Clitoria ternatea

Scientific Name

***Clitoria ternatea* L.**

Synonyms

Clitoria albiflora Mattei, *Clitoria bracteata* Poir., *Clitoria coelestris* Siebert & Voss, *Clitoria parviflora* Raf., *Clitoria philippensis* Perr., *Clitoria pilosula* Benth., *Clitoria ternatea* var. *pilosula* (Benth.) Baker, *Clitoria ternatensium* Crantz, *Lathyrus spectabilis* Forssk., *Nauchea ternatea* (L.) Descourt., *Ternatea ternatea* (L.) Kuntze, *Ternatea vulgaris* Kunth, *Ternatea vulgaris* Kuntze

Family

Fabaceae, also in Papilionaceae

Common/English Names

Asian Pigeonwing, Blue Butterfly Pea, Blue Pea, Butterfly Pea, Butterfly Pea Flower, Cordofan-Pea, Cocos

Vernacular Names

Arabic: Mazariyune-Hindi, Bazrulmazariyune-Hindi (Seeds), Bazrulmazariyunehindi, Buzrula, Mazariyunehindi

Chinese: Die Dou
Brazil: Cunha, Clitória
French: Honte, Pois Tonelle
German: Blaue Klitorie
India: Aparajita (Assamese), Aparajita (Bengali), Aparajit, Aparajita, Aprajita, Kajina, Kalina, Kalizer, Kava-Thenthi, Kavathenthi, Khagin, Kowa, Shobanjan, Wowatheti, Aparjit, Khagtu, Gokarni, Koyalri (Hindi), Girikarniballi, Kantisoppu, Karnikay, Sankhapushpaballi, Shankapushpa, Dhintina, Girikarnike, Satuga, Shankhapushpi, Giri Karnike, Girikarnikaballi, Sanka, Shanka, Shankhapushpa (Kannada), Aral, Kaka-Valli, Kakkanamkoti, Malayamukki, Samkhupuspam, Sankhankuppi, Sankhapushpam, Sankhupuspam, Schanga-Cuspi, Shankapuspam, Sankapushpam, Shankhankuppi, Shankhapushpam, Shlongokuspi, Shunkoopushpa (Malayalam), Aparajita (Manipuri), Gokurna-Mula, Gokaran, Gokarni, Gokurna, Kajli, Sholonga, Gokarana, Gokarni Suphali, Kajili, Supli (Marathi), Vryshapadi (Oriya), Ajita, Andrikarni, Aparajit, Aparajita, Aparaka, Aprajita, Ashphota, Ashvakshurardikarni, Asphota, Bhadra, Bhumilagna, Garani, Gardabhi, Gavadini, Gavakshi, Girikanya, Girikarnika, Girishalini, Gokarna, Gokarna-Mul, Gokarnika, Katabhi, Khurne, Kinihi, Nagaparyayakarni, Neela-Gheriekurnee, Nilaghiria, Nilagirikarni, Romavalli, Sankhapushpi, Sankhapuspi, Sankhini, Shankhapushpi, Shveta, Shvetavarata, Sinhapushpi, Sitapushpa, Supushpi, Suputri, Sveta, Vishnu-Kranta, Vishnukantri,

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Vishnukranta, Vishnukranti (Sanskrit), Girikanni, Kakkanam, Kakkattan, Kannikkodi, Kannikkoti, Karisanni, Karkkurattai, Karudakkovai, Karudattondai, Karuvilai, Kakkanan-Kodi, Kakkananko di-Virai, Kakkankoti, Vellai Kakkattan, Kakkana Ver, Vellai-K-Kakkanam, Canku Puspam, Kakkanam Koti, Kakkanatti, Karuppu-K-Kakkanam-Koti, Kakkanan, Kakkattan-Kodi, Kavachhi, Kodi-Kakkanam, Kuruvilai, Karkakartan Vayr, Kaakkanam, Sankapushpam, Karkakartum, Karkokartun, Venkakkattan, Ancanala, Ancanala, Aral, Atirikarni, Ayittiram, Cankuputpakkoti, Cankuputpam, Kakkam, Kakkana, Kakkanankovvai, Kakkarattan, Kakkorattai, Kakkurattai, Kakkurattai, Karkurattai, Karkurattaikkoti, Karttakakkattan, Karunkakkanam, Karunkakkattan, Karunkakkattankoti, Karunkananko ti, Karunkattan, Karunkattankoti, Karutakanatti, Karutakanattikkoti, Karutakkovai, Karutakkovvai, Karutattontai, Karuttakakkanam, Karuttakakkanan, Karuttappu, Karuttontai, Karuvilaikkakkanam, Karuvilam, Kauri 2, Kaurikkoti, Kavetanam, Kicinikkoti, Kiruttini, Kiruttinikkoti, Kokanni, Kokarni, Kollankovai, Kurattai, Kurokanatti, Kurokanattikkoti, Kurottai, Makanatti, Makanattikkoti, Mayil, Tarukanni, Minni, Muntakkini, Muntakkinikkoti, Nakanatti, Nakanattikkoti, Nilakirikaranai, Nilakkakkanam, Nilakkakkattan, Viranu, Uromavalli, Uyavaikkoti, Vainakanatti, Vainakanattikkoti, Vullay Kakartan Vayr (Tamil), Dintana, Dintena, Gilarnika, Nallavusinitige, Sankapushpam, Sanku-Pushpamu, Gantina, Nall Vusiri, Nallaghentana, Nalladintenatige, Nallavusiniige, Nelladintena, Nullaghentana, Tantiri, Telladintena, Adavichikkudu, Nalla Dintena, Shanku Poolu, Shankupushpamu, Thelladintena (Telugu), Mazeriyunihindi, Mazriyun (Urdu)

Indonesia: Kembang Telang, Mentelang (Java), Kembang Telang (Sundanese)

Japanese: Choumame

Malaysia: Bunga Biru, Kacang Telang, Kacang Puki, Kelang

Persian: Darakhte-Bikhehayat, Tukhme-Bikhehayat (Seeds), Darakhtebikhehayat, Tukhmebikhehayat

Philippines: Giting-Princesa (Bikol), Balog-Balog (Cebu Bisaya), Kalompagi, Samsamping (Iloko), Samsampin (Pangasinan), Kolokanting, Pukingan, Puki-Reyna (Tagalog)

Portuguese: Clitoria-Azul

Spanish: Azulejo, Conchitis, Papito, Zapatico De La Reina, Zapotillo, Conchita Azul, Campanilla, Bandera, Choroque, Lupita, Pito De Parra, Bejuco De Conchitas

Sri Lanka: Katarodu-Wel

Thai: Ang Chan, Daeng Chan, Uegng Chan

Tibetan: A Sa Khu Ra, A-Pa-Ra-Dzi-Ta, Ge Ri Ka Rni Ka Dkar Po, Sra Na Ma Geri Ka Rni Ka, Sve

Vietnamese: Dau Biec

Origin/Distribution

The true origin of the species is obscured by extensive naturalization; it is probable that it originated from South America. It is now distributed pantropically.

Agroecology

The plant grows wild in wasteland, thickets or disturbed areas and on most soil types at low and medium altitudes. It is adaptable to a wide range of soil types from sandy soils to heavy clays including calcareous soils and with a wide pH range from 4.5 to 8.9. It is moderately tolerant to salinity. It thrives in areas with 700–1,500 mm mean annual rainfall but will survive in areas with only 400 mm and dry periods. It tolerates short-term flooding but not prolonged waterlogging. It is tolerant to light frost and will tolerate low temperatures down to 15 °C and high temperature to 35 °C. It prefers full sun but will tolerate partial shading and is used as cover crops in rubber and coconut plantations in the tropics.

Edible Plant Parts and Uses

The flower, fruit and leaves are edible (Burkill 1966; Tanaka 1976; Facciola 1990; Kaisoon et al. 2001; Wetwitayaklung et al. 2008). In Southeast Asia, the flowers are used for colouring rice in puddings and cakes and leaves used for colouring food stuff green. In Thailand, the leaves are used in salad and for frying. Young pods are edible and eaten as vegetable.

Botany

A short-lived, fast-growing climbing perennial, leguminous herb. Stem thin, glabrous or sparsely pubescent, climbing or twining, 2–5 m long. Leaves imparipinnate, arranged in 2–3 pairs, bright green, petiolate (1.5–3 cm long), leaflets elliptic-ovate to elliptic lanceolate, 1.5–5 cm by 0.4–3 cm wide, acute or notched apex and rounded base, margin entire (Plates 1 and 2). Inflorescence axillary bearing several flowers on 4–9 mm long pedicels and with ovate, persistent bracteoles. Flowers—clitoris-like flower shape with large obovate, reflexed, funnel-shaped standard, 5 cm long, light to deep blue, mauve or white and yellow at the inner base (Plates 1 and 2). Pods flattish, linear-oblong, 6–12 cm long by 0.6–1.2 cm wide, beaked with 4–8 flat, rounded, olive-brown to black seeds.

Plate 1 Blue flowers and imparipinnate leaves

Nutritive/Medicinal Properties

Phytochemicals in Flowers

The per cent yield and the amount of total polyphenols in g/100 g calculated as gallic acid on dried flowers and crude methanol extracts basis of *C. ternatea* extract were reported as 10.23 %, 0.55 g dried flower, 2.29 g crude extract (Wetwitayaklung et al. 2008). Among 24 edible flowers tested, the lowest TEAC value was obtained from the extract of *Clitoria ternatea* (TEAC = 0.01, IC_{50} = 1.08 mg/50 µl) and *Sesbania grandiflora* (TEAC = 0.01, IC_{50} = 1.32 mg/50 µl) (Wetwitayaklung et al. 2008).

Clitoria ternatea flowers were found to contain little calcium (1.9 mg/100 g) compared to common vegetables as determined *via* inductively coupled

Plate 2 Close view of flower

plasma atomic emission spectroscopy (Chin 1992). The soluble phenol acids (per g dry weight) identified in *Clitoria ternatea* flower extract were as follows: gallic acid 33.2 µg, protocatechuic acid 1.8 µg, caffeic acid 10.03 µg, *p*-coumaric acid 11.6 µg, ferulic acid 34.8 µg, sinapic acid 152.8 µg and total phenolic acid 243.5 µg (Kaisoon et al. 2001). The flowers contained 261.5 µg total bound phenolic acid made up of ferulic acid 108 µg and sinapic acid 153.5 µg. The flowers contained 115.5 µg total soluble flavonoid made up of rutin 38.1 µg, myricetin 4.85 µg, quercetin 68.9 µg and kaempferol 3.65 µg; and bound flavonoid 141.4 µg made up of quercetin 113.2 µg, quercetin 11.1 µg and apigenin 17.2 µg. The DPPH radical scavenging activity (% inhibition) of soluble and bound phenolic fraction of the flower was 32.7 and 17.59 %, respectively. The reducing potential of the soluble and bound phenolic fraction of the flower as evaluated by FRAP (ferric-reducing antioxidant power) assay mmol $FeSO_4$/100 g dry weight was 16.37 mmol and 7.7 mmol, respectively. Bound phenolics exhibited lower antioxidant activity than soluble ones.

The anthocyanins, malvidin-3-β-glycoside and deiphinidin-3-β-glycoside were isolated from *C. ternatea* flowers (Srivastava and Pandey 1977). Saito et al. (1985) found that stability of the anthocyanins increased with the degree of acylation with cinnamic and malonic acids as well as with the degree of substitution of hydrogens on the B ring in *C. ternatea.* Other anthocyanins reported were ternatins, polyacetylated delphinidin 3,3′,5-triglucosides that conferred blue colour to the petals *C. ternatea*. Six new stable anthocyanins, named ternatin A1, A2, B1, B2, D1 and D2, were isolated from the blue flowers of *Clitoria ternatea* (Terahara et al. 1989a). The structures of two common components prepared from alkaline deacylation of ternatin mixture yielded two common components: *E*-4-*p*-coumaryl β-D-glucoside (1) and delphinidin 3,3′,5′-tri-β-D-glucoside (2). The structure of ternatin Al was elucidated as 3-*O*-(6-*O*-malonyl-β-D-glucopyranosyl)-3′,5′-di-*O*-(6-*O*-(*E*-4-*O*-(6-*O*-(*E*-4-*O*-β-D-glucopyranosyl-p-coumaryl)-β-D-glucopyranosyl)-*p*-coumaryl)-β-D-glucopyranosyl)-delphinidin (Terahara et al. 1990c). Ternatin D1, an acylated anthocyanin, was elucidated as 3-*O*-(6-*O*-malonyl-β-D-glucopyranosyl)-3′,5′-di-*O*-(6-*O*-(*E*-4-*O*-(6-*O*-E-*p*-coumaryl-β-D-glucopyranosyl)-*p*-coumaryl)-β-D-glucopyranosyl)delphinidin (Terahara et al. 1989b); ternatin A1, the largest ternatin (Terahara et al. 1990b); ternatin B1, a pentaacylated anthocyanin elucidated as 3-*O*-(6-*O*-malonyl-β-D-glucopyranosyl)-3′-*O*-ß-D-glucopyranosyl-*E*-*p*-coumaryl-ß-D-glucopyranosyl-*E*-*p*-coumaryl-ß-D-glucopyranosyl-ß-D-glucopyranosyl-5′-*O*-*E*-*p*-coumaryl-ß-D-glucopyranosyl-*E*-*p*-coumaryl-ß-D-glucopyranosyl ß-D-glucopyranosyl-delphinidin (Kondo et al. 1990). Two acyl moieties, prepared by alkaline deacylation or H2O2 oxidation of ternatin mixture from *C. ternatea* flowers, were identified as *E*-4-*O*-β-D-glucopyranosyl-*p*-coumaric acid and 6-*O*-malonyl-D-glucopyranose and six ternatins A1, A2, B1, B2, D1 from the flowers were partly characterized as highly acylated delphinidin derivatives (Terahara et al. 1990a). Deacylternatin was determined as delphinidin 3,3′,5′-tri-*O*-b-d-glucopyranoside (Terahara et al. 1990b). The structure of ternatin A2 was identified as 3-*O*-(6-*O*-malonyl-β-D-glucopyranosyl)-3′-*O*-(6-*O*-(*E-4-O*-(6-*O*-(*E*-4-*O*-β-D-glucopyranosyl-*p*-coumaryl)-β-D-glucopyraonsyl)-*p*-coumaryl)-β-D-glucopyranosyl)-5′-*O*-(6-*O*-(*E*-4-*O*-β-D-glucopyranosyl-*p*-coumaryl)-β-D-glucopyranosyl)delphinidin (Terahara et al. 1990d). Anthocyanins ternatins A1, A2, B1, B2, D1 and D2 were isolated from double blue flowers (Honda et al. 1991). Five anthocyanins, namely, ternatins A3, B4, B3, B2 and D2, were isolated from *Clitoria ternatea* flowers (Terahara et al. 1996). Eight new anthocyanins 1–8 (ternatins C1, C2, C3, C4, C5 and D3 and preternatins A3 and C4) were isolated from *Clitoria ternatea* flowers (Terahara et al. 1998). The structures of 1–6 were postulated as delphinidin 3-malonylglucoside having 3′-GCGC-5′-G, 3′-GCGCG-5′-G, 3′-GC-5′-G, 3′-GCG-5′-G, 3′-G-5′-G and 3′-GC-5′-GC, and compounds 7 and 8 as delphinidin 3-glucoside having 3′-GCG-5′-GCG and 3′-GCG-5′-G as side chains, respectively, in which Dp=delphinidin, G=D-glucose and C=*p*-coumaric acid.

The following flavonol glycosides were isolated from the petals of *Clitoria ternatea* cv Double Blue: kaempferol 3-*O*-(2″-*O*-*α*-rhamnosyl-6″-*O*-malonyl)-β-glucoside; quercetin 3-*O*-(2″-*O*-*α*-rhamnosyl-6″-*O*-malonyl)-β-glucoside; myricetin 3-*O*-(2″,6″-di-*O*-α-rhamnosyl)-β-glucoside; kaempferol 3-(2(G)- rhamnosylrutinoside 3-(2(G)-rhamnosylrutinoside; quercetin 3-(2(G)- rhamnosylrutinoside; kaempferol 3-neohesperidoside;quercetin3-neohesperidoside; myricetin 3-neohesperidoside; kaempferol 3-rutinoside; quercetin 3-rutinoside; myricetin 3-rutinoside; kaempferol 3-glucoside; quercetin 3-glucoside; myricetin 3-glucoside; and myricetin 3-*O*-(2″-*O*-α-rhamnosyl-6″-*O*-malonyl)-β-glucoside (Kazuma et al. 2003b). Delphinidin 3-*O*-(2″-*O*-*α*-rhamnosyl-6″-*O*-malonyl)-β-glucoside; 2, delphinidin 3-*O*-(6″-*O*-malonyl)-β-glucoside; 3, delphinidin 3-neohesperidoside; and 4, delphinidin 3-*O*-β-glucoside were isolated from the petals of a mauve line (WM) (Kazuma et al. 2003a). Ternatins, a group of 15 (poly)acylated delphinidin glucosides, were identified in all the blue petal lines (WB, BM-1, 'Double Blue' and 'Albiflora'), WM accumulated delphinidin 3-*O*-(6″-*O*-malonyl)-β-glucoside instead. The white petal line (WW) did not contain anthocyanins. The change in flower colour from blue to mauve was not due to a change in the structure of an anthocyanidin from delphinidin but to the lack of (polyacylated) glucosyl group substitutions at both the 3′- and 5′-positions of ternatins implying glucosylation at the 3′- and 5′-positions of anthocyanin to be a critical step in producing blue petals in *C. ternatea*. Among the ternatins, blue anthocyanins found in the petals of *Clitoria ternatea*, ternatin C5 (delphinidin 3-*O*-(6″-*O*-malonyl)-β-glucoside-3′,5′-di-*O*-β-glucoside) was found to have the structure common to all the ternatins, i.e. characterized by its glucosylation pattern: a 3,3′,5′-triglucosylated anthocyanidin (Kazuma et al. 2004). An intermediate in the biosynthesis of ternatin C5 in the blue petals, delphinidin 3-*O*-(6″-*O*-malonyl)-β-glucoside-3′-*O*-β-glucoside, was also identified. In *C. ternatea*, a blue flower cultivars (DB) and mauve flower variety (WM) accumulated polyacylated anthocyanins (ternatins) and delphinidin 3-*O*-(6″-*O*-malonyl)-β-glucoside (Kogawa et al. 2007*b*). Further, WM accumulated minor delphinidin glycosides—3-*O*-β-glucoside, 3-*O*-(2″-*O*-*α*-rhamnosyl)-β-glucoside and 3-*O*-(2″-*O*-*α*-rhamnosyl-6″-*O*-malonyl)-β-glucoside of delphinidin. These glycosidic patterns for minor anthocyanins in WM were also found among the minor flavonol glycosides in all the varieties including a white flower variety (WW) although the major flavonol glycosides were 3-*O*-(2″-*O*-*α*-rhamnosyl)-β-glucoside,3-*O*-(6″-*O*-*α*-rhamnosyl)-β-glucoside, 3-*O*-(2″,6″-di-*O*-α-rhamnosyl)-β-glucoside of kaempferol, quercetin and myricetin. A UDP-glucose: anthocyanin 3′,5′-*O*-glucosyltransferase (UA3′5′GT) was purified from the petals of *Clitoria ternatea* which accumulated polyacylated anthocyanins named ternatins (Kogawa et al. 2007a). In the biosynthesis of ternatins, delphinidin 3-*O*-(6″-*O*-malonyl)-β-glucoside (1) was first converted to delphinidin 3-*O*-(6″-*O*-malonyl)-β-glucoside-3′-*O*-β-glucoside (2). Then 2 was converted to ternatin C5 (3), which was delphinidin 3-*O*-(6″-*O*-malonyl)-β-glucoside-3′,5′-di-*O*-β-glucoside. UA3′5′GT was responsible for these two steps by transferring two glucosyl groups in a stepwise manner. Its substrate specificity revealed the regioselectivity to the anthocyanin's 3′- or 5′-OH groups. The presence of alkaloids, flavonoids, saponins, tannins, carbohydrates and proteins were reported in the methanol extract of the flowers (Uma et al. 2009).

Phytochemicals in Seeds

Sinha (1960a) identified yellow fixed oil (yield 18.78 %) from the seeds and isolated γ-sitosterol. Gupta and Lal (1968) reported hexaconazole, β-sitosterol and an anthoxanthin glucoside from the seeds; on acid hydrolysis, the anthoxanthin glucoside yielded quercetin and glucose. They also identified the following amino acids in the seed: lysine, valine, methionine, phenylalanine, isoleucine, aspartic acid, serine, glycine, alanine, glutamic acid, tyrosine, proline, arginine and histidine. Kulshrestra and Khare (1968) isolated six crystalline compounds in the seeds: adenosine,

kaempferol-3-rhamnoglucoside, *p*-hydroxycinnamic acid and ethyl-α-D-GALACTOPYRANOSIDE, and two remaining compounds a polypeptide and a phenylglycoside.

Clitoria ternatea seed was found to contain 1.75 % moisture, 10.2 % oil, 38.4 % protein, 44.8 % total sugars, 3.75 % ash and energy 500.5 cal/100 g (Joshi et al. 1981). The seed oil was found to contain palmitic, stearic, oleic, linoleic and linolenic acids in the weight ratio of 18.5, 9.5, 51.4, 16.8 and 3.8 %, respectively. The oil had a specific gravity of 0.884 at 30 °C, refractive index at 39 °C of 1.459, saponification value of 187.7, iodine value of 70.4, acid value of 0.25 and unsaponifiable matter of 1.8 %. Protein constituted 38.4 % comprising 18 amino acids. Essential amino acid profile was (%) lysine (6.40–6.55), histidine (2.03–2.15), threonine (3.13–3.2), phenylalanine (3.2–3.30), methionine (1.06–1.04), serine (6.7–6.86), tyrosine (2.05–2.17), cystine (0–0.11), arginine (7.13–7.16), glutamic acid (23.9–24.03), aspartic acid (12.5–12.7), alanine (4.6–6.8), valine (5.8), proline traces, γ-aminobutyric acid traces and leucine plus isoleucine (15.51–15.8).

The seeds were found to contain 4.79 % oligosaccharides (Revilleza et al. 1990).

Three trypsin inhibitors were isolated from the seeds (Macedo and Xavier-Filho 1992). *C. ternatea* seeds were found to contain antifungal proteins, homologous to plant defensins (Osborn et al. 1995). Low levels of condensed tannins (0–2.48 mg catechin/g) and protein precipitable polyphenols (0.16–0.77 mg tannic acid/g) were detected in the raw mature seeds (Laurena et al. 1994).

Finotin a small basic antimicrobial and insecticidal protein was isolated from the seeds (Kelemu et al. 2004). A β-D-galactoside-specific lectin, designated *C. ternatea* agglutinin (CTA), purified from *Clitoria ternatea* seeds was found to compose of two identical subunits of molecular weight 34.7 kDa associated by non-covalent bonds and belonged to Gal/Gal NAc-specific group (Naeem et al. 2007a, b). CTA agglutinated trypsin-treated human B erythrocytes and may probably exhibit sugar uptake activity. This lectin could be used as valuable tool for glycobiology studies in biomedical and cancer research since it binds β-D-galactosides. The content of lectin was found to be 30 mg/30 g dry weight of pulse. The yield was 2.8 % as compared to 0.3 % obtained on fetuin column.

Phytochemicals in Leaves

Leaf mucilage was reported to contain anhydrogalactose, anhydropentosan and methyl pentosan (Sinha 1960b). Aiyar et al. (1973) reported 3 glycosides of kaempferol from the leaves: kaempferol-3-monoglucoside, kaempferol-3-rhamnosyl (1 → 6) glucoside and kaempferol-3-rhamnosyl (1 → 6) galactoside. The light petroleum ether and ether extracts yielded waxy material, chlorophyll and β-sisterol. Four kaempferol glycosides, I, II, III and IV, were isolated from *Clitoria ternatea* leaves and identified as kaempferol 3-glucoside (I), 3-rutinoside (II) and 3-neohesperidoside (III) and IV was characterized as kaempferol-3-*O*-rhamnosyl-(1 → 2)-*O*-[rhamnosyl-(1 → 6)]-glucoside and named clitorin (Morita et al. 1977). Stigmast-4-ene-3,6-dione was isolated from the dried leaves of *C. ternatea* (Ripperger 1978). The leaves were reported to have 12.5 % moisture content, 13.2 % total ash, 4.8 % acid insoluble ash, 5.3 % water soluble ash, water soluble extractive value 25.2 % and alcohol soluble extractive value 18.4 % (Taur et al. 2010).

Phytochemicals in Aerial Parts

Phytoconstituents such as propane 1,1-diethoxy- (4.73 %), 1,6,10-dodecatriene, 7,11-dimethyl-3-methylene-, (*Z*)- (1.18 %), 1,2,3,5-cyclohexanetetrol (1à,2á,3à,5á)- (3.55 %), myo-inositol, 4-C-methyl- (31.07 %), hexadecanoic acid, ethyl ester (2.66 %), phytol (1.18 %), 9,12-octadecadienoic acid, methyl ester (*E,E*)- (0.89 %), 7,11-hexadecadienal (1.18 %), octadecanoic acid, ethyl ester (0.59 %), isoparvifuran (5.33 %), 6H-benzofuro[3,2-c][1]benzopyran, 6a,11a-dihydro-3,9-dimethoxy- (6a*Rcis*)- [synonym:

homopterocarpin] (10.66 %), petrocarpin (15.68 %) and 1H-cycloprop[e]azulene, 1a,2,3,5,6,7,7a,7b-octahydro-1,1,4,7- tetramethyl-, [1a*R*-(1aà,7à,7aá,7bà)]-[synonym: varidiflorene] were found in *C. ternatea* aerial part extract (Sarumathy et al. 2011).

C. ternatea had been reported to have cyclotides, plant-derived proteins with a unique cyclic cystine knot topology and to play a role in host defence as well as to have a diverse range of pharmaceutically important activities, including uterotonic activity and antimicrobial and anti-HIV activity and had attracted recent interest as templates in drug design (Poth et al. 2011a). The scientists confirmed the expression and correct processing of the cyclotide encoded by the Cter M precursor gene transcript following extraction from *C. ternatea* leaf. Seven additional cyclotide sequences were also identified from *C. ternatea* leaf and flower, five of which were unique. Cter M displayed insecticidal activity against the cotton budworm *Helicoverpa armigera* and bound to phospholipid membranes, suggesting its activity to be modulated by membrane disruption. Further they found 12 novel cyclotides in the seeds (Poth et al. 2011b).

Phytochemicals in Roots

Taraxerone and taraxerol were isolated from *C. ternatea* roots (Banerjee and Chakravarti 1963, 1964). The concentration of taraxerol was found to be 12.4 mg/g w/w in the hydroalcoholic extract of *C. ternatea* root (Kumar et al. 2008).

Agrobacterium rhizogenes-transformed root cultures of butterfly pea were found to produce up to fourfold more yield of taraxerol, the anticancer triterpenoid compound compared to that in natural roots (Swain et al. 2012).

Phytochemical studies reported that the root-bark contained starch, taraxerol, tannin and resins; the seeds contained a fixed oil, bitter acid resin, tannic acid and 6 % ash and an alkaloid. The flowers were found to anthocyanins such as ternatins and preternatins and flavonol glycosides; kaempferol 3-*O*-(2″-*O*-α-rhamnosyl-6″-*O*-malonyl)-β-glucoside; quercetin 3-*O*-(2″-*O*-α-rhamnosyl-6″-*O*-malonyl)-β-glucoside; myricetin 3-*O*-(2″,6″-di-*O*-α-rhamnosyl)-β-glucoside; kaempferol and quercetin 3-(2(G)-rhamnosylrutinoside); kaempferol, quercetin and myricetin 3-neohesperidosides, 3-rutinosides and 3-glucosides; and myricetin 3-*O*-(2″-*O*-α-rhamnosyl-6″-*O*-malonyl)-β-glucoside.

Antioxidant Activity

Terahara and Nishiyama (2000) considered ternatins as good radical-scavenging type antioxidants. Crude pigment extract from blue flowers of butterfly pea, containing ternatins (delphinidin 3-malonylGs connected with a series of 3′, 5′-GC… side chains (G: D-glucose, C: p-coumaric acid)), was reported to have potential as new multifunctional natural pigment for a food colourant, cosmetic and disease-preventing food material. Some reasons stipulated were the relatively high antioxidative activity of ternatin B and D groups, the stable colour of ternatins in aqueous solution and the safe traditional usage of the crude pigments as food colourant in Southeast Asia. The leaves and blue and white flowers of *Clitoria ternatea* exhibited significant antioxidant activity with the blue flower-bearing plant showing higher scavenging activity (Sivaprabha et al. 2008). Aqueous *C. ternatea* flower extracts were shown to have stronger antioxidant activity (as measured by DPPH scavenging activity) than ethanol extracts (IC_{50} values were 1 mg/ml and 4 mg/ml, respectively) (Kamkaen and Wilkinson 2009). Aqueous extracts incorporated into an eye gel formulation were also shown to retain this activity; however, it was significantly less than a commercial anti-wrinkle cream included for comparison. The total phenolic content was 1.9 mg/g extract as gallic acid equivalents.

Methanol root extracts of blue- and white-flowered varieties of *C. ternatea* showed more potent antioxidant activity in DPPH radical-

scavenging assay than the pet ether or chloroform extracts (Patil and Patil 2011). The methanol root extracts also showed significant reductive ability as well as hydroxyl radical scavenging activity. The antioxidant activity of *C. ternatea* methanol leaf extract was 67.85 % at a concentration of 1 mg/ml and was also concentration dependent, with an IC_{50} value of 420.00 µg/ml (Nithianantham et al. 2011). The amount of total phenolics and flavonoids were estimated to be 358.99 mg/g gallic acid equivalent and 123.75 mg/g catechin equivalent, respectively.

Antidiabetic Activity

Oral administration of aqueous extract of *C. ternatea* leaves (400 mg/kg body weight) and flowers (400 mg/kg body weight) for 84 days significantly reduced serum glucose, glycosylated haemoglobin, total cholesterol, triglycerides, urea, creatinine and the activity of gluconeogenic enzyme glucose-6-phosphatase, but increased serum insulin, HDL-cholesterol, protein, liver and skeletal muscle glycogen content and the activity of glycolytic enzyme glucokinase (Daisy et al. 2009). For all the above biochemical parameters investigated, *C. ternatea* leaves treated rat showed a little better activity than *C. ternatea* flowers treated diabetic rats. In another study, the ethanol seed extract of *C. ternatea* at 400 mg/kg body weight dose significantly decreased blood glucose, cholesterol, alkaline phosphatase, aspartate amino transferase and alanine amino transferase in diabetic rats when compared to streptozotocin-induced diabetic control (Kalyan et al. 2011). Ethanol extract showed the presence of various phytoconstituents, namely, sterols, alkaloids, glycosides, saponins, tannins, carbohydrates, proteins, phenolic compounds and flavonoids. Dried plant extracts of roselle, chrysanthemum, mulberry, bael and butterfly pea were found to have in-vitro inhibitory effects on intestinal α-glucosidase and pancreatic α-amylase (Adisakwattana et al. 2012). They reported that the use of plant-based foods and their combinations with inhibitory effects on intestinal α-glucosidase (maltase and sucrase) and pancreatic α-amylase could help prevent the onset of diabetes by controlling postprandial hyperglycaemia resulting in aggressive delay of carbohydrate digestion to absorbable monosaccharide. Phytochemical analysis revealed that the total phenolic content of the dried plant extracts were in the range of 460.0–230.3 mg gallic acid equivalent/g dried extract. The dried extracts contained flavonoid in the range of 50.3–114.8 mg quercetin equivalent/g dried extract. It was noted that the IC_{50} values of chrysanthemum, mulberry and butterfly pea extracts were 4.24, 0.59 and 3.15 mg/ml, respectively. Further, the IC_{50} values of chrysanthemum, mulberry and butterfly pea extracts against intestinal sucrase were 3.85, 0.94 and 4.41 mg/ml, respectively. In addition, the IC_{50} values of roselle and butterfly pea extracts against pancreatic α-amylase occurred at concentration of 3.52 and 4.05 mg/ml, respectively. Combining roselle, chrysanthemum and butterfly pea extracts with mulberry extract showed additive interaction on intestinal maltase inhibition.

Antimicrobial/Insecticidal Activity

The aqueous, methanol and chloroform extracts of *C. ternatea* flowers exhibited activity against uropathogenic *Escherichia coli*, enteropathogenic *Escherichia coli*, enterotoxigenic *Escherichia coli, Salmonella typhimurium, Klebsiella pneumoniae* and *Pseudomonas aeruginosa* (Uma et al. 2009). However, the petroleum ether and hexane extracts did not exhibit any activity. The methanol leaf extract of *C. ternatea* was found to possess a more potent inhibitory activity effect against *Bacillus cereus, Staphylococcus aureus, Klebsiella pneumonia, Proteus vulgaris* and *Salmonella typhi* when compared to the petroleum ether and ethyl acetate extracts (Anand et al. 2011).

Finotin a small basic protein was isolated from the seeds was found to be antimicrobial and insecticidal (Kelemu et al. 2004). It exhibited broad and potent inhibitory effect on the growth of various important fungal pathogens of plants, namely, *Rhizoctonia solani, Fusarium solani, Colletotrichum lindemuthianum, Lasiodiplodia*

theobromae, Pyricularia grisea, Bipolaris oryzae and *Colletotrichum gloeosporioides*. It also inhibited the common bean bacterial blight pathogen *Xanthomonas axonopodis* pv. *phaseoli.* Finotin also had powerful inhibitory properties against the bean bruchids *Zabrotes subfasciatus* and *Acanthoscelides obtectu*s. *Clitoria ternatea* leaf extract showed a favourable antifungal activity against *Aspergillus niger* with a minimum inhibition concentration 0.8 mg/ml and minimum fungicidal concentration 1.6 mg/ml (Kamilla et al. 2009). The leaf extract exhibited considerable antifungal activity on hyphal growth of *A. niger*. There was loss of cytoplasm in fungal hyphae and the hyphal wall, and its diameter became markedly thinner and distorted and resulted in cell wall disruption. In addition, conidiophore alterations were also observed.

Central Nervous System Activity

The alcoholic extracts of aerial and root parts of *C. ternatea* at 300 and 500 mg/kg doses administered orally to rats were capable of attenuating electroshock-induced amnesia (Taranalli and Cheeramkuzhy 2000). Extracts at 300 mg/kg dose produced significant memory retention, and the root parts were found to be more effective. They found that *C. ternatea* extracts increased rat brain acetylcholine content and acetyl cholinesterase activity in a similar fashion to the standard cerebroprotective drug pyritinol. Jain et al. (2003) reported *Clitoria ternatea* to possess nootropic, anxiolytic, antidepressant, anticonvulsant and antistress activities. A methanol extract of *Clitoria ternatea* was found to impact on the central nervous system. The extract decreased time required to occupy the central platform (transfer latency, TL) in the elevated plus maze (EPM) and increased discrimination index in the object recognition test, indicating nootropic activity. The extract was more active in the object recognition test than in the EPM. The extract increased occupancy in the open arm of EPM by 160 % and in the lit box of the light/dark exploration test by 157 %, indicating its anxiolytic activity. It decreased the duration of immobility in tail suspension test (suggesting its antidepressant activity), reduced stress-induced ulcers and reduced the convulsing action of PTZ and MES. The extract exhibited tendency to reduce the intensity of behaviour mediated via serotonin and acetylcholine. Recent studies by Malik et al. (2011) also showed that *C. ternatea*, commonly used as a component ingredient in the well-known Ayurveda herbal drug Shankhpushpi, exhibited nootropic, anxiolytic and CNS-depressant activity.

Neonatal rat pups (7 days old) intubated with either 50 mg/kg body weight or 100 mg/kg body weight of aqueous root extract of *Clitoria ternatea* for 30 days resulted in memory enhancement (Rai et al. 2001). There was improvement in retention and spatial learning performance at both time points of behavioural tests in neonatal rat pups, indicating the memory enhancing property of the extract which implicated a permanent change in the brain of extract treated rats. Another study showed that the plant extract enhanced memory. Treatment with 100 mg/kg of *Clitoria ternatea* aqueous root extract, for 30 days in neonatal and young adult age groups of rat, significantly increased acetylcholine (ACh) content in their hippocampi as compared to age matched controls (Rai et al. 2002). Increase in ACh content in their hippocampus may be the neurochemical basis for their improved learning and memory. Further Rai et al. (2005) found that the significant improvement in dendritic arborization of amygdaloid neurons correlated with the increased passive avoidance learning and memory in the extract treated rats. The results suggested that *Clitoria ternatea* aqueous root extract enhanced memory by increasing the functional growth of neurons of the amygdala.

Antiinflammatory, Analgesic and Antipyretic Activities

Clitoria ternatea also has antiinflammatory, analgesic and antipyretic attributes (Devi et al. 2003). Its methanol root extract when given by oral route to rats was found to inhibit both the rat paw oedema caused by carrageenan and vascular permeability induced by acetic acid in rats.

Moreover, the extract exhibited a significant inhibition in yeast-induced pyrexia in rats. In the acetic acid-induced writhing response, the extract markedly reduced the number of writhing at doses of 200 and 400 mg/kg (p.o.) in mice. The methanol root extract at doses of 200, 300 and 400 mg/kg body wt. p.o. produced significant reduction in normal body temperature and yeast-provoked elevated temperature in a dose-dependent manner. The effect extended up to 5 hours after the drug administration. The antipyretic effect of the extract was comparable to that of paracetamol (150 mg/kg body wt., p.o.), a standard antipyretic agent.

Antiplatelet Aggregating Activity

Anthocyanins ternatins (A1, A2, B1, B2, D1 and D2) isolated from *Clitoria ternatea* (double blue) were found to have blood platelet aggregation-inhibiting (Honda et al. 1991) and vascular smooth-muscle-relaxing activities.

Antihyperlipidaemic Activity

Oral administration of the hydroalcoholic extract of the roots and seeds of *C. ternatea* resulted in a significant reduction of serum total cholesterol, triglycerides, very low-density lipoprotein cholesterol and low-density lipoprotein cholesterol levels (Solanki and Jain 2010a). The atherogenic index and the HDL/LDL ratio were also normalized after treatment in diet-induced hyperlipidaemic rats. The effects were compared with atorvastatin (50 mg/kg, p.o.) and gemfibrozil (50 mg/kg, p.o.), reference standards. The authors attributed the cholesterol-lowering effect of *C. ternatea* to increased biliary excretion and decreased absorption of dietary cholesterol.

Hepatoprotective Activity

The results of the paracetamol-induced liver toxicity studies showed that mice treated with the methanol extract of *C. ternatea* leaf (200 mg/kg) showed a significant decrease in aspartate aminotransferase (AST), alanine aminotransferase (ALT) and bilirubin levels, which were all elevated in the paracetamol group (Nithianantham et al. 2011). *C. ternatea* leaf extract therapy also had protective effects against histopathological alterations. In another study, *C. ternatea* seed extract significantly decreased SGOT, SGPT, ALP and total bilirubin in both acetaminophen and CCl_4-intoxicated rats (Solanki and Jain 2011). The *C. ternatea* root extract showed similar results only in CCl_4-intoxicated rats. Hepatic collagen content as evident from decreased hydroxyproline levels and hepatic mast cell infiltration were significantly decreased in extracts pretreated animals. In addition, *C. ternatea* seed extracts significantly reduced hepatic lipid peroxidation as evident from the decreased MDA and increased antioxidant enzyme activities and GSH levels in the liver tissues. They suggested that the hepatoprotective activity of *C. ternatea* could be attributed to antioxidant properties and prevention of pre-inflammatory changes. They suggested that the hepatoprotective action was likely related to its potent antioxidative activity.

Nephroprotective Activity

Oral administration of the ethanol extract of *C. ternatea* plant elicited nephroprotective activity against acetaminophen-induced nephrotoxicity in male albino rats (Sarumathy et al. 2011). Biochemical studies showed that there was an increase in the levels of serum urea and creatinine along with an increase in the body weight and reduction in the levels of uric acid in acetaminophen-induced animals. These values were reverted significantly by treatment with *Clitoria ternatea* extracts at two different doses of 250 and 500 mg/kg body weight. The antioxidant studies revealed that the levels of renal SOD, CAT, GSH and GPx in the APAP-treated animals are increased significantly along with a reduced MDA content in ethanol extract of *Clitoria ternatea-treated* groups. Further, histopathological changes also revealed the protective nature of the *Clitoria ternatea* extract against

acetaminophen-induced necrotic damage of renal tissues.

Immunomodulatory Activity

C. ternatea seed and root extracts showed significant immunosuppressive effects as evident from significant decrease in primary and secondary antibody titres in SRBCs-sensitized rats, paw thickness in delayed type hypersensitivity (DTH) response and neutrophil adhesion and in-vitro phagocytosis (Solanki and Jain 2010b). They attributed the immunomodulatory effects of *C. ternatea* on humoral, cell-mediated and nonspecific immune response to decreased immune cell sensitization, immune cell presentation and phagocytosis. They also asserted that the antiinflammatory and antioxidant properties of plant might be playing major role in immunomodulatory activity.

Wound Healing Activity

C. ternatea seed and root extracts significantly improved wound healing in excision, incision and dead-space models in rats when administered orally by gavage as well as applied topically as ointment (Solanki and Jain 2012). These effects were comparable to that of cotrimoxazole ointment. The findings suggested that *C. ternatea* affected all three phases—inflammatory, proliferative and remodelling phases of wound healing. The plant extracts were found to contain phenolic compounds and seed extract was containing flavonol glycosides.

Antinutrient Activity

Three trypsin inhibitors with molecular weights of 20, 12 and 7 kDa and with one-chain molecule were isolated from the seeds (Macedo and Xavier-Filho 1992). The 20-kDa inhibitor had arginine in the reactive site, the 12-kDa had lysine in the reactive site, and both belonged to the Kunitz and Bowman–Birk families, respectively. The small molecular weight inhibitor (7 kDa) also had an arginine in the reactive site and was probably of the Bowman–Birk type. The seeds were found to have oligosaccharides which could be completely removed by 2 minutes roasting; germination resulted only in 30–40 % of total oligosaccharide (Revilleza et al. 1990).

Anthelmintic Activity

Clitoria ternatea was found to have an anthelmintic activity (Khadatkar et al. 2008). A crude alcoholic extract and its ethyl acetate and methanol fractions significantly demonstrated paralysis and also caused death of worms (*Pheretima posthuma*) especially at higher concentration of 50 mg/ml, as compared to standard reference piperazine citrate.

Antihistaminic Activity

The ethanol extract of *Clitoria ternatea* root was found to have antihistaminic activity using clonidine- and haloperidol-induced catalepsy in mice (Taur and Patil 2011b).

Antiasthmatic Activity

The ethanol extract of *Clitoria ternatea* root significantly decreased milk-induced leukocytosis and eosinophilia, protected egg albumin-induced degranulations of mast cells in mice and inhibited area of blue dye leakage in passive cutaneous anaphylaxis in rats at (100–150 mg/kg, i.p.) (Taur and Patil 2011a). Phytochemical studies observed the presence of steroids, saponin, flavonoids and glycosides. The results suggested that the antiasthmatic activity of ECTR may be due to the presence of flavonoids or saponins.

Mosquito Larvicidal Activity

Among the methanol extracts of *C. ternatea* leaves, roots, flowers and seeds, the seed extract was effective against the larvae of all the three

major mosquito vectors *Aedes aegypti*, *Culex quinquefasciatus* and *Anopheles stephensi* with LC_{50} values 65.2, 154.5 and 54.4 ppm, respectively (Mathew et al. 2009). Among the three plant species (*Saraca indica/asoca*, *Nyctanthes arbor-tristis* and *Clitoria ternatea*) studied, *C. ternatea* showed the most promising mosquito larvicidal activity. The phytochemical analysis of the promising methanol extract of the seed extract was positive for carbohydrates, saponins, terpenoids, tannins and proteins.

Traditional Medicinal Uses

Clitoria ternatea, a traditional Ayurvedic medicine, has been used for centuries for many diseases and disorders. It has been employed as a memory enhancer, nootropic, antistress, anxiolytic, antidepressant, anticonvulsant, tranquilizing and sedative agent and used in the traditional Indian system of medicine as a brain tonic and is believed to promote memory and intelligence (Burkill 1966; Aiyar et al. 1973; Taranalli and Cheeramkuzhy 2000; Mukherjee et al. 2008; Wetwitayaklung et al. 2008; Anand et al. 2011; Malik et al. 2011; Kaisoon et al. 2001; Stuart 2012). The plant parts have been considered cooling, acrid, purgative, laxative, diuretic, antipyretic, antiinflammatory, analgesic and anthelmintic.

The root, leaves and flowers are used in the form of powder and decoction to treat oedema, mental disorder, goitre, vitiligo, snake poisoning, toothache, eye disease, fever, asthma, jaundice, earaches, pile, throat infections, skin diseases (boils and scabies), renal stones and filariasis, and also used as an aphrodisiac. In the Philippines, the leaves were employed as wet dressing for wounds; root decoction taken to treat inflammation of joints, and the seeds used in poultices for swollen joints. In Indonesia, the seeds are considered aperient, the roots are cathartic, the leaves are used as poultices, and juice of white flowers was used for inflamed eyes. In Thailand, the flowers are used as hair tonic, for hair growth, as stimulant and for hair colouring.

Other Uses

Butterfly pea is a multipurpose forage legume. It provides bioactive compounds for medicinal use and it is also an ornamental plant on fence rows, cover crop and green manure crop. Butterfly pea, a highly palatable forage legume, is generally preferred over other legumes by livestock such as sheep, goat and cattle. It has thin stem and large leaves, nil bloat and nontoxic which make it ideal for forage and haymaking. Its vigorous growth, tolerance to frost and dry periods and heavy grazing pressures make this suitable for wasteland development. It is used as a revegetation species on coal mines in central Queensland, Australia. When grown as green manure or ley pasture, it enhances soil fertility to improve yields of subsequent crops like maize, sorghum wheat. It is used as a cover crop in rubber, cocoa and coconut plantations.

The flowers are still widely used for making dye in Southeast Asia because they are rich in blue anthocyanin, a plant pigment. The dye is added to cosmetics, fabrics and shampoo (which helps keep dyed hair dark) and used as a food colourant. The blue dye is also used as a natural pH indicator in the pharmaceutical industry.

Comments

Clitoria ternatea is readily propagated from seed and by cuttings.

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