We are IntechOpen, the world’s leading publisher of Open Access books
Built by scientists, for scientists

6,600
Open access books available

177,000
International authors and editors

195M
Downloads

154
Countries delivered to

TOP 1%
Our authors are among the most cited scientists

12.2%
Contributors from top 500 universities

WEB OF SCIENCE™
Selection of our books indexed in the Book Citation Index in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com
1. Introduction

The genus *Picea* A. Dietrich (spruce), which is a relative isolated group under evolution, belongs to Pinaceae family (Ran et al., 2006; Bobrow, 1970; Buchholz, 1929, 1931; Alvin, 1980; Mikkola, 1969). It includes 28–56 species depending on different systems of classification (Farjón, 1990; Ledig et al., 2004), most of which are in Eastern Asia, while many researchers thought that there were about 40 species in *Picea* genus and were only found in the north hemisphere (Budantsey, 1992, 1994; Wolfe, 1975, 1978; Tiffney and Manchester, 2001). The distribution range is from 21°N (Huanglian Mountains of Vietnam) to 70°N (Far Eastern area of Russia) (Fig. 1). Spruce forests are the main dominant vegetation in alpine coniferous forest in subtropical zone and temperate zone, and they are only found in alpine area, subalpine area and plateau from 21°N to 46°N (Li, 1995). In cold temperate zone and its adjacent regions (47°N to 57°N), spruce forests are the zonal vegetation types in boreal coniferous forest. From 57°N to 70°N, spruce forests transform from horizontal (latitudinal) zonal distribution to vertical (altitudinal) zonal distribution and from continuous distribution to discontinuous distribution.

In the north of Euro-Asia continent, the main spruce species are *Picea abies* (L.) H. Karst. and *P. obovata* Ledeb., which form the continuous boreal coniferous forest (Ferguson, 1967; Florin, 1954, 1963; Guerli et al., 2001). *P. abies* is found in Alps of France, the Balkan Peninsula or the Balkan Mountains in the west, Germany and Scandinavian Peninsula in the north, Poland and the north and middle region of Russia in the east. In Siberian area of Russia, *P. obovata* takes the place of *P. abies*, it is found until to Lena River Valley and Okhotsk. But in the east Siberian area, *P. obovata* retreats from the dominant position, and is taken the place by *Larix sibirica* Ledeb. due to the rigorous continental climate (Colleau, 1968; Corrigan et al., 1978; Harris, 1979; Hart, 1987).

In North America, spruce species are abundant, including *P. glauca* (Moench) Voss, *P. mariana* (Mill.) Britton and al., *P. engelmannii* Parry ex Engelm. and *P. sitchensis* (Bong.) Carrière (Barbour and Bilings, 1988; Klaus, 1987). *P. glauca* is distributed extensively in Canada and North USA, from Labradorian Peninsula and Alaska to Montana, North Dakota, Minnesota, Wisconsin, Michigan, to Massachusetts near Atlantic coast. *P. mariana* is
distributed almost in the whole Canada, and extensively in the eastern provinces and Newfoundland, to Alaska across Rocky Mountains in the west, and to Pennsylvania, north Virginia, Wisconsin, and Michigan in the south. Britain Colombia Province of Canada is the west border of *P. mariana*. *P. engelmannii* is found in the west of North America, from Alberta Province and Britain Colombia Province of Canada to Arizona and New Mexico of USA along Rocky Mountains, it is also distributed in Cascade Range in Washington and Oregon. *P. sitchensis* distributes in the northwest of North America, and can be found from Aleutian Islands to Pacific coast of the northwest of California too (Delevoryas and Hope, 1973; Hsu, 1983; Weng and Jackson, 2000).

![Fig. 1. The modern distribution range and fossil localities of *Picea* spp. in the world (based on Li, 1995, Lü et al., 2004, and McKenna, 1975) (1-7. Fossil localities: 1. Eocene; 2, 3. Oligocene; 4, 5. Miocene; 6, 7. Pliocene; 8. Modern distribution)](image)

In China, the distribution range of spruce forests is very large, from Daxinganling Mountains (north) to Gaoligong Mountains (south), and Tianshan Mountains (west) to Central Mountains of Taiwan Province (east) (Fang, 1995, 1996; Fang and Liu, 1998). The spruce forests are found as long as there are site conditions of cold-temperate moisture types. In China the spruce forests belong to vertical zonal distribution with 17 species and 8 variations of *Picea* genus and take more than 40% of the species in the world. Furthermore, the almost all of the species are endemic in China, except for those in Daxinganling Mountains which belongs to East Siberian area and Arertai Mountains (belonging to West Siberian area). In China, spruce forests are distributed in Northeast, North, Northwest and Southwest.

In the mountains of Daxinganling, Xiaoxinganling and Changbai of Northeast China, *P. koraiensis* Nakai, *P. jezoensis* var. *microsperma* (Lindl. Cheng et L. K. Fu) and *P. jezoensis* var. *komarovii* (V. Vassil.) Cheng et L. K. Fu are the edificators of upland dark coniferous forests, which are extended partition of dark coniferous forests of Far East Area of Russia (Editorial Committee of Forest of China, 1997; Li, 1980; Li and Zhou, 1979).

The distribution range of spruce forest is restricted for drought in North and Northwest China. *P. meyeri* Rehder, E. H. Wilson and *P. wilsonii* Mast. are found in Jibei Mountains, Xiaowutai Mountains of Hebei Province, Guanqin Mountains, Wutai Mountains, Guandi
Mountains of Shanxi Province in North China. In Northwest China, Arertai Mountains are the south border of *P. obovata*. *P. schrenkiana* var. *tianshanica* (Rupr.) Cheng et S. H. Fu is found in Tianshan Mountains, the west border of spruce forests in China. *P. crassifolia* Kom. is distributed extensively in Qilian Mountains, Helan Mountains and Yinshan Mountains of Qinghai Province, Gansu Province and Ningxia Hui Nation Autonomous Region (Editorial Committee of Forest of China, 1997).

In Southwest China, including West Sichuan Province, north Yunnan Province and south Tibet Autonomous Region, there are 17 spruce species, which takes 43.3% of spruce species in the world. The important species are *P. likiangensis* (Franch.) E. Pritz., *P. likiangensis* var. *linzhiiensis* Cheng et L. K. Fu, *P. likiangensis* var. *balfouriana* (Rehd. et Wils.) Hillier ex Slavin, *P. purpurea* Mast., *P. brachytyla* (Franch.) E. Pritz., and so on, they form subalpine dark coniferous forests in Southwest China (Kuan, 1981; Sun, 2002; Wu et al., 1995).

*P. spinulosa* (Griff.) A. Henry and *P. smithiana* (Wall.) Boiss. are found in moist area in Himalayas in south Tibet Autonomous Region, and they always form small pure forest or mixed forest (Kuan, 1981).

*P. morrisonicola* Hayata forms the dominant pure coniferous forest in Central Mountains in Taiwan, which is the only subalpine coniferous forest of the east China in subtropical zone (Liu, 1971).

Monophyly of *Picea* has never been debated (Wright, 1955; Prager et al., 1976; Frankis, 1988; Price, 1989; Sigurgeirsson and Szmidt, 1993), but infrageneric classification of the genus remains quite controversial (Liu, 1982; Schmidt, 1989; Farjón, 1990, 2001; Fu et al., 1999), owing to morphological convergence and parallelism (Wright, 1955), and high interspecific crossability (Ogilvie and von Rudloff, 1968; Manley, 1972; Gorden, 1976; Fowler, 1983, 1987; Perron et al., 2000). In addition, little is known about phylogenetic relationships of most species, especially the geographically restricted species growing in the montane regions of southwest China (LePage, 2001). Moreover, the origin and biogeography of *Picea* have drawn great interest from both geologists and biologists (Wright, 1955; Aldén, 1987; Page and Hollands, 1987; LePage, 2001, 2003), but they are still far from being resolved.

Spruce species are fine trees for lumbering, so researches on spruce were conducted very early in China (Editorial Committee of Vegetation of China, 1980). However, basic characteristics, flora, distribution types, and evolution relationship of the spruce species in China, and the relationship among species in China and abroad need more concern. There are many data about the topics above, but they are always scattered.

The aim of this study was (1) to summarize systematically the researches on spruce in China, and (2) to try to clarify the relationship among Chinese spruces, and among spruce in China and abroad.

### 2. Characteristics of species composition in spruce forests in China

#### 2.1 The edificators in spruce forests in China

*Picea* spp. is distributed extensively in China (Editorial Committee of Forest of China, 1997). It is difficult to expatiate on the characteristics of edificators in spruce forests, so we divided China into five parts according to their districts, including Northeast China, Northwest...
| District   | Species                        | F   | D    | RD  | P    | RP  |
|------------|--------------------------------|-----|------|-----|------|-----|
| Northeast  | *P. koraiensis*                 | 96.00 | 11.52 | 47.50 | 3.482 | 48.60 |
| China      | *P. jezoensis* var. *microsperma* | 82.50 | 7.65 | 31.80 | 2.239 | 28.50 |
|            | *Pinus koraiensis* Sieb.        | 47.50 | 1.56 | 4.29  | 0.626 | 5.21  |
|            | *Populus davidiana* Dode.       | 28.00 | 2.62 | 3.24  | 0.248 | 2.78  |
|            | *Quercus mongolica* Fischer ex Ledebour | 16.50 | 2.13 | 1.87  | 0.104 | 1.67  |
|            | *Betula platyphylla* Suk.       | 32.50 | 1.19 | 2.61  | 0.182 | 2.36  |
|            | *Betula ermanii* Cham.          | 10.50 | 0.87 | 0.99  | 0.167 | 1.98  |
|            | *Abies nephrolepis* (Trautv.) Maxim. | 31.75 | 2.95 | 2.45  | 0.204 | 3.11  |
|            | *Betula platyphylla* Suk.       | 32.50 | 1.19 | 2.61  | 0.182 | 2.36  |
|            | *Betula ermanii* Cham.          | 10.50 | 0.87 | 0.99  | 0.167 | 1.98  |
|            | *Abies nephrolepis* (Trautv.) Maxim. | 31.75 | 2.95 | 2.45  | 0.204 | 3.11  |
|            | *Larix gmelini* (Rupr.) Rupr.    | 15.38 | 1.85 | 1.98  | 0.128 | 2.52  |
|            | *Pinus sylvestriiformis* Taken.  | 9.82  | 0.62 | 0.23  | 0.075 | 0.85  |
| Northwest  | *P. schrenkiana* Fisch. et Mey.  | 88.50 | 11.00 | 35.65 | 4.457 | 42.80 |
| China      | *P. schrenkiana* var. *tianshanica* | 75.00 | 9.88 | 29.54 | 3.285 | 15.93 |
|            | *P. obovata*                    | 62.50 | 5.00 | 22.26 | 3.285 | 15.93 |
|            | *Larix sibirica*                | 28.00 | 1.61 | 3.28  | 0.241 | 2.75  |
|            | *Betula pendula* Roth.          | 15.50 | 0.95 | 1.06  | 0.113 | 0.82  |
|            | *Sorbus tianschanica* Mast.     | 9.20  | 0.43 | 0.95  | 0.108 | 0.36  |
|            | *Populus talassica*             | 11.42 | 0.87 | 0.62  | 0.168 | 1.55  |
|            | *Betula tianschanica* Cheng et S. H. Fu | 8.75  | 0.65 | 0.53  | 0.201 | 1.10  |
| North      | *P. meyeri*                     | 84.00 | 12.25 | 24.21 | 4.114 | 29.61 |
| China      | *P. wilsonii*                   | 81.30 | 11.64 | 22.80 | 4.109 | 27.52 |
|            | *P. asperata* Mast.             | 67.50 | 9.58 | 15.21 | 2.628 | 12.74 |
|            | *P. crassifolia*                | 48.00 | 6.62 | 13.45 | 2.124 | 12.74 |
|            | *Abies ernestii* Rehd.          | 26.70 | 3.15 | 5.82  | 1.100 | 3.69  |
|            | *Larix principis-ruprechtii* Maryr. | 22.58 | 2.69 | 4.63  | 0.482 | 2.37  |
|            | *Pinus tabuliformis* Carr.      | 30.50 | 2.89 | 4.97  | 0.368 | 2.15  |
|            | *Acer davidii* Franch.          | 11.20 | 1.25 | 1.35  | 0.191 | 1.26  |
|            | *Populus ninghianica* L.        | 14.70 | 1.96 | 1.45  | 0.207 | 1.18  |
|            | *Betula platyphylla*            | 11.36 | 1.82 | 0.95  | 0.158 | 1.51  |
|            | *Betula albo-sinensis* Cheng et S. H. Fu | 8.75  | 0.65 | 0.53  | 0.201 | 1.10  |
| Southwest  | *P. likiangensis*               | 65.40 | 12.27 | 17.23 | 3.885 | 17.62 |
| China      | *P. likiangensis* var. *balfouriana* | 60.37 | 12.62 | 15.81 | 4.001 | 14.56 |
|            | *P. purpurea*                   | 61.50 | 11.57 | 16.20 | 3.629 | 14.28 |
|            | *P. asperata*                   | 45.22 | 5.68 | 9.45  | 2.156 | 9.76  |
|            | *P. brachytyla*                 | 66.75 | 10.13 | 15.87 | 4.107 | 18.19 |
|            | *P. brachytyla* var. *complanata* Mast. | 62.53 | 9.69 | 14.64 | 3.982 | 15.33 |
|            | *Abies faxoniana* Rehd. et Wils. | 25.50 | 2.85 | 2.96  | 1.003 | 1.17  |
|            | *Abies spectabilis* (D. Don) Mirb. | 21.23 | 4.23 | 2.35  | 0.691 | 2.21  |
|            | *Pinus griffithii* McClelland    | 17.79 | 3.91 | 1.46  | 0.268 | 1.28  |
|            | *Pinus tabuliformis*            | 11.33 | 2.86 | 1.09  | 0.551 | 1.54  |
|            | *Pinus armandii* Franch.        | 7.83  | 2.15 | 0.78  | 0.079 | 0.08  |
|            | *Populus davidiana*             | 9.33  | 3.56 | 0.89  | 0.104 | 0.11  |
|            | *Acer flavellatum* Rehd.        | 6.74  | 3.54 | 0.34  | 0.073 | 0.08  |
|            | *Quercus sempervirens* Smith    | 8.12  | 2.31 | 0.28  | 0.097 | 0.08  |
|            | *Betula platyphylla*            | 9.92  | 1.75 | 0.34  | 0.162 | 0.09  |
|            | *Betula utilis* var. *prattii* D. Don | 2.47  | 1.10 | 0.11  | 0.052 | 0.06  |
|            | *Juglans cathayensis* Dode       | 2.24  | 0.59 | 0.05  | 0.038 | 0.04  |

www.intechopen.com
An Overview on Spruce Forests in China

Table 1. Species characters in spruce forest in different districts in China (F-Frequency (%), D-Density (/100m²), RD-Relative density (%), P-Predominance, RP-Relative predominance (%))

| District          | Species                  | F  | D  | RD  | P  | RP  |
|-------------------|--------------------------|----|----|-----|----|-----|
| Taiwan            | P. morrisonicola         | 100.00 | 14.87 | 77.77 | 5.451 | 84.72 |
|                   | Tsuga chinensis (Franch.) Pritz. | 62.50 | 1.87 | 9.80 | 0.233 | 3.62 |
|                   | Pinus armandii var. mastersiana (Hay.) Hay. | 37.50 | 1.00 | 5.22 | 0.256 | 3.97 |
|                   | Chamaecyparis obtuse var. formosana Matsum. | 25.00 | 0.62 | 3.26 | 0.241 | 3.74 |
|                   | Chamaecyparis formosensis Matsum. | 12.50 | 0.12 | 0.65 | 0.002 | 0.02 |
|                   | Cunninghamia konishii Hayata | 12.50 | 0.12 | 0.65 | 0.085 | 1.31 |
|                   | Trochodendron aralioides Sieb. et Zucc. | 12.50 | 0.50 | 0.61 | 0.166 | 2.57 |

China, North China, Southwest China and Taiwan. The characteristics of spruce forest in different districts in China are as shown in Table 1. In Northeast China, Northwest China and Taiwan, there are few edificators in spruce forests, while in North China and Southwest China, many species of spruce forests are found (Editorial Committee of Forest of China, 1997; Editorial Committee of Vegetation of China, 1980; Zhou, 1988; Chou, 1986, 1991).

2.2 Flora characters of spruce forests in China

In different districts in China, the floristic and geographical elements of spruce forests are complex (Table 2) (Wu, 1991; Wang, 1992, 2000). Generally speaking, there are more species belong to temperate zone element (Northeast China (83.39%), Northwest China (81.25%), North China (77.43%), Southwest China (72.50%), and Taiwan (70.66%)). In tropical China, spruce forest takes the following proportions: in North China (16.38%), Southwest China (22.92%), and Taiwan (24.50%). However, in temperate zone, spruce distribution in the three districts are as follows: North China (3.45%), Southwest China (2.08%), and Taiwan (2.28%) are relatively less than the other two districts (Northeast China (8.15%) and Northwest China (10.41%)). China endemic elements in the three districts (North China (23.49%), Southwest China (37.92%), and Taiwan (32.19%)) are distinctly more than the other two districts (Northeast China (10.66%) and Northwest China (7.99%)), due to these two districts are connected with other districts, such as northeastern Asia, Siberian, and Far East of Russia (Editorial Committee of Forest of China, 1997).

3. Section grouping based on cytogenetical studies

3.1 Karyotype of 17 Picea species in China

Karyotype is the basis of cladistics. We collected all the pictures on chromosome of different Picea species (Sudo, 1968; Hizume, 1988; Taylor and Patterson, 1980; von RudloV, 1967; Wang et al., 2000; Wu, 1985, 1987; Xu et al., 1994, 1998; Mehra, 1968). The pictures were treated by using the software Motic Images Advanced 3.0 to get the length of arms of chromosome. Researchers have found karyotype characters of 17 Picea species in China up to now (Table 3). Karyotype equations of these species include four types: 2n=24m, 2n=22m+2sm, 2n=20m+4sm, and 2n=16m+8sm. B chromosome is found only in P. meyeri, P. wilsonii, P. jezoensis var. microsperma, and P. obovata. There is no variation of chromosome number.
### Floristic Types and Geographical Elements

| Floristic Types | Geographical Elements | Northeast China | Northwest China | North China | Southwest China | Taiwan |
|-----------------|-----------------------|-----------------|-----------------|-------------|-----------------|--------|
| I               | (1)                   | 15 (4.70)       | 15 (5.21)       | 18 (3.70)  | 8 (2.50)       | 9 (2.56) |
|                 | (2)                   | 21 (6.58)       | 13 (4.51)       | 14 (3.59)  | 8 (2.28)       |        |
|                 | (3)                   | 5 (1.57)        | 17 (5.90)       | 4 (0.86)   | 1 (0.14)       | 0 (0.00) |
| II              | (4)                   | 45 (14.11)      | 28 (9.72)       | 19 (4.09)  | 21 (2.92)      | 3 (0.85) |
|                 | (5)                   | 46 (14.42)      | 36 (12.50)      | 34 (11.42) | 32 (9.70)      | 26 (10.26) |
|                 | (6)                   | 5 (1.57)        | 17 (5.90)       | 4 (0.86)   | 1 (0.14)       | 0 (0.00) |
|                 | (7)                   | 45 (14.11)      | 28 (9.72)       | 19 (4.09)  | 21 (2.92)      | 3 (0.85) |
|                 | (8)                   | 46 (14.42)      | 36 (12.50)      | 34 (11.42) | 32 (9.70)      | 26 (10.26) |
| III             | (9)                   | 34 (10.66)      | 23 (7.99)       | 109 (23.49)| 273 (37.92)    | 113 (32.19) |
|                 | (10)                  | 12 (3.76)       | 9 (3.13)        | 76 (16.38) | 165 (22.30)    | 86 (24.50) |
|                 | Total                 | 519 (100.00)    | 288 (100.00)    | 464 (100.00)| 720 (100.00)   | 351 (100.00) |

### Table 2. The floristic geographical elements of spruce forests in different districts in China

I (1) World element, II Cold zone element, III Temperate zone element, IV Tropical zone element.

### Table 3. Karyotype characters of 17 spruce species in China

| No. | Species            | Karyotype equation | Arm ratio | Chromosome length ratio | Karyotype type |
|-----|--------------------|--------------------|-----------|-------------------------|----------------|
| 1   | P. asperata        | 20m+4sm            | 1.31±0.04 | 1.71±0.32               | 1A             |
| 2   | P. retroflexa Mast.| 22m+2sm            | 1.24±0.14 | 1.89±0.56               | 2A             |
| 3   | P. koraiensis      | 20m+4sm            | 1.42±0.23 | 1.72±0.12               | 2A             |
| 4   | P. meyeri          | 22m+2sm+2B         | 1.36±0.15 | 1.77±0.29               | 2A             |
| 5   | P. wilsonii        | 20m+4sm+1B         | 1.27±0.28 | 1.87±0.31               | 2A             |
| 6   | P. schrenkiana     | 20m+4sm            | 1.38±0.29 | 1.83±0.42               | 2A             |
| 7   | P. schrenkiana     | var. tianshanica   | 16m+8sm   | 1.42±0.18               | 2B             |
| 8   | P. smithiana       | 20m+4sm            | 1.31±0.47 | 1.85±0.21               | 1A             |
| 9   | P. morisonicola    | 16m+8sm            | 1.50±0.33 | 1.87±0.34               | 2A             |
| 10  | P. elliottii       | 20m+4sm            | 1.27±0.18 | 1.60±0.19               | 2A             |
| 11  | P. elliottii       | var. balfouriana   | 20m+4sm   | 1.34±0.26               | 2A             |
| 12  | P. purpurea        | 20m+4sm            | 1.28±0.16 | 1.86±0.16               | 2A             |
| 13  | P. jezoensis       | 22m+2sm+1B         | 1.36±0.28 | 1.82±0.53               | 2A             |
| 14  | P. brachytyla      | 20m+4sm            | 1.34±0.32 | 1.84±0.37               | 2A             |
| 15  | P. brachytyla      | var. complanata    | 20m+4sm   | 1.36±0.17               | 2A             |
| 16  | P. mongolica       | 20m+4sm            | 1.33±0.18 | 1.83±0.15               | 1A             |
| 17  | P. obovata         | 24m+3B             | 1.35±0.27 | 1.87±0.28               | 2A             |
For karyotype type, there are 31A types (including *P. asperata*, *P. smithiana* and *P. mongolica* W. D. Xu) and 12B type (*P. schrenkiana* var. *tianshanica*). The others are 2A types.

### 3.2 Structure variation of chromosomes and evolution hierarchy

We took arm ratio as x-coordinate, and chromosome length ratio as y-coordinate. All *Picea* spp. were drawn as shown in (Fig. 2a, b). The change range of arm ratio is from 1.23 to 1.50, and most of species (22) are from 1.25 to 1.35. The change range of chromosome length ratio is from 1.60 to 2.12, and only 14 species are from 1.75 to 1.85 (Wang et al., 1990).

Structure variation of chromosomes of Chinese *Picea* spp. (Fig. 2a) is more obvious than *Picea* spp. found in other parts of the world (Fig. 2b).

![Chromosomes structure of Chinese *Picea* spp.](image1)

![Chromosomes structure of other world *Picea* spp.](image2)

**Fig. 2.** Chromosomes structure of Chinese *Picea* spp. and other world *Picea* spp. (data based on Table 5)

Some researchers (Wang et al., 1990) thought a coefficient $k$ (Karyotypic asymmetry in both average arm ratio and ratio of longest / shortest of chromosomes) was a good index for expressing the evolution hierarchy of certain species and genus.

$$k = \frac{A_i + L_i}{A_{max} + L_{max}} \times 100\%$$

(1)

Where $A_i$ – average arm ratio of species (or genus), $L_i$ – chromosome length ratio of species (or genus), $A_{max}$ – maximum arm ratio in genus (or family), $L_{max}$ – maximum chromosome length ratio in genus (or family).

According to value of $k$ of *Picea* spp., the evolution hierarchy of 17 *Picea* spp. in China (Fig. 3) and 15 *Picea* spp. abroad (Fig. 4) were determined.
3.3 Section grouping

In taxonomy, *Picea* genus in China can be divided into three sections according to their karyotypes and the coefficient $k$. These sections are Sect. *Casicta*, Sect. *Omirica*, and Sect. *Picea*. Furthermore, we can determine their evolution hierarchy as in (Fig. 5) (Ran et al., 2006; Wu, 1991).

4. Distribution types of *Picea* spp. in China

4.1 Distribution range and niches of *Picea* spp. in China

The data of some *Picea* species (including *P. koraiensis*, *P. jezoensis* var. *microsperma*, *P. jezoensis* var. *komarovi*, and *P. mongolica*) are based on our previous field investigation. And we conducted the interpretation of TM image of some pivotal regions (including Tianshan Mountains in Xinjiang Weiwuier Autonomous Region, Hengduan Mountains in Sichuan Province and Tibet Autonomous Region, Qilian Mountains in Shaanxi Province and Gansu Province) (Liu et al., 2002; Yang et al., 1994; Editorial Committee of Forest of China, 1997; Cen, 1996).

4.2 Grouping of distribution types

Principal Components Analysis (PCA) was performed to compress the autocorrelated metric environmental variables by creating a reduced number of compounds (principal components) that explain the observed variation of distribution type (Jolliffe, 2002; Norusis, 1986).
Fig. 5. Section grouping and evolution hierarchy of 17 *Picea* spp. in China

1990). Only compounds that accounted for more variation than any individual variable (eigenvalue > 1) were used in the final model. A ‘varimax’ rotation was applied to the reserved components to redistribute the variance among factors to obtain factor scores. Fuzzy clustering was then applied to the sample scores from the PCA ordination to identify the main distribution types. The fuzzy clustering specification used 3–6 clusters, a fixed fuzziness criterion of 2 and a convergence coefficient of 0.001. Then we obtained three categories of distribution types.

The first category is based on species adaptability to climate (mainly temperature, precipitation, and moisture). There are three types, including cold-moist type (10, 11, 12, 14, 15, 20, 22, 23, 25), cold-drought type (3, 6, 7, 13, 16, 17, 18, 19, 21, 24) and warm-moist type (1, 2, 4, 5, 8, 9).

The second category is based on environmental factors (particularly altitude). There are four types, including upland type (1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15, 16, 18, 19, 21, 22, 23, 25), valley type (3, 13, 20), plain type (17, 24), and sandy land type (16).

The third category is based on distribution range (longitude and latitude) of species. There are three types, including narrow-distribution type (8, 9, 16, 17, 18, 22, 23, 25), medium-distribution type (1, 2, 4, 10, 11, 12, 14, 15, 21, 24) and broad-distribution type (3, 5, 6, 7, 13, 19, 20).
5. Discussion

5.1 The origin of Picea genus

Severe climatic oscillations associated with glacial cycles in the arctic during the late Tertiary and throughout the Quaternary era resulted in great changes in species distribution and population structure (Böhle et al., 1996; Qian and Ricklefs, 2000; Liu et al., 2002; Petit et al., 2003; Hewitt, 2004; Thomas, 1965). Meanwhile, descendent sea level created land connections for intercontinental exchanges of flora and fauna, especially boreal species (Tiffney, 1985a, b; Wen, 1999; Xiang et al., 2005). Spruce, as a kind of gymnosperm, is an archaic group under evolution, although pioneer reliable fossils of Picea genus are not available so early in Oligocene (Miller, 1975, 1977). Later in Oligocene and Miocene, fossils of Picea genus appear widely in Europe, North America and Japan (Page, 1988; Axelord, 1986, 1976; Ferguson, 1967). According to the fossils and modern distribution range, it can be concluded that ancestor of Picea genus might be a branch differentiate from Pinaceae during evolvement metaphase. But until Tertiary, ancient Picea spp. became the same as modern Picea spp.

Where does Picea genus originate from? There are many hypotheses in botanical science. Wright (1955) thought Picea genus might originate from northeastern Asia, and moved to North Arctic or diffused towards south along mountains. It seems logical because there are many Picea spp. there, including P. jezoensis var. hondoensis Mayr., P. polita Sieb. et Zucc., P. jezoensis Carr., P. jezoensis var. microsperma, P. jezoensis var. komarovii, P. koraiensis. However, the hypothesis can not give a reasonable explanation to the phenomenon that
there are many *Picea* spp. in lower latitudinal regions in eastern Asia (Miller, 1988; Hopkins et al., 1994).

Wu (1991) thought the distribution center of *Picea* spp. was in East Asia, particularly in Hengduan Mountains according to his research findings. Li (1995) reported that in Hengduan Mountains, *Picea* spp. belonged to almost all of the subgroups except for an obvious evolitional subgroup – *P. pungens* subgroup originated from Rocky Range. In Hengduan Mountains in western Sichuan (Sun, 2002), northern Yunnan and eastern Tibet, there are more interspecific differentiations in *Picea* genus. Some species from Sect. *Picea* (*P. asperata*, *P. jezoensis*, and so on), Sect. *Casicta* (*P. likiangensis*, *P. likiangensis* var. *balfouriana*, and so on) and Sect. *Omirica* (*P. brachytyla*, *P. brachytyla* var. *complanata*, and so on) are found there. For example, in relatively ancient subgroup – Sect. *Picea*, there are 30 species and 2 variations in Sect. *Picea*, and 13 species and 1 variation are found here, which take 43.3% of the total species of Sect. *Picea*. So many researchers thought Hengduan Mountain was the original center of *Picea* genus, at least it was one of the most important differentiated centers.

It has proved to have been proven according to analysis on fossils and pollens of *Picea* genus (Jain, 1976; Miller, 1972, 1974, 1985; Schall and Pianka, 1978; Shi et al., 1998) that during the ice age in Quaternary, the forest composed of *Picea* spp. and *Abies* spp. and the two species were distributed widely in the mountains and plains of Southwest China, Northwest China, North China, East China, and Taiwan. During that time, cold-temperate coniferous forests have wider distribution range than present. It’s well known that glacier activity was active in Quaternary, and vegetation zone moved in both horizontal and vertical directions. With the advance and retreat of ice sheets, species went extinct over large parts of their range, and some populations were dispersed to new locations or survived in refugia and then expanded again (Hewitt, 2000; Stewart and Lister, 2001; Abbott et al., 2000). This repeated process would on the one hand stimulate adaptation and allopatric speciation (Hewitt, 2004), whereas, on the other, provide the opportunities for hybridization between recolonized populations, even reproductively unisolated species (Abbott and Broichmann, 2003). During interglacial time, because of climate warming, some cold-temperate coniferous forests retreated to north, and others moved towards the mountains when the glacier melted, which formed the modern distribution range shrinking again and again. In Hengduan Mountains, there are more spaces and diverse habitats for cold-temperate coniferous trees moving upwards to the high environments (Sun, 2002). However, it’s latitudinal is lower, so the cold-temperate coniferous species such as *Picea* spp. are distributed in the medium and top parts of mountains, which detached the distribution area into many parts, and some *Picea* spp. differentiate into many subspecies. The place became the center of geographical distribution and differentiation of *Picea* genus. The reticulate evolution and biological radiation resulted from climatic, ecological and geological changes brought many difficulties to the evolutionary and biogeographical studies of some taxa with long generation times, widespread distributions and low morphological divergence.

5.2 The relationship among Chinese *Picea* spp. and other world *Picea* spp.

Karyotype equations of 17 species of spruce in China include four types (2n=24m, 2n=22m+2sm, 2n=20m+4sm, and 2n=16m+8sm) (Table 3). Karyotype data of 15 species spruce abroad (Table 5) are shown (Hizume, 1988; Kinlaw and Neale, 1997; Niemann, 1979; Rushforth, 1987; Hilis and Ogilvie, 1970; Doyle, 1963), three of which are included in

www.intechopen.com
Karyotype equations (2n=24m (P. sitchensis), 2n=22m+2sm (12 species), 2n=20m+4sm (2 species)).

| No. | Species                        | Longitude (°) | Latitude (°) | Altitude (m) | Precipitation (mm) | Temperature (℃) | Moisture (%) |
|-----|--------------------------------|---------------|--------------|--------------|--------------------|-----------------|--------------|
| 1   | *P. asperata*                   | 100.1-106.8   | 30.2-34.6    | 2400-3600    | 550-850            | 2-12            | 60-80        |
| 2   | *P. retroflexa*                 | 100.1-103.7   | 30-33.1      | 2100-4100    | 550-800            | 2-10            | 55-70        |
| 3   | *P. koraiensis*                 | 116.4-129     | 40.7-52.5    | 300-1800     | 600-900            | 2-4             | 60-80        |
| 4   | *P. meyeri*                     | 111.4-117.5   | 37.5-40.6    | 1400-2700    | 500-900            | 2-10            | 60-70        |
| 5   | *P. wilsonii*                   | 101.7-117.5   | 30-42.2      | 1400-2800    | 500-900            | 5-11            | 50-70        |
| 6   | *P. schrenkiana*                | 75.2-95       | 37.7-45.6    | 1200-3000    | 500-600            | -3-6            | 50-65        |
| 7   | *P. schrenkiana* var. tianshanica| 77-94.5       | 37-46        | 1250-3000    | 500-600            | -3-5            | 50-70        |
| 8   | *P. Asperata*                   | 85.3          | 29           | 2300-3200    | 700-1000           | 6-13            | 50-70        |
| 9   | *P. retroflexa*                 | 120.8-121.5   | 23.2-24.5    | 2500-3000    | 1000-1400          | 10-20           | 70-85        |
| 10  | *P. koraiensis*                 | 98.9-102.1    | 26.5-30.2    | 2500-3800    | 500-1100           | 0-9             | 60-80        |
| 11  | *P. koraiensis* var. balfouriana| 93.7-102.5    | 29.5-33.8    | 3000-4100    | 700-1100           | 2-8             | 70-80        |
| 12  | *P. purpurea*                   | 100.4-105.2   | 30.6-36.3    | 2600-3800    | 450-1100           | 0-6             | 60-80        |
| 13  | *P. koraiensis* var. microsperma| 124-134       | 41-52.5      | 300-1800     | 700-900            | 0-6             | 60-80        |
| 14  | *P. bradygyla*                  | 100.4-112     | 29.2-35.2    | 1500-3300    | 700-1100           | 2-9             | 60-80        |
| 15  | *P. bradygyla* var. campplanata | 92-103.7      | 24.5-31.9    | 2000-3800    | 600-1100           | 0-9             | 60-80        |
| 16  | *P. mongolica*                  | 117.5         | 44.6         | 1100-1300    | 200-400            | -2-2            | 30-60        |
| 17  | *P. obovata*                    | 86.5-90.5     | 46.7-48.6    | 1300-1800    | 400-600            | -2-6            | 40-70        |
| 18  | *P. aurantica* Mast.            | 102.1         | 30.2         | 2600-3600    | 600-700            | -3-5            | 55-70        |
| 19  | *P. crusiformia*                | 98.4-111.2    | 32.5-41.4    | 1600-3800    | 400-600            | 0-5             | 60-75        |
| 20  | *P. koraiensis* var. komarovi*   | 124-134       | 41-52.5      | 600-1800     | 700-900            | 0-6             | 60-80        |
| 21  | *P. koraiensis* var. lirtella* Cheng et L. K. Fu | 96.4-107.2 | 28.8-31.5 | 3000-4100 | 600-900 | 0-6 | 60-75 |
| 22  | *P. koraiensis* var. linzhiensis* | 90.8-100.2 | 27.1-30.2 | 2900-3700 | 600-1000 | 4-9 | 55-70 |
| 23  | *P. koraiensis* var. montigena* Cheng ex Chen | 102.1 | 30.2 | 3300 | 600-700 | -3-5 | 55-70 |
| 24  | *P. mongolica* Mast.            | 102.5-110.8   | 31-34.6      | 1300-2000    | 400-600            | 3-8             | 50-70        |
| 25  | *P. spinulosa*                  | 85.2-89.1     | 27.8-29.9    | 2900-3600    | 450-900            | 0-8             | 60-75        |

Table 4. The distribution range and environmental factors of 25 spruce species in China

In Chinese *Picea* spp., B chromosome is found only in *P. meyeri*, *P. wilsonii*, *P. jesoensis* var. *microsperma*, and *P. obovata*. In abroad *Picea* spp., B chromosome is found only in *P. sitchensis*. There is no variation of chromosome number.

According to karyotypic asymmetry in both average arm ratio and length ratio of chromosomes, Chinese *Picea* spp. are more than that of abroad *Picea* spp. (Fig. 2, 10, 3, 9, 7). 2B karyotype is a relative evolutional type, and this type is only found in Chinese *Picea* spp.
Karyotype equation (16m+8sm) is a relative evolutional type, this type is not found in abroad Picea spp.. On the contrary, karyotype equation (24m), which is a relatively primordial chromosome, is found in them (P. sitchensis). We can conclude from karyotype structure that Chinese Picea spp. are relatively evolutional than abroad Picea spp.

Table 5. Karyotype characters of 15 spruce species abroad

| No. | Species               | Karyotype equation | Arm ratio | Chromosome length ratio | Karyotype type |
|-----|-----------------------|--------------------|-----------|-------------------------|----------------|
| 26  | P. abies              | 22m+2sm            | 1.24±0.33 | 1.74±0.34               | 2A             |
| 27  | P. orientalis (L.) Link.| 22m+2sm            | 1.31±0.42 | 1.82±0.24               | 2A             |
| 28  | P. glauca             | 22m+2sm            | 1.30±0.21 | 1.71±0.19               | 2A             |
| 29  | P. mariana            | 22m+2sm            | 1.28±0.09 | 1.84±0.53               | 1A             |
| 30  | P. rubens Sarg.       | 22m+2sm            | 1.25±0.23 | 1.83±0.18               | 2A             |
| 31  | P. engelmannii        | 20m+4sm            | 1.33±0.50 | 1.76±0.43               | 2A             |
| 32  | P. pungens Engelm.    | 22m+2sm            | 1.31±0.11 | 1.79±0.12               | 2A             |
| 33  | P. bicolor (Maxim.) Mayr. | 22m+2sm          | 1.24±0.12 | 1.98±0.24               | 2A             |
| 34  | P. glehnii (F. Schmidt) Mast. | 22m+2sm         | 1.27±0.24 | 1.72±0.18               | 2A             |
| 35  | P. koenigii Shirasawa | 20m+4sm            | 1.32±0.08 | 1.99±0.45               | 2A             |
| 36  | P. polita             | 22m+2sm            | 1.34±0.48 | 1.79±0.29               | 2A             |
| 37  | P. sitchensis         | 24m+2B             | 1.26±0.23 | 1.77±0.18               | 1A             |
| 38  | P. omorika (Pančić) Purk | 22m+2sm           | 1.27±0.12 | 1.97±0.57               | 2A             |
| 39  | P. jezoensis          | 22m+2sm            | 1.35±0.45 | 1.92±0.32               | 2A             |
| 40  | P. jezoensis var. hondoensis | 22m+2sm        | 1.32±0.09 | 1.85±0.18               | 2A             |

Table 6. Interspecific zymogram distances of Picea genus (Hu et al., 1983)

| Species               | P. abies | P. koraiensis | P. meyeri | P. crassifolia | P. schrenkiana | P. wilsonii | P. polita | P. likiangensis | P. pungens |
|-----------------------|----------|---------------|------------|----------------|----------------|-------------|------------|-----------------|-----------|
| P. abies              | 0        | 0.13          | 0.22       | 0.13           | 0.13           | 0.33        | 0.30       |                 |           |
| P. koraiensis         | 0.13     | 0            | 0.40       | 0.13           | 0.33           | 0.30        | 0.38       | 0.44            |           |
| P. meyeri             | 0.40     | 0.43          | 0.14       | 0.14           | 0.30           | 0.30        | 0.29       | 0.50            |           |
| P. crassifolia        | 0.13     | 0.25          | 0.30       | 0.45           | 0.25           | 0.44        | 0.22       |                 |           |
| P. schrenkiana        | 0.13     | 0.13          | 0.22       | 0.14           | 0.40           | 0.14        | 0.20       |                 |           |
| P. wilsonii           | 0.32     | 0.20          | 0.43       | 0.25           | 0.20           | 0.45        | 0.45       |                 |           |
| P. polita             | 0.35     | 0.55          | 0.55       | 0.44           | 0.44           |             |            |                 |           |
| P. likiangensis       | 0.35     | 0.44          | 0.44       | 0.44           | 0.44           |             |            |                 |           |
| P. pungens            | 0.35     | 0.44          | 0.44       | 0.44           | 0.44           |             |            |                 |           |

In zonal distribution, there are close contact among abroad Picea spp. and Chinese Picea spp., particularly, in Northwest China and Northeast China. In Northwest China, P. schrenkiana and P. schrenkiana var. tianshanica are distributed widely in Tianshan.
Mountains. They diffuse towards west along Tianshan Mountains into mountains of Pakistan and Afghanistan. *P. obovata* distributes in Aertai Mountains in northern Xinjiang, and it is connected with Siberian region of Russia. In Northeast China, *P. koraiensis* is found in Da Xinganling Mountains, Xiao Xinganling Mountains, Wanda Mountains, Zhangguangcailing Mountains, and Changbai Mountains. It is also found in Korean Peninsula, and Far East of Russia (Zheng and Fu, 1978). *P. jezoensis* distributes widely in Northeastern Asia, including Far East of Russia, Korean Peninsula, and North Japan (Ying, 1989). When it extends into Northeast China, it differentiates into some variations, such as *P. jezoensis* var. *microsperma* (in Da Xinganling Mountains, Xiao Xinganling Mountains, Zhangguangcailing Mountains) and *P. jezoensis* var. *komarovi* (in Changbai Mountains). In North China, Southwest China, and Taiwan, the *Picea* spp. have few connection with abroad *Picea* spp., so there are many China endemic species in spruce forests of these regions.

6. Acknowledgements

We gratefully acknowledge the financial support from the National Nature Science Foundation of China under the grants Nos. 39900019, 30070129, and 31170388, a grant from Shanghai Institute of Urban Ecology and Sustainability (SHUES2011A03), and Global Environmental Research Fund by Ministry of the Environment of Japan. We would like to thank Dr. Zhenzhu Xu, Dr. Yasumi Yagasaki and Dr. Shoko Ito for many valuable comments on the earlier versions of the manuscript and English corrections.

7. References

Abbott R.J., Brochmann C. 2003. History and evolution of the arctic flora: in the footsteps of Eric Hultén. Mol Ecol 12, 299–313.
Abbott R.J., Smith L.C., Milne R.I., Crawford R.M.M., Wolff K., Balfour J. 2000. Molecular analysis of plant migration and refugia in the Arctic. Science 289, 1343–1346.
Aldén B. 1987. Taxonomy and geography of the genus. Int. Dendr. Soc. Yearb. 1986, 85–96.
Alvin K.L. 1960. Further conifers of Pinaceae from the wealden formation of Belgium. Mem Inst Roy Sci Nat Belgium, 146, 1–39.
Axelord D.I. 1976. History of the coniferous forests, California and Nevada. Univ Calif Publ Bot 70.
Axelord D.I. 1986. Cenozoic history of some western American pines. Ann Missouri Bot Gard 73, 565–641.
Barbour M.G., Billings W.D. 1988. North American Terrestrial Vegetation. Cambridge University Press.
Bobrow E.G. 1970. Generis *Picea* Historia et Systematica. Nov Syst Pl Vasc 7, 7–39.
Böhle U.R., Hilger H.H., Martin W.F. 1996. Island colonization and evolution of the insular woody habit in *Echium* L. (Boraginaceae). Proc Natl Acad Sci USA 93, 11740–11745.
Boqrzan Z., Papes D. 1978. Karyotype analysis in Pinus: A contribution to the standardization of the karyotype analysis and review of some applied techniques. Silvae Genetica 27, 144–149.

Buchholz J.T. 1929. The embryogeny of the conifers. Pro Intern Congr Plant Sci 1, 359–292.

Buchholz J.T. 1931. The pine embryo and embryos of related genera. Trans Ill Acad Sci 23, 117–125.

Budantsey L.Y. 1992. Early stages of formation and dispersal of the temperate flora in the boreal region. Bot Rev 58 (1), 1–48.

Budantsey L.Y. 1994. The fossil flora of the Paleogene climatic optimum in northeastern Asia. In: Boulter M.C., Fisher H.C. (Eds.), Cenozoic Plants and Climates of the Arctic. Springer, Berlin, pp. 297–313.

Cen Q.Y. 1996. The study of subfamily abietoidese (Pinaceae) flora from China. Supplement to the Journal of Sun Yatsen University 2, 87–92.

Chou Y.L. 1986. Ligneous Flora of Heilongjiang. Heilongjiang Science Press, Harbin.

Chou Y.L. 1991. Vegetation of the Greater Xingan Mts., Science Press, Beijing.

Colleau C. 1968. Anatomie comparée des feuilles de Picea. Cellule 67, 185–253.

Corrigan D., Timoney R.F., Donnelly D.M.X. 1978. N-Alkanes and ω-hydroxyalkanoic acids from the needles of twenty-eight Picea species. Phytochemistry 17, 907–910.

Delevoryas T., Hope R.C. 1973. Fertile coniferophyte remains from the late Triassic Deep River Vasin, North Carolina. Amer J Bot 60, 810–818.

Doyle J. 1963. Proembryogeny in Pinus in relations to that in other conifers – A survey. Proc Roy Ir Acad 62, B. 13, 181–216.

Editorial Committee of Forest of China. 1997. Forest in China (Vol 1). Beijing: China Forestry Press, 513–574.

Editorial Committee of Vegetation of China. 1980. Vegetation of China. Beijing: Science Press.

Fang J.Y. 1995. Three–dimension distribution of forest zones in east Asia. Acta Geographica Sinica 50 (2), 160–167.

Fang J.Y. 1996. The distribution pattern of Chinese natural vegetation and its climatologic and topographic interpretations. In: Researches on Hotspots of Modern Ecology. Beijing: China Science and Technology Press 369–380.

Fang J.Y., Liu G.H. 1998. Ecology of plant distribution: historical review and modern advance. Scientific Foundation in China 12, (special issue), 48–53.

Farjón A. 1990. Pinaceae: Drawings and Descriptions of the Genera Abies, Cedrus, Pseudolarix, Keteleeria, Nothotsuga, Tsuga, Cathaya, Pseudotsuga, Larix and Picea. Koeltz ScientiWc Books, Königstein, Germany.

Farjón A. 2001. World Checklist and Bibliography of Conifers, Second edn. Royal Bot. Gard., Kew, England.

Ferguson S.K. 1967. On the phytogeography of coniferales in the European Cenozoic. Palaeogeoogr Palaeoclim Palaeocecol 3 (1), 73–100.

Florin R. 1954. The female reproductive organs of conifers and taxads. Biol Rev Cambridge Phil Soc 29, 367–389.
Florin R. 1963. The distribution of conifer and taxad genera in time and space. Acta Hort Verg 20, 194–256.

Fowler D.P. 1983. The hybrid black × sitka spruce, implications to phylogeny of the genus *Picea*. Can J For Res 13, 108–115.

Fowler D.P. 1987. The hybrid white × sitka spruce: species crossability. Can J For Res 17, 413–417.

Frankis M.P. 1988. Generic inter-relationships in Pinaceae. Notes Roy Bot Gard Edinb 45, 527–548.

Fu L., Li N., Mill R.R. 1999. *Picea*. In: Wu, Z.Y., Raven, P.H. (Eds.), Flora of China (4). Science Press, Beijing and Missouri Botanical Garden Press, St. Louis, pp. 25–32.

Gorden A.G. 1976. The taxonomy and genetics of *Picea rubens* and its relationship to *Picea mariana*. Can J Bot 54, 781–813.

Gugerli F., Sperisen C., Büchler C., Magni F., Geburek T., Jeandroz S., Senn J. 2001. Haplotype variation in a mitochondrial tandem repeat of Norway spruce (*Picea abies*) populations suggests a serious founder effect during postglacial re-colonization of the western Alps. Mol Ecol 10, 1255–1263.

Harris T.M. 1979. The Yorkshire Jurassic flora 5, Coniferales. London: British Museum (Natural History).

Hart J.A. 1987. A cladistic analysis of conifers: preliminary results. J Arm Arb 68, 269–306.

Hewitt G.M. 2000. The genetic legacy of the Quaternary ice ages. Nature 405, 907–913.

Hewitt G.M. 2004. Genetic consequences of climatic oscillations in the Quaternay. Philos Trans R Soc Lond B 359, 183–195.

Hilis L.V., Ogllvie R.T. 1970. *Picea* banks in Beaufort formation (Tertiary), Northwestern Banks Island, Arctic Canada. Can J Bot 48, 457–463.

Hipkins V.D., Krutovskii K.V., Strauss S.H. 1994. Organelle genome in conifers: structure, evolution, and diversity. For Genet 1, 179–189.

Hizume M. 1988. Karyomorphological studies in the family Pinaceae. Natural Science 8, 1–108.

Hsu J. 1983. Late cretaceous and cenozoic vegetation in China emphasizing their connections with North America. Ann Missouri Bot Gard 70, 490–508.

Hu Z.A., Wang H.X., Yan L.F. 1983. Biochemical systematics of gymnosperm: POD of Pinaceae. Acta Phytotaxonomica Sinica 4, 423–434.

Jain K.K. 1976. Note evolution of wood structure in Pinaceae. Israel Bot 25, 28–33.

Kinlaw C.S., Neale D.B. 1997. Complex gene families in pine genomes. Trends Plant Sci 2, 356–359.

Klaus W. 1987. Mediterranean pines and their history. Pl Syst Evol 162, 133–162.

Kuan C.T. 1981. Fundamental features of the distribution of coniferae in Sichuan. Acta Phytotaxonomica Sinica 19 (4), 393–407.

Ledig F.T., Hodgskiss P.D., Krutovskii K.V., Neale D.B., Eguiluz-Piedra T. 2004. Relationships among the spruces (*Picea*, Pinaceae) of southwestern North America. Syst Bot 29, 275–292.
LePage B.A. 2001. New species of *Picea* A. Dietrich (Pinaceae) from the middle Eocene of Axel Heiberg Island, Arctic Canada. Biol J Linn Soc 135, 137–167.

LePage B.A. 2003. The evolution, biogeography and palaeoecology of the Pinaceae based on fossil and extant representatives. Acta Hort 615, 29–52.

Li N. 1995. Studies on the geographic distribution, origin and dispersal of the family Pinaceae Lindl. Acta Phytotaxonomica Sinica 33 (2), 105–130.

Li W.H. 1980. Community Structure and Succession of Valley Spruce-Fir Forests of the Less Xingan Mts. J Natural Resources 4, 17–29.

Li W.H., Zhou P.C. 1979. Study on distributional general rules and mathematical models of dark coniferous forests in Asian-European Continent. J Natural Resources (1), 21–34.

Liu J.Q., Gao T.G., Chen Z.D., Lu A.M. 2002. Molecular phylogeny and biogeography of the Qinghai-Tibet Plateau endemic *Nannoglottis* (Asteraceae). Mol Phylogenet Evol 23, 307–325.

Liu T.S. 1971. A monography of the genus *Abies*. Taipei, The Department of Forestry College of Agriculture National Taiwan Univeristy.

Liu T.S. 1982. A new proposal for the classification of the genus *Picea*. Acta Phyt Geobot 33, 227–244.

Liu Z.L., Fang J.Y., Piao S.L. 2002. Geographical distribution of species in genera *Abies*, *Picea* and *Larix* in China. Acta Geographica Sinica 57 (5), 577–586.

Lü H., Wang S., Shen C., Yang X., Tong G., Liu K. 2004. Spatial pattern of modern *Abies* and *Picea* pollen in the Qinghai-Xizang Plateau. Quat Sci 24, 39–49.

Manley S.A.M. 1972. The occurrence of hybrid swarms of red and black spruce in central New Brunswick. Can J For Res 2, 381–391.

McKenna M.C. 1975. Fossil mammals and early Eocene North Atlantic land continuity. Ann Mo Bot Gard 62, 335–353.

Mehra P.N. 1968. Cytogenetical evolution of conifers. Indian Journal Genetics Plant Breeding 28, 97–111.

Mikkola L. 1969. Observations on interspecific sterility in *Picea*. Ann Bot Fenn 6, 285–339.

Miller C.N. 1972. *Pityostrobus palmeri*, A new species of petrified conifer cones from the Late Cretaceous of New Jersey. Amer J Bot 59 (4), 325–358.

Miller C.N. 1974. *Pityostrobus hallii*, A new species of structurally preserved conifer cones from the Late Cretaceous of Maryland. Amer J Bot 61, 798–804.

Miller C.N. 1975. Early evolution in the Pinaceae. Rev Palaeobot Palyno 21, 101–117.

Miller C.N. 1977. Mesozoic conifers. Bot Rev 43, 217–218.

Miller C.N. 1985. *Pityostrobus pubescens*, A new species of petrified conifer cones from the Late Cretaceous of New Jersey. Amer J Bot 92 (4), 520–529.

Miller C.N. 1988. The origin of modern conifer families. In: Beck CB ed. Origin and Evolution of Gymnosperms. New York: Colombia Univ Press, 448–487.

Niemann G.J. 1979. Some aspects of the chemistry of Pinaceae needles. Acta Bot Neerl 28 (1), 73–88.

Ogilvie R.T., von Rudlof E. 1968. Chemosystematic studies in the genus *Picea* (Pinaceae). IV. The introgression of white and Engelmann spruce as found along the Bow River. Can J Bot 46, 901–908.
Page C.N. 1988. New and maintained genera in the conifer families Podocarpaceae and Pinaceae. Notes RBG Edinb 45 (2), 377–395.

Page C.N., Hollands R.C. 1987. The taxonomic and biogeographic position of Sitka spruce. Proc R Soc Edinb 93b, 13–24.

Perron M., Perry D.J., Andalo C., Bousquet J. 2000. Evidence from sequence-tagged-site markers of a recent progenitor-derivative species pair in conifers. Proc Natl Acad Sci USA 97, 11331–11336.

Petit R.J., Aguinalde I., de Beaulieu J.L., Bittkau C., Brewer S., Cheddadi R., Ennos R., Fineschi S., Grivet D., Lascoux M., Mohanty A., Muller-Starck G., Demesure-Musch B., Palme A., Martin J.P., Rendell S., Vendramin G.G. 2003. Glacial refugia: hotspots but not melting pots of genetic diversity. Science 300, 1563–1565.

Prager E.M., Fowler D.P., Wilson A.C. 1976. Rates of evolution in conifers (Pinaceae). Evolution 30, 637–649.

Price R.A. 1989. The genera of Pinaceae in the Southeastern United States. J Arnold Arbor 70, 247–305.

Qian H., Ricklefs R.E. 2000. Large-scale processes and the Asian bias in species diversity of temperate plants. Nature 407, 180–182.

Ran J.H., Wei X.X., Wang X.Q. 2006. Molecular phylogeny and biogeography of Picea (Pinaceae): Implications for phylogeographical studies using cytoplasmic haplotypes. Molecular Phylogenetics and Evolution 41, 405–419.

Rushforth K. 1987. Conifers. Christopher Helm, London.

Schall J.J., Pianka E.R. 1978. Geographical trends in numbers of species. Science 201, 679–686.

Schmidt P.A. 1989. Beitrag zur Systematik und Evolution der Gattung Picea A. Dietr. Flora 182, 435–461.

Shi Y.F., Li J.J., Li B.Y. 1998. Uplift and Environmental Changes of Qinghai-Tibetan Plateau in the Late Cenozoic. Guangdong Science and Technology Press, Guangzhou.

Sigurgeirsson A., Smidt A.E. 1993. Phylogenetic and biogeographical implications of chloroplast DNA variation in Picea. Nordic J Bot 13, 233–246.

Stewart J.R., Lister A.M. 2001. Cryptic northern refugia and the origins of the modern biota. Trends Ecol Evol 16, 608–612.

Sudo S. 1968. Anatomical studies on the wood of species of Picea, with some considerations on their geographical distribution and taxonomy. Bull Gov For Exp Stat 215, 39–130.

Sun H. 2002. Evolution of Arctic-Tertiary flora in Himalayan–Hengduan Mountains. Acta Bot Yunnan 24, 671–688.

Taylor R.J., Patterson T.F. 1980. Biosystematics of Mexican spruce species and populations. Taxon 29, 421–469.

Thomas G. 1965. The saccate pollen grains of Pinaceae mainly of California. Grana Palynologica 6, 270–289.

Tiffney B.H. 1985a. Perspectives on the origin of the floristic similarity between Asia and eastern North America. J Arnold Arbor 66, 73–94.
Tiffney B.H. 1985b. The Eocene North Atlantic land bridge: its importance in the Tertiary and modern phytogeography of the Northern Hemisphere. J Arnold Arbor 66, 243–273.

Tiffney B.H., Manchester S.R. 2001. The use of geological and paleontological evidence in evaluating plant phytogeographic hypotheses in the Northern Hemisphere Tertiary. Int J Plant Sci 162, s3–s17.

von Rudlof E. 1967. Chemosystematic studies in the genus Picea (Pinaceae). Can J Bot 45, 891–901.

Wang H.S. 1992. Floristic Geography. Beijing: Science Press.

Wang H.S. 2000. The distribution pattern and floristic analysis of family Pinaceae of China. Bull Bot Res 20 (1), 12–19.

Wang M.L., Shi D.X., Zeng P.A. 1990. The situation of karyomorphological analysis and biological signification of Picea plants in China. J Sichuan Agric Univ 15 (1), 74–81.

Wang X.Q., Tank D.C., Sang T. 2000. Phylogeny and divergence times in Pinaceae: evidence from three genomes. Mol Biol Evol 17, 773–781.

Wen J. 1999. Evolution of eastern Asian and eastern North American disjunct distributions in flowering plants. Ann Rev Ecol Syst 30, 421–455.

Weng C., Jackson S.T. 2000. Species differentiation of North American spruce (Picea) based on morphological and anatomical characteristics of needles. Can J Bot 78, 1367–1383.

Wolfe I.A. 1978. A paleobotanical interpretation of Tertiary climates in the Northern Hemisphere. Amer Sci 66, 694–703.

Wolfe J.A. 1975. Some aspects of plant geography of the Northern Hemisphere during the Late Cretaceous and Tertiary. Ann Mo Bot Gard 62, 264–279.

Wright J.W. 1955. Species crossability in spruce in relation to distribution and taxonomy. For Sci 1, 319–340.

Wu D.X. 1985. Artificial Cultivated Picea koraiensis Forests. Newsletter of Forestry Science and Techniques 1: 16–18.

Wu H.Q. 1987. Spruce Forests in the Northeast China. Dynamics of Spruce Forests. Doctoral Thesis, Northeast Forestry University, Harbin.

Wu S.G., Yang Y.P., Fei Y. 1995. On the flora of the alpine region in the Qinghai-Xizang (Tibet) Plateau. Acta Bot Yunnannica 17, 233–250.

Wu Z.Y. 1991. The areal - types of Chinese genera of seed plants. Acta Bot Yunnannica (S), 1–139.

Xiang Q.Y., Manchester S.R., Thomas D.T., Zhang W., Fan C. 2005. Phylogeny, biogeography, and molecular dating of cornelian cherries (Cornus, Cornaceae): tracking Tertiary plant migration. Evolution 59, 1685–1700.

Yang G.T., Erich H., Sun B., Zhang J. 1994. Picea-Abies forest of the Northeast China. Bull Bot Res 14 (3), 313–328.

Ying T.S. 1989. Areography of the gymnosperms of China (I). Acta Phytotaxonomica Sinica 27 (1), 27–38.

Xu W.D., Li W.D., Zheng Y. 1994. The taxonomy of Picea mongolica in Inner Mongolia. Bull Bot Res 14 (1), 59–68.
Xu W.D., Liu G.T., Duan P.S., Zou C.J. 1998. Study on *Picea mongolica* forest ecosystem in Baiyinaobao Natural Reserve, Inner Mongolia. China Forestry Publishing House, Beijing.

Zheng W.J., Fu L.G. 1978. *Flora Replicants Sinicae*. (Tomus 7). Beijing: Science Press.

Zhou Y.L. 1988. Some vegetation types of China (VI): deciduous coniferous forests. *Biological Bulletin* 51, 6-10.
New Advances and Contributions to Forestry Research consists of 14 chapters divided into three sections and is authored by 48 researchers from 16 countries and all five continents. Section Whither the Use of Forest Resources, authored by 16 researchers, describes negative and positive practices in forestry. Forest is a complex habitat for man, animals, insects and micro-organisms and their activities may impact positively or negatively on the forest. This complex relationship is explained in the section Forest and Organisms Interactions, consisting of contributions made by six researchers. Development of tree plantations has been man’s response to forest degradation and deforestation caused by human, animals and natural disasters. Plantations of beech, spruce, Eucalyptus and other species are described in the last section, Amelioration of Dwindling Forest Resources Through Plantation Development, a section consisting of five papers authored by 20 researchers. New Advances and Contributions to Forestry Research will appeal to forest scientists, researchers and allied professionals. It will be of interest to those who care about forest and who subscribe to the adage that the last tree dies with the last man on our planet. I recommend it to you; enjoy reading it, save the forest and save life!

How to reference
In order to correctly reference this scholarly work, feel free to copy and paste the following:

Zou Chunjing, Xu Wenduo, Hideyuki Shimizu and Wang Kaiyun (2012). An Overview on Spruce Forests in China, New Advances and Contributions to Forestry Research, Dr. Dr. Andrew A. Oteng-Amoako (Ed.), ISBN: 978-953-51-0529-9, InTech, Available from: http://www.intechopen.com/books/new-advances-and-contributions-to-forestry-research/an-overview-on-spruce-forests-in-china
