· Reviews ·

Pharmacophylogenetic Study on Plants of Genus *Salvia* L. from China

LI Min-hui[1, 2], LI Qian-quan[1, 2], LIU Yan-ze[3], CUI Zhan-hu[1,2], ZHANG Na[2], HUANG Lu-qi[1*], XIAO Pei-gen[3*]

1. National Resource Center for Chinese Materia Medica, China Academy of Chinese Medical Science, Beijing 100700, China
2. Baotou Medical College, Baotou 014060, China
3. Key Laboratory of Bioactive Substances and Resources Utilization of Chinese Herbal Medicine (Peking Union Medical College), Ministry of Education, Institute of Medicinal Plant Development, Chinese Academy of Medical Science, Beijing 100193, China

Abstract: In China, many species of genus *Salvia* L. (Lamiaceae) are important medicinal plants with a long history. Due to their marked ethnopharmacological uses in folk medicine and a large number of active constituents with therapeutic potential found recently, they have become a rich source for new drug discovery, mechanism research, and biological experiment. All medicinal plants of *Salvia* L. could be divided into three groups (Groups 1, 2, and 3). The plants in Group 1 were used as "Danshen" and are rich in diterpenoids and caffeic acid derivatives. Few introduced plants in Group 2 from America or Europe have been used to clear body-heat and toxins. Abietane diterpenes of medicinal species in Group 3 (the species are from Subg. *Allagospadonopsis* Briq., Sect. *Plethiosphace*, or Sect. *Notiosphace*) are absent, and the contents of caffeic acid derivatives are considerably lower than those in plants of Group 1.

Key words: ethnopharmacology; Lamiaceae; pharmacophylogenetics; *Salvia* L.; species
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Introduction

The genus *Salvia* L., the largest one in the family Lamiaceae with nearly 1000 species, has undergone marked species radiations in three main regions of the world: Central and South America (500 species), Central Asia/Mediterranean (200 species), and Eastern Asia (100 species) (Walker and Sytsma, 2007). Eighty-four species are native to China (Li and Hedge, 1998), with their centre of distribution in southwest China, notably the Hengduan Mountain region. In *Flora of China*, the *Salvia* L. species in China are classified into four subgenera (Subg.): Subg. *Salvia* Benth., Subg. *Sclarea* (Moench) Benth., Subg. *Jungia* (Moench) Briq., and Subg. *Allagospadonopsis* Briq. (Wu and Li, 1977).

The genus is characterized by modified lever-like stamens playing a central role in the process of pollen transfer, and due to the unusual structure of the stamens, the genus as a whole has long been presumed to be monophyletic. However, there were many taxonomic uncertainties at the sub-generic level, and the most widely accepted classification was that by Bentham who divided the genus into 12 sections (Sect.) (Bentham, 1848). No comprehensive classification of the genus has been completed since then, despite the

* Corresponding authors: Huang LQ Address: National Resource Center for Chinese Materia Medica, China Academy of Chinese Medical Sciences, No.16, Neixiaojie street, Dongzhimen, Dongcheng District, China Tel: +86-10-8404 4340 E-mail: huangluqi01@126.com
Xiao PG Address: Institute of Medicinal Plant Development, Chinese Academy of Medical Science No. 151 Malianwa North Road, Haidian District, China Tel: +86-10-6289 4462 E-mail: xiaopg@public.bta.net.cn
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recognition of over 500 new species in the genus. Although many researchers (Briquet, 1897; Stibal, 1934; Pobedimova, 1954; El-Gazzar *et al*, 1968; Wood and Harley, 1989; Espejo-Serna and Ramamoorthy, 1993) have modified Bentham's classification, and these speices have been proven by their key characters to be difficult to use in practice. According to the investigation on the genus using the chloroplast DNA regions rbcL and trnL-F, Walker and Sytsma drew a surprising conclusion: *Salvia* L. was not monophyletic, but comprised three distinct lineages, such as *Salvia* L. clade I, *Salvia* L. clade II, and *Salvia* L. clade III (Walker *et al*, 2004; Walker and Sytsma, 2007).

In China, many *Salvia* L. species are used as important medicinal plants and have a long history to be used clinically. For example, *Danshen*, the root and rhizome of *S. miltiorrhiza* Bunge, has been used in the treatment of coronary heart disease, including angina pectoris, coronary artery spasm, and myocardial infarction, etc. This study explores the relationship of phylogeny, chemical constituents, ethnopharmacologic information, and pharmacology of *Salvia* L. plants, which could contribute greatly to the utilization and development of the natural drugs from Chinese *Salvia* L. species.

Chemical characteristics of *Salvia* L. species from China

The main groups of secondary metabolites found in the plants of *Salvia* L. are phenolic acids, diterpenoids, flavonoids, and so on. The aerial parts of these plants contain flavonoids, triterpenoids, and monoterpenes, particularly in the flowers and leaves, while diterpenoids and phenolic acids are found mostly in the roots (Topcu *et al*, 2006). In order to limit the information on the taxonomically most promising groups of compounds, we have concentrated our efforts on listing only the diterpenoids and the caffeic acid derivatives, which are the major characteristics for the genus.

Diterpenoids in Chinese *Salvia* L. species

Diterpenoids, a class of secondary metabolites with a large variety of structures, have been used as chemotaxonomic marker at infra- and super-genus levels in Lamiaceae (Alvarenga, Gastmans, and Rodrigues, 2001). Diterpenoids are frequently found in the plants of genus *Salvia* L. Most species from America are characterized by clerodane diterpenes, while abietane is the skeleton with the highest occurrence and most widespread distribution in the Subg. *Salvia* L. and Subg. *Sclarea* (Moench) Benth (Rodríguez-Hahn *et al*, 1992). Given that most Chinese *Salvia* L. species are mainly from the Subg. *Salvia* L. and Subg. *Sclarea* (Moench) Benth, abietane diterpenes are the most predominant diterpenes in these species, additionally, icetexane diterpenes were isolated from *S. przewalskii* Maxim, *S. yunnanensis* C. H. Wright, and *S. miltiorrhiza* Bunge, clerodane diterpenes were only yielded from *S. plebeian*, and some species were introduced from South America. For the sake of further study on the taxonomic value of diterpenoids in Chinese *Salvia* L. species, we listed the occurrences of the different types of diterpenes in Chinese *Salvia* L. species. Based on these data, the diterpenes from Chinese *Salvia* L. species could be further subdivided into 17 skeletal types (Fig. 1), and the distributions of diterpenes had some regular pattern in the subgenus levels. The abietanes (skeleton 2), 20-norabietanes (skeleton 3), and 19,20-dinorabietanes (skeleton 4) occurred frequently in the species of Subg. *Salvia* L. and Subg. *Sclarea* (Moench) Benth., while they were absent in the species of Subg. *Jungia* (Moench) Brig. and Subg. *Allagospadonopsis* Briq.

The distribution of diterpenes in Chinese *Salvia* L. species might indicate a close relationship between Sects. *Drymosphare* and *Eurysphace* Stib., which may support the circumscription of the Sect. *Drymosphare* in the original sense of Bentham (Sect. *Eurysphace* Stib. was later separated from Sect. *Drymosphare* by Stibal, 1934). It is also of note that Walker *et al* (2004), on the basis of molecular phylogeny using rbcL and trnL-F analyses, suggested that all the members of their independent monophyletic Clade III corresponded to Bentham's Sect. *Drymosphace* Benth. However, the diterpenes with skeleton 3 (tanshinone II_A or cryptotanshinone) were also isolated from some species from the new world (*S. mellifera* Greene, *S. apiana* Jeps., *S. axillaris* Moc. & Sessé ex Benth., and *S. columbariae* Benth.) (Esquivel *et al*, 1997; Esquivel *et al*, 2005; Adams Wall, and Garcia, 2005), which characterized mostly by clerodane diterpenes. Tanshinone II_A or cryptotanshinone, which occurred sporadically among

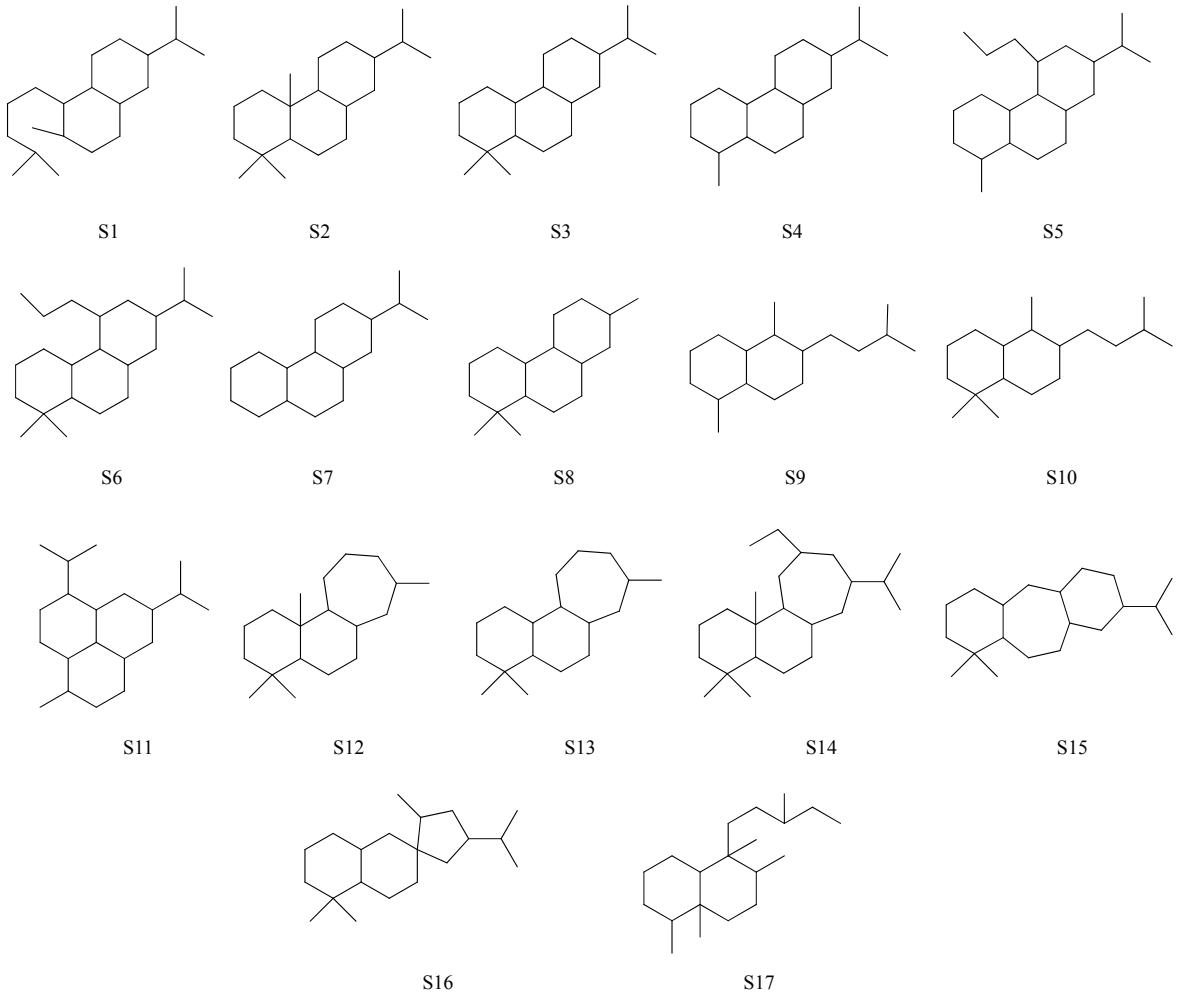

Fig. 1 Seventeen skeletal types of diterpenes from Chinese *Salvia* L. species

the American *Salvia* L. species, had been considered as chemical evidence of a probable evolutionary link between Asian and American species of *Salvia* L. (Esquivel *et al*, 1997; Esquivel *et al*, 2005).

In conclusion, the distribution data of diterpenes in Chinese *Salvia* L. species showed a very good correlation with the phylogenetic results obtained from DNA sequence data. It should be emphasized that the above chemotaxonomic conclusions have been based on the reported isolations. Many species from China and other regions around the world have not been investigated. A more thorough investigation of *Salvia* L. would probably prove to be very useful for the chemosystematic work in the genus.

Caffeic acid derivatives in Chinese *Salvia* L. species

Various caffeic acid derivatives were yielded by the chemical studies on Chinese *Salvia* L. species. Rosmarinic acid and salvianolic acids occurred as the major caffeic acid derivatives (polyphenolic acids) in Chinese *Salvia* L. species. The caffeic acid is the building block of a variety of the plant metabolites from the more simple monomers to multiple condensation products to give rise to a variety of caffeic acid derivatives in Chinese *Salvia* L. species. According to the number of caffeic acid unit in the structures of caffeic acid derivatives, these compounds could be divided into caffeic acid monomers (A), caffeic acid dimmers (B), caffeic acid trimers (C), caffeic acid tetramers (D), and higher caffeic acid oligomers (E) (Lu and Foo, 2002). Such as rosmarinic acid, a caffeic acid dimer (an ester of caffeic acid and 3,4-dihydroxy-phenyllactic acid) is more common and abundant in *Salvia* L. species, and salvianolic acid B, a caffeic acid tetramer, has been reported to be the major phenolic compound responsible for the high biological activities of *S. miltiorrhiza* and the related plants. In addition, some caffeic acid derivatives occur as

potassium, ammonium, or magnesium salts, such as magnesium lithospermate B in *S. miltiorrhiza*, while some caffeic acid derivatives occur as phenolic glycosides, such as salviaflaside (rosmarinic acid 3-glucoside), a more common compound in *Salvia* L. species (Kasimu *et al*, 1998). And the occurrence of caffeic acid derivatives in the Chinese *Salvia* L. species was listed in Table 1.

The data in Table 1 showed that the Chinese *Salvia* L. species were very rich in caffeic acid derivatives, and according to our experiments, most species from Europe and new world produced few caffeic acid derivatives, except for rosmarinic acid (Li *et al*, 2008a).

According to the data (Table1), the chemical profiles showed the diversity in Chinese *Salvia* L. species. The genetic diversity is one of the major reasons account for this result. The recent molecular systematic studies have revealed the significant genetic differences among Chinese *Salvia* L. species (Wang, Li, and Zhang, 2007; Wang and Wang, 2005). However, it should be emphasized that many species from China and other regions have not been investigated. A more thorough investigation on the genus *Salvia* L. species might lead to different conclusions.

Table 1 Diterpenoids and caffeic acid derivatives from Chinese *Salvia* L. species

Species	Diterpenoids (type)	References	Caffeic acid derivatives (type)	References
Subg. *Salvia* Bebth.				
Sect. *Eurysphace* Stib.				
S. bulleyana	cryptotanshinone (S3)	Li, Peng, and Xiao, 2010	caffeic acid (A)	Li *et al*, 2008a
	sihydrotanshinone I (S4)	Li, Peng, and Xiao, 2010	danshensu (A)	Li *et al*, 2008a
	tanshinone I (S4)	Li, Peng, and Xiao, 2010	rosmmarinic acid (B)	Li *et al*, 2008a
	tanshinone II_A (S3)	Li, Peng, and Xiao, 2010	salviaflaside (B)	Kasimu *et al*, 1998
			salvianolic acid B (D)	Kasimu *et al*, 1998
			salvianolic acid K (C)	Kasimu *et al*, 1998
S. campanulata	cryptotanshinone (S3)	Li, Peng, and Xiao, 2010	caffeic acid (A)	Li *et al*, 2008a
	dihydrotanshinone I (S4)	Li, Peng, and Xiao, 2010	danshensu (A)	Li *et al*, 2008a
	tanshinone I (S4)	Li, Peng, and Xiao, 2010	rosmmarinic acid (B)	Li *et al*, 2008a
	tanshinone II_A (S3)	Li, Peng, and Xiao, 2010	salvianolic acid B (D)	Li *et al*, 2008a
S. castanea	cryptotanshinone (S3)	Li, Peng, and Xiao, 2010	caffeic acid (A)	Li *et al*, 2008a
	dihydrotanshinone I (S4)	Li, Peng, and Xiao, 2010	danshensu (A)	Li *et al*, 2008a
	tanshinone I (S4)	Li, Peng, and Xiao, 2010	rosmmarinic acid (B)	Li *et al*, 2008a
	tanshinone II_A (S3)	Li, Peng, and Xiao, 2010	salvianolic acid B (D)	Li *et al*, 2008a
S. digitaloides	16,17-dinorpisferal A (S4)	Xu *et al*, 2010	caffeic acid (A)	Li *et al*, 2008a
	cryptotanshinone (S3)	Li, Peng, and Xiao, 2010	danshensu (A)	Li *et al*, 2008a
	dihydroneotanshinlactone (S4)	Xu *et al*, 2010	rosmmarinic acid (A)	Li *et al*, 2008a
		Li, Peng, and Xiao, 2010	salvianolic acid B (A)	Li *et al*, 2008a
	dihydrotanshinone I (S4)	Li, Peng, and Xiao, 2010		
	tanshinone I (S4)	Li, Peng, and Xiao, 2010		
	tanshinone II_A (S3)			
S. evansiana	cryptotanshinone (S3)	Li, Peng, and Xiao, 2010	caffeic acid (A)	Li *et al*, 2008a
	dihydrotanshinone I (S4)	Li, Peng, and Xiao, 2010	danshensu (A)	Li *et al*, 2008a
	tanshinone I (S4)	Li, Peng, and Xiao, 2010	lithospermic acid (C)	Li *et al*, 2008a
	tanshinone II_A (S3)	Li, Peng, and Xiao, 2010	rosmmarinic acid (B)	Li *et al*, 2008a
			salvianolic acid B (D)	Li *et al*, 2008a
S. flava	cryptotanshinone (S3)	Li, Peng, and Xiao, 2010	caffeic acid (A)	Li *et al*, 2008a
	dihydrotanshinone I (S4)	Li, Peng, and Xiao, 2010	danshensu (A)	Li *et al*, 2008a
	tanshinone I (S4)	Li, Peng, and Xiao, 2010	rosmmarinic acid (B)	Li *et al*, 2008a
	tanshinone II_A (S3)	Li, Peng, and Xiao, 2010	salviaflaside (B)	Zhao *et al*, 1996b
			salviaflaside methyl ester (B)	Zhao *et al*, 1996b
			salvianolic acid A (C)	Ai *et al*, 1994
			salvianolic acid B (D)	Kasimu *et al*, 1998
			salvianolic acid J (C)	Ai *et al*, 1994
			salvianolic acid K (C)	Kasimu *et al*, 1998

(To be continued)

(Continued Table 1)

Species	Diterpenoids (type)	References	Caffeic acid derivatives (type)	References
S. maximowicziana	cryptotanshinone (S3)	Li, Peng, and Xiao, 2010	caffeic acid (A)	Li *et al*, 2008a
	dihydrotanshinone I (S4)	Li, Peng, and Xiao, 2010	danshensu (A)	Li *et al*, 2008a
	tanshinone I (S4)	Li, Peng, and Xiao, 2010	lithospermic acid (C)	Li *et al*, 2008a
	tanshinone II_A (S3)	Li, Peng, and Xiao, 2010	rosmmarinic acid (B)	Li *et al*, 2008a
			salvianolic acid B (D)	Li *et al*, 2008a
S. omeiana	dihydrotanshinone I (S4)	Li, Peng, and Xiao, 2010	caffeic acid (A)	Li *et al*, 2008a
			danshensu (A)	Li *et al*, 2008a
			lithospermic acid (C)	Li *et al*, 2008a
			rosmmarinic acid (B)	Li *et al*, 2008a
			salvianolic acid B (D)	Li *et al*, 2008a
S. pauciflora	cryptotanshinone (S3)	Li, Peng, and Xiao, 2010	caffeic acid (A)	Li *et al*, 2008a
	dihydrotanshinone I (S4)	Li, Peng, and Xiao, 2010	danshensu (A)	Li *et al*, 2008a
	tanshinone I (S4)	Li, Peng, and Xiao, 2010	rosmmarinic acid (A)	Li *et al*, 2008a
	tanshinone II_A (S3)	Li, Peng, and Xiao, 2010	salvianolic acid B (A)	Li *et al*, 2008a
S. prattii	cryptotanshinone (S3)	Li, Peng, and Xiao, 2010	caffeic acid (A)	Li *et al*, 2008a
	dihydrotanshinone I (S4)	Li, Peng, and Xiao, 2010	danshensu (A)	Li *et al*, 2008a
	tanshinone I (S4)	Li, Peng, and Xiao, 2010	lithospermic acid (C)	Li *et al*, 2008a
	tanshinone II_A (S3)	Li, Peng, and Xiao, 2010	rosmmarinic acid (B)	Li *et al*, 2008a
			salvianolic acid B (D)	Li *et al*, 2008a
S. przewalskii	12-methoxy-carnosic acid (S2)	Xu *et al*, 2006	9″-monomethyl lithospermate B (D)	Wu, Ouyang, and Yang, 1999a
	1,2-didehydrotanshinone (S4)	Xu *et al*, 2005	9‴-monomethyl lithospermate B (D)	Wu, Ouyang, and Yang, 1999a
	8,11,13-icetantriene-10,11,12-triol (S15)	Xu *et al*, 2005	caffeic acid (A)	Wu, Ouyang, and Yang, 1999a
	barbatusol (S15)	Xu *et al*, 2005	danshensu (A)	Wu, Ouyang, and Yang, 1999a
	carnosol (S2)	Xu *et al*, 2005	dimethyl lithospermate B (D)	Wu, Ouyang, and Yang, 1999a
	cryptotanshinone (S3)	Xu *et al*, 2005	lithospermic acid (C)	Wu, Ouyang, and Yang, 1999a
	danshenspiroketallactone (S9)	Wu, Zhao, and Qin, 2002	przewalskinic acid A (C)	Lu *et al*,1991
	danshenxinkun B (S4)	Wu, Zhao, and Qin, 2002	rosmarinic acid (B)	Wu, Ouyang, and Yang, 1999a
	danshenxinkun C (S4)	Wu, Zhao, and Qin, 2002	salviaflaside (B)	Kasimu *et al*, 1998
	dihydrotanshinone I (S4)	Li, Peng, and Xiao, 2010	salvianolic acid B (D)	Wu, Ouyang, and Yang, 1999a
	epi-danshenspiroketallactone (S9)	Xu *et al*, 2005	salvianolic acid K (C)	Kasimu *et al*, 1998
	ganxintriol A (S4)	Yang *et al*, 2011		
	ganxintriol B (S4)	Yang *et al*, 2011		
	pisiferanol (S15)	Xu *et al*, 2005		
	pisiferin (S15)	Xu *et al*, 2005		
	przewaquinone A (S3)	Wu, Zhao, and Qin, 2002		
	przewaquinone B (S4)	Wu, Zhao, and Qin, 2002		
	przewaquinone C (S4)	Wu, Zhao, and Qin, 2002		
	przewaquinone D (S4)	Wu, Zhao, and Qin, 2002		
	przewaquinone F (S4)	Wu, Zhao, and Qin, 2002		
	przewaslskin (S2)	Xu *et al*, 2005		
	przewalskin A (S14)	Xu *et al*, 2006		
	przewalskin B (S16)	Xu, Hou, and Zheng, 2007		
	przewalskin C (S15)	Xu *et al*, 2005		
	przewalskin D (S15)	Xu *et al*, 2005		
	rosmadial (S2)	Xu *et al*, 2005		
	salvicanol (S15)	Xu *et al*, 2005		
	sugiol (S2)	Xu *et al*, 2005		
	tanshindiol A (S4)	Wu, Zhao, and Qin, 2002		
	tanshinone I (S4)	Xu *et al*, 2005		
	tanshinone II_A (S3)	Xu *et al*, 2005		

(To be continued)

(Continued Table 1)

Species	Diterpenoids (type)	References	Caffeic acid derivatives (type)	References
S. roborowskii	cryptotanshinone (S3)	Li, Peng, and Xiao, 2010	caffeic acid (A)	Li *et al*, 2008a
	dihydrotanshinone I (S4)	Li, Peng, and Xiao, 2010	danshensu (A)	Li *et al*, 2008a
	tanshinone I (S4)	Li, Peng, and Xiao, 2010	rosmmarinic acid (B)	Li *et al*, 2008a
	tanshinone II_A (S3)	Li, Peng, and Xiao, 2010	salvianolic acid B (D)	Li *et al*, 2008a
S. sonchifolia			caffeic acid (A)	Wu, Ouyang, and Yang, 1999b
			danshensu (A)	Wu, Ouyang, and Yang, 1999b
			lithospermic acid (C)	Wu, Ouyang, and Yang, 1999b
			rosmarinic acid (B)	Wu, Ouyang, and Yang, 1999b
			methyl rosmarinate (B)	Wu, Ouyang, and Yang, 1999b
			salvianolic acid B (D)	Wu, Ouyang, and Yang, 1999b
S. umbratica	cryptotanshinone (S3)	Li, Peng, and Xiao, 2010	caffeic acid (A)	Li *et al*, 2008a
	dihydrotanshinone I (S4)	Li, Peng, and Xiao, 2010	danshensu (A)	Li *et al*, 2008a
	tanshinone I (S4)	Li, Peng, and Xiao, 2010	rosmmarinic acid (B)	Li *et al*, 2008a
	tanshinone II_A (S3)	Li, Peng, and Xiao, 2010	salvianolic acid B (D)	Li *et al*, 2008a
Sect. *Eusphace* Benth.				
S. officinalis	cryptotanshinone (S3)	Li, Peng, and Xiao, 2010	caffeic acid (A)	Li *et al*, 2008a
	dihydrotanshinone I (S4)	Li, Peng, and Xiao, 2010	danshensu (A)	Li *et al*, 2008a
	tanshinone I (S4)	Li, Peng, and Xiao, 2010	methyl salvianolate I (C)	Lu and Foo, 1999
	tanshinone II_A (S3)	Li, Peng, and Xiao, 2010	rosmarinic acid (B)	Lu and Foo, 1999
			sagecoumarin (C)	Lu and Foo, 1999
			salvianolic acid I (C)	Lu and Foo, 1999
			salvianolic acid K (C)	Lu and Foo, 1999
			salvianolic acid L (D)	Lu and Foo, 2001
			sagerinic acid (D)	Lu and Foo, 1999
Subg. *Sclarea* Benth.				
Sect. *Notiosphace* Benth.				
S. plebeia	epoxysalviacoccin (S17)	Garcia-Alvarez *et al*, 1986	caffeic acid (A)	Li *et al*, 2008a
			danshensu (A)	Li *et al*, 2008a
	salviacoccon (S17)	Garcia-Alvarez *et al*, 1986	rosmmarinic acid (B)	Li *et al*, 2008a
			salvianolic acid B (D)	Li *et al*, 2008a
Sect. *Drymosphace* Benth.				
S. bowleyana	7-carbonyl-12-hydroxy-dehydroabietane (S2)	Shen, Wang, and Wang, 2006	caffeic acid (A)	Li, Li, and Song, 1994
			danshensu (A)	Li, Li, and Song, 1994
	cryptotanshinone (S3)	Li, Peng, and Xiao, 2010	lithospermic acid (C)	Li, Li, and Song, 1994
	dihydrotanshinone I (S4)	Li, Peng, and Xiao, 2010	methyl rosmarinate (B)	Li, Li, and Song, 1994
	dihydroisotanshinone (S2)	Shen *et al*, 2006	rosmmarinic acid (B)	Li, Li, and Song, 1994
	tanshinone I (S4)	Li, Peng, and Xiao, 2010	salviaflaside (B)	Kasimu *et al*, 1998
	tanshinone II_A (S3)	Li, Peng, and Xiao, 2010	salvianolic acid B (D)	Li, Li, and Song, 1994
	tanshinlactone (S4)	Shen, Wang, and Wang, 2006	salvianolic acid C (C)	Li, Li, and Song, 1994
			salvianolic acid K (C)	Kasimu *et al*,1998
S. cavaleriei			rosmarinic acid (B)	Wang *et al*, 2011

(To be continued)

(Continued Table 1)

Species	Diterpenoids (type)	Reference	Caffeic acid derivatives (type)	Reference
S. cavaleriei var. *simplicifolia*	dihydrotanshinone I (S4)	Li, Peng, and Xiao, 2010	caffeic acid (A)	Li *et al*, 2008a
	tanshinone I (S4)	Li, Peng, and Xiao, 2010	danshensu (A)	Li *et al*, 2008a
	cryptotanshinone (S3)	Li, Peng, and Xiao, 2010	isosalvianolic acid C (C)	Zhang and Li, 1994
	tanshinone II_A (S3)	Li, Peng, and Xiao, 2010	lithospermic acid (C)	Zhang and Li, 1994
			rosmmarinic acid (B)	Zhang and Li, 1994
			salvianolic acid A (C)	Zhang and Li, 1994
			salvianolic acid B (D)	Zhang and Li, 1994
			salvianolic acid C (C)	Zhang and Li, 1994
			salvianolic acid H (C)	Zhang and Li, 1994
			salvianolic acid I (C)	Zhang and Li, 1994
S. dabieshanensis	dihydrotanshinone I (S4)	Li, Peng, and Xiao, 2010	caffeic acid (A)	Li *et al*, 2008a
	tanshinone I (S4)	Li, Peng, and Xiao, 2010	danshensu (A)	Li *et al*, 2008a
	cryptotanshinone (S3)	Li, Peng, and Xiao, 2010	lithospermic acid (C)	Li *et al*, 2008a
	tanshinone II_A (S3)	Li, Peng, and Xiao, 2010	rosmmarinic acid (B)	Li *et al*, 2008a
			salvianolic acid B (D)	Li *et al*, 2008a
S. meiliensis	dihydrotanshinone I (S4)	Li, Peng, and Xiao, 2010	caffeic acid (A)	Li *et al*, 2008a
	tanshinone I (S4)	Li, Peng, and Xiao, 2010	danshensu (A)	Li *et al*, 2008a
	cryptotanshinone (S3)	Li, Peng, and Xiao, 2010	lithospermic acid (C)	Li *et al*, 2008a
	tanshinone II_A (S3)	Li, Peng, and Xiao, 2010	rosmmarinic acid (B)	Li *et al*, 2008a
			salviaflaside (B)	Kasimu *et al*, 1998
			salvianolic acid B (D)	Kasimu *et al*, 1998
			salvianolic acid K (C)	Kasimu *et al*, 1998
S. prionitis	1,2-didehydromiltirone (S4)	Lin *et al*, 1988a	caffeic acid (A)	Li *et al*, 2008a
	3-ketosapriparaquinone (S1)	Lin *et al*, 1988b	danshensu (A)	Li *et al*, 2000
	3-hydroxysalvilenone (S11)	Lin *et al*, 1988b	lithospermic acid (C)	Li *et al*, 2008a
	4-hydroxysapriparaquinone (S1)	Lin *et al*, 1988b Lin *et al*, 1989	rosmmarinic acid (B) methyl rosmarinate (B)	Li *et al*, 2008a Li *et al*, 2008a
	4-hydroxysaprorthoquinone (S1)	Chen *et al*, 2002 Li *et al*, 2000	salvianolic acid A (C)	Zhao, Liang, and Li, 1996a
	7,8-secoparaferruginone (S2)	Lin *et al*, 1988b		Zhao, Liang, and Li,
	8,11,13-dehydroabietane (S2)	Li, Peng, and Xiao, 2010	salvianolic acid B (D)	1996b
	arucadiol (S3)	Wu, Zhao, and Qin, 2002		Zhao, Liang, and Li,
	cryptotanshinone (S3)	Wu, Zhao, and Qin, 2002	salvianolic acid C (C)	1996b
	danshenxinkun B (S4)	Lin *et al*, 1988a		
	danshenxinkun C (S4)	Li, Peng, and Xiao, 2010		
	dehydromiltirone (S3)	Zhang and Huang, 1995		
	dihydrotanshinone I (S4)	Lin *et al*, 1988b		
	dihydroisotanshinone I (S4)	Li, Zhang, and Chen, 2001		
	ferruginol (S2)	Lin *et al*, 1988a		
	hongencaotone (S2)	Li *et al*, 2000		
	miltirone (S3)	Zhang and Huang, 1995		
	prineoparaquinone (S1)	Lin *et al*, 1988b		
	prioketolactone (S4)	Lin, Blasko, and		
	royleanone (S2)	Cordell, 1989		
	salvinolone (S3)	Lin *et al*, 1988a		
	salvilenone (S11)	Lin *et al*, 1990		
	sapriparaquinone (S1)	Chen *et al*, 2002		
	saprirearine (S11)	Lin *et al*, 1990		
	saprothoquinone (S1)	Chen *et al*, 2002		
	sclareapinone (S1)	Lin *et al*, 1988b		
	sugiol (S2)	Li *et al*, 2000		
	taxodione (S2)	Li, Peng, and Xiao, 2010		
	tanshinone I (S4)	Li, Peng, and Xiao, 2010		
	tanshinone II_A (S3)			

(To be continued)

(Continued Table 1)

Species	Diterpenoids (type)	References	Caffeic acid derivatives (type)	References
S. miltiorrhiza	1,2,5,6-tetrahydro-tanshinone I (S4)	Chang *et al*, 1990a Yang *et al*, 2006	2-(3-methoxy-4-hydro-xyphenyl)-5-(3-hydro-xypropyl)-7-methoxy benzofuran-3-carbald ehyde (B)	Yang *et al*, 1991
	1,2-didehydrotanshinone II (S3)	Chang *et al*, 1990a Luo, Wu, and Yong, 1985		
	1,2-dihydro-1,6-dimethylfuro [3,2-c]-naphtha[2,1-e] oxepine-10,12-dione (S3)	Chang *et al*, 1990a	9″-methyl lithospermate (C)	Kohda *et al*, 1989
	3-hydroxytanshinone II_A (S3)	Chang *et al*, 1990a Lin *et al*, 2003	ammonium potassium salvianolic acid B (D)	Tanaka *et al*, 1989 Yang and Zhang, 1981
	4-methylenemiltirone (S4)	Chang *et al*, 1990a		
	6,7,8,9-tetrahydro-1,6,6-trimethylfuro[3,2-c]naphtha-[2,1-e]oxepine-10,12-dione (S3)	Ginda *et al*, 1991 Asari *et al*, 2005 Wu, Zhao, and Qin, 2002	caffeic acid (A) danshensu (A) dimethyl lithospermate (C)	Yang and Zhang, 1981 Kohda *et al*, 1989 Ai and Li, 1992
	7β-hydroxy-8,13-abietadien-11,12-dione (S3)	Luo, Wu, and Yong, 1985	ethyl Salvianolic acid B (D)	Kohda *et al*, 1989
	acetyl Danshenxinkun A (S4)	Luo, Wu, and Yong, 1985	lithospermic acid (C)	Guo *et al*, 2011
	arucadiol (S3)	Luo *et al*, 1988	lithospermic acid B (D)	Tanaka *et al*, 1989
	abietatriene (S2)	Wu, Zhao, and Qin, 2002	magnesium salvianolic acid B (D)	Ai and Li, 1988
	cryptoacetalide (S10)	Wu, Zhao, and Qin, 2002	rosmarinic acid (B)	Kohda *et al*, 1989
	cryptotanshinone (S3)	CCMM, 1999	methyl rosmarinate (B)	Kasimu *et al*, 1998
	danshenol A (S5)	Asari *et al*, 2005	salviaflaside (B)	Li, Tan, and Chen, 1984
	danshenol B (S6)	Luo *et al*, 1988	salvianolic acid A (C)	Ai and Li, 1988
	danshenspiroketallactone (S3)	Chang *et al*, 1990a	salvianolic acid B (D)	Ai and Li, 1988
	danshenxinkun A (S4)	Luo, Wu, and Yong, 1985	salvianolic acid C (C)	Ai and Li, 1992
	danshenxinkun C (S4)	CCMM, 1999	salvianolic acid D (B)	Ai and Li, 1992
	dihydrotanshinone I (S4)	Han *et al*, 2005	salvianolic acid E (D)	Ai and Li, 1996
	epicryptoacetalide (S10)	Lee *et al*, 1987	salvianolic acid F (C)	Ai and Li, 1991
	epidanshenspiroketallactone (S9)	CCMM, 1999	salvianolic acid G (C)	Kasimu *et al*, 1998
	formytanshinone I (S4)	Chang *et al*, 1990a	salvianolic acid K (C)	
	hydroxytanshinone (S3)	Wu, Zhao, and Qin, 2002		
	isocryptotanshinone (S3)			
	isotanshinone I (S4)			
	isotanshinone II_B (S3)	Wu, Zhao, and Qin, 2002		
	ketoisocryptotanshinone (S3)			
	methylenedihydro-tanshinquinone (S7)	CCMM, 1999		
	miltionone I (S3)	CCMM, 1999		
	miltionone II (S3)	Lee *et al*, 1987		
	miltipolone (S12)	Lin and Chang, 2000		
	miltirone (S3)	Ginda *et al*, 1991		
	neocryptotanshinone (S3)	Lin, Ding, and Chang, 2001		
	neocryptotanshinone II (S8)	Lin, Ding, and Chang, 2001		
	nortanshinone (S7)	Lin *et al*, 2001		
	oleoyl danshenxinkun A (S4)	Li *et al*, 2008b		
	oleoyl neocryptotanshinone (S3)	Chang *et al*, 1990a		
	przewaquinone A (S3)	CCMM, 1999		
	przewalskin (S2)	Ginda *et al*, 1991		
	salvinone (S3)	Ginda *et al*, 1991		

(To be continued)

(Continued Table 1)

Species	Diterpenoids (type)	References	Caffeic acid derivatives (type)	References
S. miltiorrhiza	salviol (S2)	Li *et al*, 2008b		
	salviolone (S13)	Li, Yang, and Ma, 1991		
	secodialdialdehyde (S2)	Luo, Wu, and Yong, 1985		
	sugiol (S2)	Luo, Wu, and Yong, 1985		
	tanshinaldehyde (S3)	Wu, Zhao, and Qin, 2002		
	tanshindiol A (S4)	Lin, Chang, and Wu, 1996		
	tanshindiol B (S4)	Wu *et al*, 2007		
	tanshindiol C (S4)	CCMM, 1999		
	tanshinketolactone (S3)	CCMM, 1999		
	tanshinlacton (S4)	CCMM, 1999		
	tanshinone I (S4)	Li, Yang, and Ma, 1991		
	tanshinone II_A (S3)	Qiao *et al*, 2009		
	tanshinone II_B (S3)	Qiao *et al*, 2009		
	tanshinone VI (S4)	Qiao *et al*, 2009		
	trijuganone A (S4)			
	trijuganone B (S4)			
	trijuganone C (S3)			
S. paramiltiorrhiza	cryptotanshinone (S3)	Li, Peng, and Xiao, 2010	caffeic acid (A)	Li *et al*, 2008a
	dihydrotanshinone I (S4)	Li, Peng, and Xiao, 2010	danshensu (A)	Li *et al*, 2008a
	tanshinone I (S4)	Li, Peng, and Xiao, 2010	lithospermic acid (C)	Li *et al*, 2008a
	tanshinone II_A (S3)	Li, Peng, and Xiao, 2010	rosmmarinic acid (B)	Li *et al*, 2008a
			salviaflaside (B)	Kasimu *et al*, 1998
			salvianolic acid B (D)	Kasimu *et al*, 1998
			salvianolic acid K (C)	Kasimu *et al*, 1998
S. plectranthoides	cryptotanshinone (S3)	Li, Peng, and Xiao, 2010	caffeic acid (A)	Li *et al*, 2008a
	dihydrotanshinone I (S4)	Li, Peng, and Xiao, 2010	danshensu (A)	Li *et al*, 2008a
	tanshinone I (S4)	Li, Peng, and Xiao, 2010	lithospermic acid (C)	Li *et al*, 2008a
	tanshinone II_A (S3)	Li, Peng, and Xiao, 2010	rosmmarinic acid (B)	Li *et al*, 2008a
			salvianolic acid B (D)	Li *et al*, 2008a
S. yunnanensis	1,2-dihydrotanshinone (S4)	Xu *et al*, 2006	caffeic acid (A)	Li *et al*, 2008a
	5,6-dehydrosugiol (S2)	Xu *et al*, 2006	danshensu (A)	Li *et al*, 2008a
	cryptotanshinone (S3)	Xu *et al*, 2006	ethyl salvianolate A	Zhang *et al*, 2008
	dihydrotanshinone I (S4)	Xu *et al*, 2006	(C)	Zhang *et al*, 2008
	danshenol A (S5)	Xu *et al*, 2006	lithospermic acid (C)	Zhang *et al*, 2008
	danshenol C (S6)	Xu *et al*, 2006	methyl salvianolate A	Tanaka *et al*, 1996
	przewaslskin (S2)	Xu *et al*, 2006	(C)	Tanaka *et al*, 1996
	tanshinone I (S4)	Xu *et al*, 2006	rosmarinic acid (B)	Tanaka *et al*, 1996
	tanshinone II_A (S3)	Xu *et al*, 2006	salvianolic acid B (D)	Tanaka *et al*, 1996
	tanshinlacton (S4)	Xu *et al*, 2006	yunnaneic acid A (D)	Tanaka *et al*, 1996
	yunnanin A (S2)	Xu *et al*, 2006	yunnaneic acid B (D)	Tanaka *et al*, 1996
			yunnaneic acid C (B)	Tanaka *et al*, 1997
			yunnaneic acid D (B)	Tanaka *et al*, 1997
			yunnaneic acid E (B)	Tanaka *et al*, 1997
			yunnaneic acid F (B)	Tanaka *et al*, 1997
			yunnaneic acid G (D)	
			yunnaneic acid H (D)	
S. sinica	cryptotanshinone (S3)	Li, Peng, and Xiao, 2010	saffeic acid (A)	Li *et al*, 2008a
	dihydrotanshinone I (S4)	Li, Peng, and Xiao, 2010	danshensu (A)	Li *et al*, 2008a
	tanshinone I (S4)	Li, Peng, and Xiao, 2010	lithospermic acid (C)	Li *et al*, 2008a
	tanshinone II_A (S3)	Li, Peng, and Xiao, 2010	rosmarinic acid (B)	Li *et al*, 2008a
			salviaflaside (B)	Kasimu *et al*, 1998
			salvianolic acid B (D)	Kasimu *et al*, 1998
			salvianolic acid K (C)	Kasimu *et al*, 1998

(To be continued)

(Continued Table 1)

Species	Diterpenoids (type)	References	Caffeic acid derivatives (type)	References
S. trijuga	cryptotanshinone (S3)	Li, Peng, and Xiao, 2010	caffeic acid (A)	Li *et al*, 2008a
	dihydrotanshinone I (S4)	Li, Peng, and Xiao, 2010	danshensu (A)	Li *et al*, 2008a
	ferruginol (S2)	Lu *et al*, 1991	lithospermic acid (C)	Li *et al*, 2008a
	sugiol (S2)	Lu *et al*, 1991	rosmmarinic acid (B)	Li *et al*, 2008a
	tanshinone I (S3)	Li, Peng, and Xiao, 2010	salviaflaside (B)	Kasimu *et al*, 1998
	tanshinone II_A (S3)	Li, Peng, and Xiao, 2010	salvianolic acid B (D)	Kasimu *et al*, 1998
	tanshinone acid mester (S3)	Lu, Lou, and Niwa, 1990	salvianolic acid K (C)	Kasimu *et al*, 1998
	trijuganone A (S4)	Lu, Lou, and Niwa, 1990		
	trijuganone B (S4)	Lu, Lou, and Niwa, 1990		
	trijuganone C (S3)	Lu *et al*, 1991		
S. vasta	cryptotanshinone (S3)	Li, Peng, and Xiao, 2010	saffeic acid (A)	Li *et al*, 2008a
	dihydrotanshinone I (S4)	Li, Peng, and Xiao, 2010	danshensu (A)	Li *et al*, 2008a
	tanshinone I (S4)	Li, Peng, and Xiao, 2010	lithospermic acid (C)	Li *et al*, 2008a
	tanshinone II_A (S3)	Li, Peng, and Xiao, 2010	rosmmarinic acid (B)	Li *et al*, 2008a
			salvianolic acid B (D)	Li *et al*, 2008a
Sect. *Plethiosphace* Benth.				
S. deserta	6,7-dehydroroyleanon (S2)	Tezuka *et al*, 1998	caffeic acid (A)	Li *et al*, 2008a
	7-*O*-acethylhorminone (S2)	Tezuka *et al*, 1998	danshensu (A)	Li *et al*, 2008a
	7-*O*-methylhorminone (S2)	Tezuka *et al*, 1998	rosmmarinic acid (B)	Li *et al*, 2008a
	ferruginol (S2)	Tezuka *et al*, 1998	lithospermic acid (C)	Li *et al*, 2008a
	horminon (S2)	Tezuka *et al*, 1998	salviaflaside (B)	Kasimu *et al*, 1998
	royleanon (S2)	Tezuka *et al*, 1998	salvianolic acid B (D)	Kasimu *et al*, 1998
	taxochinon (S2)	Chang *et al*, 2001	salvianolic acid K (C)	Kasimu *et al*, 1998
	taxodione (S2)	Tezuka *et al*, 1998		
Subg. *Jungia* (Moench) Briq.				
S. splendens	olearin (S17)	Fontana, Savona, and Rodriguez, 2006	caffeic acid (A)	Li *et al*, 2008a
			rosmmarinic acid (B)	Li *et al*, 2008a
	salviaclerodan A (S17)	Shaheen, Hussain, and Ammar, 2011		
	salviarin (S17)	Fontana *et al*, 2008		
	salvisplendins A (S17)	Fontana, Savona, and Rodriguez, 2006		
	salvisplendins B (S17)	Fontana, Savona, and Rodriguez, 2006		
	salvisplendins C (S17)	Fontana, Savona, and Rodriguez, 2006		
	salvisplendins D (S17)	Fontana, Savona, and Rodriguez, 2006		
	splendidin (S17)	Fontana *et al*, 2008		
	splendidins A (S17)	Pan *et al*, 2011		
	splendidins B (S17)	Pan *et al*, 2011		
	splendidins C (S17)	Pan *et al*, 2011		
	splenolides A (S17)	Fontana *et al*, 2008		
	splenolides B (S17)	Fontana *et al*, 2008		
S. coccinea	salviacoccon (S17)	Savona *et al*, 1982		
Subg. *Allagospadonopsis* Briq.				
S. *baimaensis*			caffeic acid (A)	Li *et al*, 2008a
			danshensu (A)	Li *et al*, 2008a
			rosmmarinic acid (B)	Li *et al*, 2008a
			salvianolic acid B (D)	Li *et al*, 2008a

(To be continued)

(Continued Table 1)

Species	Diterpenoids (type)	References	Caffeic acid derivatives (type)	References
S. chienii			rosmmarinic acid (B)	Li *et al*, 2008a
S. chinensis			caffeic acid (A)	Li *et al*, 2008a
			danshensu (A)	Li *et al*, 2008a
			isosalvianolic acid C (C)	Qian and Li, 1992
				Qian and Li, 1992
			lithospermic acid (B)	Li *et al*, 2008a
			rosmmarinic acid (B)	Li *et al*, 2008a
			salvianolic acid B (D)	Qian and Li, 1992
			salvianolic acid D (C)	Liu, Su, and Xiang, 2010
			syringaresinol (B)	
S. japonica			caffeic acid (A)	Li *et al*, 2008a
			danshensu (A)	Li *et al*, 2008a
			lithospermic acid (C)	Li *et al*, 2008a
			rosmmarinic acid (B)	Li *et al*, 2008a
S. kiangsiensis			caffeic acid (A)	Li *et al*, 2008a
			danshensu (A)	Li *et al*, 2008a
			lithospermic acid (C)	Li *et al*, 2008a
			rosmmarinic acid (B)	Li *et al*, 2008a
			salvianolic acid B (D)	Li *et al*, 2008a
S. scapiformis			caffeic acid (A)	Li *et al*, 2008a
			danshensu (A)	Li *et al*, 2008a
			rosmmarinic acid (A)	Li *et al*, 2008a

A: caffeic acid monomers B: caffeic acid dimmers C: caffeic acid trimers D: caffeic acid tetramer E: higher caffeic acid oligomers

Pharmacology of Chinese *Salvia* L. species

The previous biological studies revealed that various bioactivities exhibited in both caffeic acid derivatives and diterpenoids in *Salvia* L. species mainly contributed to the pharmacology of the *Salvia* L. species (Lu and Foo, 2002). The caffeic acid derivatives in *Salvia* L. species have the significant bioactivities of anti-oxidation, anti-blood coagulation, cell protection, as well as other activities including anti-ischemia-reperfusion, antihypertension, antifibrosis, antivirus, and antitumor (Lu and Foo, 2002; Jiang *et al*, 2005). The diterpenoids exhibit a variety of biological activities including anti-oxidation, antiplatelet aggregation, increasing coronary flow, modulating mutagenic activity, and protecting the myocardium for ischaemia, antibacterial, antitumor promoting, and significant cytotoxic activity against human cancer cell lines (Wang, Morris-Natschke, and Lee, 2007; Lee, Chiu, and Yeung, 2008). According to the studies in the recent years, we listed the bioactivities of caffeic acid derivatives and diterpenoids isolated from Chinese *Salvia* L. species (Table 2).

Traditional medicinal uses

The name *Salvia* L. comes from the Latin word "salvare", which means "to heal". *Salvia* L. species have been used for more than sixty different ailments ranging from aches to epilepsy, and mainly to treat colds, bronchitis, tuberculosis, hemorrhage, and menstrual disorders (Topçu *et al*, 2006). In China, Many *Salvia* L. species have been used as medicinal plants for a long time. To investigate the resources and utilization of medicinal plants in *Salvia* L. from China, during the period of 2006—2008, we conducted six field surveys in 13 provinces (Beijing, Hebei, Henan, Shandong, Anhui, Jiangsu, Zhejiang, Hubei, Shanxi, Gansu, Sichuan, Guangxi, and Yunnan). In concert with the local herbalists, we collected the plant samples and recorded the detailed information of these medicinal plants including the local name, collecting location, growing environment, distribution, and therapeutic effects as well. The survey showed that *Salvia* L. plants in different subgenus have been used as folk medicines for different multiple therapeutic remedies in China. We listed the therapeutic effects of the species in different groups in Table 3.

Forty-three *Salvia* L. plants have been used as folk medicines for multiple therapeutic remedies in different regions of China. And the plant parts used were roots and rhizomes (27), herbs (15), fruits and seeds (3), flowers

Table 2 Pharmacological activities of caffeic acid derivatives and diterpenoids from Chinese *Salvia* L. species

Biological activity of caffeic acid derivatives	References
adenylate cyclase inhibition	Lin, Blasko, and Cordell, 1989
angiogenic activity	Lay *et al*, 2003
anticoagulant and antithrombotic effects	Jiang *et al*, 2005; Zou, Xu, and Tian, 1993
anti-HIV activity	Abd-Elazem *et al*, 2002; Hooker, Lott, and Harrich, 2001; Mazumder *et al*, 1997
anti-inflammatory activity	Peng and Chen, 2003
antihypertension	Kamata, Noguchi, and Nagai, 1994; Kang *et al*, 2003; Nagai *et al*, 1996
anti-oxidative activity	Chen, Yokozawa, and Chung, 1999; Liu *et al*, 1992 Huang and Zhang, 1992; Lin *et al*, 2002 Honda, Koezuka, and Tabata, 1998; Zhen, Li, and Su, 1995
anti-tumor activity	Honda, Koezuka, and Tabata, 1998; Zhen, Li, and Su, 1995
inhibition of 5-lipoxygenase	Tomita *et al*, 1990
inhibition of amyloid beta-protein Fibril formation	Tang and Zhang, 2001
inhibition of the gastric H^+, K^+-ATPase	Murakami *et al*, 1990
inhibitory activity against liver fibrosis and hepatoprotection	Zhao *et al*, 2004; Wang *et al*, 2002
kidney function regulation	Yokazawa *et al*, 1999
protection against cerebral and heart ischemia-reperfusion	Weng *et al*, 1992; Chen, Du, and Zhang, 2000
protection against neurotoxicity	Kim *et al*, 2004
Biological activity of diterpenoids	**References**
anti-allergic activity	Choi and Kim, 2004; Ryu, Oak, and Kim, 1999
anticholinesterase activity	Ren *et al*, 2004
anti-inflammatory and anti-immunological effects	Jang *et al*, 2003; Kang *et al*, 2000; Kim *et al*, 2002
antimicrobial activity	Honda, Koezuka, and Tabata, 1988; Luo *et al*, 1983
anti-oxidative activity	Niu *et al*, 2000; Cao *et al*, 1996; Weng and Gordon, 1992
antiplatelet aggregation activity	Yu *et al*, 1994; Chang *et al*, 1990b
antitumor activity	Yuan, Wang, and Wei, 2003; Liang *et al*, 2000; Sung *et al*, 1999
effects on heart diseases	Takahashi *et al*, 2002; Maki *et al*, 2002; Yagi and Takeo, 2003
inhibition of binding of [^{3}H] flunitrazepam	Wu, Zhao, and Qin, 2002; Chang *et al*, 1991
inhibition of hepatic fibrosis and hepatoprotection	Liu, Wang, and Liu, 2003; Kim *et al*, 2003
potential effects on ameliorating bone resorption diseases	Kim *et al*, 2004
potential nueroprotective effects	Lam *et al*, 2003
selective inhibition of cytochrome p4501A2	Ueng *et al*, 2003; Ueng *et al*, 2004
sex hormone-like activity	Gao, Wang, and Tang, 1980

(2), leaves (1), and mixture of roots and leaves (1) (Li *et al*, 2011). Decoction or infusion is almost the common method for the preparation of these medicinal plants to be used internally. Ethnopharmacologically, the medicinal plants in Sects. *Drymosphace* Benth. and *Eurysphace* Stib. have been mainly used as medicines for promoting blood circulation so as to regulate menstruation, activating meridian and collateral, and the medicinal plants in Subg. *Allagospadonopsis* Briq. have been mainly used as medicines for clearing heat from blood, which indicates that these plants may be a source for new medicines possessing antibacterial, antiviral, and antitumor activities.

Twenty-three plants in the genus have been used as "*Danshen*". And we found that all the investigated *Danshen* species belonged to Sect. *Euryshace* Stib. or Sect. *Drymophace* Benth. (Li *et al*, 2011). The distribution characteristics of *Danshen* species in the two groups were different. Danshen species from Sect. *Euryshace* were mainly distributed in the plateau area of 2500—4000 m above sea level in southwestern China, and *S. przewalskii* in this group was widely used and has been commercially available in the local herbal markets in southwestern and northwestern China. The geographical distribution and resources of other *Danshen* species in Sect. *Euryshace* were limited. And their folk applications were limited to remote mountain areas and minority region of southwestern China. Most *Danshen* species in Sect. *Drymophace* were distributed in the plain and hills of North China, East China, and

Table 3 Therapeutic effects of Chinese *Salvia* L. species

Taxon (representative species)	Growing environment and distribution	Therapeutic effects
Group 1		
Subg. *Salvia* Benth. Sect. *Eurysphace* Stib. (*S. przewalskii*)	Distributed in the region (forest margins, hillsides, streamsides, forestmargins, and thickets) of 2500—4000 m above sea level in southwestern China, with only a few species extending to northwestern and north China.	Functions: Promoting blood circulation to remove blood stasis, regulating menstruation to relieve pain, cooling the blood to relieve carbuncle, clearing away heat from the heart and tranquilize, and dispelling wind and dredging meridians. Removing pathogenic heat from blood, promoting blood circulation to regulate menstruation, relaxing muscles and tendons, activating meridians, enriching blood to anchor the mind, and relief of pain. Indications: For treatment of irregular menstruation, hepatitis, hematemesis, hemafacia, lower back pain due to deficiency in kidney, pain resulting from wind-dampness, and dizziness.
Subg. *Sclarea* (Moench) Benth. Sect. *Drymosphace* Benth. (*S. miltiorrhiza*)	Distributed in the region (hillsides, forests, streamsides, and valleys) of 200—1200 m above sea level in north China, east China, and central China, with only a few species extending to southwestern and northwestern China, with some species growing in southwestern and northwestern China.	Functions: Promoting blood circulation and removing blood stasis, clearing heat from the blood, resolving swelling, tranquilizing the mind, regulating menstruation to relieve pain, cooling the blood to relieve carbuncle, and clearing heat and toxic materials. Indications: For treatment of irregular menstruation, dysmenorrheal, amenorrhea, postpartum tormina, arthralgia-syndrome due to wind-dampness, heat invasion of nutrient ying and blood divisions in epidemic febrile disease, vexation and delirium caused by pyrexia, restlessness and the mind disturbed, pyogenic toxin, enlargement of liver and spleen.
Group 2		
Subg. *Jungia* (Moench) Briq. (*S. splendens*)	Introduced from South America and cultured in many regions of China.	Function: Clearing heat and toxic materials. Indications: For treatment of metroirrhagia, with an abdominal pain and high fever.
Subg. *Salvia* Benth. Sect. *Eusphace* Benth. (*S.officinalis*)	Introduced from Europe and cultured in many region of China.	Functions: Clearing heat and toxic materials. Indications: For treatment of swollen sore throat, hypertension and dyspepsia.
Group 3		
Subg. *Allagospadonopsis* Briq. (*S. chinensis*)	Distributed in the low mountain-hill region under 1000 m above sea level in east and south China.	Functions: For treatment of clearing heat and toxic materials, removing heat from blood, promoting blood circulation to remove obstruction from meridians, and subsidence of swelling and relief of pain. Indications: For treatment of irregular menstruation, arthralgia, swollen furuncle and hepatitis, physical wounds and rheumatism ache.
Subg. *Sclarea* (Moench) Benth. Sect. *Plethiosphace* Benth. (*S. deserta*)	Distributed in the regions (forest margins, hillsides, and grasslands) of 200—1900 m above sea level in north Xinjiang of China.	Functions: Clearing heat and toxic materials, relieving cough and resolving phlegm, subsidence of swelling and diuresis. Indications: For treatment of causing fever by cold.
Subg. *Sclarea* (Moench) Benth. Sect. *Notiosphace* Benth. (*S. plebeian*)	Distributed in the most regions of 0—2 800 m above sea level in China.	Functions: Clearing heat and toxic materials, removing heat from blood, diuresis. Indications: For treatment of bleeding, perineum edema resulting from hemorrhoids, swollen sore throat, bronchitis, cancer, nephritis, and mastitis.

Central China, with only a few species extending to southwestern and northwestern China (Li *et al*, 2008b).

Preliminary pharmacophylogenetic investigation on Chinese *Salvia* L. species

Pharmacophylogeny, a comprehensive discipline, is proposed to bridge ethnopharmacology, medicinal botanology, plant genetic, and resource of medicinal plants and developed on the top of these disciplines (Peng *et al*, 2006). Its core spirit is the connection of medicinal plants, chemical or biological composition, and therapeutic effects. It emphasizes that genetically close plants contain similar chemical or bioactive composition and so exert similar therapeutic effects. In contrast, the plants containing similar constituents and used for similar therapeutic purpose might have close genetic relation (Xiao *et al*, 2006).

As narrated above, *Salvia* L. is one of the largest genera in Lamiaceae, and the species and diversity of Chinese *Salvia* L. provided a wide research space and promising applicative future. According to our study, 43 medicinal plants of *Salvia* L. could be divided into three groups (Groups 1—3). Table 3 gave a brief description of these three groups for their taxa, growing environment, distribution, therapeutic effects, and representative species. All species of Group 1 are from Sect. *Eurysphace* Stib. or *Drymophace*, and rich in abietane diterpenes and caffeic acid derivatives. The representative plant *S. miltiorrhiza* (*Danshen*), although many other species have also been used as "*Danshen*" or its alternative, has been used as one of the most popular Chinese herbal medicines with the function of promoting blood circulation to treat various cardiovascular diseases. All medicinal plants in Group 2 were introduced from South America (Subg. *Jungia*) and Europe (Sect. *Eusphace*). *S. officinalis* (sage) from Sect. *Eusphace* Benth. is one of the most popular herbs and aromatic plants in western countries. They have been used to clear body-heat and toxic materials to balance the normal condition. Abietane diterpenes of medicinal species in Group 3 (the species from Subg. *Allagospadonopsis* Briq., Sect. *Plethiosphace*, or Sect. *Notiosphace*) are absent, and the contents of caffeic acid derivatives are considerably lower than those in the plants in Group 1 (Li *et al*, 2008a). Ethnopharmacologically, several medicinal plants in Group 3 (*S. plebeia*, *S. chinensis*) have been mainly used to treat cancer. However, only a little data published are concerned to the phytochemisty and pharmacology of these species.

Conclusion

According to the pharmacophylogenetic study of Chinese *Salvia* L. species, the medicinal plants from the genus could be divided into three groups (Groups 1—3). All species of Group 1 are from Sect. *Eurysphace* Stib. or *Drymophace*, and rich in abietane diterpenes and caffeic acid derivatives. These plants have been used as "*Danshen*" in folk to promote blood circulation, regulate menstruation, and activate meridian and collateral. The medicinal plants in Group 2 introduced from South America (Subg. *Jungia*) and Europe (Sect. *Eusphace*) have been used to clear heat and toxic materials from the body. But their ornamental values are higher than medicinal value. Abietane diterpenes of medicinal species in Group 3 (the species from Subg. *Allagospadonopsis* Briq., Sect. *Plethiosphace*, or Sect. *Notiosphace*) are absent, and the contents of caffeic acid derivatives are considerably lower than those in the plants in Group 1. Ethnopharmacologically, several medicinal plants in Group 3 (*S. plebeian* and *S. chinensis*) have been mainly used to treat cancer. However, only a little data published are concerned to the phytochemisty and pharmacology of these species.

There were still many problems in the classification, identification, and resources utilization of Chinese *Salvia* L. species. Such problems are not unique to *Salvia* L., as with most herbs that have many species which are morphologically similar. And further botanical, molecular systematic, and phytochemical studies on the *Salvia* L. species would probably prove to be very useful for their better medicinal utilization.

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