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Phytochemical and biological research of Polygonaceae medicinal resources

12

12.1 Introduction

Polygonaceae plants have a worldwide distribution, most of which are in the temperate region of the Northern Hemisphere. There are 235 Polygonaceae species and 37 varieties in China. The use of medicinal species is listed in Table 12.1. In the tribe Polygonaceae of the subfamily Polygonaceae, there are seven genera (<http://frps.eflora.cn/frps/Trib.%20Polygoneae>), namely, *Antenoron*, *Fagopyrum*, *Fallopia*, *Koenigia*, *Polygonum*, *Pteroxygonum*, and *Reynoutria*. *Polygonum* is the largest genus of the family Polygonaceae. This chapter summarizes the current knowledge of phytochemistry, bioactivity, phylogeny, and omics of Polygonaceae medicinal plants.

12.2 Chemical components

12.2.1 Phenolics, flavonoids, and phenylpropanoids

Examples of Polygonaceae compounds are shown in Figure 12.1 and Table 12.2. Gallic acid, rutin, coumaric acid, and quercetin were found in the leaves of *P. minus* (Vikram et al., 2014). Polyphenolic compounds, such as hydroxyanthraquinones, stilbenoids, and proanthocyanidins, are abundant in Polygonaceae plants.

12.2.2 Essential oil, terpenoids, steroids, and benzoquinones

Nonane, heptane, octadecanal, β -caryophyllene, *trans*- α -bergamotene, β -farnesene, α -caryophyllene, *p*-benzoquinone, phenol, α -panasinsen, pentanoic acid, octane, heptane, undecane, 1,2 benzenedicarboxylic acid, and nonane were found in the roots of *P. minus* (Vikram et al., 2014). Many other components of essential oil are also present in *P. minus* (Vikram et al., 2014).

Twenty-one compounds were separated and determined from *P. cuspidatum* flower, which amounted to 99.29% of the total volatiles (Sun et al., 2012). (E)-2-hyexenoic acid methyl ester, 1-phenyl-L-pentanone, (E)-4-hexenoic acid methyl ester, 3-hexenoic acid methyl ester, 2-methyl-6-methylene-1, and 7-octadien-3-one were the main constituents of *P. cuspidatum* flower, which amounted to 63.23% of the total volatiles. Organic ester compounds amounted to 52.09% of the total volatiles. Hexenoic acid methyl ester compounds were highly abundant, corresponding to

Table 12.1 Polygonaceae plants used in traditional Chinese medicine and folk medicine

Species	Chinese name	Habitat	Distribution	Therapeutic use	Note
<i>Antenoron filiforme</i> (<i>Polygonum filiforme</i>)	Jin Xian Cao, Ren Zi Cao (Zhe Jiang), Hua Xue Gui (Hu Bei), Xue Jing Cao (Hu Nan)	Altitude 500–1200 m, hillside, forest, bushes, ditch, creek	Central south China, Shan Xi, Shaan Xi, Shan Dong, Jiang Su, Zhe Jiang, Jiang Xi, Fu Jian, Tai Wan, Si Chuan, Gui Zhou, Yun Nan	Root tuber/whole plant: pungent, cool; blood-cooling, hemostasis, stasis-removing and pain-relieving; rheumatism, stomachache, hemoptysis, hematemesis, postpartum abdominal pain due to blood stasis, traumatic injury	<i>A. neofoliforme</i> (<i>Polygonum neofoliforme</i>) has the same therapeutic use; east China, Shan Xi, Shaan Xi, Gan Su, He Nan, Hu Bei, Hu Nan, Guang Dong, Si Chuan, Gui Zhou, Yun Nan
<i>Calligonum leucocladum</i>	Bai Pi Sha Guai Zao	Desert	North Xin Jiang	Whole plant: astringing to stop diarrhea	
<i>Calligonum mongolicum</i>	Sha Guai Zao	Desert	Inner Mongolia, Gan Su, Ning Xia, Xin Jiang	Root/twig with fruit: bitter, astringent, lukewarm; cloudy urine, chapped skin	
<i>Fagopyrum dibotrys</i> (<i>P. cymosum</i>)	Jin Qiao Mai, Qiao Mai Dang Gui (Hu Bei), Qiao Mai San Qi (Zhe Jiang)	Altitude 600–1000 m, ditch, roadside	Central south China, southwest China, Shaan Xi, Gan Su, Jiang Su, Zhe Jiang, Jiang Xi, Fu Jian	Root/rhizome: slightly pungent, astringent, cool; heat-clearing and detoxification, blood-activating and stasis-dissipating, wind-expelling and dampness-removing; sore throat, ulcerative carbuncle, scrofula, hepatitis, lung abscess, wind syndrome of head, stomachache, dysentery, leukorrheal disease	

<i>Fagopyrum esculentum</i> (<i>P. fagopyrum</i>)	Qiao Mai, Hua Mai (Hu Nan), Qiao Zi (Gui Zhou)		Cultivated all over China; semiwild, roadside	Stem/leaf: acid, cold; antihypertension, hemostasis; choking, carbuncle; seed: sweet, cool; lower Qi and comfort intestine, stagnation-relieving, detumescence; dyspepsia, diarrhea, carbuncle back, burn	
<i>Fagopyrum gracilipes</i> (<i>P. gracilipes</i>)	Xi Geng Qiao Mai	Altitude 300–2000 m, hillside, roadside, forest, riverside, crop field	Shaan Xi, Gan Su, Hu Bei, Si Chuan, Yun Nan	Whole plant: heat- clearing and detoxification, blood- activating and stasis- dissipating, spleen- invigorating and diuresis- promoting; seed: appetizer, comfort intestine	
<i>Fagopyrum tataricum</i> (<i>P. tataricum</i>)	Ku Qiao Mai, Qiao Ye Qi (Shaan Xi), Ku Qiao Tou (Gui Zhou)	Altitude 700–2000 m, hill, valley, riverside, in cultivation/ semiwild	Northeast China, northwest China, southwest China	Root tuber/rhizome: sweet, bitter, flat; stomach-invigorating and comfort Qi, dehumidification and pain-relieving; stomachache, dyspepsia, dysentery, internal lesion caused by overexertion, pain in waist and lower extremities	

Continued

Table 12.1 Continued

Species	Chinese name	Habitat	Distribution	Therapeutic use	Note
<i>Muehlenbeckia platycladum</i> (<i>Coccoloba platyclada</i> ; <i>Homalocladium platycladum</i>)	Zhu Jie Liao, Fei Tian Wu Gong (Guang Xi), Bai Zu Cao (Guang Zhou)	Native to south Pacific Solomon islands	Cultivated in garden and greenhouse throughout China	Stem/leaf: sweet, light, flat; stasis-removing, growth-promoting and itch-relieving, swell-relieving/pain killer; carbuncle, traumatic injury, snakebite, centipede bite	
<i>Oxyria digyna</i> (<i>Rumex digynus</i>)	Shen Ye Shan Liao, Suan Jiang Cao (Shaan Xi)	Altitude 2000–3600 m, mountain grassland, hillside, valley	Ji Lin, Shaan Xi, Gan Su, Qing Hai, Si Chuan, Yun Nan, Tibet	Whole plant: acid, cool; heat-clearing and diuresis-promoting; depression of hepatic Qi, hepatitis, scurvy	
<i>P. alatum</i> (<i>P. nepalense</i> ; <i>Persicaria alata</i>)	Tou Zhuang Liao, Nepal Liao, Mao Er Yan Jing (Si Chuan)	Altitude 800–2700 m, hillside, valley, wetland, roadside, crop field	All over China	Whole plant: bitter, cold; heat-clearing and detoxification, astringe and secure the intestine; sore throat, bloodshot eyes, painful swollen gums, bloody dysentery, joint pain, stomachache	
<i>P. alopecuroides</i>	Hu Wei Liao	Riverside, water meadow	Ji Lin, Inner Mongolia	Rhizome: heat-clearing and detoxification, blood-cooling and hemostasis; used as <i>Paris polyphylla</i> (Cao He Che) in Inner Mongolia	

<i>P. amphibium</i> (<i>Persicaria</i> <i>amphibia</i>)	Liang Qi Liao, Xiao Huang Yao (Gui Zhou)	Low-altitude lake, shallow water, wetland	Northeast China, north China, Shaan Xi, Ning Xia, Shan Dong, north Jiang Su, An Hui, He Nan, Hu Bei, Si Chuan, Gui Zhou, Yun Nan	Whole plant: bitter, flat; heat-clearing and diuresis- promoting; dysentery; external use on furuncle	Used for hypertrophic spondylitis in Chang Wei, Shan Dong; <i>P.amphibium</i> var. <i>terrestre</i> has the same therapeutic efficacy and distribution area
<i>P. amplexicaule</i> (<i>Bistorta</i> <i>amplexicaule</i>)	Bao Jing Liao	Altitude >1000 m, mountain woodside, bushes, valley, ditch	Hu Bei, Si Chuan, Yun Nan	Rhizome: spasm- relieving, stasis-removing and hemostasis, myogenic/pain killer, antibacterial, anti- inflammatory	
<i>P. amplexicaule</i> var. <i>sinense</i>	Zhong Hua Bao Jing Liao, Xue San Qi (Hu Bei), Hong Hai Er (Si Chuan)	Altitude 1300– 1500 m, wet valley, bushes	Shaan Xi, Hu Bei, Si Chuan, Yun Nan	Rhizome: slightly bitter, astringent, flat; slightly poisonous; heat-clearing and detoxification, astringing to stop diarrhea; blood-promoting and pain-relieving; dysentery, diarrhea, traumatic injury, bleeding	Not with the cockscomb and <i>Uncaria</i>
<i>P. attenuatum</i>	Mao Ye Er Liao	Mountain bushes	Ji Lin	Rhizome: heat-clearing and detoxification, blood- cooling, detumescence, and convulsion-relieving	

Continued

Table 12.1 Continued

Species	Chinese name	Habitat	Distribution	Therapeutic use	Note
<i>P. aubertii</i> (<i>Fallopia aubertii</i>)	Mu Teng Liao	Altitude 500–2000 m, hillside, ravine sunny shrubs, or in cultivation	southwest China, Inner Mongolia, Shaan Xi, Gan Su, Ning Xia	Root tuber: bitter, astringent, cool; heat-clearing and detoxification, regulate menstrual cycle and hemostasis; dysentery, dyspepsia, stomachache, irregular menstruation	
<i>P. aviculare</i>	Bian Xu, Niu Jin Cao (Shaan Xi), Tai Yang Cao (Zhe Jiang), Ban Jiu Tai (An Hui), Di Liao	Open field, wetland	All over China	Aboveground part: bitter, cool; disinhibit urine and free strangury, insecticidal, anti-itching; urinary infection, oliguria with reddish urine, urine leaching/acerbity/painful, eczema, pruritus vulvae disease, leukorrheal disease	China Pharmacopoeia 1990 version; <i>P. aviculare</i> var. <i>rigidum</i> has similar efficacy, distributed in Helan Mountains, Ning Xia; <i>P. aviculare</i> var. <i>vegetum</i> , distributed in Jiang Su, An Hui, Zhe Jiang, He Nan, Si Chuan, Gui Zhou
<i>P. barbatum</i>	Mao Liao, Si Ji Qing	Altitude <1000 m, roadside, ditch, woodland	Jiang Su, An Hui, Zhe Jiang, Fu Jian, Tai Wan, Hu Bei, Guang Dong, Guang Xi, Si Chuan, Gui Zhou, Yun Nan	Root: pungent, warm; astringent; whole plant: toxin-removing and myogenic, stranguria; seed: emetic, antidiarrheal	

<i>P. barbatum</i> var. <i>gracile</i> (<i>P. barbatum</i> subsp. <i>gracile</i>)	Xi Mao Ci Liao, Xiao Mao Liao, Liao Zi Cao (Si Chuan)	Altitude 500–1000 m, hill, ditch, roadside	Jiang Su, Shang Hai, Guang Xi, Si Chuan, Gui Zhou	Whole plant/root: slightly pungent, warm; cold dispelling and blood-activating; measles, deficiency-cold after disease, abdominal pain, take a chill after traumatic injury, Yin coldness, stale coldness	China Pharmacopoeia 1990
<i>P. bistorta</i> (<i>Bistorta vulgaris</i>)	Quan Shen, Zi Shen (He Bei, Hu Nan, Gui Zhou), Dao Gen Cao (Xin Jiang), Xia Shen (Shan Dong), Ma Feng Qi (Guang Xi)	Hillside meadow, forest meadow	North China, northwest China, Ji Lin, Shan Dong, Jiang Su, An Hui, Zhe Jiang, He Nan, Hu Bei, Si Chuan, Gui Zhou; main producing area: He Bei, Shan Xi, Shan Dong, He Nan	Rhizome: bitter, astringent, cool; heat-clearing and detoxification, apocatastasis, hemostasis; bloody dysentery, heat diarrhea, cough with lung heat, scrofula, aphtha, hematemesis, epistaxis, hemorrhoidal bleeding, snakebite	
<i>P. bungeanum</i>	Liu Ye Ci Liao	The edge of the field, roadside wetland	North China, Hei Long Jiang, Liao Ning, Shan Dong	Root: heat-clearing/ detoxification, diuresis	
<i>P. caespitosum</i> (<i>Persicaria caespitosa</i>)	Cong Zhi Liao, Tai Yang Cao (Si Chuan), Gu Zhi Lian (Gui Zhou)	Altitude 700–2000 m, hillside forest, roadside, ditch	Central south China, Shaan Xi, Gan Su, Jiang Su, Shang Hai, Jiang Xi, Fu Jian, Si Chuan, Gui Zhou, Yun Nan	Whole plant: heat-clearing/detoxification, blood-cooling and hemostasis; abdominal pain, diarrhea, dysentery	

Continued

Table 12.1 Continued

Species	Chinese name	Habitat	Distribution	Therapeutic use	Note
<i>P. campanulatum</i>	Zhong Hua Liao	Altitude 1200 m, hillside shrubs	Si Chuan, Gui Zhou, Yun Nan	Whole plant: blood-activating/stasis-removing, swell-reducing; innominate toxic swelling, dorsal furuncle, scrofula, leukorrheal disease	
<i>P. capitatum</i> (<i>Persicaria capitata</i>)	Tou Hua Liao, Yan Qiao Mai (Hu Bei), Shui Xiu Qiu (Gui Zhou), Shi Mang Cao (Guang Xi)	Altitude 250–500 m, hillside, roadside, rock seam	Jiang Xi, Hu Bei, Hu Nan, Guang Dong, Guang Xi, Si Chuan, Gui Zhou, Yun Nan	Whole plant: acid, cold; detoxification/stasis-removing, disinhibit urine and free strangury; dysentery, stone strangury, edema, rheumatism, traumatic injury, skin and external disease, eczema	
<i>P. chinense</i> (<i>Persicaria chinensis</i>)	Huo Tan Mu, Chi Di Li (Zhe Jiang), Bai Fan Cao (Guang Dong), Lao Shu Zhe (Guang Xi), Yun Yao (Si Chuan)	Altitude 1200–2200 m, hillside, roadside, creek, beside the house	Southwest China, An Hui, Zhe Jiang, Jiang Xi, Fu Jian, Tai Wan, Hu Bei, Hu Nan, Guang Dong, Guang Xi	Whole plant: slightly acid, cool; heat-clearing/detoxification, diuresis-promoting and anti-dyspepsia; diarrhea, dysentery, jaundice, wind-heat sore throat, heat dizziness, leukorrheal disease, scabies, carbuncle; root: acid, sweet, flat; Qi-promoting; Qi deficiency and dizziness, tinnitus and deafness, traumatic injury	<i>P. chinense</i> f. <i>ovalifolium</i> has similar efficacy, distributed in Gui Zhou and Yun Nan

<i>P. chinense</i> var. <i>hispidum</i>	Cu Mao Huo Tan Mu, Xiao Hong Ren (Si Mao, Yun Nan)	Valley, wetland, roadside	Gui Zhou, Yun Nan	Root tuber: acid, flat; collateral-dredging and blood-activating, hemostasis, detoxification; dysentery, diarrhea, irregular menses, metrorrhagia, postpartum bleeding	
<i>P. cilinerve</i> (<i>Pleuropterus ciliinervis</i> ; <i>P. multiflorum</i> var. <i>cillinerve</i>)	Mao Mai Liao, Zhu Sha Qi (Shaan Xi), Zhu Sha Lian (Hu Bei)	Altitude 800–1800 m, hillside forest, ditch, roadside, chaotic crevice	Northeast China, Shaan Xi, Gan Su, Ning Xia, He Nan, Hu Bei, Si Chuan, Gui Zhou	Root tuber: sweet, slightly astringent, cool; slightly poisonous; heat-clearing/detoxification, pain-relieving, hemostasis, regulate menstrual cycle; tonsillitis, vomiting and diarrhea, ulcer, dysentery	
<i>P. convolvulus</i> (<i>P. dumctorum</i>)	Juan Jing Liao, Qiao Mai Man (Gui Zhou)	Altitude 600–1600 m, hillside grassland, crop field	Northeast China, north China, Shaan Xi, Gan Su, Xin Jiang, Shan Dong, north Jiang Su, He Nan, Gui Zhou	Whole plant: heat-clearing/detoxification, swell-reducing; root: strengthening the stomach, cough-relieving, analgesia, detoxification; tuberculosis hemoptysis, pertussis, peratodynia	
<i>P. coriaceum</i>	Ge Ye Liao, Ban She Lian (Guang Xi)	Roadside wetland, ditch	Guang Xi, Yun Nan, Tibet	Rhizome: bitter, cold; slightly poisonous; heat-clearing/detoxification; dysentery, oral ulceration, gingivitis, carbuncle, hemorrhoids, burn	

Continued

Table 12.1 Continued

Species	Chinese name	Habitat	Distribution	Therapeutic use	Note
<i>P. cuspidatum</i> (<i>Pleuropterus cuspidatus</i>)	Hu Zhang, Huo Xue Dan (Jiang Su), Suan Tong Gan (Hu Nan), Da Ye She Zong Guan (Guang Xi), Wo Gong Liao (Miao ethnic group)	Altitude <2500 m, hillside grassland, forest, ditch, roadside	East China, central south China, Liao Ning, Shaan Xi, Gan Su, Si Chuan, Gui Zhou, Yun Nan; in cultivation	Root/rhizome: slightly bitter, cool; wind-dispelling and diuresis-promoting, stasis-removing, analgesia, relieving cough and reducing sputum; joint pain, jaundice with damp-heat, amenorrhea, cough with abundance of phlegm, traumatic injury; leaf: slightly acidic, cool; wind-dispelling, blood-cooling, detoxification	China Pharmacopoeia 1990
<i>P. cynanchoides</i>	Niu Pi Xiao Liao, Mao Xue Teng (Gui Zhou)	Altitude 750–1200 m, riverbank, ravine	Shaan Xi, Gan Su, Hu Bei, Si Chuan, Gui Zhou, Yun Nan	Root: pungent, astringent, cool; astringing the lung to stop cough, spasm pain-relieving; tuberculosis hemoptysis, pertussis, peratodynia, overstrained cough, rheumatoid arthritis	
<i>P. denticulatum</i>	Xue Shao	Hillside sunny shrubs, winding from other plants	Gui Zhou	Root tuber: heat-clearing, detoxification, stasis-dissipating, hemostasis with astringents, relieving asthma; dysentery, tormina postpartum, traumatic swelling	

<i>P. denta-alatum</i>	Chi Chi Liao	Altitude 500–2000 m, hillside shrubs, riverbank, wasteland	Hei Long Jiang, Liao Ning, He Bei, Shaan Xi, Gan Su, He Nan	Whole plant: red eyes
<i>P. dissitiflorum</i> (<i>Persicaria</i> <i>dissitiflorum</i>)	Xi Hua Liao, Hong Xiang Long Cao (Hu Bei)	Altitude 750–1500 m, forest wetland, riverbank	Northeast China, north China, east China, central south China, Shaan Xi, Gan Su	Whole plant: detoxification, diuresis; snakebite, stranguria
<i>P. divaricatum</i> (<i>Persicaria</i> <i>divaricata</i>)	Cha Fen Liao, Suan Bu Liu (northeast China), Suan Jiang (northeast China, desert)	Hillside grassland	North China, Ji Lin, Liao Ning, Qing Hai, Shan Dong, Hu Bei, Si Chuan, Tibet	Root: acid, sweet, warm; dispelling cold, warming the kidney; cold hernia, scrotal sweating
<i>P. emodi</i> (<i>Bistorta</i> <i>emodi</i>)	Hong Teng Liao	Hillside grassland	Si Chuan, Yun Nan	Whole plant: light, lukewarm; muscle- relaxing and blood- activating; traumatic injury, rheumatalgia
<i>P. excurrens</i> (<i>Persicaria</i> <i>excurrens</i>)	Zhong Zhou Liao	Altitude <1000 m, hillside bushes, valley	Northeast China, north China, An Hui, Jiang Xi, Hu Bei	Whole plant: relieve pain, insecticide

Continued

Table 12.1 Continued

Species	Chinese name	Habitat	Distribution	Therapeutic use	Note
<i>P. flaccidum</i> (<i>P. hydropiper</i> var. <i>flaccidum</i> ; <i>Persicaria</i> <i>flaccida</i>)	La Liao, La Ma Liao (Jiang Xi), Liao Zi Cao (Si Chuan)	Waterfront, wetland	Northeast China, Jiang Xi, Fu Jian, Guang Dong, Si Chuan, Gui Zhou	Whole plant: pungent, warm; slightly poisonous; wind-dispelling and diuresis-promoting, stagnation-removing, stasis-dissipating, relieve pain, insecticide; dysentery, diarrhea, uterine bleeding, tonsillitis, rheumatagia, traumatic swelling	
<i>P. giraldii</i>	Yi Liao	Altitude 600–1800 m, hillside, roadside, ditch, bushes	He Bei, Shan Xi, Shaan Xi, Gan Su, He Nan, Hu Bei, Si Chuan, Gui Zhou	Root tuber: acid, bitter, cool; heat-clearing, detoxification, hemostasis, pain- relieving; diarrhea, dysentery, pain in waist and lower extremities, hemafecia, uterine bleeding; external use for burn, sore and furuncle, dog bite	
<i>P. griffithii</i>	Chang Geng Liao	Altitude 3300–4400 m, hillside grassland, stone crevice	Cona and Zayü of Tibet	Rhizome: heat-clearing, detoxification	

<i>P. heterophyllum</i>	Yi Ye Liao	Roadside	Northeast China	Whole plant: heat-clearing, diuresis, insecticide	
<i>P. hydro Piper</i> (<i>Persicaria hydro Piper</i>)	Shui Liao, La Ren Cao (Zhe Jiang), Tong Gu Xiao (Guang Xi), Yao Liao (Si Chuan), Hu La Liao (northeast China)	Altitude <1500 m, hillside, roadside bushes, ditch, wetland	All over China	Whole plant: pungent, warm; slightly poisonous, wind-dispelling and diuresis-promoting, stagnation-reducing, stasis-dissipating, pain-relieving, insecticide; dysentery, diarrhea, indigestion, malnutrition, eczema, stubborn dermatitis, rheumatism, injuries from falls	<i>P. hydro Piper</i> var. <i>angustifolia</i> and <i>P. hydro Piper</i> var. <i>diffusa</i> of Hei Long Jiang have similar efficacy
<i>P. hydro Piper</i> var. <i>hispidum</i>	Mao Shui Liao	Wetland	Fu Jian, Gui Zhou	Whole plant: bitter, slightly pungent, cool; dysentery, diarrhea, heatstroke, abdominal pain	
<i>P. japonicum</i> (<i>Persicaria japonica</i>)	Can Jian Cao, Liao Cao (Zhe Jiang), Shui Liao (Hu Bei), Hong Liao Zi (Gui Zhou)	Hill, plain roadside, bushes, ditch, wetland	Jiang Su, An Hui, Zhe Jiang, Jiang Xi, Fu Jian, Tai Wan, He Nan, Hu Bei, Guang Dong, Guang Xi, Si Chuan, Gui Zhou	Whole plant: pungent, warm; stasis-dissipating and blood-activating; waist and knee pain, measles, dysentery	
<i>P. jucundum</i> (<i>Persicaria jucunda</i>)	Yu Yue Liao	Altitude 200–700 m, hillside bushes, valley, roadside, ditch, wetland	Yangtze River basin, southeast China	Whole plant: diarrhea	<i>P. minus</i> (<i>Persicaria minor</i>) has the same efficacy, distributed in northeast, north, east, central south, and southwest China

Continued

Table 12.1 Continued

Species	Chinese name	Habitat	Distribution	Therapeutic use	Note
<i>P. lapathifolium</i> (<i>Persicaria</i> <i>lapathifolia</i>)	Suan Mo Ye Liao, Liao Diao Zi (northeast China), Han Tian Liao (Si Chuan), Da Ma Liao	Altitude <1900 m, hillside, roadside, creek	Northeast China, north China, Shaan Xi, Gan Su, Ning Xia, Shan Dong, Jiang Su, An Hui, Zhe Jiang, He Nan, Hu Bei, Guang Dong, Guang Xi, Si Chuan, Gui Zhou	Whole plant: pungent, bitter, cool; heat-clearing, detoxification, diuresis- promoting, relieve itching; dysentery, diarrhea; external use for eczema, scrofula	
<i>P. lapathifolium</i> var. <i>salicifolium</i>	Mian Mao Suan Mo Ye Liao, Hong La Liao (Hu Bei), La Liao Cao (Jiang Su), Liu Ye Liao (Gui Zhou)	Low mountain ditch, waterfront, wet lowland	All over the country	Whole plant: wind- dispelling and diuresis- promoting, heat-clearing, detoxification, hemostasis, help digestion	
<i>P. lapathifolium</i> var. <i>xanthophyllum</i>	Huang Ban Suan Mo Ye Liao, Liao Zi Cao (Si Chuan)	Altitude 500–1500 m, hillside grassland	Shaan Xi, Gan Su, Ning Xia, Hu Bei, Si Chuan	Whole plant: heat- clearing, diuresis	
<i>P. lapidosum</i>	Shi Sheng Liao	Hillside, hayfield	Northeast China, He Bei	Rhizome: bitter, slightly cold; slightly poisonous; heat-clearing, detoxification, blood- cooling, hemostasis	Used as <i>P. bistorta</i> in northeast China
<i>P. longisetum</i> (<i>Persicaria</i> <i>Longiseta</i>)	Chang Zong Liao, La Liao (Hu Bei), Shui Hong Hua (Si Chuan)	By the fountain valley, damp place	All over the country	Whole plant: blood- activating and stasis- dissipating, apocatastasis, pain-relieving	Used as <i>P. flaccidum</i> in some regions

<i>P. macranthum</i> (<i>P. japonicum</i> var. <i>conspicuum</i> ; <i>Persicaria</i> <i>conspicua</i>)	Da Hua Liao, Da Chang Hua Liao (Gui Zhou)	Altitude <700 m, hillside, roadside, bushes, wetland	Shan Xi, Shaan Xi, Jiang Su, An Hui, Zhe Jiang, Tai Wan, Hu Bei, Si Chuan, Gui Zhou, Yun Nan	Whole plant: rheumatagia, injuries from falls, dysentery, diarrhea	
<i>P. macrophyllum</i> (<i>Bistorta</i> <i>macrophylla</i> ; <i>P.</i> <i>sphaerostachyum</i>)	Yuan Sui Liao, Xie Zi Qi (Shaan Xi), Ran Bo (Tibetan)	Hilly area	Southwest China, Shaan Xi, Gan Su, Qing Hai, Hu Bei	Rhizome: bitter, astringent, cool; astringent, hemostasis, blood-activating, stop diarrhea; dysentery, hematemesis, bleeding from five sense organs, uterine bleeding, leukorrhoeal disease, injuries from falls	
<i>P. mandshuriense</i>	Er Ye Liao, Bei Chong Lou (Liao Ning)	Hillside, wet grassland	Northeast China, He Bei	Rhizome: bitter, cool; slightly poisonous; heat- clearing, detoxification, blood-cooling, hemostasis	Local standard of Liao Ning
<i>P. microcephalum</i>	Xiao Tou Liao	Altitude 1500–1800 m, forest, roadside bushes	Southwest China, He Nan, Hu Bei, Hu Nan	Whole plant: anti- inflammation, hemostasis	
<i>P. molle</i> (<i>Ampelgonum</i> <i>molle</i> ; <i>Aconogonon</i> <i>molle</i>)	Juan Mao Liao	Waterfront, roadside wetland	Guang Xi	Whole plant: sores	

Continued

Table 12.1 Continued

Species	Chinese name	Habitat	Distribution	Therapeutic use	Note
<i>P. muricatum</i> (<i>P. strigosum</i> var. <i>muricatum</i>)	Fu Jing Liao	Low-altitude hillside, roadside bushes, wetland	Middle and lower reaches of the Yangtze River to the south	Whole plant: itch of skin, dysentery	
<i>P. multiflorum</i> (<i>Pleuropterus multiflorus</i> ; <i>Reynoutria multiflora</i> ; <i>Tiniaria multiflora</i> ; <i>Fallopia multiflora</i>)	He Shou Wu, Jin Shou Wu (Zhe Jiang), Ye Shao (Hu Bei), Wo Pu Weng (Miao ethnic group), Ma Gan Shi	Altitude 500–2200 m, hillside, roadside, valley, waterfront, bushes	He Bei, Shan Xi, Shaan Xi, Gan Su, Xin Jiang, Shan Dong, Jiang Su, An Hui, Zhe Jiang, Jiang Xi, He Nan, Hu Bei, Guang Dong, Guang Xi, Si Chuan, Gui Zhou, Yun Nan; main producing area: He Nan, Hu Bei, Si Chuan	Root tuber: bitter, sweet, astringent, warm; detoxification, boils, relaxing bowel; scrofula, sore carbuncle, rubella itching, dry intestinal constipation, hyperlipemia; rattan: sweet, flat; nourishing the blood and tranquilization, wind-dispelling and collateral-dredging; insomnia and dreamful sleep, blood deficiency and body pain, rheumatalgia; external use for itch of skin	China Pharmacopoeia 1990
<i>P. nodosum</i> (<i>Persicaria nodosa</i>)	Jie Liao, Qu La Liao (Hu Bei)	Altitude 600–1400 m, ravine waterfront, roadside wetland	Northeast China, north China, northwest China, southwest China	Whole plant with root: insecticide, detoxification, stasis-dissipating and resuscitation-inducing; sores, toxic heat	Aboveground part is used as <i>P. orientale</i>

<i>P. ochotense</i>	Dao Gen Liao	Alpine tundra	Changbai Mountain, Ji Lin	Rhizome: blood-cooling, detoxification	Used as <i>Paris polyphylla</i> in Ji Lin China Pharmacopoeia 1990
<i>P. orientale</i> (<i>Persicaria orientalis</i>)	Hong Liao, Jia Liao (Xin Jiang), Jiu Yao Cao (Zhe Jiang), Ba Zi Liao (Fu Jian), Dong Fang Liao	Low mountain, hills, plain, ditch, roadside, grassland, wetland, often grow in plots, or in cultivation	All over the country; main producing area: Jiang Su, Liao Ning	Fruit: saline, cool; blood-scattering and bulk breakdown, stagnation-reducing and pain-relieving; lump in the abdomen, cancer pain, indigestion, epigastric pain; whole plant: pungent, cool; slightly poisonous; wind-dispelling and diuresis-promoting, blood-activating and pain-relieving; rheumatism, malaria, hernia, smelly feet	
<i>P. pacificum</i> (<i>Bistorta pacifica</i>)	Pacific Liao	High mountain bushes, forest, wet meadow	Hei Long Jiang	Rhizome: heat-clearing, detoxification, blood-cooling, hemostasis, astringent; bloody dysentery, hematemesis, burn, bleeding wound	
<i>P. paleaceum</i> (<i>Bistorta chinensis</i>)	Cao Xue Jie, Xia Zi Qi (Hu Bei), Zi Hua Gen (Yun Nan), Yi Kou Xue (Si Chuan)	Altitude 2000 m, alpine meadow	Qing Hai, Hu Bei, Si Chuan, Gui Zhou, Yun Nan	Rhizome: bitter, astringent, lukewarm; blood-activating and stasis-dissipating, pain-relieving, hemostasis; stomachache, indigestion, irregular menses, edema, injuries from falls	

Continued

Table 12.1 Continued

Species	Chinese name	Habitat	Distribution	Therapeutic use	Note
<i>P. perfoliatum</i> (<i>Persicaria</i> <i>perfoliata</i> ; <i>Ampelgoum</i> <i>perfoliatum</i> ; <i>Truellum</i> <i>perfoliatum</i>)	Gang Ban Gui, Shui Ma Ling (Shang Hai), Lan Lu Hu (Fu Jian), Da Meng Tui (Guang Xi), She Dao Tui (Si Chuan)	Altitude <1700 m, valley shrubs, ditch	All over the country	Whole plant: acid, cool; heat-clearing, detoxification, diuresis, apocatastasis; edema, jaundice, diarrhea, malaria, pertussis, eczema, scabies	Tibetan medicine
<i>P. peregrinatoris</i> (<i>Aconogonon</i> <i>peregrinatoris</i>)	Ni A Luo (Tibetan)	Altitude 3800–4900 m, hillside meadow, flood land	Tibet	Root: pungent, warm; antidysentery with astringent; dysentery, diarrhea	
<i>P. persicaria</i> (<i>Persicaria</i> <i>vulgaris</i>)	Tao Ye Liao, Shan La Liao (Hu Bei)	Altitude <1000 m, ditch, roadside wetland	Ji Lin, He Bei, Shaan Xi, Gan Su, Xin Jiang, Shan Dong, Jiang Xi, Fu Jian, He Nan, Hu Bei, Si Chuan, Gui Zhou, Tibet	Whole plant: pungent, warm; sweating dehumidification, help digestion; dysentery, diarrhea, snakebite	
<i>P. pinetorum</i> (<i>Persicaria</i> <i>pinetorum</i>)	Song Lin Liao	Altitude 2000–2500 m, coniferous and broadleaved mixed forest, wet valley, roadside	Shaan Xi, Gan Su, Hu Bei, Si Chuan	Whole plant: heat- clearing, detoxification, wind-dispelling and diuresis-promoting, reduce phlegm	

<i>P. plebeium</i>	Ye Hua Liao, Mi Zi Liao (Guang Xi), Xi Jian Liao (Gui Zhou)	Low mountain, hills, plain, hillside, roadside	Central south China, southwest China, He Bei, Shaan Xi, Jiang Su, An Hui, Jiang Xi, Fu Jian, Tai Wan	Whole plant: diuresis-promoting, stranguria, resolving turbidity, insecticide; malignant sore scabies, stranguria with turbid discharge, ascariasis	
<i>P. polystachyum</i> (<i>Aconogonon polystachyum</i> ; <i>Persicaria polystachya</i>)	Duo Sui Liao, Zi Zi Sa Zeng (Tibetan)	Barren hills	Si Chuan, Tibet	Whole plant: pungent, cool; wind-dispelling and damp-removing, heat-clearing, detoxification, insecticide; dysentery, diarrhea, infantile indigestion, injuries from falls, rheumatism	Tibetan medicine; used as <i>P. flaccidum</i> in Tibet
<i>P. rude</i> (<i>Persicaria rudia</i> ; <i>Aconogonon molle</i> var. <i>nide</i>)	Jiu Gu Niu	Ditch	Gui Zhou	Whole plant: pungent, slightly sweet, warm; collateral-dredging, analgesia; internal lesion caused by overexertion, irregular menses, arthralgia, and myalgia	
<i>P. runcinatum</i> (<i>Persicaria runcinata</i>)	Chi Jing San, Fei E Qi (Hu Bei), She Tou Liao (Guang Xi), Xue Dang Gui (Yun Nan), Ku Cha Tou Cao	Altitude 1000–2500 m, hillside bushes, ditch wetland	Tai Wan, He Nan, Hu Bei, Hu Nan, Guang Xi, Si Chuan, Gui Zhou, Yun Nan	Whole plant: acid, bitter, cool; heat-clearing, detoxification, blood-activating, swell-reducing; dysentery, stomachache, leukorrheal disease, amenorrhea	<i>P. runcinatum</i> var. <i>corymbosum</i> of Gui Zhou has similar efficacy

Continued

Table 12.1 Continued

Species	Chinese name	Habitat	Distribution	Therapeutic use	Note
<i>P. runcinatum</i> var. <i>sinense</i>	Hua Chi Jing San, San Xue Dan (Hu Bei), Hua Liao Zi Cao (Si Chuan)	Altitude 1300–2600 m, forest, roadside bushes, ditch	Shaan Xi, Gan Su, He Nan, Hu Bei, Hu Nan, Guang Xi, Si Chuan, Yun Nan	Root/whole plant: bitter, astringent, cold; swell- reducing and detoxicating, blood-activating and muscle-relaxing; overstrained cough, irregular menses, rheumatagia, injuries from falls	
<i>P. sagittifolium</i>	Da Jian Ye Liao, She Zi Cao (Guang Xi), She Dao Tui (Hu Bei)	Altitude 800–1500 m, mountain roadside, ditch wetland	Shaan Xi, Hu Bei, Hu Nan, Si Chuan, Gui Zhou	Whole plant: heat- clearing, detoxification, dysentery, furunculosis, itch of skin, snakebite	
<i>P. senticosum</i> (<i>Persicaria</i> <i>senticosa</i>)	Ci Liao, Mao Er Ci (Zhe Jiang)	Altitude <1000 m, hillside, roadside bushes, forest, ditch, rock seam	East China, centralsouth China, Ji Lin, Liao Ning, He Bei, Bei Jing, Gui Zhou	Whole plant: acid, slightly pungent, flat; detoxification, apocatastasis, diuresis- promoting, itch-relieving; paronychia, refractory carbuncle furuncle, hurt, eczema, itching and pain, internal and external hemorrhoids	

<i>P. sibiricum</i> (<i>Persicaria sibirica</i> ; <i>Aconogonon sibiricum</i>)	Siberia Liao, Jian Dao Gu (Si Chuan)	Altitude <1600 m, saline meadow, saline lowland, gravel saline alkali soil	Hei Long Jiang, Liao Ning, He Bei, Bei Jing, Inner Mongolia, Gan Su, Ning Xia, Qing Hai, Shan Dong, north Jiang Su, He Nan, Si Chuan, Yun Nan, Tibet	Root: edema; whole plant: heat-clearing, detoxification, wind-dispelling, and damp-removing	
<i>P. sieboldii</i> (<i>Persicaria sieboldii</i>)	Jian Ye Liao, Ju Ju Cao (Hu Bei), Zou You Cao (Si Chuan), Que Chi	Altitude <1800 m, hillside, ditch, wet bushes	Northeast China, He Bei, Shan Dong, Jiang Su, An Hui, Fu Jian, Hu Bei, Hu Nan, Si Chuan, Gui Zhou	Whole plant: acid, astringent, flat; wind-dispelling and damp-removing, heat-clearing, detoxification; rheumatalgia, snakebite	
<i>P. suffultum</i> (<i>Bistorta suffulta</i>)	Zhi Zhu Liao, Xue San Qi (Zhe Jiang), Suan Pan Qi (Hu Bei), Niu Zi Qi (Si Chuan), Hong San Qi (Shaan Xi)	Altitude 1200–2000 m, forest, wet bushes, creek, roadside	Southwest China, He Bei, Shan Xi, Shaan Xi, Gan Su, Ning Xia, Qing Hai, An Hui, Zhe Jiang, Jiang Xi, He Nan, Hu Bei, Hu Nan	Rhizome: bitter, astringent, cool; hemostasis with astringents, analgesia, myogenic; traumatic injury, overstrained hemoptysis, hemafecia, irregular menses	<i>P. suffultum</i> var. <i>pergracile</i> has similar efficacy, distributed in Shaan Xi, Gan Su, Hu Bei, Si Chuan, Yun Nan
<i>P. taipaiashanense</i>	Tai Bai Liao	Altitude 2800–3200 m, mountain meadow	Taibai Mountain, Shaan Xi	Rhizome: bitter, astringent, cool; heat-clearing, detoxification, stasis-removing, hemostasis	Endemic in Shaan Xi

Continued

Table 12.1 Continued

Species	Chinese name	Habitat	Distribution	Therapeutic use	Note
<i>P. thunbergii</i> (<i>Persicaria thunbergii</i>)	Ji Ye Liao, Lu Ti Cao (Jiang Su), Shui Hu Die (Hu Bei), Shui Ma Liao	Altitude <1850 m, valley, forest, wet meadow	Northeast China, He Bei, Shaan Xi, Shan Dong, Jiang Su, An Hui, Zhe Jiang, Fu Jian, Tai Wan, Hu Bei, Hu Nan, Guang Xi, Si Chuan, Gui Zhou, Yun Nan	Rhizome/whole plant: acid, slightly pungent, flat; heat-clearing, detoxification, blood-cooling, hemostasis, wind-dispelling, analgesia, cough-relieving; acute filthy disease, snakebite, dysentery	
<i>P. tinctorium</i> (<i>Persicaria tinctoria</i>)	Liao Lan, Da Qing Ye (northeast and northern China), Qing Ban Shui La Liao (Zhe Jiang), Lan Dian, Lan Liao (northeast China)	Native to China, in cultivation/semiwild throughout the country	He Bei, Shan Xi	Leaf: bitter, cold; heat-clearing, detoxification, blood-cooling, removing ecchymoses; febrile fever, rash, dyspnea and cough due to lung heat, pharyngitis, mumps, erysipelas, carbuncle; processed (indigo naturalis): saline, cold; heat-clearing, detoxification, blood-cooling, arresting convulsion; febrile disease, hot blood and vomiting, chest pain, hemoptysis, aphtha, child's epilepsy	China Pharmacopoeia 1990

<i>P. viscosum</i> (<i>Persicaria viscosa</i>)	Nian Mao Liao	Low-altitude, roadside wetland, waterfront	Central south China, Ji Lin, Liao Ning, Shaan Xi, Jiang Su, Zhe Jiang, Jiang Xi, Fu Jian, Tai Wan, Si Chuan, Gui Zhou, Yun Nan	Rhizome: heat-clearing, detoxification, blood-cooling, hemostasis	
<i>P. viviparum</i> (<i>Bistorta vivipara</i>)	Zhu Ya Liao, Hong San Qi (Ning Xia), Hou Er Qi (Hu Bei), Ye Gao Liang (Si Chuan)	Altitude 1200–3000 m, alpine grassland, wetland, creek	North China, southwest China, Ji Lin, Shaan Xi, Gan Su, Qing Hai, Xin Jiang, He Nan	Rhizome: bitter, astringent, cool; heat-clearing, detoxification, stasis-removing, hemostasis; tonsillitis, sore throat, dysentery, diarrhea, leukorrheal disease, hemafecia	
<i>Rheum altaicum</i>	Altai Da Huang	Mountain rock seam, gravel	Xin Jiang	Root/rhizome: reducing excess heat, bowel-relaxing, break and remove stasis, swell-reducing	<i>R. compactum</i> has the same efficacy and distribution area
<i>Rheum delavayi</i>	Sha Qi, Bai Xiao Huang (Yun Nan)	Mountainous region	Yun Nan	Root: bitter, cool; heat-clearing, detoxification, hemostasis, myogenic; lung heat and cough, sore throat, hemafecia, traumatic bleeding, fracture, traumatic sprain, rheumatic arthralgia	

Continued

Table 12.1 Continued

Species	Chinese name	Habitat	Distribution	Therapeutic use	Note
<i>Rheum emodi</i>	Zang Bian Da Huang, Bai Niu Wei Qi	Altitude 3200–4300 m, hillside shrubs, boulders beach, cliff	Yun Nan, Tibet; cultivated in northwest China	Root: bitter, sweet, cold; heat-clearing, detoxification, hemostasis, myogenic; lung heat and cough, sore throat, hemafecia, carbuncle, traumatic bleeding	
<i>Rheum forrestii</i>	Niu Wei Qi, Hong Ma Ti Niao (Si Chuan), Xue San Qi (Yun Nan)	Altitude 3000 m, rock	Si Chuan, Yun Nan	Root: bitter, cool; muscle-relaxing and blood-activating, hemostasis, heat-clearing; sore throat, mumps, constipation, traumatic injury, and bleeding	
<i>Rheum franzenbachii</i>	Bo Ye Da Huang, Hua Bei Da Huang, Tang Da Huang	Hillside meadow	North China, Ji Lin, Liao Ning, Xin Jiang, Hu Bei; in cultivation	Rhizome: bitter, cold; purging heat, bowel-relaxing, break and remove stasis; heat constipation, jaundice with damp-heat, furuncle and carbuncle, traumatic stasis pain, aphthous ulcer, burn	<i>R.nanum</i> has similar efficacy, distributed in Inner Mongolia, Gan Su, Xin Jiang

<i>Rheum nobile</i>	Gao Shan Da Huang, Ta Huang (Tibet)	Altitude 4500–5200 m, mountainside, meadow	Tibet	Rhizome: bitter, cold; reducing excess heat, stagnation-breaking, stasis-removing; heat constipation, delirium, dyspeptic hysteresis, dysentery, abdominal pain, tenesmus, hygropyretic jaundice, edema, red eyes, headache, amenorrhea	
<i>Rheum officinale</i>	Da Huang, Nan Da Huang, Xi Da Huang, Chuan Jun, Jun (Tibetan)	Altitude 1300–1600 m, hilly area, rand, hillside	Southwest China, Shaan Xi, Gan Su, Qing Hai, He Nan, Hu Bei; main producing area: Gan Su, Qing Hai	Root/rhizome: bitter, cold; purgating heat and bowels, blood-cooling and detoxification, stasis- removing and collateral- dredging; heat constipation, stagnation of abdominal pain, uncomfortable diarrhea, hygropyretic jaundice, hot blood and vomiting, red eyes, sore throat, blood stasis/amenorrhea, traumatic injury	China Pharmacopoeia 1990; <i>R.tibeticum</i> of Qing Hai has similar efficacy; <i>R.witrocki</i> , distributed in north and south Xin Jiang
<i>Rheum palmatum</i>	Zhang Ye Da Huang, Bei Da Huang, Jin Da Huang (Hu Bei)	Hilly area, forest, grass slope	Shaan Xi, Gan Su, Qing Hai, Hu Bei, Si Chuan, Tibet; in cultivation	Root/rhizome: same as <i>R.</i> <i>officinale</i>	China Pharmacopoeia 1990

Continued

Table 12.1 Continued

Species	Chinese name	Habitat	Distribution	Therapeutic use	Note
<i>Rheum pumilum</i>	Xiao Da Huang	Shady mountain slope, semishady slope, meadow	Qing Hai	Root: bitter, cold; purging stomach/bowel stagnation, reducing excess heat, blood stasis-discharging, subduing inflammation; stagnation, dyspepsia, abdominal pain, endoretenion of heat, constipation	China Pharmacopoeia 1990; <i>R. tanguticum</i> has similar efficacy
<i>Rheum tanguticum</i>	Tang Gu Te Da Huang, Ji Zhua Da Huang	Mountain shrubs, woodside, damp place	Gan Su, Qing Hai, Hu Bei, Si Chuan, Tibet; cultivated in Shaan Xi	Root/rhizome: same as <i>R. officinale</i>	
<i>Rumex acetosa</i>	Suan Mo, Suan Jiang (northeast China), Shan Bo Cai (Hu Bei), Niu Er Da Huang (Hu Nan, Si Chuan, Gui Zhou)	Low-altitude to 3100 m, mountain, wet valley, woodside, meadow	North China, northwest China, Ji Lin, Liao Ning, Jiang Su, An Hui, Zhe Jiang, Jiang Xi, He Nan, Hu Bei, Hu Nan, Si Chuan, Gui Zhou, Yun Nan	Root/whole plant: acid, bitter, cold; blood-cooling, detoxification, bowel-relaxing, insecticide; heat dysentery, stranguria, hematemesis, malignant sore, scabies	
<i>Rumex aquaticus</i>	Shui Sheng Suan Mo	Altitude <2400 m, valley, ditch	Northeast China, North China, northwest China, Hu Bei	Root: dyspepsia, acute hepatitis, eczema, stubborn dermatitis	

<i>Rumex chalepensis</i>	Zhong Ya Suan Mo	Open field, riverside, wetland, roadside, wasteland, grassland	Northeast China, He Bei, Shaan Xi, Shan Dong, Jiang Su, Jiang Xi, He Nan, Hu Bei	Root: bitter, acid, cold; blood-cooling, hemostasis, heat-clearing, detoxification, insecticide; uterine bleeding, hematemesis, hemoptysis, nasal bleeding, stomach bleeding, hemafecia, hemokelidosis, constipation, edema	
<i>Rumex crispus</i>	Zhou Ye Suan Mo, Niu She Tou (Ning Xia), Yang Ti Gen (Ji Lin), Si Ji Cai Gen (Si Chuan)	Roadside, damp place, waterfront	Northeast China, He Bei, Inner Mongolia, Shaan Xi, Ning Xia, Qing Hai, Jiang Su, An Hui, Zhe Jiang, Fu Jian, Tai Wan, He Nan, Hu Bei, Guang Xi, Si Chuan, Gui Zhou, Yun Nan	Root/whole plant: bitter, acid, cold; heat-clearing, blood-cooling, bowel-relaxing, insecticide, resolve phlegm and relieve cough; acute hepatitis, cough and phlegm, hematemesis, metrorrhagia, constipation, dysentery, scabies	<i>R. crispus</i> var. <i>unicallosus</i> of Ning Xia has similar efficacy
<i>Rumex dentatus</i>	Chi Guo Suan Mo, Niu Er Da Huang (Si Chuan), Niu She Cao (Jiang Su)	Altitude 400–1200 m, fringe wetland	He Bei, Shan Xi, Shaan Xi, Gan Su, Qing Hai, Jiang Su, An Hui, Zhe Jiang, He Nan, Hu Bei, Si Chuan, Gui Zhou, Yun Nan	Root/whole plant: similar to <i>R. crispus</i> ; leaf: breast swelling	

Continued

Table 12.1 Continued

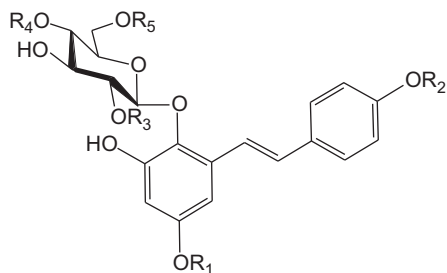
Species	Chinese name	Habitat	Distribution	Therapeutic use	Note
<i>Rumex gmelini</i>	Mao Mai Suan Mo	Waterfront, wet meadow	Northeast China, He Bei, Inner Mongolia	Root: hemostasis, laxative	
<i>Rumex hastatus</i>	Chuan Dian Tu Da Huang	Hillside meadow	Si Chuan, Yun Nan	Whole plant: acid, astringent, slightly pungent, warm; inducing sweat and dispelling exogenous evils, moistening lung to arrest cough; common cold, cough, edema, asthma due to excessive phlegm	
<i>Rumex japonicus</i>	Yang Ti, Yang She Tou (Zhe Jiang), Niu Li Cai (Guang Xi), Niu She Da Huang	Mountains and plains, roadside damp place	East China, central south China, Gui Zhou	Root: bitter, acid, cold; slightly poisonous; blood-cooling and hemostasis, loosen stools, detoxification, insecticide; constipation, stranguria with turbid discharge, jaundice, hematemesis, hemorrhoidal hamorrhage, favus of the scalp; leaf: sweet, cold; hemorrhoidal hamorrhage, constipation, infantile malnutrition; fruit: bitter, astringent, flat; mixed red and white dysentery	<i>R.nepalensis</i> has the same efficacy, distributed in southwest China, Shaan Xi, Gan Su, Qing Hai, Jiang Xi, He Nan, Hu Bei

<i>Rumex maritimus</i>	Chang Ci Suan Mo, Niu Shi Cao (Hu Bei), Xue Da Huang (Si Chuan), Zhou Ye Yang Ti (Guang Xi)	Roadside, ditch, damp place	Northeast China, north China, Yangtze River basin, Fu Jian, Guang Xi, Gui Zhou	Whole plant: slightly sweet, slightly bitter, cool; heat-clearing and blood-cooling, insecticide/detoxification; tuberculosis hemoptysis, carbuncle, favus of the scalp itch, itch of skin, traumatic injury, hemorrhoidal bleeding	
<i>Rumex obtusifolius</i> (<i>R. madaio</i>)	Dun Ye Suan Mo, Xue San Qi, Hua Xue Lian (Jiang Su)	Hillside, damp place, open forest	Yangtze River basin	Root: bitter, cold; clearing away heat and loosening the bowels, killing parasites to relieve itshing, hemostasis; lung abscess, hemoptysis, hepatitis, constipation; external use in traumatic injury, burn	
<i>Rumex patientia</i>	Ba Tian Suan Mo, Tu Da Huang (Shaan Xi), Niu Xi Xi (Jiang Xi)	Roadside, village wetland, ditch	Hei Long Jiang, Liao Ning, He Bei, Shan Xi, Shaan Xi, Gan Su, Qing Hai, south Jiang Su, Hu Bei, Gui Zhou	Root: bitter, acid, cold; slightly poisonous; blood-cooling and hemostasis, heat-clearing and detoxification, laxative, insecticide; dysentery, diarrhea, hepatitis, traumatic injury, constipation, ulcerative carbuncle, scabies	<i>R. patientia</i> var. <i>callosus</i> of northeast China has the same efficacy

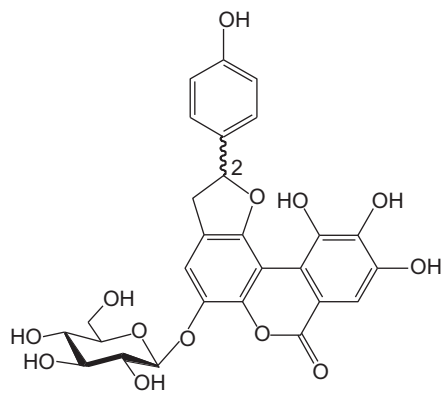
Continued

Table 12.1 Continued

Species	Chinese name	Habitat	Distribution	Therapeutic use	Note
<i>Rumex stenophyllus</i>	Zhai Ye Suan Mo	Wet meadow, saline soil	Northeast China, north China, Xin Jiang	Root: bitter, acid, cold; blood-cooling and hemostasis, heat-clearing and detoxification, insecticidal; uterine bleeding, gastrorrhagia, hemafecia, hemokelidosis, edema	<i>R. stenophyllus</i> var. <i>ussuriensis</i> of Hei Long Jiang has the same efficacy



No.	R ₁	R ₂	R ₃	R ₄	R ₅
1	H	H	H	H	H
2	H	H	H	H	Galloyl
3	H	H	Galloyl	H	H
4	H	H	H	α -D-Glc	H
5	H	H	H	H	α -D-Glc
6	H	α -D-Glc	H	H	H
7	α -D-Glc	H	H	H	H
8	H	H	β -D-Fru (f)	H	H



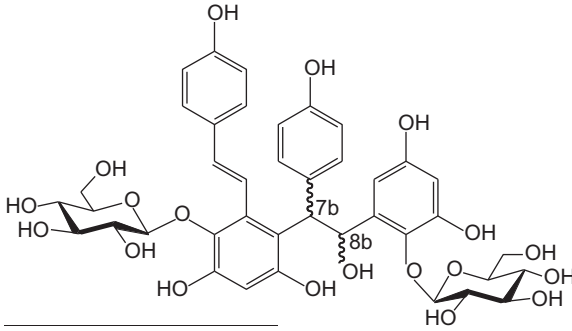
No. 2

9 S

Figure 12.1 Examples of compounds isolated from the *Polygonum* species. Refer to [Table 12.2](#) for more details.

(Continued)

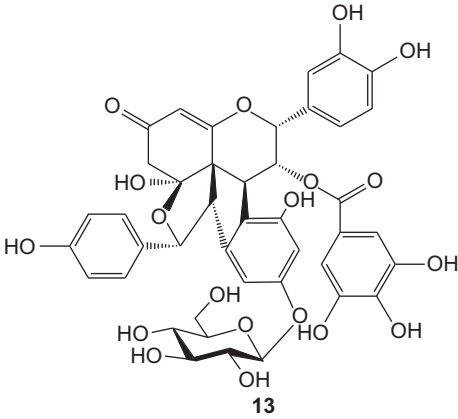
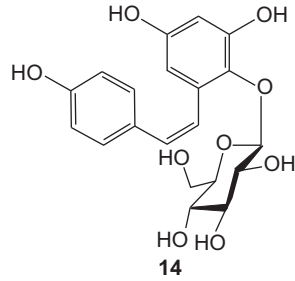
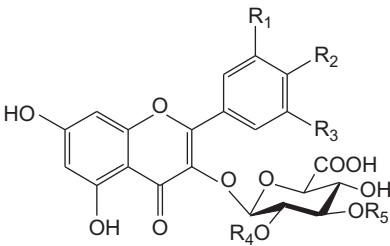
10 R



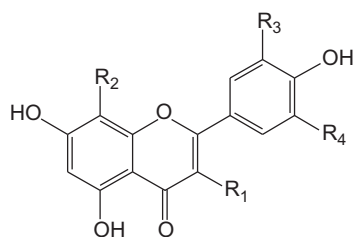
 No. 7b 8b

11 R S

12 S R

**13****14**
Figure 12.1 Continued.

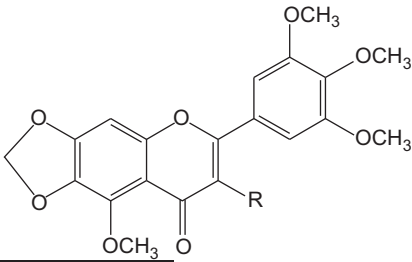
No.	R ₁	R ₂	R ₃	R ₄	R ₅
15	OH	OH	OH	H	H
16	OH	OCH ₃	OH	H	H
17	H	OH	OH	H	H
18	H	OH	OCH ₃	H	H
19	H	OCH ₃	H	H	H
20	H	OH	H	H	H
21	H	OH	H	COCH ₃	H
22	H	OH	OCH ₃	COCH ₃	H
23	H	OH	OH	COCH ₃	H
24	H	OH	OH	H	COCH ₃
25	H	OH	H	H	COCH ₃
26	OH	OH	H	H	H
27	OH	OH	H	α-L-Rha	H
28	OH	OH	H	α-L-Rha	H



No.	R ₁	R ₂	R ₃	R ₄
29	OR _x	H	H	OCH ₃
30	OR _y	H	H	OCH ₃
31	OH	H	OH	H

Figure 12.1 Continued.

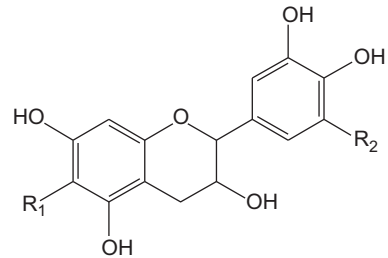
32	OH	H	OH	OH
33	O-β-D-Gal	H	OH	OH
34	O-α-L-Rha	H	OH	OH
35	O-β-D-Gal	H	OH	H
36	O-β-D-Glc(6-1)-α-L-Rha	H	OH	H
37	OH	H	O-β-D-Gal	H
38	OH	OCH ₃	OH	H
39	H	H	H	H
40	H	H	OH	H
41	OH	H	H	H
42	O-(6''-galloyl)-β-D-Gal	H	OH	H



No.	R
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43	H
----	---

44	OCH ₃
----	------------------



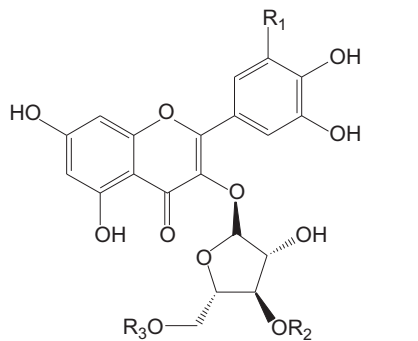
No.	R ₁	R ₂
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45	H	H
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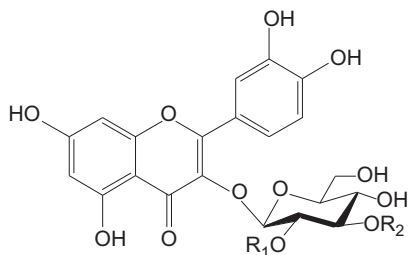
46	H	OH
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47	OH	H
----	----	---

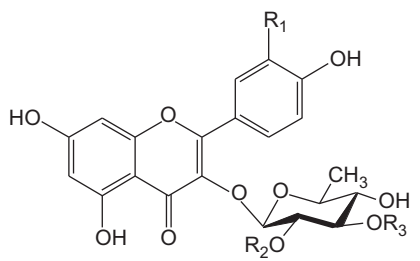
Figure 12.1 Continued.



No.	R ₁	R ₂	R ₃
48	H	COCH ₃	COCH ₃
49	H	COCH ₃	H
50	H	H	H
51	OH	COCH ₃	COCH ₃
52	OH	H	H

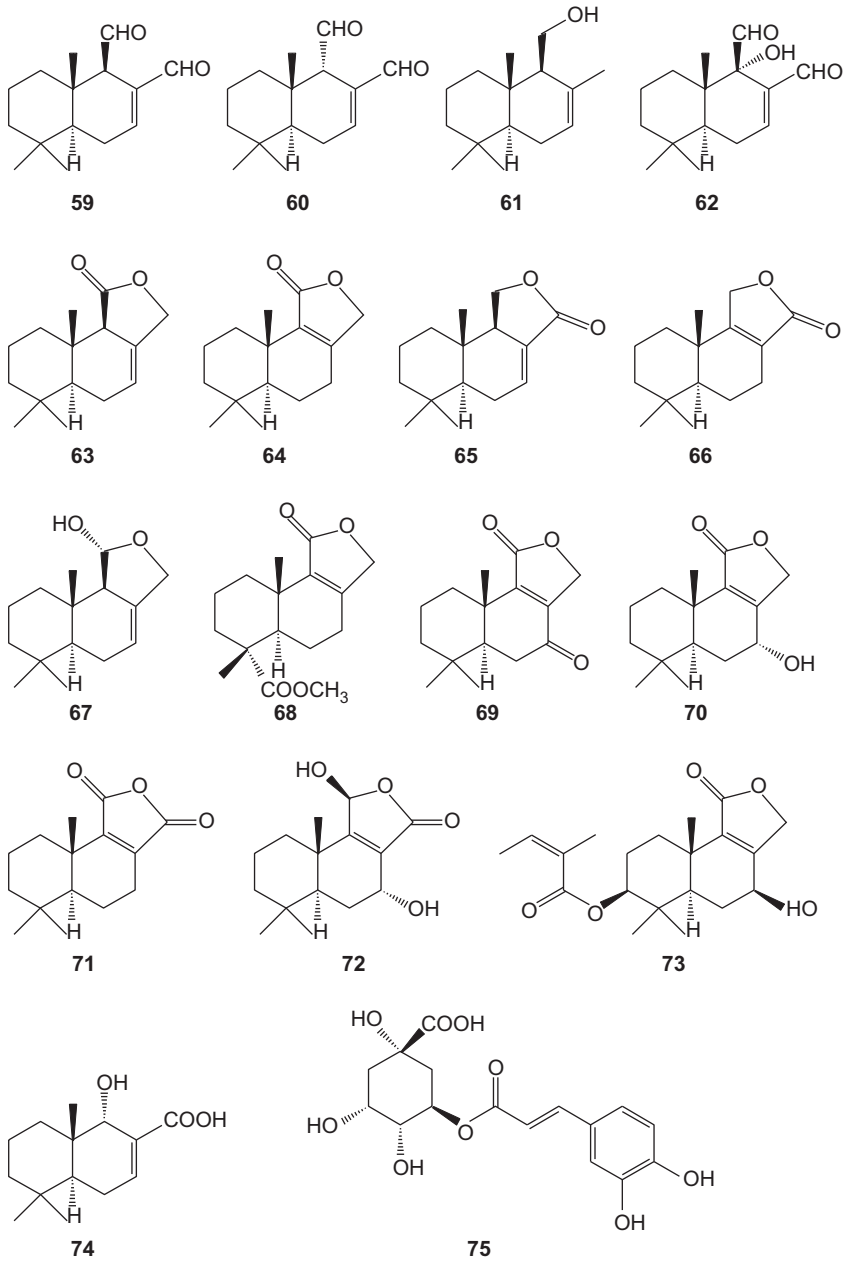


No.	R ₁	R ₂
53	Galloyl	H
54	H	Galloyl



No.	R ₁	R ₂	R ₃
55	OH	Galloyl	H
56	OH	H	Galloyl
57	OH	H	H
58	H	H	H

Figure 12.1 Continued.

**Figure 12.1** Continued.

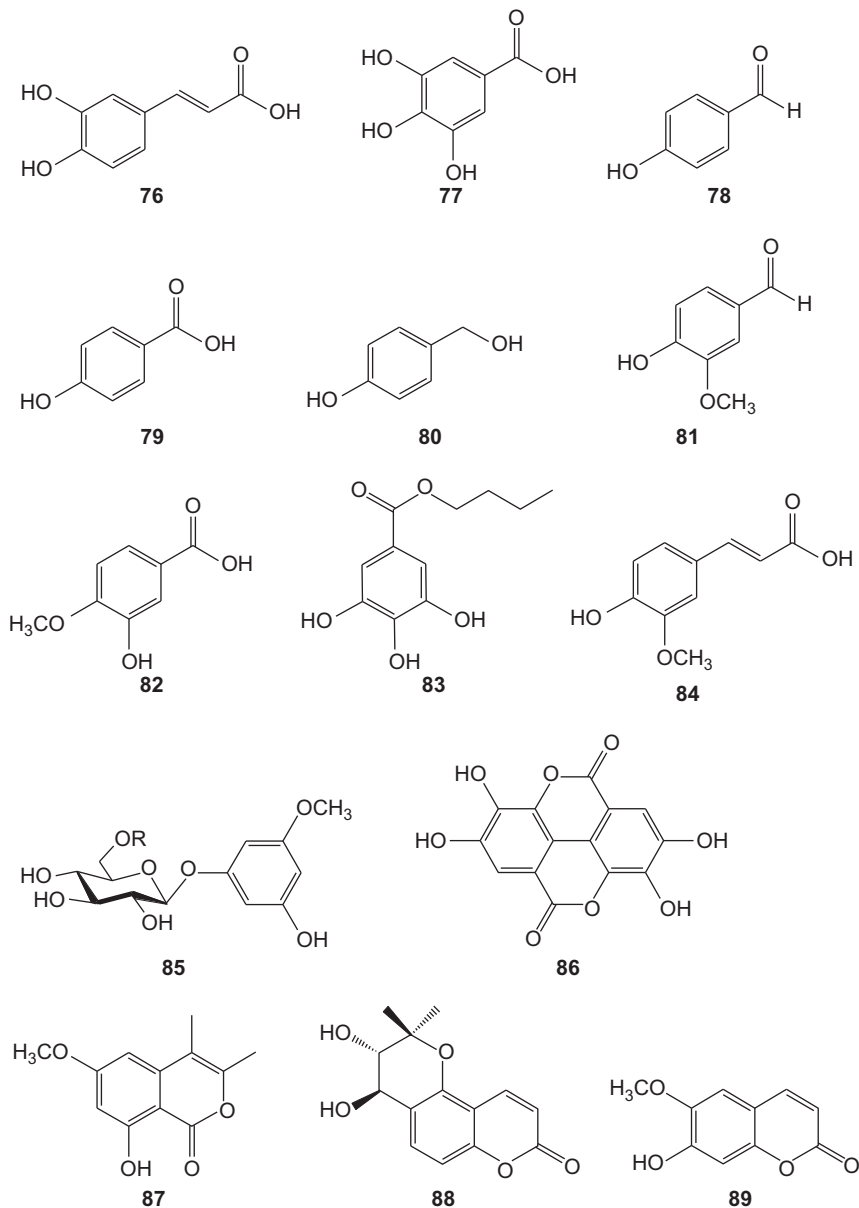
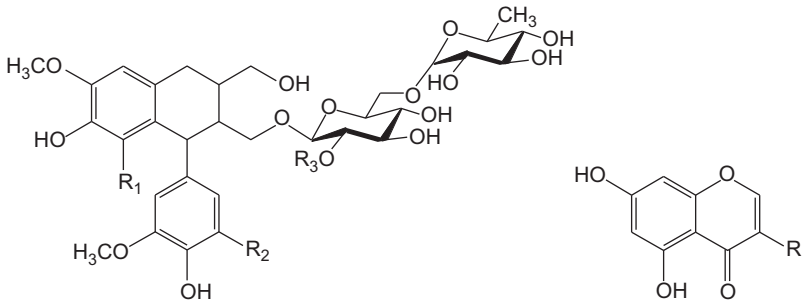
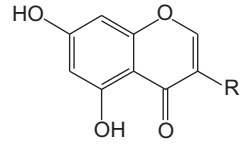


Figure 12.1 Continued.



No.	R ₁	R ₂	R ₃
90	OCH ₃	OCH ₃	H
91	H	H	α -L-Rha



No.	R
92	OH
93	H

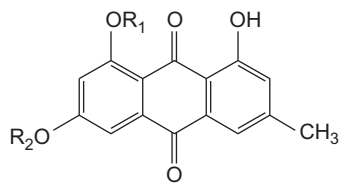
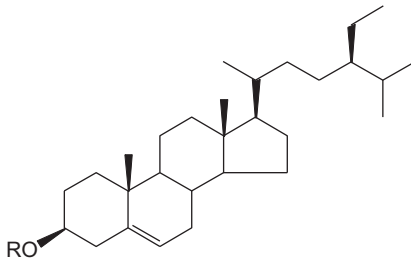
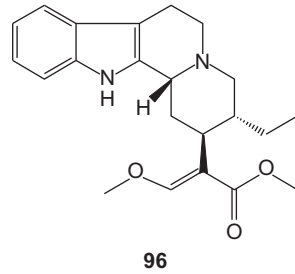
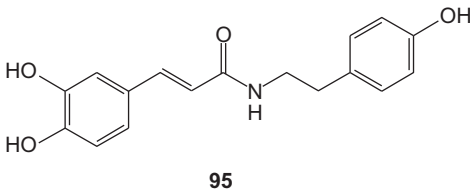
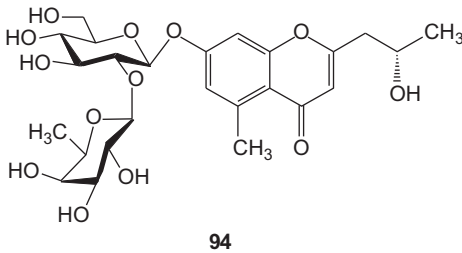
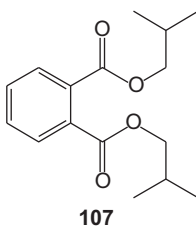
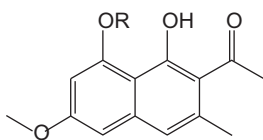
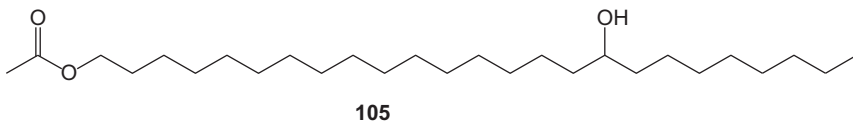
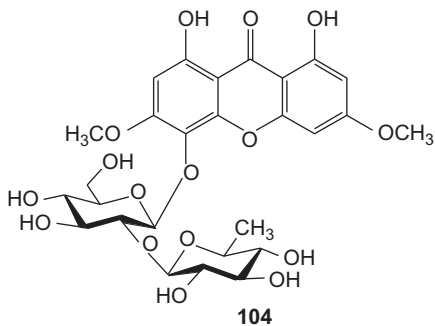
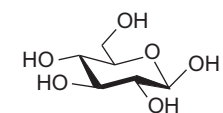


Figure 12.1 Continued.

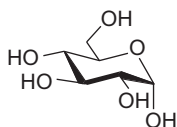
No.	R	No.	R ₁	R ₂
97	Ac	100	H	CH ₃
98	H	101	H	H
99	β-D-Glc	102	β-D-Glc	H
		103	β-D-Glc	CH ₃



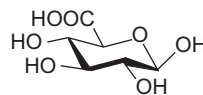
No.	R
106	β-D-Glc



Glc: β-D-glucopyranosyl



Glc: α-D-glucopyranosyl



GlcA: β-D-glucuropyranosyl

Figure 12.1 Continued.

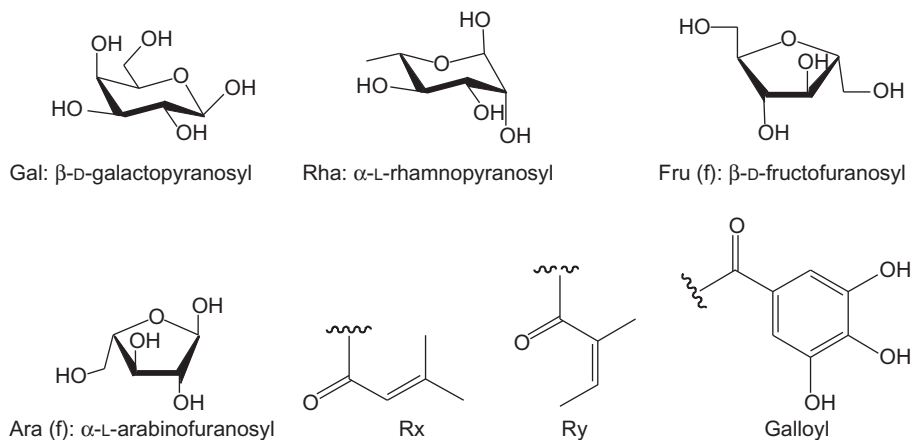


Figure 12.1 Continued.

85.66% of the total organic ester compounds. 1-Phenyl-1-pentanone and acetophenone were 16.30% and 4.33% of the total volatiles, respectively.

The liverwort (*Porella vernicosa*) complex produces a very hot tasting polygodial, a drimane-type sesquiterpene dialdehyde. The same compound has been isolated from two ferns, *Thelypteris hispidula* and *Blechnum fluviatile*, as well as from the higher plants *Polygonum hydropiper* and *P. hydropiper* f. *purpurascens* (Polygonaceae); *Cinnamosma*, *Caspicodendron*, *Canella*, and *Warburgia* species (Canellaceae); and *Pseudowintera colorata*, *Tasmannia lanceolata*, *Drimys*, and *Zygogynum* species (Winteraceae) (Asakawa et al., 2012). In addition, the liverworts and higher plants that elaborate polygodial and its related pungent drimane dials contain a small amount of α -tocopherol, γ -tocopherol, or δ -tocotrienol. The drimane-type sesquiterpenoids and tocopherols might be useful chemotaxonomic markers in some lower and higher plants, including Polygonaceae.

12.2.3 Other compounds

2-Furanmethanol, 2 (5H)-furanone, 2-hydroxy-2-cyclopenten-1-one, 2, 4-dihydroxy-2,5-dimethyl-3(2H)-furan-3-one, 2H-pyran-2,6 (3H)-dione, 2-hydroxy-gamma-butyrolactone, 2,5-dimethyl-4-hydroxy-3 (2H)-furanone, 2,5-furandicarboxaldehyde, 2,3-dihydro-3,5-dihydroxy-6-methyl 4H-pyran-4-one, (S)-(+)-2', 3'-dideoxyribonolactone, 5-(hydroxymethyl)-furancarboxaldehyde, 3-deoxy-D-mannonic lactone, etc. were found in the callus of *P. minus* (Vikram et al., 2014).

Table 12.2 Various types of compounds found in *Polygonum* medicinal plants in recent years

No.	Compounds	Types	Species	Tissues	References
1	2,3,5,4'-Tetrahydroxystilbene-2- <i>O</i> - β -D-glucopyranoside	A	a	Tubers, roots	Cheung et al. (2014), Kim et al. (2008a,b), and Xu et al. (2006)
2	(<i>E</i>)-2,3,4',5-Tetrahydroxystilbene-2- β -D-(6''-galloyl)-glucopyranoside	A	a	Roots	Kim et al. (2008a,b)
3	(<i>E</i>)-2,3,4',5-Tetrahydroxystilbene-2- β -D-(2''-galloyl)-glucoside	A	a	Roots	Kim et al. (2008a,b)
4	(<i>E</i>)-2,3,5,4'-Tetrahydroxystilbene-2- <i>O</i> -(4''- <i>O</i> - α -D-glucopyranosyl)- β -D-glucopyranoside	A	a	Roots	Li et al. (2013a)
5	(<i>E</i>)-2,3,5,4'-Tetrahydroxystilbene-2- <i>O</i> -(6''- <i>O</i> - β -D-glucopyranosyl)- β -D-glucopyranoside	A	a	Roots	Li et al. (2013a)
6	(<i>E</i>)-2,3,5,4'-Tetrahydroxystilbene-2- <i>O</i> - β -D-glucopyranosyl-4'- <i>O</i> - α -D-glucopyranoside	A	a	Roots	Li et al. (2013a)
7	(<i>E</i>)-2,3,5,4'-Tetrahydroxystilbene-2- <i>O</i> - β -D-glucopyranosyl-5- <i>O</i> - α -D-glucopyranoside	A	a	Roots	Li et al. (2013a)
8	(<i>E</i>)-2,3,5,4'-Tetrahydroxystilbene-2- <i>O</i> -(2''- <i>O</i> - β -D-fructofuranosyl)- β -D-glucopyranoside	A	a	Roots	Li et al. (2013a)
9	Polygonumside A	A	a	Roots	Yan et al. (2014)
10	Polygonumside B	A	a	Roots	Yan et al. (2014)
11	Polygonumside C	A	a	Roots	Yan et al. (2014)
12	Polygonumside D	A	a	Roots	Yan et al. (2014)
13	Polyflavanostilbene A	A	b	Rhizomes	Li et al. (2013b)
14	(<i>Z</i>)-2,3,4',5-Tetrahydroxystilbene-2- β -D-glucoside	A	a	Roots	Kim et al. (2008a,b) and Xu et al. (2006)
15	Myricetin 3- <i>O</i> - β -D-glucuronide	B	c	Herbs	Granica et al. (2013)
16	Mearsetin 3- <i>O</i> - β -D-glucuronide	B	c	Herbs	Granica et al. (2013)

Continued

Table 12.2 Continued

No.	Compounds	Types	Species	Tissues	References
17	Quercetin 3- <i>O</i> - β -D-glucuronide	B	c	Herbs	Granica et al. (2013)
18	Isorhamnetin 3- <i>O</i> - β -D-glucuronide	B	c	Herbs	Granica et al. (2013)
19	Kaempferide 3- <i>O</i> - β -D-glucuronide	B	c	Herbs	Granica et al. (2013)
20	Kaempferol 3- <i>O</i> - β -D-glucuronide	B	c	Herbs	Granica et al. (2013)
21	Kaempferol 3- <i>O</i> - β -(2''- <i>O</i> -acetyl- β -D-glucuronide)	B	c	Herbs	Granica et al. (2013)
22	Isorhamnetin 3- <i>O</i> - β -(2''- <i>O</i> -acetyl- β -D-glucuronide)	B	c	Herbs	Granica et al. (2013)
23	Quercetin 3- <i>O</i> - β -(2''- <i>O</i> -acetyl- β -D-glucuronide)	B	c	Herbs	Granica et al. (2013)
24	Quercetin 3- <i>O</i> - β -(3''- <i>O</i> -acetyl- β -D-glucuronide)	B	c	Herbs	Granica et al. (2013)
25	Kaempferol 3- <i>O</i> - β -(3''- <i>O</i> -acetyl- β -D-glucuronide)	B	c	Herbs	Granica et al. (2013)
26	Quercetin-3- <i>O</i> - β -glucuronide	B	d	Herbs	Smolarz et al. (2008)
27	Quercetin-3- <i>O</i> - α -rhamnosyl-(1 \rightarrow 2)- β -glucuronide	B	d	Herbs	Smolarz et al. (2008)
28	Kaempferol-3- <i>O</i> - α -rhamnosyl-(1 \rightarrow 2)- β -glucuronide	B	d	Herbs	Smolarz et al. (2008)
29	3- <i>O</i> -senecieryl-isorhamnetin	B	e	Herbs	Lajter et al. (2013a)
30	3- <i>O</i> -angeloyl-isorhamnetin	B	e	Herbs	Lajter et al. (2013a)
31	Quercetin	B	f, i, h, b	Aerial parts (f), herbs (i,h), roots (b)	Moradi-Afrapoli et al. (2012a) , Lin et al. (2009) and Zhang et al. (2012c)
32	Myricetin	B	f	Aerial parts	Moradi-Afrapoli et al. (2012a)
33	Myricetin 3- <i>O</i> - β -D-galactopyranoside	B	f	Aerial parts	Moradi-Afrapoli et al. (2012a)
34	Myricetin 3- <i>O</i> - α -L-rhamnopyranoside (myricitrin)	B	f, h	Aerial parts (f), herbs (h)	Moradi-Afrapoli et al. (2012a) and Zhang et al. (2012c)
35	Quercetin 3- <i>O</i> - β -D-galactopyranoside	B	f, g	Aerial parts	Moradi-Afrapoli et al. (2012a) and Tantry et al. (2012)
36	Rutin	B	g, h,b	Aerial parts (g), herbs (h), leaves (b)	Tantry et al. (2012) and Zhang et al. (2012c)

37	Quercetin-3'- <i>O</i> -β-D-galactopyranoside	B	i	Herbs	Lin et al. (2009)
38	8-Methoxyquercetin	B	i	Herbs	Lin et al. (2009)
39	Apigenin	B	i,b	Herbs (i), roots (b)	Lin et al. (2009)
40	Luteolin	B	i	Herbs	Lin et al. (2009)
41	Kaempferol	B	h	Herbs	Zhang et al. (2012c)
42	Quercetin 3- <i>O</i> -(6''-galloyl)-β-D-galactoside	B	j	Whole plant	Datta et al. (2000)
43	5, 3',4',5'-Tetramethoxy-6,7-methylenedioxyflavone	B	e	Herbs	Lajter et al. (2013a)
44	3,5,3',4',5'-Pentamethoxy-6,7-methylenedioxyflavone	B	e	Herbs	Lajter et al. (2013a)
45	(+) Catechin	B	f, g, b	Aerial parts (f, g), roots (b)	Moradi-Afrapoli et al. (2012a) and Tantry et al. (2012)
46	(-) Gallocatechin	B	f	Aerial parts	Moradi-Afrapoli et al. (2012a)
47	Amplexicine	B	g	Aerial parts	Tantry et al. (2012)
48	Quercetin 3- <i>O</i> -α-L-(3'',5''-diacetyl-arabinofuranoside)	B	f	Aerial parts	Moradi-Afrapoli et al. (2012a)
49	Quercetin 3- <i>O</i> -α-L-(3''-acetyl-arabinofuranoside)	B	f	Aerial parts	Moradi-Afrapoli et al. (2012a)
50	Quercetin 3- <i>O</i> -α-L-arabinofuranoside (avicularin)	B	f	Aerial parts	Moradi-Afrapoli et al. (2012a)
51	Myricetin 3- <i>O</i> -α-L-(3'',5''-diacetyl-arabinofuranoside)	B	f	Aerial parts	Moradi-Afrapoli et al. (2012a)
52	Myricetin 3- <i>O</i> -α-L-arabinofuranoside	B	f	Aerial parts	Moradi-Afrapoli et al. (2012a)
53	Quercetin-3- <i>O</i> -(2''- <i>O</i> -galloyl)-β-D-glucopyranoside	B	h	Herbs	Zhang et al. (2012c)
54	Quercetin-3- <i>O</i> -(3''- <i>O</i> -galloyl)-β-D-glucopyranoside	B	h	Herbs	Zhang et al. (2012c)
55	Quercetin-3- <i>O</i> -(2''- <i>O</i> -galloyl)-α-L-rhamnopyranoside	B	h	Herbs	Zhang et al. (2012c)
56	Quercetin-3- <i>O</i> -(3''- <i>O</i> -galloyl)-α-L-rhamnopyranoside	B	h	Herbs	Zhang et al. (2012c)
57	Quercitrin	B	h, b	Herbs (h), roots (b)	Zhang et al. (2012c)
58	Kaempferol-3- <i>O</i> -α-L-rhamnopyranoside	B	h	Herbs	Zhang et al. (2012c)
59	Polygodial	C	k, l, m, n	Whole plant (k, l), leaves, stem (m, n)	Asakawa et al. (2012)

Continued

Table 12.2 Continued

No.	Compounds	Types	Species	Tissues	References
60	Isopolygodial	C	k, l, m, n	Whole plant (k,l), leaves (m,n), stem (m)	Asakawa et al. (2012)
61	Drimenol	C	k1, k3, l, m, n	Whole plant (k1, k3, l), leaves (m, n)	Asakawa et al. (2012)
62	Warburganal	C	k3	Leaves	Asakawa et al. (2012)
63	Drimenin	C	k1, k3, l	Whole plant (k1, l), leaves (k3)	Asakawa et al. (2012)
64	Isodrimenin	C	k1, k3, l	Whole plant (k1, l), leaves (k3)	Asakawa et al. (2012)
65	Cinnamolide	C	k3, m, n	Leaves (k3, m, n), stem (m)	Asakawa et al. (2012)
66	Confertifolin	C	k3, l	Whole plant (l), leaves (k3)	Asakawa et al. (2012)
67	Isodrimeninol	C	k3	Leaves	Asakawa et al. (2012)
68	Poygonumate	C	k2	Whole plant	Asakawa et al. (2012)
69	7-Ketocoisodrimenin	C	k2	Whole plant	Asakawa et al. (2012)
70	Futronolide	C	k2	Whole plant	Asakawa et al. (2012)
71	Winterin	C	k2	Whole plant	Asakawa et al. (2012)
72	Dendocarbin L	C	k2	Whole plant	Asakawa et al. (2012)
73	7 β -Hydroxyiso-angeloyloxy-7-epi-futronolide	C	k2	Whole plant	Asakawa et al. (2012)
74	Changweikagnic acid A	C	k2	Whole plant	Asakawa et al. (2012)
75	Chlorogenic acid	D	g, b	Aerial parts (g), roots (b)	Tantry et al. (2012)
76	Caffeic acid	D	g	Aerial parts	Tantry et al. (2012)

77	Gallic acid	D	g, b	Aerial parts (g), roots (b)	Tantry et al. (2012)
78	<i>p</i> -Hydroxybenzaldehyde	D	i	Herbs	Lin et al. (2009)
79	<i>p</i> -Hydroxybenzoic acid	D	g	Rhizomes	Xiang et al. (2012)
80	<i>p</i> -Hydroxybenzoic ethanol	D	g	Rhizomes	Xiang et al. (2012)
81	Vanillin	D	g	Rhizomes	Xiang et al. (2012)
82	Isovanillic acid	D	g	Rhizomes	Xiang et al. (2012)
83	3,4,5-Trihydroxy-benzoic acid-butyl ester	D	g	Rhizomes	Xiang et al. (2012)
84	4-Hydroxy-3-methoxycinnamic acid	D	g	Rhizomes	Xiang et al. (2012)
85	1- <i>O</i> -β-D-(6'- <i>O</i> -galloyl)-glucopyranosyl-3-methoxy-5-hydroxybenzene	D	h	Herbs	Zhang et al. (2012c)
86	Ellagic acid	D	h	Herbs	Zhang et al. (2012c)
87	Polygonolide	E	k3	Leaves	Asakawa et al. (2012)
88	5, 6-Dihydropyranobenzopyrone	E	g	Aerial parts	Tantry et al. (2012)
89	Scopletin	E	g	Aerial parts, rhizomes	Tantry et al. (2012) and Xiang et al. (2012)
90	(+)-Lyoniresinol-3a- <i>O</i> -[α-L-rhamnopyranosyl-(1''' → 6'')]-β-D-glucopyranoside	F	o	Aerial parts	Abd El-Kader et al. (2013a,b)
91	(+)-Isolariciresinol-3a- <i>O</i> -[α-L-rhamnopyranosyl-(1''' → 2'')-α-L-rhamnopyranosyl-(1'''' → 6'')]-β-D-glucopyranoside	F	o	Aerial parts	Abd El-Kader et al. (2013a,b)
92	3,5,7-Trihydroxychromone	G	i	Herbs	Lin et al. (2009)
93	5,7-Dihydroxy-4H-chromen-4-one	G	h	Herbs	Zhang et al. (2012c)
94	(S)-2-(2'-hydroxypropyl)-5-methyl-7-hydroxychromone-7- <i>O</i> -α-L-fucopyranosyl(1 → 2)-β-D-glucopyranoside	G	a	Roots	Zhao et al. (2014)

Continued

Table 12.2 Continued

No.	Compounds	Types	Species	Tissues	References
95	N- <i>trans</i> -caffeoyl-tyramine	H	f	Aerial parts	Moradi-Afrapoli et al. (2012b)
96	Hirsutine	H	h	Herbs	Zhang et al. (2012c)
97	β -Sitosterol-3- <i>O</i> -acetate	I	o	Aerial parts	Abd El-Kader et al. (2013a,b)
98	β -Sitosterol	I	i,a	Herbs (i), roots (a)	Lin et al. (2009) and Xu et al. (2006)
99	β -Sitosterol-3- <i>O</i> - β -D-glucoside	I	a	Roots	Xu et al. (2006)
100	Physcion	J	a	Roots	Kim et al. (2008a,b) and Xu et al. (2006)
101	Emodin	J	a	Roots	Kim et al. (2008a,b)
102	Emodin-8- <i>O</i> - β -D-glucoside	J	a	Roots	Kim et al. (2008a,b)
103	Physcion-8- <i>O</i> - β -D-glucoside	J	a	Roots	Kim et al. (2008a,b) and Xu et al. (2006)
104	1,8-Dihydroxy-3,6-dimethoxy-xanthone-5- <i>O</i> -[α -L-rhamnopyranosyl-(1'' \rightarrow 2')]- β -D-glucopyranoside	K	o	Aerial parts	Abd El-Kader et al. (2013a,b)
105	17-Hydroxypentacosanyl acetate	L	o	Aerial parts	Abd El-Kader et al. (2013a,b)
106	Torachryson-8- <i>O</i> - β -D-glucoside	M	a	Roots	Kim et al. (2008a,b)
107	Diisobutyl phthalate	N	g	Rhizomes	Xiang et al. (2012)

A, stilbene type (No. 1–14); B, flavonoid type (No. 15–58); C, drimane sesquiterpenoid type (No. 59–74); D, phenol type (No. 75–86); E, coumarin and isocoumarin types (No. 87–89); F, lignan type (No. 90–91); G, chromone type (No. 92–94); H, alkaloid type (No. 95–96); I, sterol type (No. 97–99); J, anthraquinone type (No. 100–103); K, xanthone type (No. 104); L, fatty alcohol acetate type (No. 105); M, naphthalene type (No. 106); N, ester type (No. 107).

a, *P. multiflorum* Thunb.; b, *P. cuspidatum* Sieb. et Zucc.; c, *P. aviculare* L.; d, *P. amphibium* L.; e, *P. persicaria* L. (syn. *Persicaria maculosa* Gray); f, *P. hyrcanicum* Rech. f.; g, *P. amplexicaule* D. Don; h, *P. capitatum* Burch. –Ham. ex D. Don; i, *P. jucundum* Meisn.; j, *P. viscosum* Burch. –Ham. ex D. Don; k, *P. hydropiper* (k1, French *P. hydropiper*; k2, Bangladesh *P. hydropiper*; k3 Japanese *P. hydropiper*); l, *P. hydropiper* f. *purpurascens*; m, *P. minus* Huds.; n, *P. punctatum* var. *punctatum*; o, *P. bellardii*.

12.3 Bioactivities and therapeutic uses

12.3.1 Effects on cardiovascular system

Resveratrol (3,5,4'-trihydroxy-*trans*-stilbene) is a natural polyphenolic compound that exists in *P. cuspidatum*, grapes, peanuts, and berries, as well as their manufactured products. Resveratrol is a pharmacologically active compound that interacts with multiple targets in a variety of cardiovascular disease models to exert protective effects or induce a reduction in cardiovascular risk parameters (Tang et al., 2014). Endothelial hyperpermeability induced by hyperglycemia is the initial step in the development of atherosclerosis, one of the most serious cardiovascular complications in diabetes. Resveratrol ameliorates high-glucose-induced hyperpermeability mediated by caveolae via VEGF/KDR pathway (Tian et al., 2013). Polydatin, a resveratrol glucoside extracted from *P. cuspidatum*, attenuates cardiac hypertrophy through modulation of cardiac Ca²⁺ handling and calcineurin-NFAT signaling pathway (Ding et al., 2014).

2,3,4',5-Tetrahydroxystilbene-2-O- β -D-glucoside (TSG), extracted from the root of *P. multiflorum* (He Shou Wu), had inhibitory effects on angiotensin II-induced proliferation of vascular smooth muscle cells (Xu et al., 2014a). Its antiproliferative effect might be associated with the downregulation of intracellular reactive oxygen species (ROS), followed by the suppression of the Src-MEK1/2-ERK1/2 signaling pathway, hence blocking cell cycle progression. TSG could prevent cardiac remodeling induced by pressure overload in rats (Xu et al., 2014b), which may be related to a decreasing angiotensin II level, an antioxidant effect, suppression of transforming growth factor- β 1 expression, and inhibition of extracellular signal-regulated kinase 1/2 and p38 mitogen-activated protein kinase activation. Proteomic analysis was used to investigate the molecular events occurring in the atherosclerotic rats after TSG treatment (Yao et al., 2013). TSG treatment suppresses atherosclerosis by altering the expression of different proteins. Calreticulin, vimentin, HSP 70, lipocortin 1, and Apo A-I are key proteins that may be novel molecular targets responsible for atherogenesis suppression induced by TSG treatment.

Dysregulated tonic tension and calcium sensitization in blood vessels have frequently been observed in many cardiovascular diseases. Emodin of *P. multiflorum* inhibits tonic tension through suppressing PKC δ -mediated inhibition of myosin phosphatase in rat isolated thoracic aorta (Lim et al., 2014).

P. viviparum (PV) is a perennial herb and widely distributed in high-elevation mountain regions, such as the Tibetan Plateau. In Tibetan traditional medicine, PV is usually used to boost the blood circulation to dissipate blood stasis. PV induces vasorelaxation in the rat thoracic aorta via activation of nitric oxide (NO) synthase in endothelial cells (Chang et al., 2014).

2,3,4',5-Tetrahydroxystilbene-2-O- β -D-glucoside (TSG) of *P. multiflorum* could raise the content of CYP (cytochrome p450) 7A and then promote the lipolysis of cholesterol (Wang et al., 2014a). TSG also showed the best LDL-reducing effect. Emodin could inhibit HMG-CoA reductase and DGAT1, which were key enzymes in the synthesis of TC and TG. Physcion increased the content of HTGL and then could boost the lipolysis of triglyceride. Physcion showed the best VLDL-reducing effect. The lipid regulation activity might be due to an overall synergy of TSG, emodin, and

physcion. TSG attenuates human platelet aggregation, secretion, and spreading *in vitro* (Xiang et al., 2014).

Antiatherosclerotic effects of *P. aviculare* L. ethanol extract in ApoE knockout mice fed a Western diet are mediated via the MAPK pathway (Haeng Park et al., 2014).

Extracts of *P. persicaria* inhibit G protein-activated inwardly rectifying K⁺ channels (Lajter et al., 2013a). The electrophysiologically active agents, not the new flavonoids from the chloroform extract, are among the minor compounds of HPLC eluates.

12.3.2 Anti-inflammatory activity

Resveratrols and catechin-(4 α → 8)-catechin, the newly found constituents in the invasive variety, have similar NO inhibition potency as that of piceid (the major constituent of *P. cuspidatum*) (Fan et al., 2013b), but the newly found major constituent, that is, piceatannol glucoside, showed no apparent effect. The total content of resveratrol measured in the root extracts of the Swiss sample was about 2.5 times less than that of the Chinese one. When the invasive variety of *P. cuspidatum* is used in traditional medicine, the chemical difference should be kept in mind.

P. tinctorium, a traditional medicine used in China and Korea, improves 2, 4-dinitrofluorobenzene-induced atopic dermatitis-like lesional skin (Han et al., 2014). *P. tinctorium* inhibited IL-32 and TSLP production through the attenuation of caspase-1 activation in an animal model of allergic rhinitis (Jeong et al., 2014).

Flavonol glucuronides at physiologically achievable concentrations within the range of 0.5–10 μ M significantly inhibited the production of ROS as well as elastase release in human neutrophils model and should be considered as responsible for the anti-inflammatory activity of the *P. aviculare* (Granica et al., 2013).

P. chinense aqueous leaf extract has gastroprotective activity on ethanol-induced hemorrhagic mucosal lesions in rats (Ismail et al., 2012). *P. viviparum* inhibits the lipopolysaccharide-induced inflammatory response in RAW264.7 macrophages through heme oxygenase-1 induction and activation of the Nrf2 pathway (Cheng et al., 2013).

12.3.3 Antimicrobial, antiparasitic, and insecticidal activities

Guizhou Miao medicine *P. capitatum* has antibacterial activity and can be used in bladder infection (Hu et al., 2014). Methanolic crude extract of aerial parts of *P. maritimum* showed a high antibacterial activity against gram-positive bacterial strains: *Bacillus cereus*, *Bacillus subtilis*, and *Staphylococcus aureus* with a highest MIC of 120 μ g/ml (El-Haci et al., 2013). *P. orientale* extracts had protective effect against *Clavibacter michiganense* subsp. *sepedonicum*, the causal agent of bacterial ring rot of potato (Cai et al., 2013).

Ethanol extracts of *P. cuspidatum*, resveratrol, (+)-catechin, and emodin 8-*O*- β -D-glucopyranoside inhibit HIV-1-induced syncytium formation (Zhang et al., 2013b). An ethyl acetate subfraction separated from *P. cuspidatum* root and its major component, emodin, inhibited Epstein-Barr virus lytic cycle (Yiu et al., 2014). *In vitro* and *in vivo* studies suggested the inhibitory effects of emodin isolated from *P. cuspidatum*

on Coxsackievirus B₄ (Liu et al., 2013). Resveratrol, (E)-3, 5, 12-trihydroxystilbene-3-O-beta-D-glucopyranoside-2'-(3'', 4'', 5''-trihydroxybenzoate), and catechin-3-O-gallate, isolated from *P. cuspidatum*, had inhibitory effect against neuraminidase (NA) activity (Chen et al., 2012), with IC₅₀ values of 129.8, 44.8, and 21.3 μmol/l, respectively. (E)-3, 5, 12-trihydroxystilbene-3-O-beta-D-glucopyranoside-2'-(3'', 4'', 5''-trihydroxybenzoate) and catechin-3-O-gallate had significant inhibitory effect against H1N influenza virus (EC₅₀ = 5.9, 0.9 μmol/l, respectively), with very low cytotoxicity to the host cells; their therapeutic selective index (SI) in MDCK cells ranged from 56 to 269. Emodin blocks the SARS coronavirus spike protein and angiotensin-converting enzyme 2 interaction (Ho et al., 2007).

P. chinense had antidiarrheal activity (Xiao et al., 2013). Ellagic acid and corilagin are two components contributing to this effect. Cinnamoylphenethyl amides from *P. hyrcanicum* possess antitrypanosomal activity (Moradi-Afrapoli et al., 2012b).

The essential oil of *P. hydropiper* exhibited LC₅₀ values of 194.63 and 199.65 and confertifolin exhibited LC₅₀ values of 2.02 and 3.16 against the second and fourth instar larvae of *Aedes albopictus* (dengue vector mosquito), respectively (Maheswaran and Ignacimuthu, 2014). The ovicidal activity of 100% on 0–6 h old eggs, repellent activity of 320.6 min, oviposition deterrent activity of 98.51%, and adulticidal activity of 100% at 10 ppm concentration of confertifolin were recorded.

12.3.4 Anticancer activity

Trans-piceid (T-Pc) is abundant in *P. cuspidatum* and in grapes and grape products such as wine. Piceid presents antiproliferative effects in intestinal epithelial Caco-2 cells, which is unrelated to resveratrol release (Stormiolo et al., 2014). 2-Methoxystypandrone of *P. cuspidatum* inhibits signal transducer and activator of transcription 3 and nuclear factor-κB signaling by inhibiting Janus kinase 2 and IκB kinase (Kuang et al., 2014). Resveratrol inhibits invasion and metastasis of colorectal cancer cells via MALAT1-mediated Wnt/β-catenin signal pathway (Ji et al., 2013). Constitutively activated STAT3 plays a pivotal role in oncogenesis and metastasis in many human cancers, and STAT3 has been validated as a novel anticancer drug target. 2-Methoxystypandrone of *P. cuspidatum* demonstrated a potent inhibitory effect on STAT3 activation and significantly inhibited cell proliferation of human breast cancer cells (Liu et al., 2012b), especially those with constitutively activated STAT3 (IC₅₀ 2.7–3.1 μM). The SAR analysis of quinone analogs suggested that the phenolic and carbonyl groups are the key structures contributing to their inhibitory activities against the STAT3 signaling.

Aqueous and organic extracts of 27 selected species from five genera (*Fallopia*, *Oxyria*, *Persicaria*, *Polygonum*, and *Rumex*) of the family Polygonaceae occurring in the Carpathian Basin were screened *in vitro* for antiproliferative activity against HeLa (cervix epithelial adenocarcinoma), A431 (skin epidermoid carcinoma), and MCF7 (breast epithelial adenocarcinoma) cells (Lajter et al., 2013b), using the 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide assay. A total of 196 *n*-hexane, chloroform, 50% methanol, and water extracts of different plant parts were investigated. Extracts of *P. hydropiper*, *Rumex acetosa*, *R. alpinus*, *R. aquaticus*,

R. scutatus, and *R. thyrsoiflorus* at 10 or 30 µg/ml demonstrated substantial cell growth inhibitory activity (at least 50% inhibition of cell proliferation) against one or more cell lines. *R. acetosa* and *R. thyrsoiflorus* proved to be the most active and are considered worthy of activity-guided phytochemical investigations.

3,5-Dihydroxybenzyl alcohol of *Reynoutria japonica* (*P. cuspidatum*) showed more potent inhibitory activity against topoisomerase I (IC₅₀ 4 µM) than camptothecin (Hwangbo et al., 2012), the positive control (IC₅₀ 18 µM). 3,5-Dihydroxybenzyl alcohol, citreorosein, *cis*-resveratrol, *trans*-resveratrol, and *trans*-resveratrol-5-*O*-β-D-glucopyranoside showed stronger inhibitory activities toward DNA topoisomerase II (IC₅₀ 0.54, 14, 15, 0.77, and 3 µM, respectively) than the positive control, etoposide (IC₅₀ 44 µM). Emodin and citreorosein displayed weak cytotoxicities against human lung cancer (A549), ovarian cancer (SK-OV-3), human liver hepatoblastoma (HepG2), and colon adenocarcinoma (HT-29) cell lines.

Flavonoid glucuronides of *P. amphibium* had antileukemic activity (Smolarz et al., 2008). A potential antitumor ellagitannin of *P. capitatum*, davidiin, inhibited hepatocellular tumor growth by targeting EZH2 (Wang et al., 2014b). The *n*-butanol extract of *P. bellardii* has the highest cytotoxicity in HeLa, MCF-7, and HepG-2 cells, with IC₅₀ values of 15.26, 50.66, and 30.09 µg/ml, respectively (Abd El-Kader et al., 2013b). Myricetin-3-*O*-(5''-acetyl-α-arabinofuranoside) exhibited a marked cytotoxicity in HeLa (IC₅₀ 75.04 µg/ml) and HepG-2 (41.03 µg/ml) cells.

(-)-Loliolide of *P. aviculare* exerted inhibitory activity against cellular senescence in human dermal fibroblasts (Yang et al., 2014a). Quercetin-3-*O*-β-D-glucuronide isolated from *P. aviculare* inhibits cellular senescence in human primary cells (Yang et al., 2014b).

Apoptosis induction by *P. minus* is related to antioxidant capacity, alterations in expression of apoptotic-related genes, and S-phase cell cycle arrest in HepG2 cell line (Mohd Ghazali et al., 2014). Resveratrol-4-*O*-D-(2'-galloyl)-glucopyranoside isolated from *P. cuspidatum* exhibits anti-hepatocellular carcinoma viability by inducing apoptosis via the JNK and ERK pathway (Xie et al., 2014). Polydatin inhibits growth of lung cancer cells by inducing apoptosis and causing cell cycle arrest (Zhang et al., 2014).

8-Methyltryptanthrin of *P. tinctorium* induced differentiation of P19CL6 embryonal carcinoma cells into spontaneously beating cardiomyocyte-like cells (Seya et al., 2014).

12.3.5 Antioxidant activity

Polydatin from *P. cuspidatum* exhibited protective effects against carbon tetrachloride-induced liver injury in mice (Zhang et al., 2012a). *P. cuspidatum* contained many more contributing antioxidants other than resveratrol (Kurita et al., 2014).

Tetrahydroxystilbene glucoside of *P. multiflorum* exhibited protective effect against hydrogen peroxide-induced dysfunction and oxidative stress in osteoblastic MC3T3-E1 cells (Zhang et al., 2012b). Compared with *P. multiflorum* polysaccharide PMP-1, PMP-2 exhibited a much stronger antioxidant capacity against free radicals, lipid oxidation, and protein glycation (Lv et al., 2014). The IC₅₀ values of PMP-2 were 0.47, 0.6, and 0.93 mg/ml for superoxide anion scavenging, hydroxyl radical

scavenging, and hydroxyl peroxide scavenging, respectively. The inhibitory ability of PMP-2 on lipid oxidation marked in the rat liver, followed by the heart and kidney. PMP-2 also showed satisfactory suppression of AGEs formation.

The EtOAc fraction of *P. aviculare* displayed the highest content of flavonoids (sum, 208.9 mg/g) with the strongest peroxynitrite scavenging activity (IC₅₀, 2.68 µg/ml) (Nugroho et al., 2014). The activities of the eight compounds (myricitrin, isoquercitrin, avicularin, quercitrin, myricetin, desmanthin-1, quercetin, and kaempferol) were comparable to that of the positive control (l-penicillamine; IC₅₀: 1.03 µg/ml). The folkloric medicinal uses of *P. aviculare* are mainly attributed to flavonoids, such as particularly highly contained myricetin, myricitrin, and desmanthin-1.

Xanthone and lignan glycosides from the aerial parts of *P. bellardii* showed significant antioxidant potential by DPPH(·) scavenging activity test (Abd El-Kader et al., 2013a). 5, 6-Dihydropyranobenzopyrone, amplexicine, catechin, rutin, quercetin-3-O-β-D-galactopyranoside, chlorogenic acid, galloyl glucose, caffeic acid, gallic acid, and scopoletin, isolated from *P. amplexicaule*, exhibited considerable antioxidant activity in a DPPH radical scavenging assay (Tantry et al., 2012).

12.3.6 Effects on the nervous system

Resveratrol reverses the effects of chronic unpredictable mild stress on behavior, serum corticosterone levels, and BDNF expression in rats (Liu et al., 2014). Resveratrol attenuates oxidative damage and ameliorates cognitive impairment in the brain of senescence-accelerated mice (Liu et al., 2012a).

P. minus possesses antioxidant and anticholinesterase activity and demonstrated enhanced cognition *in vivo* (George et al., 2014). The data suggest neuroprotective properties of the extract. Hexane extracts of *P. multiflorum* improve tissue and functional outcome following focal cerebral ischemia in mice (Lee et al., 2014). Tetrahydroxystilbene glucoside of *P. multiflorum* attenuates neuroinflammation through the inhibition of microglia activation (Zhang et al., 2013a). 8-Hydroxycalamenene of *Reynoutria elliptica* (*P. ellipticum*) attenuated the cell death of transformed RGC-5 cells (Jo et al., 2013).

Neurons rely on the release and subsequent cleavage of GSH to cysteinylglycine (Cys-Gly) by astrocytes in order to maintain optimal intracellular GSH levels. In neurodegenerative diseases characterized by oxidative stress, neurons need an optimal GSH supply to defend themselves against free radicals released from activated microglia and astroglia. The rate of GSH synthesis is controlled largely by the activity of γ-glutamyl cysteine ligase. Expression of γ-glutamyl cysteine ligase and of the Xc-system, which facilitates cysteine uptake, is regulated by the redox-sensitive transcription factor, nuclear factor erythroid-2-related factor 2 (Nrf2). Resveratrol and *P. multiflorum* were all identified as potent Nrf2 activators and “GSH and Cys-Gly boosters” (Steele et al., 2013).

The antidepressant-like effects of resveratrol in the FST (forced swim test) and TST (tail suspension test) are mediated, at least in part, by modulating hypothalamic-pituitary-adrenal axis, BDNF expression, and ERK phosphorylation in the brain region of mice (Wang et al., 2013a).

12.3.7 Other activities

The antimelanogenic activity of 2,3,5,4'-tetrahydroxystilbene-2-*O*- β -D-glucopyranoside, isolated from *P. multiflorum*, is likely mediated through a noncompetitive inhibition on tyrosinase, downregulation of the expression of melanogenic proteins, and reduction of tyrosinase/TRP-1 complex formation (Cheung et al., 2014).

Supplementation for 12 weeks with *P. minus* and the proprietary *Eurycoma longifolia* extract, Physta, was well tolerated and more effective than placebo in enhancing sexual performance in healthy volunteers (Udani et al., 2014). *P. cuspidatum* inhibits pancreatic lipase activity and adipogenesis via attenuation of lipid accumulation (Kim et al., 2013), thus having antiobesity effect.

Constituents from the root of *P. multiflorum* have promotion effect on hair growth (Sun et al., 2013).

The semialcoholic extract of *P. senegalensis* possesses α -glucosidase inhibitory activity and antioxidant potency (Bothon et al., 2013). Proanthocyanidins, isolated from stems of *P. multiflorum*, strongly inhibit α -amylase with an acarbose equivalence (AE) value of 1954.7 μ mol AE/g and inhibit α -glucosidase with an AE value of 211.1 μ mol AE/g (Wang et al., 2013b). They have potential as functional ingredients in reducing postprandial hyperglycemia. Phenolic constituents from aerial parts of *P. hyrcanicum* had *in vitro* α -glucosidase inhibitory activity (Moradi-Afrapoli et al., 2012a).

12.3.8 Toxicity and safety

Adverse reactions induced by *P. multiflorum* are common, with patients developing drug-induced liver injury (DILI) and even liver failure (Ma et al., 2014). Although the mechanism is unknown, many studies have suggested that an idiosyncratic reaction occurs, which is related to genetic polymorphisms of CYP1A2. The influence of stilbene glucoside on the pharmacokinetics of emodin may be attributed to the inhibition of UGT1A8 mRNA expression (Ma et al., 2013). *P. cuspidatum* markedly increased the systemic exposure and brain concentration of carbamazepine (CBZ) and CBZE through inhibiting the activities of CYP 3A and MRP 2 (Chi et al., 2012).

12.4 Molecular biology and genomics

12.4.1 Molecular marker

Molecular markers can help elucidate how neutral evolutionary forces and introduction history contribute to genetic variation in invaders. Genetic diversity, population structure, and colonization patterns in the invasive *P. cespitosum*, a highly selfing, tetraploid Asian annual introduced to North America, were examined using nine diploidized polymorphic microsatellite markers (SSR; Matesanz et al., 2014). Low heterozygosity was found in all 16 populations, consistent with the selfing mating system of *P. cespitosum*. Despite the high selfing levels, substantial genetic variation

within and among *P. cespitosum* populations was revealed, based on the percentage of polymorphic loci, allelic richness, and expected heterozygosity. Inferences from individual assignment tests and pairwise F_{ST} values indicated high among-population differentiation, which indicates that the effects of gene flow are limited relative to those of genetic drift, probably due to the high selfing rates and the limited seed dispersal ability of *P. cespitosum*. Population structure appears to be the result of the random movement of propagules across the introduced range, possibly associated with human dispersal. The high population differentiation, genetic diversity, and fine-scale genetic structure (populations founded by individuals from different genetic sources) in the introduced range suggest that multiple introductions to this region may have occurred. High genetic diversity may further contribute to the invasive success of *P. cespitosum* in its introduced range.

Among 50 RAPD primers, only C29 primer had two specific bands, which could distinguish *P. capitatum* from *P. nepalense* (Zhou et al., 2013). Four pairs of specific primers were designed based on the two sequences of RAPD marker bands, and only one pair primer (Z1-2) was successfully converted into SCAR marker, which could be used as an effective SCAR mark to identify Z300 DNA for *P. capitatum*.

AFLP was used to identify the knotgrass (*P. aviculare*) population at the crime site as the most likely origin of the botanical evidence (Koopman et al., 2012). The genetic diversity of 48 representational populations of *P. capitatum* including 240 individuals was investigated by ISSR marker (Zhou et al., 2010). SRAP (sequence-related amplified polymorphism) was used to detect the polymorphisms of *Radix Polygoni Multiflori* in Chongqing (Cheng et al., 2013). SRAP might be superior to RAPD in genetic diversity studies.

Analysis of nuclear internal transcribed spacer (nrITS) sequences reveals polymorphism among five *P. barbata* populations belonging to five geographic locations in India (Choudhary et al., 2011). UPGMA analysis based on the ITS datasets shows that the sampled populations are grouped according to their geographic locations and are supposed to evolve under reproductive isolation, which most likely are due to the long-distance distribution and population fragmentation.

DNA bar codes are used to discriminate the Polygonaceae in China Pharmacopoeia and their adulterants (Song et al., 2009). The amplification efficiency of six candidate DNA bar codes (rbcL, trnH-psbA, ndhJ, rpoB, rpoC1, and accD) was 100%, while the efficiency of YCF5 and nrITS was 56% and 44%, respectively. The interspecific divergence was highest for the trnH-psbA (20.05%), followed by the nrITS (14.01%) across all species pairs, while intraspecific variation both within populations and between populations was absent. The trnH-psbA can not only distinguish 10 species of Polygonaceae in China Pharmacopoeia but also recognize eight other species of Polygonaceae including their adulterants.

P. multiflorum (*Fallopia multiflora*) is often confused and substituted with the roots of *Fallopia multiflora* var. *ciliinervis*, *Pteroxygonum giraldii*, *Cynanchum auriculatum*, and *Stephania cepharantha*. The nrITS regions of six *Fallopia* species were sequenced and analyzed (Zheng et al., 2009). The diagnostic primers PMITS28 and PMITS545, which amplified an expected 517 bp ITS fragment from *F. multiflora*, were designed. No amplified product was observed when other species was used. Based on

18S rRNA gene sequence analysis, *P. multiflorum* could be easily distinguished from adulterants and other herbs with similar medicinal components (Yan et al., 2008). All *P. multiflorum* samples were divided into four clades based on matK sequence. Permutations of matK were related to the geographic distributions of the samples. These markers can be used to authenticate the botanical origin of *P. multiflorum*. The best bar code of *P. multiflorum* is psbA-trnH, with significant interpopulation variability (Sun et al., 2013). The combination of loci gave better performance for distinguishing populations than a single locus. It could be good to use matK + rbcL + psbA-trnH + ITS2 or psbA-trnH alone for *P. multiflorum* in geoherbalism identification.

12.4.2 Transcriptome

cDNA-amplified fragment length polymorphism (cDNA-AFLP) transcript profiling was applied to generate the expression profiles of *P. minus* in response to salicylic acid (SA) and methyl jasmonate (MeJA) elicitions (Ee et al., 2013). Two sets of genes were induced by SA and MeJA, respectively. Stress-related genes were proved to lead to the expression of genes involved in secondary metabolite biosynthetic pathways. A total of 98 transcript-derived fragments (TDFs) were upregulated, including 46 from SA-treated and 52 from MeJA-treated samples. The cDNA-AFLP transcripts generated using 64 different MseI/TaqI primer combinations showed that treatments with SA and MeJA induced genes mostly involved in scavenging ROS, including zeaxanthin epoxidase, cytosolic ascorbate peroxidase 1, and peroxidase. Of these stress-related genes, 15% of other annotated TDFs are involved mainly in secondary metabolic processes, and two genes encoding (+)-delta cadinene synthase and cinnamoyl-CoA reductase were highlighted.

The leaf of an aromatic plant *P. minus* is widely used as a food additive and in the perfume industry. The leaf also accumulates secondary metabolites such as flavonoid. A standard cDNA library of *P. minus* leaves was constructed, and two normalized full-length enriched cDNA libraries were constructed from stem and root in order to create a gene resource for the biosynthesis of secondary metabolites, especially flavonoid biosynthesis (Roslan et al., 2012). Large-scale sequencing of *P. minus* cDNA libraries identified 4196 expressed sequence tags (ESTs). From the three cDNA libraries, 11 ESTs encoding seven genes were mapped to the flavonoid biosynthetic pathway. Three flavonoid biosynthetic pathway-related ESTs, namely, chalcone synthase, CHS (JG745304); flavonol synthase, FLS (JG705819; Figure 12.2); and leucoanthocyanidin dioxygenase, LDOX (JG745247), were selected for further examination by quantitative RT-PCR (qRT-PCR) in different *P. minus* organs. Expression was detected in leaf, stem, and root. Based on transcriptome data, gene expression studies can be initiated to better understand the underlying physiological processes.

Various active components have been extracted from the root of *P. cuspidatum*. However, the genetic basis for their activity is little known. 25,600,002 short reads (2.3 Gb) of *P. cuspidatum* root transcriptome were obtained via Illumina HiSeq 2000 sequencing (Hao et al., 2012). A total of 86,418 unigenes were assembled de novo and annotated. 12, 18, 60, and 54 unigenes were, respectively, mapped to the mevalonic acid (MVA), methyl-D-erythritol 4-phosphate (MEP), shikimate (Figure 12.3), and resveratrol biosynthesis pathways, suggesting that they are

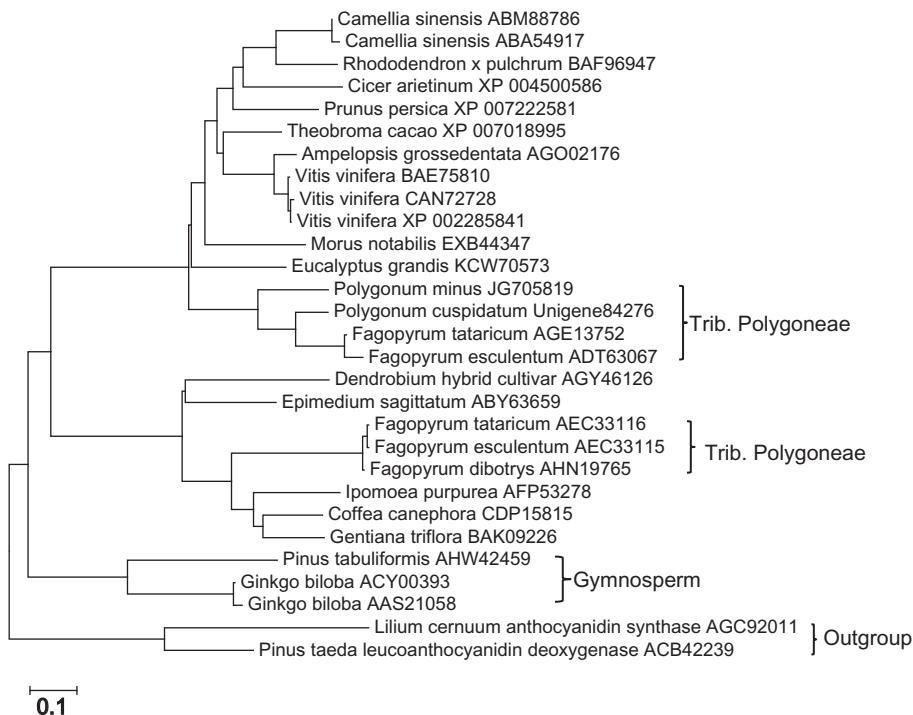


Figure 12.2 Phylogenetic relationship of plant flavonol synthases. The evolutionary history was inferred by using the ML method and the JTT+I (13.26% sites)+G model. The tree is drawn to scale, with branch lengths measured in the number of substitutions per site. The analysis involved 29 amino acid sequences, including a *P. cuspidatum* sequence predicted from transcriptome Unigene 84276 (Hao et al., 2012) and a *P. minus* sequence predicted from EST (Roslan et al., 2012). There were a total of 365 positions in the final dataset. Evolutionary analyses were conducted in MEGA6.

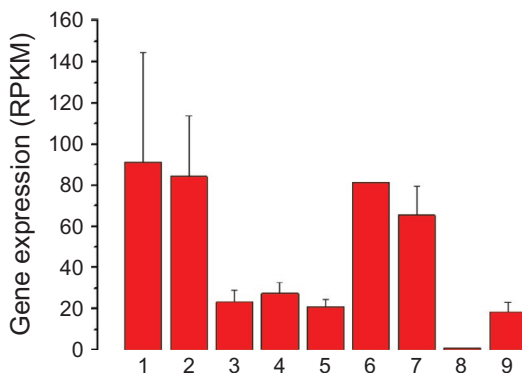


Figure 12.3 Expression levels (RPKM value) of the *P. cuspidatum* unigene in shikimate metabolic pathway (Hao et al., 2012), which is responsible for biosynthesis of anthraquinone and stilbene. 1, 3-deoxy-D-arabino-heptulosonate-7-phosphate (DAHP) synthase; 2, 3-dehydroquinase; 3, shikimate 5-dehydrogenase; 4, shikimate: NADP oxidoreductase; 5, shikimate kinase; 6, EPSP synthase; 7, chorismate synthase; 8, isochorismate synthase; 9, chorismate mutase. Bars represent the standard error of the average.

involved in the biosynthesis of pharmaceutically important anthraquinone and resveratrol. Eighteen potential UDP-glycosyltransferase unigenes were identified as the candidates most likely to be involved in the biosynthesis of glycosides of secondary metabolites. Identification of relevant genes could be important in eventually increasing the yields of the medicinally useful constituents of the *P. cuspidatum* root. From the previously published transcriptome data of 19 nonmodel plant taxa, 1127 shared orthologs were identified and characterized. This information will be very useful for future functional, phylogenetic, and evolutionary studies of these plants.

12.5 Phylogeny

The buckwheat family Polygonaceae is a diverse group of plants and is a good model for investigating biogeography, breeding systems, coevolution with symbionts such as ants and fungi, functional trait evolution, hybridization, invasiveness, morphological plasticity, pollen morphology, and wood anatomy. Age estimates for Polygonaceae were obtained by calibrating a Bayesian phylogenetic analysis (Schuster et al., 2013), using a relaxed molecular clock with fossil data. Eighty-one species of Polygonaceae were analyzed with MrBayes to infer species relationships. One nuclear (nrITS) and three chloroplast (cp) markers (the trnL-F spacer region and matK and ndhF genes) were used. Seven calibration points including fossil pollen and a leaf fossil of *Muehlenbeckia* (a Southern Hemisphere group) were used to infer node ages. Results of the Beast analyses indicate an age of 110.9/118.7 million years (My) with an uncertainty interval of 90.7–125.0 My for the stem age of Polygonaceae. This age is older than previously thought (approximately 65.5–70.6 My). The estimated divergence time for *Muehlenbeckia* is 41.0/41.6 (39.6–47.8) My and its crown clade is 20.5/22.3 (14.2–33.5) My. Because the breakup of Gondwana occurred from 95 to 30 My ago, diversification of *Muehlenbeckia* is best explained by oceanic long-distance and maybe stepping-stone dispersal rather than vicariance.

Interspecific hybridization and the following polyploidization play a major role in plant diversification, but quantifying the contribution of this mechanism to diversification within taxonomically complex clades remains difficult. Incongruence among gene trees can provide critical insights, especially when combined with data on chromosome numbers, morphology, and geography. Molecular phylogenetic studies using three cpDNA regions and nrITS sequences were performed to explore the hybrid speciation in *Persicaria* (*Polygonum*, Polygonaceae; Figure 12.4) (Kim and Donoghue, 2008), with an emphasis on sampling within section *Eupersicaria*. There are major conflicts between the combined cpDNA tree and the nrITS tree; a variety of incongruence tests rejected stochastic error as the cause of incongruence in most cases. Both the tree incongruence results and information on chromosome numbers suggest that the origin of 10 polyploid species involved interspecific hybridization. The recognition of several previously named species that have been treated as belonging within other species was supported. Repeated allotetraploidy (as distinct from radiation at the

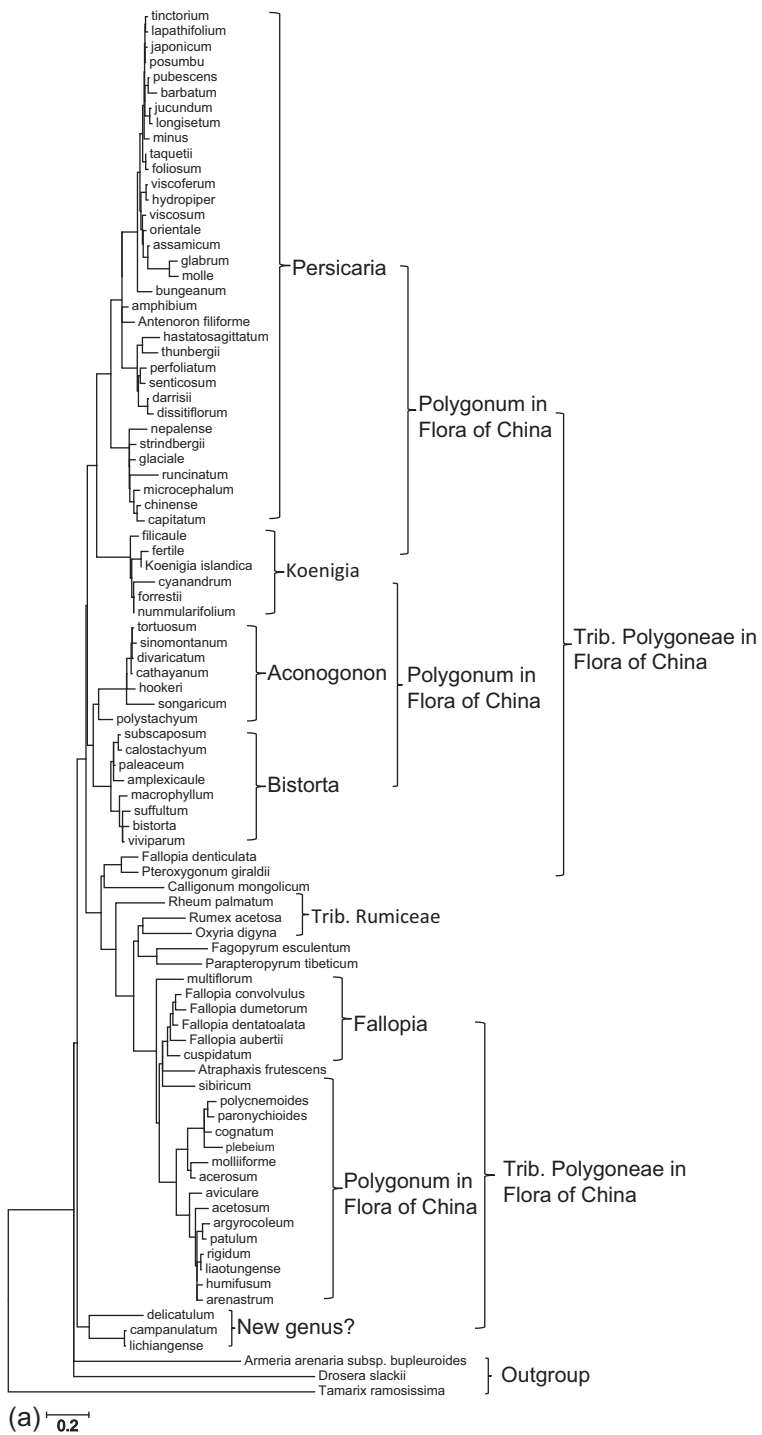


Figure 12.4 Phylogenetic relationship of *Polygonum* and related groups. A, ITS tree inferred from maximum likelihood (ML) method based on GTR+I (10.90% sites)+G model.

(Continued)

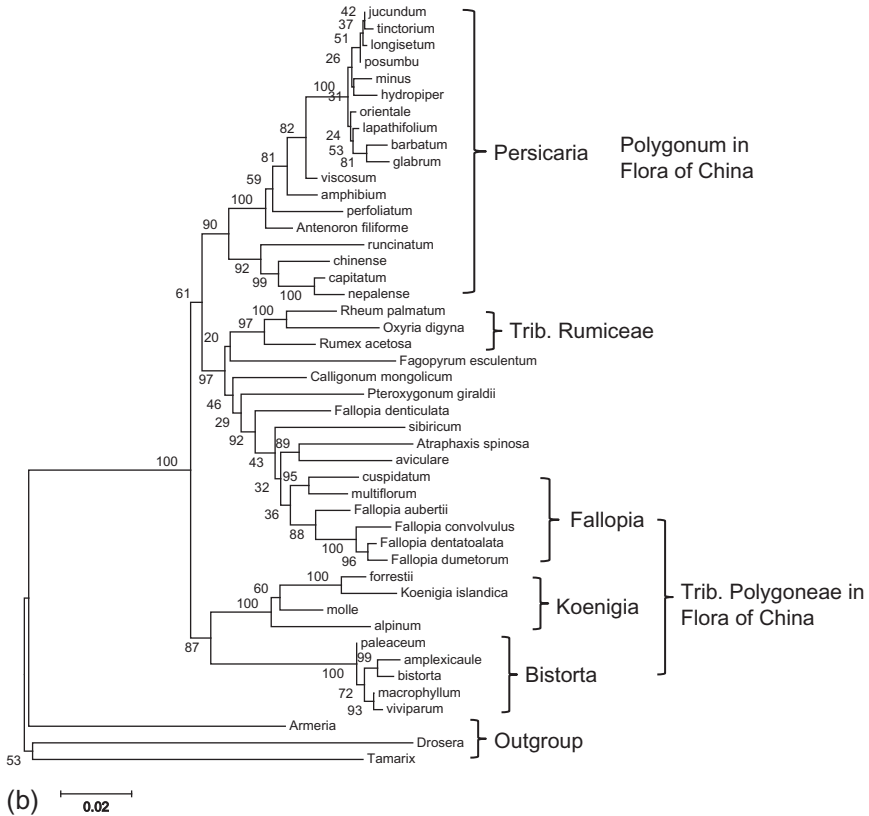


Figure 12.4 Continued. The tree is drawn to scale, with branch lengths measured in the number of substitutions per site. The analysis involved 91 nucleotide sequences. There were a total of 1006 positions in the final dataset. Evolutionary analyses were conducted in MEGA6 (Tamura et al., 2013). B, matK + rbcL + trnL-F tree inferred from neighbor joining method. The tree is drawn to scale, with branch lengths in the same units as those of the evolutionary distances used to infer the phylogenetic tree. The evolutionary distances were computed using the maximum composite likelihood method and are in the units of the number of base substitutions per site. The analysis involved 46 nucleotide sequences. All ambiguous positions were removed for each sequence pair. There were a total of 4645 positions in the final dataset.

tetraploid level) might be the key mechanism governing the diversification of this taxonomically challenging group.

Multiple instances of allopolyploid speciation were also shown in *Persicaria* using a low-copy nuclear gene region (LEAFY second intron) (Kim et al., 2008b), which belong to *Polygonum* in Flora of China. Fifteen species seem to be allopolyploids, which is higher than the number found in previous comparisons of cp DNA and nrITS

phylogenies (Kim and Donoghue, 2008). This underestimation of the extent of allopolyploidy is due in at least three cases to homogenization of nrITS toward the maternal lineage. The diploid species, *P. lapathifolia*, has been involved in at least six cases of allopolyploid speciation. Of the diploids, this species is the most widespread geographically and ecologically and also bears more numerous and conspicuous flowers, illustrating ecological factors that may influence hybridization frequency. With a few exceptions, the allopolyploid species also are widespread, plastic, ecological generalists. Hybridization events fostered by human introductions may be fueling the production of new species that have the potential to become aggressive weeds.

ITS sequences from 44 Indian *Polygonum* taxa were examined to investigate relationships among various sections proposed previously (Choudhary et al., 2012). The maximum parsimony trees obtained from ITS sequences suggested eight major groups of the Indian *Polygonum* spp. The relationships among different sections were largely congruent with those inferred from morphological characters as described by Hooker. The treatment of the *Persicaria* suggested by Haraldson on the basis of anatomical characters proved to be nearly in line with that based on ITS data. A high resolution of phylogeny of the Himalayan *Polygonum* (e.g., *P. microcephalum*, *P. assamicum*, *P. recumbens*, and *P. effusum*) was provided and merger of the section *Amblygonon* in the section *Persicaria* was supported. Molecular differences were detected among *Persicaria barbata* collected from different geographic locations of India, although these were not differentiated at the morphological level.

To examine the phylogenetic relationships of *Koenigia* (Polygonaceae), 43 samples representing all species of *Koenigia* and closely related taxa (*Aconogonon*, *Bistorta*, and *Persicaria*) were sequenced for nr ITS and four cp regions (trnL-F, atpB-rbcL, rbcL, and rpl32-trnL(UAG); Fan et al., 2013a,b). Trib. Polygonaceae and trib. Rumiceae are recovered on both cp and ITS trees (Figure 12.4), while trib. Atraphaxideae is not. The placement of *P. bistorta* is uncertain due to conflict between cp and ITS trees (Figure 12.4). It was proposed that the genus *Koenigia* be circumscribed to include five species, that is, perennials (*K. forrestii* and *K. nummularifolia*) and annuals (*K. islandica*, *K. pilosa*, and *K. nepalensis*). However, on both cp and ITS trees, *K. nepalensis* (*P. nepalense*) is more closely related to *P. capitatum* and *P. chinense* (Figure 12.4), instead of *Koenigia*. *K. islandica* and *K. fertilis* (*P. fertile*, Figure 12.4a), both of which are from the Himalayan region, can be merged into a single species. *P. delicatulum* (*K. delicatula*), *P. campanulatum*, and *P. lichiangense* occupy an isolated position at the base of the Polygonaceae (Figure 12.4a), which might be reassigned to a new genus.

The tetraploid *P. minor* (*P. minus*), which is sister to the *P. hydropiperoides* complex in the nrITS tree (Kim and Donoghue, 2008), may have arisen through hybridization between an unknown diploid lineage or possibly a tetraploid in the *P. hydropiperoides* complex and the diploid *P. hydropiper*. It is not entirely clear that *P. hydropiper* served as the maternal parent, since the relationship between *P. hydropiper* and *P. minor* is weakly supported in the cpDNA tree (Figure 12.4b). Morphologically, *P. minor* is more similar to the diploid *P. foliosa* (*P. foliosum*), which should also be considered as a possible diploid maternal lineage for *P. minor* (Kim and Donoghue, 2008).

The pollen apertures likely evolved in parallel in the *Aconogonon-Koenigia-Bistorta* clade and *Persicaria* clade (Fan et al., 2013a,b), and tricolpate pollen is probably the ancestral one. Quincuncial aestivation likely evolved during the early evolution of *Koenigia* and its close relatives. The uplift of the Himalayas has played a vital role in promoting species diversification of *Koenigia*. *K. islandica* expanded its range during Pleistocene glacial cycles by tracking changes in newly available habitats.

12.6 Conclusion

There is little study addressing chemotaxonomy and metabolomics of *Polygonum* and related genera, although such studies can provide vital information for sustainable utilization of Polygonaceae medicinal resources. The family Polygonaceae has been supported as monophyletic, but the circumscription of some subgroups, especially *Polygonum* and related taxa, has been controversial. The use of population genetic approaches, sampling from multiple populations, would shed light on this issue. More extensive sampling inside and outside the Himalayas and Hengduan Mountains is indispensable to explore the phylogenetic hypothesis and facilitate species diversity conservation.

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