Iris x germanica

Scientific Name

***Iris x germanica* L.**

Synonyms

Iris × *alba* Savi, *Iris* × *amoena* DC., *Iris* × *atroviolacea* Lange, *Iris* × *australis* Tod., *Iris* × *belouinii* Bois & Cornuault, *Iris* × *biliottii* Foster, *Iris* × *buiana* Prodán, *Iris* × *buiana* var. *virescens* Prodán, *Iris* × *croatica* Prodán, *Iris* × *croatica* Horvat & M.D.Horvat (Illeg.), *Iris* × *cypriana* Foster & Baker, *Iris* × *deflexa* Knowles & Westc., *Iris* × *florentina* L., *Iris* × *florentina* var. *pallida* Nyman, *Iris* × *florentinoides* Prodán ex Nyar., *Iris* × *germanica* var. *alba* Dykes, *Iris* × *germanica* var. *amas* Dykes, *Iris* × *germanica* var. *askabadensis* Dykes, *Iris* × *germanica* var. *australis* (Tod.) Dykes

Iris × *germanica* var. *florentina* (L.) Dykes, *Iris* × *germanica* var. *fontarabie* Dykes, *Iris* × *germanica* var. *gypsea* Rodigas, *Iris* × *germanica* var. *kharput* Dykes, *Iris* × *germanica* var. *lurida* (Aiton) Nyman, *Iris* × *germanica* var. *nepalensis* (Wall. ex Lindl.) Herb., *Iris* × *germanica* var. *sivas* G.Nicholson, *Iris* × *humei* G.Don, *Iris* × *laciniata* Berg, *Iris* × *latifolia* Gilib. (Inval.), *Iris* × *lurida* Aiton, *Iris* × *macrantha* Simonet, *Iris* × *mesopotamica* Dykes, *Iris* × *murorum* Gaterau, *Iris* × *neglecta* Hornem., *Iris* × *nepalensis* Wall. ex Lindl., *Iris* × *nostras* Garsault (Inval.), *Iris* × *nyaradyana* Prodán, *Iris* × *officinalis* Salisb., *Iris* × *pallida* Ten. (Illeg.), *Iris pallida* subsp. *australis* (Tod.) K.Richt., *Iris* × *piatrae* Prodán, *Iris* × *redouteana* Spach, *Iris* × *repanda* Berg, *Iris* × *rothschildii* Degen, *Iris* × *sambucina* L., *Iris* × *spectabilis* Salisb., *Iris* × *squalens* L., *Iris* × *squalens* var. *biflora* Prodán & Buia, *Iris* × *squalens* var. *rosea* Prodán & Buia, *Iris* × *superba* Berg, *Iris* × *tardiflora* Berg, *Iris* × *trojana* A.Kern. ex Stapf, *Iris* × *varbossania* K.Malý, *Iris variegata* var. *lurida* (Aiton) Nyman, *Iris* × *venusta* J.Booth ex Berg, *Iris* × *violacea* Savi, *Iris* × *vulgaris* Pohl

Family

Iridaceae

Common/English Names

Bearded Iris, Common Orrisroot, Flag, Florentine Orris, Florentine Iris, Garden Iris, German Iris, German Orrisroot, Iris, Orris, Orrisroot, Purple Flag, Queen Elizabeth Root, Tall Bearded German Iris, Tall Bearded Iris

Vernacular Names

Arabic: Irsa

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Chinese: Déguó Yuānwěi
Czech: Kosatec Německý
Danish: Have-Iris, Iris, Sværdlilie
Dutch: Blauwe Lis, Duitse Lis, Duitse Lis Sort, Lis Sort
Esperanto: Irido Ĝardena, Irido Germana
Estonian: Aediiris
Finnish: Saksankurjenmiekka, Sininen Kurjenmiekka
French: Flambe, Iris, Iris Allemande, Iris d'Allemagne, Iris Germanique
German: Deutsche Schwertlilie, Echte Schwertlilie, Gelbe Schwertlilie, Himmelschwertel, Ritter-Schwertlilie, Türk Schwertlilie
Hungarian: Kerti Nőszirom, Kék Nőszirom, Nepáli Nőszirom
India: Puskaramulam (Malayalam), Kombirei (Manipuri), Haimavati, Mulam, Padma-Pushkara, Parasikavaca, Puskaramulam (Sanskrit)
Italian: Giaggiolo Paonazzo, Giaggiolo Maggiore
Japanese: Ayame, Hanashoubu, Kakitsubata
Korean: Ailiseu Germanica
Persian: Bikh-I-Banafshah
Polish: Kosaciec Bródkowy, Kosaciec Niemiecki, Kosaciec Ogrodowy
Portuguese: Lírio-Cardano, Lírio-Cardeno, Lírio-Da-Alemanha, Lírio-Germânico, Lírio-Roxo
Slovaščina: Bradata Perunika, Nemška Perunika, Perunika Nemška
Slovencina: Kosatec Nemecký
Spanish: Iris, Lirio Cardeno, Lirio Común
Swedish: Trädgårdsiris
Thai: Māntā Germanica
Tibetan: Su Dag Dkar Po
Turkish: Mor Süsen, Navruzu, Türk Süzeni
Vietnamese: Diên Vỹ German hoa tím
Welsh: Gellesgen Farfog

Origin/Distribution

I. x germanica probably originated in central southern Europe and the Balkan Peninsula. *Iris germanica* is considered to be a natural and fertile hybrid between *I. pallida* and *I. variegata* L., both of which also have the chromosome number $2n=24$ (Henderson 1992, 2002).

Agroecology

Iris x germanica thrives in full sun, in fertile, well-drained, neutral to slightly acidic soil with pH 6–7. It needs light watering. It is widely grown as a garden ornamental in the temperate regions of Australia and has become naturalised along roadsides, in waste areas and in bushland.

Edible Plant Parts and Uses

Orrisroot is often included as one of the many ingredients of *Ras el hanout*, a blend of herbs and spices used across the Middle East and North Africa, primarily associated with Moroccan cuisine (Surhone et al. 2011). Peeled rhizomes of *I. germanica* (orrisroots) can be used as a flavouring in ice cream, confectionery and baked goods (Bender 2009). Orris is also an ingredient in many brands of gin. Orrisroot has been used in tinctures to flavour syrups; its taste is said to be indistinguishable from raspberry (Chase 1900). In France, starch of *I. germanica* root had been recommended a famine food for extending bread flour, after removal of the bitter element (Parmentier 1781, cited by Freedman 2009).

Botany

Iris x germanica is a rhizomatous, perennial herb, growing to 120 cm high, forming a large clump to 30 cm wide (Plate 1). Rhizomes are homogeneous, creeping on soil surface or to 10 cm depth, usually many-branched, light brown, 1.2–2 cm in diameter and smooth, with nodal rings; branches may arise in the fan or as many as 15–20 nodes are produced prior to active leaves. Stems are green, 2–3-branched, solid, 60–120 cm × 1–1.5 cm and glaucous. Leaves are purplish at base and folded midrib to base, glaucous, ensiform and 45 cm long by 3.5 cm wide. Inflorescences with

Plate 1 Orrisroot plant habit

terminal unit are 2–3-flowered, and branch units 1–2-flowered; spathes are green, sometimes with purple base, and 2–5 cm, with narrow, scarious margins and tip. For the flowers, the perianth has shades of blue-violet, yellow, brown or white (Plate 2) with various patterns of pigment distribution; floral tubes are 1–2.5 cm; sepals are spreading, drooping or reflexed and have shades of blue-violet, yellow, brown or white with patterned overlay of darker blue-violet, with white or yellow beard along midrib of claw and lower part of limb; obovate limbs taper gradually to claw, 6–7.5 by 4–5.5 cm; petals alternate with sepals and are erect and obovate, 5–7 by 4–5.5 cm, with short, 1.5–2 cm, channelled claw; the ovary is bluntly trigonal, 1.5–2.5 cm and slightly wider than floral tube. Capsules are bluntly angled, 3-lobed borne on ends of stems and branches and 3–5 × 2.5 cm containing reddish-brown, wrinkled, oval seeds, 3–4 mm in 2 rows per locule.

Nutritive/Medicinal Properties

Rhizome Phytochemicals

The following compounds were isolated from *I. germanica* rhizomes: irisolone (Dhar and Kalla 1972), 5,4′-dihydroxy-6,7-methylenedioxyisoflavone (irilone) (Dhar and Kalla 1973) and 2,4,6,4′-tetrahydroxybenzophenone (Dhar and Kalla 1974). Acetovanillon (4-hydroxy-3-methoxyacetophenon) and the known flavonoids irisolidone, irigenin, irisolone, tectorigenin and dihydroquercetin-7.3′-dimethylether were detected in *Iris germanica* rhizomes (Pailer and Franke 1973). Also, a few unknown compounds were isolated and their structure elucidated as 9-methoxy-7-(3′.4′.5′-trimethoxyphenyl)-8H-1.3-dioxolo[4.5-g] [1]-benzopyran-8-on (=5.3′.4′.5′-tetramethoxy-6.7-methylenedioxyisoflavone (III A); 9-methoxy-7-(3′.4′-dimethoxyphenyl)-8H-1.3-dioxolo[4.5-g] [1]-benzopyran-8-on (=5.3′.4′-trimethoxy-6.7-methylenedioxyisoflavone(III B); 9-hydroxy-7-(p-hydroxyphenyl)-8H-1.3-dioxolo[4.5-g] [1]-benzopyran-8-on (=5.4′-dihydroxy-6.7-methylenedioxyiosoflavone (IX); 5.7-dihydroxy-3-(3′-hydroxy-4′-methoxyphenyl)-6-methoxy-4H-1-benzopyran-4-on (=5.7.3′-trihydroxy-6.4′-dimethoxyisoflavone (XI B); 5.7-dihydroxy-3-(4′-hydroxy-3′-methoxyphenyl)-6-methoxy-4H-1-benzopyran-4-on (=5.7.4′-trihydroxy-6.3′-dimethoxyisoflavone (XI C). The ethanol rhizome extract of *I. germanica* afforded an isoflavone homotectoridin with the structure 5, 4′-dihydroxy-8, 3′-dimethoxy-isoflavone-7-*O*-mono-D-glucoside and tectoridin (Kawase et al. 1973). Acetovanillon, irigenin and its glucoside iridin, *β*-sitosterol, *α*-amyrin and *β*-amyrin were isolated from the fresh rhizomes of *I. germanica* (El-Moghazzy et al. 1980). Bicyclic triterpenoids, *α*-irigermanal and *γ*-irigermanal, and a monocyclic triterpenoid, iridogermanal, were the major extractable lipids isolated from the rhizomes, constituting about 1 % of the fresh weight (Marner et al. 1982). From the rhizome, one new hexaoxygenated isoflavone, 5,3′-dihydroxy-4′,5′-dimethoxy-6,7-methylenedioxyisoflavone; two new polyox-

Plate 2 White flowers

ygenated isoflavone glucosides, 5-hydroxy-6,4′-dimethoxyisoflavone 7-glucoside and 5,3′-dihydroxy-4′,5′-dimethoxyisoflavone 7-glucoside; and the known isoflavonoids irisolidone, irigenin and iridin and acetovanillone, sitosterol, α-amyrin and β-amyrin were isolated (Ali et al. 1983).

Glucose content of *I. germanica* rhizomes, kept under anoxia (absence of oxygen), rapidly and dramatically decreased during the first 30 days and then increased at the same time as adenylate energy charge values started to decline (Hanhijarvi 1995). The amount of non-reducing sugars decreased gradually during the anoxic incubation. Under aerobic control conditions, adenylate energy charge (AEC) of *I. germanica* rhizome tissue was 0.81. Under anoxia the energy charge of *I. germanica* rhizome tissue remained above 0.6 for 4 days only. Large amounts of ethanol were found in anoxic rhizome (0.06 M) after 8 days. Long-lived free radicals were rapidly generated in *I. germanica* plant tissues when treated anoxically and subsequently returned to aerobic conditions (Crawford et al. 1994). The free radicals in *I. germanica* rhizomes were extracted into aqueous alkali and found to be flavonoids including quercetin, irisolone, selenone and derivatives of irigenin. The main flavonoids had more reduced and/or more alkylated structures than those from *I. germanica* grown under normal aerobic conditions. Semiquinone radical anions could readily be generated from quercetin, and similar flavonoids with 1,2-dihydroxy-, 1,4-dihydroxy- or trihydroxy-substitution patterns, by interaction with superoxide.

Three piscidal triterpenes named irisgermanicals A, B and C and seven known iridal-type tripenes, namely, iripallidal, iriflorental, α-irigermanal, γ-irigermanal, isoiridogermanal, 16-*O*-acetyl-isoirigermanal and α-dehydroirigermanal, were isolated (Ito et al. 1995). Iridal triterpenoids isolated from the rhizome included irisgermanicals A, B and C, isoiridogermanal, 16-*O*-acetylisoiridogermanal, a-irigermanal, g-irigermanal, a-dehydroirigermanal, iridal, iriflorental and iripallidal (Miyake et al. 1997). Four isoflavones glycoside iriskashmirianin 4′-*O*-β-D-glucoside, nigricin 4′-*O*-β-D-glucoside, irilone 4′-*O*-β-D-glucoside and iridin were isolated from the rhizomes (Atta-ur-Rahman et al. 2002). A monocyclic triterpene ester iristectorone K was isolated from the rhizomes of *Iris germanica* from Turkey (Orhan et al. 2002). Six known isoflavones, irisolidone, irisolidone 7-O-α-D-glucoside, irigenin, irilone, iriflogenin and iriskashmirianin, were isolated from *Iris germanica* rhizomes (Wollenweber et al. 2003). Five new di- and triglycosides, irigenin 7-[*O*-β-D-glucopyranosyl-(1 → 6)-β-D-glucopyranoside]; 6-hydroxygenistein 4′-[*O*-β-D-glucopyranosyl-(1 → 6)-β-D-glucopyranoside]; nigricin 4′-[*O*-β-D-glucopyanosyl-(1 → 6)-β-D-glucopyranoside]; nigricin 4′-[*O*-β-D-glucopyanosyl-(1 → 2)-*O*-[α-L-rhamnopyranosyl-(1 → 6)]-β-D-glucopyranoside]; and 7-4′-{[2″-*O*-(4′′′′-acetyl-2′′′′-methoxyphenyl)-β-D-glucopyranosyl]oxy}-3′-(β-D-glucopyranosyloxy)phenyl]-9-methoxy-8*H*-1,3-dioxolo[4,5-*g*]-[1 benzopyran-8-one-]

along with a known compound, nigricin 4′-(β-D-glucopyranoside), were isolated from *Iris germanica* rhizomes (Atta-ur-Rahman et al. 2003a). Nine isoflavonoids: 5,7-dihydroxy-3-(3′-hydroxy -4′,5′dimethoxy)-8-methoxy-4*H*-1-benzopyran-4-one; 5,7-dihydroxy-3-(3′-hydroxyl-4′, 5′-dimethoxy)-6-methoxy-4*H*-1-benzopyran-4-one; 5, 7-dihydroxy-3-(4′-hydroxy)-6-methoxy-4*H*-1-benzopyrane-4-one; 5-hydroxy-3-(4′-hydroxy)-6,7-methylenedioxy-4*H*-1-benzopyran-4-one; 5-hydroxy-3-(4′-methoxy)-6,7-methylenedioxy-4*H*-1-benzopyran-4-one; 5-methoxy-3-(4′-hydroxy)-6,7-methyenedioxy-4*H*-1-benzopyran-4-one; 5,7-dihydroxy-3-(3′-hydroxy-4′-methoxy)-6-methoxy-4*H*-1-benzopyran-4-one; 5,7-dihydroxy -3-(3′-methoxy-4′-hydroxy)-6-methoxy-4*H*-1-benzopyran-4-one and isopeonol were isolated from the rhizome (Atta-ur-Rahman et al. 2003b). Five new di- and triglycosides, irigenin 7-[*O*-β-D-glucopyranosyl-(1 → 6)-β-D-glucopyranoside] (1);6-hydroxygenistein4′-[*O*-β-D-glucopyranosyl-(1 → 6)-β-D-glucopyranoside] (2); nigricin 4′-[*O*-β-D-glucopyanosyl-(1 → 6)-β-D-glucopyranoside] (3); nigricin 4′-[*O*-β-D-glucopyanosyl-(1 → 2)-*O*-[α-L-rhamnopyranosyl-(1 → 6)]-β-D-glucopyranoside] (4) and 7-{4′-{[2″-*O*-(4′′′′-acetyl-2′′′′-methoxyphenyl)-β-D-glucopyranosyl]oxy}-3′-(β-D-glucopyranosyloxy)phenyl]-9-methoxy-8*H*-1, 3-dioxolo[4,5-*g*]-[1 benzopyran-8-one-] (5), along with a known compound, nigricin 4′-(β-D-glucopyranoside), were isolated from *Iris germanica* rhizomes (Nasim et al. 2003). Irigenin (5,7,3′-trihydroxy-6,4′,5′-trimethoxyisoflavone) and iristectorigenin A (5,7,3′-trihydroxy-6,4′-dimethoxyisoflavone) along with their 7-O-β-D-glucosides, iridin and iristectorin A, respectively, were found as the major components in adventitious roots in the liquid medium, and the total isoflavone content was about 3.6 μmol per g fresh weight in 3-week-old *I. germanica* cultures (Akashi et al. 2005). The total isoflavone content (glucosides + aglycones) at 6 h after the start of $CuCl_2$ treatment was 1.4-fold the initial value, and nearly the same content was maintained for 48 h. Thus, the main effect of $CuCl_2$ treatment appeared to be the induction of hydrolysis of isoflavone glucosides. Two novel compounds 5,2-dihydroxy-3-methoxy-6,7-methylenedioxyflavone and 5,7,2-trihydroxy-6-methoxyflavanone were isolated from the fraction B of the rhizome chloroform extract (Singab et al. 2006). The methanol extract of *Iris germanica* rhizome afforded one new compound, 6,6-ditetradecyl-6,7-dihydrooxepin-2(3H)-one and five known compounds, 1-(2-(6′-hydroxy-2′-methylcyclohex-1′-enyloxy)-5-methoxyphenyl) ethanone; 4-hydroxy-3-methoxyacetophenone; irisolone; irisolidone and 2-acetoxy-3,6-dimethoxy-1,4-benzoquinone (Asghar et al. 2009).

A total of 20 compounds identified as isoflavones, isoflavone glycosides and acetovanillone were isolated from the lipophilic and polar extracts of *Iris germanica* rhizomes (Schütz et al. 2011). A new isoflavone glycoside, iriflogenin-4′-O-gentiobioside, was isolated. Nine isoflavones (totalling 180 mg/g) were identified in *I. germanica* resinoid: irigenin, iristectorigenin A, nigricin, nigricanin, irisflorentin, iriskumaonin methyl ether, irilone, iriflogenin and irisolidone (Roger et al. 2012). The methanolic extract of *Iris germanica* rhizomes yielded two new compounds, irigenin S and iriside A, together with known compounds: stigmasterol, α-irone, γ-irone, 3-hydroxy-5-methoxyacetophenone, irilone, irisolidone, irigenin, stigmasterol-3-*O*-β-D-glucopyranoside, irilone 4′-O-β-D-glucopyranoside and iridin (Ibrahim et al. 2012). Two new compounds, 5-methoxy-3′,4′-dihydroxy-6,7-methylenedioxy-4*H*-1-benzopyran-4-one (iriskashmirianin A) and 5,3′-dihydroxy-3-(4′-β-D-glucopyranosyl)-6,7-methylenedioxy-4*H*-1-benzopyran-4-one (germanaism H), along with eight known compounds, namely, irilone, iriskumaonin methyl ether, iriflogenin, irisolone, irifloside, irilone 4′-*O*-β-glucopyranoside, germanaism A and germanaism B were isolated from the rhizomes (Xie et al. 2013). New ceramides irisamides A and B and isoflavone iridin S were isolated from the rhizome (Mohamed et al. 2013). The methanol extract of *Iris germanica* afforded a new benzene derivative 2′-methyl-6′-hydroxy cyclohexenyl-

3-methyl-1-acetophenone ether and another known benzene derivative isopenol together with two known isoflavones, irisolone and irisolidone (Asghar et al. 2010). Twenty-one compounds were isolated from the rhizomes of *Iris germanica* and identified as ombuin (1); 5, 3, 3′-trihydroxy-7, 4′-dimethoxyflavanone (2); naringenin (3); cirsiliol-4′-glucoside (4); 3*β*, 4′-dihydroxy-7,3′-dimethoxyflavonone-5-*O*-*β*-D--glucopyranoside (5); genistein (6); irilin D (7); muningin (8); 5, 7, 4′-trihydroxy-6, 3′, 5′-trimethoxyisoflavone (9); tectorigenin (10); irigenin (11); tectoridin (12); iridin (13); mangiferin (14); irisxanthone (15); pyroglutamic acid (16); 2, 4′, 6-trihydroxy-4-methoxybenzophenone-2-*O*-*β*-D-glucoside (17); apocynin (18); androsin (19); *β*-sitosterol (20); and daucosterol (21) (Xie et al. 2014).

Eleven compounds were identified in the petroleum ether extract (oil) of *I. germanica*: 9-hexadecanoic acid methyl ester; 9-octadecenoic acid methyl ester; 8-octadecenoic acid methyl ester; 11-octadecenoic acid methyl; 10-octadecenoic acid methyl ester; 13-octadecenoic acid methyl ester; 16-octadecenoic acid methyl ester; 1, 2-benzenedicarboxylic acid diisooctyl ester; bis(2-ethylhexyl) phthalate; methyl 6-methyl heptanoate; and nonanoic acid, 9-oxo-methyl ester (Asghar et al. 2011). Twenty-three compounds were identified in the essential oil of Syrian *Iris germanica* with myristic acid (61.42 %) as the major component (Almaarri et al. 2013). The other sub-major compounds obtained were elaidic acid methyl ester (9-octadecenoic acid methyl ester) (6.61 %), lauric acid (5.69 %), octadecanoic acid methyl ester (stearic acid methyl ester) (5.40 %), palmitic acid methyl ester (5.10 %) and palmitic acid (4.87 %). The minor compounds were linoleic acid methyl ester (1.19 %); linoleic acid (1.1 %); docosane (1.08 %);10-octadecenoic acid, methyl ester (0.7 %); 3-methyl-1,2-benzoisoselenazple (0.61 %); nonadecane (0.55 %); oleic acid (0.53 %); sulphurous acid,2-propyl tetradecyl ester (0.28 %); *α*-irone (0.25 %); 2-propenoic acid, 3-4(-methoxy-phenyl)-2ethyl-hexyl ester (0.16 %); 1,2-benzenedicarboxylic acid, dioctyl ester (0.15 %); decanoic acid (capric acid) (0.14 %); benzoic acid, 4-ethoxy-, ethylester (0.12 %); hexadecane (0.11 %); thiosulfuric acid, S-(2aminoethyl) ester (0.1 %); tetradecane (0.08 %); and decane (0.06 %).

Orrisroot is used as an aromatic agent. *Iris pallida* is the best for extractive purposes followed by *I. germanica* and *I. florentina* for botanical sources of orrisroot preparations (concrete, liquid, oil, root extract) (Fenaroli 1994). Orris absolute consists mainly of isomeric irones (Guenther 1952). Orris absolute (alcoholic extraction or distillation of orris concrete) was reported to have a yield of 0.03–0.05 % dried rhizome and to contain 55–58 % ketones (irones), free or partially esterified fatty acids (methyl myristate, methyl caprylate, methyl laurate, methyl oleate, methyl linoleate), aldehydes (oleic, benzoic), alcohols (benzylic), terpene and sesquiterpene (Burdock 1994). Orris resinoid (yield 1–3.3 %) was reported to contain 62–78 % ketones (irones) (Burdock 1994). Orris absolute prepared from *Iris x germanica* was reported to contain (Z)-*a*-irone (558.4–62.7 %), (Z)-*γ*-irone (32.2–36.9), (*E*)-*α*-irone (1.7–3.9 %) and (*Z*)-*β*-irone (0.4–2.3 %) and orris essential oil to contain (*Z*)-*α*-irone (57.6–66.2 %), (*Z*)-*γ*-irone (33.8–39.4 %), (*E*)-*α*-irone (0.5–2.7 %) and (*Z*)-*β*-irone (0–2.2 %) (Galfre et al. 1993). (+)-*cis*-*γ*-Irone and (+)-*cis*-*α*-irone were found to have the most interesting organoleptic properties. Orris essential oil is a cream-coloured solid and is often referred to as orris butter and often and erroneously referred to as orris concrete which is a dark, viscous material perhaps more correctly referred to as a resinoid.

Irones extracted from *Iris* species are aromatic principles used in the perfume and flavour industry to impart violet fragrance. Four major irone compounds (*trans α*-, *cis α*-, *cis γ*- and *β*-irones) had been described (Naves et al. 1947; Schinz et al. 1947; Jaenick and Marner 1990) as responsible for the characteristic scent of Iris oil. Natural irones (terpenoids) in essential oil of Iris rhizomes were found to be formed by oxidative degradation of other higher terpenes C31-triterpenoids produced by the plant (Krick et al. 1984). Triterpenoids called iridals were shown to be irone precursors (Jaenick and Marner 1990). Iridals originated from C30 olefin squalene (Jaenick and Marner 1990, Marner et al. 1988; Marner 1997). The incorporation of [2-^{14}C]acetate, [2-^{14}C]mevalonate and [^{3}H]squalene proved the squalenoid nature of the iridals (Marner et al. 1988). Methionine was readily incorporated into cycloiridals of *Iris pallida dalmatica*, thus indicating that the methylation of iridals via S-adenosyl-L-methionine led to the formation of the irone moiety of the bicyclic compounds. The cycloiridals, C31-triterpenoids, also served as precursors of the irones (Marner et al. 1990). Since 1982, more than 25 different iridal structures were characterised (Jannick and Marner 1990, Abe et al. 1991; Marner and Kerp 1992) and separated into 3 classes monocycloiridals, bicycloiridals and spiroiridals. Rhizomes of both *I. pallida* varieties were found to contain 0.1–1.1 %, and *I. germanica* 0.1–0.5 % of iridals and their esters (Marner and Kerp 1992). Bonfils et al. (1996) found iridals were membrane located. Two triterpenoids iripallidal and iriflorental, known irone precursors, were found to be solubilised by phosphatidylcholine. These cycloiridals were found to be integrated within liposomal membranes and appeared to have a structural role within cells comparable to that of sterols. *Iris germanica* had high levels of (+)*cis*-*α*-irone and low content of *trans*-*α*-irone, while *I. pallida* had a high content of (-) *cis*-*α*-irone (Maurer et al. 1989; Firmin et al. 1998). Dehydration of rhizome slices led to an increase of iridal esters with a concomitant drop of free iridals, as well as phospholipids, in the drought-resistant species, *Iris germanica* (Bonfils et al. 1994). Analysis of the intracellular membranes of *Iris germanica* rhizomes indicated high amounts of iridals when compared to sterols and lower sterol amounts than in other plant microsomes (Bonfils et al. 1995). Incubation of a monocyclic iridal (a triterpenoid from *Iris* species) with rat liver microsomes in the presence of NADPH led to the degradation of this substrate and to the generation of 16-hydroxy-iridal (isoiridogermanal) (Bonfils et al. 1955). Iridal composition was also found to differ, depending on the age of *Iris germanica* rhizomes (Bonfils and Sauvaire 1996). Monocycloiridals were mostly represented in young rhizomes, whereas cycloiridals appeared to be the main iridal formed in the old ones. The study of the ratio of free iridals (FI)/iridal esters (IE) revealed a higher ratio in the youngest rhizomes. In addition 20 irone-related compounds containing 10-16C-atoms were detected in orris concrete of Moroccan origin (*I. germanica*) (Maurer et al. 1989). *Iris germanica* was found to have a fresh mass of 1342 g/plant and a dry mass of 437 g/plant and to contain 595 mg/kg DM irone content that was composed of 79.1 % *cis*-*γ*-irone and 20.9 % *cis*-*α*-irone (Firmin et al. 1998). An epoxidised iridal 18,19-epoxy-10-deoxyiridal was isolated from rhizomes of *Iris germanica* var. 'Rococo' (Bonfils et al. 1998). Ten enantiopure isomers of irone were reported to be the odoriferous principle of orrisroot oil, by means of enzyme-mediated approaches, starting from commercial racemic *Irone alpha*® (Brenna et al. 2003). A new iridal irigermanone and nine known congeners were isolated from the dried rhizomes of German iris (*Iris germanica*) (Potterat et al. 2014). The compound was a structurally unique noriridal and possessed an unprecedented methylcarbonyl group instead of the *α*,*β*-unsaturated aldehyde function typical for this group of triterpenes.

Other Plant Parts' Phytochemicals

A C-glycosyl flavone, embinin, is isolated from the petals of *I. germanica* (Kawase and Yagishita 1968). In *Iris germanica*, flower colour was found to be determined by two distinct biochemical pathways, the anthocyanin biosynthetic and the carotenoid biosynthetics (Warburton et al. 1978; Meckenstock 2005). In cyanic iris flowers, the main pigments reported were delphinidin-type anthocyanins imparting blue, violet and maroon colours, while in acyanic flowers, the main pigments were carotenoids, producing orange, yellow and pink colours. A red iris does not naturally exist because of a deficiency in the synthesis of pelargonidin- and cyanidin-type anthocyanins, usually responsible for red and orange hues or that red carotenoids, such as lycopene, do not accumulate in large concentrations, thus producing only pink flowers, as opposed to red ones (Jeknić et al. 2014). With a goal of developing iris cultivars with red flowers, they transformed a pink iris *I. germanica*, 'Fire Bride', with a bacterial phytoene synthase gene (*crtB*) from *Pantoea agglomerans* under the control of the promoter region of a gene for capsanthin–capsorubin synthase from *Lilium lancifolium* (Llccs). They showed that ectopic expression of a *crtB* could be used to successfully alter the colour of certain flower parts in *I. germanica* 'Fire Bride' and produce new flower traits. The colour changes were confirmed primarily due to the accumulation of lycopene. Other carotenoids and chlorophyll found in both control and *crtB* perigon (standards and falls), ovaries and flower stalk were neoxanthin, violaxanthin, lutein, lycopene, chlorophyll *a*, chlorophyll *b* and $\alpha+\beta$-carotene.

Carotenoids β-carotene 7.1 % (4.3 mg), lutein 87.8 % (53.2 mg), neochrome (zeaxanthin furanoxide) 3.5 % (2.1 mg) and 7 minor constituents 1.6 % (1 mg) were found in the green aerial parts of *I. germanica* (Buchecker and Liaaen-Jensen 1975). From the leaves of *I. pallida*, 0.1–0.7 % of iridals and their esters were extracted and from *I. germanica* leaves 0.05–0.3 % (Marner and Kerp 1992).

Antioxidant Activity

Both aqueous and ethanol *I. germanica* rhizome extracts exhibited strong total antioxidant activity, showing 95.9, 88.4, 79.9 % and 90.5, 78.0, 65.3 % inhibition on peroxidation of linoleic acid emulsion at concentrations of 10, 30 and 50 μg/ml, respectively, and in all cases exceeded the effect of 30 μg/ml α-tocopherol solution (36.6 %) (Nadaroğlu et al. 2007). Both extracts also possessed effective reducing power and exhibited free radical scavenging, superoxide anion radical scavenging, hydrogen peroxide scavenging and metal chelating activities at concentrations of 20, 40 and 60 μg/ml. The reducing power of aqueous and ethanol iris extracts and reference compounds was rated in the following order: BHA > BHT > α-tocopherol >> aqueous iris extract > ethanol iris extract. The scavenging effect of the aqueous and ethanol iris extracts and the reference compounds on the DPPH* radical decreased in the following order: BHA > α-tocopherol > BHT > aqueous iris > ethanol iris extract. These results indicated that both iris extracts produced a noticeable scavenging of free radicals; free radical scavenging activity also increased with the concentration of iris extracts. The metal chelating effect of both iris extracts and the reference compounds decreased in the following order: aqueous iris extract > ethanol iris extract > BHA > α-tocophero l > BHT. The results indicated that iris had in-vitro antioxidant properties, which could be the major factor responsible for the inhibition of lipid peroxidation. The petroleum ether extract (oil) of *I. germanica* exhibited good DPPH scavenging activity but showed moderate inhibition in linoleic acid oxidation as compared to BHT (Asghar et al. 2011). The radical scavenging activity of the ethanolic extracts of the aerial parts and rhizomes of *I. germanica* were found to have IC_{50} values of 5.38 and 12.3 mg/ml, respectively, whereas total antioxidant activity of the extracts (at 3.15 mg/ml) was 98.7 % and 97.4 %, respectively, and total phenolic content was 267.36 and 331.96 8 mg gallic acid equivalent/g extract, respectively (Burcu et al. 2014). HPLC analysis of phenolic compounds identified protocatechuic acid (0.356 mg/g extract), chlorogenic acid (0.164 mg/g extract) and ferulic acid (0.164 mg/g extract) as the main phenolic acids contained in the extract of the aerial parts of *I. germanica*, whereas chlorogenic acid (2.44 mg/g extract), (+)-catechin (2.14 mg/g extract) and ferulic acid (0.452 8 mg/g extract) were identified as the main phenolic acids contained in the extract of the rhizome.

Anticancer Activity

Isoflavones from *I. germanica* rhizomes, irigenin, irilone and iriskashmirianin exhibited moderate activity as inducers of NAD(P)H:quinone reductase (QR) in cultured mouse Hepa 1c1c7 cells, with CD values (concentration required to double the specific activity of QR) of 3.5–16.7 μM, whereas weak activity was observed with compounds iriflogenin and iriskashmirianin in the radical (DPPH) scavenging bioassay (IC_{50} values 89.6 and 120.3 μM, respectively) (Ito et al. 1995). Iridals extracted from *Iris germanica* exhibited antitumour effects in-vitro against human tumour cell lines: A2780 and K562 (and for each one, a drug-sensitive and a drug-resistant cell line) with IC_{50} values of 0.1–5.3 μg/ml (Bonfils et al. 2001). Some of them were shown to be more effective than doxorubicin. Studies by Halpert et al. (2011) found that the lipidic extract from *Iris germanica* was able to increase HeLa cell area and adhesion and augment the formation of actin stress fibres. This effect was not observed when Ref52 fibroblasts were tested and was not the result of disruption of microtubules. Further, the increase in cell area was Rac1 dependent, and the iris extract led to slight Rac activation. The increase in HeLa cell area in the presence of iris extract was accompanied by impairment of cell migration and arrest of the cell cycle at G1 although there is involvement of Rac1. The active compounds were found to iridals, a known group of triterpenoid. Purified iripallidal was able to increase cell area of both HeLa and SW480 cells.

With respect to antitumour-promoting potential based on anti-inflammatory mechanisms, none of the compounds demonstrated significant activity in the concentration range tested. *Iris germanica* ceramides irisamides A and B were active against mouse lymphoma L5178Y and cervical cancer HeLa cell lines, but inactive against PC12 rat pheochromocytoma (Mohamed et al. 2013). Irisamides A and B gave 76 % and 63 % growth suppression against the L5178Y and HeLa cell lines at a concentration of 12.67 mM as well as 68 % and 49 % at a concentration of 3.81 mM, with ED_{50}(s) of 0.91 and 2.40 mM, respectively. The isoflavone iridin S was inactive against the three cell lines. Among the compounds isolated from the rhizome, the isoflavone iriskashmirianin A possessed the best cytotoxic activity in Ehrlich's ascites carcinoma (EAC) cancer cell line with IC_{50} of 20.9 7 and 4.3 μM for 3-(4, 5-dimethylthiazole-2-yl)-2, 5-diphenyltetrazoli-umbromide (MTT) and ATP assay methods, respectively (Xie et al. 2013).

Antimutagenic Activity

The ethanolic extract of the aerial parts of *I. germanica* exhibited antimutagenic effects at 3 and 0.3 mg/plate concentrations as assessed using the Ames *Salmonella typhimurium*/microsome mutagenicity test (Burcu et al. 2014). The rhizomes also exhibited antimutagenic effects at 1.5, 0.15 and 0.015 mg/plate concentrations.

Antimicrobial Activity

The chloroform and ethyl acetate extracts of *I. germanica* rhizomes exhibited bactericidal activity, while the petroleum ether extract did not exhibit any bactericidal, fungicidal and insecticidal activities (Orhan et al. 2003). It was also inactive in the brine shrimp toxicity test, whereas it showed significant phytotoxicity against the plant *Lemna aequinoctialis.* The hexane fraction of the methanol rhizome extract showed significant inhibitory activity against *Fusarium solani* (70 %) and moderate activity against *Trichophyton longifusus* (50 %) and *Microsporum cani*s (30 %), while the ethyl acetate and chloroform fractions exhibited moderate activity against the tested fungi (Asghar et al. 2009). It was observed that the growth of bacteria (*Pasteurella multocida*, *Escherichia coli*, *Bacillus subtilis*, *Staphylococcus aureus*) and fungi (*Ganoderma lucidum*, *Aspergillus flavus*, *A. niger*, *Alternaria alternata*) were inhibited in *I. germanic*a petroleum ether extract (oil) as compared to the reference standards (rifampicin/ terbinafine) (Asghar et al. 2011). The methanolic rhizome extract showed antimicrobial activity against *Staphylococcus aureus*, *Serratia marcescens*, *Escherichia coli*, *Candida albicans* and *Aspergillus flavus* with the highest antimicrobial effect against *S. aureus* (Ibrahim et al. 2012).

Antihyperlipidemic Activity

Administration of the ethanolic extract of *Iris germanica* rhizomes for 10 weeks significantly lowered the lipid components especially the cholesterol and triglycerides in rats fed a high-fat diet (Choudhary et al. 2005)

Drug Metabolising Activity

Six isoflavones irisolidone, irisolidone 7-*O*-*α*-D-glucoside, irigenin, irilone, iriflogenin and iriskashmirianin isolated from *Iris germanica* rhizomes were shown to be potent inhibitors of cytochrome P450 1A activity with IC_{50} values in the range of 0.25–4.9 μM (Wollenweber et al. 2003).

Anti-inflammatory Activity

Isoflavonoids isolated from *I. germanica* rhizome exhibited ant-inflammatory activity determined by a spectrophotometric assay using the activated human neutrophils (Attar-ur-Rahman et al. 2003b). The methanolic rhizome extract and the isolated flavonoids exhibited potent anti-inflammatory effects by suppressing hind paw oedema (skin oedema) induced by 4 % formalin in albino rats (Ibrahim et al. 2012). Irigenin S showed activity similar to that of dexamethasone.

Immunomodulatory Activity

Two isoflavones, 5,7-dihydroxy-6,4′-dimethoxyisoflavone (irisolidone) and 5,4′-dihydroxy-6,7-methylenedioxyisoflavone (irilone) isolated from *Iris germanica*, exhibited immunomodulatory activities (Nazir et al. 2009). They influenced the production of T lymphocytes (CD4+ and CD8+ cells) and T cell cytokines, namely, Th1: IL-2, IFN-gamma and Th2: IL-4 and IL-5 in a dose-dependent manner, as studied by the flow cytometric method. Oral administration of the isoflavones in Balb/c mice at doses of 0.1–0.8 mg/kg per oral dose showed irisolidone to possess stimulatory activity on T lymphocytes (CD4+ and CD8+ cells) and Th1: IL-2, IFN-gamma cytokine production, while irilone acted as an immunosuppressant for T lymphocytes (CD4+ and CD8+ cells) and T cell cytokines, namely, Th1: IL-2, IFN-gamma and Th2: IL-4 and IL-5. The methylated products of both isoflavones showed a similar trend to that of their parent compounds, but their activity was drastically decreased revealing the importance of free phenolic groups for their immunomodulating activities.

Antimalarial Activity

Iridal, a triterpenoidic compound isolated from *I. germani*ca, exhibited antiplasmodial activity (Benoit-Vical et al. 2003). The IC_{50} obtained in-vitro on human malaria *Plasmodium falciparum* chloroquine-resistant and chloroquine-sensitive strains ranged from 1.8 to 26.0 μg/ml and the ED_{50} in-vivo for *P. vincke* was about 85 mg/kg/day by intraperitoneal route. Iridal presented an antiplasmodial activity similar to that obtained with extracts from the plant *Azadirachta indica* classically taken as reference in malaria phytomedicine

Molluscicidal Activity

Iris germanica rhizome chloroform extract showed the highest molluscicidal activity (LC_{90} = 1.26 mg/l) against *Biomphalaria alexandrina* snails among the tested extracts of the rhizomes (Singab et al. 2006). Fraction B prepared from the chloroform extract was the most potent molluscicide (LC_{90} = 0.96 mg/l); in addition, it showed a significant heart rate reduction in the snail after a 6- to 24-h exposure period. It also displayed a significant level of cercaricidal potential in a time-concentration-dependent manner.

Piscidal Activity

Among the iridals isolated from the rhizome, the most potent piscidal activity was observed for iriflorental with medial tolerance (TL_m) value after 24 h of 0.1 μg/ml (Ito et al. 1995). The TL_m of the bicyclic iridals irisgermanical A was 0.8 μg/ml and irisgermanicals Band C were 3 μg/ml. The monocyclic iridals, isoiridogermanal and 16-*O*-acetyl-isoirigermanal, were inactive. Of the iridals isolated from *I. germanica*, iriflorental, iripallidal and γ-irigermanal exhibited a potent piscidal activity (using killifish, *Oryzias latipes*) at a concentration of less than 1 μg/mL (Miyake et al. 1997).

Allergy Issue

Allergic manifestations caused by the use of a dentifrice containing orrisroot *(Iris × germanica* L. nothovar. *Florentina)* powder was reported by Winter (1948).

Toxicological Studies

The acute oral LD_{50} value for orris absolute in rats was reported as 9.4 g/kg (Moreno 1972). Undiluted orris absolute applied to the backs of hairless mice and swine was found to be not irritating (Urbach and Forbes 1972). No phototoxic effects were reported for undiluted orris absolute on hairless mice and swine. A patch test using orris at full strength for 24 h produced no irritation reactions in 20 subjects (Katz 1946). Orris absolute tested at 3 % in petrolatum produced no irritation after a 48-h closed-patch test on human subjects (Kligman 1972). Orris produced no primary irritation in a repeated insult patch test on 43 human subjects (Majors 1972).

Traditional Medicinal Uses

The root is diuretic, emetic, expectorant and mildly purgative (Grieve 1971; Usher 1974; Launert 1981; Chiej 1984). Juice from the root is a powerful cathartic and used for the treatment of dropsy (Grieve 1971). Orrisroot is also employed for complaints of the lungs, coughs and hoarseness, bronchitis and chronic diarrhoea. If taken in large doses, it can cause nausea, vomiting, purging and colic (Grieve 1971).

Other Uses

Iris resinoid obtained from *Iris germanica* or *Iris pallida* rhizomes is widely used in the perfume industry (Roger et al. 2012). Whole roots of Orris, resembling the human form, are used in voodoo performances, and the powdered root is an ingredient in 'love potions'. A black dye is obtained from the roots and a blue dye from the flowers (Grae 1974). The seeds are used as rosary beads (Usher 1974). Powdered orrisroot is sometimes put into rinsing water in laundries and imparts a refreshing and fragrant scent to the linen (Grieve 1971). Orrisroot, mixed with anise, was used in England as a perfume for linen as early as 1480. The root is a source of orris powder which is much used as a fixative and base note in perfumery and pot-pourri, as an ingredient of dentifrices, toothpastes, breath fresheners, face powders, foot powders, sachet powder, violet-scented soaps and cachous and as a food flavouring. Orris oil is used commercially in the preparation of the finest scents and is also blended with artificial violet perfumes, the odour of which it renders more subtle (Grieve 1971).

Comments

Bearded iris is propagated by division or cutting from the original rhizome and by seed.

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