Senna alata

Scientific Name

***Senna alata* (L.) Roxb.**

Synonyms

Cassia alata L. basionym, *Cassia alata* var. *perennis* Pamp., *Cassia alata* var. *rumphiana* DC., *Cassia bracteata* L. f., *Cassia herpetica* Jacq. (nom. illeg.), *Cassia rumphiana* (DC.) Bojer, *Herpetica alata* Cook & Collins, *Herpetica alata* (L.) Raf.

Family

Fabaceae also placed in Caesalpiniaceae

Common/English Names

Candelabra Bush, Candelabra Plant, Candle Bush, Candlestick Senna, Empress-Candle-plant, Emperor's Candlesticks, Christmas-Candle, Emperor's Candle Plant, Emperor's Candlesticks, Golden-Candle Senna, Golden Candelabra Tree, King-of-the-Forest, Ringworm Bush, Ringworm Plant, Ringworm Senna, Ringworm Bush, Ringworm Shrub, Roman Candle Tree, Seven Golden Candles, Seven-Golden-Candlesticks, Stick Senna, Winged Senna, Yellowtop

Vernacular Names

Antilles: Taratana
Argentina: Taperibá Guazú
Bangladesh: Dadmardan, Dadmari
Brazil: Café-Beirão, Fedegoso-Gigante, Fedegoso-Grande, Mangerioba-Do-Pará, Mangerioba-Grande, Mata-Pasto (Portuguese)
Brunei: Raun Suluk (Dusun), Paaul-Ul, Tarump (Malay)
Burmese: Pway-Mezali, Pwé: Hsé:Mè:Za.Li, Thinbaw-Mezali
Chamorro: Acapulco, Akapuku, Andadose, Candalaria, Take-Biha
Chinese: Chi Jia Jue Ming, Yi Bing Jue Ming
Chuukese: Arakak, Arekak, Yarakaak
Creole: Kas Ailé, Zèb À Dartres
Czech: Kasie Křídlatá
Fijian: Mbai Ni Thangi
French: Bois Dartre, Catépen, Dartrier, Epis D'or, Quatre Épingle; Dartrier, Casse Ailée, Plante Des Cros-Cros, Buisson De La Gale, Quatre Épingles
Cuba: Guacamayón, Palo Santo
German: Kerzenstrauch
India: Kharpat (Assamese), Dadmari, Dadmardan (Bengali), Dadmari, Dadmurdan, Dat-Ka-Pat, Datkapat, Vilayati-Agati, Deo-Mardon (Hindi), Doddasagate, Sheemigida, Shime-Agase, Simyagase, Dhavala Gida, Dodda Thagache, Seeme Agase, Seeme Thangadi, Dodda Thangadi, Daddumardu, Dahvala, Doddacagate, Doddachagate, Puritappu, Simeagase,

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Simeyagase, Dhawala Gida, Dodda Chagache (Kannada), Elakajam, Shima-Akatti, Simayakatti, Shimayakatti, Simaagati (Malayalam), Daopata (Manipuri), Dadamardana (Marathi), Tuihlo (Mizoram), Jadumari (Oriya), Dadrughna, Dvipagasti (Sanskrit), Anjali, Shimai-Agatti, Vandukolli, Simaiyagatti, Vandugolli, Peyakatti, Vantukkolli, Vandu-Rolli, Alata, Malai Tagarai, Seemai Agathi, Vandu Kolli, Pei Agathi, Seemai Agathy, Seemaiagatti, Semmai Agatti, Sheemai-Agatti, Vendukolli, Vendu-Kolli, Vandu Kollu, Seemie Aghatee, Calavakatti, Calavakatticceti, Cimaiakatti, Cimaiyakatti, Cimaiyavutti, Cintuki, Cintukiyakatti, Cirikai, Kacampakatti, Karccakkinam2, Pairavam, Pairavamaram, Ponnakatti, Puliyacikacceti, Puliyacikam, Pulukkolli 2, Tatturukkinam, Tiruttakatti-maram, Tiruttavutti, Vantukatiyilai, Vantunelli 2 (Tamil), Mettatamara, Sheemaavisi, Shima-Avishi-Chettu, Sima Avisl, Simayavisa, Mitta Tamara, Seemaavasie, Seemaavise, Simaavishi, Simaavisi, Simayavise, Mettataamara, Seema Avise, Seemayavisa (Telugu)

Indonesia: Ketepeng, Daun Kupang (Malay, Manado), Ketepeng, Ketepeng Kebo, Ketepeng China (Java), Ketepeng Badak, Ketepeng Manila (Sundanese)

Japanese: Kasshia Arata, Kyandorubusshu

Kapingamarangi: Rakau Honuki, Tirakahonuki, Tuhkehn Kilin Wai

Khmer: Dang Het

Kwara'Ae: Bakua

Laotian: Khi Let Ban

Malaysia: Gelenggang, Gelenggang Besar, Ludangan, Daun Kurap (Peninsular), Daun Sulok, Gelingok, Rugan, Serugan (Iban—Sarawak), Daun Ingram, Tarum (Melanau—Sarawak), Solok (Malay—Sarawak)

Mexico: Flor Del Secreto

Nicaragua: Soroncontil

Niuean: Mulamula

Palauan: Kerula Besokel, Yult

Papua New Guinea: Kabaiuara (Harigen, Sepik), Levoanna (Gaire and Tubusereia, Central Province), Orere (Awala, Northern Province)

Philippines: Buni-Buni (Bagobo), Kasitas (Bikol), Kasitas, Palo-China (Bisaya), Sunting (Cebu Bisaya), Ancharasi (Igorot), Andadasi, Andadasi-A-Dadakell, Andadasi-Ng-Bugbugtong (Iloko), Pakayomkom-Kastila (Pampangan), Kapis (Subanum), Akapulko, Andalan (Sulu), Akapulko, Bayabasin, Bikas-Bikas, Gamotsa-Buni, Kapurko, Katanda, Pakagonkon, Sonting (Tagalog), Adadisi (Tinggian)

Pohnpeian: Truk-En-Kili-N-Wai

Portuguese: Alcapulco, Dartial, Cortalinde, Café Beirão, Fedegoso, Fedegosão, Fedegoso-Gigante, Mangerioba-Do-Pará, Mangerioba-Grande, Mata-Pasto-Grande

Samoan: Fa'I Lafa, Fa'I Lafa, La'Au Fa'I Lafa, La'Au Fa'I Lafa

Spanish: Bajagua, Flor Del Secreto, Guacamaya Francesa, Guajavo, Hierba De Playa, Majaguilla, Majaguillo, Mocuteno, Mocoté, Soroncontil

Sri Lanka: Eth Thora (Sinhala)

Swahili: Upupu Wa Mwitu

Tanzania: Muambangoma

Thai: Khi-Kak (Northern), Chumhet-Yai, Chum Het Thet (Central), Chum Het Tet (Peninsular)

Tongan: Fa'I Lafa, La'Au Fa'I Lafa, Te'Elango

Venezuela: Mocote

Vietnamese: Muồng Trâu

Yapese: Flay-N-Sabouw

Origin/Distribution

Senna alata is indigenous to tropical South America (French Guiana, Guyana, Surinam, Venezuela, Brazil and Colombia). It has been distributed globally and has naturalized in Central America, southeastern United States (Florida), tropical Africa, tropical Asia, the Caribbean and on several Pacific Islands (the Cook Islands, Fiji, Guam, Palau, Tonga, Western Samoa and Hawaii), Papua New Guinea and throughout northern and eastern Australia.

Agroecology

S. alata is found in diverse habitats: alongside waterways, rivers and drainage channels, margins tof ponds and ditches, in open forest, coastal

plains, floodplains, wetlands, native bushland, disturbed sites, waste areas, roadsides, overgrazed pastures, orchards and around villages. However, it prefers open areas and sunny locations at low to medium altitude but can also be found up to 1,400 m altitude. It often forms thickets and is aggressive in areas where there is a high water table. It is reported to tolerate an annual rainfall of 600–4,300 mm and average annual temperatures of 15–30 °C and is frost sensitive. It grows on both heavy and sandy, acid to slightly alkaline, well-drained soils but thrives best in deep, well-drained soil rich in organic matter with a pH range of 5.5–6.5.

Edible Plant Parts and Uses

Flowers or leaves are edible after cooking and may be used as a laxative (Burkill 1966). The inflorescence are boiled with chilli and consumed for constipation (Monkheang et al. 2011). In Myanmar, fresh leaves and flowers are used as vegetables and in curries (Myanmar Department of Traditional Medicine 2008). In Sabah and Peninsular Malaysia, the young shoots are cooked and eaten as vegetable. Toasted leaves along with *Glycine* beans are sometimes made into a drink similar to coffee (Burkill 1966). Young immature pods are eaten in small quantities, raw or steamed in the Philippines (Pardo de Tavara 1901).

Botany

Coarse, erect, branched shrub growing from 1.5 to 4 m tall; leaves to about 50–80 cm long, alternate, pinnate, with 8–14 pairs of large leaflets (the distal ones largest), up to 17 cm long, ovate-oblong, obtuse, truncate or even slightly notched at apex, margin entire, subsessile (Plates 1 and 2). The inflorescence is a long-pedunculate, erect, dense, oblong spike, terminal or axillary, 10–15 cm long, with overlapping and crowded yellow flowers, 4 cm in diameter. Flowers are enclosed within dark-yellow or orangey bracts which shed off during flower opening (Plate 1). Flower bisexual, zygomorphic and pentamerous, with 5 oblong sepals, 5 bright yellow ovate-orbicular petals (20 mm long by 12 wide), 10 stamens, 2 fertile with elongated anthers and 8 with rudimentary anthers; elongated recurved, pubescent ovary with short slender style and stigma. Pod is green, ripening brown to black, straight, papery in texture, winged, up to 15–20 cm long and slightly over 1 cm wide; seeds numerous (to 50), shiny, flat and triangular.

Plate 1 Terminal inflorescences and yellow flowers

Plate 2 Slender upright branches and pinnate leaves

Nutritive/Medicinal Properties

Nutrient and Phytochemicals in the Leaves

Nutrient composition of the edible leaves per 100 g based on analyses carried out in Nigeria was reported as moisture 58.4 g, energy 159 kcal, protein 6.8 g, fat 0.6 g, carbohydrate 31.5 g, fibre

0.1 g, ash 1.8 g, vitamin A 52 μg RE, vitamin A 26 RAE μg, β-carotene 310 μg, thiamine 0.45 mg, riboflavin 0.58 mg, niacin 0.54 mg, folic acid 15 μg, vitamin C 7.74 mg, calcium 755 mg, phosphorus 739 mg, iron 14.8 mg and zinc 3.7 mg (CINE 2007).

Hauptmann and Nazario (1950) isolated rhein (1,8-dihydroxyanthraquinone-3-carboxylic acid) along with hydroxymethyl anthraquinones and chrysophanic acid from the alcoholic leaf extract. Physcione, kaempferol, rhein methyl ester diacetate and β-sitosterol (Rao et al. 1975); 1,3,8-trihydroxy-2-methylanthraquinone (aloe-emodin), chrysophanol, deoxycoelulatin, sennoside A, sennoside B, sennoside C and sennoside D (Mulchandani and Hassrajani 1975; Villaroya and Bernal-Santos 1976); aloe-emodin, rhein glycoside and aloe-emodin glycoside (Rai 1978); anthraquinones and anthracene derivatives of rhein, emodol, aloe-emodin, sennosides A and B, 4,5-dihydroxy-1-hydroxymethylanthrone and 4,5-dihydroxy-2-hydroxymethylanthrone (Fuzellier et al. 1982); aloe-emodin and chrysophanol (Harrison and Garro 1997), isochrysophanol and physcion-L-glucoside (Smith and Sadaquat 1979); rhein (cassic acid) (Palanichamy et al. 1991); and aloe-emodin (1,8-dihydroxy-3-(hydroxymethyl) anthraquinone), sitosterol and stigmasterol (Hofileña et al. 2000), 3,5,7,4′-tetrahydroxy flavone and 2,5,7,4′-tetrahydroxyisoflavone (Rahaman et al. 2006, 2008) were isolated from the leaves. Kaempferol-3-*O*-gentiobioside was the major flavonoid glycoside in *Senna alata* (Moriyama et al. 2003c) The mature leaf was found to contain the highest content of this metabolite. The contents ranged from 2.0 to 5.0 % and 1.0 to 4.0 % in mature and juvenile leaves, respectively. Kaempferol-3-*O*-gentiobioside was not detected in the seed. Earlier, Moriyama et al. (2001) reported the disappearance of kaempferol 3-gentiobioside in the sun-dried leaves, while there was little or no change in the kaempferol 3-gentiobioside concentration in the heat-treated leaves when incubated in an aqueous solution, suggesting a possible presence of enzymatic activities in the sun-dried leaves. They concluded that heat treatment may be a good method to stabilize kaempferol 3-gentiobioside in *Cassia alata* leaves.

Hazni et al. (2008) isolated kaempferol, kaempferol 3-*O*-β-glucopyranoside, kaempferol 3-*O*-gentiobioside and aloe-emodin from the leaves. Cassiaindoline, a dimeric indole alkaloid (Villaseñor and Sanchez 2009) and kaempferol-3-*O*-β-D-glucoside (astragalin) (Saito et al. 2012) were isolated from *Cassia alata* leaves. Four anthraquinones (rhein (cassic acid), aloe-emodin, emodin and chrysophanol) were isolated from *Senna alata* leaves (Panichayupakaranant et al. 2009). Twelve compounds were isolated from *C. alata* leaves and identified as chrysoeriol (1), kaempferol (2), quercetin (3), 5,7,4′-trihydroflavanone (4), kaempferol-3-*O*-β-D-glucopyranoside (5), kaempferol-3-*O*-β-D-glucopyranosyl-(1→6)-β-D-glucopyranoside (6), 17-hydrotetratriacontane (7), *n*-dotriacontanol (8), *n*-triacontanol (9), palmitic acid ceryl ester (10), stearic acid (11) and palmitic acid (12) (Liu et al. 2009). Six compounds (kaempferol, kaempferol-*O*-diglucoside, kaempferol-*O*-glucoside, quercetin-*O*-glucoside, rhein and danthron) were isolated from the aqueous leaf extract (Saito et al. 2010). Leaves were also found to contain saponins (1.22 %), flavonoids (1.06 %), cardiac glycosides (0.20 %), cardenolides and dienolides (0.18 %), phenolics (0.44 %) and alkaloids (0.52 %) (Yakubu and Musa 2012).

The essential oil obtained by hydrodistillation of leaves of *C. alata* collected in Gabon afforded 44 compounds representing 92.5 % of the oil; the major constituents were linalool (23.0 %), borneol (8.6 %) and pentadecanal (9.3 %) (Agnaniet et al. 2005). The antioxidant activity of the oil was found to be low compared to that of butylated hydroxytoluene (BHT). Fifteen out of twenty-five constituents of *C. alata* leaf essential oil were identified in trace amount (i.e. <0.1 %) (Ogunwande et al. 2010). The oil was dominated by mono- and sesquiterpene compounds (48.7 and 47.9 %, respectively). The essential oil constituents were 1,8-cineole 39.8 %, β-caryophyllene 19.1 %, caryophyllene oxide 12.7 %, germacrene D 5.5 %, α-selinene 5.4 %, bicyclogermacrene 5.4 %, limonene 5.2 %, α-cadinol 4.2 %, α-phellandrene 3.7 %,

(*E*)-2-hexenal 3.3 %, α-bulnesene 1.0 %, tricyclene trace, (*E*)-β-ionone trace, benzaldehyde trace, α-terpinene trace, *n*-pentadecane trace, *p*-cymene trace, δ-cadinene trace, β-elemene trace, *n*-hexadecane trace, humulene epoxide II trace, (*E*)-geranyl acetone trace, tetradecanal trace, α-humulene trace and (*E*)-β-farnesene trace.

Phytochemicals in the Stem

Stems of *Cassia alata* were found to contain 1,5,7-trihydroxy-3-methylanthraquinone (alatinone) and dalbergin, 2,6-dimethoxybenzoquinone, santal, luteolin, β-sitosterol and β-sitosteryl-β-D-glucoside (Hemlata and Kalidhar 1993) and alatonal (Hemlata and Kalidhar 1994).

Phytochemicals in the Flower, Pod and Seed

Two glycosides, chrysoeriol-7-*O*-(2″-*O*-β-D-mannopyranosyl)-β-D-allopyranoside and rhamnetin-3-*O*-(2″-*O*-β-D-mannopyranosyl)-β-D-allopyranoside, were isolated from the *Cassia alata* seeds (Gupta and Singh 1991). Two polyalcohols, glycerol and erythritol, were found in the seeds (Singh 1998). Hydroxyanthracene derivatives were found in the leaves, flowers and pods of *Cassia alata* (Panichayupakaranant and Intaraksa (2003). A water-soluble galactomannan with molecular weight 26,400 was isolated from the seeds (Gupta et al. 1987). The polysaccharide comprised of heptasaccharide units joined by β-(1→4) linkages.

Phytochemicals in the Roots

Two new anthraquinone pigments 1,3,8-trihydroxy-2-methyl anthraquinone (A) and 1,5-dihydroxy-8-methoxy-2-methyl-anthraquinone-3-*O*-β-D-(+)-glucopyranoside (B) and β-sitosterol were isolated from the roots (Tiwari and Yadav 1971). Alquinone, an anthraquinone (Yadav and Kalidhar 1994); stigmasterol; and emodin (1,6,8-trihydroxy-3-methylanthraquinone) (Husain et al. 2005) were isolated from the roots. Chatsiriwej et al. (2006) found that root cultures established from the high-anthraquinone-producing plants accumulated higher amounts of emodin and chrysophanol than those established from the low-anthraquinone-producing plants and leaves and roots of the intact plants.

Six phenolic compounds, five anthraquinones (rhein, aloe-emodin, emodin, chrysophanol and physcion) and a flavonoid (kaempferol) were isolated from *C. alata* roots (Fernand et al. 2008).

Various plant parts of *Senna alata* have multifarious pharmacological activities that include laxative, antimicrobial, antiinflammatory, antimutagenic, analgesic, choleretic, hypoglycaemic and hepatoprotective.

Antioxidant Activity

Methanol extracts of ten selected Nigerian medicinal plants including *C. alata* were found to contain steroids, terpenoids and cardiac glycosides, alkaloids, saponins, tannins and flavonoids (Akinmoladun et al. 2010). The highest amounts of total flavonoids were found in the leaf extracts of *C. alata* (275.16 μg/mL quercetin equivalent). The extract demonstrated significant antioxidant and radical scavenging activities, namely, 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging and hydroxyl radical scavenging activities, high lipid peroxidation inhibitory activity but low nitric oxide radical scavenging activity. The ethyl acetate extract of *S. alata* aerial parts was found to possess antioxidant properties as expressed by increase in antioxidant enzymes and the presence of phenolic compounds flavonoids naringin and apigenin (Okpuzor et al. 2009).

A refined *C. alata* leaf extract exhibited strong DPPH free radical scavenging activity with an IC_{50} value of 2.27 μg/mL and showed no prooxidant activity in yeast, *Saccharomyces cerevisiae* (Saito et al. 2012). Three of its major components were shown to bind to DNA in vitro. One major component, identified as kaempferol-3-*O*-β-D-glucoside (astragalin), showed high affinity to DNA. The astragalin-DNA binding

was found to occur through interaction with G–C base pairs, possibly by intercalation stabilized by H-bond formation.

Laxative Activity

Cassia alata and *Cassia podocarpa* have identical laxative potency and were the most likely candidates for laxative drug development in Nigeria (Elujoba et al. 1989). *Senna alata* leaves were found to have laxative effect and presumed to be due to active ingredient anthraquinones. In a multicentre randomized controlled clinical trial involving 80 adult patients with constipation, 28 patients were given at bedtime 120 mL of fluid with caramel colour, 28 administered mist. alba and 24 given *Cassia alata* infusion (Thamlikitkul et al. 1990). Eighteen per cent of patients in the placebo group passed stools within 24 hours, whereas 86 and 83 % of patients in mist. alba and *Cassia alata* groups, respectively, passed stools. The differences observed between placebo and mist. alba and placebo and *Cassia alata* were statistically highly significant. Minimal self-limited side effects, that is, nausea, dyspepsia, abdominal pain and diarrhoea, were noted in 16–25 % of the patients. Studies found *Cassia alata* fresh leaves showed significant purgative efficacy on volume and frequency in healthy subjects compared to placebo (Than et al. 2002).

In Thailand, *Senna alata* has been approved as a laxative drug in the Thai Herbal Pharmacopoeia 1998 and the Thai National List of Essential Drug 1999 (Panichayupakaranant and Intaraksa 2003). Hydroxyanthracene derivatives were demonstrated as the active constituents in this plant for the laxative property. The efficiency of herbal medicines depended on the plant raw material quality, which was usually related to the content of the active compounds. Recently, poor quality of *S. alata* leaves due to lower content of hydroxyanthracene derivatives relative to the standard value (i.e. not less than 1.0 % w/w of hydroxyanthracene derivatives, calculated as rhein-8-glucoside on a dried basis) had been a major problem in the production of the herbal medicines from *S. alata.* Studies found that the method and temperature of drying markedly affected the hydroxyanthracene derivative content. Drying of the leaves in a hot air oven at 50 °C gave a higher hydroxyanthracene derivative content (1.43 % w/w) than drying in a hot air oven at 80 °C (0.44 % w/w) or drying in the sun (0.95 % w/w). Study on the stability of hydroxyanthracene derivatives in *C. alata* leaf powder, which was kept in tight container at room temperature, found that the hydroxyanthracene derivative content did not decrease within 9 months.

Antimicrobial Activity

In-Vitro Studies Leaf Extracts

Aqueous leaf extract of *C. alata* exhibited significant antifungal activity in-vitro against dermatophytes (Pankajalakshmi et al. 1993). *C. alata* leaf extract exerted no significant in-vitro activity against *Candida albicans, Penicillium* sp., *Aspergillus fumigatus, A. flavus, Mucor* sp. or *Rhizopus* sp., but at a dose of 2.5 % w/v, it completely inhibited the growth of *Trichophyton mentagrophytes, Trichophyton rubrum* and *Microsporum gypseum* (Palanichamy and Nagarajan 1990b). A combination of ethanol extracts of leaves of *Senna alata* and *Ocimum sanctum* exhibited anti-*Cryptococcus* activity. The activity of combination of the extracts was heat stable and worked at acidic pH. A 10-year human study indicated that the leaf extract could be reliably used as an herbal medicine to treat *Pityriasis versicolor,* a yeast fungus that causes skin disease (Damodaran and Venkataraman 1994). The leaf extract had no side effects.

Fuzellier et al. (1982) also found that rhein, emodol and some anthrones in *S. alata* leaves possessed antifungal activity against some fungal dermatophytes and yeast. The minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) for the water extract of *S. alata* against *Escherichia coli* were 1.6 and 60 mg/mL, respectively; corresponding data for chloramphenicol were 2 and 10 μg/mL (Crockett et al. 1992). Similarly, the MIC and minimum fungicidal concentration (MFC) for the extract against *Candida albicans* were 0.39 and 60 mg/mL in

contrast to 0.58 and 0.98 µg/mL for amphotericin B. From the dose–response curve plots, the extract had an IC_{50} of 31 mg/mL for *E. coli* and 28 mg/mL for *C. albicans*. The scientists suggested that *S. alata* extracts contained agent(s) with therapeutic potential and might be useful if isolated and developed for the treatment of opportunistic infections of AIDS patients. Ethanol leaf extract exhibited high in vitro activity against various species of dermatophytic fungi but low activity against non-dermatophytic fungi (Ibrahim and Osman 1995). However, bacterial and yeast species showed resistance. The minimum inhibitory concentration (MIC) values of the extract revealed that *Trichophyton mentagrophytes* var. *interdigitale, Trichophyton mentagrophytes* var. *mentagrophytes, Trichophyton rubrum* and *Microsporum gypseum* had an MIC of 125 mg/mL, whereas *Microsporum canis* had MIC of 62.5 mg/mL. The inhibition observed on the macroconidia of *Microsporum gypseum* was structural degeneration related to cell leakage as observed by irregular, wrinkle shape and loss in rigidity of the macroconidia. Both aqueous and ethanol bark extracts of *Cassia alata* inhibited growth of *Candida albicans* in vitro (Reezal et al. 2002). The inhibitory activity was comparable to miconazole.

Aloe-emodin from *C. alata* leaves was found to be active against *Bacillus subtilis, Pseudomonas aeruginosa, Candida albicans, Trichophyton mentagrophytes* and *Aspergillus niger* with inhibitory activity indices of 1.8, 0.5, 0.5, 0.5 and 0.2, respectively (Hofilena et al. 2000). *Candida albicans* showed concentration-dependent susceptibility towards both the ethanol and water extracts from the barks but was resistant towards the extracts of leaves (Somchit et al. 2003). The growth of *Aspergillus fumigatus* and *Microsporum canis* was not affected by all types of the plant extracts. The antibacterial activity of *S. alata* extracts on *Staphylococcus aureus* was detected with only the leaf extracts using water and ethanol. The water extract exhibited higher antibacterial activity than the ethanol leaf extract.

The chloroform leaf extract was the most active against *Trichophyton mentagrophytes*, at a concentration of 50 mg/mL but it had no activity against *Candida albicans* (Villaseñor et al. 2002). The hexane and ethyl acetate extracts showed some activity against both organisms, with the ethyl acetate extract being more active against *C. albicans*. Crude leaf extract of *Senna alata* showed significant inhibitory effect on *Streptococcus mutans,* a prominent bacterium that causes teeth decay (Limsong et al. 2004). In-vitro study showed that ethanol extract of *Senna alata* at 0.5 % inhibited adherence of *S. mutans* on glass surface significantly. The extract inhibited adherence of *S. mutans* ATCC 25175 and TPF-1 onto hydroxyapatite coated with saliva with IC_{50} 0.5 and 0.4 %, respectively, as well as reduction of activities of glucosyltransferase and glucan-binding lectin by *Streptococcus mutans* strains. The findings showed that *Senna alata* could be a promising herb for toothpaste formulation with anti-teeth decay property. Among the methanol leaf extract of *Cassia alata, Cassia fistula* and *Cassia tora, C. alata* was the most effective leaf extract against *Trichophyton rubrum* and *Microsporum gypseum* with the 50 % inhibition concentration (IC_{50}) of hyphal growth at 0.5 and 0.8 mg/mL, respectively, whereas the extract of *C. fistula* was the most potent against *Penicillium marneffei* with the IC_{50} of 0.9 mg/mL (Phongpaichit et al. 2004). Furthermore, all three *Cassia* leaf extracts also affected *M. gypseum* conidial germination where treated hyphae and macroconidia were shrunken and collapsed, which might be due to cell fluid leakage.

Of three crude leaf extracts, the methanol extract showed the highest activity followed by the ethanol extract and petroleum ether extract (Owoyale et al. 2005). The leaf extract exhibited higher activity against *Mucor* sp., *Rhizopus* sp. and *Aspergillus niger* with MIC of 70 µg/mL and lower activity against *Escherichia coli, Bacillus subtilis, Salmonella typhi, Pseudomonas aeruginosa, Staphylococcus aureus* and *Candida albicans* with MIC of at 860 µg/mL. Both aqueous and methanol leaf extracts of *C. alata* exhibited more antifungal than antibacterial activity (Makinde et al. 2007). The in vitro growth of the following fungi was inhibited (*Microsporum canis, Blastomyces dermatitidis, Trichophyton mentagrophytes, Candida albicans*

and *Aspergillus* flavus), while only two bacteria species were inhibited (*Dermatophilus congolensis* and *Actinomyces bovis*). Both aqueous and ethanol *S. alata* leaf inhibited the growth of *Candida albicans, Microsporum canis* and *Trichophyton mentagrophytes* better than the ketoconazole 200 mg used as a positive control (Timothy et al. 2012b). The minimum inhibitory concentration (MIC) of the water leaf extract for *Candida albicans, Aspergillus niger, Penicillium notatum, Microsporum canis* and *Trichophyton mentagrophytes* were 26.90, 32.40, 29.50, 30.30 and 27.80 mg, respectively, while the MIC of ethanol leaf extract for *Candida albicans, Aspergillus niger, Penicillium notatum, Microsporum canis* and *Trichophyton mentagrophytes* were 5.60, 3.50, 4.90, 12.60 and 9.80 mg, respectively. In another study, Timothy et al. (2012a) found that the aqueous leaf extract showed higher activity on *Escherichia coli* than ethanol leaf extract at 160 mg, whereas ethanol leaf extract had higher activity than aqueous leaf extract on *Salmonella typhi* at the same dose. The MIC for aqueous leaf extract ranged between 3.50 and 25.15 mg, while that of ethanol leaf extract was from 1.41 to 3.55 mg on the organisms tested. The presence of saponins, anthraquinones, cardiac glycosides, flavonoids, reducing sugars and terpenes were detected in both extracts.

The butanol and chloroform leaf extracts of *S. alata* both exhibited inhibition against methicillin-resistant *Staphylococcus aureus* (MRSA) with inhibition indexes of 1.03 and 0.78 at the concentration of 50 mg/mL (Hazni et al. 2008). The butanol leaf extracts afforded kaempferol (1), kaempferol 3-*O*-β-glucopyranoside (2), kaempferol 3-*O*-gentiobioside (3) and aloe-emodin (4) on purification. The four constituents showed varying degrees of inhibition against MRSA. Both 1 and 4 exhibited MIC_{50} values of 13.0 and 12.0 μg/mL, respectively. The kaempferol glycosides 2 and 3 were less active with MIC_{50} values of 83.0 and 560.0 μg/mL, respectively.

The acetone and ethanol (95 %) extract of *Senna alata* showed high antimicrobial activity against nearly all test microorganisms: *Staphylococcus aureus*, *Staphylococcus aureus* coagulase positive, *Bacillus subtilis*, *Bacillus cereus, Bacillus stearothermophilus*, *Escherichia coli*, *Vibrio cholerae*, *Salmonella typhi*, *Shigella dysenteriae* and *Klebsiella pneumoniae* (Sakharkar and Patil 1998) The inhibitory effects of extracts were very close and identical in magnitude and were comparable with that of standard antibiotics used.

Cassia alata aqueous leaf extract exhibited antimicrobial activity against *Pseudomonas aeruginosa, Staphylococcus epidermidis, Staphylococcus aureus* and *Bacillus subtilis* (Saito et al. 2010). The extract also inhibited biofilm formation of *S. epidermidis* and *P. aeruginosa*. Six compounds from four bioactive fractions were identified as kaempferol, kaempferol-*O*-diglucoside, kaempferol-*O*-glucoside, quercetin-*O*-glucoside, rhein and danthron. In the *Salmonella*/microsome assay, the leaf extract showed weak mutagenicity (MI <3) only in strain TA98. *Cassia alata* leaf extract was found to have antibacterial activity in vitro against *Staphylococcus aureus* and *Bacillus subtilis* (Alalor et al. 2012).

Both flavonoid compounds 3,5,7,4′-tetrahydroxy flavone and 2,5,7,4′-tetrahydroxy isoflavone (100 μg/disc) from *C. alata* leaves exhibited antifungal activity against most of the fungi, namely, human pathogens (*Trichophyton schoenleinii, Trichophyton longifurus, Pseudallescheria boydii, Candida albicans, Aspergillus niger*), animal pathogens (*Microsporum canis, Trichophyton mentagrophytes*) and plant pathogens (*Fusarium oxysporum* var. *lycopersici, Fusarium solani var. lycopersici, Macrophomina phaseolina, Rhizoctonia solani*) except for the human pathogen *Epidermophyton floccosum* (Rahaman et al. 2008). Compound 2,5,7,4′-tetrahydroxyisoflavone was highly active against *Trichophyton longifurus* and *Pseudallescheria boydii*, while compound 3,5,7,4′-tetrahydroxy flavones were moderately active against *Trichophyton longifurus* and *Pseudallescheria boydii.* Both compounds were moderately active against *Microsporum canis* and *Trichophyton mentagrophytes.* Both compounds were active against the plant pathogen *Fusarium solani var. lycopersici* but showed no activity against the other three plant pathogens.

S. alata leaf extract containing 16.7 % w/w anthraquinone exhibited antifungal activity against

Trichophyton rubrum, T. mentagrophytes and *Microsporum gypseum* with MIC values of 15.6, 62.5 and 250 µg/mL, respectively (Sakunpak et al. 2009). Five extracts of *Senna alata* leaf powder, namely, anthraquinone aglycone extract, anthraquinone glycoside extract, anthraquinone aglycones from glycosidic fraction, crude ethanol extract and anthraquinone aglycone from crude ethanol extract, were tested against clinical strain of dermatophytes: *Trichophyton rubrum, T. mentagrophytes, Epidermophyton floccosum* and *Microsporum gypseum* (Wuthiudomlert et al. 2010). The anthraquinone aglycones from glycosidic fraction qualitatively and quantitatively gave the best antifungal activity compared to the other extracts.

In-Vitro Studies Other Plant Part Extracts

The methanol extracts of *C. alata* leaves, flowers, stem and root barks exhibited a broad spectrum of antibacterial activity (Khan et al. 2001). The activity was increased on fractionation (petrol, dichloromethane, ethyl acetate), the dichloromethane fraction of the flower extract being the most effective. No activity was shown against tested fungi.

The crude *S. alata* flower extracts, containing steroids, anthraquinone glycosides, volatile oils and tannins, exhibited a high MIC of 500 µg/mL against *Staphylococcus aureus, Streptococcus faecalis, Micrococcus luteus, Bacillus subtilis* and *Pseudomonas putida* but was generally inactive against *Escherichia coli, Proteus vulgaris, Pseudomonas aeruginosa, Serratia marcescens* and *Pseudomonas fluorescens* (MIC >1,000 µg/mL) (Adedayo et al. 2001). However, the partially purified flower extract was bacteriostatic at a low concentration of 100 µg/mL, with a minimum bactericidal concentration of 500 µg/mL, primarily against the Gram-positive organisms. At a concentration slightly above the MIC, the purified extract was nearly as potent as standard antibiotics, even against multiple antibiotic-resistant local isolates that were resistant to methicillin, penicillin and streptomycin. The partially purified extract of *Senna alata* flower exhibited appreciable antibacterial activity against *Staphylococcus aureus, Bacillus subtilis, Micrococcus luteus* and *Pseudomonas putida* (Adedayo et al. 2002). The mechanism of antibacterial activity of the *Senna alata* plant extract involved potassium ion and protein leakage. While maximum potassium leakage occurred within 30 minutes, protein efflux was at a peak after 75 minutes. Microscopic examination suggested that *Bacillus subtilis* cells were mummified while *Staphylococcus aureus* cells were lysed.

Extracts of water, methanol, chloroform and petroleum ether of *Senna alata* flowers also exhibited antimicrobial properties (Idu et al. 2007). Extracts tested at a final concentration of 500 µg/mL produced in vitro antimicrobial activities in assays against clinical isolates of *Staphylococcus aureus, Candida albicans, Escherichia coli, Proteus vulgaris, Pseudomonas aeruginosa* and *Bacillus subtilis*. Preliminary phytochemical analysis of the plant extracts showed the presence of phenols, tannins, anthraquinones, saponins and flavonoids. In another study, aqueous flower extract of *Senna alata* elicited 100 growth inhibition of aflatoxin-producing fungi *Aspergillus flavus* and *A. parasiticus* at 10 and 15 mg/mL concentrations (Abubacker et al. 2008). For the pathogenic fungi *Candida albicans* and *Microsporum audouinii* and plant pathogenic fungi *Fusarium oxysporum* and *Helminthosporium oryzae*, total inhibition occurred at 15 mg/mL concentration. The MIC values of the extract varied from 5.75 to 8.00 mg/mL for these fungi. *Senna alata* crude stem exhibited marked in vitro antifungal effects against *Microsporum canslaslomyces, Trichophyton verrucosum and Trichophyton mentagrophytes* at concentrations of 10.00 and 5.00 mg/mL and *Epidermophyton floccosum* at concentration of 10.00 mg/mL (Sule et al. 2011). Phytochemical analysis revealed the presence of important secondary metabolites (tannins, steroids, alkaloids, anthraquinones, terpenes, carbohydrates and saponins) in the plant.

An herbal soap formulated with ethanol extract of *Cassia alata* exhibited excellent antimicrobial effect against Gram-positive bacteria and opportunistic yeast in the in vitro studies as well as in the palm-washing studies on volunteers

(Esimone et al. 2008). At a reduction time of 5 minutes, the herbal soap recorded a significantly lower mean viable microbial count of 2.12×10^4 cfu/mL (a reduction in microbial load of 94.78 %) as against the 4.07×10^5 cfu/mL recorded before the application of the soap. The herbal soap formulated with *Cassia alata* may have potential as an excipient in the production of antiseptic soaps.

Clinical Studies

Oladele et al. (2010) conducted a clinical trial involving 33 prison inmates; 19 were treated with *S. alata* soap and 14 untreated control (placebo). The *S. alata* soap consisted of *S. alata* leaf powder incorporated with caustic soda and palm kernel oil to make 1.5 % w/w. *Tinea versicolor* and *Tinea corporis* were the major fungal infections found on the skin lesions prior to study commencement, while *Epidermophyton floccosum* and *Cryptococcus* sp. were microscopically observed to be responsible for the lesions. After 4 weeks, *S. alata* soap significantly cleared the lesions on 16 subjects (94.1 %), comprising (11) *T. versicolor* and (5) *T. corporis*. None of the controls was cleared significantly. The study clearly confirmed the folkloric claims on *S. alata* as an antimicrobial agent for treating skin infections.

Hypoglycaemic Activity

Senna alata leaf extract administered orally had no effect on glucose levels in normoglycaemic animals, but it reduced the blood sugar value in streptozotocin-induced hyperglycaemic animals (Palanichamy et al. 1988). The ethyl acetate leaf extract was found to be hypoglycaemic (Villaseñor et al. 2002). At a dosage of 5 mg/20 g mouse, it decreased the blood sugar level of mice by 58.3 %.

Antiplatelet Activity

Adenine was isolated as a platelet-aggregating inhibitor from the leaves of *Senna alata* (Moriyama et al. 2003a). The inhibitory effect of adenine was observed in the platelet aggregation induced by collagen (1.0 μg/mL as the final concentration), but little inhibitory effect was noted in the aggregation induced by ADP (adenosine 5′-diphosphate), whereas adenosine exhibited potent inhibitory effects on platelet aggregation induced both by collagen and ADP under the same experimental conditions.

Antiinflammatory Activity

Both the hexane and ethyl acetate leaf extracts exhibited antiinflammatory activity at a dosage of 5 mg/20 g mouse with a 65.5 and 68.2 % decrease in carrageenan-induced inflammation, respectively (Villaseñor et al. 2002). Antiinflammatory activities of heat-treated *Senna alata* leaf extract and kaempferol 3-*O*-gentiobioside (K3G) isolated from *C. alata*, a flavonoid glycoside, were demonstrated (Moriyama et al. 2003b). Strong inhibitory effects on concanavalin A-induced histamine release from rat peritoneal exudate cells both in the extracts of heat-treated and sun-dried *S. alata* leaves were observed. The heat-treated leaf extract was observed to exhibit stronger inhibitory effects than the effects of the sun-dried leaf extract at low concentrations in the studies of concanavalin A-induced histamine release, 5-lipoxygenase inhibition and also inhibition of cyclooxygenases (COX-1 and COX-2). In contrast, K3G showed weak inhibitory effects on concanavalin A-induced histamine release, 5-lipoxygenase and COX-1. No anti-hyaluronidase effect was detected in any of the materials tested.

Cassia alata hexane leaf extract significantly reduced knee circumference swelling in complete Freund's adjuvant (CFA) arthritic rats (Lewis and Levy 2011). Total and differential leukocyte counts in both blood and synovial fluid from *Cassia alata*-treated animals were significantly lower than in control animals. Protective effects against cartilage degradation on the femoral head of the knee joint were observed in *Cassia alata*-treated animals, as normal cartilage structure and chondrocyte arrangement were maintained. The results indicated that *Cassia alata* exerted

antiinflammatory activities that could potentially be exploited for antiarthritic therapies.

Hepatoprotective Activity

Crude extracts of flower petals in 0.5 % ethanol administered into the rats by intubation for 14 days prior to injection of 0.5 mL carbon tetrachloride (CCl_4)/kg elicited hepatoprotective activity (Wegwu et al. 2005). Serum aspartate aminotransferase and alanine aminotransferase levels decreased significantly in rats treated with the flower extract than in CCl_4-treated rats. In another study, pretreatment of *Cassia alata* leaf extract reduced the biochemical markers of hepatic injury-like elevated levels of serum glutamate pyruvate transaminase (SGPT), serum oxaloacetate transaminase (SGOT), alkaline phosphatase (ALP), total bilirubin and gamma glutamate transpeptidase (GGTP) induced by paracetamol in albino rats (Jayakar et al. 2009). Histopathological observations also revealed that pretreatment with the extract protected the animals from paracetamol-induced liver damage.

Anticancer Activity

Cassia alata was one of 29 Malaysian plants screened that exhibited in-vitro photocytotoxic activity by means of a cell viability test using a human leukaemia cell line HL60 (Ong et al. 2009). These 29 plants were able to reduce e in vitro cell viability by more than 50 % when exposed to 9.6 J/cm^2 of a broad spectrum light when tested at a concentration of 20 μg/mL.

Cassia alata leaf extract was cytotoxic in parental A549 lung cancer cells and caspase-9 negative but not caspase-3 and -8 negative A549 cells (Levy and Lewis 2011). The IC_{50} values were 143 and 145 μg/mL in parental and caspase-9 negative A549 cells, respectively. The flavonoid kaempferol was identified as a constituent of *Cassia alata* leaf extract and may be responsible for the effect. Rhein (4,5-dihydroxyanthraquinone-2-carboxylic acid), the primary anthraquinone in the roots of *Cassia alata,* inhibited vascular endothelial growth factor (VEGF(165))-stimulated human umbilical vein endothelial cell (HUVEC) tube formation, proliferation and migration under normoxic and hypoxic conditions (Fernand et al. 2011). Further, rhein suppressed in vitro angiogenesis by inhibiting the activation of phosphatidylinositol 3-kinase (PI3K), phosphorylated-AKT (p-AKT) and phosphorylated extracellular signal-regulated kinase (p-ERK) but showed no inhibitory effects on total AKT or ERK. Rhein dose-dependently inhibited the viability of MCF-7 and MDA-MB-435s breast cancer cells under normoxic or hypoxic conditions and inhibited cell cycle in both cell lines. Additionally, rhein inhibited heat shock protein 90alpha (Hsp90α) activity to induce degradation of Hsp90 client proteins including nuclear factor-kappa B (NF-κB), COX-2 and HER-2. Rhein also inhibited the expression of hypoxia-inducible factor-1 alpha (HIF-1α), vascular endothelial growth factor (VEGF(165)), epidermal growth factor (EGF) and the phosphorylation of inhibitor of NF-κB (I-κB) under normoxic or hypoxic conditions. The findings indicated rhein to be a promising antiangiogenic compound for breast cancer cell viability and growth.

Antimutagenic Activity

Aloe-emodin from *C. alata* leaves was found to have antimutagenic activity (Hofilena et al. 2000). Micronucleus test indicated a 71 % reduction in the number of micronucleated polychromatic erythrocytes induced by mitomycin C. The chloroform leaf extract was antimutagenic, at a dosage of 2 mg/20 g mouse, with a 65.8 % inhibition in the mutagenicity of tetracycline (Villaseñor et al. 2002).

Anthelmintic Activity

C. alata leaves are used as anthelmintic for dogs in Trinidad and Tobago (Lans et al. 2000). *C. alata* leaf extracts inhibited egg hatchability and killed infective larvae of *Haemonchus*

contortus in a concentration-dependent manner (Ademola and Eloff 2011). The best-fit values were 0.562, 0.243, 0.490, 0.314 and 0.119 mg/mL for the acetone extract, chloroform, hexane, butanol and 35 % water in methanol fractions, respectively, when tested against nematode eggs. The best-fit LC_{50} values were 0.191, 0.505, 1.444, 0.306 and 0.040 mg/mL for acetone extract, chloroform, hexane, butanol and 35 % water in methanol fractions, respectively, when tested against larvae. The 35 % water in methanol fraction was the most active against the larvae and eggs of *H. contortus* demonstrating the lowest LC_{50} values.

Cestode parasites *Hymenolepis diminuta* treated with *C. alata* leaf extract showed a decrease in motility with an increase in concentrations and complete immobilization took lesser time compared to control (Kundu et al. 2012). Ultrastructural micrographs of paralyzed worms revealed swelling of the tegument and blebbing on the tegumental surface throughout the body accompanied with destruction of microtriches and changes such as shrinkage in the scolex region. Depletion of parenchyma cells and destruction in the connective tissues along with sparsely cytoplasmic cytons were also observed, and these observations were similar with worms treated with a known drug praziquantel.

Antiallergic Activity

The hydroalcoholic extract of *Cassia alata* leaves significantly inhibited mast cell degranulation at 200 mg/kg dose in rats (Singh et al. 2012). Both its chemical constituents rhein and kaempferol also showed potent (>76 %) inhibition of mast cell degranulation at 5 mg/kg. The extract and rhein inhibited lipoxygenase enzyme with IC_{50} values of 90.2 and 3.9 μg/mL, respectively, whereas kaempferol was inactive. The results suggested that *Cassia alata* exhibited antiallergic activity through mast cell stabilization and lipoxygenase have inhibition and may have potential as alternative treatment for allergic diseases.

Antimalarial Activity

Saye, a combination remedy prepared from N'Dribala, *Cochlospermum planchonii* root, *Cassia alata* leaf, *Phyllanthus amarus* whole plant and *Azadirachta indica* fruits, is a plant remedy commonly used by traditional healers for the treatment of malaria in Burkina Faso (Traoré et al. 2008; Yerbanga et al. 2012). 'Saye' showed a significant effect against *Plasmodium falciparum* and *Plasmodium berghei* parasites grown in vivo (IC_{50} = 80.11 μg/mL; ED_{50}) = 112.78 mg/kg). In vitro the activity was lower. Aqueous extracts of Saye, N'Dribala and *Azadirachta indica* preparations orally administered to mice elicited prophylactic activity and reduced *Plasmodium berghei* parasitaemia in treated mice, with respect to controls, by 52.0, 45.5 and 45.0 %, respectively (Yerbanga et al. 2012). No evidence of transmission blocking effects was detected with any of the tested remedies.

Choleretic Activity

Studies in rats showed that choleretic activity of *Senna alata* at 15 mg/kg was better than 15 mg/kg of hydroxycyclohexenyl-butyrate (Hebecol ND), a synthetic choleretic, but at elevated doses, the plant extract inhibited bile secretion (Assane et al. 1993).

Analgesic Activity

The extract of the leaves of *Senna alata* and kaempferol 3-*O*-sophoroside exhibited analgesic activity (Palanichamy and Nagarajan 1990a). Maximum analgesic activity of the extract was apparent 120 minutes after intraperitoneal injection using the tail clip, tail-flick, tail immersion and acetic acid-induced writhing methods. Fifty milligrams of kaempferol 3-*O*-sophoroside appeared equivalent to 100 mg of the extract. Cassiaindoline, a dimeric indole alkaloid isolated from *Cassia alata* leaves, exhibited analgesic activity at a dosage of 125.0 mg/kg mouse and decreased the number of writhings induced by acetic acid by 49.4 % (Villaseñor and Sanchez

2009). It also showed a 57.1 % antiinflammatory activity at a dosage of 75 mg/kg mouse.

Acaricidal Activity

The ethanol leaf extract of *C. alata* produced a concentration-dependant increase in the adult tick *Rhipicephalus (Boophilus) annulatus* mortality (Ravindran et al. 2012). The highest mortality (45.8 %) and inhibition of fecundity (10.9 %) were observed at the highest concentration tested (100 mg/mL). The leaf extract did not affect egg hatchability.

Hypolipidaemic/Anti-obesity Activity

Studies demonstrated that *Cassia fistula* and *S. alata* methanol leaf extracts could significantly lower body weight of diet-induced lipidaemic mice (Chichioco-Hernandez and Leonido 2011). Furthermore, parametrial fat weight of mice was also decreased in a dose-dependent manner, thus confirming the weight-lowering potential of both plants.

Immunological Activity

Among the eight pollen types sample extract tested, *Ricinus communis* was found to contain the highest amount of soluble protein, free amino acid and total carbohydrate, per gram of dry weight followed by *Imperata cylindrica* and *Cassia alata* (Sharma et al. 2009). Maximum numbers of protein polypeptide bands were detected in the sample extract of *Cassia alata* followed by *Acacia auriculiformis, Imperata cylindrica* and *Cocos nucifera*. IgE binding protein fractions were maximum in *Cassia alata* and minimum in *Trewia nudiflora*.

Abortifacient Activity

Senna alata leaf extract (250, 500, 100 mg/kg bw) administered to pregnant Wistar rats significantly reduced the number of live foetus, weight and survival ratio of the foetus, numbers of implantations and corpora lutea, implantation index, progesterone, prolactin, estradiol, follicle stimulating and luteinizing hormones whereas the number of dead foetus, number and percentage of rats that aborted, percentage vaginal opening, resorption index and pre- and post-implantation losses increased significantly (Yakubu et al. 2010). The abortifacient effects were most pronounced at 500 and 1,000 mg/kg body weight of the extract and were similar to the animals treated with 2.85 mg/kg body weight of mifepristone, the reference drug. All cases of abortion were accompanied with vaginal bleeding. Although, the final weight of the rats increased significantly, the feed and water intake were not significantly altered in all the treatment groups. The weight of the uterus, uterine-body weight ratio, length of the right uterus horn and uterine cholesterol decreased significantly in all the treatment groups. The uterine alkaline phosphatase activity and glucose concentration increased in only the extract-treated animals, whereas mifepristone decreased the uterine alkaline phosphatase activity and glucose content of the animals. Hormonal influence, changes in implantation site, estrogenicity and uterogenicity were suggested as possible mechanism of abortifacient activity of aqueous extract of *S. alata* leaves. Phytochemical screening of the leaf extract showed positive results for saponins (1.22 %), flavonoids (1.06 %), cardiac glycosides (0.20 %), cardenolides and dienolides (0.18 %), phenolics (0.44 %) and alkaloids (0.52 %). Overall, the extract may be used as an abortifacient especially at 500 and 1,000 mg/kg body weight and therefore not safe for consumption as oral remedy during pregnancy. The results provided evidence to the age-long claim of *S. alata* leaves in 'washing the uterus'. In subsequent studies, they found that administration of the crude alkaloids from *Senna alata* leaves elicited decreases in the activities of alkaline phosphatase (ALP), gamma glutamyl transferase (GGT), aspartate (AST) and alanine transaminases in the liver and kidney of the animals by the alkaloids and were accompanied by corresponding increases in the serum enzymes (Yakubu and

Musa 2012). The alkaloids reduced liver- and kidney-body weight ratios, serum globulin, urea, uric acid and phosphate ions, while the serum concentrations of albumin, bilirubin, creatinine, potassium ions, AST/ALT ratio and blood urea nitrogen to creatinine ratio increased. They concluded that the alkaloid at doses of 250–1,000 mg/kg body weight produced permeability changes in the plasma membrane of the organs and adversely affected the normal secretory, synthetic and excretory functions of these organs.

Miscellaneous Pharmacological Activities

Pharmacological studies showed that the hexane, chloroform and ethyl acetate leaf extracts caused an immediate decrease in motor activity, enophthalmos, hyperaemia, micturition and diarrhoea (Villaseñor et al. 2002). At a dosage of 150 mg/20 g mouse, the ethyl acetate leaf extract caused paralysis, screen grip loss and enophthalmos accompanied by drooping and closure of the eyelids.

Toxicity Studies

The aqueous leaf extract of *Senna alata* induced an adverse effect on haematological indices in albino rats (Sodipo et al. 1998). Increasing doses (10, 50, 100 and 150 mg/kg bw) of the extract administered orally to different groups of rats daily for a period of 14 days produced significant dose-dependent decreases in the levels of haemoglobin (Hb) and erythrocyte count. However, mean corpuscular haemoglobin (MCH) did not show any change. Clinical symptoms of loss of appetite, emaciation and loss of weight in the treated rats indicated toxicity. The observed symptoms of toxicity were attributed to the saponin content of the plant extract. Contradictory results were found in another study. Acute and subacute toxicity study of aqueous ethanol leaf extracts of *S. alata* in Swiss mice and Wistar albino rats found no observable toxicity symptoms or animal death during or at the end of the experimental period (Pieme et al. 2006). The results indicated that the medium lethal dose (LD_{50}) was about 18.50 g/kg of body weight. Rats treated with various doses of hydroethanolic leaf extract had a progressive weight gained, and this increase in weight was significantly different from that of the control. The effect of *S. alata* appeared to have a protective effect, after 26 days dosage of hydroalcoholic extract of *S. alata*; there were no significant changes in alanine aminotransferase (ALT), aspartate aminotransferase (AST) and alkaline phosphatase (APL) activities in the serum of both sexes and the 20 % homogenate liver samples. The extract had a protective effect on hepatocytes and appeared to improve liver architecture. The study presented strong evidence of the nontoxic effect of the hydroethanolic leaf extract of *S. alata*.

The TRAMIL research group in the Caribbean validated the recommendation of the use of the leaves to cure eczema and 'ringworm', by rubbing on the skin or using an infusion of 15–20 leaflets per litre of water to wash affected areas of the skin (Robineau 1995). TRAMIL researchers have shown that following peritoneal dosing in rats at 2 g/kg, the ethanol extract from the leaf showed no significant toxicity. In all cases extemporaneous preparation should not be kept for more than 1 day. They also found the bark to be rich in tannins and seeds to be a good source of gums for use in ointments and herbal soaps. They found that sennosides are contraindicated in cases of obstruction, acute intestinal inflammation, ulcerative colitis, appendicitis and abdominal pain of unknown origin and for children under the age of 12. With chronic use, hypokalaemia may occur. During the first trimester of pregnancy, senna pod preparations should be used only if a therapeutic effect cannot be obtained with a change in diet or through the use of bulk laxatives.

Traditional Medicinal Uses

The leaves, flowers, fruits, seeds and root bark are used for medicinal purposes in folkloric medicine. In the Indian system of medicines, namely,

Ayurveda, Siddha and Unani, decoctions of the leaves, flowers, bark and wood are used in skin diseases like eczema, pruritus, itching and constipation (Kirtikar and Basu 1975). In the Philippines, the leaves are employed for ringworm and other skin diseases, like itches (BPI 2005). According to Philippines Bureau of Plant Industry (BPI 2005), the leaves are official in the Pharmacopoeia of India. The Pharmacopoeia of India mentions an effective ointment made of the leaves. In India, the plant is regarded as a cure for poisonous bites and for venereal eruptions. The sap of the leaves is an efficient antiherpetic. The leaves are taken internally as an aperient. A decoction of the leaves and flowers is used as an expectorant in bronchitis, asthma and dyspnoea; as an astringent; and also as a mouthwash in stomatitis. A strong decoction of the leaves and flowers is a good wash for eczema. A strong decoction of the leaves is abortifacient. The seeds are used as a vermifuge. A decoction of the roots is used against tympanitis. The wood is used as an alternative. Decoctions of the wood are used to treat liver problems, urticaria, rhinitis and loss of appetite caused by gastrointestinal problems. In the Antilles, Reunion and Indo-China, it is reported that the plant is reputed as hydragogue, sudorific and diuretic. Decoctions of the leaves, flowers, bark and wood are used in skin diseases such as eczema, pruritus and itching and in constipation (Palanichamy and Nagarajan 1990b). The flowers are also used in bronchitis and asthma. The leaves are traditionally used for the treatment of skin diseases such as ringworm and pityriasis versicolor (Husain et al. 2005). An infusion of the roots is used to treat rheumatism and also used as a strong laxative (Reezal et al. 2002). The seeds and leaves are used as fungicide, vermifuge and for skin problems in Mangalore, India (Shiddamallayya et al. 2010).

For laxative purposes usually a decoction of the leaves is drunk, and less often the flowers, roots or the stem are used. Skin problems treated with *Senna alata* include ringworm, favus and other mycoses, impetigo, syphilis sores, psoriasis, herpes, chronic lichen planus, scabies, rash and itching (Bosch 2007). Other ailments treated in tropical Africa with *Senna alata* include stomach pain during pregnancy, dysentery, haemorrhoids, blood in the urine (schistosomiasis, gonorrhoea), convulsions, heart failure, oedema, jaundice, headache, hernia and one-sided weakness or paralysis. A strong decoction made of dried leaves is used as an abortifacient. In veterinary medicine too, a range of skin problems in livestock is treated with leaf decoctions. Such decoctions are also used against external parasites such as mites and ticks. *Cassia alata* extract is used in traditional medicine practice for the treatment of some external skin infections in Nigeria, the juice expressed from the young leaves being applied topically to the skin (Benjamin and Lamikanra 1981; Alalor et al. 2012). *Senna alata* is widely used in ethnomedicine practice for the treatment of hypertension, sickle cell anaemia and diabetes in southwestern Nigeria (Okpuzor et al. 2009). Saye, a combination remedy prepared from *Cochlospermum planchonii, Cassia alata* and *Phyllanthus amarus*; N'Dribala, a *Cochlospermum planchonii* root decoction; and a fruit preparation of *Azadirachta indica* are plant remedies of the folk medicine in Burkina Faso and are commonly used by traditional healers for the treatment of malaria (Yerbanga et al. 2012) Leaves are commonly employed for constipation in Nigeria and other African countries. Leaves are used as tea for intestinal worm infestation and a leaf decoction drunk for gonorrhoea in Ghana (Irvine 1961) and in Senegal (Kerharo and Adam 1974), while a root decoction is drunk for gonorrhoea in Congo (Bouquet 1969). In Togo and Gabo, pounded leaves are used directly on the skin or mixed with palm oil for dermatitis (Adjanohoun et al. 1986; Akendengue and Louis 1994).

In Thailand, *S. alata* has been approved as a laxative drug in the Thai Herbal Pharmacopoeia 1998 and the Thai National List of Essential Drug 1999. In Thailand, aqueous extracts of the leaves of *Cassia alata* and Lawsonia alba are used in native medicine for ringworm infections (Pankajalakshmi et al. 1993). In Thailand, the leaves are used as laxative for treating constipation; fresh leaves are pounded with water, garlic and red lime and smear on ringworm-infected skin; shoots and leaves are boiled and used and

the preparation used for cleaning abscesses and wounds as antiinflammatory (Monkheang et al. 2011). In Vietnam, *C. alata* is employed to treat constipation, oedema, hepatalgia and jaundice (Le and Nguyen 1999). It is used externally for ringworm, tinea imbricata (tokelau) and herpes circinatus. In Peninsular Malaysia, the juice of the leaves is used or sometimes mixed with lime for ringworm infestations (Burkill 1966). Roots are also used externally for ringworm and also prescribed for constipation. The pods and seeds are eaten as vermifuge. A decoction of the cooked leaves or flowers was taken as purgative in Indonesia. In Sarawak, pounded fresh leaves are rubbed on ringworm infestations and for dhobi itch, and a drink is prepared from young leaves and roots for diarrhoea (Chai 2006).

Other Uses

The tree is planted as shade tree, for soil covering, as protection against driver ants and as medicinal plant. It is often grown as an ornamental, and in the Pacific Islands, it is sometimes planted to improve taro patches. The seeds are a source of gum.

The leaf extract can be used in veterinary medicine. The use of ointments made with ethanol leaf extracts of leaves of *Senna alata*, as topical treatments on chronic crusty or acute lesions of bovine dermatophilosis, induced healing of the disease in infected animals treated without recurrence for more than 3 years (Ali-Emmanuel et al. 2003).

Comments

S. alata has been introduced and naturalized in many countries, and in some countries, it has become a weed. For instance, *Senna alata* is regarded as a significant environmental weed in the Northern Territory and as an environmental weed in Queensland and Western Australia. It is also regarded as a potential environmental weed or 'sleeper weed' in northern New South Wales.

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