

Flavonoid Properties of five Families newly Incorporated into the Order Caryophyllales (Review)

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Abstract Five families, Tamaricaceae, Plumbaginaceae, Polygonaceae, Droseraceae and Nepenthaceae, were newly incorporated into the order Caryophyllales by APG. Nine families of original Caryophyllales, i.e. Phytolaccaceae including Acanthocarpaceae, Nyctaginaceae, Aizoaceae, Didiereaceae, Cactaceae, Chenopodiaceae, Amaranthaceae, Portulacaceae and Basellaceae, synthesize betalain pigments but not anthocyanins. However, other flavonoid classes can make in the flowers, leaves, stems, fruits and so on. In this paper, the flavonoid properties of the five families which were newly incorporated into the Caryophyllales are reviewed. As the results, anthocyanins have been reported from their families, together with other flavonoid classes, flavones, flavonols, C-glycosylflavones, flavan and proanthocyanidins, and rarely chalcones, aurones, flavanones and dihydroflavonols, except for the family Nepenthaceae.

Key words: APG, Caryophyllales, Droseraceae, flavonoids, Plumbaginaceae, Polygonaceae, Nepenthaceae, Tamaricaceae.

Introduction

Red to purple pigments in the colored flowers, fruits, leaves, stems and sometimes roots and seeds of the vascular plants are anthocyanins. However, the pigments in nine families of the order Caryophyllales, i.e. Phytolaccaceae including Acanthocarpaceae, Nyctaginaceae, Aizoaceae, Didiereaceae, Cactaceae, Chenopodiaceae, Amaranthaceae, Portulacaceae and Basellaceae, are betalain pigments, red purple betacyanins and yellow betaxanthins (Clement *et al.*, 1994; Piatelli and Minale, 1964), and they are completely absent the anthocyanins. Though the Molluginaceae and Caryophyllaceae also belong to the Caryophyllales (Cronquist, 1981), their families synthesize the anthocyanins but not betalains. Other flavonoids such as flavones, flavonols, flavanones, chalcones, aurones and so on have been reported from the betalain families as major compounds (Iwashina, 2001). Recently, five fam-

ilies, i.e. Tamaricaceae, Plumbaginaceae, Polygonaceae, Droseraceae and Nepenthaceae, were incorporated into the order Caryophyllales by Angiosperm Phylogeny Group (APG). In this paper, the flavonoid properties of their five families, which were newly admitted to the Caryophyllales, are reviewed.

Flavonoids of Tamaricaceae

The family Tamaricaceae consists of ca. 120 species of 4 genera and chiefly temperate and subtropical, growing in maritime or sandy places in Norway and from the Mediterranean North Africa and south-eastern Europe through central Asia to India and China, and southwestern Africa (Heywood, 1978).

Flavonoids of the Tamaricaceae have been reported to 26 taxa of 3 genera (Table 1). Major flavonoid class is flavonol and found in all species except for three species, *Tamarix pariflora*, *T.*

Table 1. Reports of the flavonoids from the family Tamaricaceae

Species
Flavonoids
<i>Myricaria alopecuroides</i>
Flavonol: Quercetin, Rhamnazin, Rhamnetin (lv) (Chumbalov <i>et al.</i> , 1975)
<i>Myricaria bracteata</i>
Flavone: Chrysoeriol (wp) (Zhou <i>et al.</i> , 2006); Flavonol: Kaempferol, Quercetin, Quercetin 3- <i>O</i> -rhamnoside, Rhamnazin, Rhamnetin, Rhamnocitrin (wp) (Zhou <i>et al.</i> , 2006)
<i>Myricaria germanica</i>
Flavonol: Kaempferol 3-sulphate, Kaempferol 7-sulphate, Quercetin, Quercetin 3-sulphate, Quercetin 7-sulphate (lv) (Harborne, 1975), Kaempferol (lv, tw) (Harborne, 1975; La <i>et al.</i> , 2011), Kaempferide, Kaempferol 3- <i>O</i> -glucuronide, Kaempferol 3- <i>O</i> -rhamnoside, Quercetin 3- <i>O</i> -glucoside, Quercetin 3- <i>O</i> -rhamnoside, Quercetin 3- <i>O</i> -glucuronide, Rhamnetin, Rhamnocitrin, Tamarixetin (tw) (La <i>et al.</i> , 2011)
<i>Reaumuria mucronata</i>
Flavonol: Kaempferol 3,7-disulphate (lv) (Nawwar <i>et al.</i> , 1977)
<i>Reaumuria soongarica</i>
Flavonol: Isorhamnetin 7- <i>O</i> -rhamnoside, Kaempferol 3- <i>O</i> -diglucoside, Quercetin 7- <i>O</i> -arabinoside, Quercetin 3- <i>O</i> -glucoside, Quercetin 3- <i>O</i> -glucuronide, Quercetin 3-methyl ether, Quercetin 3-methyl ether 7- <i>O</i> -glucoside, Quercetin 3-methyl ether 4'- <i>O</i> -glucoside, Quercetin 7- <i>O</i> -rhamnoside, Quercetin 3- <i>O</i> -rutinoside (ap) (Iwashina <i>et al.</i> , 2012)
<i>Tamarix africana</i>
Flavonol: Kaempferol, Kaempferol 3-sulphate, Kaempferol 7-sulphate, Quercetin, Quercetin 3-sulphate, Quercetin 7-sulphate (lv) (Harborne, 1975), Kaempferide 3-sulphate, Tamarixetin 3-sulphate (bk) (Tomás-Barberán <i>et al.</i> , 1990)
<i>Tamarix aphylla</i>
Flavonol: Quercetin 3- <i>O</i> -glucoside (lv, gl) (Chakrabarty <i>et al.</i> , 1965; Ishak <i>et al.</i> , 1972), Tamarixetin 3- <i>O</i> -glucoside (lv) (Chakrabarty <i>et al.</i> , 1965); Quercetin (gl, lv, fl) (Chakrabarty <i>et al.</i> , 1965; Ishak <i>et al.</i> , 1972; Harborne, 1975; Nawwar <i>et al.</i> , 1975), Tamarixetin (gl) (Ishak <i>et al.</i> , 1972), Kaempferol, Kaempferol 3-sulphate, Kaempferol 7-sulphate, Quercetin 3-sulphate, Quercetin 7-sulphate (lv) (Harborne, 1975), Kaempferol 7,4'-dimethyl ether, Quercetin 3- <i>O</i> -rhamnoside, Rhamnetin, Rhamnocitrin, Rhamnocitrin 3- <i>O</i> -glucoside, Rhamnocitrin 3- <i>O</i> -rhamnoside (fl) (Nawwar <i>et al.</i> , 1975), Rhamnetin 3'- <i>O</i> -glucuronide-3,5,4'-trisulphate (lv) (Saleh <i>et al.</i> , 1975), Kaempferol 7,4'-dimethyl ether 3-sulphate, Quercetin 3- <i>O</i> -(isoferuloyl)glucuronide (fl) (El Ansari <i>et al.</i> , 1976)
<i>Tamarix aplexicaulis</i>
Flavonol: Quercetin 3- <i>O</i> -glucoside, Quercetin 3-sulphate (ap) (Umbetova <i>et al.</i> , 2005)
<i>Tamarix bobeana</i>
Flavonol: Kaempferide 3-sulphate, Tamarixetin 3-sulphate (bk) (Tomás-Barberán <i>et al.</i> , 1990)
<i>Tamarix canariensis</i>
Flavonol: Kaempferol, Kaempferol 3-sulphate, Kaempferol 7-sulphate, Quercetin, Quercetin 3-sulphate, Quercetin 7-sulphate (lv) (Harborne, 1975)
<i>Tamarix chinensis</i>
Flavone: Apigenin 7,4'-dimethyl ether (tw) (Wang <i>et al.</i> , 2009); Flavonol: Dillenetin, Kaempferide, Kaempferol, Kaempferol 7,4'-dimethyl ether, Quercetin, Rhamnocitrin (tw) (Wang <i>et al.</i> , 2009)
<i>Tamarix dioica</i>
Flavone: Apigenin, Gardenin A, Gardenin B, Gardenin C, Gardenin E, Nevadensin, Tamadone, Tamaridone (ap) (Parmar <i>et al.</i> , 1994); Flavonol: Kaempferide, Tamarixetin (lv) (Bahl <i>et al.</i> , 1967), Isorhamnetin (lv) (Khan <i>et al.</i> , 1979)
<i>Tamarix elongata</i>
Flavone: Chrysoeriol (tw) (Umbetova <i>et al.</i> , 2004), Luteolin 5-methyl ether (Umbetova <i>et al.</i> , 2005); Flavonol: Isorhamnetin, Quercetin, Tamarixetin, Tamarixetin 3-sulphate (tw) (Umbetova <i>et al.</i> , 2004), Dillenetin, Isorhamnetin 3- <i>O</i> -glucoside, Isorhamnetin 3-sulphate, Kaempferol 5-methyl ether, Kaempferol 3- <i>O</i> -glucoside, Quercetin 3- <i>O</i> -glucoside, Quercetin 3-sulphate, Tamarixetin 3- <i>O</i> -rhamnoside (ap) (Umbetova <i>et al.</i> , 2005)
<i>Tamarix gallica</i>
Flavan and Proanthocyanidin: Procyanidin (lv) (Lebreton and Bouchez, 1967); Flavonol: Kaempferide (lv) (Lebreton and Bouchez, 1967), Kaempferol, Quercetin (lv) (Lebreton and Bouchez, 1967; Harborne, 1975), Kaempferol 3-sulphate, Kaempferol 7-sulphate, Quercetin 3-sulphate, Quercetin 7-sulphate (lv) (Harborne, 1975), Kaempferide 3-sulphate, Tamarixetin 3-sulphate (bk) (Tomás-Barberán <i>et al.</i> , 1990)
<i>Tamarix hispida</i> var. <i>aestivalis</i>
Flavonol: Kaempferol, Kaempferol 3-sulphate, Kaempferol 7-sulphate, Quercetin, Quercetin 3-sulphate, Quercetin 7-sulphate (lv) (Harborne, 1975)
<i>Tamarix hispida</i> var. <i>hispida</i>
Flavonol: Quercetin 3- <i>O</i> -glucoside, Quercetin 3-sulphate (ap) (Umbetova <i>et al.</i> , 2005)

Table 1. Continued

Species
Flavonoids
<i>Tamarix hokenakeri</i>
Flavonol: Kaempferide, Kaempferide 7-sinapolate, Kaempferol, Quercetin (tw) (Bikbulatova and Korul'kina, 2001)
<i>Tamarix laxa</i>
Flavone: Chrysoeriol (tw) (Umbetova <i>et al.</i> , 2004), Luteolin 5-methyl ether (ap) (Umbetova <i>et al.</i> , 2005); Flavonol: Isorhamnetin, Quercetin, Rhamnazin, Tamarixetin, Tamarixetin 3- <i>O</i> -arabinoside, Tamarixetin 3- <i>O</i> -glucoside, Tamarixetin 3-sulphate (tw) (Umbetova <i>et al.</i> , 2004), Dillenetin, Kaempferol 5-methyl ether, Kaempferol 3- <i>O</i> -glucoside, Isorhamnetin 3- <i>O</i> -glucoside, Isorhamnetin 3-sulphate, Quercetin 3- <i>O</i> -glucoside, Quercetin 3-sulphate, Tamarixetin 3- <i>O</i> -rhamnoside (ap) (Umbetova <i>et al.</i> , 2005)
<i>Tamarix nilotica</i>
Flavonol: Kaempferol 3- <i>O</i> -glucoside, Kaempferol 7,4'-dimethyl ether 3- <i>O</i> -glucoside, Quercetin 3- <i>O</i> -glucoside, Tamarixetin 3- <i>O</i> -glucoside (tw) (El Sissi <i>et al.</i> , 1973), Kaempferol 7,4'-dimethyl ether (tw, fl) (El Sissi <i>et al.</i> , 1973; Nawwar <i>et al.</i> , 1984), Kaempferol, Kaempferol 7,4'-dimethyl ether 3-sulphate, Kaempferol 3- <i>O</i> -glucuronide, Kaempferol 3- <i>O</i> -(glucuronide-6"-ethyl ester), Quercetin, Quercetin 3- <i>O</i> -glucuronide, Quercetin 3- <i>O</i> -(glucuronide-6"-ethyl ester), Quercetin 3- <i>O</i> -(glucuronide-6"-methyl ester) (fl) (Nawwar <i>et al.</i> , 1984)
<i>Tamarix parviflora</i>
Anthocyanin: Cyanidin 3- <i>O</i> -glycoside (fl) (Forsyth and Simmonds, 1954)
<i>Tamarix pentandra</i> var. <i>rubra</i>
Flavonol: Kaempferol, Kaempferol 3-sulphate, Kaempferol 7-sulphate, Quercetin, Quercetin 3-sulphate, Quercetin 7-sulphate (lv) (Harborne, 1975)
<i>Tamarix ramosissima</i>
Flavonol: Kaempferide, Kaempferide 7-sinapolate, Kaempferol, Quercetin (tw) (Bikbulatova and Korul'kina, 2001)
<i>Tamarix</i> sp.
Anthocyanin: Cyanidin glycoside, Delphinidin glycoside (fl) (Forsyth and Simmonds, 1954)
<i>Tamarix smyrnensis</i>
Flavonol: Kaempferol, Kaempferol 3-sulphate, Kaempferol 7-sulphate, Quercetin, Quercetin 3-sulphate, Quercetin 7-sulphate (lv) (Harborne, 1975)
<i>Tamarix tetrandra</i>
Anthocyanin: Cyanidin 3,5-di- <i>O</i> -glucoside, Cyanidin 3- <i>O</i> -glucoside (fl) (Scogin, 1977)
<i>Tamarix troupii</i>
Flavonol: Tamarixetin glycoside (lv) (Gupta and Seshadri, 1954), Tamarixetin, Tamarixetin 3- <i>O</i> -glucoside (lv) (Chakrabarty <i>et al.</i> , 1965)

ap = aerial parts, bk = barks, fl = flowers, gl = galls, lv = leaves, tw = twigs, wp = whole plants.

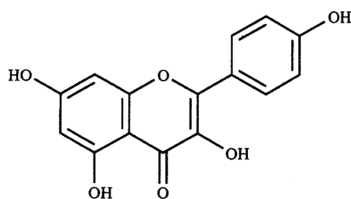


Fig. 1. Kaempferol.

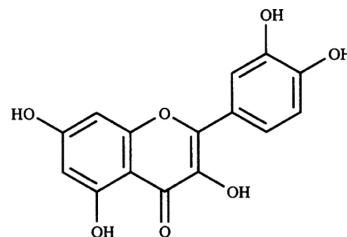


Fig. 2. Quercetin.

sp. and *T. tetrandra*. Common flavonols, kaempferol and quercetin, and methylated rhamnetin, rhamnazin, tamarixetin, kaempferide and dillene-
tin (Figs. 1–7) are reported from many species as aglycones and/or glycosides. Flavonol sulphates, e.g. quercetin 3-sulphate and 7-sulphate from *Myricaria germanica* and some *Tamarix* species

(Harborne, 1975), kaempferol 3,7-disulphate from *Reaumuria mucronata* (Nawwar *et al.*, 1977), kaempferol 3-sulphate and 7-sulphate, and kaempferide and tamarixetin 3-sulphates from *Tamarix africana* and *T. bobeana* (Tomás-Barberán *et al.*, 1990), rhamnetin 3'-glucuronide-

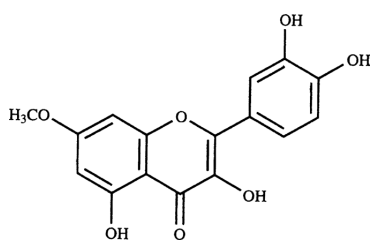


Fig. 3. Rhamnetin.

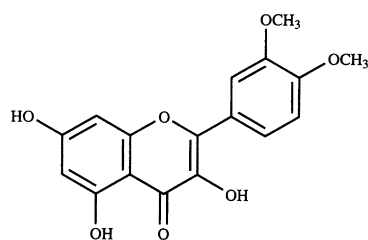


Fig. 7. Dillenetin.

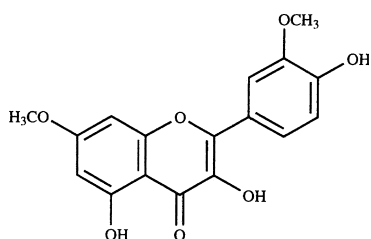


Fig. 4. Rhamnazin.

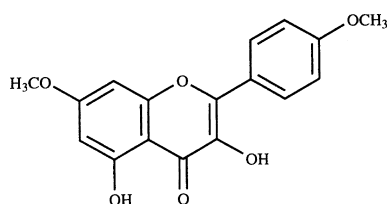


Fig. 8. Kaempferol 7,4'-dimethyl ether.

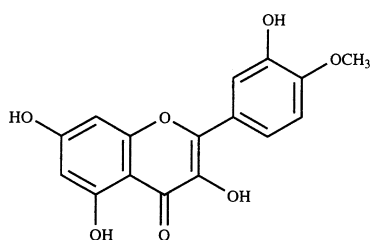


Fig. 5. Tamarixetin.

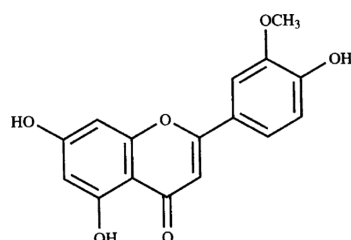


Fig. 9. Chrysoeriol.

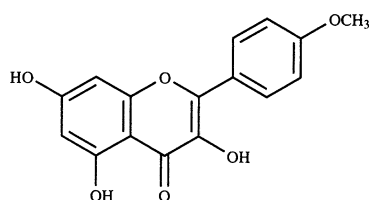


Fig. 6. Kaempferide.

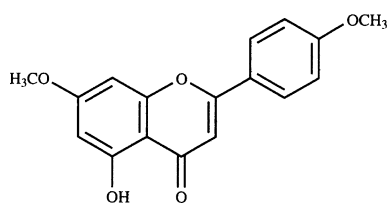


Fig. 10. Apigenin 7,4'-dimethyl ether.

3,5,4'-trisulphate and kaempferol 7,4'-dimethyl ether (Fig. 8) 3-sulphate from *Tamarix aphylla* (El Ansari *et al.*, 1976) and *T. nilotica* (Nawwar *et al.*, 1984), are found in many species as major compounds.

Flavones were reported from five species, *Myricaria bracteata*, *Tamarix elongata* and *T.*

laxa (chrysoeriol, Fig. 9) (Zhou *et al.*, 2006; Umbetova *et al.*, 2004), and *Tamarix chinensis* (apigenin 7,4'-dimethyl ether, Fig. 10) (Wang *et al.*, 2009). Rare polymethylated flavones, gardenins A–C and E, nevadensin, tamadone, and tamaridone (Figs. 11–17) were isolated from the aerial parts of *Tamarix dioica* (Parmar *et al.*, 1994). Procyanidin was also found in the leaves

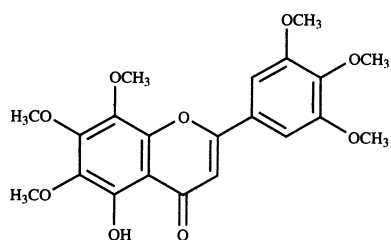


Fig. 11. Gardenin A.

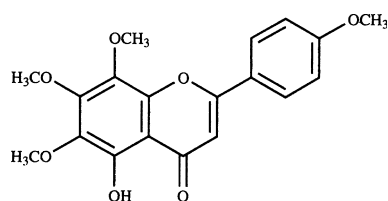


Fig. 12. Gardenin B.

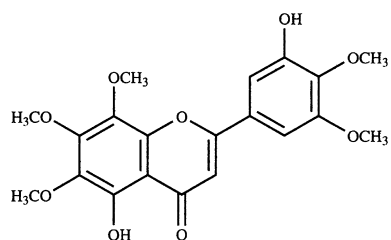


Fig. 13. Gardenin C.

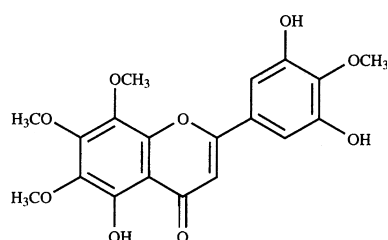


Fig. 14. Gardenin E.

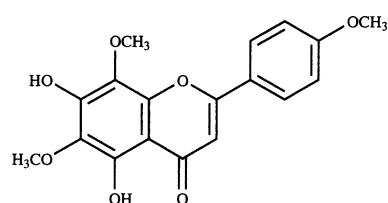


Fig. 15. Nevadensin.

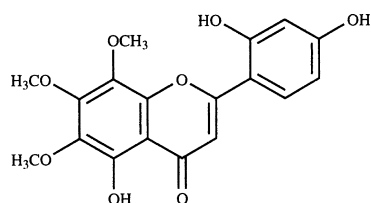


Fig. 16. Tamadone.

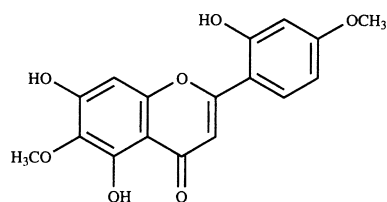


Fig. 17. Tamaridone.

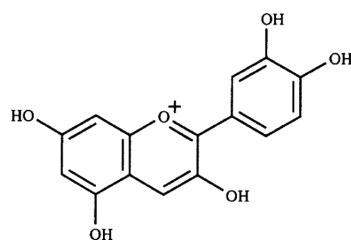


Fig. 18. Cyanidin.

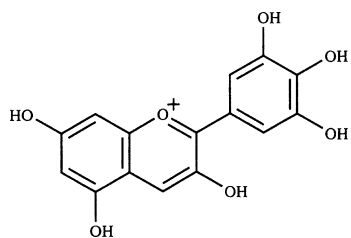


Fig. 19. Delphinidin.

of *Tamarix gallica* (Lebreton and Bouchez, 1967).

Anthocyanins were reported from three *Tamarix* species, *T. parviflora*, *T. sp.* and *T. tetrandra*, and characterized as cyanidin (Fig. 18) 3-*O*-glycoside, cyanidin and delphinidin (Fig. 19) glycoside, and cyanidin 3,5-di-*O*-glucoside and 3-*O*-glucoside, respectively (Forsyth and Simmonds, 1954; Scogin, 1977). Other flavonoids,

Table 2. Reports of the flavonoids from the family Plumbaginaceae

Species	Flavonoids
<i>Armeria maritima</i>	Flavonol: Isorhamnetin glycoside, Kaempferol glycosides, Myricetin glycosides, Quercetin glycoside (lv) (Lauranson <i>et al.</i> , 1995)
<i>Ceratostigma plumbaginoides</i>	Anthocyanin: Peonidin glycoside (lv) (Beck <i>et al.</i> , 1962), Cyanidin 3- <i>O</i> -galactoside, Delphinidin 3- <i>O</i> -galactoside (lv) (Harborne, 1967), Europinidin 3- <i>O</i> -galactoside (fl) (Harborne, 1967); Flavan and Proanthocyanidin: Prodelphinidin (lv) (Harborne, 1967); Flavonol: Azaleatin 3- <i>O</i> -galactoside, Myricetin 5-methyl ether 3- <i>O</i> -galactoside (lv) (Harborne, 1967, 1969), Myricetin 3- <i>O</i> -rhamnoside, Quercetin 3- <i>O</i> -rhamnoside (lv) (Harborne, 1967)
<i>Ceratostigma willmottianum</i>	Anthocyanin: Europinidin 3- <i>O</i> -galactoside (fl) (Harborne, 1967); Flavonol: Azaleatin 3- <i>O</i> -galactoside (lv) (Harborne, 1967, 1969), Quercetin 3- <i>O</i> -galactoside (lv) (Harborne, 1967)
<i>Dyerophytum africanum</i>	Flavonol: Azaleatin glycoside (lv) (Harborne, 1967, 1969), Myricetin 3- <i>O</i> -rhamnoside, Quercetin glycoside (lv) (Harborne, 1967)
<i>Limonium</i> cv. 'American Beauty'	Anthocyanin: Delphinidin 3- <i>O</i> -glucoside (fl) (Asen <i>et al.</i> , 1973); Flavone: Luteolin (fl) (Asen <i>et al.</i> , 1973); C-Glycosylflavone: Isoorientin (fl) (Asen <i>et al.</i> , 1973)
<i>Limonium</i> cv. 'Blue Bonnet'	Anthocyanin: Delphinidin 3- <i>O</i> -glucoside (fl) (Asen <i>et al.</i> , 1973); Flavone: Luteolin (fl) (Asen <i>et al.</i> , 1973); C-Glycosylflavone: Isoorientin (fl) (Asen <i>et al.</i> , 1973)
<i>Limonium</i> cv. 'Gold Coast'	Aurone: Aureusidin, Aureusidin 4- <i>O</i> -glucoside, Aureusidin 6- <i>O</i> -glucoside, 4,6,4'-Trihydroxyaurone (fl) (Asen and Plimmer, 1972); Chalcone: 3,4,2',4',6'-Pentahydroxychalcone (fl) (Asen and Plimmer, 1972); Flavone: Apigenin, Luteolin (Asen and Plimmer, 1972; Asen <i>et al.</i> , 1973); Flavonol: Myricetin 3'- <i>O</i> -rhamnoside, Quercetin, Quercetin 3- <i>O</i> -rhamnoside (fl) (Asen and Plimmer, 1972); C-Glycosylflavone: Isoorientin (fl) (Asen and Plimmer, 1972; Asen <i>et al.</i> , 1973)
<i>Limonium</i> cv. 'Iceberg'	Flavone: Luteolin (fl) (Asen <i>et al.</i> , 1973); C-Glycosylflavone: Isoorientin (fl) (Asen <i>et al.</i> , 1973)
<i>Limonium</i> cv. 'Midnight Blue'	Anthocyanin: Delphinidin 3,5-di- <i>O</i> -glucoside (fl) (Asen <i>et al.</i> , 1973); Flavone: Luteolin (fl) (Asen <i>et al.</i> , 1973); C-Glycosylflavone: Isoorientin (fl) (Asen <i>et al.</i> , 1973)
<i>Limonium</i> cv. 'Twilight Lavender'	Anthocyanin: Delphinidin 3,5-di- <i>O</i> -glucoside (fl) (Asen <i>et al.</i> , 1973); Flavone: Luteolin (fl) (Asen <i>et al.</i> , 1973); C-Glycosylflavone: Isoorientin (fl) (Asen <i>et al.</i> , 1973)
<i>Limonium sinense</i>	Flavan and Proanthocyanidin: (–)-Epigallocatechin 3-gallate, (–)-Epigallocatechin 3-(3,5-dimethoxygallate), (–)-Epigallocatechin 3-(3-methoxygallate) (ap) (Lin and Chou, 2000); Flavanone: Eriodictyol, Homoeriodictyol, Naringenin (ap) (Lin and Chou, 2000); Flavone: Apigenin, Luteolin (ap) (Lin and Chou, 2000); Flavonol: Myricetin, Myricetin 3- <i>O</i> -arabinopyranoside, Myricetin 3- <i>O</i> -galactoside, Myricetin 3- <i>O</i> -(6"-galloylgalactoside), Myricetin 3- <i>O</i> -(2"-galloylrhamnoside), Myricetin 3- <i>O</i> -(3"-galloylrhamnoside), Myricetin 3- <i>O</i> -(4"-galloylrhamnoside), Myricetin 3- <i>O</i> -(2"- <i>p</i> -hydroxybenzoylrhamnoside), Myricetin 3- <i>O</i> -rhamnoside, Quercetin, Quercetin 3- <i>O</i> -(2"-galloylrhamnoside), Quercetin 3- <i>O</i> -rhamnoside (ap) (Lin and Chou, 2000)
<i>Limonium</i> sp.	Aurone: Aureusidin (fl) (Harborne, 1966)
<i>Limonium wrightii</i>	Flavonol: Kaempferol 3- <i>O</i> -glucoside, Myricetin 3- <i>O</i> -arabinoside, Myricetin 3- <i>O</i> -glucoside, Myricetin 3- <i>O</i> -rhamnoside, Quercetin 3- <i>O</i> -arabinoside, Quercetin 3- <i>O</i> -galactoside, Quercetin 3- <i>O</i> -glucoside (ap) (Iwashina <i>et al.</i> , unpublished data)
<i>Plumbagella micrantha</i>	Anthocyanin: Cyanidin 3- <i>O</i> -glucoside (lv) (Harborne, 1967); Flavonol: Kaempferol glycoside, Quercetin glycoside (lv) (Harborne, 1967)
<i>Plumbago capensis</i>	Anthocyanin: Cyanidin 3,5-di- <i>O</i> -glycoside (fl) (Forsyth and Simmonds, 1954), Delphinidin glycoside (fl) (Beck <i>et al.</i> , 1962), Capensinidin 3- <i>O</i> -rhamnoside (fl) (Harborne, 1967); Flavan and Proanthocyanidin: Prodelphinidin (lv) (Harborne, 1967); Flavonol: Azaleatin 3- <i>O</i> -rhamnoside (fl) (Harborne, 1962, 1967, 1969)
<i>Plumbago coerulea</i>	Anthocyanin: Delphinidin 3- <i>O</i> -rhamnoside, Pulchellidin 3- <i>O</i> -rhamnoside (fl) (Harborne, 1967); Flavonol: Kaempferol 3- <i>O</i> -rhamnoside, Quercetin 3- <i>O</i> -rhamnoside (fl), Myricetin 3- <i>O</i> -glucoside (lv) (Harborne, 1967)

Table 2. Continued

Species
Flavonoids
<i>Plumbago europaea</i>
Anthocyanin: Cyanidin glycoside, Delphinidin glycoside (lv) (Beck <i>et al.</i> , 1962), Europinidin 3- <i>O</i> -glucoside (fl) (Harborne, 1967); Flavonol: Europetin 3- <i>O</i> -rhamnoside (lv) (Harborne, 1967), Myricetin 5-methyl ether glycoside (lv) (Harborne, 1967, 1969)
<i>Plumbago indica</i>
Anthocyanin: Cyanidin glycoside, Pelargonidin glycoside (fl) (Forsyth and Simmonds, 1954); Dihydroflavonol: Plumbaginol (ap) (Dinda <i>et al.</i> , 1994)
<i>Plumbago pulchella</i>
Anthocyanin: Delphinidin 3- <i>O</i> -glucoside, Pulchellidin 3- <i>O</i> -glucoside (fl) (Harborne, 1967); Flavan and Proanthocyanidin: Prodelphinidin (lv) (Harborne, 1967); Flavonol: Azaleatin 3- <i>O</i> -rhamnoside (fl) (Harborne, 1967, 1969), Quercetin 3- <i>O</i> -rhamnoside (fl), Europetin 3- <i>O</i> -glucoside, Myricetin 3- <i>O</i> -glucoside, Quercetin 3- <i>O</i> -glucoside (lv) (Harborne, 1967)
<i>Plumbago rosea</i>
Anthocyanin: Cyanidin 3- <i>O</i> -rhamnoside, Delphinidin 3- <i>O</i> -rhamnoside, Pelargonidin 3- <i>O</i> -rhamnoside (fl) (Harborne, 1962, 1967); Flavan and Proanthocyanidin: Prodelphinidin (lv) (Harborne, 1967); Flavonol: Kaempferol 3- <i>O</i> -rhamnoside (fl) (Harborne, 1962, 1967)
<i>Plumbago scandens</i>
Flavonol: Azaleatin 3- <i>O</i> -rhamnoside (fl) (Harborne, 1967, 1969)
<i>Plumbago zeylanica</i>
Flavan and Proanthocyanidin: Prodelphinidin (lv) (Harborne, 1967); Flavonol: Azaleatin 3- <i>O</i> -rhamnoside (fl) (Harborne, 1967, 1969), Quercetin 3- <i>O</i> -rhamnoside (lv) (Harborne, 1967)
<i>Statice latifolia</i>
Anthocyanin: Cyanidin glycoside, Delphinidin glycoside (lv) (Beck <i>et al.</i> , 1962)
<i>Statice sinuata</i>
Anthocyanin: Delphinidin glycoside (fl) (Beck <i>et al.</i> , 1962)

ap = aerial parts, fl = flowers, lv = leaves.

chalcone, aurone, flavanone, dihydroflavonol and so on have not been reported from the Tamaricaceae.

Flavonoids of Plumbaginaceae

The family Plumbaginaceae consists of 10 genera including ca. 600 species and is a medium-sized family of annual or perennial herbs and shrubs or climbers, many of which are cultivated as ornamentals (Heywood, 1978). The family is cosmopolitan but especially frequent in dry or saline habitats such as sea coast and salt steppes.

Twenty-four taxa and cultivars of 7 genera, *Armeria*, *Ceratostigma*, *Dyerophytum*, *Limonium*, *Plumbagella*, *Plumbago* and *Statice*, were investigated for flavonoids (Table 2). Major flavonoid is flavonol based on kaempferol, quercetin and myricetin (Fig. 20) in almost species. Rare azaleatin (Fig. 21) glycosides were found in three species, *Ceratostigma plumbaginoides*,

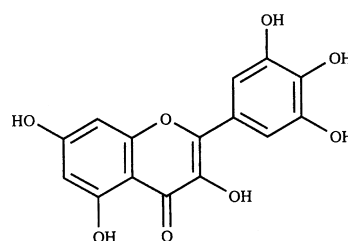


Fig. 20. Myricetin.

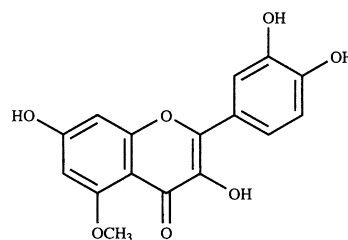


Fig. 21. Azaleatin.

Dyerophytum africanum and *Plumbago capensis* (Harborne, 1962, 1967, 1969). Europetin (Fig. 22) and myricetin 5-methyl ether (Fig. 23) glyco-

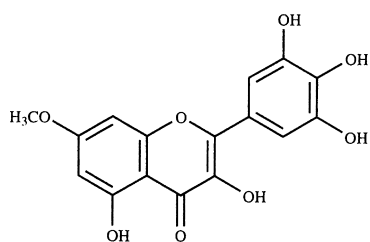


Fig. 22. Europetin.

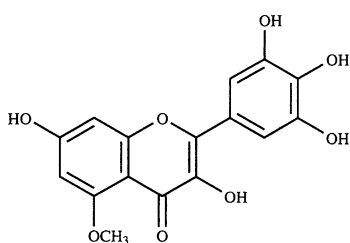


Fig. 23. Myricetin 5-methyl ether.

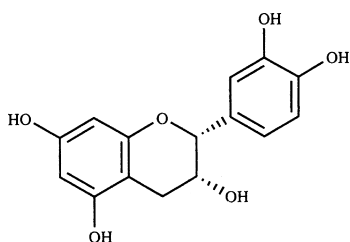


Fig. 24. (+)-Epicatechin.

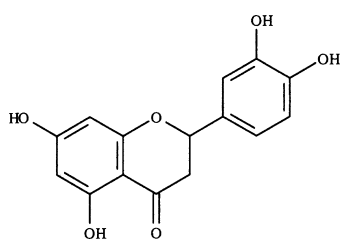


Fig. 25. Eriodictyol.

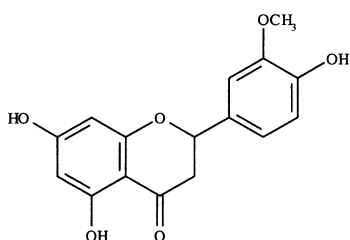


Fig. 26. Homoeriodictyol.

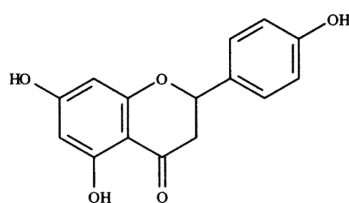


Fig. 27. Naringenin.

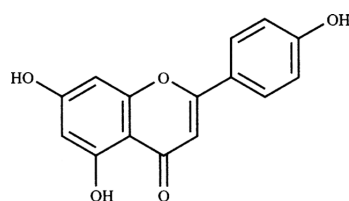


Fig. 28. Apigenin.

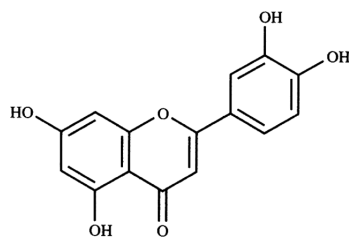


Fig. 29. Luteolin.

sides were isolated from the leaves of *Ceratostigma plumbaginoides* and *Plumbago europaea* (Harborne, 1967, 1969). Myricetin and quercetin 3-*O*-glycosides acylated with gallic acid or *p*-hydroxybenzoic acid were isolated from the aerial parts of Chinese species, *Limonium sinense*, together with flavan and proanthocyanidins, (+)-epicatechin (Fig. 24) 3-gallate, 3-(3,5-dimethoxygallate) and 3-(3-methoxygallate), flavanones, eriodictyol, homoeriodictyol and naringenin (Figs. 25–27), and flavones, apigenin and luteolin (Figs. 28, 29) (Lin and Chou, 2000). Flavan and proanthocyanidins were also found in *Ceratostigma plumbaginoides*, *Plumbago capensis* and *P. rosea* (Harborne, 1967). Though flavones, apigenin and luteolin, and C-glycosylflavone, orientin (Fig. 30), were reported from the flowers of *Limonium* cv. 'Gold Coast' (Asen and Plimmer, 1972), they are relatively minor compounds.

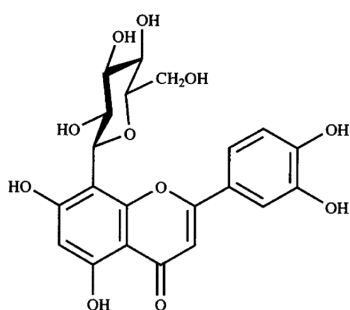


Fig. 30. Orientin.

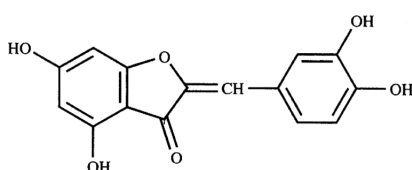


Fig. 31. Aureusidin.

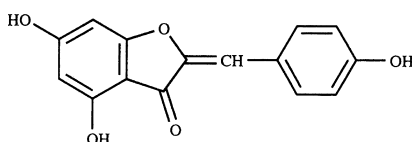


Fig. 32. 4,6,4'-Trihydroxyaurone.

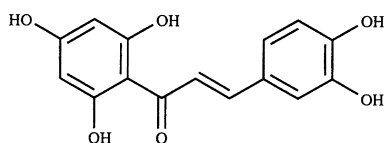


Fig. 33. 3,4,2',4',6'-Pentahydroxychalcone.

As other flavonoids, aurones, aureusidin (Fig. 31) and its 4-*O*-glucoside and 6-*O*-glucoside and 4,6,4'-trihydroxyaurone (Fig. 32) were isolated from *Limonium* cv. 'Gold Coast' flowers, together with chalcone, 3,4,2',4',6'-pentahydroxychalcone (Fig. 33) (Asen and Plimmer, 1972). Aureusidin 4-*O*-glucoside was also isolated from *Limonium bonduelli* (Harborne, 1966). Rare dihydroflavonol, plumbaginol (Fig. 34), was reported from the aerial parts of *Plumbago indica* (Dinda *et al.*, 1994).

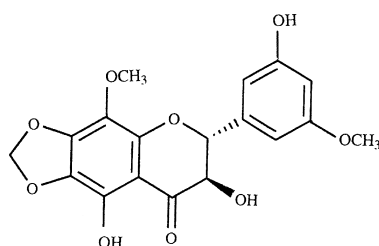


Fig. 34. Plumbaginol.

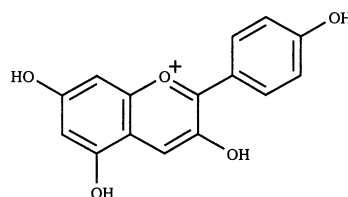


Fig. 35. Pelargonidin.

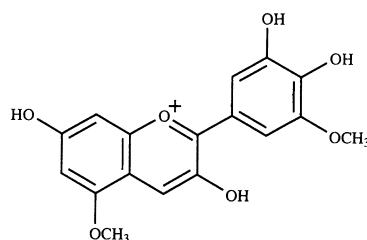


Fig. 36. Europinidin.

Anthocyanins were found in relatively many species, i.e. *Ceratostigma plumbaginoides* (Beck *et al.*, 1967; Harborne, 1967), *C. willmottianum*, *Plumbagella micrantha* (Harborne, 1967), *Plumbago capensis* (Forsyth and Simmonds, 1954; Beck *et al.*, 1962; Harborne, 1967), *P. coerulea* (Harborne, 1967), *P. europaea* (Beck *et al.*, 1962; Harborne, 1967), *P. indica* (Forsyth and Simmonds, 1954), *P. pulchella* (Harborne, 1967), *P. rosea* (Harborne, 1962, 1967), *Statice latifolia* and *S. sinuata* (Beck *et al.*, 1962). Though cyanidin, delphinidin and pelargonidin (Fig. 35) 3-*O*-glycosides are major compounds, rare methylated anthocyanin, europinidin (Fig. 36) 3-*O*-galactoside and 3-*O*-glucoside, were also isolated from the flowers of *Ceratostigma plumbaginoides* and *C. willmottianum*, and *Plumbago*

Table 3. Reports of the flavonoids from the family Polygonaceae

Species	Flavonoids
<i>Antenoron filiforme</i> (= <i>Polygonum filiforme</i>)	Anthocyanin: Cyanidin 3- <i>O</i> -glucoside (fl) (Yoshitama <i>et al.</i> , 1980), Cyanidin 3- <i>O</i> -galactoside (fl, st) (Yoshitama <i>et al.</i> , 1984, 1987, 1988), Cyanidin 3- <i>O</i> -rhamnosylgalactoside (fl, st) (Yoshitama <i>et al.</i> , 1987, 1988); Flavonol: Myricetin 3- <i>O</i> -rhamnoside (ap) (Isobe <i>et al.</i> , 1981), Quercetin, Quercetin 3- <i>O</i> -(2"-galloylglucoside), Quercetin 3- <i>O</i> -rhamnoside (ap, lv) (Isobe <i>et al.</i> , 1981; Kawasaki <i>et al.</i> , 1986), Kaempferol (lv) (Kawasaki <i>et al.</i> , 1986)
<i>Antenoron neo-filiforme</i> (= <i>Polygonum filiforme</i> var. <i>neo-filiforme</i>)	Flavonol: Myricetin 3- <i>O</i> -rhamnoside, Quercetin 3- <i>O</i> -(2"-galloylrhamnoside), Quercetin 3- <i>O</i> -rhamnoside (lv) (Isobe and Noda, 1987a)
<i>Antigonon leptopus</i>	Anthocyanin: Cyanidin glycoside (fl) (Forsyth and Simmonds, 1954); Flavonol: Quercetin 3- <i>O</i> -(2"-galloylglucoside), Quercetin 3- <i>O</i> -rhamnoside (lv) (Kawasaki <i>et al.</i> , 1986)
<i>Atraphaxis frutescens</i>	Flavonol: Kaempferol 3- <i>O</i> -glucoside, Myricetin 3- <i>O</i> -glucoside, Quercetin 3- <i>O</i> -glucoside (lv) (Chumbalov and Omurkamzinova, 1975)
<i>Bistorta major</i> var. <i>japonica</i> (= <i>Polygonum bistorta</i>)	Anthocyanin: Cyanidin 3- <i>O</i> -glucoside (fl) (Yoshitama <i>et al.</i> , 1987, 1988)
<i>Bistorta suffulta</i> (= <i>Polygonum suffultum</i>)	Anthocyanin: Cyanidin 3- <i>O</i> -glucoside, Cyanidin 3- <i>O</i> -rutinoside (st) (Yoshitama <i>et al.</i> , 1987, 1988); C-Glycosylflavone: Isoorientin <i>O</i> -glycoside, Orientin <i>O</i> -glycoside, Vitexin <i>O</i> -glycoside (lv) (Kawasaki <i>et al.</i> , 1986)
<i>Bistorta tenuicaulis</i> (= <i>Polygonum tenuicaule</i>)	Anthocyanin: Cyanidin glycoside (st) (Yoshitama <i>et al.</i> , 1987), Cyanidin 3- <i>O</i> -glucoside, Cyanidin 3- <i>O</i> -rutinoside (st) (Yoshitama <i>et al.</i> , 1987, 1988)
<i>Bistorta viviparum</i> (= <i>Polygonum viviparum</i>)	Anthocyanin: Cyanidin glycoside (ap) (Yoshitama <i>et al.</i> , 1987, 1988)
<i>Coccoloba uvifera</i>	Flavonol: Myricetin 3- <i>O</i> -glucoside, Myricetin 3- <i>O</i> -rhamnoside, Quercetin 3- <i>O</i> -arabinoside, Quercetin 3- <i>O</i> -rhamnoside (lv) (Kawasaki <i>et al.</i> , 1986)
<i>Fagopyrum cymosum</i>	Anthocyanin: Cyanidin 3- <i>O</i> -glucoside (st) (Yoshitama <i>et al.</i> , 1988)
<i>Fagopyrum esculentum</i>	Anthocyanin: Cyanidin 3- <i>O</i> -glycoside (lv) (Saunders and McClure, 1976), Cyanidin 3- <i>O</i> -glucoside (st) (Yoshitama <i>et al.</i> , 1988); Dihydroflavonol: Aromadendrin 3- <i>O</i> -galactoside, Taxifolin 3- <i>O</i> -xyloside (sd) (Samaiya and Saxena, 1989); Flavan and Proanthocyanidin: (+)-Catechin, (-)-Epicatechin, (-)-Epicatechin 3-gallate, Procyanidin B-2, Procyanidin B-2 3-gallate (rt) (Trotin <i>et al.</i> , 1993); Flavonol: Quercetin (sd) (Sato and Sakamura, 1975), Quercetin 3- <i>O</i> -rutinoside (ct, hp, lv, sd) (Sato and Sakamura, 1975; Saunders and McClure, 1976; Margna and Vainjärv, 1981, 1983, 1985; Margna <i>et al.</i> , 1985; Ohta <i>et al.</i> , 1998), Quercetin 3- <i>O</i> -galactoside, Quercetin 3- <i>O</i> -rhamnoside (sd, lv) (Sato and Sakamura, 1975; Ohta <i>et al.</i> , 1998), Quercetin 3- <i>O</i> -glucoside (lv) (Ohta <i>et al.</i> , 1998); C-Glycosylflavone: Isoorientin, Isovitexin, Orientin, Vitexin (ct, lv) (Margna <i>et al.</i> , 1967, 1985; Saunders and McClure, 1976; Margna and Vainjärv, 1981, 1983, 1985)
<i>Fagopyrum tataricum</i>	Flavonol: Kaempferol, Kaempferol 3- <i>O</i> -rutinoside, Quercetin, Quercetin 3- <i>O</i> -rutinoside, Quercetin 3- <i>O</i> -rutinoside-7- <i>O</i> -galactoside (sd) (Sato <i>et al.</i> , 1980)
<i>Fallopia cilinodis</i>	Flavonol: Kaempferol 3- <i>O</i> -glucoside, Kaempferol 3- <i>O</i> -rhamnosylgalactoside, Kaempferol 3- <i>O</i> -rhamnosylglucoside, Quercetin, Quercetin 3- <i>O</i> -arabinoside, Quercetin 3- <i>O</i> -galactoside, Quercetin 3- <i>O</i> -glucoside, Quercetin 3- <i>O</i> -rhamnosylgalactoside, Quercetin 3- <i>O</i> -rhamnosylglucoside, Quercetin 3- <i>O</i> -xyloside (lv) (Kim <i>et al.</i> , 2000)
<i>Fallopia convolvulus</i>	Flavonol: Kaempferol 3- <i>O</i> -galactoside, Kaempferol 3- <i>O</i> -glucoside, Kaempferol 3- <i>O</i> -rhamnosylglucoside, Myricetin 3- <i>O</i> -glucoside, Quercetin, Quercetin 3- <i>O</i> -arabinoside, Quercetin 3- <i>O</i> -galactoside, Quercetin 3- <i>O</i> -glucoside, Quercetin 3- <i>O</i> -rhamnoside, Quercetin 7- <i>O</i> -glucoside, Quercetin 3- <i>O</i> -rhamnosylglucoside (lv) (Kim <i>et al.</i> , 2000); C-Glycosylflavone: Apigenin 6- <i>C</i> -glycoside (lv) (Kim <i>et al.</i> , 2000)
<i>Fallopia dentata-alata</i>	Flavonol: Kaempferol 3- <i>O</i> -glucoside, Kaempferol 3- <i>O</i> -rhamnosylglucoside, Myricetin 3- <i>O</i> -glucoside, Quercetin, Quercetin 3- <i>O</i> -arabinoside, Quercetin 3- <i>O</i> -galactoside, Quercetin 3- <i>O</i> -glucoside, Quercetin 3- <i>O</i> -rhamnoside, Quercetin 7- <i>O</i> -glucoside, Quercetin 3- <i>O</i> -rhamnosylglucoside (lv) (Kim <i>et al.</i> , 2000); C-Glycosylflavone: Apigenin 6,8-di- <i>C</i> -glycoside, Apigenin 6- <i>C</i> -glycoside, Apigenin 8- <i>C</i> -glycoside (lv) (Kim <i>et al.</i> , 2000)

Table 3. Continued

Species

Flavonoids

Fallopia dumetra (= *Polygonum dumetrum*)

Anthocyanin: Cyanidin 3-*O*-galactoside, Cyanidin glycoside (fl, st) (Yoshitama *et al.*, 1984, 1988); **Flavonol:** Kaempferol 3-*O*-galactoside, Kaempferol 3-*O*-glucoside, Myricetin 3-*O*-glucoside, Quercetin, Quercetin 3-*O*-arabinoside, Quercetin 3-*O*-galactoside, Quercetin 3-*O*-glucoside, Quercetin 7-*O*-glucoside, Quercetin 3-*O*-rhamnosylgalactoside (lv) (Kim *et al.*, 2000)

Fallopia scandens

Flavonol: Kaempferol 3-*O*-galactoside, Kaempferol 3-*O*-glucoside, Myricetin 3-*O*-glucoside, Quercetin, Quercetin 3-*O*-arabinoside, Quercetin 3-*O*-galactoside, Quercetin 3-*O*-glucoside, Quercetin 7-*O*-glucoside, Quercetin 3-*O*-rhamnosylgalactoside (lv) (Kim *et al.*, 2000)

Mehlenbeckia platyclada

Flavonol: Quercetin 3-*O*-rhamnoside (lv) (Kawasaki *et al.*, 1986); **C-Glycosylflavone:** Apigenin 6,8-di-*C*-glycoside (lv) (Kawasaki *et al.*, 1986)

Oxyria digyna

Flavan and Proanthocyanin: (–)-Epicatechin, (–)-Epicatechin 3-gallate, (–)-Epigallocatechin, (–)-Epigallocatechin 3-gallate (wp) (Li *et al.*, 2008); **Flavonol:** Kaempferol 3-*O*-glucoside, Kaempferol 3-*O*-(6″-*p*-coumaroylglucoside), Quercetin, Quercetin 3-*O*-rhamnoside (wp) (Li *et al.*, 2008)

Persicaria chinensis (= *Polygonum chinense*)

Anthocyanin: Cyanidin 3-*O*-glucoside, Delphinidin 3-*O*-glucoside (st) (Yoshitama *et al.*, 1988)

Persicaria conspicua (= *Polygonum conspicuum*)

Anthocyanin: Cyanidin 3-*O*-galactoside (fl) (Yoshitama *et al.*, 1984, 1987, 1988), Peonidin glycoside (fl) (Yoshitama *et al.*, 1987, 1988), Cyanidin glycoside (fl) (Yoshitama *et al.*, 1984, 1988); **Flavonol:** Quercetin 3-*O*-rhamnoside (lv) (Isobe and Noda, 1987b)

Persicaria debilis (= *Polygonum debile*)

Anthocyanin: Cyanidin 3-*O*-glucoside (st) (Yoshitama *et al.*, 1984); **Flavonol:** Quercetin 3-*O*-glucuronide, Quercetin 3-*O*-rhamnoside (lv) (Kawasaki *et al.*, 1986)

Persicaria dichotoma (= *Polygonum dichotomum*)

Flavone: Luteolin (lv) (Park, 1987); **Flavonol:** Quercetin, Quercetin 3-*O*-arabinoside, Quercetin 3-*O*-glucoside, Quercetin 3-*O*-glucuronide, Quercetin 3-*O*-rhamnoside, Quercetin 3-*O*-rhamnosylglucoside (lv) (Park, 1987)

Persicaria hastato-auriculata (= *Polygonum hastato-auriculatum*)

Anthocyanin: Cyanidin 3-*O*-glucoside (fl, st) (Yoshitama *et al.*, 1988)

Persicaria hastato-sagittata (= *Polygonum hastato-sagittatum*)

Flavone: Luteolin (lv) (Park, 1987); **Flavonol:** Quercetin, Quercetin 3-*O*-arabinoside, Quercetin 3-*O*-galactoside, Quercetin 3-*O*-rhamnoside (lv) (Park, 1987); **C-Glycosylflavone:** Luteolin *C*-glycoside (lv) (Park, 1987)

Persicaria hydropiper (= *Polygonum hydropiper*)

Anthocyanin: Cyanidin 3-*O*-galactoside (fl, sd) (Yoshitama *et al.*, 1984, 1987, 1988), Peonidin glycoside (st) (Yoshitama *et al.*, 1987, 1988); **Flavonol:** Kaempferol (ap) (Yusif and Blinova, 1984), Rhamnazin (ap, lv) (Yusif and Blinova, 1984; Haraguchi *et al.*, 1996), Isorhamnetin (ap, lv) (Yusif and Blinova, 1984; Haraguchi *et al.*, 1992, 1996), Quercetin (lv) (Kawasaki *et al.*, 1986; Haraguchi *et al.*, 1992, 1996), Isorhamnetin 3-sulphate (lv) (Kawasaki *et al.*, 1986; Haraguchi *et al.*, 1996), Quercetin 3-*O*-arabinoside, Quercetin 3-*O*-galactoside, Quercetin 3-*O*-rhamnoside (lv) (Kawasaki *et al.*, 1986), Quercetin 3-*O*-glucoside (lv) (Haraguchi *et al.*, 1992, 1996), Ombuin (lv) (Haraguchi *et al.*, 1992), Isorhamnetin 3,7-disulphate, Quercetin 3-sulphate, Tamarixetin 7-sulphate 3-*O*-glucoside (lv) (Yagi *et al.*, 1994; Haraguchi *et al.*, 1996), Rhamnazin 3-sulphate (lv) (Haraguchi *et al.*, 1996)

Persicaria lapathifolia (= *Polygonum lapathifolia* var. *nodosum* = *P. nodosum*)

Anthocyanin: Peonidin 3-*O*-arabinoside-5-*O*-glucoside (fl) (Yoshitama *et al.*, 1984), Cyanidin 3-*O*-galactoside (fl, st, lv) (Yoshitama *et al.*, 1984, 1988), Peonidin 3,5-di-*O*-glucoside (fl) (Yoshitama *et al.*, 1988); **Dihydroflavonol:** (2*R*, 3*R*)-3-Hydroxy-5-methoxy-6,7-methylenedioxyflavanone, Pinobanksin, Taxifolin (ap, lv) (Kuroyanagi *et al.*, 1982; Abe *et al.*, 2007); **Flavonol:** Quercetin (ap, lv) (Kawasaki *et al.*, 1986; Isobe *et al.*, 1980), Quercetin 3-*O*-(2″-galloylglucoside) (ap, lv, wp) (Isobe *et al.*, 1979, 1980; Kuroyanagi *et al.*, 1982; Kawasaki *et al.*, 1986; Park *et al.*, 1999), Kaempferol, Kaempferol 3-*O*-(2″-galloylglucoside) (ap) (Isobe *et al.*, 1980), Quercetin 3-*O*-glucoside (ap, wp) (Isobe *et al.*, 1980; Park *et al.*, 1999), Kaempferol 3-*O*-arabinopyranoside, Kaempferol 3-*O*-galactoside, Kaempferol 3-*O*-glucoside, Kaempferol 3-*O*-(6″-*p*-hydroxybenzoylglactoside), Quercetin 3-*O*-arabinopyranoside, Quercetin 3-*O*-(6″-feruloylglactoside), Quercetin 3-*O*-galactoside, Quercetin 3-*O*-(2″-galloylrhamnoside) (wp) (Park *et al.*, 1999)

Table 3. Continued

Species

Flavonoids

Persicaria longiset (= *Polygonum blumei* = *P. longisetum*)

Anthocyanin: Cyanidin 3-*O*-arabinoside-5-*O*-glucoside, Peonidin 3-*O*-arabinoside-5-*O*-glucoside (fl) (Yoshitama *et al.*, 1984), Cyanidin 3,5-di-*O*-glucoside, Peonidin 3,5-di-*O*-glucoside (fl) (Yoshitama *et al.*, 1988); **Flavone:** Apigenin 7-*O*-(glucoside-6"-methyl ester) (lv) (Isobe and Noda, 1987a); **Flavonol:** Isorhamnetin 3-*O*-rutinoside, Quercetin 3-*O*-arabinosylglucoside (lv) (Kawasaki *et al.*, 1986), Quercetin 3-*O*-rutinoside (lv) (Kawasaki *et al.*, 1986; Ohta *et al.*, 1998), Isorhamnetin, Kaempferol 3-*O*-glucoside (lv) (Isobe and Noda, 1987a), Quercetin 3-*O*-rhamnoside (lv) (Isobe and Noda, 1987a; Ohta *et al.*, 1998), Quercetin 3-*O*-galactoside, Quercetin 3-*O*-glucoside (lv) (Ohta *et al.*, 1998)

Persicaria maackiana (= *Polygonum maackianum*)

Anthocyanin: Cyanidin 3-*O*-glucoside (fl, st) (Yoshitama *et al.*, 1984, 1988), Delphinidin 3-*O*-glucoside (fl) (Yoshitama *et al.*, 1988); **Flavonol:** Quercetin, Quercetin 3-*O*-glucoside, Quercetin 3-*O*-rhamnoside (lv) (Isobe and Noda, 1987b)

Persicaria nepalensis (= *Polygonum nepalense*)

Anthocyanin: Cyanidin glycoside (fl) (Yoshitama *et al.*, 1987), Cyanidin 3-*O*-glucoside, Cyanidin 3-*O*-rutinoside (st), Delphinidin 3-*O*-glucoside, Delphinidin 3-*O*-rutinoside (fl) (Yoshitama *et al.*, 1987, 1988); **Chalcone:** β -Hydroxy-2,3,4,5,2',4',5'-heptamethoxychalcone (wp) (Rathore *et al.*, 1987); **Flavonol:** Quercetin 3-*O*-galactoside (lv, wp) (Rathore *et al.*, 1987; Isobe and Noda, 1987b), Quercetin 3-*O*-rhamnoside (wp) (Rathore *et al.*, 1987), Quercetin 3-*O*-glucoside (lv) (Isobe and Noda, 1987b); **C-Glycosylflavone:** Isoorientin (wp) (Rathore *et al.*, 1987)

Persicaria nipponensis (= *Polygonum nipponense*)

Anthocyanin: Cyanidin 3-*O*-galactoside, Cyanidin 3,5-di-*O*-glucoside, Malvidin 3,5-di-*O*-glucoside (fl) (Yoshitama *et al.*, 1984, 1988); **Flavonol:** Kaempferol 3-*O*-glucoside, Quercetin 3-*O*-arabinoside, Quercetin 3-*O*-glucoside, Quercetin 3-*O*-rhamnoside (lv) (Isobe and Noda, 1987b)

Persicaria perfoliata (= *Polygonum perfoliatum*)

Anthocyanin: Cyanidin 3-*O*-arabinoside (st), Malvidin 3,5-di-*O*-glucoside (fl, fr) (Ishikura and Sugahara, 1979; Yoshitama *et al.*, 1984, 1988); **Flavonol:** Quercetin 3-*O*-glucuronide (lv) (Kawasaki *et al.*, 1986), Kaempferol 3-*O*-diglucuronide, Quercetin, Quercetin 3-*O*-diglucuronide (lv) (Park, 1987)

Persicaria pilosa (= *Polygonum orientale*)

Anthocyanin: Cyanidin 3-*O*-arabinoside-5-*O*-glucoside (fl) (Yoshitama *et al.*, 1984), Cyanidin 3-*O*-galactoside (st), Cyanidin 3,5-di-*O*-glucoside (fl) (Yoshitama *et al.*, 1988); **Flavonol:** Digicitrin, 5,3'-Dihydroxy-3,8,4',5'-tetramethoxy-6,7-methylenedioxyflavone, Exoticin, 3,5,8,3',4',5'-Hexamethoxy-6,7-methylenedioxyflavone, 3,5,6,7,8,3'-Hexamethoxy-4',5'-methylenedioxyflavone, 3'-Hydroxy-3,5,6,7,8,4',5'-heptamethoxyflavone, 3'-Hydroxy-3,5,8,4',5'-pentamethoxy-6,7-methylenedioxyflavone, 5-Hydroxy-3,6,7,8,3'-pentamethoxy-4',5'-methylenedioxyflavone, Quercetin 3-*O*-rhamnoside, 3,5,8,3'-Tetramethoxy-6,7,4',5'-dimethylenedioxyflavone (ap) (Kuroyanagi and Fukushima, 1982); **C-Glycosylflavone:** Orientin, Vitexin (lv) (Hörhammer *et al.*, 1958)

Persicaria pubescens (= *Polygonum pubescens*)

Anthocyanin: Cyanidin glycoside, Peonidin glycoside (fl) (Yoshitama *et al.*, 1984, 1988); **Flavonol:** Myricetin 3-*O*-rhamnoside, Quercetin 3-*O*-(2"-galloylrhamnoside), Quercetin 3-*O*-rhamnoside (lv) (Isobe and Noda, 1987a)

Persicaria senticosa (= *Polygonum senticosum*)

Anthocyanin: Cyanidin 3-*O*-arabinoside, Cyanidin 3-*O*-arabinosylglucoside (st), Cyanidin 3,5-di-*O*-glucoside, Malvidin 3,5-di-*O*-glucoside, Peonidin 3,5-di-*O*-glucoside (fl) (Yoshitama *et al.*, 1984, 1988); **Flavonol:** Quercetin 3-*O*-arabinoside, Quercetin 3-*O*-galactoside, Quercetin 3-*O*-glucuronide (lv) (Kawasaki *et al.*, 1986), Quercetin 3-*O*-rhamnoside (lv) (Kawasaki *et al.*, 1986; Isobe and Noda, 1987a), Kaempferol 3-*O*-glucoside (lv) (Isobe and Noda, 1987a), Quercetin 3-*O*-glucoside (lv) (Aritomi, 1962; Isobe and Noda, 1987a), Kaempferol 3-*O*-diglucuronide, Quercetin, Quercetin 3-*O*-diglucuronide (lv) (Park, 1987)

Persicaria sieboldii (= *Polygonum sagittatum* var. *sieboldii*)

Anthocyanin: Cyanidin 3-*O*-galactoside, Malvidin 3,5-di-*O*-glucoside (fl) (Yoshitama *et al.*, 1984, 1988); **Flavonol:** Quercetin, Quercetin 3-*O*-rhamnoside (ap) (Isobe *et al.*, 1981), Quercetin 3-*O*-arabinoside, Quercetin 3-*O*-galactoside, Quercetin 3-*O*-rutinoside (lv) (Kawasaki *et al.*, 1986)

Persicaria thunbergii (= *Polygonum thunbergii*)

Anthocyanin: Cyanidin 3-*O*-galactoside (fl) (Yoshitama *et al.*, 1987), Cyanidin 3-*O*-glucoside (lv, fl, st) (Yoshitama *et al.*, 1972, 1984, 1987, 1988), Cyanidin glycoside, Peonidin glycoside (st), Malvidin 3,5-di-*O*-glucoside (fl) (Yoshitama *et al.*, 1984, 1987, 1988), Delphinidin 3-*O*-glucoside (fl) (Yoshitama *et al.*, 1987, 1988); **Flavone:** Apigenin 7-*O*-glucoside, Luteolin 7-*O*-diglucoside, Luteolin 3'-*O*-glycoside (lv) (Park, 1987); **Flavonol:** Isorhamnetin 3-*O*-rutinoside (lv) (Kawasaki *et al.*, 1986), Isorhamnetin 3-sulphate (fl, lv) (Matsushita, 1972; Kawasaki *et al.*, 1986; Park, 1987), Quercetin (fl, lv) (Matsushita, 1972; Park, 1987), Isorhamnetin, Quercetin 3-*O*-(acylrhamnoside), Quercetin 3-*O*-diglucuronide, Quercetin 3-*O*-glucuronide, Quercetin 3-methyl ether, Quercetin 3-sulphate, Rhamnazin (lv) (Park, 1987), Quercetin 3-*O*-glucoside, Quercetin 3-*O*-rhamnoside (lv) (Park, 1987; Ohta *et al.*, 1998), Quercetin 3-*O*-galactoside, Quercetin 3-*O*-rutinoside (lv) (Ohta *et al.*, 1998)

Table 3. Continued

Species	Flavonoids
<i>Persicaria trigonocarpha</i> (= <i>Polygonum trigonicarpum</i>)	Flavonol: Quercetin 3- <i>O</i> -glucoside (lv) (Isobe and Noda, 1987b)
<i>Persicaria viscosa</i> (= <i>Polygonum viscosum</i>)	Anthocyanin: Cyanidin 3- <i>O</i> -galactoside, Cyanidin 3,5-di- <i>O</i> -glucoside (fl) (Yoshitama <i>et al.</i> , 1988); Flavonol: Quercetin, Quercetin 3- <i>O</i> -(6"-galloyl)galactoside (wp) (Datta <i>et al.</i> , 2000)
<i>Persicaria vulgaris</i> (= <i>Polygonum persicaria</i>)	Anthocyanin: Cyanidin glycoside, Peonidin glycoside (fl) (Yoshitama <i>et al.</i> , 1984, 1988)
<i>Persicaria yokusaiana</i> (= <i>Polygonum caespitosum</i> subsp. <i>yokusaianum</i>)	Anthocyanin: Cyanidin 3- <i>O</i> -arabinoside-5- <i>O</i> -glucoside, Peonidin 3- <i>O</i> -arabinoside-5- <i>O</i> -glucoside (fl) (Yoshitama <i>et al.</i> , 1984), Cyanidin glycoside, Peonidin 3,5-di- <i>O</i> -glucoside (fl) (Yoshitama <i>et al.</i> , 1988); Flavone: Luteolin 7- <i>O</i> -glucoside (lv) (Kawasaki <i>et al.</i> , 1986), Apigenin 7- <i>O</i> -(glucoside-6"-methyl ester) (lv) (Isobe and Noda, 1987a); Flavonol: Quercetin 3- <i>O</i> -glucoside, Quercetin 3- <i>O</i> -rutinoside (lv) (Kawasaki <i>et al.</i> , 1986; Isobe and Noda, 1987a), Kaempferol 3- <i>O</i> -glucoside, Quercetin, Quercetin 3- <i>O</i> -rhamnoside (lv) (Isobe and Noda, 1987a)
<i>Pleuropterypyrum nakaii</i> (= <i>Polygonum nakaii</i>)	Anthocyanin: Cyanidin 3- <i>O</i> -glucoside (st) (Yoshitama <i>et al.</i> , 1984, 1988)
<i>Pleuropterypyrum weyrichii</i> var. <i>alpinum</i> (= <i>Polygonum weyrichii</i> var. <i>alpinum</i>)	Anthocyanin: Cyanidin 3- <i>O</i> -glucoside (fl) (Yoshitama <i>et al.</i> , 1984, 1988)
<i>Pleuropterypyrum weyrichii</i> var. <i>weyrichii</i> (= <i>Polygonum weyrichii</i> var. <i>weyrichii</i>)	Flavan and Proanthocyanidin: (+)-Catechin, (+)-Epicatechin (ap) (Levashova and Zhdanova, 1990); Flavonol: Quercetin, Quercetin 3- <i>O</i> -arabinofuranoside, Quercetin 3- <i>O</i> -galactoside, Quercetin 3- <i>O</i> -rhamnoside, Quercetin 3- <i>O</i> -rutinoside (ap) (Levashova and Zhdanova, 1990)
<i>Pleuropterus multiflorus</i> (= <i>Polygonum multiflorum</i>)	Anthocyanin: Cyanidin 3- <i>O</i> -rutinoside (lv) (Yoshitama <i>et al.</i> , 1972, 1984, 1988), Cyanidin glycoside (lv, st) (Yoshitama <i>et al.</i> , 1984, 1988); Flavonol: Quercetin 3- <i>O</i> -galactoside, Quercetin 3- <i>O</i> -rutinoside (lv) (Kawasaki <i>et al.</i> , 1986); C-Glycosylflavone: Isovitexin, Vitexin (lv) (Kawasaki <i>et al.</i> , 1986)
<i>Polygonum affine</i>	C-Glycosylflavone: Isoorientin, Isoorientin X"- <i>O</i> -arabinoside, Isovitexin, Isovitexin X"- <i>O</i> -arabinoside (lv) (Krause, 1976a), Isoaffnetin (lv) (Krause, 1976a, 1976b)
<i>Polygonum arifolium</i>	Flavone: Luteolin (lv) (Park, 1987); Flavonol: Quercetin, Quercetin 3- <i>O</i> -glucoside, Quercetin 3- <i>O</i> -glucuronide (lv) (Park, 1987); C-Glycosylflavone: Isoorientin, Isovitexin, Orientin, Vitexin (lv) (Park, 1987)
<i>Polygonum aviculare</i>	Anthocyanin: Cyanidin 3- <i>O</i> -glucoside (fl) (Yoshitama <i>et al.</i> , 1984, 1988); Flavonol: Quercetin 3- <i>O</i> -xyloside (lv) (Kutani <i>et al.</i> , 1959), Myricetin 3- <i>O</i> -arabinoside, Myricetin 3- <i>O</i> -glucoside, Myricetin 3- <i>O</i> -rhamnosylglucoside (lv) (Kawasaki <i>et al.</i> , 1986), Quercetin 3- <i>O</i> -arabinofuranoside (lv, wp) (Kutani <i>et al.</i> , 1959; Kawasaki <i>et al.</i> , 1986; Kim <i>et al.</i> , 1994; Zhao <i>et al.</i> , 2002), Kaempferol 3- <i>O</i> -arabinofuranoside, Kaempferol 3- <i>O</i> -glucoside (wp) (Kim <i>et al.</i> , 1994; Zhao <i>et al.</i> , 2002), Myricetin 3- <i>O</i> -arabinofuranoside (wp) (Kim <i>et al.</i> , 1994), Quercetin 3- <i>O</i> -galactoside, Quercetin 3- <i>O</i> -glucoside, Quercetin 3- <i>O</i> -rutinoside (lv) (Kutani <i>et al.</i> , 1959; Ohta <i>et al.</i> , 1998), Quercetin 3- <i>O</i> -rhamnoside (lv) (Kutani <i>et al.</i> , 1959; Ohta <i>et al.</i> , 1998; Zhao <i>et al.</i> , 2002), Kaempferol, Myricetin 3- <i>O</i> -rhamnoside, Quercetin (wp) (Zhao <i>et al.</i> , 2002)
<i>Polygonum dissitiflorum</i>	Flavone: Luteolin 7- <i>O</i> -diglucoside, Luteolin 7- <i>O</i> -glucoside (lv) (Park, 1987); Flavonol: Myricetin 3- <i>O</i> -rhamnoside, Quercetin 3- <i>O</i> -glucuronide, Quercetin 3- <i>O</i> -rhamnoside (lv) (Park, 1987); C-Glycosylflavone: Apigenin C-glycoside, Luteolin C-glycoside (lv) (Park, 1987)
<i>Polygonum divaricatum</i>	Flavan and Proanthocyanidin: (+)-Catechin, (+)-Epicatechin (ap) (Levashova and Zhdanova, 1990); Flavonol: Quercetin, Quercetin 3- <i>O</i> -arabinofuranoside, Quercetin 3- <i>O</i> -galactoside, Quercetin 3- <i>O</i> -rhamnoside, Quercetin 3- <i>O</i> -rutinoside (ap) (Levashova and Zhdanova, 1990)
<i>Polygonum meisnerianum</i> var. <i>beyrichianum</i>	Flavone: Luteolin, Luteolin 7- <i>O</i> -diglucoside (lv) (Park, 1987); Flavonol: Quercetin, Quercetin 3- <i>O</i> -arabinoside, Quercetin 3- <i>O</i> -glucoside, Quercetin 3- <i>O</i> -rhamnoside, Quercetin 3- <i>O</i> -rhamnosylglucoside (lv) (Park, 1987)
<i>Polygonum meisnerianum</i> var. <i>meisnerianum</i>	Flavone: Luteolin, Luteolin 7- <i>O</i> -diglucoside (lv) (Park, 1987); Flavonol: Quercetin, Quercetin 3- <i>O</i> -arabinoside, Quercetin 3- <i>O</i> -glucoside, Quercetin 3- <i>O</i> -rhamnoside, Quercetin 3- <i>O</i> -rhamnosylglucoside (lv) (Park, 1987)
<i>Polygonum minus</i>	Flavone: 5,3',4',5'-Tetramethoxy-6,7-methylenedioxyflavone (ap) (Urones <i>et al.</i> , 1990); Flavonol: 3,5,3'-Trimethoxy-6,7: 4',5'-dimethylenedioxyflavone (ap) (Urones <i>et al.</i> , 1990)
<i>Polygonum muricatum</i>	Flavone: Luteolin (lv) (Park, 1987); Flavonol: Quercetin, Quercetin 3- <i>O</i> -arabinoside, Quercetin 3- <i>O</i> -galactoside (lv) (Park, 1987); C-Glycosylflavone: Luteolin C-glycoside (lv) (Park, 1987)

Table 3. Continued

Species
Flavonoids
<i>Polygonum polystachyum</i> Flavonol: Quercetin 3- <i>O</i> -arabinoside (wp) (Hörhammer <i>et al.</i> , 1955)
<i>Polygonum praetermissum</i> Flavone: Luteolin (lv) (Park, 1987); Flavonol: Quercetin, Quercetin 3- <i>O</i> -arabinoside, Quercetin 3- <i>O</i> -glucoside, Quercetin 3- <i>O</i> -glucuronide, Quercetin 3- <i>O</i> -rhamnoside (lv) (Park, 1987)
<i>Polygonum recumbens</i> Flavonol: Vogeletin 3- <i>O</i> -rhamnoside (wp) (Sen <i>et al.</i> , 1971)
<i>Polygonum sagittatum</i> Flavone: Chrysoeriol 7- <i>O</i> -glycoside, Luteolin, Tricin (lv) (Park, 1987); Flavonol: Isorhamnetin, Isorhamnetin 3- <i>O</i> -glycoside, Isorhamnetin 3- <i>O</i> -rhamnosylglucoside, Kaempferol 3- <i>O</i> -rhamnosylglucoside, Quercetin, Quercetin 3- <i>O</i> -glucoside, Quercetin 3- <i>O</i> -rhamnoside, Quercetin 3- <i>O</i> -rhamnosylglucoside (lv) (Park, 1987)
<i>Polygonum senegalense</i> Chalcone: 2',4'-Dihydroxy-3',6'-dimethoxychalcone (lv, sd) (Maradufu and Ouma, 1978)
<i>Polygonum stagninum</i> Flavanone: Onysilin (ap) (Datta <i>et al.</i> , 2002); Flavonol: Quercetin 3- <i>O</i> -galactoside, Quercetin 3- <i>O</i> -glucoside, Rhamnocitrin (ap) (Datta <i>et al.</i> , 2002)
<i>Polygonum stelligerum</i> Flavone: Chrysoeriol 7- <i>O</i> -glycoside, Luteolin, Luteolin 7- <i>O</i> -diglucoside (lv) (Park, 1987); Flavonol: Quercetin, Quercetin 3- <i>O</i> -glucoside, Quercetin 3- <i>O</i> -rhamnoside (lv) (Park, 1987), Isorhamnetin 3- <i>O</i> -glucoside, Quercetin 3- <i>O</i> -rutinoside (lv) (Sartor <i>et al.</i> , 1999); C-Glycosylflavone: Isoorientin, Orientin (lv) (Park, 1987)
<i>Polygonum strigosum</i> Flavone: Chrysoeriol 7- <i>O</i> -glycoside, Luteolin, Luteolin 7- <i>O</i> -diglucoside, Luteolin 7- <i>O</i> -glucoside (lv) (Park, 1987); Flavonol: Quercetin, Quercetin 3- <i>O</i> -glucoside, Quercetin 3- <i>O</i> -glucuronide, Quercetin 3-methyl ether, Quercetin 3- <i>O</i> -rhamnoside (lv) (Park, 1987); C-Glycosylflavone: Apigenin <i>C</i> -glycoside, Luteolin <i>C</i> -glycoside (lv) (Park, 1987)
<i>Polygonum tinctorium</i> Flavonol: Kaempferol 3- <i>O</i> -glucoside, Gomphrenol 3- <i>O</i> -glucoside (ap) (Kohda <i>et al.</i> , 1990)
<i>Reynoutria japonica</i> var. <i>compacta</i> (= <i>Polygonum cuspidatum</i> f. <i>compacta</i>) Anthocyanin: Cyanidin 3- <i>O</i> -glucoside (st, lv) (Yoshitama <i>et al.</i> , 1984, 1988)
<i>Reynoutria japonica</i> var. <i>japonica</i> (= <i>Polygonum cuspidatum</i>) Anthocyanin: Cyanidin 3- <i>O</i> -glucoside (fl, lv, sd) (Yoshitama <i>et al.</i> , 1972, 1980, 1984, 1988; Kawasaki and Yoshitama, 1986), Cyanidin 3- <i>O</i> -rutinoside (fl, sd) (Kawasaki and Yoshitama, 1986; Yoshitama <i>et al.</i> , 1988); Flavan and Proanthocyanidin: Catechin, Epicatechin (rt) (Fan <i>et al.</i> , 2009); Flavone: Apigenin 7- <i>O</i> -glucoside (lv) (Kawasaki and Yoshitama, 1986); Flavonol: Quercetin 3- <i>O</i> -xyloside (lv) (Nakaoki and Morita, 1956; Kutani and Kawase, 1961), Quercetin 3- <i>O</i> -arabinosylgalactoside, Quercetin 3- <i>O</i> -glucuronide, Quercetin 3- <i>O</i> -rhamnosylgalactoside (lv) (Kawasaki and Yoshitama, 1986), Quercetin (lv) (Kutani and Kawase, 1961, 1966), Quercetin 3- <i>O</i> -arabinoside (lv) (Kutani and Kawase, 1961; Kawasaki <i>et al.</i> , 1986; Kawasaki and Yoshitama, 1986), Quercetin 3- <i>O</i> -rhamnoside (lv, st) (Kutani and Kawase, 1961; Kawasaki <i>et al.</i> , 1986; Kawasaki and Yoshitama, 1986; Ohta <i>et al.</i> , 1998; Fan <i>et al.</i> , 2009), Quercetin 3- <i>O</i> -galactoside (lv) (Kutani and Kawase, 1961, 1996; Ohta <i>et al.</i> , 1998), Quercetin 3- <i>O</i> -glucoside, Quercetin 3- <i>O</i> -rutinoside (lv) (Kutani and Kawase, 1961; Ohta <i>et al.</i> , 1998); C-Glycosylflavone: Apigenin 6,8-di- <i>C</i> -glycoside, Luteolin 6,8-di- <i>C</i> -glycoside (lv) (Kawasaki <i>et al.</i> , 1986; Kawasaki and Yoshitama, 1986), Isoviteixin, Vitexin (sd) (Kawasaki and Yoshitama, 1986)
<i>Reynoutria sachalinensis</i> (= <i>Polygonum sachalinensis</i>) Anthocyanin: Cyanidin 3- <i>O</i> -glucoside, Cyanidin 3- <i>O</i> -rutinoside (st, lv) (Yoshitama <i>et al.</i> , 1984, 1988); Flavonol: Quercetin 3- <i>O</i> -rhamnoside (lv) (Nakaoki and Morita, 1956; Kawasaki <i>et al.</i> , 1986; Ohta <i>et al.</i> , 1998), Quercetin 3- <i>O</i> -glucoside, Quercetin 3- <i>O</i> -rutinoside (lv) (Ohta <i>et al.</i> , 1998), Quercetin 3- <i>O</i> -galactoside (lv, st) (Ohta <i>et al.</i> , 1998, Fan <i>et al.</i> , 2009), Quercetin 3- <i>O</i> -arabinofuranoside (st) (Fan <i>et al.</i> , 2009)
<i>Rheum nobile</i> Flavonol: Kaempferol glycoside, Quercetin, Quercetin 3- <i>O</i> -arabinopyranoside, Quercetin 3- <i>O</i> -[6''-(3-hydroxy-3-methylglutaroyl)-glucoside], Quercetin 3- <i>O</i> -galactoside, Quercetin 3- <i>O</i> -glucoside, Quercetin 7- <i>O</i> -glycoside, Quercetin 3- <i>O</i> -rutinoside (lv, br) (Iwashina <i>et al.</i> , 2004)
<i>Rheum palmatum</i> var. <i>tanguticum</i> Anthocyanin: Cyanidin 3- <i>O</i> -glucoside, Cyanidin 3- <i>O</i> -rutinoside (lv) (Yoshitama <i>et al.</i> , 1988); Flavonol: Quercetin 3- <i>O</i> -glucuronide, Quercetin 3- <i>O</i> -rutinoside (lv) (Kawasaki <i>et al.</i> , 1986); C-Glycosylflavone: Apigenin 6,8-di- <i>C</i> -glycoside (lv) (Kawasaki <i>et al.</i> , 1986)

Table 3. Continued

Species	Flavonoids
<i>Rheum rhaponticum</i>	Anthocyanin: Cyanidin 3- <i>O</i> -glucoside, Cyanidin 3- <i>O</i> -rutinoside (lv) (Wrolstad and Heatherbell, 1968; Fureki, 1969; Wrolstad and Struthers, 1971; Yoshitama <i>et al.</i> , 1984, 1988); Flavan and Proanthocyanidin: (+)-Catechin, Epicatechin-(4 β →8)-epicatechin-(4 β →8)-catechin, Epicatechin 3-gallate-(4 β →6)-epicatechin 3-gallate-(4 β →8)-catechin, Epicatechin 3-gallate-(4 β →8)-epicatechin 3-gallate-(4 β →6)-catechin, Epicatechin-[4 β →8] ₂ -catechin, (–)-Epicatechin 3-gallate, Epicatechin 3-gallate-(4 β →6)-epicatechin 3-gallate-(4 β →6)-epicatechin 3-gallate, Epicatechin 3-gallate-(4 β →6)-epicatechin 3-gallate-(4 β →8)-epicatechin 3-gallate, Epicatechin 3-gallate-(4 β →8)-epicatechin 3-gallate-(4 β →8)-epicatechin 3-gallate, Procyanidin B-1, Procyanidin B-1 3-gallate, Procyanidin B-2, Procyanidin B-2 3,3'-digallate, Procyanidin B-2 3'-gallate, Procyanidin B-3, Procyanidin B-4, Procyanidin B-4 3'-gallate, Procyanidin B-5, Procyanidin B-5 3,3'-digallate, Procyanidin B-7, Procyanidin B-7 3-gallate, Procyanidin C-1, Procyanidin C-1 3',3''-digallate, Procyanidin C-1 3,3',3''-trigallate (wp) (Kashiwada <i>et al.</i> , 1986); Flavonol: Quercetin 3- <i>O</i> -glucoside, Quercetin 3- <i>O</i> -rhamnoside (ap) (Blundstone, 1967), Quercetin 3- <i>O</i> -rutinoside (ap, lv) (Blundstone, 1967; Kawasaki <i>et al.</i> , 1986); C-Glycosylflavone: Apigenin 6,8-di- <i>C</i> -glycoside (lv) (Kawasaki <i>et al.</i> , 1986)
<i>Rheum undulatum</i>	Anthocyanin: Cyanidin 3- <i>O</i> -glucoside (fl, lv), Cyanidin 3- <i>O</i> -rutinoside (lv) (Yoshitama <i>et al.</i> , 1984, 1988); Flavonol: Myricetin 3- <i>O</i> -rhamnoside, Quercetin 3- <i>O</i> -rutinoside (lv) (Kawasaki <i>et al.</i> , 1986); C-Glycosylflavone: Apigenin 6,8-di- <i>C</i> -glycoside (lv) (Kawasaki <i>et al.</i> , 1986)
<i>Rumex acetocella</i>	Anthocyanin: Cyanidin 3- <i>O</i> -glucoside (fl) (Yoshitama <i>et al.</i> , 1980, 1984, 1988); Flavone: Luteolin 7- <i>O</i> -glucoside (lv) (Kawasaki <i>et al.</i> , 1986); Flavonol: Kaempferol, Quercetin, Sexangularetin (po) (Wiermann <i>et al.</i> , 1981)
<i>Rumex acetosa</i>	Anthocyanin: Cyanidin 3- <i>O</i> -glucoside (fl, lv) (Yoshitama <i>et al.</i> , 1980, 1984, 1988); Flavonol: Kaempferol, Quercetin, Sexangularetin (po) (Wiermann <i>et al.</i> , 1981); Quercetin 3- <i>O</i> -galactoside (lv) (Kawasaki <i>et al.</i> , 1986; Ohta <i>et al.</i> , 1998), Quercetin 3- <i>O</i> -glucoside, Quercetin 3- <i>O</i> -rhamnoside, Quercetin 3- <i>O</i> -rutinoside (lv) (Ohta <i>et al.</i> , 1998); C-Glycosylflavone: Vitexin (lv) (Aritomi <i>et al.</i> 1965; Kawasaki <i>et al.</i> , 1986), Isoorientin, Isovitexin, Orientin (lv) (Kawasaki <i>et al.</i> , 1986)
<i>Rumex aegyptiacus</i>	Flavonol: Quercetin 3- <i>O</i> -glucuronide (lv, st) (Saleh <i>et al.</i> , 1993)
<i>Rumex conglomeratus</i>	Flavonol: Quercetin 3- <i>O</i> -glucuronide, Quercetin 3- <i>O</i> -rhamnoside (lv) (Kawasaki <i>et al.</i> , 1986)
<i>Rumex crispus</i>	Anthocyanin: Cyanidin glucoside (lv) (Koukol and Dugger, Jr., 1967); Flavonol: Quercetin 3- <i>O</i> -glucoside, Quercetin 3- <i>O</i> -glucuronide (lv, st) (Saleh <i>et al.</i> , 1993)
<i>Rumex cyprius</i>	C-Glycosylflavone: Isovitexin, Isoorientin, Orientin, Vitexin (lv, st) (Saleh <i>et al.</i> , 1993)
<i>Rumex dentatus</i>	Flavonol: Kaempferol 3- <i>O</i> -glucuronide, Quercetin 3- <i>O</i> -glucuronide (lv, st) (Saleh <i>et al.</i> , 1993)
<i>Rumex japonicus</i> (= <i>R. crispus</i> subsp. <i>japonicus</i>)	Anthocyanin: Cyanidin 3- <i>O</i> -rutinoside (fl, lv) (Yoshitama <i>et al.</i> , 1984), Cyanidin 3- <i>O</i> -glucoside (fl, lv) (Yoshitama <i>et al.</i> , 1984, 1988); Flavonol: Quercetin 3- <i>O</i> -rhamnoside (lv) (Aritomi <i>et al.</i> , 1965; Kawasaki <i>et al.</i> , 1986; Ohta <i>et al.</i> , 1998), Quercetin 3- <i>O</i> -glucuronide (lv) (Kawasaki <i>et al.</i> , 1986), Quercetin 3- <i>O</i> -galactoside, Quercetin 3- <i>O</i> -glucoside, Quercetin 3- <i>O</i> -rutinoside (lv) (Ohta <i>et al.</i> , 1998)
<i>Rumex longifolius</i>	Flavonol: Quercetin 3- <i>O</i> -glucoside, Quercetin 3- <i>O</i> -rhamnoside (lv) (Kawasaki <i>et al.</i> , 1986)
<i>Rumex montanus</i> (= <i>R. arifolius</i>)	Anthocyanin: Cyanidin 3- <i>O</i> -glucoside (fl) (Yoshitama <i>et al.</i> , 1984, 1988)
<i>Rumex obtusifolius</i>	Anthocyanin: Cyanidin 3- <i>O</i> -glucoside (fl, lv) (Yoshitama <i>et al.</i> , 1980, 1984, 1988); Flavonol: Quercetin 3- <i>O</i> -glucuronide (lv) (Kawasaki <i>et al.</i> , 1986), Quercetin 3- <i>O</i> -rhamnoside (lv) (Kawasaki <i>et al.</i> , 1986; Ohta <i>et al.</i> , 1998), Quercetin 3- <i>O</i> -galactoside, Quercetin 3- <i>O</i> -glucoside, Quercetin 3- <i>O</i> -rutinoside (lv) (Ohta <i>et al.</i> , 1998)
<i>Rumex pictus</i>	Flavone: Apigenin, Luteolin (lv, st) (Saleh <i>et al.</i> , 1993); C-Glycosylflavone: Isovitexin, Isoorientin, Orientin, Vitexin (lv, st) (Saleh <i>et al.</i> , 1993)
<i>Rumex pulcher</i>	Flavonol: Quercetin 3- <i>O</i> -glucuronide (lv, st) (Saleh <i>et al.</i> , 1993)
<i>Rumex simpliciflorus</i>	C-Glycosylflavone: Isovitexin, Isoorientin, Orientin, Vitexin (lv, st) (Saleh <i>et al.</i> , 1993)

Table 3. Continued

Species
Flavonoids
<i>Rumex vesicarius</i>
Flavone: Apigenin, Luteolin (lv, st) (Saleh <i>et al.</i> , 1993); C-Glycosylflavone: Isovitexin, Isoorientin, Orientin, Vitexin (lv, st) (Saleh <i>et al.</i> , 1993)
<i>Triplaris americana</i>
Flavonol: Quercetin, Quercetin 3- <i>O</i> -arabinofuranoside (fr, lv, st) (Oliveira <i>et al.</i> , 2008)
<i>Triplaris cumingiana</i>
Flavonol: Kaempferol 3- <i>O</i> -(5''-galloylarabinoside), Quercetin 4'- <i>O</i> -arabinoside, Quercetin 3- <i>O</i> -(4'',6''-digalloylglucoside), Quercetin 3- <i>O</i> -(5''-galloylarabinoside), Quercetin 3- <i>O</i> -(6''-galloylglucoside) (lv) (Hussein <i>et al.</i> , 2005)

ap = aerial parts, br = bracts, ct = cotyledons, fl = flowers, fr = fruits, hp = hypocotyls, lv = leaves, po = pollen, rt = roots, sd = seeds, st = stems, wp = whole plants.

europaea, respectively (Harborne, 1967). Thus, the presence of anthocyanins in the Plumbagina-ceae was proved.

Flavonoids of Polygonaceae

The Polygonaceae is a very large cosmopolitan family of herbs, some shrubs and a few trees, with a number of cultivated ornamentals, and consists of ca. 30 genera and ca. 750 species. Most genera inhabit the temperate northern regions (Heywoods, 1978).

Flavonoids are reported from many species (87 taxa of 17 genera) (Table 3). Major flavonoid class is flavonol and found in many species which were surveyed for flavonoids. Various 3-*O*-glycosides, e.g. glucoside, galactoside, rhamnoside, arabinoside, glucuronide, xyloside and rutinoside, based on kaempferol, quercetin and myricetin, were isolated from the various species. Quercetin 3-*O*-glycosides were isolated from the translucent bracts of the Himalayan species, *Rheum nobile*, as UV shields (Iwashina *et al.*, 2004). Of their compounds, quercetin 3-*O*-[6''-(3-hydroxyl-3-methylglutaryl)-glucoside] was reported as a new compound. Acylated flavonol glycosides such as quercetin 3-*O*-(galloylrhamnoside), 3-*O*-(2''-galloylglucoside), 3-*O*-(6''-feruloylgalactoside), 3-*O*-(5''-galloylarabinoside) and 3-*O*-(4'',6''-digalloylglucoside), kaempferol 3-*O*-(6''-*p*-hydroxybenzoylgalactoside) were found in some species, e.g. *Triplaris cumingiana* (Hussein *et*

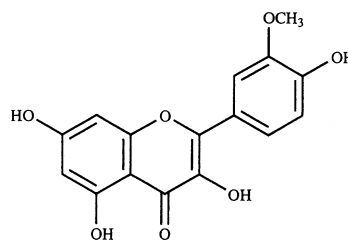


Fig. 37. Isorhamnetin.

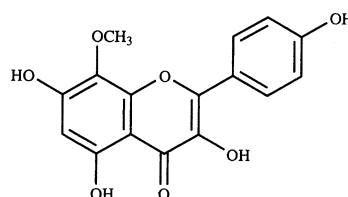


Fig. 38. Sexangularetin.

al., 2005), *Persicaria viscosa* (Datta *et al.*, 2000), *P. pubescens* (Isobe and Noda, 1987a), *P. lapathifolia* (Park *et al.*, 1999), *Oxyria digyna* (Li *et al.*, 2008), *Antenoron filiforme* and *Antigonon leptopus* (Kawasaki *et al.*, 1986). Flavonol sulphates, quercetin 3-sulphate, isorhamnetin (Fig. 37) 3,7-disulphate, tamarixetin 7-sulphate 3-*O*-glucoside and rhamnazin 3-sulphate were isolated from the leaves of *Persicaria hydropiper* (Yagi *et al.*, 1994; Haraguchi *et al.*, 1996). Other sulphates, isorhamnetin 3-sulphate and quercetin 3-sulphate were reported from *Persicaria thunbergii* (Matsushita, 1972; Kawasaki *et al.*, 1986; Park, 1987). Rare flavonols, sexangularetin (Fig.

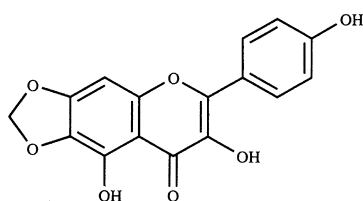


Fig. 39. Gomphrenol.

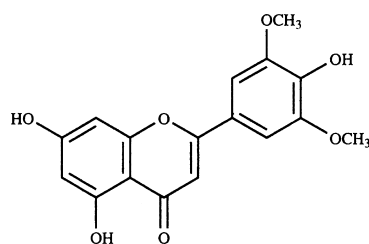


Fig. 43. Tricin.

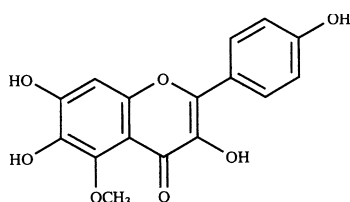


Fig. 40. Vogetetin.

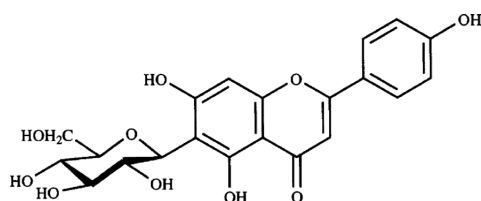


Fig. 44. Isovitexin.

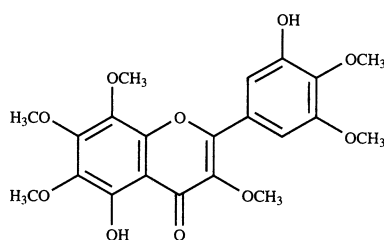


Fig. 41. Digicitrin.

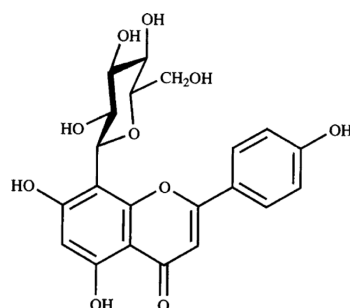


Fig. 45. Vitexin.

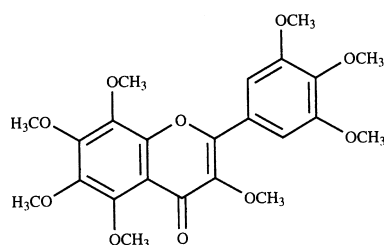


Fig. 42. Exoticin.

38), gomphrenol (Fig. 39) 3-*O*-glucoside and vogetetin (Fig. 40) 3-*O*-rhamnoside, were isolated from the pollens of *Rumex acetosa* (Wiermann *et al.*, 1981), the aerial parts of *Polygonum tinctorum* (Kohda *et al.*, 1990) and the whole plants of *Polygonum recumbens* (Sen *et al.*, 1971), respectively. Some polymethoxyflavonols such as digicitrin (Fig. 41) and exoticin (Fig. 42)

were isolated from the aerial parts of *Persicaria pilosa* (Kuroyanagi and Fukushima, 1982).

Flavones and *C*-glycosylflavones were scatteredly found in some species, e.g. luteolin and its 7-*O*-glucoside, 7-*O*-diglucoside, 3'-*O*-glycoside, apigenin and its 7-*O*-glucoside, triclin (Fig. 43) and chrysoeriol 7-*O*-glycoside from *Persicaria dichotoma*, *P. hastato-sagittata*, *P. thunbergii*, *Polygonum arifolium*, *P. dissitiflorum*, *P. meisnerianum* var. *beyrichianum* and var. *meisnerianum*, *P. muricatum*, *P. praetermissum*, *P. sagittatum*, *P. stelligerum*, *P. strigosum* (Park, 1987), *Reynoutria japonica* var. *japonica* (Kawasaki and Yoshitama, 1986), *Rumex acetocella* (Kawasaki *et al.*, 1986), *Rumex pictus* and *R. vesicarium* (Saleh *et al.*, 1993). *C*-Glycosylfla-

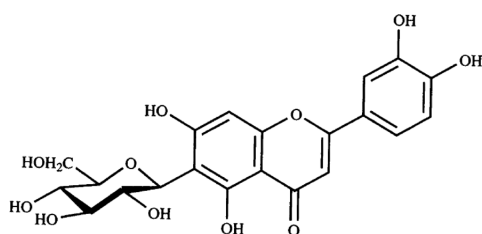


Fig. 46. Isoorientin.

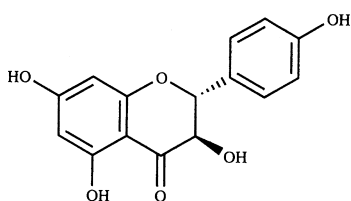


Fig. 47. Aromadendrin.

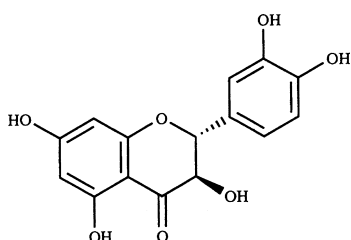


Fig. 48. Taxifolin.

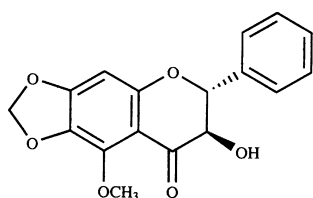


Fig. 49. 3-Hydroxy-5-methoxy-6,7-methylene-dioxyflavanone.

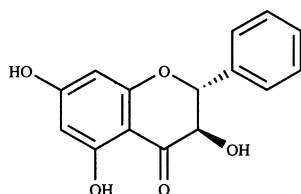


Fig. 50. Pinobanksin.

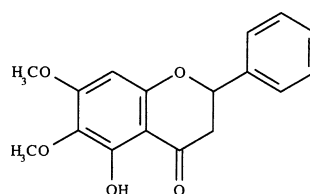


Fig. 51. Onysilin.

vones, isovitexin (Fig. 44), vitexin (Fig. 45), isoorientin (Fig. 46), orientin, and apigenin and luteolin 6-, 8- and 6,8-di-*C*-glycosides were isolated from *Bistorta suffulta* (Kawasaki *et al.*, 1986), *Fagopyrum esculentum* (Margna *et al.*, 1967, 1985; Saunders and McClure, 1975; Margna and Vainj  r, 1981, 1983, 1985), *Fallopia convolvulus*, *F. dentata-alata*, *F. dumetra* (Kim *et al.*, 2000), *Mehlenbeckia platyclada* (Kawasaki *et al.*, 1986), *Persicaria hastato-sagittata* (Park, 1987), *Persicaria nepalensis* (Rathore *et al.*, 1987), *Pleuropterus multiflorus* (Kawasaki *et al.*, 1986), *Polygonum arifolium*, *P. muricatum*, *P. stelligerum*, *P. strigosum* (Park, 1986) *Reynoutria japonica* var. *japonica*, *Rheum palmatum* var. *tanguticum*, *R. raponticum*, *R. undulatum* (Kawasaki *et al.*, 1986; Kawasaki and Yoshitama, 1986), *Rumex cyprius*, *R. simpliciflorum*, *R. vesicarium* (Saleh *et al.*, 1993).

Dihydroflavonols, aromadendrin (Fig. 47) 3-*O*-galactoside and taxifolin (Fig. 48) 3-*O*-xyloside, were isolated from the seeds of *Fagopyrum esculentum* (Samaiya and Saxena, 1984). Other dihydroflavonols, (2*R*,3*R*)-3-hydroxy-5-methoxy-6,7-methylenedioxyflavanone (Fig. 49), pinobanksin (Fig. 50) and taxifolin were found in *Persicaria lapathifolia* (Kuroyanagi *et al.*, 1982; Abe *et al.*, 2007). A rare flavanone, onysilin (Fig. 51), was isolated from the aerial parts of *Polygonum stagninum* (Datta *et al.*, 2002).

Rare chalcones, 2',4'-dihydroxy-3',6'-dimethoxylchalcone (Fig. 52) and β -hydroxy-2,3,4,5,2',4',5'-heptamethoxylchalcone (Fig. 53), were detected from the leaves and seeds of *Polygonum senegalense* (Maradufu and Ouma, 1978) and the whole plants of *Persicaria nepalensis* (Rathore *et al.*, 1987), respectively. Flavan and proanthocyan-

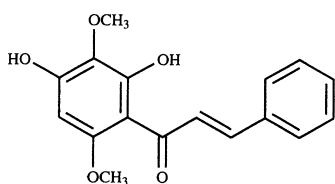


Fig. 52. 2',4'-Dihydroxy-3',6'-dimethoxychalcone.

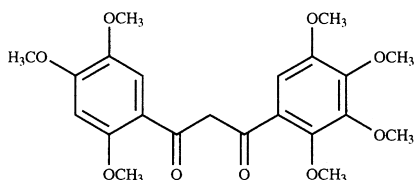
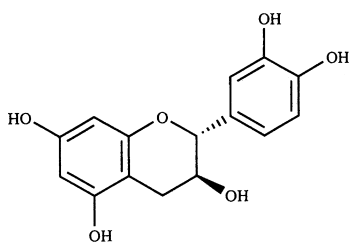

 Fig. 53. β -Hydroxy-2,3,4,5,2',4',5'-heptamethoxychalcone.


Fig. 54. (+)-Catechin.

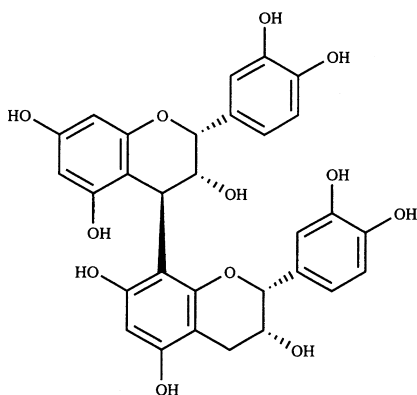


Fig. 55. Procyanidin B-2.

dins were scatteredly found in some Polygonaceous species. (+)-Catechin (Fig. 54), (–)-epicatechin, (–)-epicatechin 3-gallate, and procyanidin B-2 (Fig. 55) and its 3-gallate were

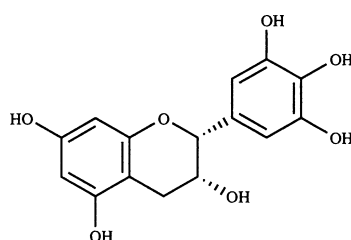


Fig. 56. (–)-Epigallocatechin.

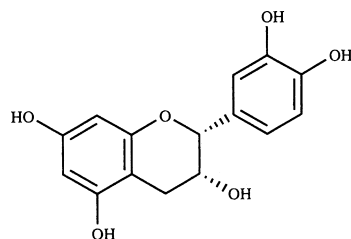


Fig. 57. (+)-Epicatechin.

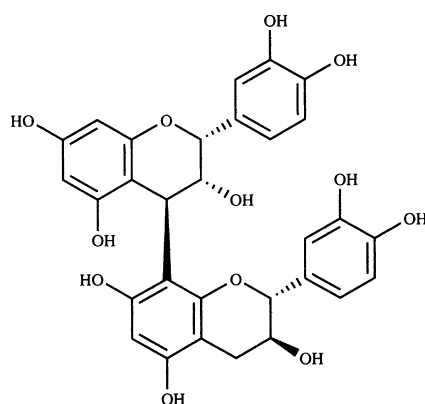


Fig. 58. Procyanidin B-1.

isolated from the roots of *Fagopyrum esculentum* (Trotin *et al.*, 1993). (–)-Epigallocatechin (Fig. 56) and (–)-epicatechin, and their 3-gallates were found in the whole plants of *Oxyria digyna* (Li *et al.*, 2008). (+)-Catechin and (+)-epicatechin (Fig. 57) were also found in the aerial parts of *Pleuropterypyrum weyrichii* and *Polygonum divaricatum* (Levashova and Zhdanova, 1990), and the roots of *Reynoutria japonica* var. *japonica* (Fan *et al.*, 2009). Many flavan and proanthocyanidins such as procyanidin B-1, B-2, B-3, B-4, B-5, B-7, C-1 (Figs. 55, 58–63) and their

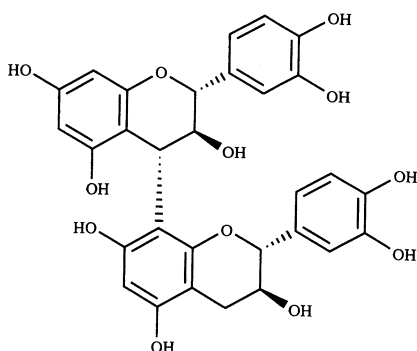


Fig. 59. Procyanidin B-3.

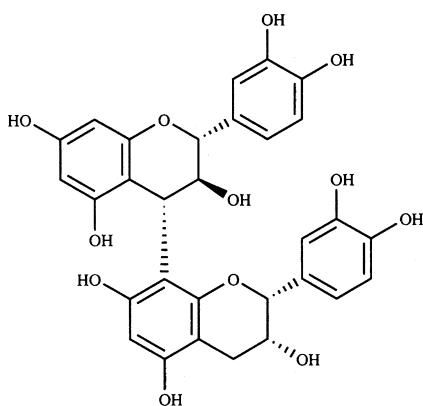


Fig. 60. Procyanidin B-4.

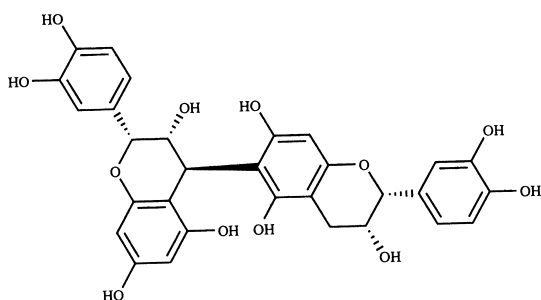


Fig. 61. Procyanidin B-5.

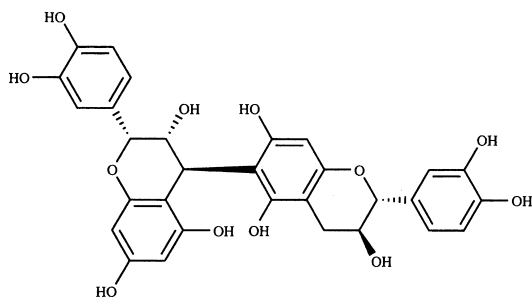


Fig. 62. Procyanidin B-7.

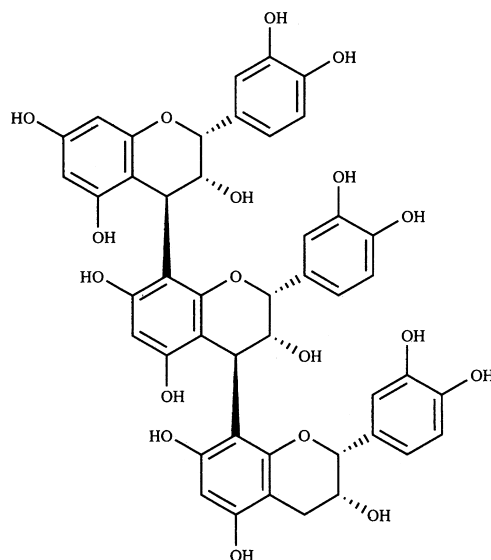


Fig. 63. Procyanidin C-1.

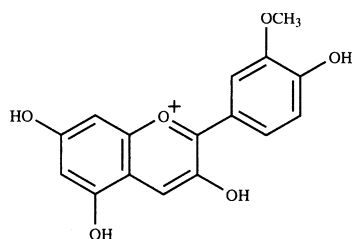


Fig. 64. Peonidin.

3'-, 3',3''-di-, 3,3'-di-, 3,3',3''-trigallates, and epicatechin and epigallocatechin trimers were isolated from the whole plants of *Rheum rhaponticum* (Kashiwada *et al.*, 1986).

In the Polygonaceae, anthocyanins occur in many species. The common anthocyanins are cyanidin glycosides such as 3-*O*-glucoside and

3-*O*-rutinoside, and rarely 3-*O*-arabinoside-5-*O*-glucoside and 3-*O*-arabinoside, and also delphinidin glycosides as 3-*O*-glucoside and 3-*O*-rutinoside from *Persicaria chinensis*, *P. maackiana* and *P. nepalensis* (Yoshitama *et al.*, 1988), peonidin (Fig. 64) glycosides as 3-*O*-arabinoside-5-*O*-glu-

Table 4. Reports of the flavonoids from the family Droseraceae

Species	Flavonoids
<i>Dionaea muscipula</i>	Anthocyanin: Cyanidin 3- <i>O</i> -glucoside (wp) (Di Gregorio and Di Palma, 1966; Ichiishi <i>et al.</i> , 1999; Kondo <i>et al.</i> , 2002), Delphinidin 3- <i>O</i> -glucoside (wp) (Ichiishi <i>et al.</i> , 1999; Kondo <i>et al.</i> , 2002); Flavonol: Kaempferol 3- <i>O</i> -glycoside, Quercetin 3- <i>O</i> -glycoside (wp) (Iwashina <i>et al.</i> , unpublished data)
<i>Drosera anglica</i>	Anthocyanin: Cyanidin glycoside, Pelargonidin glycoside (wp) (Bendz and Lindberg, 1968)
<i>Drosera intermedia</i>	Anthocyanin: Cyanidin glycoside, Pelargonidin glycoside (wp) (Bendz and Lindberg, 1968)
<i>Drosera rotundifolia</i>	Flavonol: Quercetin (ap) (Bienenfeld and Katzlmeier, 1966), Quercetin 3- <i>O</i> -digalactoside, Quercetin 3- <i>O</i> -galactoside (ap) (Bienenfeld and Katzlmeier, 1966; Schölly and Kapetanidis, 1989), Gossypetin, Gossypetin 7- <i>O</i> -glucoside, Kaempferol 3- <i>O</i> -glucoside, Quercetin 3- <i>O</i> -glucoside (ap) (Schölly and Kapetanidis, 1989)
<i>Drosera spathulata</i>	Anthocyanin: Cyanidin 3,5-di- <i>O</i> -glucoside, Cyanidin 3- <i>O</i> -galactoside, Cyanidin 3- <i>O</i> -glucoside, Pelargonidin 3- <i>O</i> -galactoside, Pelargonidin 3- <i>O</i> -glucoside (wp) (Ichiishi <i>et al.</i> , 1999); Flavonol: Myricetin 3- <i>O</i> -galactoside, Quercetin 3- <i>O</i> -galactoside (wp) (Iwashina <i>et al.</i> , unpublished data)

ap = aerial parts, wp = whole plants.

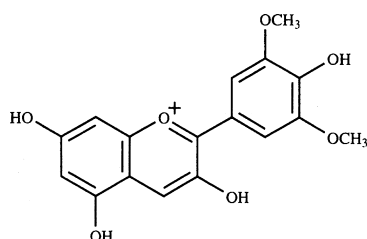


Fig. 65. Malvidin.

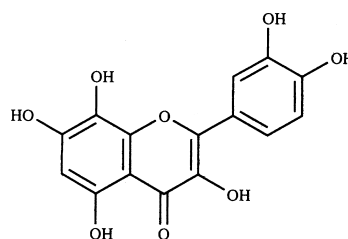


Fig. 66. Gossypetin.

coside and 3,5-di-*O*-glucoside from *Persicaria lapathifolia*, *P. longiseta* and *P. yokusaiana* (Yoshitama *et al.*, 1984, 1988), and malvidin (Fig. 65) glycoside as 3,5-di-*O*-glucoside from *Persicaria nipponensis*, *P. perfoliata*, *P. senticosa* and *P. sieboldii* (Yoshitama *et al.*, 1984, 1988) were detected.

Flavonoids of Droseraceae

The Droseraceae is a family of carnivorous annual or perennial herbs, sometimes with woody stems, comprising the genera *Drosera*, *Drosophyllum*, *Aldrovanda* and *Dionaea*. *Drosera* is cosmopolitan, with concentrations in Australia and New Zealand. Other three genera are monotypic genus.

Four *Drosera* species, *D. anglica*, *D. interme-*

dia, *D. rotundifolia* and *D. spathulata*, and *Dionaea muscipula* have been surveyed for flavonoids (Table 4). Of their species, flavonols, kaempferol and quercetin 3-*O*-glycosides were isolated from *D. muscipula* (Iwashina *et al.*, unpublished data). Quercetin and its 3-*O*-galactoside, 3-*O*-glucoside and 3-*O*-digalactoside, gossypetin (Fig. 66) and its 7-*O*-glucoside, and kaempferol 3-*O*-glucoside were found in *D. rotundifolia* (Bienenfeld and Katzlmeier, 1966; Schölly and Kapetanidis, 1989), and myricetin and quercetin 3-*O*-galactosides from *D. spathulata* (Iwashina *et al.*, unpublished data).

Anthocyanins were isolated from four species except for *D. rotundifolia*, i.e. cyanidin and delphinidin 3-*O*-glucosides from *Dionaea muscipula* (Di Gregorio and Di Palma, 1966; Ichiishi *et al.*, 1999; Kondo *et al.*, 2002), cyanidin and pel-

argonidin from *Drosera anglica* and *D. intermedia* (Bendz and Lindberg, 1968), and cyanidin 3,5-di-*O*-glucoside and 3-*O*-galactoside, and pelargonidin 3-*O*-galactoside and 3-*O*-glucoside from *D. spathulata* (Ichiishi *et al.*, 1999). Other flavonoid classes except for anthocyanins and flavonols are not found in the Droseraceae.

Flavonoids of Nepenthaceae

The Nepenthaceae is also a family of carnivorous tropical herbs and shrubs. The family consists of only one genus, *Nepenthes* and ca. 70

species are included (Heywood, 1978). The family has representatives cattered throughout the Old World tropics, with a center of distribution in Borneo.

Six species, *Nepenthes burbidgeae*, *N. gracilis*, *N. mirabilis*, *N. muluensis*, *N. rajah* and *N. tentaculata* have been surveyed for flavonoids. Flavonols were found in all species which were surveyed for flavonoids, i.e. kaempferol and quercetin glycosides from *N. burbidgeae*, *N. mirabilis*, *N. muluensis* and *N. rajah*, and kaempferol glycoside alone from *N. tentaculata* (Table 5) (Adam *et al.*, 2002). Procyanidins were

Table 5. Reports of the flavonoids from the family Nepenthaceae

Species
Flavonoids
<i>Nepenthes burbidgeae</i>
Flavan and Proanthocyanidin: Procyanidin (lv) (Adam <i>et al.</i> , 2002); Flavonol: Kaempferol glycoside, Quercetin glycoside (lv) (Adam <i>et al.</i> , 2002)
<i>Nepenthes gracilis</i>
Flavan and Proanthocyanidin: Epicatechin 3-gallate (lv) (Fan <i>et al.</i> , 2010); Flavonol: Quercetin 3- <i>O</i> -(2"-galloylarabinofuranoside), Quercetin 3- <i>O</i> -(6"-galloylglucoside), Quercetin 3- <i>O</i> -(3"-galloylrhamnoside), Quercetin 3- <i>O</i> -(2"-galloylxylopyranoside), Quercetin 3- <i>O</i> -(3"-galloylxylopyranoside) (lv) (Fan <i>et al.</i> , 2010)
<i>Nepenthes mirabilis</i>
Flavan and Proanthocyanidin: Procyanidin (lv) (Adam <i>et al.</i> , 2002); Flavonol: Kaempferol glycoside, Quercetin glycoside (lv) (Adam <i>et al.</i> , 2002)
<i>Nepenthes muluensis</i>
Flavone: Luteolin glycoside (lv) (Adam <i>et al.</i> , 2002); Flavonol: Kaempferol glycoside, Quercetin glycoside (lv) (Adam <i>et al.</i> , 2002)
<i>Nepenthes rajah</i>
Flavan and Proanthocyanidin: Procyanidin (lv) (Adam <i>et al.</i> , 2002); Flavone: Luteolin glycoside (lv) (Adam <i>et al.</i> , 2002); Flavonol: Kaempferol glycoside, Quercetin glycoside (lv) (Adam <i>et al.</i> , 2002)
<i>Nepenthes tentaculata</i>
Flavonol: Kaempferol glycoside (lv) (Adam <i>et al.</i> , 2002)

lv = leaves.

Table 6. Occurrence of flavonoid classes in five families newly incorporated into the order Caryophyllales

Classes	Tamaricaceae	Plumbaginaceae	Polygonaceae	Droseraceae	Nepenthaceae
Anthocyanin	3	11	44	4	0?
Flavone	5	2	19	0	2
C-Glycosylflavone	0	1	23	0	0
Flavonol	21	15	68	3	6
Chalcone	0	1	2	0	0
Aurone	0	2	0	0	0
Flavanone	0	1	1	0	0
Dihydroflavonol	0	1	2	0	0
Flavan and Proanthocyanidin	1	6	6	0	4
Numbers of species examined	24	19	87	5	6

* Number of taxa which the flavonoid classes were found.

detected from four species except for *N. muluensis* and *N. tentaculata* (Adam *et al.*, 2002), and that of *N. gracilis* was identified as epicatechin 3-gallate (Fan *et al.*, 2010). Though anthocyanins were not isolated from the Nepenthaceae, the presence of unknown anthocyanin was reported from *Nepenthes* species (Schaefer and Ruxton, 2008).

The occurrence of the flavonoid classes in five families which were newly incorporated into the order Caryophyllales were shown in Table 6. Flavonols were detected in all five families as major flavonoids. Though flavones occurred as minor compounds, they were not apparently present in the Droseraceae. Chalcones, aurones, flavanones and dihydroflavonols were rarely isolated from a few species which belong to the Tamaricaceae, Plumbaginaceae and Polygonaceae. Flavan and proanthocyanidins were also found in four families except for Droseraceae. Anthocyanins, which were never found in eight betacyanin families, Aizoaceae, Nyctaginaceae, Amaranthaceae including Chenopodiaceae, Basellaceae, Portulacaceae, Phytolaccaceae, Cactaceae and Didieaceae, were isolated from the four families, Tamaricaceae, Plumbaginaceae, Polygonaceae and Droseraceae except for Nepenthaceae. However, the presence of anthocyanins in the Nepenthaceae was presumed by Schaefer and Ruxton (2008). Thus, it was shown that the newly incorporated five Caryophyllales families can synthesize the anthocyanins.

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