhi*, *Klebsiella pneumonia*, *Micrococcus luteus* and *Shigella flexneri* (Kumar et al. 2008). The MIC values ranged from 62.5 to 1,000 μg/ml. The highest synergism effect was attained against *Shigella boydii*. The flower extracts showed good activity against *Pseudomonas aeruginosa*, *Staphylococcus aureus* and *Escherichia coli* (Munde-Wagh et al. 2012). Polyphenolic extracts (PE) of edible flower of *Sesbania grandiflora* exhibited in-vitro inhibitory effect against *Staphylococcus aureus*, *Shigella flexneri*, *Salmonella typhi*, *Escherichia coli* and *Vibrio cholerae*. The Gram-positive organism *S. aureus* was the most sensitive to the extract with minimum inhibitory concentration (MIC) of 0.013 mg/ml, where *V. cholerae* was not sensitive with a high MIC of 0.25 mg/ml (China et al. 2012).

The butanol fraction of the crude ethanol extract of the stem bark was found to possess the most pronounced antibacterial activity against Gram-negative bacteria (Anantaworasakul et al. 2011). Isovestitol (1), medicarpin (2), sativan (3) and betulinic acid (4) isolated from the roots exhibited antituberculosis activity against *Mycobacterium tuberculosis* H37Rv, with MIC values of 50 μg/ml for compounds 1–3 and 100 μg/ml for compound 4, whereas the methanol root extract exhibited antituberculosis activity of 625 μg/ml.

Das et al. (2013) developed a simple, rapid and effective method for the green synthesis of silver nanoparticles (AgNPs) using leaf extract of *Sesbania grandiflora* and demonstrated their in-vitro potent antibacterial activity against multidrug-resistant (MDR) bacteria such as *Salmonella enterica* and *Staphylococcus aureus*.

Antiviral Activity

Of all the flower extracts (petroleum ether, chloroform, ethyl acetate, ethanol, methanol and water) of *S. grandiflora*, the methanol flower extract exhibited the strongest antiviral activity against the following viruses grown in different cell lines like Hel, HeLa, Crandell Reus feline kidney and Vero cell (Arthanari et al. 2012). *S. grandiflora* flower extracts were found not to be toxic with MIC at 20 μg/ml in Vero cells and 100 μg/ml in the other cell lines. The methanol extract exhibited potent activity against herpes simplex 1 and 2, respiratory syncytical, parainfluenza, reo-1, sindbis, coxsackie and Punta Toro viruses with EC_{50} = 20 and 45 μg/ml and moderate activity against vaccinia, vesicular stomatitis, feline corona, feline herpes and viruses (EC_{50} = 100 μg/ml).

Probiotics Stimulating Activity

Polyphenolic extracts of edible flower of *Sesbania grandiflora* exhibited growth-promoting effect on the common probiotic bacterium *Lactobacillus acidophilus* (China et al. 2012). *S. grandiflora* extract induced a significant biomass increase of *L. acidophilus* grown in liquid culture media.

Antiurolithiatic Activity

The leaf juice of *S. grandiflora* showed significant antiurolithiatic activity against calcium oxalate-type stones as evaluated by a calculi-producing diet model in rats (Doddola et al. 2008). It also exhibited antioxidant properties in scavenging of nitric oxide and 2-diphenyl-2-picrylhydrazyl-free (DPPH) radicals. The leaf juice of *S. grandiflora* was safe orally and exhibited no gross behavioural changes except for an increase in urination.

Antihyperlipidaemic Activity

Administration of a dose of 200 μg/kg (p.o.) aqueous leaf extract of *S. grandiflora* to the triton-induced hyperlipidaemic rats significantly decreased levels of serum cholesterol, phospholipid, triglyceride, LDL and VLDL and significantly increased serum HDL level (Saravanakumar et al. 2010).

Anticonvulsant and Anxiolytic Activities

Studies showed that the benzene:ethyl acetate fraction (BE) of a petroleum ether leaf extract of *S. grandiflora* significantly delayed the onset of convulsions in pentylenetetrazol- and strychnine-induced seizures in mice and reduced the duration of tonic hindleg extension in the maximum electroconvulsive shock (MES)-induced seizures in mice (Kasture et al. 2002). The BE fraction was found to contain a triterpene as a major component. BE also suppressed electrically induced kindled seizures in mice and lithium-pilocarpine-induced status epilepticus in rats. It prolonged the duration of sleep induced by pentobarbital and antagonized the effect of D-amphetamine. Mice treated with BE preferred to remain in the open arm of the elevated plus maze indicating anxiolytic activity. The BE raised the brain contents of gamma-aminobutyric acid and serotonin. Thus, the triterpene containing fraction of *S. grandiflora* exhibited a wide spectrum of anticonvulsant profile and anxiolytic activity.

Hepatoprotective and Nephroprotective Activities

Oral administration of an ethanol extract of *S. grandiflora* leaves (200 mg/kg/day) for 15 days produced significant hepatoprotection against erythromycin estolate (800 mg/kg/day)-induced hepatotoxicity in rats (Pari and Uma 2003). The increased level of serum enzymes (aspartate transaminase, alanine transaminase, alkaline phosphatase), bilirubin, cholesterol, triglycerides, phospholipids, free fatty acids, plasma thiobarbituric acid-reactive substances and hydroperoxides observed in rats treated with erythromycin estolate was significantly decreased

in rats treated concomitantly with sesbania extract and erythromycin estolate. The sesbania extract also restored the depressed levels of antioxidants to near normal. The results of the study reveal that sesbania could afford a significant protective effect against erythromycin estolate-induced hepatotoxicity.

The ethanol extract at doses of 250 and 500 mg/kg, p.o. and aqueous extract at a dose of 500 mg/kg, p.o. of *Sesbania grandiflora* flowers exhibited significant hepatoprotective effect against carbon tetrachloride-induced hepatotoxicity in the liver of Swiss Albino rats (Kale et al. 2012). Both extracts were effective in bringing about functional improvement of hepatocytes.

The petroleum ether extract of *Sesbania grandiflora* fruit exhibited significant dose-dependent (100 mg, 200 mg/kg p.o.) protective effect against thioacetamide- and ranitidine-induced hepatotoxicity in Wistar albino rats (Ramakrishna et al. 2012). The fruit extract completely prevented the toxic effects of thioacetamide and ranitidine on biochemical parameters like serum glutamic oxaloacetic transaminase, serum glutamic pyruvic transaminase, alkaline phosphatase, total bilirubin, total cholesterol, total protein and histopathological alterations.

The results of studies by Ramesh et al. (2010) indicated that *S. grandiflora* aqueous leaf suspension significantly decreased the elevated hepatic, renal and lipid peroxidation markers and ameliorated the diminished antioxidant levels while restoring the hepatic and renal architecture in cigarette smoke-exposed rats. They concluded that *S. grandiflora* leaves ameliorated cigarette smoke-induced oxidative damage in liver and kidney of rats.

Studies by Kumaravel et al. (2011) found that *Sesbania grandiflora* protected kidney against alcohol and polyunsaturated fatty acid-induced oxidative stress. The elevated levels of thiobarbituric acid-reactive substances (TBARS) and lipid hydroperoxides induced by oxidative stress were reduced by treatment with the extract. The decreased levels of both enzymatic and non-enzymatic antioxidants were restored on treatment with *S. grandiflora.* The authors attributed this nephroprotective effect to the phenolic compounds and anthocyanins present in the plant.

Cardioprotective and Pulmoprotective Activities

Treatment of adult male Wistar-Kyoto rats (exposed to cigarette smoke for a period of 90 days) with *S. grandiflora* aqueous suspension (SGAS, 1,000 mg/kg bw per day orally) for a period of 3 weeks restored the antioxidant status and retained the levels of micronutrients (Ramesh et al. 2008). In contrast rats exposed to cigarette smoke had significantly increased lactate dehydrogenase activity in serum and cardiac lipid peroxidation product level, and the levels of cardiac superoxide dismutase, catalase, glutathione peroxidase, glutathione reductase, glutathione-S-transferase and glucose-6-phosphate dehydrogenase and levels of reduced glutathione, vitamin C and vitamin E were significantly decreased. Besides, copper level was elevated, whereas zinc, manganese and selenium levels were significantly diminished in the heart of rats exposed to cigarette smoke. The results suggested that *S. grandiflora* protected the heart from the oxidative damage through its antioxidant potential. Similarly, they found that *S. grandiflora* protected the lungs of cigarette smoked-exposed rats against chronic oxidative stress and damage through its antioxidative potential (Ramesh et al. 2007).

Analgesic and CNS Depressant Activities

The leaf extract of *S. grandiflora* was found to have analgesic and CNS depressant activity (Sutradhar and Choudhury 2012). In the acetic writhing test, a dose-dependent reduction in the number of abdominal constriction was observed in animals treated with different concentration of methanol leaf extract of *S. grandiflora*. At the dose of 250 and 500 mg/kg, 68.13 and 85.56 % inhibition of writhing response was observed, respectively. In the tail-flick method, the duration

of heat tolerance was dependent on the dose of the extract, and the onset of action was very rapid, faster than diclofenac Na. The tail-flick test and acetic acid writhing test were used to elucidate central and peripheral antinociceptive effect, which were both central and peripheral, and the results indicated the extract to have analgesic activity. In the open field and whole cross tests, both 250 and 500 mg/kg leaf extract of *S. grandiflora* gave rapid onset of action and produced rapid sleeping, indicating the extracts had neurological activity, namely, CNS depressant activity.

Antiinflammatory and Analgesic Activities

S. grandiflora flower extract exhibited antiinflammatory activity in the rat paw oedema test (Tamboli 1996), and the flower extracts also demonstrated analgesic (tail-flick test) and antipyretic activity (Brewer's yeast-induced pyrexia assay) (Tamboli 2000).

The methanol flower extracts of *S. grandiflora* showed significant inhibitory activity against inflammation in the carrageenan and cotton pellet-induced animal models and analgesic activity in hot-plate pain model (Loganayaki et al. 2012). The inhibitory values were comparable with positive standards.

Increased paw oedema of the injected paw measured on 1st to 12th hours, a feature of carrageenan-induced inflammation in Wistar arts, was significantly reduced after prophylactic oral administration of petroleum ether, chloroform and methanol extracts of bark of *Sesbania grandiflora* (300 mg/kg bw) and *Sesbania sesban* (300 mg/kg bw) (Patil et al. 2010). Increased swelling of the non-injected paw (secondary paw) measured on days 14 and 21; injected paw swelling (primary paw) measured on days 3, 14 and 21; splenomegaly; thymic involutions; and loss in body weight, all features of adjuvant-induced arthritis, were effectively reduced after prophylactic administration of extracts of bark of *Sesbania grandiflora* and *Sesbania sesban*. Albino rats treated with the ethanol stem bark extract of *S. grandiflora* showed significant increase in the tail-flick latency compared to control, and the ethanol extract suppressed carrageenan-induced oedema in rats when compared to control (Swetha et al. 2012).

Antiulcerogenic Activity

Animal studies showed that the ethanol bark extract of *S. grandiflora* had antiulcer potential (Serti et al. 2001). The extract significantly prevented stress and nonsteroidal antiinflammatory drug-induced gastric lesions in rats. At a dose of 36.75 mg/kg (ED_{50}) p.o., the extract did not modify the volume, pH and hydrochloric acid contents of gastric secretion. The ethanol leaf extract of *S. grandiflora* at a dose of 400 mg/kg produced a significant reduction in the ulcer index of rats with gastric injury induced by aspirin, ethanol and indomethacin (Bhalke et al. 2010). The extract significantly suppressed gastric mucosal damaged induced by aspirin, ethanol and indomethacin. In pylorus-ligated Shay rats, the extract significantly reduced basal gastric secretion. The antiulcer effect was further confirmed histologically.

Wound Healing Activity

Both concentrations (2 and 4 % w/w ointment) of ethanol flower extract of *S. grandiflora* showed significant wound healing (wound closure) and tensile strength increase in both excision and incision wound models tested in Wistar rats when compared with control group (Sheikh et al. 2011). The effects were comparable to the standard nitrofurazone ointment (0.2 %w/w).

Anthelmintic Activity

S. grandiflora seed oil exhibited high anthelmintic activity in both paralysis and time of death of test earthworm, *Pheretima posthuma* (Jalalpure et al. 2010).

Adverse Haemolytic Activity

Aqueous leaf extract of *Sesbania grandiflora* produced haemolysis of human and sheep erythrocytes even at very low concentrations (Kumar et al. 1982). Haemolysis was greater when the pH was acidic. The liberation of phospholipids and sterols into the supernatant as a result of haemolysis indicated possible damage to the erythrocyte membrane. The aqueous flower extracts *S. grandiflora* produced haemolysis of human and sheep erythrocytes even at low concentration (Kalyanagurunathan et al. 1985). The active principle responsible for the haemolytic effect was characterized as the methyl ester of oleanolic acid.

Traditional Medicinal Uses

Various parts of the tree have been used in folkloric medicine in south and Southeast Asian countries (Burkill 1966; CSIR 1972; Stuart 2012; Kirtikar 1993; Tanaka and Nguyen 2007; Wagh et al. 2009). According to Duke and Wain (1981), *S. grandiflora* is reported to be aperient, diuretic, emetic, emmenagogue, febrifuge, laxative, and tonic and used as a folk remedy for bruises, catarrh, dysentery, eyes, fevers, headaches, smallpox, sores, sore throat and stomatitis. Bark, roots, leaves, gum and flowers are considered medicinal.

Sesbania grandiflora is widely used in Ayurveda for the treatment of diseases and for processing of various formulations in Rasashastra (Yadav et al. 2010). It is used for its astringent, antihistaminic, anxiolytic, anticonvulsive and febrifugal properties. Ayurvedics, believing the fruits to be alexeteric, laxative and intellectually stimulating, prescribe them for anaemia, bronchitis, fever, pain, thirst, ozena and quartan fever (Ramakrishna et al. 2012). Yuani considers the tonic levels useful in biliousness, fever and nyctalopia. In local folk medicine, it is applied as aperients, diuretic, emetic, emmenagogue, febrifuge, laxative and tonic (Wagh et al. 2009). In the indigenous system of medicine in India, *Sesbania grandiflora* is claimed to be useful for various ailments, and one such use is for the treatment of renal calculi (Doddola et al. 2008). One traditional use of *S. grandiflora* is in the treatment of smoke-related diseases (Ramesh and Begum 2008). *Sesbania grandiflora* is widely used in Indian folk medicine for the treatment of liver disorders (Pari and Uma 2003). Various parts of this plant are used in Indian traditional medicine for the treatment of a broad spectrum of illness including leprosy, gout, rheumatism and liver disorders. The bark is reported to cure diarrhoea, dysentery, paludism, snakebite, malaria, smallpox, eruptive fever, scabies, ulcer and stomach disorders in children; in high doses it causes vomiting and mild diarrhoea (Kirtikar 1993). Indians apply the roots in rheumatism and the juice of the leaves and flowers for headache and nasal catarrh (Saravanakumar et al. 2010). The Yanadi tribe in the Chittoor District of Andhra Pradesh used the flowers for cataract, conjunctivitis, kidney and bladder stones and alopecia (Vedavathy et al. 1997).

Burkill (1966) has reported on its medicinal uses in Malaysia, Java and also in India. The bark is considered tonic and is bitter the bark extract acts as aperient and larger doses are emetic, and small doses are prescribed for dysentery and other bowel complaints. Bark extract is also prescribed for ulceration of the tongue and alimentary tract. In Java, it is used for thrush and infantile disorders of the stomach. Dried powdered bark is used as cosmetic in Java. An infusion of the leaves is used as aperients, leaf juice prescribed for dim vision and the leaves boiled in vinegar or arrack applied to sprains. In Amboina, flower juice is squeezed into the eye to correct dim vision. The bark is used in infusions for smallpox. An herbal preparation of dried powered leaves mixed with leaves of *Citrus* lime, *Parkia* seeds and wood ash moistened with vinegar is rubbed on the abdomen for a fortnight after confinement. Consumption of large quantities of leaves can cause diarrhoea. Saidin (2000) reported that the leaf juice is taken to reduce nose inflammation and cough and to expel mucus in Malaysia. The cortex has been used to treat dysentery, indigestion and diarrhoea in Vietnam (Tanaka and Nguyen 2007). In the Philippines, the pounded bark is employed for haemoptysis;

the powdered bark is also recommended for ulcers of the mouth and alimentary canal (Stuart 2012). Cambodians consider the flowers emollient and laxative and the bark for diarrhoea, dysentery and paludism.

Other Uses

According to NAS (1979, 1980), *S. grandiflora* is an important source of firewood, forage, pulp and paper, food, medicine, green manure and shade tree and has potential for reforesting eroded and grassy wastelands throughout the tropics. The tree combines well with agriculture (agroforestry) in areas where trees are not normally grown and becomes an important fuel-wood source. The small tree is often grown as a light shade tree for companion plants such as turmeric, galangal and ginger and as a live support tree for climbing plants such as black pepper and betel vine. It is also grown as an ornamental in home gardens, as living fences and as windbreak. The tree is also grown around fields, eroded hill slopes and wastelands as it is planted to ameliorate soils and improve their fertility, especially their nitrogen content. In South Asia and Southeast Asia, its foliage is valued as fodder for cattle and goats. The fast-growing seedlings and the tree foliage make excellent green manure. In Java, the tree is extensively used as a pulp source. The trunks may be used for light construction like bamboos and have been used as poles for temporary shelters and sheds, but they may not last very long due to rots and insect infestation. The bark yields a tanning agent. The gum exuding from a cut in the bark has properties of gum Arabic and is used by fisher-folks for toughening nets and lines. An aqueous extract of bark is said to be toxic to cockroaches. The inner fibrous bark and the white, soft wood can be used for cork.

Comments

The toxic compound, sesbanimide, was detected in seeds of *Sesbania drummondii*, *S. punicea* and *S. vesicaria* but not detected in seeds of *S. grandiflora*, *S. emerus*, *S. exaltata*, *S. sesban*, *S. speciosa* and *S. sonorae* (Powell et al. 1990) and has been erroneously reported in literature to be present in the seeds of *S. grandiflora*.

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