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The relationship between geography and climate in the generic-level patterns of Chinese seed plants

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Abstract This paper aims to illustrate the distribution patterns of generic-level elements of Chinese seed plants and their correlations to climatic and geographic gradients. A total of 204 regional floras covering all of China were used to make distribution maps for all seed plant genera using GIS (Geographic Information Systems) technology. Climatic gradients were based on data sets from 841 meteorological stations throughout China. Definitions for floristic distributional patterns were based upon the work of Prof. Z. Y. Wu. Most of these floristic distributional patterns were strongly correlated with the geographic gradients in climate, except for cosmopolitan, cultivated and invasive genera. Tropical genera form a large fraction of the total genera (ranging from 0.84% to 94.38% in the regional floras) with the highest proportion in southern Yunnan and Hainan Island. Tropical genera occur predominantly in southern China of <30^{o} N latitude and decreased with increasing latitude, as would be expected. Interestingly, the disjunct Tropical Asia and Tropical America distribution were not restricted to southern latitudes. Temperate genera account for 5.1% to 98.83% of the total genera in regional floras with the highest proportion in the province of Xinjiang. Most of these genera followed geographic gradients in climate as expected (temperate genera conspicuously dominate the landscape at higher latitudes), except the East Asian and North American disjunct distribution, Eastern Asian distribution and Chinese endemic distribution. Generally, most plant genera demonstrated some correlation with climatic and geographic gradients. The most important gradients were those of annual air temperature and precipitation. A small fraction did not demonstrate significantly particular pattern: “Cosmopolitan”, “East Asian and North American disjunct”, “Eastern Asian” and “Chinese endemic” distributions. The North Temperate distribution had the highest correlation with mean annual air temperature and precipitation. These results demonstrate that the Chinese seed plant genera correspond well to recognized vegetation zones and floristic regions, providing further support for the current phytogeographic definitions.
Key words genera of Chinese seed plants, geographical elements, distribution patterns, correlation to climatic factors and geography.

Within the country of China, plant systematic studies have a long history. Hu (1926, 1929, 1935, 1936) gave a primary viewpoint on the characteristic elements of the Chinese flora. Liu (1934) gave a framework for the geographic distribution of these floristic elements, while Li (1944) discussed these distribution patterns in more detail, based on studies of the family Araliaceae. Wu (1965) studied the distribution patterns of Chinese seed plants at the generic level (ca. 2980 genera), pointing out the country’s tropical affinity. Zhang (1962, 1980) analyzed the floristic composition and characteristics of southern China and discussed its origins. Wu and Wang (1983) systematically summarized the floristic composition, characteristics and affinities of Chinese flora, while Wu and Wu (1996) further affirmed the

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uniqueness of the Chinese flora and suggested an Eastern Asiatic floristic kingdom.

More recently, Zhu & Roos (2004) discussed the tropical flora in southern China and its affinity to the tropical Asian flora based on comparisons of floristic similarities between southern Yunnan and Hainan Island, Vietnam, Malay Peninsula and Brunei of western Malesia, and confirmed that the flora of southern China is of tropical nature with a strong tropical Asian affinity. Qian et al. (2003) studied large-scale phytogeographical patterns in East Asia, based upon a total of 45 regional floras at the generic level, including 23 Chinese floras. The geographic and climatic patterns of the floristic elements were examined among cosmopolitan, tropical and temperate genera.

In this study, we examine the distribution patterns of Chinese seed plants at generic level, based upon the classification system of Wu (1991). Wu's classification system is quite important to Chinese botany, because a large number of papers following his system have been published. We used 204 regional floristic works (see Appendix 1), which cover almost all climatic zones and terrestrial ecosystems present in China, from Hainan Island in the south (18.61° N), Altai of Xinjiang Province in the northwest (48.88° N), the upper Ürümqi in the west (87.03° E), to Changbai Mountains in the east (128.33° E) (Fig. 1). We then compared Wu's phytogeographic classification system to the geographic patterns in long-term climatic data sets. Using a range of factors, the correlation between Wu's phytogeographic classification system of Chinese seed plants at generic level and observed climatic patterns are examined.

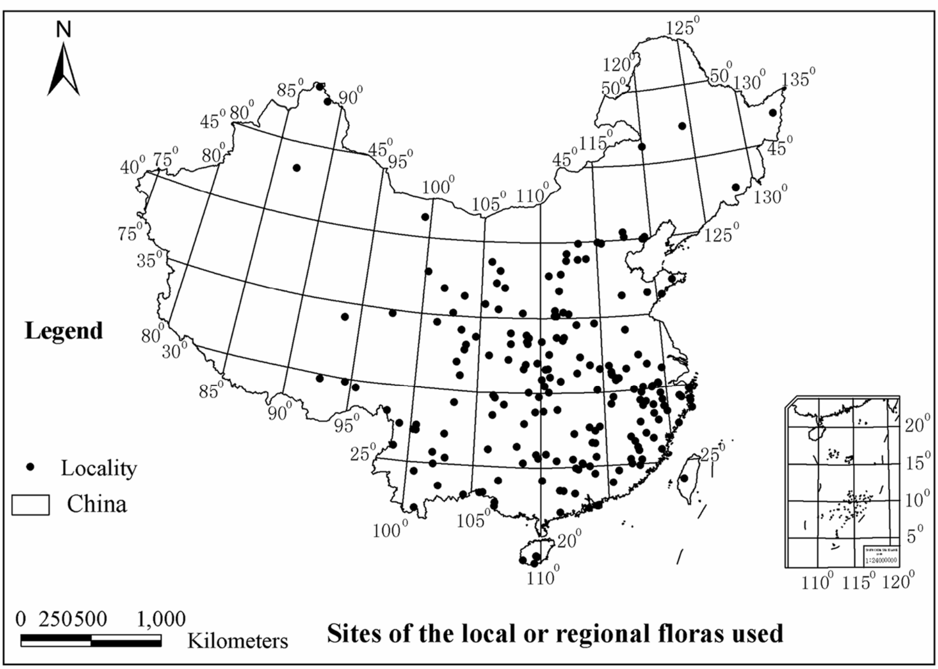

Fig. 1. Sites of the local or regional floras used.

1 Material and methods

The genera of Chinese seed plants were placed into 15 phytogeographic distribution patterns defined by Wu (1991). Most of the 204 regional floras already classified the plant genera based on Wu's classification, although a few earlier works had to be independently classified. This large database of phytogeographic patterns of Chinese seed plant genera provides as complete coverage of the country as possible. We chose to ignore "Cosmopolitan" genera because they have little biogeographical significance. The Arcview software (ArcGIS9.2) was used for making frequency maps of distribution types of the Chinese genera. On each map, the frequency distribution was grouped into five classes, defined by identifying natural breakpoints between classes using the Jenk's optimization method, a default classification method in Arcview.

The 15 phytogeographic distribution patterns documented by Wu (1991) and used in this paper are concisely explained as following:

1. "Cosmopolitan"

Cosmopolitan distribution includes the genera which are widely distributed across every continent of the world without special distribution centers.

2. "Pantropical"

Pantropical distribution includes the genera which are distributed throughout the tropics of the Western and Eastern Hemispheres or those genera which have one or more than one distribution centers in the tropics, but with some species distributed in other regions.

3. "Tropical Asia and Tropical America disjunct"

Included in this category are those genera which are disjunctly distributed in warm regions of America and Asia.

4. "Old World Tropic"

Those are the genera which are distributed throughout the tropical areas of Asia, Africa, Australia and their adjacent islands.

5. "Tropical Asia and Tropical Australia"

This distribution type is the east wing of the "Old World Tropic" distribution. Its western boundary is sometimes in Madagascar but never in the continental Africa.

6. "Tropical Asia to Tropical Africa"

This distribution type includes the genera which are distributed from tropical Africa to Indo-Malaysia region, as the west wing of the "Old World Tropic" distribution.

7. "Tropical Asia (Indo-Malaysia)"

This distribution type includes the genera which are distributed throughout Tropical Asian (Indo-Malaysia) region. Its eastern boundary reaches Fiji or the island of the South Pacific but never on the continent of Australia, and the northern boundary mostly reaches Southwest and South China and Taiwan.

8. "North Temperate"

This distribution type includes the genera which are widely distributed in the temperate regions of Europe, Asia and North America. Some of them can extend to the tropical mountains.

9. "East Asia and North America disjunct"

The genera of this distribution type are discontinuously distributed in the temperate and subtropical areas of East Asia and North America.

10. "Old World Temperate"

This type generally includes the genera which are widely distributed in temperate and cold temperate regions from high latitudes to middle latitudes of Eurasia.

11. "Temperate Asia"

This type includes the genera which are confined to the temperate regions of Asia with a range from Central Asia in Russia (or south Russia) to Eastern and Western Siberia and Northeastern Asia, southward to North China, Korea and northern Japan.

12. "Mediterranean, West Asia to Central Asia"

This distribution type includes the genera which are distributed around the Mediterranean, through West Asia or Southwest Asia to the Central Asia of Russia and Chinese Xinjiang, the plateaus of Qinghai and Tibet and plateau of Mongolia.

13. "Central Asia"

This type includes the genera which are distributed in Central Asia (particularly mountainous regions), but not in West Asia and the Mediterranean region.

14. "East Asia"

This type includes the genera which are distributed from Himalayas to Japan. The distribution ranges of this type do not extend beyond the northern IndoChina, and its northwest boundaries are coincided with the forest boundaries in Northwest China.

15. "Endemic to China"

This distribution type is centered in the natural floristic regions of China as a whole, with their distributional limits not far from Chinese national boundaries.

The relation coefficients of these distribution types to longitudinal and latitudinal gradients in the climatic data were calculated. The climatic data were collected between 1951 and 1980 from 841 meteorological stations throughout China including four major factors: (1) average monthly or annual air temperature, (2) average annual maximum or minimum air temperature, (3) average annual precipitation, and (4) average annual air relative humidity (Chinese Central Meteorological Office, 1984). The correlations of these floristic elements to climatic gradients were established based on comparing these two large datasets: the phytogeographic patterns and the long term climate data.

2 Results

2.1 Frequency patterns of the distribution types

2.2.1 "Pantropical" distribution (Type 2)

The "Pantropical distribution" includes 362 genera in China and contributes to 11.61% of the total Chinese genera (Table 1). The frequency of "Pantropical" genera in the regional floras across China is directly related to latitude (Fig. 2). The lowest proportion in any flora was 0.58% in the upper Ürümqi of Xinjiang in northwestern China (~87.03° E, 43.20° N), while the highest proportion was 45.73% in the Nujiang region of western Yunnan (~98.90° E, 26° N).

Table 1 Areal-types of genera of the Chinese seed plants*

Areal-type	No. of genus	%
1 Cosmopolitan	104	3.34
2 Pantropical	362	11.61
3 Tropical Asia & Tropical America disjuncted	62	1.99
4 Old World Tropic	177	5.68
5 Tropical Asia to Tropical Australia	148	4.75
6 Tropical Asia to Tropical Africa	164	5.26
7 Tropical Asia	611	19.60
8 North Temperate	302	9.69
9 East Asia and North America disjuncted	124	3.98
10 Old World Temperate	164	5.26
11 Temperate Asia	55	1.76
12 Mediterranean, W Asia to C Asia	171	5.49
13 Central Asia	116	3.72
14 East Asia	300	9.62
15 Endemic to China	257	8.25
Total	3117	100.00

* After Wu (1991).

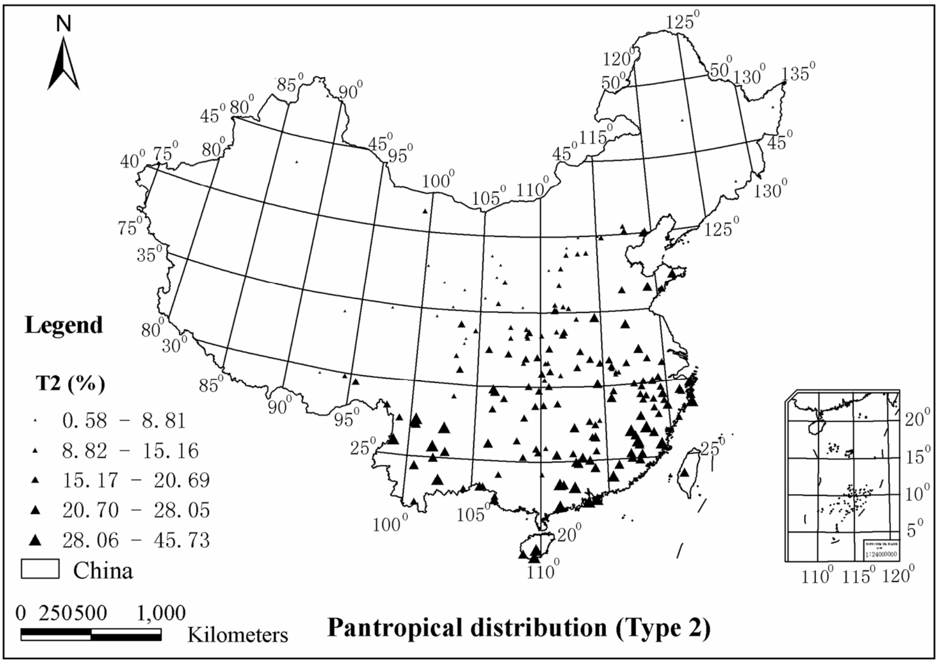

Fig. 2. Pantropical distribution.

"Pantropical" genera are the dominant tropical group in China, having the second highest proportion among Chinese tropical floristic elements. The relative frequency of "Pantropical" genera was generally greater than 20% in areas south of 30° N, except in regions with high elevations.

2.1.2 "Tropical Asia and Tropical America disjunct" distribution (Type 3)

This distribution type includes a total of 62 genera in China. However, the relative frequency of these genera ranged from 0% to 9.35% in the regional floras. Their geographic distribution did not correlate well with any latitudinal gradients, although their relative proportion generally increased at lower latitudes (Fig. 3).

2.1.3 "Old World Tropical" distribution (Type 4)

The "Old World Tropical" distribution includes 177 genera in China and contributes to 5.68% of the total Chinese genera (Table 1). These genera are completely absent from several northern floras while they are most frequent (15.68% of the total genera) in the Longgang limestone area of Guangxi Province (~106.7° E, 22.3° N). The relative frequency of these genera decreases dramatically with increasing latitude (Fig. 4). Regional floras containing between 10%–15% of "Old World Tropical" genera were mainly found south of 25° N latitude, except some are in deep valleys with a dry and hot climate in south-western China, for example, the floras from the valley of Jinshajiang river at ca. 102.69° E, 27.07° N and the valley of Nujiang river in western Yunnan at 98.9° E, 26° N.

2.1.4 "Tropical Asia to Tropical Australia" distribution (Type 5)

The genera of "Tropical Asia to Tropical Australia" are also completely absent from several northern regional floras and reach their highest proportion (12.6% of the total genera)

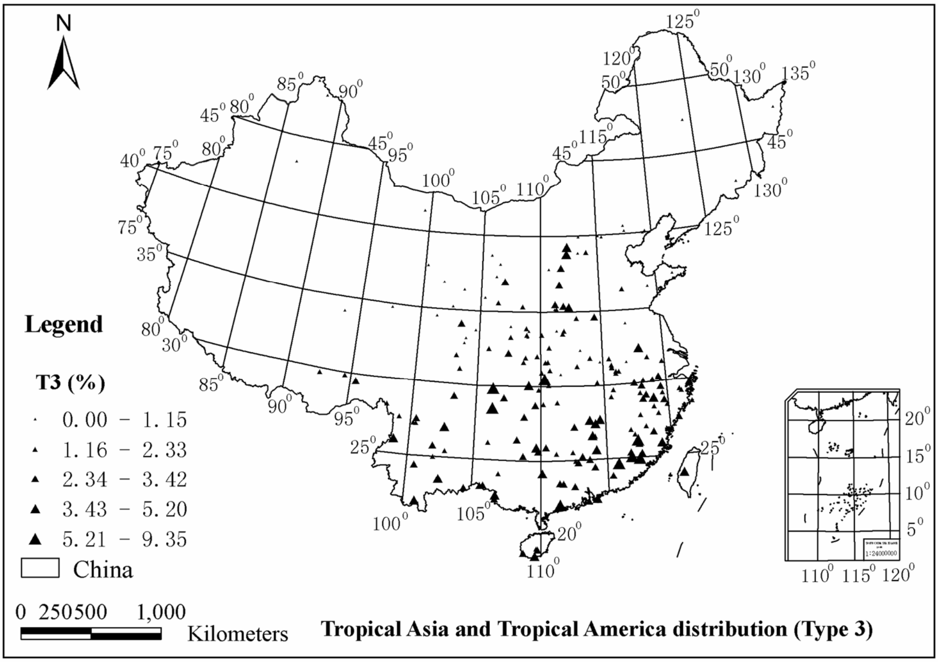

Fig. 3. Disjunct Tropical Asia and Tropical America distribution.

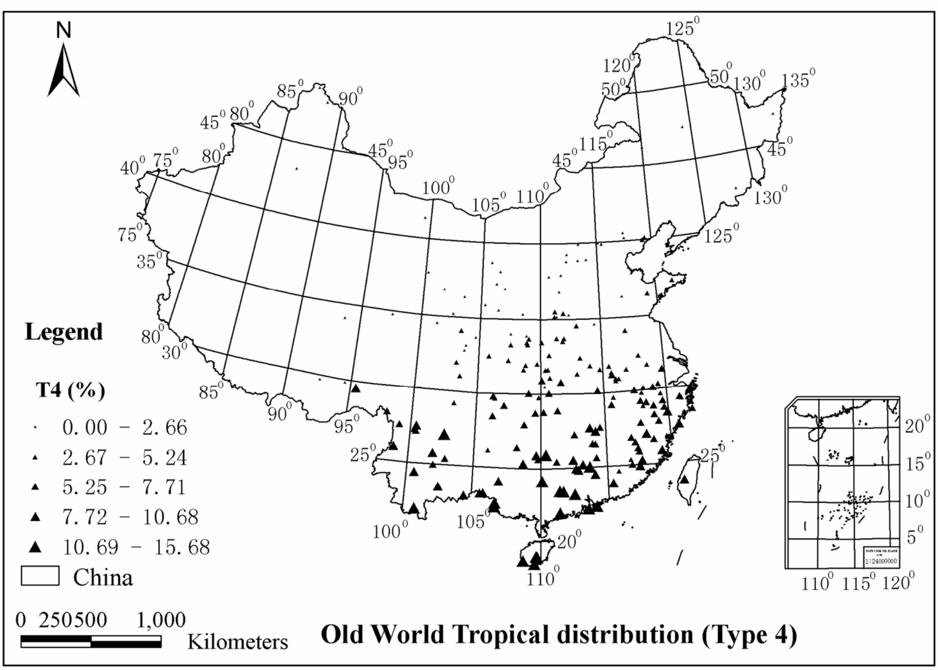

Fig. 4. Old Word Tropical distribution.

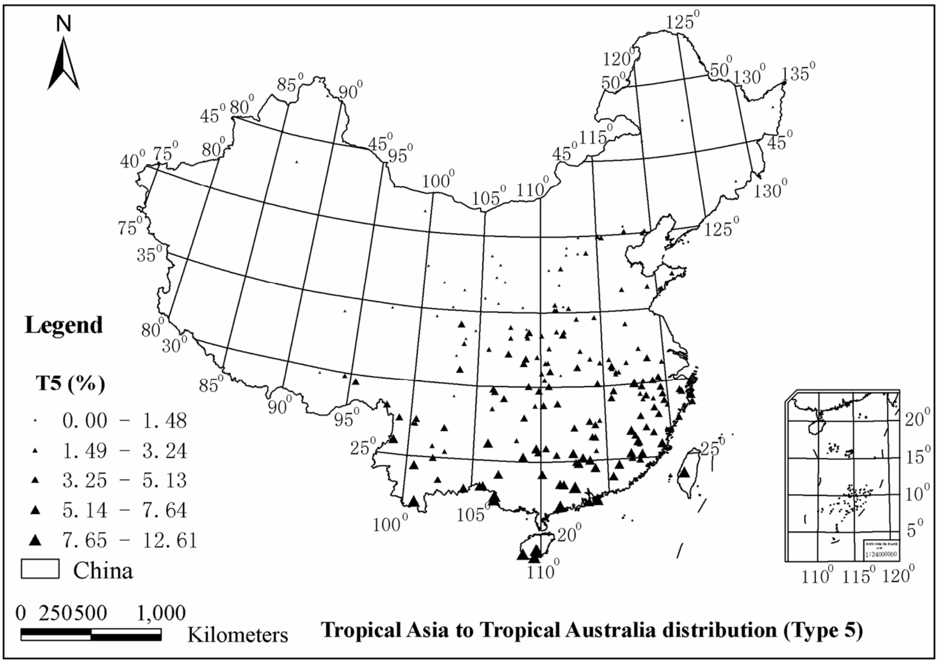

Fig. 5. Tropical Asia to Tropical Australia distribution.

on Hainan Island (~109.6° E, 18.4° N). The relative frequencies of these genera also show strong correspondence to latitudinal gradients, as expected (Fig. 5). The regional floras with the proportion of these genera accounting for more than 7% were found from the areas of <23° N latitude in southwestern China and the areas of <25° N latitude in southeastern China.

2.1.5 "Tropical Asia to Tropical Africa" distribution (Type 6)

These tropical genera are also missing from several northern regions, while they reach their highest proportion (10.29% of the total genera) in the dry and hot climate of the Yuanjiang region of Yunnan Province (~102.5° E, 23.5° N). Their relative frequencies also show strong correspondence to latitudinal gradients (Fig. 6). In the hot, dry valleys of the Jinshajiang river (south of 27.5° N) and in southeastern China (south of <23.5° N), these Type 6 genera were quite frequent (>6.7%).

2.1.6 "Tropical Asia" distribution (Type 7)

The "Tropical Asia" distribution includes 611 genera in China and is the largest group of tropical floristic elements in China (Table 1). These genera are the most dominant floristic element in regional floras in southern China. Missing in the northern latitudes, they account for up to 42.26% of the total genera in southern Yunnan Province (~100.9° E, 21.9° N), with the second highest relative frequency (29.95%) observed on the island of Hainan (~109.7° E, 18.9° N) (Fig. 7). The regional floras with these genera accounting for more than 20% of the total genera were found in the areas south of 23° N in southwestern China and south of 25° N in southeastern China. These genera decreased conspicuously with increasing latitude, dropping below 3% of the total genera in areas north of 32° N.

2.1.7 "North Temperate" distribution (Type 8)

The "North Temperate" distribution includes 302 genera in China and is the largest group of temperate floristic elements in China. These genera were present in all regional

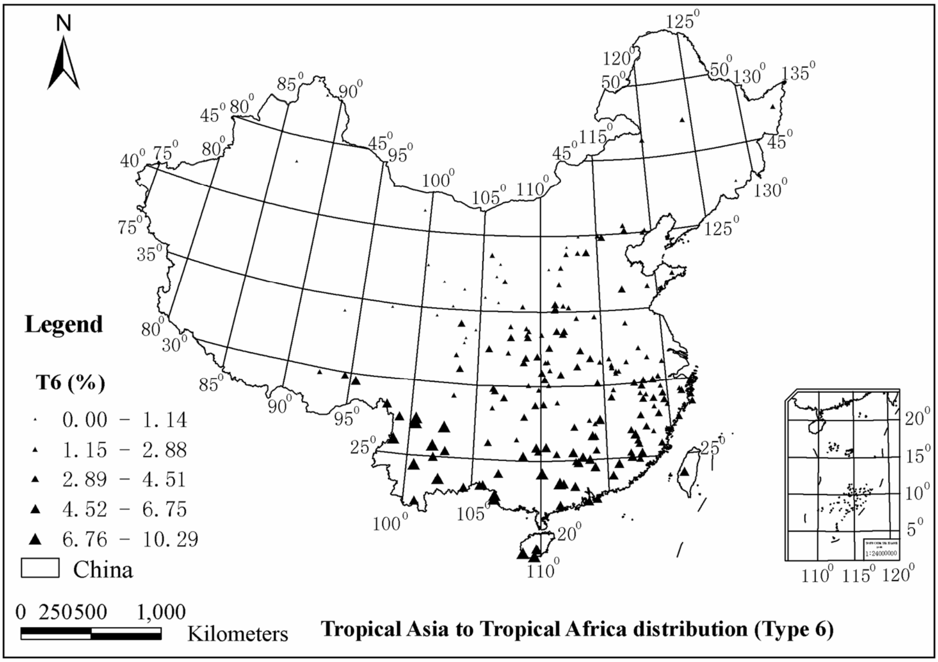

Fig. 6. Tropical Asia to Tropical Africa distribution.

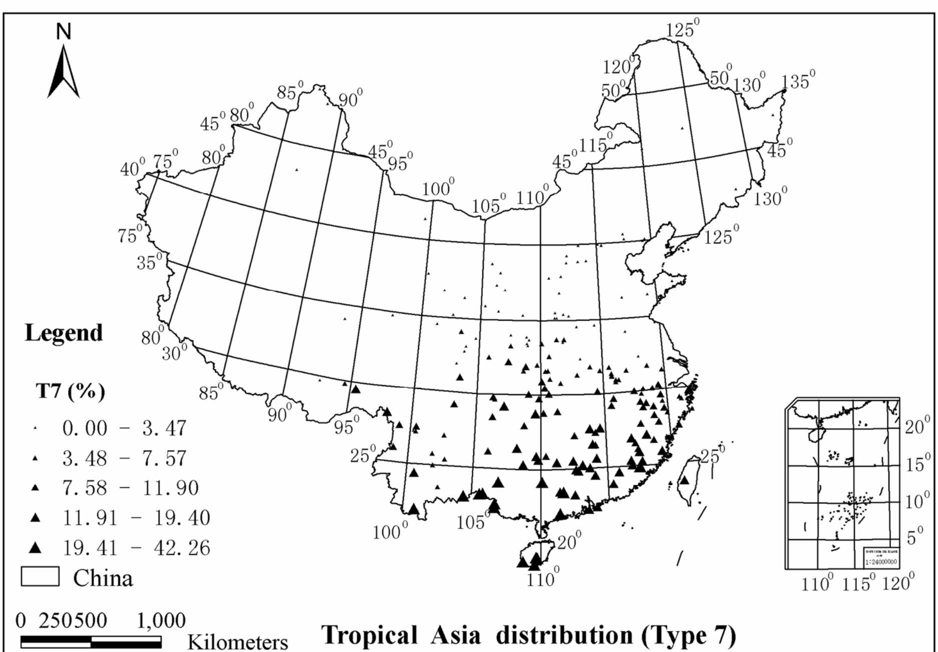

Fig. 7. Tropical Asia distribution.

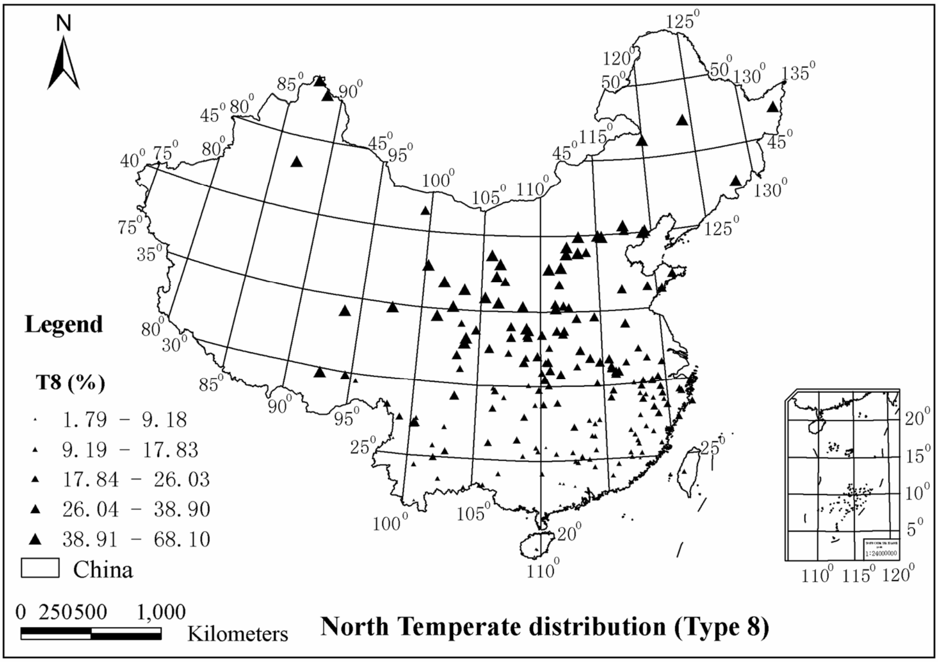

Fig. 8. North Temperate distribution.

floras and show a strong correspondence with latitudinal gradients, accounting for 1.79% of the total genera in southern Yunnan Province (~100.9° E, 21.88° N) at its lowest proportion to 68.1% in temperate northwestern China (~106.6° E, 38.1° N) (Fig. 8). These genera are the dominant elements in regional floras throughout northern China. The local floras with these genera forming less than 10% of the total genera were found mainly from the areas <25° N latitude, and the floras with the proportion less than 20% were found mainly in the areas of <30° N latitude.

2.1.8 "East Asia and North America disjunct" distribution (Type 9)

The genera of "East Asia and North America disjunct" distribution are most frequent in regional floras in centre-east China, and missing from several north-western most regions of China. They reach their highest proportion (16.16% of the total genera) in the subtropical area of eastern China (~118.9° E, 28.9° N) (Fig. 9).

2.1.9 "Old World Temperate" distribution (Type 10)

The genera of this type have their highest proportion (20.18% of the total genera) in Altai of Xinjiang (~88.5° E, 48° N) in northwestern China, while they are almost absent from several south-western most regions in China. They occur mainly in the temperate north and west China (Fig. 10). The regional floras with these genera accounting for more than 10% of the total genera were found mainly in the areas of >32° N latitude except fewer sites, for example in the northwestern Yunnan owing to high altitude.

2.1.10 "Temperate Asia" distribution (Type 11)

The genera of "Temperate Asia" distribution in China have a similar pattern to these of

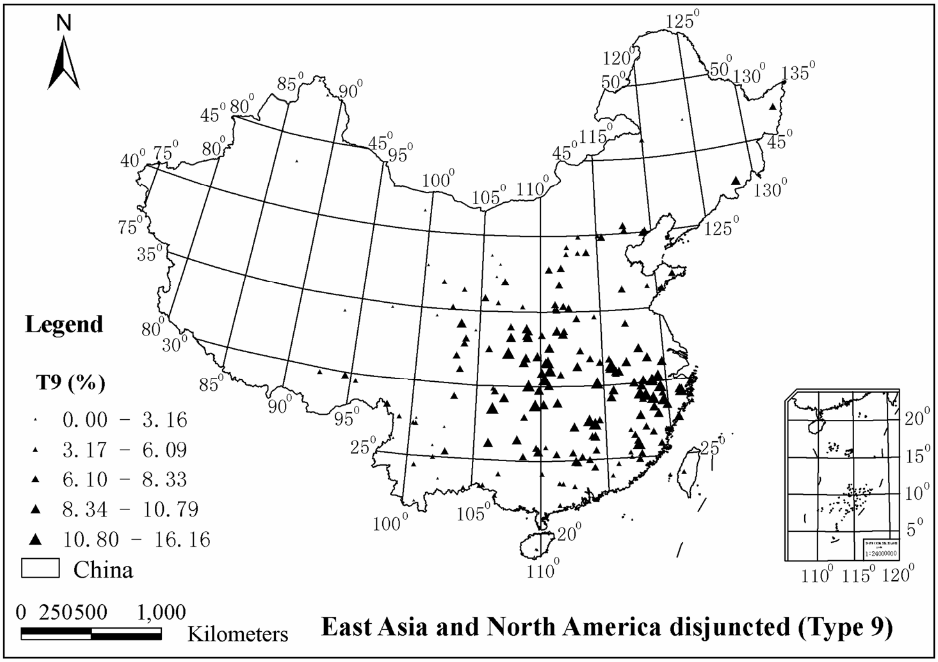

Fig. 9. Disjunct East Asia and North America distribution.

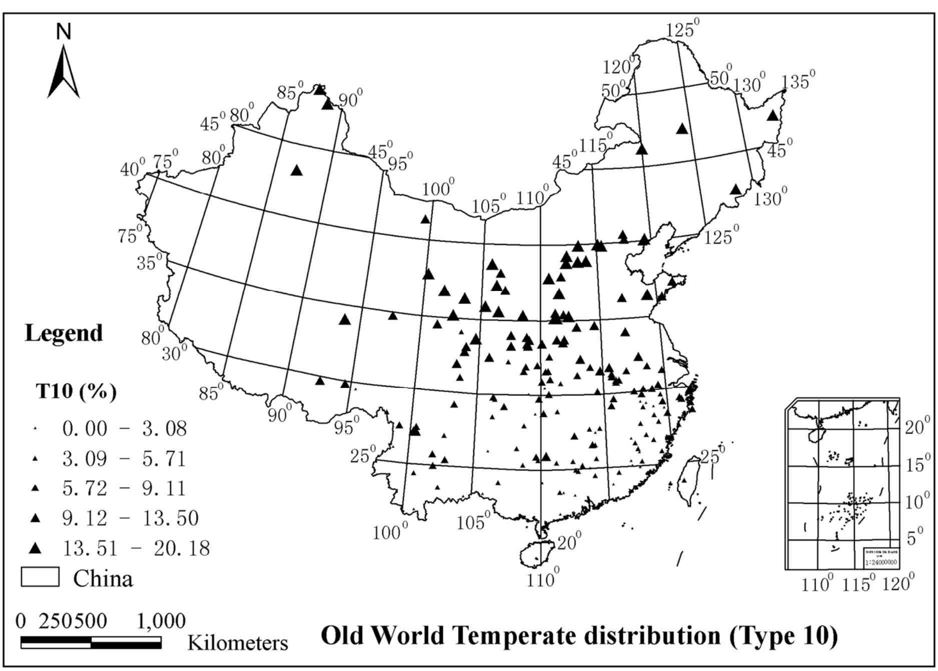

Fig. 10. Old World Temperate distribution.

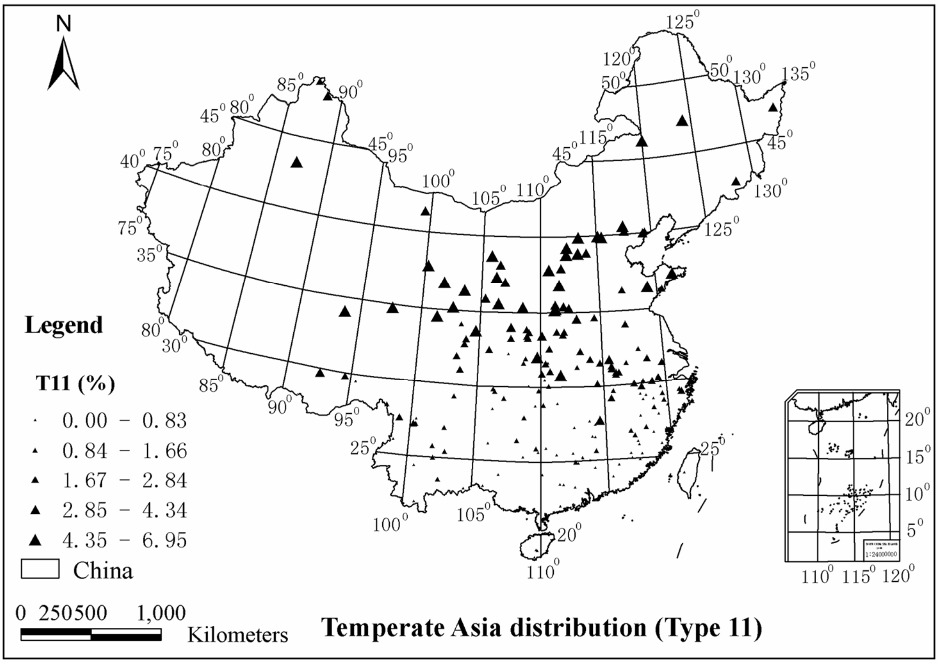

Fig. 11. Temperate Asia distribution.

"Old World Temperate" distribution. These genera reach their highest proportion (6.95% of the total genera) in Ningxia (~105.8° E, 38.7° N) in northwestern China and their second highest proportion (6.32% of the total genera) in Heilongjiang (~120.0° E, 46.2° N) in northeastern China, and show strong correspondence to latitudinal gradients (Fig. 11). The regional floras with these genera accounting for more than 3% of the total genera were found mainly in the areas of >32° N latitude with the sole exception of one in Jiangxi at ca. 114.63° E and 27.67° N.

2.1.11 "Mediterranean, West Asia to Central Asia" distribution (Type 12)

The genera of this distribution occur mainly in temperate northwest China (Fig. 12). The genera reach their highest proportion (30% of the total genera) in western Nei Mongol (~99.53° E, 41.38° N) in northern China, while they have their lowest proportion in regions in southern China.

2.1.12 "Central Asia" distribution (Type 13)

The genera of "Central Asia" distribution occur mainly also in the temperate northwest China (Fig. 13), with their highest proportion (7.58% of the total genera) in Altai of Xinjiang (~88.5° E, 48° N) in northwestern China. The regional floras with these genera accounting for more than 3% of the total genera were mainly found in the areas of >34° N latitude.

2.1.13 "Eastern Asia" distribution (Type 14)

The "Eastern Asian" distribution includes 300 genera in China and is the second largest group of temperate floristic elements in China. These genera occur mainly in the subtropical area of China (Fig. 14). They reach their highest proportion (24.44% of the total genera) in northern Guangxi (~110.5° E, 25.9° N) in centre-south China. The regional floras with these genera accounting for more than 17% of the total genera were mainly found in the areas between 103° E and 122° E longitudes, and between 25° N and 34° N latitudes.

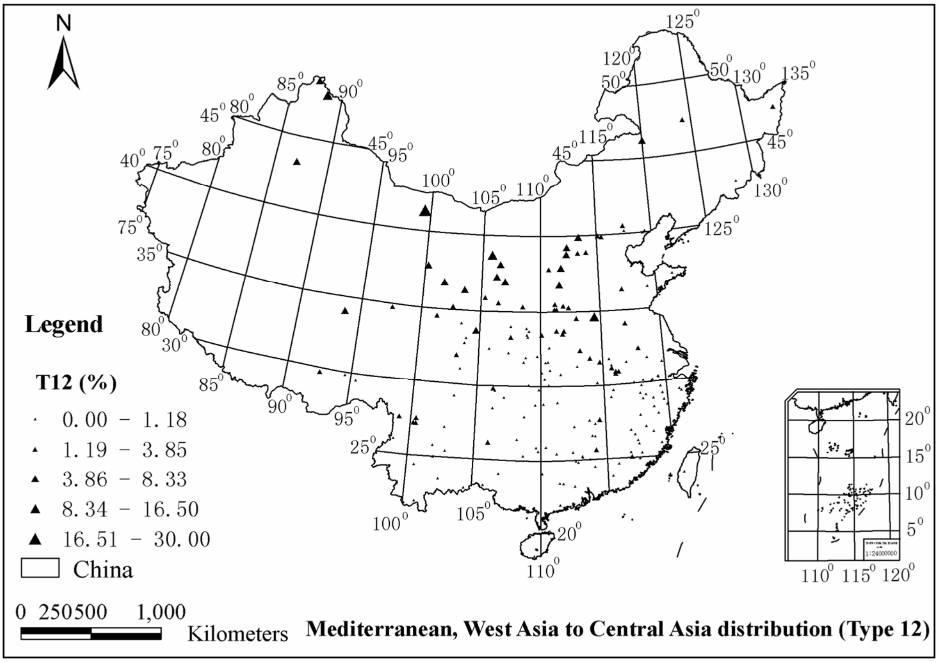

Fig. 12. Mediterranean, West Asia to Central Asia distribution.

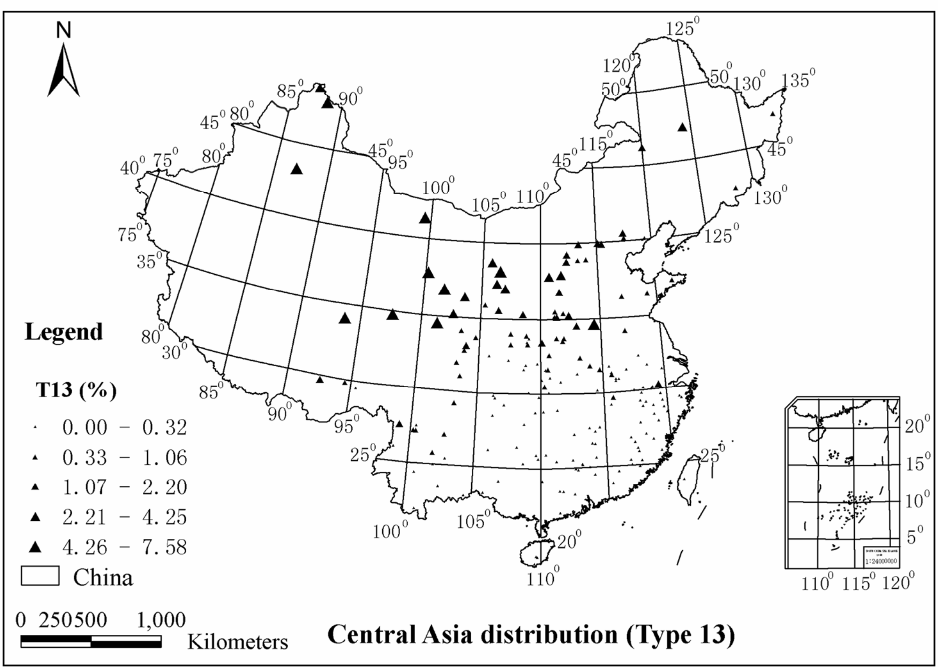

Fig. 13. Central Asia distribution.

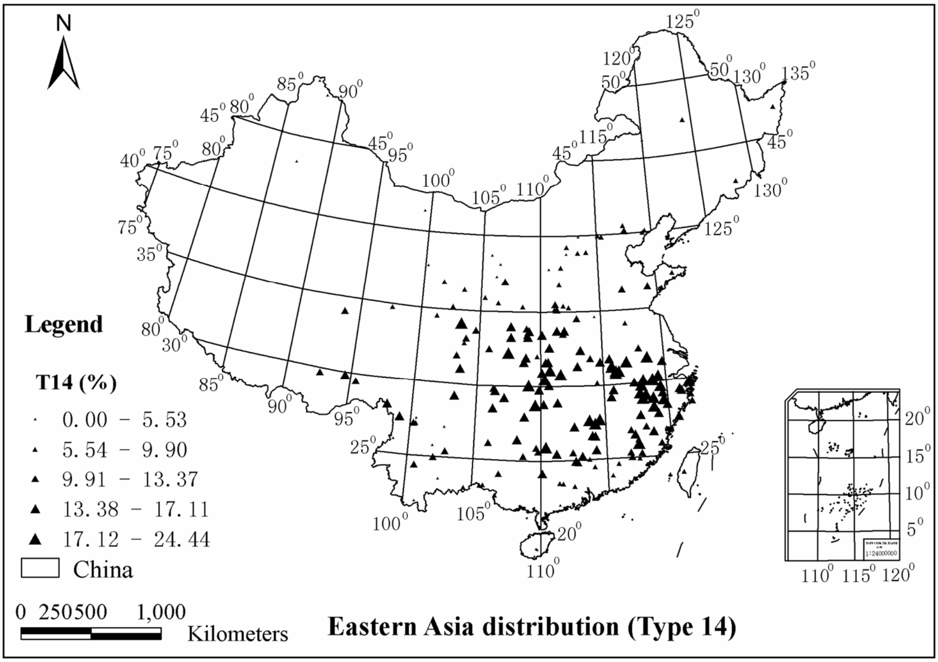

Fig. 14. Eastern Asia distribution.

2.1.14 "Chinese Endemics" (Type 15)

The genera of endemic to China occur mainly in subtropical area of China (Fig. 15). These genera reach their highest proportion (7.35% of the total genera) in Dabashan (~107.5° E, 32.2° N) in Sichuan Province in centre-south China. The regional floras with these genera in a very low proportion were found in the areas of >40° N latitude. It is interesting that the proportion of these Chinese endemic genera was only 1.53% of the total genera in the flora of Taiwan Island.

2.2 Correlation to longitudinal and latitudinal gradients

All these phytogeographic distribution types, except "Chinese endemics", were correlated with geography, most strongly with latitudinal gradients (Table 2). The lack of correlation between the relative frequency of endemic taxa and geography would be expected if endemic taxa are generated equally across the regional floras of China. Both temperate and tropical groups responded strongly to geographic gradients, particularly the "North Temperate", "Old World Temperate", "Old World Tropic", "Tropical Asia to Tropical Australia" and "Temperate Asia" phytogeographic classes (Table 2).

2.3 Correlation to climatic gradients

2.3.1 Correlation to air temperature

The relative frequencies of most phytogeographic classes in the regional floras of China were closely correlated with all four aspects of air temperature examined: annual mean, annual maximum air temperature, annual minimum air temperature and ⩾10°C accumulated air temperature (Figs. 16–19, respectively). Three classes ("East Asia and North America disjunct", "Eastern Asian" and "Chinese endemics") were not well correlated with these climate factors. The "North Temperate" class was most closely correlated with the first three descriptors for air temperature while the "Tropical Asian to Tropical Australian" class was

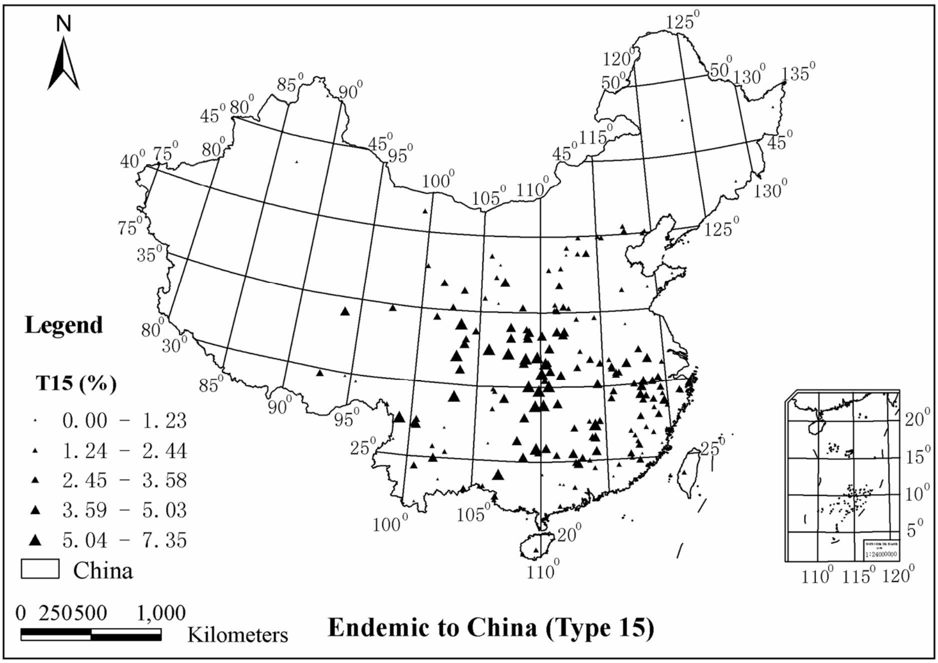

Fig. 15. Endemic to China.

most closely correlated with ⩾10°C accumulated air temperature. The combined tropical genera (Types 2–7) and combined temperate genera (Types 8–14) have very high correlation values with all four aspects of air temperature.

Table 2 The relation coefficients of distribution types to longitudinal and latitudinal gradients

Distribution types	Constant	Longitude	Latitude	Relation coefficients
2 Pantropical	20.115	0.242	–0.949	0.743**
3 Tropical Asia & Tropical America disjuncted	4.280	0.025	–0.155	0.583**
4 Old World Tropic	17.116	0.032	–0.501	0.838**
5 Tropical Asia to Tropical Australia	9.059	0.040	–0.327	0.819**
6 Tropical Asia to Tropical Africa	14.073	–0.023	–0.265	0.745**
7 Tropical Asia	42.320	–0.020	–1.037	0.816**
8 North Temperate	1.910	–0.364	2.078	0.879**
9 East Asia and North America disjuncted	–12.936	0.187	–0.028	0.452**
10 Old World Temperate	–4.468	–0.089	0.731	0.872**
11 Temperate Asia	–2.198	–0.030	0.247	0.806**
12 Mediterranean, W Asia to C Asia	7.010	–0.124	0.275	0.616**
13 Central Asia	5.696	–0.087	0.154	0.735**
14 East Asia	–8.666	0.235	–0.186	0.396**
15 Endemic to China	6.782	–0.026	–0.037	0.179*

*, p<0.05; **, p<0.00001

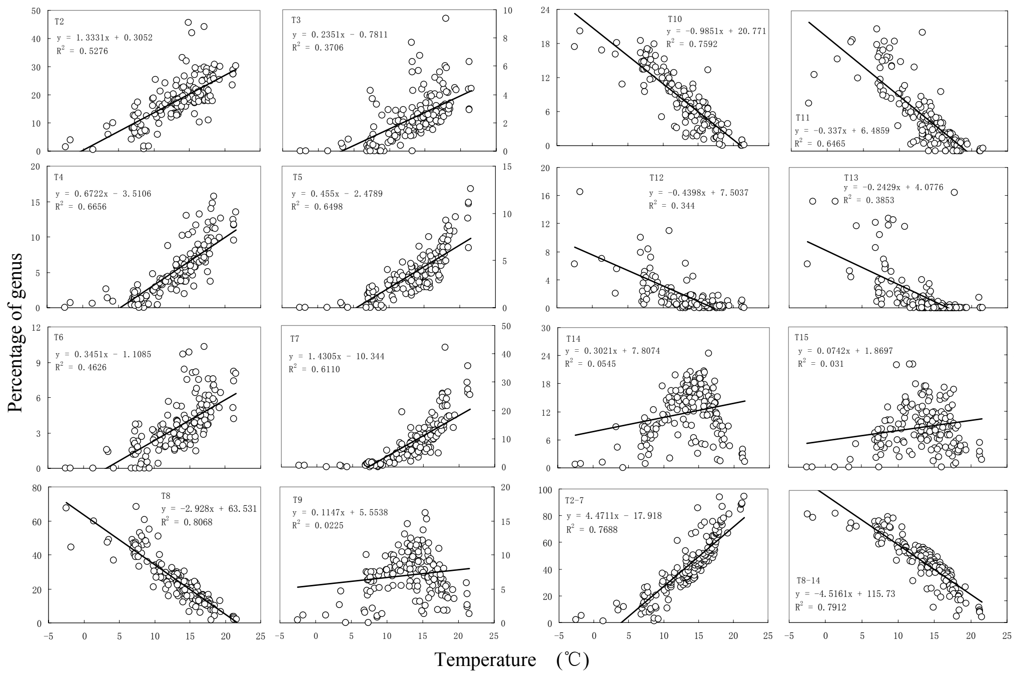

Fig. 16. The relations of distribution types of genera to mean annual air temperature.

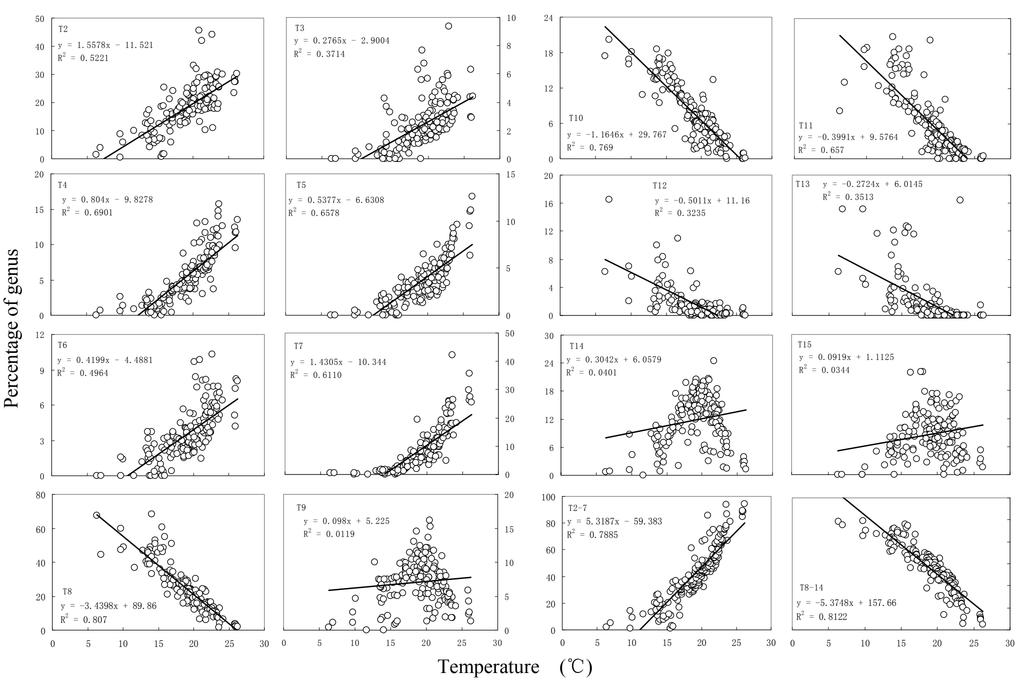

Fig. 17. The relations of distribution types of genera to maximum air temperature.

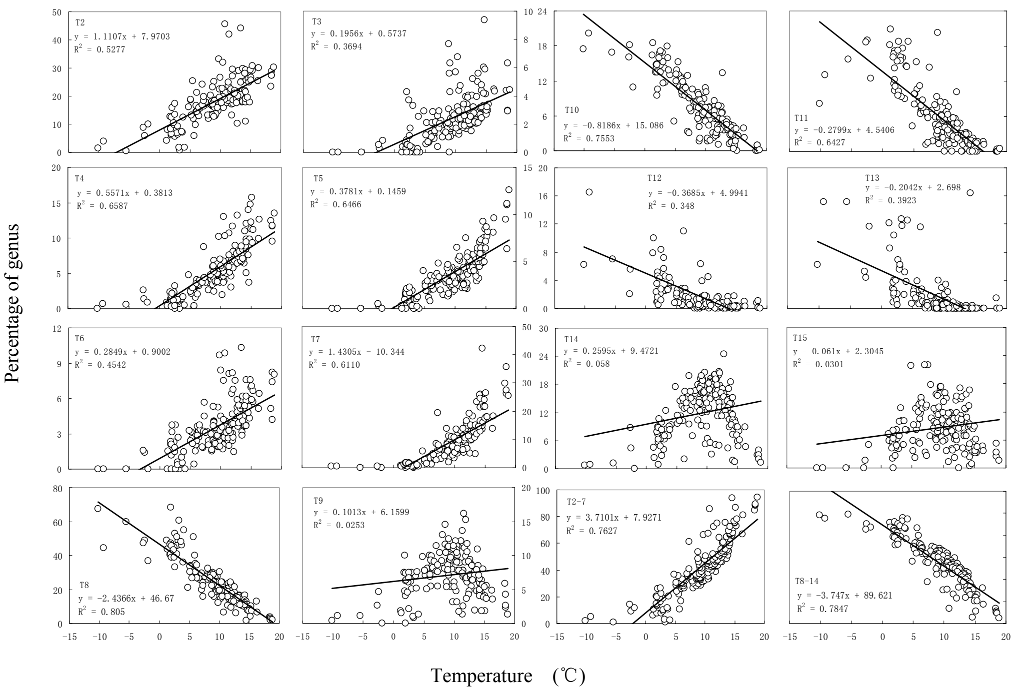

Fig. 18. The relations of distribution types of genera to minimum air temperature.

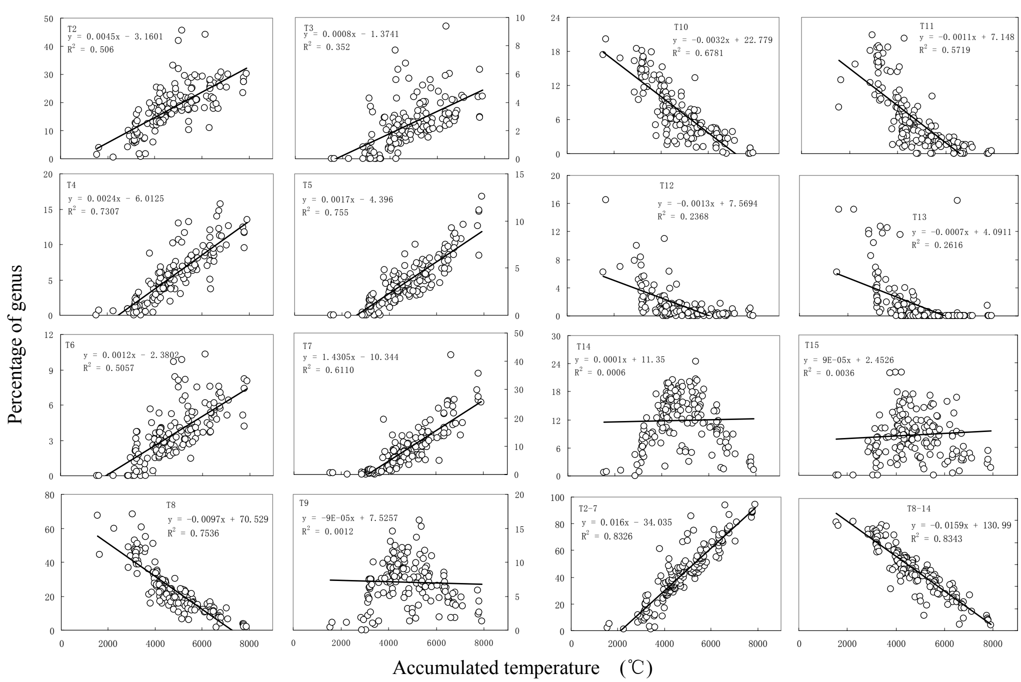

Fig. 19. The relations of distribution types of genera to ≥10 ℃ accumulated air temperature.

2.3.2 Correlation to mean annual precipitation and mean annual air relative humidity

The same three classes mentioned above ("East Asia and North America disjunct", "Eastern Asian" and "Chinese endemics") were not correlated with precipitation or humidity. The "North Temperate" class has the closest correlation to mean annual precipitation and mean annual air relative humidity (Figs. 20, 21). The combined tropical genera (Types 2–7) and combined temperate genera (Types 8–14) show high correlation values to mean annual precipitation and mean annual air relative humidity, particularly with the first factor.

3 Summary and discussion

In our analysis, the combined phytogeographic patterns of Chinese seed plant genera largely support and further refine Wu's classification system (Wu 1980). The boundary between tropical and subtropical genera determined here (~22° 30' N), south of which regional floras are dominated by tropical genera, corresponds well with previously recognized boundaries between "subtropical evergreen broad-leaved" and "tropical monsoon and rain" forests (Wu, 1980; Wu & Wu 1996; Hou, 1988). It also agrees approximately with the geographic definition of the East Asiatic (Wu, 1989; Wu & Wu, 1996), Holarctic (Takhtajan, 1978), and Paleotropical Kingdoms (Fig. 24).

This main conclusion from our study is similar to the results found by Qian et al. (2003), although we found that the boundary between tropical and temperate regions was further south by 3° latitude. This difference in our results is due to the greater geographic detail used here. Qian et al. (2003) used provincial floras of China (23 total), while we used 204 regional floras. H Qian et al. then defined midpoint latitudes for each province, which were grouped into five latitudinal zones. This approach may mask natural environment heterogeneity within

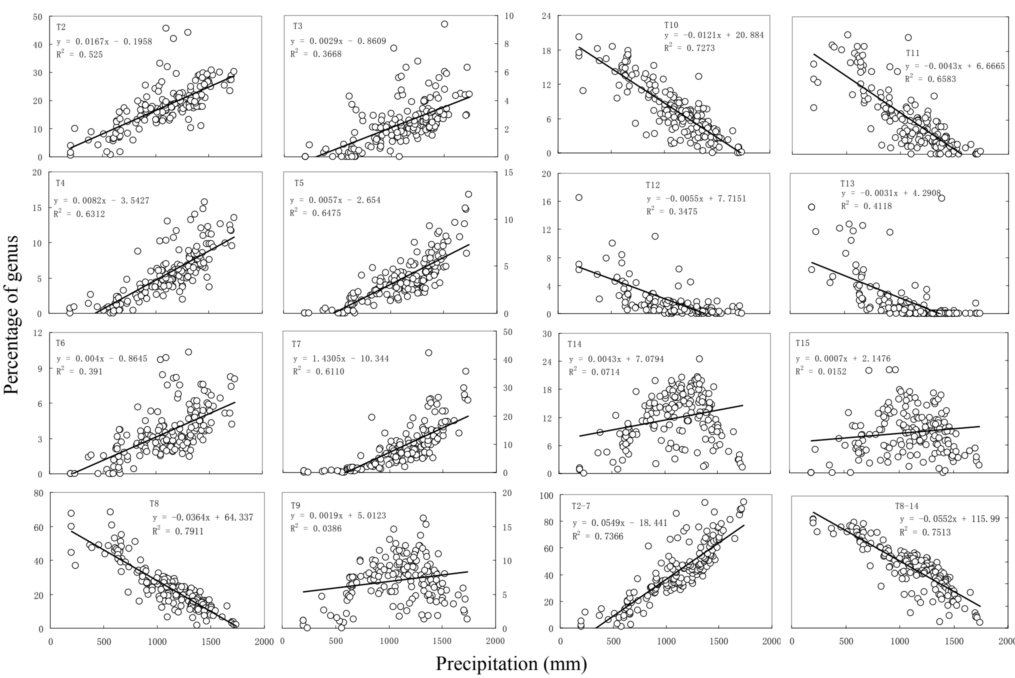

Fig. 20. The relations of distribution types of genera to mean annual precipitation.

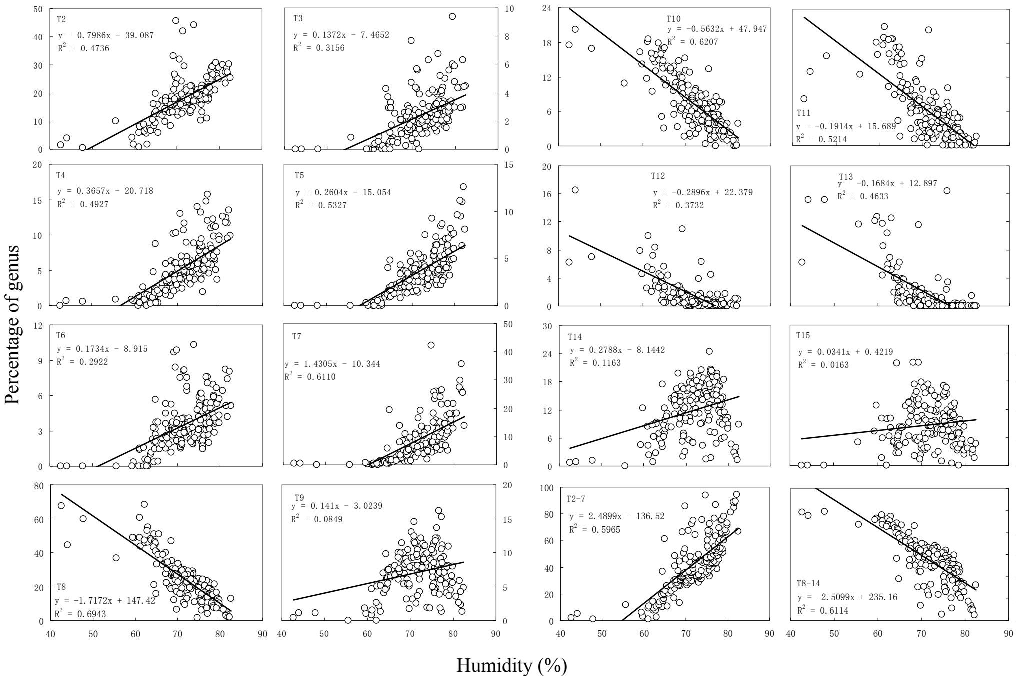

Fig. 21. The relations of distribution types of genera to mean annual air relative humidity.

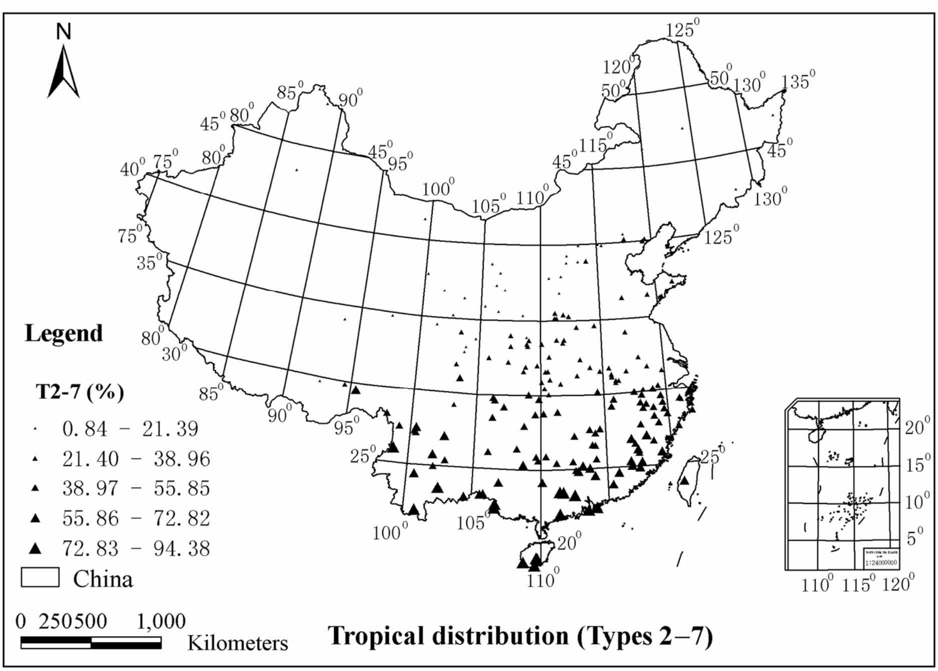

Fig. 22. Tropical distributions combined.

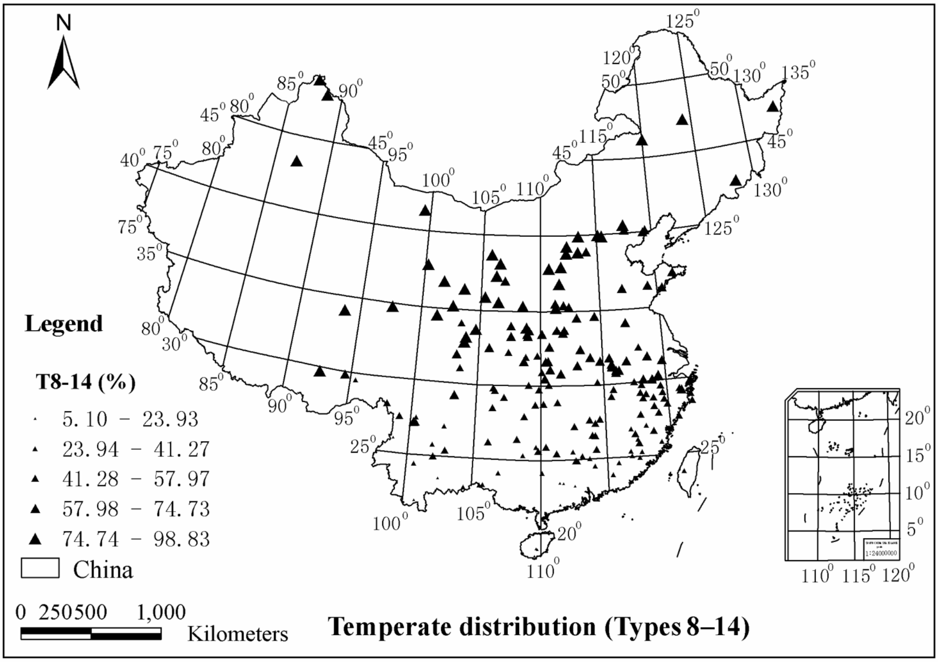

Fig. 23. Temperate distributions combined.

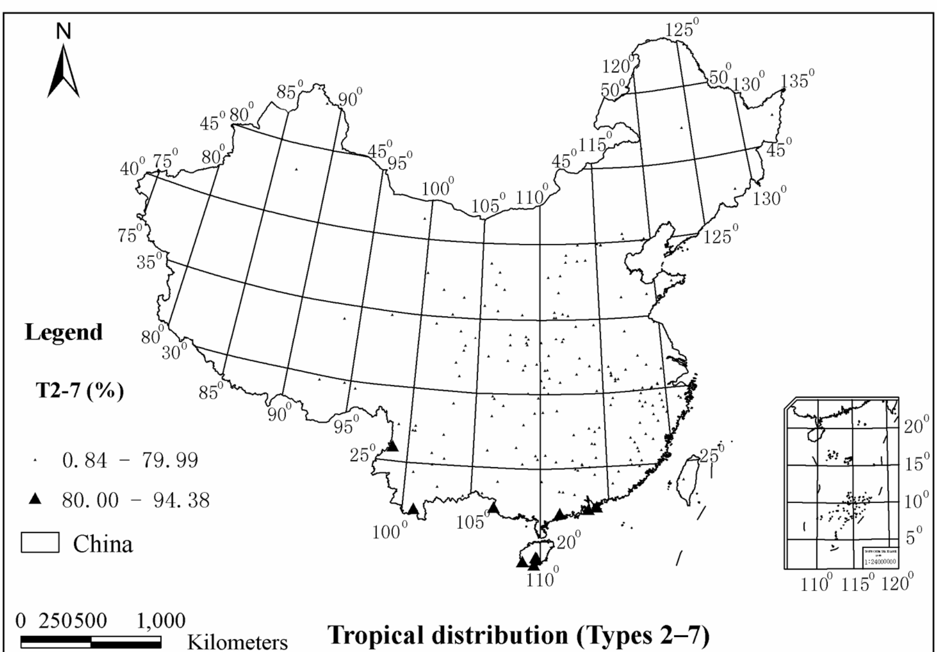

Fig. 24. Tropical distributions combined (Two classes with arbitrary break at proportion of 80% of the total genera).

provinces to some extent. The local floras used in our study have latitudinal attributions at their points and the classes of frequency of distribution types were classified by natural breaks.

The boundary between temperate and subtropical genera determined in this analysis (~32° 30′ N), north of which regional floras are composed of ⩾70% temperate genera (Fig. 25), more or less corresponds to the boundary between "warm temperate deciduous broad-leaved" and "subtropical evergreen broad-leaved" forest in eastern China (Wu, 1980; Hou, 1988). If the threshold for this boundary is raised to 80% temperate genera in local floras, its geographic position approximately matches the boundaries between "warm temperate deciduous broad-leaved" and "temperate coniferous/deciduous broad-leaved mixed" forest in northern China, "temperate grassland" and "warm temperate deciduous broad-leaved" forest in north-eastern China, and "cold temperate alpine" and "sub-alpine" vegetation areas in western China and the so called forest area in eastern China (Wu, 1980; Hou, 1988) (Fig. 27).

Biogeographical divisions of China were recently suggested based mainly on distributions of 171 mammal species and 509 plant species (Yan et al., 2004). In that study, the tropical zone merged southern Yunnan, south-western Guangxi, and Hainan Island into a single, large biogeographical unit of "coast and islands of southern China" with its northern boundary at ~30° N latitude. This one biogeographical region was composed of several different zones in our study. Our study revealed that the line of ~22° 30′ N latitude, south of which regional floras are dominated by tropical genera, corresponds well with previously recognized boundaries between "subtropical evergreen broad-leaved" and "tropical monsoon and rain" forests (Wu, 1980; Wu and Wu 1996; Hou, 1988) and also agrees approximately with the geographic definition of the East Asiatic (Wu, 1989; Wu and Wu, 1996), Holarctic (Takhtajan, 1978), and Paleotropical Kingdoms.

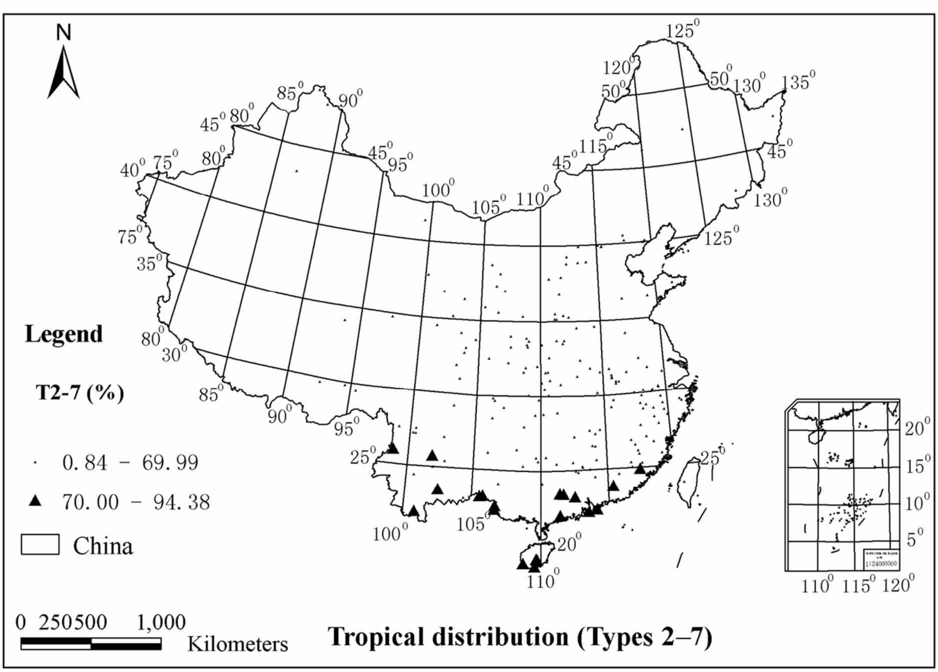

Fig. 25. Tropical distributions combined (Two classes with arbitrary break at proportion of 70% of the total genera).

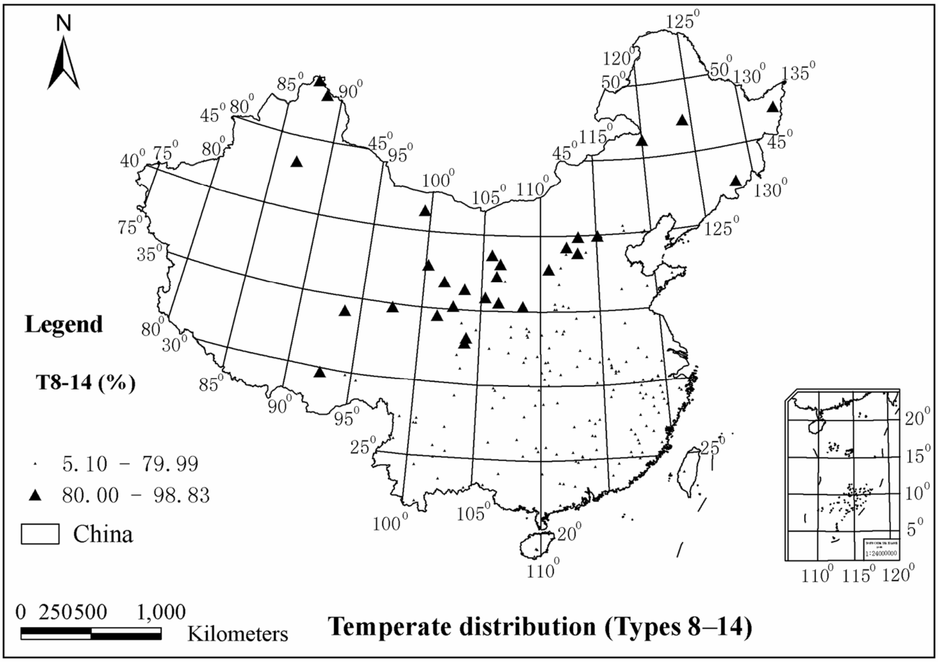

Fig. 26. Temperate distributions combined (Two classes with arbitrary break at proportion of 80% of the total genera).

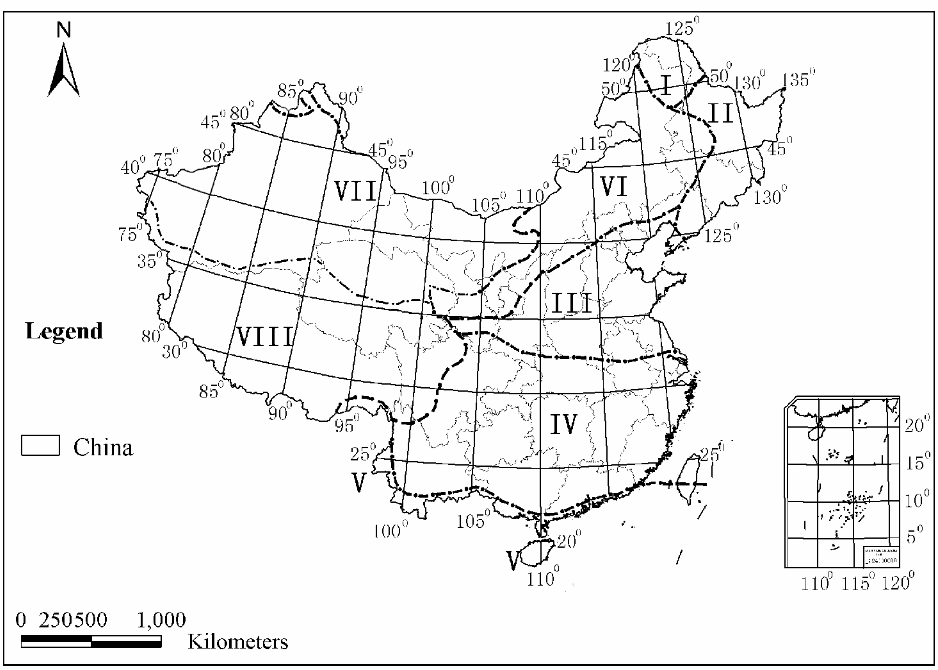

Fig. 27. The regionalization of Chinese vegetation. I: Cold temperate coniferous forest region; II: Temperate coniferous–broad-leaved mixed forest region; III: Warm temperate deciduous broad-leaved forest region; IV: Subtropical evergreen broad-leaved forest region; V: Tropical monsoon forest and rain forest region; VI: Temperate grassland region; VII: Temperate desert region; VIII: Cold alpine region in Tibetan-Qinghai highland. Redraw from Wu, 1980. Vegetation of China, the map of the regionalization of Chinese vegetation.

Many genera of disjunct Tropical Asia and Tropical America distribution are not native but introduced or invasive in China, for example, *Ageratum, Opuntia, Thevetia, Tridax* etc. Their distributions in China more correspond to human activities than natural dispersion.

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中国种子植物属的地理成分分布格局及其与气候和地理的关系

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摘要 基于覆盖了全中国各地理区的204个地区植物区系研究资料和这些地区的841个气象站资料, 我们对中国种子植物属的地理成分分布格局及其与气候、经纬度分布的关系进行了研究, 并结合这些分布格局探讨了中国植被分带和植物区系分区。结果如下: (1) 除世界分布、栽培和入侵成分外, 大部分中国种子植物属的地理成分的分布与地理相关密切; (2) 热带分布属(泛热带分布、热带亚洲至热带美洲间断分布、旧世界热带分布、热带亚洲至热带大洋洲分布、热带亚洲至热带非洲分布及热带亚洲分布合计)占各地方植物区系的0.84%到94.38%, 其最低值出现在中国西北部的新疆和青海地区, 最高值出现在中国云南南部和海南; (3) 热带分布属在<北纬30º的地区占优势, 除热带亚洲至热带美洲间断分布外, 其它热带成分随纬度增加迅速减少; (4) 温带分布属(北温带分布、东亚和北美间断分布、旧世界温带分布、温带亚洲分布、地中海区、西亚到中亚分布、中亚分布和东亚分布合计)占各地方植物区系的5.1%至98.83%, 其最高值出现在中国西北部的新疆地区, 最低值出现在中国云南南部和海南; (5) 除东亚和北美间断分布、东亚分布和中国特有分布外, 其它温带成分随纬度增加迅速增加; (6) 在温带成分中, 东亚和北美间断分布及东亚分布属主要出现在中国亚热带到暖温带地区, 北温带分布、旧世界温带分布和温带亚洲分布属在中国北部占优势, 而地中海区、西亚到中亚分布和中亚分布属则在中国西北部占优势; (7) 除世界分布、东亚和北美间断分布、东亚分布和中国特有分布外, 所有其他成分都显示了与气候因素(主要是气温和降雨量)密切相关, 其中, 北温带分布属与年均温和年降雨量最为密切相关。中国种子植物属的地理成分的分布格局与现行的中国植被分带和植物区系分区密切匹配, 支持现行的中国植被分带和植物区系分区方案。

关键词 中国种子植物属; 地理成分; 分布格局; 气候和地理相关性

Appendix 1 Location of regional floras used in this paper

Region	Province	Longitude	Latitude	References
Banqiao	Anhui	118.63	31.70	Zhang G-F & Song Y-C, 2001
Dabie Mt.	Anhui	116.08	30.75	Liu B, 1991
Dabie Mt.	Anhui	115.78	31.18	Liu P & Wu G-F, 1994
Dali	Anhui	117.47	30.04	Jiang M-Q et al., 1990
Duozhijian, Dabie	Anhui	116.08	30.88	Xie Z-W & Wu G-F, 1993
Huangshan	Anhui	118.18	30.17	Hu J-Q & Liang S-W, 1996
Huangshan	Anhui	118.18	30.17	Zhang G-F, 2003
Huangzangyu	Anhui	117.08	34.05	Xie Z-W et al., 1995
Mazongling, Dabieshan	Anhui	115.75	31.31	Liu P et al., 1992
Qingliangfeng	Anhui	118.87	30.12	Huang C-L, 1993
Shiweng, Qinling	Anhui	109.10	33.68	Chen S-Q & Ma W-L, 1999
Tiantangzhai	Anhui	115.76	31.11	Shen X-S, 1989
Yaoluoping	Anhui	116.30	30.88	Xie Z-W & Cai Y-L, 1994
Zhutoujian, Shucheng	Anhui	116.96	31.46	Zou L-X & Wu G-F, 1997
Huangfushan	Anhui	118.01	32.35	Wang X et al., 2003
Qiyun	Anhui	118.03	29.81	Zhang H-C, 2003
Hua-an	Fujian	117.50	24.91	Li K-.M, 1996
Longqi mountain	Fujian	117.27	26.55	Li Z-Y, 1994
Mengtongyang, Nanping	Fujian	118.67	26.67	You S-S, 1992
Rongyan Zijin Mountain	Fujian	116.93	25.07	Li X-Q & Lin L-G, 1998
Sanming	Fujian	117.43	26.17	Shen Z-H & Zhang X-S, 2000

Appendix 1 (continued)

Region	Province	Longitude	Latitude	References
Shibachong	Fujian	119.23	25.87	Lin C-C et al., 1994
Tianbaoyan, Yongan	Fujian	117.53	25.94	Li M-B et al., 1999
Wanmulin	Fujian	118.15	27.05	Gao J & Yang B-S, 1995
Wuyi	Fujian	117.78	27.85	Ma K-P et al., 1995
Anxi	Fujian	117.68	25.31	Lin Y-M et al., 2002
Minjiang Yuan	Fujian	116.98	26.88	Liu J-Q et al., 2003
Qilianshan	Gansu	100.29	37.79	Wang G-H et al., 1995
Taohe River	Gansu	102.71	35.17	Zhang Y-J et al., 1997
Xiaolong	Gansu	104.71	33.68	Mao X-W et al., 2003
Kongdong	Gansu	106.52	35.55	Wu X-J et al., 2003
Chebaling	Guangdong	114.11	24.50	Chen X-M et al., 1994
Dadongshan	Guangdong	112.70	24.92	Tang S-Q et al., 1997
Danxiashan	Guangdong	113.75	25.02	Liu W-Q et al., 1999
Dinghu	Guangdong	112.58	23.18	Ma K-P et al., 1995
Heishiding	Guangdong	111.75	23.38	Shi S-H, 1987
Lechang	Guangdong	113.21	25.23	Ye H-G et al., 1992
Nanling	Guangdong	112.88	24.82	Chen X-M et al., 1999
Pingyuan	Guangdong	115.90	24.66	Feng Z-J et al., 1994
Qimuzhang	Guangdong	115.42	23.85	Wang Y-J et al., 1993
Dayao	Guangdong	113.22	25.18	Miao S-Y & Wang H-L, 2003
E'Huangzhang	Guangdong	111.48	21.91	Wang F-G et al., 2003
Zhaoqing	Guangdong	111.47	23.40	Cheng Q-Y et al., 1999
Dayao Mt.	Guangxi	110.18	24.07	Shen Z-H & Zhang X-S, 2000
Huaping	Guangxi	109.89	25.59	Shen Z-H & Zhang X-S, 2000
Jiuwandashan	Guangxi	108.72	25.29	Ma K-P et al., 1995
Karst region	Guangxi	106.71	22.57	Shen Z-.H & Zhang X-S, 2000
Longhua	Guangxi	105.58	23.20	Liu N et al., 1994
Miaoer Mt.	Guangxi	110.46	25.88	Shen Z-H & Zhang X-S, 2000
Napo	Guangxi	105.80	23.23	Yan L-C & Qin H-N, 2001
Nonggang	Guangxi	106.70	22.30	Shen Z-H & Zhang X-S, 2000
Bailongjiang Watershed	Gansu	103.50	34.09	Kang Y-X et al., 1999
Lanzhou	Gansu	103.58	36.34	Ju T-Z & Zhang S-L, 1997
Leigong Mt.	Guizhou	108.24	26.39	Shen Z-H & Zhang X-S, 2000
Longgong, Anshun	Guizhou	106.08	26.18	Deng L-L et al., 1993
Wenjinshan	Guizhou	108.79	27.93	Ma K-P et al., 1995
Bawangling	Hainan	109.25	18.96	Lian J-Y & Yu S-X, 2001
Ganshiling	Hainan	109.63	18.39	Xing F-W et al., 1993
Jianfengling	Hainan	108.34	18.61	Huang S-N et al., 2000
Wuzhishan	Hainan	109.73	18.90	Tang T et al., 2002
Diaoluo	Hainan	109.83	18.83	Ding T et al., 2002
Baihuashan	Hebei	115.49	39.87	Zhu H, 1997
Baxianzhuozi	Hebei	117.55	40.21	Ma K-P et al., 1995
Donglinshan	Hebei	115.50	39.90	Ma K-P et al., 1995
Qinhuangdao	Hebei	119.22	40.00	Zeng X-F, 1999
Wulin	Hebei	117.50	40.55	Feng T-J et al., 1999
Laoling	Hebei	119.42	40.13	Xu X-Y et al., 2003
Naolihe	Heilongjiang	133.27	46.93	Wu H-Y, 2001
Baotianman	Henan	111.90	33.50	Shi Z-M et al., 1996; Zhang N-Q, 1999
Funiushan	Henan	112.00	33.68	Ma K-P et al., 1995
Jigongshan	Henan	114.06	31.82	Ye Y-Z et al., 1992
Jingangtai	Henan	115.57	31.73	Shen Z-H & Zhang X-S, 2000
Kaifeng	Henan	114.53	34.60	Zhang G-B & Song S-Y, 1992
Laojieling	Henan	111.40	33.70	Shen Z-H & Zhang X-S, 2000
Sonshan	Henan	113.05	34.52	Ma K-P et al., 1995
Tongbai	Henan	113.28	32.38	Shen Z-H & Zhang X-S, 2000
Zhalong	Heilongjiang	124.20	47.22	Guo C-J et al., 1998.
Hong Kong	Hong Kong	114.18	22.32	Xing F-W et al., 1999

Appendix 1 (continued)

Region	Province	Longitude	Latitude	References
Dahongshan	Hubei	113.00	31.30	Deng M et al., 1996
Dalaoling	Hubei	110.83	31.05	Wu J-Q et al., 1996
Mufu	Hubei	114.55	30.14	Qiu D-R & Chen D-M, 1997
Mulinzi	Hubei	110.38	30.45	Song J-Z & Li B, 1990
Shengnongjia	Hubei	110.45	31.60	Zheng Z, 1993
Shiyan	Hubei	110.78	32.59	Shen Z-H & Zhang X-S, 2000
Taiyangping	Hubei	110.65	31.61	Shen Z-H & Zhang X-S, 2000
Xingdou	Hubei	109.12	30.05	Shen Z-.H & Zhang X-S, 2000
Yuquan	Hubei	111.67	30.78	Shen Z-H & Zhang X-S, 2000
Zhuxi	Hubei	109.81	32.00	Shen Z-H & Zhang X-S, 2000
Badagongshan	Hunan	109.93	29.74	Qi C-J et al., 1994
Baiyun, Baojing	Hunan	109.64	28.72	Cao T-R et al., 1996
Dupangling	Hunan	111.26	25.43	Yu X-L & Xue S-G, 1999
Hunan-Guizhou and Guangxi border region	Hunan Guizhou Guangxi	109.72	25.84	Zhao Y-L et al., 1997
Hupinshan	Hunan	110.73	30.05	Ma K-P et al., 1995
Jiaomuxi	Hunan	111.38	28.88	Liu N et al., 1994
Taoyuandong .	Hunan	114.00	26.61	Liu K-W & Hou B-Q, 1991
Nanyue	Hunan	112.65	27.25	Zuo J-B et al., 2002
Wulingshan	Hunan-Hubei	110.29	28.78	Chen G-X et al., 2002
Erjina county	Nei Mongol	99.53	41.38	Zhang Y-L, 1997
Daxinanlin	Nei Mongol	120.02	46.15	Ma K-P et al., 1995
Lushan	Jiangxi	115.80	29.61	Song J-Z & Li B, 1991
Pingxiang	Jiangxi	113.83	27.66	Liu R-L et al., 2003
Shanghai	Jiangsu	121.30	31.00	Shen Z-H & Zhang X-S, 2000
Zijin, Nanjing	Jiangsu	118.84	32.07	Shen Z-H & Zhang X-S, 2000
Congyi	Jiangxi	114.28	25.66	Song J-Z & Li B, 1991
Dagangshan	Jiangxi	114.63	27.67	Shen Z-H & Zhang X-S, 2000
Jinggang Mountain	Jiangxi	114.23	26.58	Liu R-L & Tang G-C, 1995
Sangqingshan	Jiangxi	118.07	28.92	Tang Y-F & Wu G-F, 1990
Wugong, Anfu	Jiangxi	114.27	27.42	Gao X-M, 1991
Wuyuan	Jiangxi	117.88	29.30	Rao P-C, 1996
Yixing	Jiangxi	119.81	31.36	Zhang L-X et al., 1998
Yunjushan Mt.	Jiangxi	115.60	29.16	Xie G-W et al., 1991
Changbai Mt.	Jilin	128.33	42.58	Fu P-Y et al., 1995
Macau	Macau	113.56	22.16	Xing F-W et al., 2003
Da Luo Mt.	Ningxia	106.29	37.30	Xu X-M & Dong Y-Z, 1997
Henanshan	Ningxia	105.82	38.73	Song J-Z & Li B, 1991
Source area of Changjiang	Qinghai	93.75	34.04	Wu Y-H, 2000
Source of the Yellow River	Qinghai	97.67	34.75	Wu Y-H, 1995
Xiqing	Qinghai	101.42	34.48	Wu Y-H, 2000
Huangshui	Qinghai	101.83	36.78	Wu Y-H, 2003
An-qiu	Shandong	119.20	36.42	Zang D-K & Liang Y-T, 1999
Kunyu Mountain	Shandong	121.40	37.30	Song B-H & Li F-Z, 1999
Taishan Mountain	Shandong	117.02	36.35	Zang D-K et al., 1994
Laoshan	Shandong	120.42	36.22	Wang S-Q et al., 2001
Kunyu	Shandong	121.43	37.15	Zhang X-Q et al., 2003
Changqing	Shaanxi	107.62	33.26	Zhao H et al., 1999
Loess Plateau	Shaanxi	101–113	34–40	Zhang W-H et al., 2003
Niubeiliang	Shaanxi	108.90	33.86	Li J-X et al., 1999
Qinling	Shaanxi	110.18	33.42	Ying T-S, 1994
Taibaishan, Qinling	Shaanxi	107.61	33.98	Ying T-S et al., 1990
Xunhe, Qinling	Shaanxi	108.93	33.44	Wang C-K et al., 2000
Guandi Mt.	Shanxi	110.80	37.83	Zhang F et al., 1998
Lishan	Shanxi	111.97	35.36	Zhang J-M et al., 2002
Liupanshan	Shanxi	105.38	35.88	Ma K-P et al., 1995

Appendix 1 (continued)

Region	Province	Longitude	Latitude	References
Luya	Shanxi	112.33	38.82	Shangguan T-L et al., 1999
Manghe	Shanxi	112.44	35.24	Zhang Y-B et al., 2003
Shuo Xian	Shanxi	112.37	39.29	Shangguang T-L et al., 1991.
Taiyuan	Shanxi	111.83	37.93	Teng C-D et al., 1991
Taiyue Mt.	Shanxi	111.67	36.79	Li Z-Y et al., 1993
Wutai	Shanxi	113.33	38.88	Ru W-M & Zhang F, 2000
Wutaishan	Shanxi	115.17	39.98	Ma K-P et al., 1995
Zhongtiao Mt.	Shanxi	111.43	35.13	Fu Z-J & Zheng X-T, 1994
Hengshan	Shanxi	113.42	39.96	Shangguan T-L, 2001
Elaeagnus mollis area	Shanxi	111.27	35.48	Zhang F, 2003
Ziwuling	Shanxi	108.58	35.33	Zhang X-B et al., 2004
Mid-Yellow River	Shanxi, Henan	111.23	35.12	Fan J et al., 2003
Chongqing	Sichuan	106.48	29.67	Xu H-Y et al., 1993
Dabashan	Sichuan	107.46	32.21	Zhu W-Z, 1992
Dujiangyan	Sichuan	103.61	31.06	Shen Z-H & Zhang X-S, 2000
Heizhugou, Ebian	Sichuan	103.28	29.22	He M-Y et al., 1996
Jinfushan	Sichuan	106.60	29.00	Ma K-P et al., 1995
Jinyunshan	Sichuan	106.33	29.82	Ma K-P, et al., 1995
Jiuzhai Gou	Sichuan	103.93	33.13	Liu Y-C et al., 1991
Ningnan	Sichuan	102.69	27.07	Wu N & Qiao Y-K, 1994
Simian	Sichuan	106.33	28.50	Shen Z-H & Zhang X-S, 2000
Huanglong	Sichuan	103.85	32.77	Chen J-M et al., 2003
Zigui	Sichuan	110.15	30.91	Li E-H et al., 2003
Xie Bao Shan	Sichuan	108.71	31.60	Liu Y-C et al., 2003
Wanchanggou	Sichuan	105.87	32.49	Qin Z-G et al., 2003
Dabashan	Sichuan	108.86	31.91	Xu D-Y, 2003
Jinfo	Sichuan	107.18	29.20	Yi S-R & Huang Y, 2004
Minjiang	Sichuan	103.26	31.95	Zhang W-H et al., 2003
Taiwan	Taiwan	120.67	23.74	Ying T-S & Xu G-S, 2002
Yalutsangpu	Xizang (Tibet)	95.48	29.50	Sun H & Zhou Z-K, 1996
Shegyla	Xizang (Tibet)	94.58	29.77	Chai Y et al., 2003
Mila	Xizang (Tibet)	92.60	29.72	Luo J et al., 2003
Dulongjiang	Yunnan	98.13	28.25	Li H, 1994
Daxigou, upper Urumqi	Xinjiang	87.03	43.20	Lu X-F et al., 2000
Kanas, Altai	Xinjiang	87.40	48.88	Pan X-L & Zhang H-D, 1996
Altai	Xinjiang	88.50	48.00	Chen W-L & Yang C-Y, 2000
Dian-Qian-Gui border	Yunnan Guizhou Guangxi	106.92	24.08	Fang R-Z et al., 1996
Gulinqing	Yunnan	104.39	23.00	Shen Z-H & Zhang X-S, 2000
Hengduan Mountain	Yunnan	99.20	27.50	Li X-W & Li J, 1993
Jinshajian	Yunnan	100.50	27.50	Jin Z-Z et al., 1994
Jinshajiang	Yunnan	100.50	27.17	Jin Z-Z, 1998
Jinshajiang	Yunnan	100.50	24.83	Jin Z-Z, 1999
Lujiangba .	Yunnan	98.90	26.00	Cao Y-H, 1993
Shishan	Yunnan	102.86	25.46	Guo Q-F, 1988
Wuliangshan	Yunnan	100.65	24.38	Peng H, 1997
Xishuangbanna	Yunnan	100.90	21.88	Zhu H et al., 2001
Yuanjiang	Yunnan	102.50	23.50	Shen Z-H, Zhang X-S, 2000
Yuanmou	Yunnan	101.89	25.78	Ou X-K, 1988
Yulongshan	Yunnan	100.32	27.18	Ma K-P et al., 1995
Beilun, Ningbo	Zhejiang	121.87	29.83	Shi M-Z et al., 1995
Jiande	Zhejiang	119.52	29.68	Ma K-P et al., 1995
Taizhou Islands	Zhejiang	121.85	28.50	Shi D-.F et al., 1996
Bei, Jinhua	Zhejiang	119.63	29.22	Guo S-L & Liu P, 1993
Fengyangshan	Zhejiang	119.18	27.87	Ding B-Y et al., 2000

Appendix 1 (continued)

Region	Province	Longitude	Latitude	References
Islands	Zhejiang	121.80	28.97	Cheng Z-H et al., 1995
Jiulong	Zhejiang	118.87	28.35	Shen Z-H & Zhang X-S, 2000
Kaihua	Zhejiang	118.31	29.20	Chen L-R & Liu P, 1996
Longtang	Zhejiang	118.93	30.17	Zheng C-Z, 1996
Longwangshan	Zhejiang	119.38	30.38	Zhou Y & Feng Z-J, 1993
Quxian	Zhejiang	118.89	28.93	Hu S-Q, 1995
Tianmu	Zhejiang	119.42	30.33	Shen Z-H & Zhang X-S, 2000
Tiantai	Zhejiang	121.10	29.25	Jin Z-X, 1994
Tiantong	Zhejiang	121.78	29.80	Shen Z-H & Zhang X-S, 2000
Wuyi	Zhejiang	119.71	28.78	Liu P et al., 1997
Yucang	Zhejiang	120.72	27.55	Chen X-X et al., 2003
Xinchang	Zhejiang	120.96	29.39	Jin M-L, 2004
Baiyun, Lishui	Zhejiang	119.92	28.42	Mei X-M, 2004

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