Dianthus caryophyllus

Scientific Name

***Dianthus caryophyllus* L.**

Synonyms

Caryophyllus tunica Garsault [Invalid], *Dianthus acinifolius* Schur, *Dianthus arbuscula* Lindl., *Dianthus arrectus* Dumort., *Dianthus binatus* Schur, *Dianthus caryophyllus* var. *coronarius* L., *Dianthus coronarius* (L.) Burm.f., *Dianthus corsicus* Link ex Spreng., *Dianthus kayserianus* Schur, *Dianthus longicaulis* Costa, *Dianthus miniatus* A. Huet ex Nyman, *Dianthus morrsii* Hance, *Dianthus moschatus* J.F. Gmel., *Dianthus multinervis* Vis., *Silene caryophylla* E.H.L. Krause, *Tunica caryophyllus* Scop., *Tunica morrisii* (Hance) Walp.

Family

Caryophyllaceae

Common/English Names

Border Carnation, Carnation, Common Carnation, Clove Pink, Dianthus, Divine Flower, Gillyflower, Pinks, Wild Carnation

Vernacular Names

Bohemian: Hvozdik, Vrsta Karanfila
Brazil: Craveiro, Cravo
Burmese: Zaw-Hmwa-Gyi
Catalan: Clavell, Claveller, Clavellina, Clavells, Clavillinera, Clevellina
Chinese: Kang Nai Xin
Corsican: Caròfanu, Gaiofinu, Uchjellu
Czech: Hvozdík Karafiát, Hvozdík Zahradní
Danish: Havenellike
Dutch: Tuinanjelier
Estonian: Šaboonelk
Esperanto: Dianto Ĝardena
Finnish: Tarhaneilikka
French: Oeillet Des Fleuristes, Oeillet Girofle
German: Garten-Nelke, Land-Nelke, Nelke
Hungarian: Kerti Szegfű
Icelandic: Goðadrottning
Indonesia: Bunga Anyelir
Italian: Dianto, Garofano, Garofano Coltivato
Japanese: Oranda-Nadeshiko
Malaysia: Bunga Teluki
Norwegian: Hagenellik
Polish: Goździk Ogrodowy
Portuguese: Craveiro, Cravelinha, Cravina, Cravo, Cravina-Dos-Jardins
Russian: Gvozdika Gollandskaja, Gvozdika Sadovaja
Slovaščina: Vrtni Nageljček
Slovencina: Klinček Záhradný

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Spanish: Clavel, Clavel Canario, Clavel Común, Claveles, Clavelina
Swedish: Trädgårdsnejlika
Turkish: Bahçe Karanfili, Karanfil Familyasından Çiçek
Vietnamese: Cẩm Chướng Thơm, Cẩm Nhung, Hương Nhung Hoa
Welsh: Ceinan Gwyllt, Clows, Penigan Pêr, Penigan Rhuddgoch

Origin/Distribution

Carnation is probably indigenous to the Mediterranean region, but its exact range is unknown due to extensive cultivation for the last 2,000 years.

Agroecology

Carnation is a cool climate crop. Carnation is a heliophilous and a facultative long-day plant. Temperature, light intensity and day length affect carnation growth. Optimum growth has been reported in location of high light intensity during winter and cool temperatures during summers. During summer, the optimum temperature for achieving good plant growth and flowers is between 13 and 15 °C, while during winter a relatively lower temperature 10–11.1 °C is preferred; carnation is not frost tender. Hot dry wind during summer months is very detrimental for the growth and development of plants.

A well-drained, rich sandy-loam or loamy sand soil is considered to be the most ideal for successful production of carnation. Soils with higher amount of clays or silt should be amended by incorporating organic matter or compost. The optimum soil pH is between 6.0 and 7.0.

Edible Plant Parts and Uses

Petals are edible (Facciola 1990; Barash 1993; Creasey 1999; Roberts 2000; Brown 2011; Rop et al. 2012). The flower petals have a strong smell of cloves and are candied and used as a garnish in salads, for flavouring fruit, fruit salads, soups, punch bowl, etc. They can also be used as a substitute for rose petals in making a syrup. The petals should be removed from the calyx, and their bitter white base should be removed.

Botany

An herbaceous perennial plant growing to 50–80 cm tall with erect, branching herbaceous stem that is woody at the base. Leaves are opposite, glaucous, lanceolate to linear lanceolate 10–15 cm long (Plate 1). Flowers solitary or in few-flowered cymes, sweetly scented, bisexual, 3.5–6 cm diameter, single flowers with 5 petals, double flowers with 10–40 petals, peduncle with swollen nodes. Calyx with four leafy ovate bracteoles at the base, gamosepalous, cylindric and five dentate. Petals obovate or broadly cuneate, clawed or serrated, red, purple, orange, pink, white, yellow and green, spotted or variegated (Plates 1, 2, 3 and 4). Stamens 10 in two whorls, ovary one celled, styles two. Capsule with many seeds.

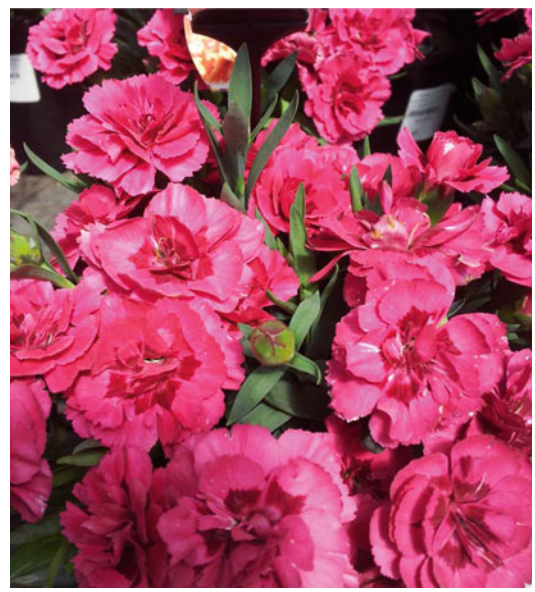

Plate 1 Red carnations and leaves

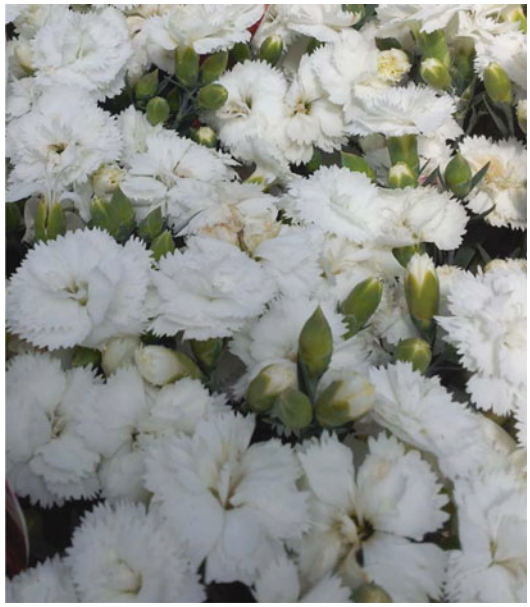

Plate 2 White carnations

Plate 3 Purple carnations cv. Moondust

Plate 4 Variegated carnations

Nutritive/Medicinal Properties

Flower Nutrients and Phytochemicals

Rop et al. (2012) reported that edible flowers of *Dianthus caryophyllus* had a dry matter content (%w/w) of 11.55 %, crude protein of 6.89 g/kg and the following elements (mg/kg fresh mass (FM)): P 531.35 mg, K 3544.81 mg, Ca 491.89 mg, Mg 186.55 mg, Na 114.29 mg, Fe 9.85 mg, Mn 7.49 mg, Cu 2.88 mg, Zn 7.17 mg and Mo 0.55 mg. The flowers had total antioxidant capacity of 6.96 g ascorbic acid equivalents/kg FM, total phenolic content of 5.28 g gallic acid/kg FM and total flavonoid content of 2.27 g rutin/kg FM.

Cytosolic lipid-protein particles containing phospholipid as well as the same fatty acids were found in microsomal membranes of carnation petals (Hudak and Thompson 1997). The lipid-protein particles were also enriched in hexanal, *trans*-2-hexenal, 1-hexanol, 3-hexen-1-ol and 2-hexanol, volatiles of carnation flower fragrance that were derived from membrane fatty acids through the lipoxygenase pathway.

The flower scent volatiles of flowering carnations were differentiated by the proportion of eugenol (trace-84.1 %) and methyl salicylate (0.1–1.4 %) (Clery et al. 1999). Some modern varieties produce low levels of eugenol but higher levels of benzoic acid derivatives (methyl benzoate and benzyl benzoate) and the sesquiterpene β-caryophyllene (Clery et al. 1999; Lavy et al. 2002). At the petal emerging from the bud stage (6 days before anthesis), only five scent volatiles (μg/g) were detected in carnation cv. Eilat-detached petal extract, dominated by *p*-vinylphenol (65.5 μg) and 4-vinyl guaiacol (10 μg); the remaining volatiles included maltol (5.4 μg), guaiacol (1.1 μg) and *cis*-3-hexenylbenzoate (0.1 μg) (Lavy et al. 2002). At the mature flower opened stage (anthesis), benzoic acid (40 μg) and its derivatives, benzyl benzoate (19.7 μg) and phenylethyl benzoate (13.4 μg), predominated 4-vinyl guaiacol (16.8 μg) and *p*-vinylphenol (21.6 μg) and were

still high but the latter less than in the young flower stage. Other scent volatiles (μg/g) detected included *cis*-3-hexenyl benzoate (6.5 μg), benzyl salicylate (2.8 μg), hexyl benzoate (0.6 μg), vanillic acid (4.3 μg), methyl homovanillate (3.1 μg), coumaric acid (3.9 μg), guaiacol (1.1 μg), nonanal (1.7 μg) maltol (0.8 μg), nonanoic acid (0.6 μg) and the sesquiterpene β-caryophyllene oxide (0.8 μg). No monoterpenes were detected. The profile of the major scent volatiles in carnation flower headspace was different. The young flower contained *cis*-3-hexenyl acetate (82.3 %), 3-hexen-1-ol (9.9 %), *cis*-3-hexenyl tiglate (2.2 %),1-hexyl acetate (0.5 %), methyl benzoate (0.2 %), nonanal (1.6 %), decanal (0.4 %), *cis-3*-hexenyl isovalerate (0.3 %), β-caryophyllene (1 %) and *cis*-3-hexenyl benzoate (0.8 %). The mature opened flower contained β-caryophyllene (23.4 %), *cis*-3-hexenyl acetate (19.6 %), methyl benzoate (17.9 %), *cis*-3-hexenyl benzoate (16.8 %), 3-hexen-1-ol (1.3 %), *cis*-3-hexenyl tiglate (1.0 %),1-hexyl acetate (0.6 %), nonanal (0.4 %), decanal (0.5 %), *cis*-3-hexenyl isovalerate (0.3 %), phenylacetaldehyde (1.3 %), 2-hydroxy methyl benzoate (0.6 %), pentyl benzoate (0.4 %), hexyl benzoate (3.5 %), caryophyllene oxide (5.6 %), benzyl benzoate (1.7 %) and isoamyl salicylate (2.6 %). Transgenic plants expressing the linalool synthase gene from *Clarkia breweri* were generated, and from their leaves and flowers, linalool and its derivatives, *cis*- and *trans*-linalool oxide, were detected.

In an another study, 12 volatiles were identified as the main components of carnation flower fragrance signature (El-Ghorab et al. 2006). The major components of the volatiles found were phenyl ethyl alcohol, eugenol, hexyl benzoate, hexenyl benzoate (z), benzyl benzoate, benzoin, nootkatone, benzyl salicylate, m-cresyl phenyl acetate, hexadecanoic acid and eicosane.

Anthocyanin flower pigments of carnations had been reported for some pink, red, red-purple and mauve cultivars. Pelargonidin 3-*O*-glycoside was found in salmon and red cultivars, pelargonidin 3,5-di-*O*-glycoside in pink, cyanidin 3-*O*-glycoside in lavender and crimson and cyanidin 3,5-di-*O*-glycoside in lavender and magenta ones (Geissman and mehlquist 1947; Geissman et al. 1955). Cyanic carnation flowers (reds and pinks) that contained the factor *R* in homozygous or heterozygous conditioned were found to contain cyanidin glycosides; the homozygous recessive *rr* contained pelargonidin derivatives (Geissman et al. 1962). Kaempferol was clearly visible in all the red and pink genotypes and quercetin absent from these but visible in the Woburn sample. All the acyanic white genotypes contained kaempferol, but only one contained quercetin as well. Apigenin was not observed in these whites. Isosalipurposide was identified as the yellow pigment in carnation petals (Harborne 1966). Carnation genotypes with recessive (ii) alleles were found to produce yellow flowers, which contained the chalcone isosalipurposide (naringenin-chalcone-2′-glucoside) as the major petal pigment in the vacuole (Forkmann and Dangelmayr 1980). This naringenin-chalcone was the first product of the synthesis of the flavonoid skeleton and that only the conversion of naringenin-chalcone to naringenin furnishing the substrate for the further reactions to flavonol and anthocyanin. Based on the analysis of pigment composition, Onozaki et al. (1999) classified 13 white cultivars into three types: nearly pure white cultivar, ‘White Mind’ lacking flavonoid compounds in the petals, ‘Kaly’ and ‘White Barbara’ accumulating a large amount of naringenin derivatives and the normal white cultivars containing kaempferol derivatives as the major flavonoid. Ogata et al. (2004) reported that chalcone, which was synthesized from the condensation of *p*-coumaroyl-CoA and malonyl-CoAs by chalcone synthase, was converted to chalcone 2′-*O*-glucoside by UDP-Glc: chalcone glucosyltransferase (chalcone 2 -GT). Chalcone 2′-*O*-glucoside could then be transported and accumulated into vacuoles.

Incubation of crude extracts prepared from pink, magenta or white carnation flowering genotype with [2-^{14}C]malonyl-CoA and 4-coumaroyl-CoA and co-chromatography on cellulose TLC plates with different solvent systems and enzymatic conversion yielded naringenin, naringenin chalcone, eriodictyol, eriodictyol chalcone, dihydrokaempferol and

dihydroquercetin (Spribille and Forkmann 1982). In carnation genotypes with wild-type alleles (R), 4′- and 3′,4′-hydroxylated flavonoids were formed. Independent of the genetic state at the locus r, however, naringenin chalcone T-glucoside (isosalipurposide) was the only chalcone present in the flowers of genotypes which lack chalcone isomerase activity. Eriodictyol chalcone 2′-glucoside was not detected in either the flowers of genotypes with the dominant allele R or in the flowers of recessive (rr) genotypes. 3′-Hydroxylase activity could be readily detected in the flower extracts of all genotypes with the wild-type allele R but was completely deficient in the flower extracts of recessive (rr) genotypes. The gene r is known to control the hydroxylation pattern of the B-ring of anthocyanins. Recessive genotypes (rr) produced pelargonidin derivatives in the flowers, whereas cyanidin was formed under the influence of wild-type alleles R. The gene i is known to control the activity of chalcone isomerase Recessive genotypes (ii) lacked chalcone isomerase activity, and therefore, naringenin chalcone 2′-glucoside (isosalipurposide) was accumulated. In contrast chalcone isomerase activity being present in genotypes with the wild-type allele, higher oxidized flavonoids, including anthocyanins, were synthesized. The gene a interferes with the anthocyanin pathway after dihydroflavonol formation but before anthocyanin synthesis. Recessive genotypes (aa) produced white flowers containing flavonols. Thus, six carnation genotypes were established based on chemogenetic and enzymatic characteristics (Spribille and Forkmann 1982):

(a) IIAARR with magenta flower, producing cyanidin, isomerase and 3′-hydroxylase activities present
(b) IIAArr pink flower, producing pelargonidin derivatives, isomerase activity present, 3′-hydroxylase activity absent
(c) IIaarr with white flower producing kaempferol, isomerase activity present, 3′-hydroxylase activity absent
(d) iiAARR yellow-magenta flower producing isosalipurposide (naringenin chalcone 2′-glucoside) some cyanidin, isomerase activity absent, 3′-hydroxylase activity present
(e) iiAArr yellow-pink flower producing isosalipurposide some pelargonidin, isomerase and 3′-hydroxylase absent
(f) iiaarr pure yellow flower producing isosalipurposide some kaempferol, isomerase and 3′-hydroxylase absent

Malylated anthocyanins from carnation *Dianthus caryophyllus* flowers were confirmed as pelargonidin3-*O*-(6-*O*-malyl-β-D-glucopyranoside) from red cv. 'Scania' and cyanidin 3-*O*-(6-*O*-malyl-β-D-glucopyranoside) from the purplish-red 'Nina' (Terahara and Yamaguchi 1986; Yamaguchi et al. 1988). The major anthocyanin in pink and red forms of *Dianthus caryophyllus* was identified as pelargonidin 3-malylglucoside (Terahara et al. 1986). Flowers of the red\mauve carnation cultivars 'Kortina Chanel' and 'Purple Torres' contained a macrocyclic anthocyanin pigment, a malylated cyanidin 3,5-diglucoside that readily converted by ring opening to yield cyanidin 3-*O*-(6-*O*-malyl glucoside)-5-*O*-glucoside (Bloor 1998). Cyclic-malyl anthocyanins 3, 5-di-*O*-(β-glucopyranosyl) pelargonidin 6″-*O*-4, 6‴-*O*-L-cyclic malate and a 3, 5-di-*O*-(β-glucopyranosyl) cyanidin 6″-*O*-4, 6‴-*O*-L-cyclic malate were identified from petals of deep pink and red-purple flower cultivars of *Dianthus caryophyllus*, respectively (Nakayama et al. 2000). White-flowered Sim carnations were found to contain mainly flavonol glycosides: kaempferol glycosides and naringenin glycosides and the genes dihydroflavonol 4-reductase and anthocyanidin synthase involved in flavonoid biosynthesis (Mato et al. 2000). A new macrocyclic anthocyanin, pelargonidin 3,5-di-*O*-β-glucoside(6″, 6‴-malyl diester), and 3-*O*-(6″-*O*-malylglucoside)-5-*O*-glucoside were found in 'cyclamen' red (or pink) colours in carnation flowers–cultivars Red Rox and eight others (Gonnet and Fenet 2000). Characterization of anthocyanins in the flowers of the modern carnation cv Eilat revealed that only the orange pelargonidin accumulated, due to a lack of both flavonoid 3′,5′-hydroxylase and flavonoid3′-hydroxylase activities (Zuker et al. 2002).

Wild-type carnations with a flavonoid 3′,5′-hydroxylase gene were found to contain pelargonidin- or cyanidin-type anthocyanins, such as pelargonidin or cyanidin 3,5-diglucoside-6″-*O*-4, 6‴-*O*-L-cyclic-malyl diester (Fukui et al.

2003). In contrast, the anthocyanins in the transgenic flowers of cv Moondust and Moonshadow were delphinidin 3,5-diglucoside-6″-*O*-4, 6‴-*O*-L-cyclic-malyl diester (main pigment), delphinidin 3,5-diglucoside-6″-malyl ester and delphinidin 3,5-diglucoside-6″,6‴-dimalyl ester. Additionally, the petals contained flavonol and flavone glycosides. Three of them were identified to be kaempferol 3-*O*-(6‴-rhamnosyl-2‴-glucosyl-glucoside), kaempferol 3-*O*-(6‴-rhamnosyl-2‴-(6-malyl-glucosyl)-glucoside) and apigenin 6-C-glucosyl-7-*O*-glucoside-6‴-malyl ester. This flavonoid exhibited the strongest copigment effect. Chalcononaringenin 2′-*O*-glucoside (Ch2′G) was found to be the major pigment molecule in the petals of carnations bearing yellow flowers (Yoshida et al. 2004). The concentration of this pigment varied from 5.5 to 100.0 %.

Transcription of the following genes was found in the yellow flowers: anthocyanidin synthase, anthocyanin acyltransferase, chalcone 2′-glucosyltransferase, chalcone–flavanone isomerase, chalcone synthase, dihydroflavonol 4-reductase, flavanone 3-hydroxylase, UDP-glucose:flavonoid glucosyltransferase and phenylalanine ammonia-lyase. The activity of flavanone 3β-hydroxylase gene (FHT) was demonstrated in carnation flowers (Dedio et al. 1995). A phenylalanine ammonia-lyase (PAL) cDNA clone was isolated from carnation petals (Yoshimoto et al. 2001). The yellow colour of the carnation petals was attributed to the synthesis and accumulation of chalcone 2′-glucoside (Itoh et al. 2002). In several of the carnation cultivars that bear yellow flowers variegated with white flecks and sectors, both the chalcone isomerase (*CHI*) and dihydroflavonol 4-reductase (*DFR*) genes were disrupted by a transposable element *dTdic1*. Glucosylation of anthocyanin in carnations was found to involve novel sugar donors, aromatic acyl-glucoses, in a reaction catalyzed by the enzymes acyl-glucose-dependent anthocyanin 5(7)-*O*-glucosyltransferase (AA5GT and AA7GT) (Matsuba et al. 2010).

An acyl donor substance of anthocyanin malyltransferase, 1-*O*-β-D-malylglucose, was extracted and partially purified from carnation petals (Abe et al. 2008). This was synthesized chemically to analyse AMalT activity in a crude extract from carnation. Changes in the AMalT activity showed close correlation to the accumulation of pelargonidin 3-malylglucoside (Pel 3-malGlc) during the development of red petals of carnation, but neither AMalT activity nor Pel 3-malGlc accumulation was detectable in roots, stems and leaves.

Three flavonol glycosides were isolated from the flowers of carnation cultivars ‘White Wink’ and ‘Honey Moon’ and their structures established as kaempferol 3-*O*-neohesperidoside, kaempferol 3-*O*-sophoroside and kaempferol 3-*O*-glucosyl-(1 → 2)-[rhamnosyl-(1 → 6)-glucoside] (Iwashina et al. 2010).

Leaf/Plant Phytochemicals

Dianthin 30 and dianthin 32, two proteins with molecular weights 29,500 and 31,700, respectively, were isolated from the leaves of *Dianthus caryophyllus* (carnation) (Stirpe et al. 1981). Both dianthins were glycoproteins containing mannose. Three gypsogenic acid glycosides including 3-*O*-β-D-glucopyranoside of gypsogenic acid with the trivial name diantoside A, 3,28-*O*-diglucopyranoside of gypsogenic acid with the trivial name dianoside A and 3-*O*-glucopyranosy1,28-*O*-[glucopyranosyl(1 → 6)] glucopyranoside with the trivial name azukisaponin IV were isolated from aerial parts of carnation (*Dianthus caryophyllus* var. remontant) (Gumnicka and Oleszek 1998). *Lepidium sativum* seedling root growth was affected severely at the presence of gypsogenic acid 3-*O*-glucopyranoside. Bidesmosidic form showed marginal stimulatory activity.

Two benzoic acid derivatives, protocatechuic acid (3,4-dihydroxybenzoic acid) and vanillic acid (4-hydroxy-3-methoxybenzoic acid), and together with the flavonol glycoside peltatoside (3-[6-*O*-(α-L-arabinopyranosyl)-β-D-glucopyranosyl] quercetin) were found within healthy and fungal-inoculated tissues of carnation cultivars (Curir et al. 2003a). 2,6-Dimethoxybenzoic acid was detected in small amounts only in the inoculated cultivar ‘Gloriana’, while the highly resistant cultivar ‘Roland’ showed the presence of the flavone datiscetin (3,5,7,2′-tetrahydroxyflavone).

A new enzyme, *S*-adenosyl-L-methionine:flavonoid 4′-*O*-methyltransferase (F 4′-OMT), has been purified 1,399-fold from carnation tissues (Curir et al. 2003b). Arginine decarboxylase (ADC), a key enzyme in the biosynthesis of polyamines, comprising 725 amino acids with a molecular mass of 78 kDa was found in carnation (Ha et al. 2004).

Flavonoids, kaempferol 3-*O*-β-D-glucopyranosyl (1→2)-*O*-β-D-glucopyranosyl (1→2)-*O*-[α-L-rhamnopyranosyl-(1→6)]-β-D-glucopyranoside; apigenin 6,8-di-C-β-D-glucopyranoside; kaempferol 3-*O*-β-D-glucopyranosyl (1→2) –*O*-[α-L-rhamnopyranosyl-(1→6)]-β-D-glucopyranoside; kaempferol *O*-diglycosides; and rutin, were isolated from carnation (*Dianthus caryophyllus*) (Galeotti et al. 2008a). One flavone-C-glycoside apigenin 6,8-di-C-β-D-glucopyranoside (vicenin-2) and two flavonol-*O*-glycosides kaempferol 3-*O*-β-D-glucopyranosyl-(1 → 2)-*O*-[α-L-rhamnopyranosyl-(1→6)]-β-D-glucopyranoside and kaempferol 3-*O*-[α-l-rhamnopyranosyl-(1→6)]-β-D-glucopyranoside (nicotiflorin) isolated as the main flavonoidal components in nine different carnation cultivars (Galeotti et al. 2008b).

Yang et al. (1997) reported that benzoyl-CoA:anthranilate *N*-benzoyltransferase catalyzed the first committed reaction of phytoalexin biosynthesis in carnation, and the product *N*-benzoylanthranilate was found to be the precursor of several sets of dianthramides. Cell suspension cultures of *Dianthus caryophyllus* was found to accumulate, upon challenge with crude fungal elicitor, various dianthramide phytoalexins, all of which were derived from *N*-benzoylanthranilate (Reinhard and Matern 1991). In-vitro, microsomes from the elicited carnation cells hydroxylated *N*-benzoylanthranilate to yield the hydroxyanthranilate and/or salicyloyl derivatives, and both these activities depended strictly on NADPH and molecular oxygen. 2′-Hydroxylation was shown to precede 4-hydroxylation in the formation of *N*-salicyloyl-4-hydroxyanthranilate. 4-Hydroxylation was shown to be catalyzed by cytochrome P-450-dependent monooxygenase(s), whereas the 2′-hydroxylating activity appeared to be due to a novel class of enzymes, also responding synergistically to NADH in combination with NADPH and showing apparent inhibition by cytochrome c but not by carbon monoxide. The results demonstrated the requirement of two different classes of hydroxylase activities that appeared to introduce the antimycotic quality to the dianthramides for phytoalexin defence. Further, they proposed that methoxydianthramide B was derived from *N*-benzoylanthranilic acid via *N*-benzoyl-4-hydroxyanthranilic acid catalyzed by increases in *N*-benzoyltransferase and phenylalanine ammonia-lyase activities (Reinhard and Matern 1989). The rapid induction of both enzyme activities suggested that the shikimate pathway was of crucial importance in the disease-resistance response of carnation cells.

Antioxidant Activity

Treating carnation plants with 400 ppm stigmasterol gave the highest DPPH scavenging of the oil compared to other treatments (El-Ghorab et al. 2006).

Antimicrobial Activity

Two known compounds were isolated from the essential oils of aerial parts of *Thymus kotschyanus*, and flower buds of *Dianthus caryophyllus* exhibited antibacterial activity (Mohammed and Al-Bayati 2009). Thymol MIC values ranged from 15.6 to 250 μg/ml, and *Bacillus cereus* was found to be the most sensitive pathogen with an MIC value of 15.6 μg/ml. Eugenol achieved stronger MIC values against most tested pathogens, and the best MIC value (15.6 μg/ml) was observed against *Bacillus cereus*, *Listeria monocytogenes* and *Klebsiella pneumoniae*, whereas *Staphylococcus aureus*, *Proteus mirabilis* and *Escherichia coli* were inhibited with an MIC value of 31.2 μg/ml.

Antiviral Activity

The virus inhibitor from carnation was found to compose of probably ϵ-groups of lysine that were

responsible for the biological activity of the molecule (Ragetli and Weintraub 1962). Acid hydrolysis yielded 14 amino acids, none of which contained sulphur. The inhibitor, which had already been found to protect *Nicotiana glutinosa* from infection by either intact tobacco mosaic virus (TMV) or the infectious nucleic acid (RNA) derived from it, was shown to possess no ribonuclease (RNase) activity and to be unable to prevent enzymatic breakdown of RNA by pancreatic RNase.

Dianthin 30 and dianthin 32, two antiviral proteins isolated from the leaves, inhibited protein synthesis in a lysate of rabbit reticulocytes, with an ID_{50} (concentration giving 50 % inhibition) of 9.15 ng/ml (dianthin 30) and 3.6 ng/ml (dianthin 32) (Stirpe et al. 1981). They acted by damaging ribosomes in a less-than-equimolar ratio. Protein synthesis by intact cells was partially inhibited by dianthins at a concentration of 100 μg/ml. Dianthins mixed with tobacco mosaic virus strongly decreased the number of local lesions on leaves of *Nicotiana glutinosa*.

Nontoxic concentration (20 μg/ml) of *Dianthus caryophyllus* seed extracts applied to both Vero and HepG2 cells showed potent antiviral activity against herpes simplex virus (HSV-1) and hepatitis A virus (HAV-27) using plaque infectivity count assay (Barakat et al. 2010). *D. caryophyllus* exhibited strong virucidal activity against HSV-1 and HAV-27, 92.3 and 92.6 %, respectively.

Anticancer Activity

In in-vitro studies, kaempferide triglycoside, a glycosylated flavonol from carnation, inhibited proliferation of native and oestrogen receptor beta overexpressing HTC8 colon cancer cells through a mechanism not mediated by ligand binding dependent oestrogen receptor activation (Martineti et al. 2010). It arrested G0/G1 phase of HCT8 cell-cycle progression. The biological effects of this kaempferide triglycoside were strengthened by the presence of high levels of oestrogen receptor beta.

Parasitic Activity

The essential oil of *D. caryophyllus* exhibited moderate larvicidal activity, displaying an $LC_{50} > 50$ mg/l against the West Nile vector *Culex pipiens* (Kimbaris et al. 2012). Its component eugenol had an LC_{50} of 18.28 mg/l.

Traditional Medicinal Uses

Carnation has been prescribed in European traditional herbal medicine to treat coronary and nervous disorders (Chevallier 1996). It is an aromatic, stimulant herb that has been used in tonic cordials in the past to treat fevers, though this use is now obsolete (Bown 1995). The flowers are reared to be alexiteric, antispasmodic, cardiotonic, diaphoretic and nervine and used as a vermifuge (Chopra et al. 1986).

Other Uses

Carnation is a very popular ornamental and cut-flower crop. Carnations are be cultivated the world over for cut flowers. It has excellent postharvest quality, a wide array of forms and colours, capacity to withstand long-distance transportation and a remarkable ability to rehydrate; the carnations are preferred for commercial purpose than other flowers by growers.

An essential oil obtained from the flowers is used in perfumery (Hill 1952; Uphof 1968). The flower heads are dried and used in potpourri, scented sachets and cosmetic products (Bown 1995). The leaves can be simmered in water, and this water can then be used as a soap for cleaning the skin, clothes, etc. (Allardice 1993).

The plant also has antifungal activity. Flavonoid glycosides isolated from carnation exhibited antifungal activity against different *Fusarium oxysporum* f.sp. *dianthi* pathotypes (Galeotti et al. 2008a). Two benzoic acid derivatives, protocatechuic acid and vanillic acid; the flavonol glycoside peltatoside; and 2,6-dimethoxybenzoic acid, from carnation plant tissues, exhibited weak inhibitory activity

towards the phytopathogen, *Fusarium oxysporum* f. sp. *dianthi*, while the flavone datiscetin exhibited an appreciable fungitoxic activity towards the pathogen (Curir et al. 2003a).

Comments

Colombia is the largest carnation producer in the world; other leading producers include Israel, Kenya and Spain where carnation is the national flower (Perry 2001).

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