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Distribution pattern of genuine species of rhubarb as traditional Chinese medicine

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The distribution pattern of *Rheum palmatum*, *Rheum officinale* and *Rheum tanguticum*, as three Chinese official genuine and endemic species of rhubarb and the monophyletic group in the genus *Rheum*, was analyzed based on the field survey and the herbarium specimens in the present paper. *R. palmatum* occupies the widest geographic range, that is Qinling, Daba, Wuling, Dalou, Min, Qilian, Hengduan, the south part of Taihang mountain range and the centre to the east of Qinghai-Tibet Plateau. The distribution of *R. tanguticum* is overlapped with that of *R. palmatum* in the north-west areas and occupies the higher altitude and the lower longitude areas, whereas the distribution of *R. officinale* is overlapped with that of *R. palmatum* in the south-east and occupies the lower altitude and the higher longitude areas. The overlapped between *R. palmatum* and *R. tanguticum* + *R. officinale* and the vicarious between *R. tanguticum* and *R. officinale* distribution pattern, combined with the minimum and ambiguous morphological differences and the diversified results on the relationship from the molecular studies of these three species, we considered that these three species might not be good species.

Key words: *Rheum tanguticum*, *Rheum officinale*, *Rheum palmatum*, rhubarb, distribution pattern.

INTRODUCTION

Rhubarb, one of the most well-known, commonly used, and important traditional Chinese medicine, is characterized by bitter in taste and cold in nature, and related to spleen, stomach, colon, liver, and pericardium channels (Chinese Pharmacopoeia Committee, 2010). In China, rhubarb has been used for thousands of years as an important component in many Chinese patents or compound medicines with the functions including cooling blood detoxification, expelling stasis pass through, removing dampness, abating jaundice and others (Chinese Pharmacopoeia Committee, 2010). It is bulk market demand is increasing and has been exported to Japan, Korea and some other countries. For the chemical compounds and pharmacological actions of rhubarb, the detailed information can be viewed in our previous studies (Wang and Ren, 2009; Wang, 2010). As described in the

Chinese Pharmacopoeia, rhubarb consists of the roots and rhizomes of three genuine species, *Rheum officinale* Baill., *Rheum palmatum* Linn., and *Rheum tanguticum* Maxim. ex Balf. (Chinese Pharmacopoeia Committee, 2010), all of which belong to *Rheum* Sect. *Palmata* (Polygonaceae) and are endemic to China (Bao and Grabovskaya-Borodina, 2003) and monophyletic (Wang et al., 2005). Based on China National Knowledge Infrastructure (<http://www.cnki.net>), more than 8000 papers mainly on the pharmacology, clinic, chemical compounds of rhubarb and/or its compound medicine, as well as the cultivation, anatomy, and genetic diversity of the genuine species of rhubarb were published in the last three decades. Among these papers, about 700 were published from 1980 to 1989, 2300 from 1990 to 1999, and more than 5000 from 2000 to 2009. It is well known in Chinese medicinal materials markets that the rhubarb from the roots and rhizomes of *R. tanguticum* is called "north rhubarb" and has the best quality, while those of *R. palmatum* and *R. officinale* called "south rhubarb". It has been reported that the quality of the rhubarbs from

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different species and locations is different (Wang et al., 2007; He et al., 2007. Rong et al., 2009), moreover, even from the same species is also different (Lin et al., 2008) according to the criterion listed in Chinese Pharmacopoeia. Rhubarb has been cultivated in different scales, but usually very small scales in farmers' gardens and/or around their houses, in many places of China for a long history and the cultivation methods are skilled (Wang, 1990; Chen, 2003; Jiao and Zhang, 2006; Zhang, 2008; Ding and An, 2009). Because of the increasing market demand on the rhubarb, the wild resources are decreasing rapidly and the large scaled cultivation of rhubarb is becoming the main source for the market (Li and Li, 2001) and some GAP (good agricultural practice) bases have been established to cultivate the genuine species of rhubarb in Qinghai, Gansu, and Sichuan provinces (Li et al., 2006).

Comparing with the long history of medicinal usage (Shen, 1989), the knowledge on the distribution pattern of the genuine species of rhubarb is very poor, although, there were some reports on the distribution pattern of the genus *Rhuem* (Cheng and Gao, 1993; Gao, 1998; Bao and Grabovskaya-Borodina, 2003) and that of genuine species of rhubarb in Gansu province (Shen et al., 1996). Because of the increasing interest on the medicinal and functional food usage and the quality control of the rhubarb (Miao, 2001; Xiong and Zhang, 2003), the genetic diversity studies of the genuine species of rhubarb (Wang et al., 2005; Chen et al., 2008; Wu et al., 2008; Chen et al., 2009; Suo et al., 2010), and the establishment of the more and more GAP bases, the accurate and overall knowledge on the distribution pattern of the genuine species of rhubarb becomes necessary and timely. Unfortunately, no data provide a useful and satisfactory outline on the distribution pattern of rhubarb up till now. The descriptions on the distribution of the genuine species of rhubarb were jumbled due to the following reasons: (1) The distribution of the species was mainly based on the herbarium specimens, however, if the specimens were misidentified, then the distribution description would be wrong. (2) There were distribution records in some provinces, for example, in Guizhou province (Wu, 1982), but there is no specimens to prove the truth. (3) In some cases, the cultivated individuals were recorded as wild ones on the field notes of the specimens. According to the specimen (Yu, Lu, and Zhao 30, PE), *R. palmatum* is distributed in Wu'an county of Hebei province, but the present survey confirmed that the individuals in Wu'an county were introduced from Sichuan province and cultivated in the medicinal farm from 1960s', for example. Therefore, one aim of the present paper is to clarify the distribution pattern of the genuine species of rhubarb based on the field survey and the herbarium specimens all over China. The other aim is to outline a clear and accurate distribution pattern of these species for the protection of the rhubarb resources, the genetic diversity and other studies of the genuine species.

MATERIALS AND METHODS

The distribution information of the genuine species of rhubarb, that is *R. officinale* Bill., *R. palmatum* Linn., and *R. tanguticum* Maxim. ex Balf. (including var. *liupanshanense* C. Y. Cheng and T. C. Kao, the same in below), was obtained through field survey and the herbarium specimens. The field survey was carried out in the major parts of the distribution of the three species (Table 1, marked with *). The specimens were collected, identified, and stowed in the Herbarium of Shaanxi Normal University (SANU) (Table 1). The information of 199 herbarium specimens was listed in Table 1. The following specimens were not used in the present study: (1) the individuals were noted as cultivated ones or recorded as wild ones on the field notes but were proved as cultivated ones in the later field survey, (2) there is no location information below the provincial level on the field notes, (3) the field notes were ambiguous and indistinct, and (4) the young individuals or the specimens which have only one or two basal leaf which is not lobed or slightly lobed in three species and might lead the misidentification.

Determination of longitudes and latitudes of specimens

The longitudes and latitudes of specimens were obtained by two ways. One of the ways was from the field notes directly, if the collectors have recorded it by a Global Positioning System (GPS). However, for the specimens which have no longitude and latitude record on the field notes, we searched the collecting sites and got the longitudes and latitudes on Google Earth. If the collecting sites of the specimens were limited only on the level of the countries, then the longitudes and latitudes of the county towns were used.

Mapping the distribution pattern of specimens

Only one specimen from the same county was used in mapping the distribution pattern unless the linear distance between two specimens is more than 100 km or the altitudes are more than 100 m. The diagrams of the relationship between altitudes and longitudes or latitudes were carried out using Microsoft Excel. The specimens that have no altitude record on the field notes were not used in the diagrams.

RESULTS

The valid specimen information of three genuine species of rhubarb was listed in Table 1.

Horizontal and vertical distribution

The horizontal distribution pattern of three genuine species of rhubarb was showed in Figure 1. *R. palmatum* occupies the widest geographic range, and the geographic coordinates are 28.08° - 38.84°N and 83.01° - 113.92°E. This distribution range includes the south part of Taihang (the south of Shanxi), Qinling (the central south of Shaanxi and south-east of Gansu), Daba (the west of Hubei, the south of Shaanxi, and the north of Sichuan and Chongqing), Wuling (south-west of Hubei), Dalou (the south of Chongqing), Hengduan (the central west of Sichuan and the east of Tibet), Min (the south of Gansu and the north-west of Sichuan), Qilian (the central

Table 1. Specimen information of *R. palmatum*, *R. officinale* and *R. tanguticum*.

Location	Altitude (m)	Latitude (N)	Longitude (E)	Geography affiliation	Voucher
<i>R. palmatum</i>					
Shanxi province					
Huangguman, Tongshan, Hengqu county	1000	35.29°	113.92°	Taihang mountain range	Shanxi Team 2369, WUN
*Shunwangping, Xiashui, Zhongcong, Qingshui county	1766	35.42°	111.92°	Taihang mountain range	Xiao-qi Hou 10100705, SANU
Gansu province					
Zhucha, Tianzhu county	3000	36.95°	102.65°	Qilian mountain range	Ye-qi He 4903, WUN
Sunan county	2900	38.84°	99.61°	Qilian mountain range	Ming-zhao Yang 69109, Herbarium of Gansu Medicine Co.
Zhuoni county	2900	34.56°	103.47°	Min mountain range	Shu-hua Hu 291, LZU
Maliu, Luotang, Wudu county	2200	33.16°	105.21°	Qinling mountain range	Zhi-ying Zhang 1900, WUN
Yangbugou, Shatan Forest Farm, Zhouqu county	3400	33.69°	104.05°	Qinling mountain range	Ben-zhao Guo 5257, WUN
Shaanxi province					
Nangoutan, Mt. Xinjia, Feng county	2240	34.18°	106.58°	Qinling mountain range	Ji-meng Liu 10740, KUN, PE, WUN
Mt. Xinjia, Feng county	2200	34.16°	106.58°	Qinling mountain range	Kun-jun Fu 16107, WUN
Mt. Qiaomai, Zushitai, West Mt. Taibai, Taibai county	3100	33.94°	107.45°	Qinling mountain range	Kun-jun Fu 10387, WUN
Taibaiyuan, West Mt. Taibai, Taibai county	2900	35.97°	107.37°	Qinling mountain range	Kun-jun Fu 9489, WUN
Mingxingsi, Mt. Taibai, Mei county	2900	33.99°	107.74°	Qinling mountain range	T. P. Wang 1724, WUN
*Xiabansi, Mt. Taibai, Mei county	2599	38.02°	107.82°	Qinling mountain range	Xu-mei Wang 10061001, SANU
Xiaonangou, Taishanba, Ningshan county	1400	33.31°	108.55°	Qinling mountain range	Shiquan 4 th Team 0204, HNWP
Laolinggou, Taoping, Danfeng county	1900	33.76°	110.78°	Qinling mountain range	Shaanxi Wild Plant Survey Team 476, WUN
Mt. Hua, Huaying county	1800	34.47°	110.08°	Qinling mountain range	K. S. Hao 3950, WUN
Luzigou, Madi, Zhouzhi county	2000	33.96°	107.99°	Qinling mountain range	Ben-zhao Guo 1339, WUN
*Mt. Guangtou, Fengyu, Chang'an county	2578	33.87°	108.76°	Qinling mountain range	Xu-mei Wang 10053103, SANU
Zhuzigou, Qinggangping, Lantian county	2300	34.26°	109.81°	Qinling mountain range	Zuo-bin Wang 15650, WUN
Zeping, Taohe, Langao county	1700	32.18°	108.96°	Daba mountain range	Pei-yuan Li 7722, KUN, WUN
Tibet Autonomous Region					
Jiangzemu to Benbujian, Nanmulin county	4500	29.47°	88.96°	Qinghai-Tibetan Plateau	Tibet Vegetation Team 6111, PE
Erdui, Bola, Rendui, Nanmulin county	4400	30.20°	88.96°	Qinghai-Tibetan Plateau	Qinghia-Tibet Team 7531, PE, KUN
Lulong, Nanmulin county	4100	29.68°	89.10°	Qinghai-Tibetan Plateau	Tibet Chinese Medicine Survey Team 1010, HNWP, PE

Table 1. Contd.

Nanmulin county	4380	29.68°	89.10°	Qinghai-Tibetan Plateau	Jiu-dan Li , Ji Zhang 77-036, PE
*Langqin, Rendui, Nanmulin county	4368	30.06°	89.10°	Qinghai-Tibetan Plateau	Xu-mei Wang 09081705, SANU
*Luoza, Rendui, Nanmulin county	4498	30.13°	89.09°	Qinghai-Tibetan Plateau	Xu-mei Wang 09081708, SANU
Sajia county	4450	28.87°	88.01°	Qinghai-Tibetan Plateau	Guo-xun Fu 823, PE
Near city of Baqing county	4300	31.92°	94.05°	Qinghai-Tibetan Plateau	De-ding Tao 11111, PE, KUN
Rongxi, Mangkang county	4100	29.59°	98.18°	Hengduang mountain range	Qinghai-Tibet Scientific Survey Team 12005, HNWP, PE, KUN
Tuoba, Changdu county	4000	31.29°	97.53°	Hengduang mountain range	Qinghai-Tibet Scientific Survey Team 12713, PE, KUN
Mt. Damala, Changdu	4500	29.67°	97.84°	Hengduang mountain range	Qinghai-Tibet Team, Vegetation group 10004, PE
Near Changmaoling, Leiwuqi county	4100	31.39°	96.36°	Hengduang mountain range	Anonymous 1724, KUN
Zuogong county	4700	29.67°	97.84°	Hengduang mountain range	Yong Fei, Hang Song et al. 90, KUN
Qusong county	4320	29.06°	92.20°	Hengduang mountain range	Jiu-dan Li , Ji Zhang 77-022, PE
*Qingnidong, Jiangda county	4000	31.37°	97.90°	Hengduang mountain range	Xu-mei Wang 09082114, SANU
Qinghai province					
Jiqu, Nangqian county	4050	31.89°	96.10°	Qinghai-Tibetan Plateau	Yong-chang Yang 01148, PE, HNWP
Chaidamu, Maduo county	3900	31.91°	96.14°	Qinghai-Tibetan Plateau	Gansu-Qinghai Team 1223, PE, WUN
Mt. Halage, Xiligou, Chaidamu, Maduo county	3800	31.90°	96.13°	Qinghai-Tibetan Plateau	Gansu-Qinghai Team 638, PE, WUN
Shangbeishan Forest Farm, Ledu county	2700	36.66°	102.39°	Qilian mountain range	Yu-hu Wu et al. 3609, HNWP
Yaoshuiquan, Chapu, Hualong county	2875	36.24°	101.89°	Qilian mountain range	Yu-hu Wu 28571, HNWP
Sichuan province					
Kangding county	4200	30.21°	101.76°	Hengduang mountain range	Ke-jian Guan et al. 573, PE
Kangding county	3650	30.14°	101.90°	Hengduang mountain range	Xing-lin Jiang 36330, PE
Gan-Bai Lu, Baiyu county	4255	31.21°	98.83°	Hengduang mountain range	D. E. Boufford et al. 36882, PE
Near mountain pass of Mt. Kazila, from Litang county to Yajiang county	4400	30.17°	100.65°	Hengduang mountain range	Kai-yong Lang, Liang-qian Li, Yong Fei 2740, KUN
Haiziping, Danba county	3800	31.19°	102.03°	Hengduang mountain range	Sichuan 8 th Forest Team 2503, IBSC
Mairi meadow, Muli county	5100	28.55°	100.80°	Hengduang mountain range	De-sheng Zhao 6430, SZ
Shaoxiangliangzi, Muli county	3600	28.08°	101.09°	Hengduang mountain range	De-sheng Zhao, Ke-hua Li, Ya-bin Yang 6828, SZ
Li county	4200	31.45°	103.16°	Hengduang mountain range	Shu Jiang, Cun-li Jin 00860, PE
Hongshuigou, Anning, Jinchuan county	4200	31.31°	102.19°	Hengduang mountain range	Xin Li 77786, PE, WUN
Chalisi, Aba county	3320	32.91°	101.69°	Hengduang mountain range	South-to-North Water Diversion Team 01246, SZ
Baoxing county	3200	30.37°	102.82°	Hengduang mountain range	T. T. Yu 2290, PE
Yarituo, Xinlong county	4400	30.94°	100.31°	Hengduang mountain range	Zi-sheng Qin 06381, CDBI, PE
*Aji, Dagai, Xinlong county	3760	31.30°	100.05°	Hengduang mountain range	Xu-mei Wang 09082516, SANU

Table 1. Contd.

*Hongxi Forest Farm, Meigu county	3623	28.67°	102.97°	Hengduang mountain range	Yu-qu Zhang, Xiao-qj Hou 09091824, SANU
Nuo'ergai county	3430	33.58°	102.96°	Min mountain range	Anonymous 10387, PE
Nuo'ergai county	3560	33.58°	102.96°	Min mountain range	Shu Jiang, Cun-li Jin 01377, PE
*Baodinggou, Mt. Baoding, Mao county	3102	31.93°	103.92°	Min mountain range	Yu-qu Zhang, Xiao-qj Hou 09083001, SANU
*Fenghe, Xiaohe, Songpan county	2749	32.60°	104.16°	Min mountain range	Yu-qu Zhang, Xiao-qj Hou 09090607, SANU
*Xiaogou, Sigou, Huanglong, Songpan county	2831	37.80°	103.58°	Min mountain range	Yu-qu Zhang, Xiao-qj Hou 09090817, SANU
Chongqing Municipality					
Folaimiao, Mt. Jinfo, Nanchuan county	1750	28.93°	107.10°	Dalou mountain range	Guo-feng Li 61049, SZ
<i>R. officinale</i>					
Shaanxi province					
Xiangshuiyan, Mingxingsi, Mt. Taibai, Mei county	2700	33.98°	107.75°	Qinling mountain range	Qinling Team 10709, PE
*Xiabansi, Mt. Taibai, Mei county	2599	38.02°	107.82°	Qinling mountain range	Xu-mei Wang 10061002, SANU
Baihe'an, West Mt. Taibai, Taibai county	2540	34.00°	107.37°	Qinling mountain range	Kun-jun Fu 10238, WUN
Hongkangshan, West Mt. Taibai, Taibai county	1700	34.03°	107.34°	Qinling mountain range	Zhi-ping Wei 949, WUN
*Haitanggou, Taibaihe, Huangbaiyuan, Mt. Taibai, Taibai county	2400	33.90°	107.56°	Qinling mountain range	Yu-qu Zhang 09081003, SANU
*Longdonggou, Laoxiancheng, Mt. Taibai, Zhouzhi county	2658	33.87°	107.71°	Qinling mountain range	Yu-qu Zhang 09080801, SANU
Mt. Xinjia, Tangzang, Feng county	1850	34.30°	106.60°	Qinling mountain range	Kun-jun Fu 13234, WUN
Xiaozigou, Xunyangba, Ninshan county	1450	33.38°	108.36°	Qinling mountain range	Ji-qing Xing 6584, WUN
Mt. Guangtou, Laoyu, Hu county	2800	33.86°	108.78°	Qinling mountain range	Ben-zhao Guo 4662, WUN
Mengqingang, Qiuping, Pingli county	1800	32.04°	109.33°	Daba mountain range	Pei-yuan Li 2544, WUN, PE
*Sanchahe, Mt. Hualong, Pingli county	2263	31.89°	109.26°	Daba mountain range	Xu-mei Wang 10052804, SANU
Sichuan province					
Mo-tian-ling, Guangyuan county	1500	32.60°	104.49°	Daba mountain range	F. T. Wang 22499, PE
Yingshuiba, Guanba, Nanjiang county	1400	32.56°	107.10°	Daba mountain range	Chuan Liang Jin 2961, KUN
Dawan, Nanjiang county	1650	32.69°	106.93°	Daba mountain range	Shao-bin Wan 2605, CDBI
Shaoxiangliangzi, Muli county	3900	28.25°	101.16°	Hengduang mountain range	Anonymous s. n., HITBC
Mt. Ka, Wanlicheng, Wanli, Jinchuan county	4600	31.47°	102.32°	Hengduang mountain range	Xin Li 78177, NAS, WUN

Table 1. Contd.

Dapingzi, Yuexi county	3700	28.96°	102.44°	Hengduang mountain range	Vegetation Team 3933, CDBI, PE
Leibo county	3300	28.58°	103.27°	Hengduang mountain range	Zhong-tian Guan 8720, PE
Huangmaogeng, Leibo county	3000	28.50°	103.26°	Hengduang mountain range	Liangshan Wild Plant Survey Team 0856, CDBI, PE
Mianning county	3800	28.57°	102.34°	Hengduang mountain range	Su-gong Wu 1986, KUN
Hongqi, Xiangcheng county	4000	28.58°	103.27°	Hengduang mountain range	Zhao-guang Liu 1039, CDBI
Chongqing municipality					
Mt. Jinfo, Nanchuan county	1650	29.04°	107.19°	Dalou mountain range	Jinfoshan Survey Team 1737, PE
Nanchuan county	2667	29.03°	107.20°	Dalou mountain range	Wen-pei Fang 1037, PE
Mt. Jinfo, Nanchuan county	1700	29.04°	107.18°	Dalou mountain range	Guo-feng Li 61727, PE
Mt. Jinfo, Nanchuan county	2050	29.04°	107.18°	Dalou mountain range	Guo-feng Li 62241, PE
*Changgang, Mt. Jinfo, Nanchuan county	1832	29.00°	107.20°	Dalou mountain range	Xu-mei Wang, Xiao-qi Hou 09072609, SANU
*Xilaisi, Mt. Jinfo, Nanchuan county	1390	28.97°	107.18°	Dalou mountain range	Xu-mei Wang, Xiao-qi Hou 09072815, SANU
Chengkou county	2300	32.05°	108.63°	Daba mountain range	Tian-lun Dai 106997, PE
Chengkou county	1250	32.00°	108.65°	Daba mountain range	Tian-lun Dai 105200, PE
Wuxi county	2700	31.52°	109.89°	Daba mountain range	Guang-hui Yang 58826, PE
Borderline between Hanrui, Fengjie county and Banqiao, Shi'en county, Hubei province	1400	30.61°	109.37°	Daba mountain range	Ming-yuan Fang 24221, KUN
Yunnan province					
Gongshan county	3600	27.87°	98.47°	Hengduang mountain range	De-jun Yu 19722, KUN
Peak of Mt. Rijue, Fugong county	3800	26.67°	98.99°	Hengduang mountain range	Anonymous 18, HITBC
Habaxiazaza to Heihai, Zhongmian county	3400	27.23°	100.15°	Hengduang mountain range	Zhongmian Team 2838, KUN
*Shuiguala, haba, Sanba, Xianggelila county	4007	27.39°	100.05°	Hengduang mountain range	Xiao-qi Hou 09080517, SANU
*Parch house, Haba, Sanba, Xianggelila county	3727	27.40°	100.04°	Hengduang mountain range	Xiao-qi Hou 09080720, SANU
Hubei province					
Qiujiaping, Mt. Laojun, Mt. Shennongjia	1340	31.66°	110.61°	Daba mountain range	Hubei Shennongjia Plant Survey Team 30583, PE
Muyuping, Mt. Shennongjia	1280	31.47°	100.40°	Daba mountain range	Hubei Shennongjia Team 20001, PE
Jiudahu, Mt. Shennongjia	1800	31.46°	100.11°	Daba mountain range	Zai-jin Ren 1-2524, PE
*Taiziya, Muyu, Mt. Shennongjia, Xingshan county	2575	31.45°	110.19°	Daba mountain range	Xu-mei Wang, Xiao-qi Hou 09071101, SANU
*Banbiyan, Muyu, Mt. Shennongjia, Xingshan county	2920	31.45°	110.27°	Daba mountain range	Xu-mei Wang, Xiao-qi Hou 09071204, SANU
Badong county	1800	31.32°	110.48°	Daba mountain range	T. P. Wang 11104, PE
Liujiaipo, Badagongshan Chinese Medicine Farm, Xuan'en county	1330	29.66°	109.78°	Wuling mountain range	Hong-jun Li 3522, KUN, PE, IBSC, WUM, SZ

Table 1. Contd.

Gansu province					
Yerengou, Min county	2500	34.50°	104.31°	Min mountain range	Taohe Team 3092, WUN
Near Baipobao, Min county	2500	34.53°	104.08°	Min mountain range	Zuo-bin Wang 14069, WUN
Henan province					
Laochunshan, Lushi county	1440	33.81°	111.47°	Qinling mountain range	K. M. Liou 5208, WUN
Mt. Laojun, Xixia county	2100	33.26°	111.50°	Qinling mountain range	Ke-jian Guan, Tian-lun Dai 1253, PE
*Baotianman Reserve, Mt. Funiu, Neixiang county	1100	32.75°	110.50°	Qinling mountain range	Xu-mei Wang 08082417, SANU
Guizhou province					
*Hailongtun, Gaoping, Zunyi county	1252	27.81°	106.82°	Dalou mountain range	Xu-mei Wang, Xiao-qi Hou 2009-7-31, SANU
<i>R. tanguticum</i>					
Gansu province					
Xiahe county	2800	35.20°	102.52°	Min mountain range	K. T. Fu 1007, PE
Min county	2500	34.44°	104.03°	Min mountain range	Zuo-bin Wang 14064, PE
Dangchang county	2200	34.05°	104.39°	Min mountain range	Guo-liang Zhang 2020, LZU
Li county	2800	34.19°	105.18°	Min mountain range	Ru-neng Zhao 616002, Herbarium of Medical College of Lanzhou
Maqu county	3550	33.99°	102.08°	Qinling mountain range	Xue-rui Chen 65, LZU
Tianzhu county	2560	36.97°	103.14°	Qilian mountain range	Shi-lin Shen 570123, Herbarium of Medical College of Lanzhou
*Wangbalangyan, Mt. Qilian, Yongchang county	3006	37.00°	97.63°	Qilian mountain range	Xu-mei Wang 08071807, SANU
*Heilingou, Mt. Qilian, Yongchang county	2575	38.17°	101.43°	Qilian mountain range	Xu-mei Wang 08071910, SANU
Qinghai province					
Grassland Station, Heka, Xinghai county	3250	35.89°	99.99°	Qinghai-Tibetan Plateau	Zhen-lan Wu 00165, HNWP
Jiangqungou, Xiuma, Tongde county	3440	35.06°	100.34°	Qinghai-Tibetan Plateau	Yu-hu Wu et al. 6734, HNWP
Maixiu Forest Farm, Zeku county	3650	35.27°	101.93°	Qinghai-Tibetan Plateau	Ben-zhao Guo 26109, HNWP
Peak behind Guanxiu, Duohe, Zeku county	3500	35.07°	101.82°	Qinghai-Tibetan Plateau	Yong-chang Yang 2009, HNWP
South-west slop, Ninmute, Henan county	3410	34.59°	101.34°	Qinghai-Tibetan Plateau	Yong-chang Yang 1799, HNWP
Minshi, Maqin county	3870	34.47°	100.25°	Qinghai-Tibetan Plateau	Yu-hu Wu 25700, HNWP
Mt. Namulengji, Maqin county	3700	35.12°	98.73°	Qinghai-Tibetan Plateau	Maqin Team 98, HNWP
Minshi, Maqin county	3870	34.47°	100.25°	Qinghai-Tibetan Plateau	Yu-hu Wu 25700, HNWP
Mt. Namulengji, Maqin county	3700	35.12°	98.73°	Qinghai-Tibetan Plateau	Maqin Team 98, HNWP
Jianglang Power Station, Dawu, Maqin county	3680	34.49°	100.22°	Qinghai-Tibetan Plateau	H. B. G 644, HNWP
In front of Mt. Hongtu, Maqin county	3400	34.69°	100.65°	Qinghai-Tibetan Plateau	Yu-hu Wu et al. 18640, HNWP

Table 1. Contd.

Jiangbei Water Power Station, Maqin county	3400	34.47°	100.24°	Qinghai-Tibetan Plateau	Yu-hu Wu et al. 18709, HNWP
Xihalong Valley, Maqin county	3600	34.53°	100.43°	Qinghai-Tibetan Plateau	Yu-hu Wu et al. 5630, HNWP
Kepei Nursery, Makehe Forest Farm, Banma county	3700	32.71°	100.87°	Qinghai-Tibetan Plateau	Wei-yi Wang et al. 27044, HNWP
North slop of Mt. Nianbo, Jiuzhi county	4350	33.42°	101.48°	Qinghai-Tibetan Plateau	Guoluo Team 396, HNWP
Beside Longka lake, Jiuzhi county	3990	33.35°	101.11°	Qinghai-Tibetan Plateau	Guoluo Team 545, HNWP
Near Suohurima, Jiuzhi county	4400	33.53°	100.93°	Qinghai-Tibetan Plateau	Tibet Medicine Team 462, HNWP
Shanggongma, Gande county	3875	33.86°	99.65°	Qinghai-Tibetan Plateau	Yu-hu Wu 25791, HNWP
Tiandigou, Mengda, Xunhua county	2650	35.83°	102.64°	Qilian Mountain range	Ben-zhao Guo , Wei-yi Wang 25276, HNWP
Donggou, Youhulugou, Yeniugou, Qilian county	3000	38.52°	99.48°	Qilian mountain range	Qinhai-Gansu Team 110, WUN
Sichuan province					
Heirixia, Dege county	4400	31.80°	98.58°	Hengduan mountain range	Sichuan Vegetation Team 4184, CDBI
Beside Yalong River, Xinrong, Shiqu county	4000	33.06°	98.28°	Hengduan mountain range	Yu-hu Wu 29976, HNWP
Xinrong, Shiqu county	4000	33.06°	98.28°	Hengduan mountain range	Yu-hu Wu 29960, HNWP
Qika Dairy Farm, Daofu county	4000	30.99°	101.12°	Hengduan mountain range	Sichuan Chinese Medicine Survey Team 15789, NAS
Suomu, Markang county	4000	31.86°	102.49°	Hengduan mountain range	Sichuan Chinese Medicine Survey Team 22396, NAS
Songpan county	3300	32.65°	103.59°	Min mountain range	Songpan Group 1567, PE
*Yaogou, Huanglong, Songpan county	3597	32.80°	103.87°	Min mountain range	Yu-qu Zhang, Xiao-qi Hou 09090812, SANU
Duoniao near county city, Ruo'ergai county	3600	33.58°	102.96°	Min mountain range	Sichuan Chinese Medicine Survey Team 2083, NAS
*Baishagou, Wanglang Reserve, Pingwu county	3193	32.87°	104.05°	Min mountain range	Yu-qu Zhang, Xiao-qi Hou 09091121, SANU
Tibet Autonomous Region					
Mt. Dongdala, Zuogong county	4410	29.76°	97.97°	Hengduan mountain range	Anonymous 76-792, PE
<i>R. tanguticum var. liupanshanense</i>					
Ningxia Autonomous Region					
Mt. Liupan, Longde county	2200	35.49°	106.31°	Liupan mountain range	Zuo-bin Wang 17215, WUN
Longdegou, Jingyuan county	2500	35.51°	106.26°	Liupan mountain range	Zuo-bin Wang 17055, WUN
*Longwangmiaogou, Mt. Liupan, Jingyuan county	2224	35.67°	106.22°	Liupan mountain range	Xu-mei Wang 08072513, SANU
Gansu province					
Li county	2060	34.19°	105.18°	Min mountain range	Ru-neng Zhao 5507067, Herbarium of Medical College of Lanzhou
Li county	2500	34.19°	105.18°	Min mountain range	Shi-lin Shen 570111, Herbarium of Medical College of Lanzhou

CDBI: Herbarium of Chengdu Institute of Biology, CAS, HITBC: Herbarium of Xishuangbanna Tropical Botanical Garden, CAS, IBK: Herbarium of Institute of Botany, Guangxi Province and CAS, IBSC: South China Botanical Garden Herbarium, CAS, KUN: Herbarium of Kunming Institute of Botany, CAS, LZU: Herbarium of School of Life Sciences, Lanzhou University, NAS: Herbarium of Institute of Botany, Jiangsu Province and CAS, PE: National Herbarium of China, QTPMB and HNWP: Herbaria of Northwest Institute of Plateau, CAS (Chinese Academy of Sciences), SANU: Herbarium of College of Life Sciences, Shaanxi Normal University, SZ: Herbarium of School of Life Sciences, Sichuan University, WNU: Herbarium of School of Life Sciences, Northwest University, WUK: Herbarium of Northwest Agriculture and Forestry University.

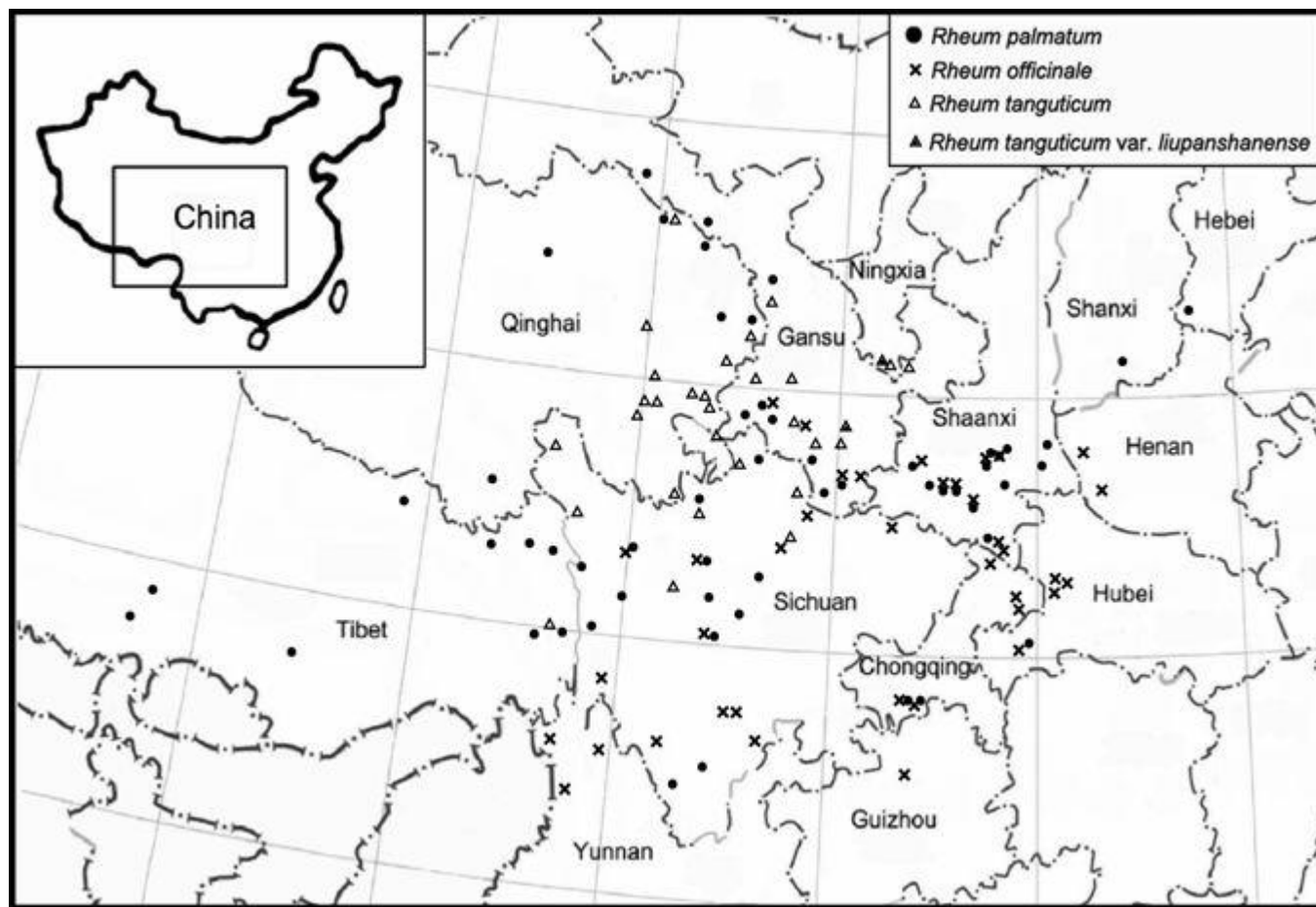


Figure 1. Geographic distribution pattern of three genuine species of rhubarb.

west of Gansu and the east of Qinghai) mountain range, and Qinghai-Tibet Plateau (the centre and central east of Tibet and the centre to the east of Qinghai). The altitude of *R. palmatum* is from 1000 to 5100 m. The geographic coordinates of *R. officinale* are 26.67°-34.53°N and 98.47°-111.50°E. This distribution range includes Qinling (the west of Henan, the central south of Shaanxi), Daba (the south of Shaanxi, the north of Sichuan and Chongqing, and the west of Hubei), Wuling (the south-west of Hubei), Dalou (the south of Chongqing and the north of Guizhou), Hengduan (the central west of Sichuan and the north-west of Yunnan), and Min (the north-west of Sichuan and the south of Gansu) mountain range. The altitude of *R. officinale* ranges from 1100 to 4600 m. The geographic coordinates of *R. tanguticum* are 29.76°-38.52°N and 97.63°-106.31°E. This distribution range includes Liupan (the south of Ningxia), Qilian (the east of Qinghai and the central west of Gansu), Min (the north-west of Sichuan and the south of Gansu), the north of Hengduan (the north-west of Sichuan) mountain range, and the east of Qinghai-Tibet Plateau (the east of Qinghai). The altitude of *R. tanguticum* ranges from 2060 to 4410 m.

Relationship between altitudes and latitudes of three genuine species of rhubarb

The samples from three genuine species of rhubarb showed replacement pattern except a few of samples (Figure 2). *R. officinale* occupies the lower altitudes and latitudes, *R. palmatum* in middle altitudes and latitudes, whereas *R. tanguticum* in higher altitudes and latitudes. In the same altitude, *R. officinale* is distributed in lower latitudes, *R. tanguticum* in higher latitudes, and most of samples of *R. palmatum* in the middle and a few of them in both lower and higher latitudes. Likewise, in the same latitude, *R. officinale* is distributed in lower altitudes, *R. tanguticum* in higher altitudes, and most of the individuals of *R. palmatum* in the middle and a few of them in both lower and higher altitudes.

Relationship between altitudes and longitudes of three genuine species of rhubarb

The altitudes and longitudes of samples from three species shows a weakly linear relation ($R^2 = 0.6138$)

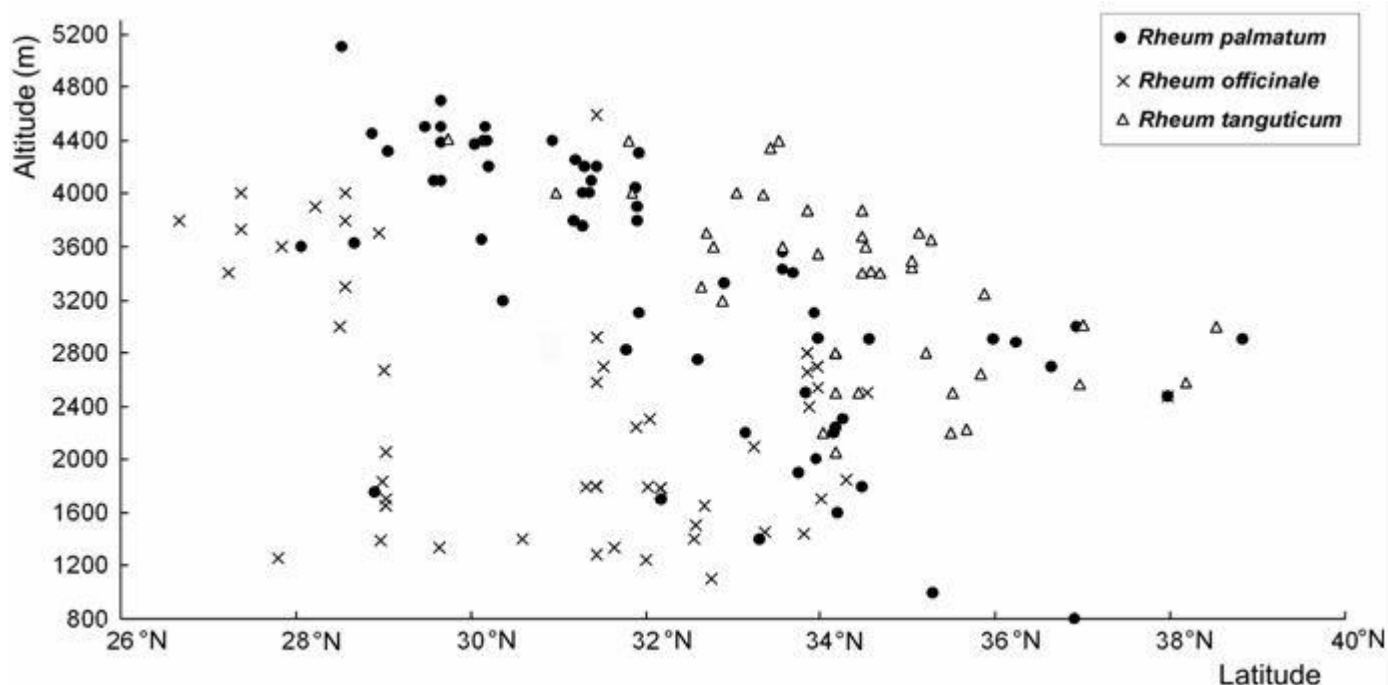


Figure 2. Relationship between altitudes and latitudes of three genuine species of rhubarb.

(Figure 3). In general, *R. officinale* tends to be distributed in lower altitudes and higher longitudes, *R. tanguticum* in higher altitudes and lower longitudes, whereas *R. palmatum* from the lowest to the highest altitudes and longitudes in the distribution area of three species.

DISCUSSION

Three genuine species of rhubarb shows overlapped and vicarious distribution pattern. *R. palmatum* occupies the widest distribution range. The distribution of *R. officinale* and *R. tanguticum* is overlapped with *R. palmatum* in the north-west and the south-east areas, respectively, whereas that of *R. tanguticum* and *R. officinale* is vicarious with the former in the north-west and the later in the south-east areas. *R. tanguticum* is distributed in the east of Qinghai-Tibet Plateau, Qilian and the north of Hengduan mountain range to Min and Liupan mountain range that represents the higher altitude and lower longitude area of the distribution of three species as a whole, while *R. officinale* is distributed in Min, Hengduan, Qinling, Daba, Wuling, and Dalou mountain range that represents the lower altitude and higher longitude area of the distribution of three species as a whole. The vicarious area of *R. officinale* and *R. tanguticum* is in Min and the north-west of Hengduan mountain range. It is well known that each species has its own distribution area. But the distribution pattern of these three species is rare and might suggest the possibility that they are not good species and may

belong to one species. In the view of morphology, the diagnostic characteristic of three species is mainly in leaf morphology, that is the blades of *R. officinale* are lobed and the lobed parts are broadly triangular, that of *R. palmatum* are also lobed and the lobed parts are narrowly triangular, whereas that of *R. tanguticum* are parted and the lobed parts are narrow, triangular-lanceolate (Gao, 1998; Bao and Grabovskaya-Borodina, 2003).

The transition form of the lobed and parted leaves can be frequently found in the vicarious areas, for example, the blades from the individuals in Mt. Qinling are various from slightly lobed to parted and the lobed parts from broadly triangular to triangular-lanceolate. So these individuals were once treated as another species, *R. qinlingense* Y. K. Yang, D. K. Zhang et al. and J. K. Wu, in the same section (Wu et al., 1992).

The molecular systematics results from different markers are different. Suo et al. (2010) concluded that *R. officinale* and *R. palmatum* are sisters and they together are sister with *R. tanguticum* based on the samples from Sichuan and Gansu provinces by using AFLP (amplified fragment length polymorphism) marker. Whereas Yang et al. (2004) reported that *R. officinale* and *R. tanguticum* are sisters and they together are sister with *R. palmatum* based on the samples from Qinghai, Sichuan, and Gansu provinces by using chloroplast DNA *matK* gene sequence. Based on the samples from Chongqing Municipality, Sichuan, and Qinghai provinces by using chloroplast DNA *trnL-F* sequences, Wang et al. (2005)

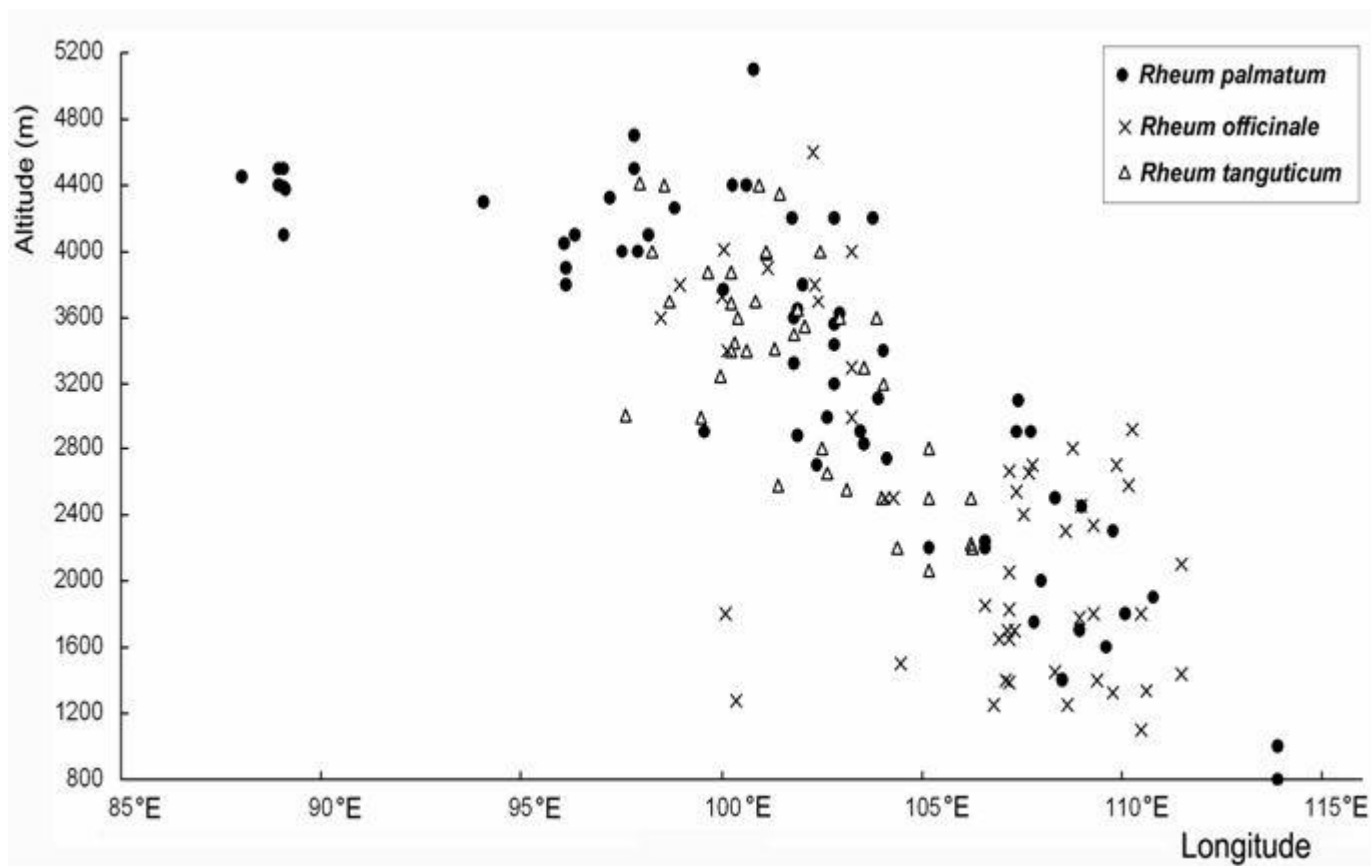


Figure 3. Relationship between altitudes and longitudes of three genuine species of rhubarb.

considered that the individuals of *R. palmatum*, *R. officinale*, and *R. tanguticum* are nested one by another in the systematic tree. Based on the nuclear DNA ITS (internal transcribed spacer) sequence analysis on eight samples from Qinghai and Gansu provinces, Li et al. (2010) concluded that the only sample of *R. officinale* in their study is sister with other seven samples of *R. palmatum* and *R. tanguticum*. The seven samples of *R. palmatum* and *R. tanguticum* are nested to one another. Although, the sampling of above mentioned series studies is limited and defective, the different results based on different DNA markers gives us an obvious sign that these three species might not be good species. Detailed studies of the morphology and the molecular systematic of the genuine species of rhubarb are currently under way and should yield valuable information for the species delimitation of three species of rhubarb.

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